Universidade Federal do Amapá
Pró-Reitoria de Pesquisa e Pós-Graduação
Programa de Pós-Graduação em Biodiversidade Tropical
Mestrado e Doutorado
UNIFAP / EMBRAPA-AP / IEPA / CI-Brasil

OMAR STALIN LANDÁZURI PAREDES

EFEITOS DAS VARIÁVEIS AMBIENTAIS E DISPONIBILIDADE DE FRUTOS NA DISTRIBUIÇÃO ESPACIAL DE VERTEBRADOS TERRESTRES NA AMAZÔNIA ORIENTAL, BRASIL

MACAPÁ, AP
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Dissertação apresentada ao Programa de Pós-Graduação em Biodiversidade Tropical (PPGBIO) da Universidade Federal do Amapá, como requisito parcial à obtenção do título de Mestre em Biodiversidade Tropical.

Orientadora: Dra. Fernanda Michalski

MACAPÁ, AP

2016

Dados Internacionais de Catalogação na Publicação (CIP)
Biblioteca Central da Universidade Federal do Amapá

363

P227e Paredes, Omar Stalin Landázuri.

Efeitos das variáveis ambientais e disponibilidade de frutos na distribuição especial de vertebrados terrestres na Amazônia oriental, Brasil / Omar Stalin Landázuri Paredes; orientadora, Fernanda Michalski. – Macapá, 2016.
61 f.

Dissertação (mestrado) – Fundação Universidade Federal do Amapá, Programa de Pós-Graduação em Biodiversidade Tropical.

OMAR STALIN LANDÁZURI PAREDES

WATER AVAILABILITY NOT FRUITFALL MODULATES THE DRY SEASON DISTRIBUTION OF FRUGIVOROUS TERRESTRIAL VERTEBRATES IN A LOWLAND AMAZON

Dra. Fernanda Michalski

Universidade Federal do Amapá (UNIFAP)

Dr. Marco Tavares

Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA-AP)

Dra. Ana Cristina Mendes de Oliveira

Universidade Federal do Pará (UFPA)

Aprovada em 09 de dezembro de 2016, Macapá, AP, Brasil

A mi esposa y mi hija, a quienes dedico cada palabra, latido y pensamiento.

Para mi abuelita, padres y hermanos; mi admiración y orgullo.

AGRADECIMENTOS

Chegar aqui não teria sido possível sem o amor e apoio da minha esposa, quem acreditou num sonho e caminho comigo, mesmo sabendo que seria um caminho difícil. Eu devo tudo a você, te amo;

A minha filha, quem com cada palavra deu me a força para continuar com o desejo de estar juntos novamente.

Ao meus pais, irmãos e minha “mamita”. Vocês são minha inspiração e a base de todas as minhas conquistas. Amo vocês;

À família da minha esposa por me acolher como mais um filho e apoiar nossa família, sobretudo durante esta etapa;

À Dra. Fernanda Michalski, agradecimentos pela sua orientação e ajuda durante o mestrado;

À Dr. Darren Norris, pelo financiamento e conhecimentos compartilhados.

À Dr. Tadeu Gomes de Oliveira por disponibilizar os equipamentos para o projeto e o grande aporte de ideias para o mesmo.

À Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – CAPES pela concessão da bolsa de mestrado;

Agradeço à Universidade Federal do Amapá – UNIFAP e ao Programa de Pós-Graduação em Biodiversidade Tropical – PPGBio, pela ajuda com os equimantos e logistica durante o projeto.

Ào LECOV pelos equipamentos, logística durante o projeto e a oportunidade.

A minha Turma PPGBio 2015, pelos momento compartidos e por se tornar os melhores amigos em pouco tempo;

Agradeço a Cledinaldo e Cremilson pela amizade e ajuda durante o projeto.

RESUMO

Landázuri, Omar. Efeitos das variáveis ambientais e disponibilidade de frutos na distribuição espacial de vertebrados terrestres na Amazônia oriental, Brasil. Macapá, 2016. Dissertação (Mestre em Biodiversidade Tropical) – Programa de Pós-graduação em Biodiversidade Tropical – Pró-Reitoria de Pesquisa e Pós-Graduação - Universidade Federal do Amapá.

Os Frugívoros constituem um dos maiores grupos nas florestas tropicais. Estudos anteriores mostram que a distribuição a meso-escala desse grupo é fracamente explicada por variáveis como altitude e área basal de árvores. Pela primeira vez testamos se a limitação sazonal de recursos (água e frutos caídos) afeta a distribuição durante a estação seca de 25 espécies de vertebrados terrestres. Para examinar os efeitos da disponibilidade espacial de frutas e água em vertebrados terrestres, usamos um sistema padronizado e regularmente espaçado de armadilhas fotográficas dentro de 25 km^2 de floresta amazônica. Modelos lineares generalizados (GLMs) foram usados para examinar a influência de cinco variáveis (altitude, distância ao rio maior, distância para a água mais próxima, e presença vs ausência de frutos e flores) no número de fotos de cinco grupos funcionais (todos os frugívoros , pequenos, médios, grandes e muito grandes frugívoros) e em sete das espécies de frugivoros mais abundantes (*Cuniculus paca*, *Dasyprocta leporina*, *Mazama americana*, *Mazama nemorivaga*, *Myoprocta acouchy*, *Pecari tajacu e Psophia crepitans*). Um total de 279 fotos independentes de 25 espécies foram obtidas a partir de 900 dias armadilha. Para a maioria das espécies e grupos funcionais, a variação no número de fotos fracamente explicado pelos GLMs (explicação de variação de 17.4 a 56.8 %). Em geral, encontramos que a disponibilidade de água foi claramente mais importante do que a presença de frutos caídos para os grupos e espécies estudadas. Frugívoros de corpo grande and dois das espécies mais abundantes (*C. paca* e *P. crepitans*) foram registrados mais freqüentemente próximos dos corpos de água; enquanto nenhum dos grupos funcionais nem alguma das espécies mais abundantes apresentaram relação significativa com a presença de frutos caídos. Um grupo funcional e três das sete espécies de frugívoros mais comuns avaliadas nos GLMs mostraram resultados significativos com respostas espécie-específicas à altitude. Nosso estudo fornece informações para entender a resposta espécie-especifica das espécies e grupos para lidar com períodos de escassez de água e frutos em terras baixas da floresta amazônica, fornecendo dados base para planos de manejo e conservação de florestas tropicais.

Palavras-chave: Floresta amazônica; disponibilidade de alimentos; espécies terrestres; recursos hídricos.

ABSTRACT

Landázuri, Omar. Effects of environmental variables and availability of fruits in the spatial distribution of terrestrial vertebrates in the eastern Amazon, Brazil. Macapá. 2016. Dissertação (Mestre em Biodiversidade Tropical) – Programa de Pós-graduação em Biodiversidade Tropical – Pró-Reitoria de Pesquisa e Pós-Graduação - Universidade Federal do Amapá.

Terrestrial vertebrate frugivores constitute one of the major guilds in tropical forests. Previous studies show that meso-scale distribution of this group is only weakly explained by variables such as altitude and tree basal area in lowland Amazon forests. For the first time we test whether seasonally limiting resources (water and fallen fruit) affect the dry season distribution in 25 species of terrestrial vertebrates. To examine the effects of the spatial availability of fruit and water on terrestrial vertebrates we use a standardized, regularly spaced arrangement of camera-traps within 25km2 of lowland Amazon forest. Generalized linear models (GLMs) were then used to examine the influence of five variables (altitude, distance to large rivers, distance to nearest water, and presence vs absence of fruits and flowers) on the number of photos on five functional groups (all frugivores, small, medium, large and very large frugivores) and on seven of the most abundant frugivore species (*Cuniculus paca*, *Dasyprocta leporina*, *Mazama americana*, *Mazama nemorivaga*, *Myoprocta acouchy*, *Pecari tajacu* and *Psophia crepitans*). A total of 279 independent photos of 25 species were obtained from 900 camera-trap days. For most species and two functional groups, the variation in the number of photos per camera was only significantly but weakly explained by the GLMs (deviance explained ranging from 17.4 to 56.8%). Generally, we found that the presence of water availability was clearly more important than the presence of fallen fruit for the groups and species studied. Large-bodied frugivores, and two of the more abundant species (*C. paca* and *P. crepitans*) were recorded more frequently closer to water bodies; while none of the functional groups nor most abundant species showed significant relationship with presence of fallen fruit. One functional group and three of the seven most common frugivore species assessed in the GLMs showed significant results with species-specific responses to altitude. Our findings provide information to understand functional groups and species-specific responses to cope with periods of water and fruit scarcity in lowland Amazon forest, providing baseline data for management and conservation plans for tropical forests.

Keywords: Amazon forest; food availability; terrestrial species; water resources.

SUMÁRIO

1. INTRODUÇÃO GERAL

Vertebrados são essenciais para manter a estrutura e composição de florestas tropicais (Wright et al. 2007, Beck et al. 2013). Dentro deste grupo, os frugívoros são constituídos por um grande número de espécies com funções importantes para a viabilidade dos ecossistemas (Cordeiro and Howe 2001), sendo responsáveis por dispersar mais de 94% de todas as espécies de plantas lenhosas no ecossistema amazônico (Hawes and Peres 2014). Os frugívoros também são considerados críticos para o recrutamento demográfico de muitas espécies de plantas tropicais (Howe 1984). De fato, cerca de 50 a 90% das árvores de dossel tem frutos adaptados para a dispersão zoocórica (realizada pelos animais)(Howe 1984).

A disponibilidade de recursos alimentares para a comunidade de frugívoros não é constante (Howe 1984). Na floresta tropical, a produção de frutos varia anualmente, entre as espécies, entre os indivíduos, e pode tornar-se instável em um mesmo período anual. A produção de frutos em florestas tropicais é geralmente avaliada por frutos caídos; mas as comparações sistemáticas em estudos de frutos caídos são poucas (Hanya and Aiba 2010). Pouco ou nada se sabe sobre padrões, variações ou a quantidade total de produção de frutos na maioria das espécies arbóreas tropicais, e muito menos sobre a sua relação com as dispersões de sementes. As conclusões fornecidas por Smythe (1986), Howe (1984) e Howe and Smallwood (1982) são de que existe sazonalidade na produção de frutos nas florestas sendo mais acentuada nas florestas com estações de estiagem e úmidas; e menos acentuada em florestas com chuva intensa ao longo de todo o ano.

Hanya and Aiba (2010) descreveram que os fatores climáticos como temperatura, evapotranspiração e precipitação não são fatores limitantes para a queda de frutos em florestas tropicais. Embora neste estudo os autores identificaram que um único fator climático não foi um preditor forte da queda de frutos, mas que a precipitação pode ter um efeito positivo sobre a queda de frutos se adicionado os dados de florestas em épocas secas. Para Chapman and Balcomb (1998) a precipitação é um indicador de produtividade de habitat e pode ser usado como um sinal de que há recurso disponível para os vertebrados frugívoros, sendo a época de estiagem um período com disponibilidade de agua e frutos limitados. Assim, *espécies-chave* é um termo usado em ecologia que explica o papel de certas espécies para manter a estabilidade nas interações nos trópicos(Paine 1969, Power et al. 1996). Este conceito pode ser estendido para incluir certas espécies de plantas que representam recursos nutricionais importantes para os animais durante o período de escassez (Peres 2000), formando "*keystone plant resource*" (KPR). Este adaptação explica que a comunidade de frugívoros da floresta neotropical depende desproporcionalmente de um pequeno grupo de plantas que fornecem frutos, principalmente durante a transição de estação seca e chuvosa, quando a disponibilidade de frutos é pequena (Diaz-Martin et al. 2014). A relação próxima entre a disponibilidade de recursos e a presença de frugívoros pode também determinar o tamanho de uma comunidade; (Smythe 1970) concluiu que uma escassez sazonal de frutos é suficiente para causar uma redução significativa em um grupo de frugívoros.

Alguns traços funcionais das espécies (e,x., tamanho do corpo, área de vida e dieta) são usualmente usadas para explicar a resposta a variáveis ambientais e distúrbios antropogênicos. (Bicknell and Peres 2010, Benchimol and Peres 2014, 2015, Peres et al. 2016). Os frugívoros terrestres de grande porte, por exemplo, são particularmente afetados em áreas com alteração antrópica e estão em maior perigo pela atividade de caça seletiva; o que significa uma simultânea ameaça à viabilidade demográfica de plantas dispersas por esse groupo de vertebrados (Smythe 1986, Beckman and Muller-Landau 2007, Wright et al. 2007).

Informações sobre questões relacionadas aos frugívoros terrestres e suas interações é limitada (Smythe 1986). Muitos dos estudos que investigaram a interação entre a disponibilidade de frutos e frugívoros tem se concentrado sobre o grupo de frugívoros arborícolas e voadores (Gaulin et al. 1980, Kissling et al. 2007, Hanya and Aiba 2010). Dessa forma, ainda existe uma lacuna de conhecimento sobre frugívoros terrestres e suas interações com disponibilidade de frutos (Smythe 1986). Dos poucos estudos na floresta amazônica, Michalski et al. (2015) determina que as variáveis ambientais podem não ser tão influentes na distribuição, riqueza e abundância de vertebrados terrestres e menciona que as interações bióticas e disponibilidade de recursos poderiam ser mais explicativas. Não em tanto, dada a variabilidade dentro uma meso-escala na Amazônia florestal Norris et al. (2010) determina que é preciso avaliar o efeito da altitude dentro das distribuições e abundancias das espécies e comparar variações na altitude com variações nas respostas das espécies e comunidades.

A Amazônia tem a maior diversidade de vertebrados frugívoros, tanto terrestres e aquáticos, e também possui a maior variedade morfológica de frutos em todo o mundo (Hawes and Peres 2014). No entanto, apenas 37% da Amazônia brasileira está sobre proteção legal, e mais de 80% das áreas protegidas permite algum tipo de uso humano (Peres 2011). O crescimento demográfico da região e o uso de novas tecnologias para a extração de recursos madeireiros e não madeireiros causar declínio na disponibilidade de frutos (Aizen and Feinsinger 1994) com consequências ainda desconhecidas. A utilização de armas, luzes e transporte motorizado, substitui a caça tradicional dos povos indígenas e causa reduções significativas na abundância de animais (Beckman and Muller-Landau 2007, Wright et al. 2007) e o grupo de vertebrados terrestres é o mais afetado por perturbações antrópicas como a caça (Smythe 1986), sendo vital o entendimento das relações dos mesmos com a disponibilidade de frutos para fins de conservação e uso dos recursos naturais.

A pergunta desse trabalho é se existe uma relação entre a disponibilidade de recursos (frutos, flores e água) e a abundância e distribuição espacial de vertebrados terrestres frugívoros durante uma época de escassez em uma área continua de floresta amazônica? O uso de uma metodologia espacial padronizada para o estudo dos fatores que afetam a distribuição espacial dos frugívoros terrestres durante uma época com limitados recursos é vital para podermos realizar comparações e gerar mais informações; consequentemente, permitindo a criação de protocolos para a conservação deste grupo e da manutenção dos serviços ecossistêmicos de florestas tropicais.

2. HIPÓTESES

- Durante uma época de escassez de recursos alimentícios, as variações espaciais na presença de frutos e flores caídos determinaram a distribuição espacial de frugívoros terrestres.

- Durante uma época de estiagem a disponibilidade de agua afeta a distribuição espacial de frugívoros terrestres.

- A altitude pode explicar padrões de distribuição de vertebrados terrestres em uma meso-escala durante uma época de escassez.

3. OBJETIVOS

3. 1. GERAL

Determinar como as variações espaciais na distribuição de frugívoros terrestres está relacionada com a disponibilidade de recursos (flores, frutos e agua) durante uma época de escassez em uma área continua de floresta na Amazônia Oriental brasileira.

3. 2. ESPECÍFICOS

- Determinar a riqueza de vertebrados terrestres frugívoros;
- Determinar as variações espaciais na abundância das espécies de vertebrados terrestres identificadas;
- Determinar a relação entre a presença de recursos (flores, frutos e agua) e a distribuição espacial das espécies terrestres frugívoras mais abundantes.
- Examinar a importância dos traços funcionais das espécies na resposta a disponibilidade de recursos (flores, frutos e agua).

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Water availability not fruitfall modulates the dry season distribution of frugivorous terrestrial vertebrates in a lowland Amazon forest

Artigo submetido ao periódico "PlosOne"

Water availability not fruitfall modulates the dry season distribution of frugivorous terrestrial vertebrates in a lowland Amazon forest

Omar Stalin Landázuri Paredes [1], Darren Norris [1,2], Tadeu Gomes de Oliveira [3,4], Fernanda Michalski [1,2,4,*]

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

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

[3] Departamento de Biologia, Centro de Ciências Exatas e Naturais, Universidade Estadual do Maranhão, São Luís, Maranhão, Brazil

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

* Corresponding author

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

Running Title: Water and fruitfall effects on frugivorous terrestrial vertebrates

ABSTRACT

Terrestrial vertebrate frugivores constitute one of the major guilds in tropical forests. Previous studies show that meso-scale distribution of this group is only weakly explained by variables such as altitude and tree basal area in lowland Amazon forests. For the first time we test whether seasonally limiting resources (water and fallen fruit) affect the dry season distribution in 25 species of terrestrial vertebrates. To examine the effects of the spatial availability of fruit and water on terrestrial vertebrates we used a standardized, regularly spaced arrangement of camera-traps within 25km^2 of lowland Amazon forest. Generalized linear models (GLMs) were then used to examine the influence of five variables (altitude, distance to large rivers, distance to nearest water, and presence vs absence of fruits and flowers) on the number of photos on five functional groups (all frugivores, small, medium, large and very large frugivores) and on seven of the most abundant frugivore species (*Cuniculus paca*, *Dasyprocta leporina*, *Mazama americana*, *Mazama nemorivaga*, *Myoprocta acouchy*, *Pecari tajacu* and *Psophia crepitans*). A total of 279 independent photos of 25 species were obtained from 900 camera-trap days. For most species and two functional groups, the variation in the number of photos per camera was significantly but weakly explained by the GLMs (deviance explained ranging from 17.4 to 56.8%). Generally, we found that the presence of water availability was clearly more important than the presence of fallen fruit for the groups and species studied. Large-bodied frugivores, and two of the more abundant species (*C. paca* and *P. crepitans*) were recorded more frequently closer to water bodies; while none of the functional groups nor most abundant species showed any significant relationship with the presence of fallen fruit. One functional group and three of the seven most common frugivore species assessed in the GLMs showed significant results with species-specific responses to altitude. Our findings provide information to understand how frugivorous vertebrates cope with periods of water and fruit scarcity in lowland Amazon forests, providing baseline data for management and conservation plans for tropical forests.

Keywords: Amazon forest; Food availability; Terrestrial species; Water resources

5. 1 Introduction

Environmental features such as water availability and food resources may influence the spatial distribution of wildlife in varying degrees depending on species specificity. For example, many species of mammals showed a positive association between occupancy patterns and permanent water sources [1-6]. Similarly, a preference to areas with proximity to bodies of water for some species of terrestrial birds has also been documented in tropical forests [7, 8].

In tropical forests frugivorous species represent the majority of the mammalian and avian biomass [9] and depend on both unripe and ripe fruits as well as some species of flowers as key resource [10], with the degree of dependency related with the specificity of their diet [7, 11-13]. However, the availability of resource is not a constant in tropical forests [14] and has been found to be extremely variable in both space and time. Even continuous tracts of tropical forests can show distinct vertebrate species distributions [15], a phenomena that could be related with habitat suitability and resource availability. Although the fruit production vary in space and time, a fruit scarcity period exist everywhere [16]. Some studies use precipitation as indicator of food availability for frugivores, being the dry season a period of limited food and water availability [17].

Seasonal shortages are sufficient to cause several effects in a local frugivore community [18]. A species' response to fruit and water availability may be influenced by its life-history traits (e.g., dietary guild, body mass, home range size) and competitive pressure [2-4, 19, 20]. Species traits are also used to explain variations on species' abundances in responses to environmental variables and anthropogenic disturbances [5, 20-26].

Studies on dependency of water and fruit and its relationship with life-history traits are still scarce for tropical terrestrial vertebrates. Studies focusing on frugivores are especially limited [27], and few studies have attempted to study this group of vertebrates in lowland Amazonia [8, 23, 24, 28]. Moreover, reviews comparing different taxa are available for only a limited number of frugivores [3, 4, 7, 11, 19, 29, 30]. As Amazonia holds both, the highest diversity of terrestrial and aquatic frugivorous vertebrates [12, 31] and the widest spectrum of morphological fruit types anywhere on Earth [32] it is surprising that more studies on this topic are not found.

Thus, based on changes in temperature and precipitation regimes predicted by climate change models in the next decades and their possible influence on resource availability through changes in their abundance (e.g., fruits and water) [1] may influence frugivores population parameters. There is a need to understand the ecological factors affecting the distribution of different species and obtain basic information of the species-specific responses to cope with water and fruit scarcity. This information may feed models for understanding or predicting the potential impact of anthropogenic and climate change on the species in the future, including potential frugivore resilience to disturbances [2].

In this study we used camera-trapping to survey mid-sized and large- bodied vertebrates with a standardized sampling regime that has been utilized in other tropical studies to survey terrestrial vertebrates within a 25 km^2 area [8]. Here we focused on evaluating the spatial effects of (1) fruit and flower availability, (2) water availability and (3) altitude on vertebrate frugivores during the peak of the dry season, a period of reduced resources in eastern Amazonia. Additionally, we examined the importance of species life-history traits in the responses to these environmental variables. We predict that presence of fallen fruit and water availability would affect functional groups and species of terrestrial frugivores. To test this hypothesis we evaluated whether water and fruit availability act additively with the altitude to explain abundance patterns in terrestrial vertebrates during the dry season in a continuous forest site.

5. 2. Materials and Methods

5. 2. 1. Study area

This study was conducted in Amapá National Forest (Floresta Nacional Amapá – hereafter ANF), a sustainable-use protected area of approximately 412,000 ha, centered in the state of Amapá in north-eastern Brazilian Amazonia (0°55’29”, 51°35’45”W, Fig 1) [33]. The ANF consists of continuous tropical rainforest vegetation, predominantly never-flooded closed canopy ‘‘terra firme” forest [33].

The ANF currently experiences low levels of anthropogenic perturbation (there has been no mechanized logging within the boundaries of ANF) and is part of a large (> 4 million hectares) connected group of protected areas [33] that maintain both continuous undisturbed forests and the complete regional community of medium-sized and large-bodied vertebrates [8].

The regional climate is hot and humid, with annual rainfall ranging from 2300 mm to 2900 mm [34]. During the wettest months (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 [34].

5. 2. 2. Sampling design

Data was sampled between October and December 2015, months that historically represent the peak of the dry season in the study area (mean ± SD = 108 mm ± 47 mm, range = 60 mm – 154 mm, annual cumulative precipitation for 2010 to 2014) [35]. Our research was conducted within 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) [36, 37] (Fig. 1). The RAPELD grid is a system of standardized trails and permanent plots. This standard grid consists of six north-south and six east-west 5 km trails. The permanent plots are a total of 30 regularly spaced sample plots, with 250 m length, established at 1 km intervals along the east-west trails [37]. This sample size and arrangement has been shown to be generally robust and representative for quantifying meso-scale spatial patterns in lowland Amazon biodiversity [38]. The current study used the 30 permanent plots and permanent sample points regularly spaced distributed at 1 km intervals along east-west trails in the RAPELD grid [8, 36, 37].

5. 2. 3. Vertebrate sampling

We used camera traps equipped with infrared triggers (Bushnell Trophy Cam, 8MP, Overland Park, KS, USA) to sample terrestrial vertebrates in the RAPELD grid. Due to financial constraints we did not have sufficient cameras to survey all 30 points simultaneously. Thus, cameras were placed at 20 points for 30 consecutive days then immediately transferred to the remaining 10 points. All cameras were unbaited, installed at 30-40 cm above the ground and facing the trails to ensure the capture of a wide spectrum of vertebrates (from small to large terrestrial body-sized species). Cameras were deployed for periods of 30 days, functioning continuously (24 hours a day). We configured cameras to film for 40 seconds post-activation, with intervals of 15 seconds between videos, with date-time stamp enabled.

In order to estimate the relative abundance of vertebrates, we considered only independent videos, with over 30 min intervals when the same species was recorded during the same day on the same camera [8, 39, 40]. This minimum 30-min interval reduces the temporal dependence between camera trap detections [39]. Vertebrates were identified using field guides of mammals and birds [41-43]. All identifications were double-checked by two researchers with more than 10 years of experience (FM and DN).

5. 2. 4. Species traits

We conducted a literature survey to obtain two morphological and ecological traits (trophic guild and body mass) for the 25 vertebrates studied (Table 1). All 25 vertebrates were classified into frugivores and non-frugivores based on previously published data (Table 1). We grouped mammals and birds into small species (< 1 kg), medium species (1–5 kg), large species (5–15 kg) and very large species (>15 kg) according to their body size distribution [25, 44] (Table 1). Finally, we defined five functional groups as follows: (i) All frugivores, (ii) Small frugivores, (iii) Medium frugivores, (iv) Large frugivores and (v) Very large frugivores.

Table 1. Trophic guild, body mass, number of occupied sites, relative abundances and number of independent videos (Detections) for all 25 species examined.

Class/Order/Family	Species	Trophic Guild*	Body Mass (kg)	Occupied Sites	RA** (Detections)
Birds					
Gruiformes					
Psophiidae	*Psophia crepitans*	Fr/In [a, b]	1.50 [c]	21	0.61 (55)
Cracidae	*Crax alector*	Fr/Sp [c]	3.40 [c]	4	0.07 (6)
Tinamiformes					
Tinamidae	*Crypturellus erythropus*	In/Fr [a]	0.42 [a]	4	0.07 (6)
Tinamidae	*Tinamus major*	Sp/Fr/In [a]	1.20 [c]	4	0.04 (4)

Mammals					
Didelphimorphia					
	Didelphis marsupialis	In/Fr/Vp [d]	1.05 [d]	3	0.03 (3)
Artiodactyla					
Cervidae	*Mazama americana*	Fr/Fo [d]	30.0 [d]	9	0.36 (32)
	Mazama nemorivaga	Fr/Fo [d]	18.0 [d]	9	0.18 (16)
Tayassuidae	*Pecari tajacu*	Sp/Fr/Vp [d]	25.0 [d]	14	0.49 (44)
Perissodactyla					
Tapiridae	*Tapirus terrestris*	Fr/Fo [d]	150.0 [d]	4	0.07 (6)
Carnivora					
Canidae	*Speothos venaticus*	Vp [d]	6.32 [e]	1	0.01 (1)
Felidae	*Leopardus pardalis*	Vp [d]	11.90 [c]	2	0.09 (8)
	Leopardus wiedii	Vp [d]	3.25 [c]	1	0.01 (1)
	Puma concolor	Vp [d]	51.60 [c]	2	0.02 (2)
	Panthera onca	Vp [d]	80.00 [c]	1	0.01 (1)
Mustelidae	*Eira barbara*	Fr/In/Vp [d]	4.80 [d]	2	0.02 (2)
Procyonidae	*Nasua nasua*	In/Vp/Fr [d, f]	3.10 [d]	1	0.01 (1)
	Procyon cancrivorus	In/Vp/Fp/Fr [d, f]	6.93 [e]	1	0.01(1)
Cingulata					
Dasypodidae	*Dasypus kappleri*	In [d]	9.50 [c]	2	0.06 (5)
	Dasypus novemcinctus	In [d]	5.50 [d]	4	0.06 (5)
	Priodontes maximus	In [d]	38.00 [c]	1	0.01 (1)
Pilosa					
Myrmecophagidae	*Myrmecophaga tridactyla*	In [d]	22.33 [c]	3	0.03 (3)
Rodentia					
Cuniculidae	*Cuniculus paca*	Sp/Fr [d]	8.00 [d]	6	0.31 (28)
Dasyproctidae	*Myoprocta acouchy*	Sp/Fr [a]	0.95 [c]	9	0.41 (37)

	Dasyprocta leporina	Sp/Fr [a]	3.50 [c]	7	0.11 (10)
Sciuridae	*Sciurus aestuans*	Sp/Fr [d, g]	0.19 [c]	1	0.01 (1)

*Trophic guild: (Fr) frugivore, (Fo) folivore, (Sp) seed predator, (Fu) fungus, (In) Invertebrate predator, (Vp) terrestrial vertebrate predator, (Fp) fish predator.

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

Source: [a]Peres and Palacios [45], [b]Erard, Thery [46], [c]Benchimol and Peres [23], [d]Peres [28], [e]Jones, Bielby [47],[f]Oliveira and Pereira [48], [g]Emmons and Feer [43].

5. 2. 5. Environmental variables

We used a total of five environmental variables to explain the dry season distribution of the vertebrate groups and species (S1 Table). In order to evaluate fruit and flower availability, we used three plots (250 x 2 m) for all 30 permanent sampling points where camera traps were located: (1) the RAPELD permanent plot and (2) another two trail plots located 250 m before and after the location of the camera along the east-west trails. All fallen fruits and flowers within the plots were identified *in situ* using field guides [49, 50]. Identification of all fruits and flowers found in the field were also confirmed with the aid of a trained technician from the Amapá State Scientific Research and Technology Institute (Instituto de Pesquisas Científicas e Tecnológicas do Estado de Amapá - IEPA) and the Emilio Goeldi Museum of Pará State - MPEG. Only known animal-consumed fruit and flower species were considered [18, 27, 51] (S2 Table). Finally, we registered the presence or absence of fruits and flowers for each of the 30 sample points.

To evaluate the spatial distribution of water availability we used two variables at different scales: (1) distance from camera traps to the nearest large river and (2) distance from camera traps to the nearest stream with water. The distance from the camera traps to the nearest large river was estimated by using shapefiles of the Araguari and Falsino rivers (available at http://hidroweb.ana.gov.br/HidroWeb.asp?TocItem=4100), and measured as a straight line (Euclidian) distance with ArcGIS version 10.2 [52]. Distance from the camera traps to the nearest stream with water was estimated *in situ*, using a Global Positioning System (GPS) handheld while walking along the east-west trails in the RAPELD grid at the same period of the camera trapping survey. After, we measured the linear distance from each camera station to the nearest stream with water using ArcGIS version 10.2 [52].

To estimate the altitude of the terrain at the camera trap locations, we used a digital elevation model (DEM) produced by the Shuttle Radar Topographic Mission (SRTM) [53], with spatial resolution of 3 arc-second (approximately 90 m on the Equator), consisting of a set of elevations in digital format freely available online (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).

5. 2. 6. Data analysis

The relative abundance of each species was expressed as the number of independent videos per 10 trap-days, with which we were able to make comparisons with other vertebrate studies that were conducted in the Amazon forest [8, 40].

To assess whether the sampling effort was sufficient to record the majority of the species, we constructed and compared cumulative species curves with function *specaccum* of the *Vegan* package [54]. To predict the total number of species that could be potentially detected in the study area, we used the First order jackknife estimator to extrapolate the species richness (i.e., estimate the number of undetected species) based on the frequency of recorded species (function *specpool*, package *Vegan*) [54].

We used Spearman correlation values to evaluate independence between environmental variables. This analysis showed that there were no strong pairwise correlations (Spearman r ranging between 0.00 and 0.28) between the environmental variables. Based on the weak correlations we retained all five variables for use 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 = Tweedie) [55]. GLMs were preferred to alternatives such as occupancy models because the number of videos (i.e., potential of recaptures) and naïve occupancy (proportion of cameras with records) was low for most species.

The GLMs were run separately for each species and for the five functional groups of vertebrates (Table 1). For the GLM analysis we selected only groups/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 [56].

5. 3. Results

5. 3. 1. Sampling effort and species richness

Following a sampling effort of 900 trap-days (30 days for each camera-trap), we obtained 279 independent videos of 25 vertebrate species (Table 1). We obtained an overall capture rate of 0.31 videos per trap-day (279 independent videos /900 trap-days). This total included four bird and 21 mammal species, representing 10 orders: Birds – Tinamiformes, Galliformes, Gruiformes; Mammals – Artiodactyla, Perissodactyla, Carnivora, Cingulata, Pilosa, Didelphimorphia and Rodentia (Table 1). From all vertebrates sampled, 16 were frugivores, including four bird and 12 mammal species (four rodents, four ungulates, three carnivores and one marsupial), all of which that include fruits as part of their diet (Table 1, S3 Table).

The species accumulation curves reached an asymptote for all birds, frugivorous mammals and frugivorous birds (Fig. 2). Although the accumulation curve did not reach an asymptote for all mammals (Fig. 2A), we obtained 75.63% of the expected mammal species. For all birds we obtained 100% of the species pool. This suggests that sampling effort was sufficient for frugivorous vertebrates.

5. 3. 2. Functional groups

The Generalized Linear Models (GLM's) revealed that the explanatory power of the model was low for almost all groups (Table 2), with a maximum deviance explained of 57% (for large frugivores) and a minimum of 21% (for all frugivorous). Three groups (all frugivores, small frugivores and medium frugivores) were not significantly influenced by any of the environmental variables measured. The group containing only large frugivores (5 – 15 kg) was negatively influenced by altitude and distance to nearest water. The group of very large frugivores was positively influenced only by altitude. None of the groups showed a statistically significant association with the presence of fruits or flowers (Fig. 3).

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

	All frugivores[a]		Small frugivores[b]		Medium frugivores[c]		Large frugivores[d]		Very large frugivores[e]	
	Slope (SE)[f]	t value	Slope (SE)[f]	t value	Slope (SE)[f]	t value	Slope (SE)[f]	t value	Slope (SE)[f]	t value
Altitude	0.005 (0.012)	0.45	-0.002 (0.026)	-0.10	-0.023 (0.012)	-1.85	-0.119 (0.036)	-3.29**	0.058 (0.019)	3.08**
Distance to large rivers	0.207 (0.179)	1.16	0.380 (0.345)	1.10	-0.154 (0.160)	-0.96	0.279 (0.415)	0.67	0.377 (0.277)	1.36
Distance to nearest water	-0.516 (0.394)	-1.31	-0.927 (0.934)	-0.99	-0.757 (0.378)	-2.00	-4.031 (1.228)	-3.28**	0.983 (0.591)	1.66
Fruit (presence vs absence)	0.344 (0.348)	0.99	-0.350 (0.684)	-0.51	-0.420 (0.332)	-1.26	-1.352 (0.934)	-1.45	0.932 (0.511)	1.82
Flower (presence vs	0.747	1.45	2.766	0.01	-0.486	-1.10	2.508	0.15	1.346	1.87

absence)	(0.515)	(2.262)	(0.443)	(1.634)	(0.721)
Model deviance explained (%)[g]	20.70	26.30	23.90	56.80	35.40
Model AIC[h]	195.96	101.00	129.36	70.23***	145.98**

Significance values: *p <0.05, **p<0.01, ***p<0.001.

[a] Includes relative abundances of all frugivores recorded in the study area;

[b] Includes relative abundances of only small frugivores (< 1 kg);

[c] Includes relative abundances of only medium frugivores (1 - 5 kg);

[d] Includes relative abundances of only large large frugivores (5 - 15 kg);

[e] Includes relative abundances of only very large frugivores (> 15 kg);

[f] Slope for variables and Standard Error (SE);

[g] Percentage of Deviance Explained for each model (%);

[h] Akaike Information Criterion value for each model (AIC);

5. 3. 3. Species

Psophia crepitans was the most frequently recorded species with 55 records (0.61 records/10 trap-days), followed by *Pecari tajacu* with 44 records (0.49 records/10 trap-days), *Myoprocta acouchy* with 37 records (0.41 records/10 trap-days) and *Mazama americana* with 32 records (0.36 records/10 trap-days) (Table 1). Of the seven most common species assessed in the GLMs, five showed statistically significant results (Table 3). The percentage of variation explained by the models ranged from a minimum of 17% for *Pecari tajacu* to a maximum of 56% for *Cuniculus paca*. Of these seven species, the rodent *C. paca*, the ungulates *M. nemorivaga* and *M. americana* and the rodent *D. leporina* were the species where the model provided the highest percentage of explanation for their distributions, ranging from 40 to 56% (Table 3).

Cuniculus paca, M. nemorivaga and *P. crepitans* were the only species with two significant variables in the model. *D. leporina* and *M. americana* were significantly associated with one variable in the model, while *P. tajacu* and *M. acouchy* were not associated significantly with any of the environmental variables in the GLMs (Table 3).

The variable altitude had a positive influence on the relative abundance of the two ungulates (*M. americana and M. nemorivaga)* and negative influence for *C. paca*. The distance to large river had a negative influence only for the bird *P. crepitans.* Finally, distance to nearest water had a positive effect on *D. leporina* and *M. nemorivaga,* while it influenced negatively *C. paca* and *P. crepitans*.

Table 3. Parameter (Slope) estimates of explanatory variables from the GLMs on the abundance of most common species of vertebrates in the eastern Brazilian Amazon.

	Cuniculus paca		*Dasyprocta leporina*		*Mazama americana*		*Mazama nemorivaga*		*Myoprocta acouchy*		*Pecari tajacu*		*Psophia crepitans*	
	Slope (SE)[a]	t value	Slope (SE)[a]	t value	Slope (SE)[a]	t value	Slope (SE)[a]	t value	Slope (SE)[a]	t value	Slope (SE)[a]	t value	Slope (SE)[a]	t value
Altitude	-0.118 (0.036)	-3.26**	0.025 (0.033)	0.74	0.133 (0.030)	4.47***	0.086 (0.027)	3.23**	0.002 (0.027)	0.09	0.030 (0.023)	1.30	-0.015 (0.015)	-0.97
Distance to large rivers	0.274 (0.414)	0.66	0.398 (0.303)	1.32	0.242 (0.473)	0.51	0.315 (0.414)	0.76	0.402 (0.375)	1.07	0.264 (0.345)	0.77	-0.450 (0.213)	-2.11*
Distance to nearest water	-3.993 (1.226)	-3.26**	2.229 (1.052)	2.12*	1.099 (0.138)	0.97	1.989 (0.793)	2.51*	-0.569 (0.975)	-0.58	0.550 (0.699)	0.79	-1.703 (0.594)	-2.87**
Fruit (presence vs	-1.355 (0.931)	-1.46	-1.477 (0.822)	-1.80	0.540 (0.748)	0.72	1.142 (0.676)	1.69	-0.101 (0.732)	-0.14	0.957 (0.650)	1.47	-0.677 (0.430)	-1.57

absence)														
Flower (presence vs absence)	2.507 (1.845)	0.15	1.888 (1.333)	1.42	0.688 (1.079)	0.64	2.183 (3.227)	0.01	2.465 (2.928)	0.01	1.577 (1.022)	1.54	-0.885 (0.598)	-1.48
DE (%)[b]	56.20		40.40		46.40		48.00		21.10		17.40		36.40	
Model AIC[c]	70.12***		58.24*		81.82***		62.78***		88.31		106.46		108.79**	

Significance values: *p <0.05, **p<0.01, ***p<0.001.

[a] Slope for variables and Standard Error (SE);

[b] Percentage of Deviance Explained for each model (DE(%));

[c] Akaike Information Criterion value for each model (AIC);

5. 4. Discussion

Our study demonstrates that water availability is clearly more important than the presence of fallen fruit during an event of resource scarcity in a lowland Amazon forest. Thus, our findings support the prediction that water availability would affect functional groups and species of terrestrial frugivores but reject the prediction that fallen fruit would also affect them. Distance to nearest water was an important variable for one functional group (large frugivores) and for four terrestrial frugivore species at a meso-scale level. These observations allow understanding species-specific responses to cope with water scarcity, and provide basic information to monitoring groups of tropical frugivores to future environmental changes.

5. 4. 1. Sampling effort and species richness

The difference between the observed and extrapolated species richness values obtained indicates that our sampling effort was sufficient to record the full spectrum of frugivorous birds and mammals of the study area. Indeed, the 25 species recorded in our study is similar to the composition and number of species recorded for other Amazonian regions [57-59]. A previous camera-trap survey in the same study area reported a total richness of 25 species with a sampling effort of 1800 trap-days (900 each for the dry and rainy seasons), with 21 vertebrate species recorded during the 2013 dry season [8]. Based on these findings we consider the results from the present study to be representative of the terrestrial vertebrate species in the study area.

For mammals, the species compositions of the two studies during the dry season were similar, with a difference that *Tamandua tetradactyla* was detected only in 2013 [8] and *Priodontes maximus* was detected only in the 2015. We also detected four species that were not recorded in a previous study [8] during the dry season but were registered in the rainy season: *Sciurus aestuans, Procyon cancrivorus, Nasua nasua* and *Speothos venaticus*. Such differences are consistent with the findings from previous studies that show spatial and temporal variations in the species recorded using camera-trap surveys in tropical forests [21, 57, 60, 61].

Four mid-sized and large-bodied terrestrial bird species were recorded in our study. Due to their body sizes and habit of foraging on the ground [7, 46], these birds are likely to be recorded by camera trap studies [8, 23]. The same bird species during the dry season with similar relative abundances that we found in our study were reported in a previous study [8]. Although our extrapolated bird richness values suggest that we registered all the bird species that could possibly be recorded with camera traps, the frequency with which they were registered was low for most birds. This result may suggest that this technique might not be ideal for this group of birds, being necessary the use of complementary techniques; the combination of indirect and direct techniques have been proven to be more efficient than cameras traps only [62].

Camera trapping studies are often conducted during the dry season in tropical forests. For example, dry season surveys from the basis of the camera-trap protocols implemented globally by the Tropical Ecology Assessment and Monitoring Network [61, 63]. This preference for dry season surveys is mainly due to the logistical constraints associated with rainy season surveys (e.g. restricted access and cameras malfunctioning). A previous study in our study area [8] found fewer records for some frugivore species during the dry compared with the rainy season. In our study, there were several vertebrates represented by only a few photographs, showing the difficulty of detecting some frugivorous during the dry season (e.g., *Tapirus terrestris*, *Crax alector*, *Crypturellus erythropus* and *Tinamus major*).

5. 4. 2. Differences between functional groups

Our results agree with previous studies that found other factors to be more important than fruit availability to explain variation in the abundance of terrestrial frugivores [1, 2, 4, 64]. Large frugivores were most strongly influenced by distance to nearest water and altitude, while very large frugivores were only influenced by altitude. Large frugivores were associated negatively with distance to nearest water showing a significant increase in the number of records in areas closer to water bodies within the study area. This finding supports previous studies of large bodied terrestrial mammals that show water shortage may play a stronger role in driving behavior than food searching during the dry season [1-4].

The group of medium to large-bodied vertebrates is one of the most affected by subsistence hunting [27] and it has been shown that these vertebrates can be more easily hunted closer to water during the dry season [65]. Although the rivers are the main means of transport of habitants in the Amazon region [25], we did not find any negative effect in the abundance of these frugivorous groups close to the large rivers, which supports the idea that there is little anthropogenic impacts within the ANF [8].

Altitude was the best predictor of the relative abundances of the large and very large-bodied frugivores. However, while large frugivores were negatively associated with altitude, very large frugivores were positively associated with the same variable. A similar pattern was observed in some large-body terrestrial frugivores that remained in the highlands during the rainy season but moved to lowlands in the dry season, potentially attracted to the renewed supply of resources after the rainy season [12, 66].

We found a lack of association between the sampled community of terrestrial frugivores and the ameso-scale availability of fallen fruits and flowers. This result could be attributed in part to differences in ecological plasticity within the tropical fruit–frugivore networks. In tropical forests, the degree of generalization in the plant–frugivore network is determined by the vertical stratification of the forest [67]. These authors showed that canopy plants depended mostly on obligate frugivores, midstory plants on partial frugivores, and understory plants on opportunistic terrestrial frugivores [67]. Canopy plants contributed most to the overall fruit crop, therefore attracting a wide spectrum of obligate frugivores that moved over large distances choosing fruiting plants according to spatial and temporal availability. In contrast, opportunistic terrestrial frugivores foraged mostly in lower forest strata where fruit availability and choice were relatively more limited. As such, our findings support the idea that terrestrial fruit-frugivore relationships tend to be less strong and less affected by the fruit availability [67].

Studies from other Amazon terra firme forests can help to understand our observations of the groups of small to large frugivores in the ANF. Previous studies suggest that species dietary diversity and ability to adapt to a changing resource base are important traits in determining vertebrate responses to relative food reduction within terra firme forests [24]. It has also been shown that fruit–frugivore networks are also highly diffuse in this biome [12]. The interaction between medium to large-bodied frugivores and fruit resource suggests frugivory generalization in terra firme forests, compared with greater specialization in varzea forests for this group [12]. One driver of generalization in fruit–frugivore relationships could be dietary complementarity [67]. Diets of the studied groups are rarely entirely frugivorous, with fruit consumed in varying ratios depending on species specific interactions with habitat, season, fruit availability and the availability of alternative food sources [16, 27, 29, 30]. Thus, for small frugivorous mammals, there is evidence that leaf and fibre consumption increases during periods of fruit scarcity [29]. It has also been suggested that small-bodied species are less likely to be affected by habitat changes because they may be able to diverge through microhabitat specialization [24], supporting our results in this body-sized group.

5. 4. 3. Differences between species

Our study supports the preference of *Cuniculus paca* for low-lying areas near permanent water source [8]. On the other hand, *Mazama americana* and *Mazama nemorivaga* showed a greater number of detections in uplands within the study area. These observations support the importance of altitude as a driver and modulator of species meso-scale distribution patterns [38]. *Mazama nemorivaga* was also detected more frequently in areas further from water sources. Similarly, a previous study [8] found the same association in relation to streams for both *Mazama americana* and *Pecari tajacu* within the ANF. These results contrast to those from other studies in more arid regions, which found the dry season distribution of some ungulates were strongly influenced by water availability [1-4]. Keuroghlian, Eaton [68] reported seasonal movements of some ungulates apparently driven by availability of key fruits in the tropical forest. However, in our study the fruit and flower availability were not significant variables for recorded ungulates during the dry season.

Psophia crepitans was the only bird species with sufficient records for analysis. Fruit and seeds are known to form the bulk of the diet in *Psophia crepitans, Crax alector* and *Tinamus major,* however, it is known that *Psophia crepitans* also eats invertebrates in relatively large quantities [7]. We found that during the dry season, the presence of fruit and flowers had no significant effect on the abundance of *P. crepitans,* the most common bird in our study. Chatterjee and Basu [64] suggest that other factors like insect abundance may be important for frugivore bird groups that also rely on insects as their secondary diet. For these authors, a combination of fruit availability along with insect availability should explain the variation in frugivore bird density in space and time rather than fruit availably alone. Although our observation might support this conclusion, *C. alector* and *T. major* were bird species with insufficient number of records (< 5 records in different camera traps) and the relationship with the fruit and flower availability could not be evaluated. However, our study supports findings that *P. crepitans* has a preference for areas close to water availability and close to large rivers within Amazonian forests [7, 8].

Although camera traps are efficient for rapid inventories during the dry season [69], we must remain cautious in our conclusions. Capture frequencies with camera traps can give an idea of the relative abundance of different species, but may be affected by a variety of factors such as species-specific behavior (e.g. use or avoidance of trails, partly arboreal versus exclusively terrestrial, or habitat specialist versus generalist) [57, 60]. For this reason we limit our conclusions to differences in spatial encounter rates and do not attempt to imply population parameters (e.g. density).

5. 5. Conclusions

Our models could only partially explain abundance patterns in the recorded species and groups of frugivores during the dry season. The lack of association between frugivores and the fruit and flower availability could suggest that, at the meso-scale level (25 km^2), other factors may have more decisive roles during a scarcity period. We found that, at this scale, the distribution of frugivore species and functional groups can be partly explained by variables such as water availability and altitude. However, a substantial survey effort is necessary to ensure a representative sample of terrestrial frugivorous and to better understand the processes driving the spatial distribution of these vertebrate groups.

5. 6. Acknowledgments

The Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio) and the Federal University of Amapá (UNIFAP) provided logistical support. We thank IBAMA for authorization to conduct research in ANF (IBAMA/SISBIO permit 47859-1). We thank the Long-term Biodiversity Monitoring Program (PPBIO) for providing the grid system used during field activities. We are grateful to Cremilson and Cledinaldo Alves Marques for their invaluable assistance during fieldwork. We thank to Patrick Cantuária and Tonny Medeiros of the Instituto de Pesquisas Científicas e Tecnológicas do Estado de Amapá (IEPA) and to Antônio Magalhães of the Emilio Goeldi Museum of Pará State for helping with the botanical identifications. We are grateful to Yuri Breno da Silva, Victor Rodríguez-Chuma and Alexander Arevalo for their help during data collection and identification.

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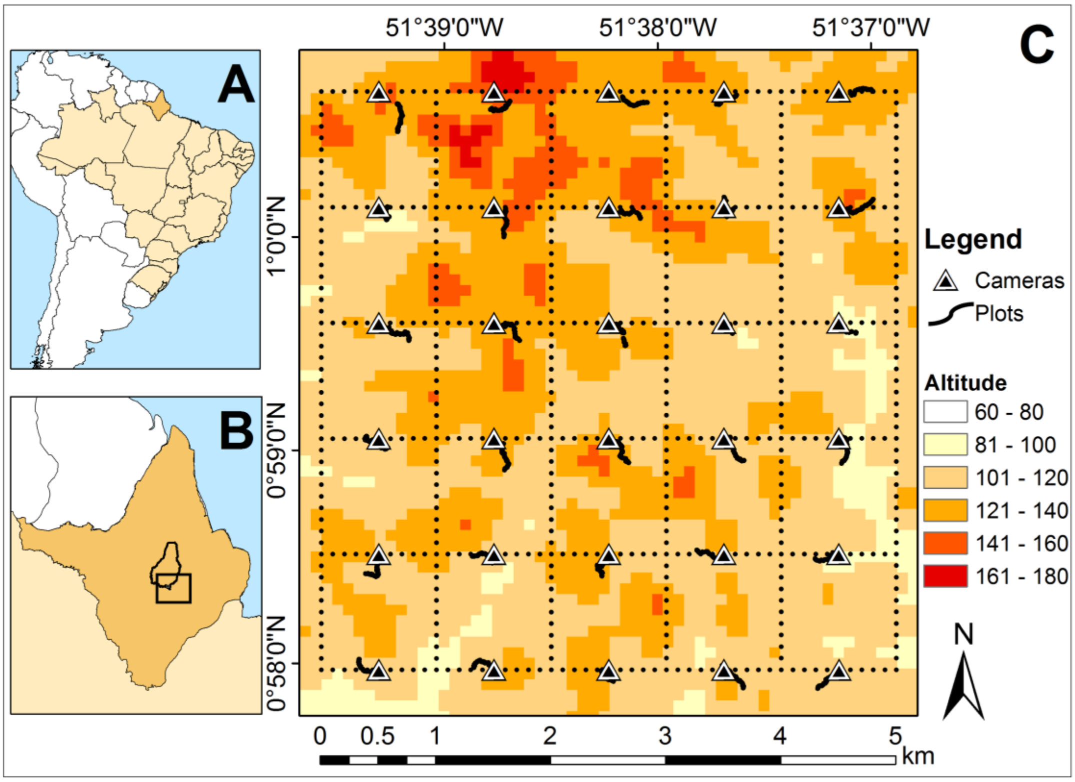
5. 8. Figure legends

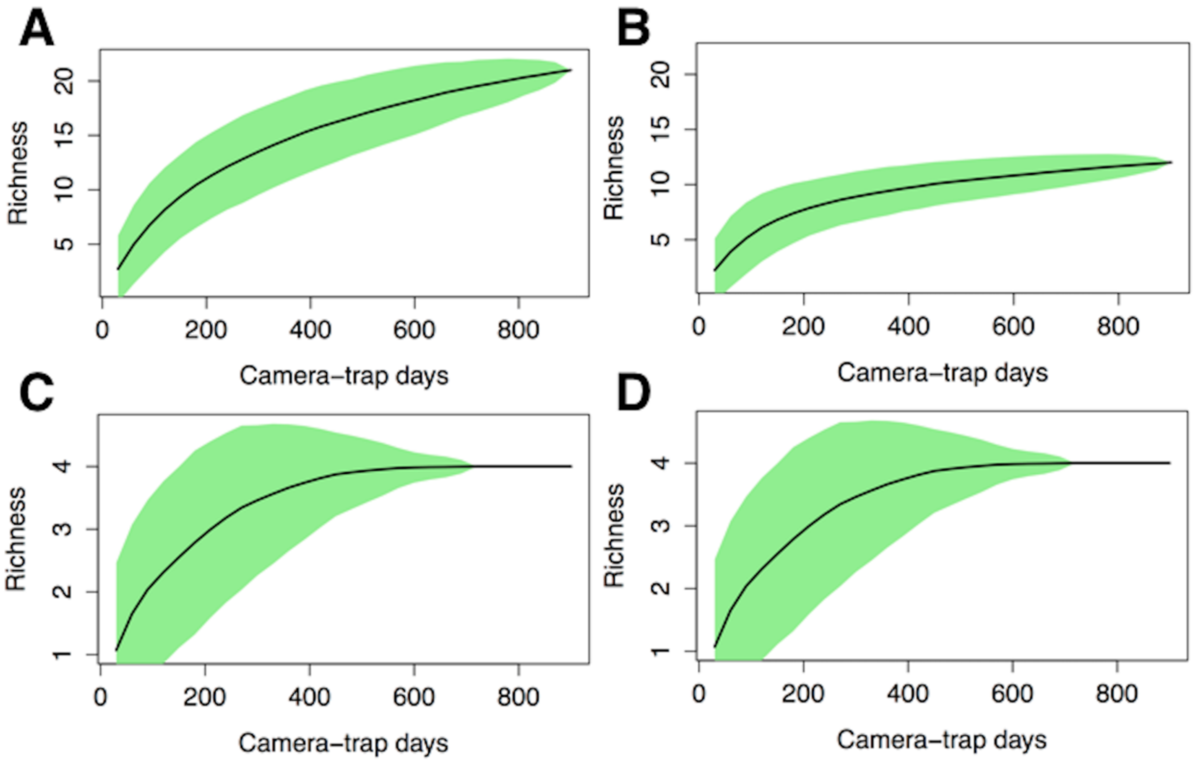
Figure 1. Location of the study region in the Amapá National Forest (ANF), Amapá State, eastern Brazilian Amazon. (A) Amapá State in Brazil; (B) ANF (polygon) in Amapá State; (C) Altitude (m) across the grid system (dotted lines), non-linear plots placed along topographic contours and linear plots along the trails (solid back lines) where the study was conducted. Camera traps were placed at 30 regularly spaced sample points (triangles).

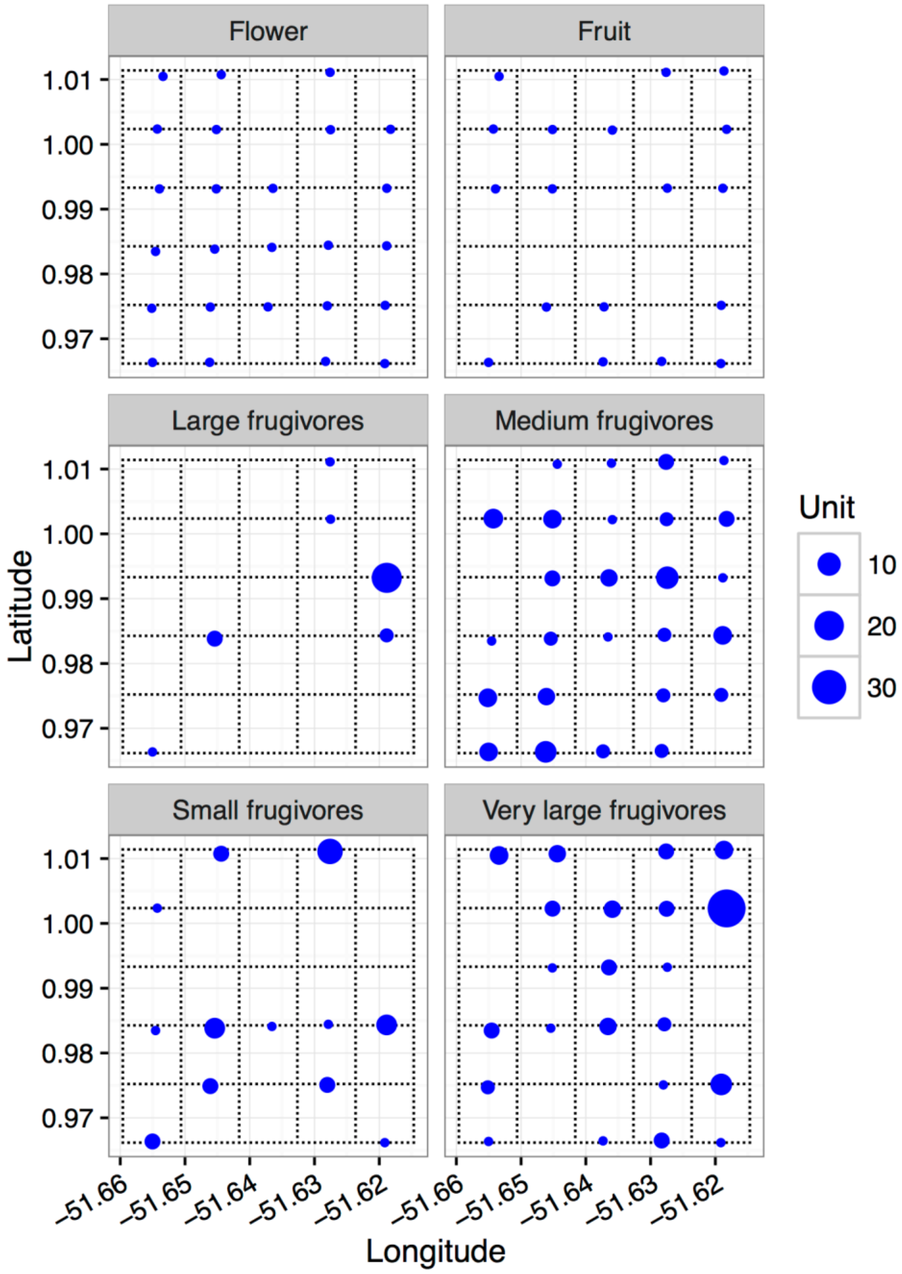
Figure 2. Cumulative curves for mammal and bird species sampled with camera traps in the dry season in the Amapá National Forest. Detection of species recorded in 900 camera-trap days randomized 1000 times and results used to derive mean (black line) 95% confidence intervals of the mean (light grey polygon). (A) Cumulative curve for all mammal species; (B) Cumulative curve for frugivorous mammals; (C) Cumulative curve for all bird species; (D) Cumulative curve for frugivorous birds.

Figure 3. Presence of fruits and flowers and number of photos of functional groups of frugivores per sampling point on a 25 km^2 grid, during the dry season in the Amapá National Forest, Brazil.



A
B
C
51°39'0"W
51°38'0"W
51°37'0"W
1°0'0"N
0°59'0"N
0°58'0"N
Legend
Cameras
Plots
Altitude
60 - 80
81 - 100
101 - 120
121 - 140
141 - 160
161 - 180
N
0
0.5
1
2
3
4
5
km


A
B
C
D
Richness
Camera–trap days
0
200
400
600
800
5
10
15
20
1
2
3
4


Flower
Fruit
Large frugivores
Medium frugivores
Small frugivores
Very large frugivores
Latitude
1.01
1.00
0.99
0.98
0.97
Longitude
-51.66
-51.65
-51.64
-51.63
-51.62
Unit
10
20
30

5. 9. Supporting Information Captions

S1 Table. Explanatory variables obtained during the dry season (October-December 2015) in the Amapá National Forest, eastern Brazilian Amazon.

S2 Table. List of fruits and flowers identified during the dry season (October-December 2015) in the Amapá National Forest, eastern Brazilian Amazon.

S3 Table. Number of independent captures obtained by camera trapping for all frugivorous obtained during the dry season (October-December 2015) in the Amapá National Forest, eastern Brazilian Amazon.

S1 Table. Exploratory variables obtained during the dry season (October-December 2015) in the Amapá National Forest, eastern Brazilian Amazon.

Exploratory variables (A – E) per sampling point on a 25 km^2 grid obtained during the dry season in the Amapá National Forest, Brazil.

Site	A*	B*	C*	D*	E*
1	110.44	2.19	1.68	1	1
2	107.58	2.23	1.04	1	1
3	123.89	1.90	1.14	1	0
4	119.17	1.13	0.53	0	1
5	117.92	0.76	0.43	1	1
6	100.36	2.70	1.38	1	1
7	120.39	3.17	0.40	0	1
8	127.94	2.50	0.63	1	1
9	105.22	1.96	0.15	1	1
10	115.72	1.37	1.05	0	1
11	110.53	3.16	0.99	0	1
12	110.19	3.97	0.71	0	1
13	124.61	3.20	0.33	0	1
14	124.58	2.24	0.34	0	1
15	116.67	1.23	0.70	0	1
16	101.64	2.85	0.01	1	1
17	101.53	3.79	0.03	1	0
18	115.50	4.79	0.98	0	1
19	129.44	2.25	0.39	1	1
20	118.11	1.35	0.60	1	1

21	140.31	2.63	0.50	1	1
22	112.69	3.66	0.54	0	1
23	136.25	3.56	1.13	1	0
24	140.58	2.65	0.11	1	1
25	104.53	1.78	0.09	1	1
26	132.06	2.81	0.67	1	0
27	124.72	3.76	0.33	1	1
28	134.06	4.16	1.28	0	0
29	148.39	3.15	0.46	0	1
30	132.53	2.30	0.14	1	1

* Variable names correspond to: A – Altitude (m), B – Distance to large rivers (km), C – Distance to nearest water (km), D – Fruit (presence vs absence), E – Flower (presence vs absence).

S2 Table. List of fruits and flowers identified during the dry season (October-December 2015) in the Amapá National Forest, eastern Brazilian Amazon.

List of 14 families and 21 species of fruits and flowers identified in all sampling points on a 25 km^2 grid during the dry season in the Amapá National Forest, Brazil.

Type	Family	Species
Flower	Caryocaraceae	*Caryocar glabrum*
		Caryocar villosum
	Lecythidaceae	*Eschweilera* sp.
Fruit	Annonaceae	*Guateria* sp.
	Arecaceae	*Astrocaryum* sp.
		Euterpe oleracea
		Oenocarpus bacaba
	Caryocaraceae	*Caryocar villosum*
	Chrysobalanaceae	*Licania* sp.
	Clusiaceae	*Clusia grandiflora*
	Fabaceae	*Inga* sp.
		Parkia pendula
		Vatairea guianensis
		Vouacapoua americana
	Lecythidaceae	*Eschweilera* sp.
		Gustavia augusta
	Malvaceae	*Theobroma subincanum*
	Melastomataceae	*Bellucia grossularioides*
	Meliaceae	*Carapa guianensis*
	Myristicaceae	*Virola surinamensis*
	Sapotaceae	*Chrysophyllum durifructum*

S3 Table. Number of independent captures obtained by camera trapping for all frugivorous obtained during the dry season (October-December 2015) in the Amapá National Forest, eastern Brazilian Amazon.

Number of independent captures obtained by camera trapping for 16 species of frugivorous (A-P) per sampling point on a 25 km^2 grid during the dry season in the Amapá National Forest, Brazil.

Site	A*	B*	C*	D*	E*	F*	G*	H*	I*	J*	K*	L*	M*	N*	O*	P*
1	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0
2	0	0	0	0	1	0	0	3	0	0	0	0	0	0	1	0
3	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0
4	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	5	0	0	0	0	0	1	0	0	0	0	0	1	3	0	0
6	0	0	0	1	1	0	2	6	0	0	0	0	0	0	0	0
7	1	0	0	0	0	1	0	0	0	0	0	0	0	3	1	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	2	2	0	0	0	0	0	0	0	0	0	0	0	3	0	0
10	2	0	0	0	0	1	1	0	0	0	1	0	0	0	2	0
11	4	0	0	0	0	0	0	0	0	1	0	0	2	7	0	0
12	1	1	0	0	0	0	1	0	1	0	0	0	0	0	0	1
13	1	0	1	0	0	0	0	4	0	0	0	0	0	0	0	0
14	2	0	3	0	0	1	0	0	0	0	0	0	3	4	0	0
15	1	0	0	0	0	0	0	3	0	0	0	0	0	1	0	0
16	1	0	0	0	0	0	0	0	0	0	0	1	20	0	0	0
17	7	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0
18	1	0	0	0	0	1	1	0	1	0	0	0	0	0	3	0
19	3	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0

20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	2	0	0	0	0	18	7	11	3	0	0	0	0	0	1	0
22	0	1	0	0	0	0	0	3	0	0	0	0	1	0	1	0
23	1	0	0	0	0	3	0	0	1	0	0	0	0	0	0	0
24	3	0	0	1	0	0	1	2	0	1	0	0	0	0	0	0
25	6	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	1	0	4	0	1	0	0	0	0	0	0	0	0
27	2	0	1	0	1	1	0	2	0	0	0	0	1	12	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
29	1	0	0	0	0	2	1	1	0	0	0	0	0	3	0	0
30	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0

* Species names correspond to: A – *Psophia crepitans*, B – *Crax alector*, C – *Crypturellus erythropus*, D – *Tinamus major*, E – *Didelphis marsupialis*, F – *Mazama americana*, G – *Mazama nemorivaga*, H – *Pecari tajacu*, I – *Tapirus terrestris*, J – *Eira barbara*, K – *Nasua nasua*, L – *Procyon cancrivorus*, M – *Cuniculus paca*, N – *Myoprocta acouchy*, O – *Dasyprocta leporina*, P – *Sciurus aestuans*.

6. CONCLUSÕES

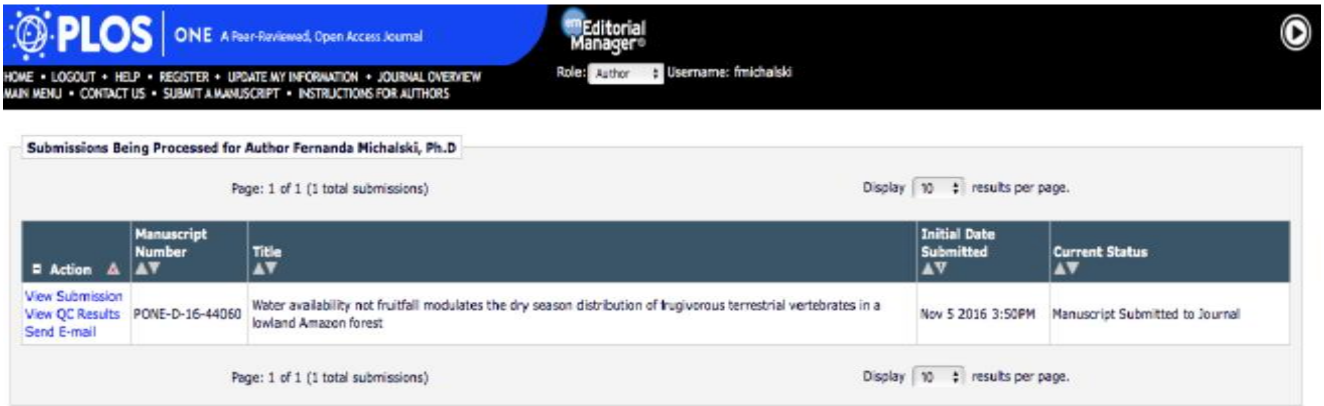
- Nosso estudo demonstra que durante um evento de escassez de recursos em florestas tropicais, a disponibilidade de água é claramente mais importante do que a presença de frutos caídos.

- No nível meso-escala (25 km^2), a distribuição de espécies frugívoras e grupos funcionais podem ser parcialmente explicados por a altitude.

- O tamanho do corpo não foi um determinante forte nas respostas dos frugívoros terrestres ao período de escassez de frutos; aparentemente outros traços funcionais como a diversidade alimentar e capacidade de adaptação de uma espécie poderiam ser características mais importantes na determinação de respostas de vertebrados à redução relativa de alimentos em florestas de terra firme.

- Um grande esforço de amostragem e o uso de técnicas complementares é necessário para assegurar a captura de todo o espectro de frugívoros terrestres e compreender melhor os processos que conduzem à distribuição espacial destes grupos.

ANEXO 1. Submission Confirmation for PLOS ONE



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