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**INTERAÇÃO ENTRE VERTEBRADOS E FRUTOS/SEMENTES EM UMA
FLORESTA DE IGAPÓ NA AMAZÔNIA CENTRAL**

ANA CAROLINA ANTUNES

Manaus, Amazonas
Abril, 2016

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FLORESTA DE IGAPÓ NA AMAZÔNIA CENTRAL**

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Sinopse

Estudou-se as interações animal-planta que ocorrem em uma floresta de igapó. Avaliou-se a possível interação entre roedores e frutos/sementes baseado na dimensão das mordidas deixadas nos frutos, bem como o papel de agregados de sementes no uso do habitat por espécies de vertebrados em uma floresta de Igapó, no Parque Nacional do Jaú.

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INTERAÇÃO ENTRE VERTEBRADOS E FRUTOS/SEMENTES EM UMA FLORESTA DE IGAPÓ NA AMAZÔNIA CENTRAL

Resumo

Em florestas de igapó, a dinâmica da água durante a vazante dos rios é responsável pela formação de agregados de sementes. As interações animal-planta que ocorrem nesse ambiente, bem como a influência dos agregados de sementes na ocorrência de vertebrados frugívoros e granívoros são desconhecidas. Este trabalho está dividido em dois capítulos e investigamos i) a possível interação entre roedores e frutos/sementes baseado na dimensão das mordidas deixadas nos frutos e ii) o papel dos agregados de sementes no uso do habitat por espécies de vertebrados em uma área de floresta de Igapó, no Parque Nacional do Jaú. Roedores possuem dentição altamente especializada, e as dimensões dos incisivos são características para cada espécie. No capítulo um, testamos uma metodologia raramente utilizada: usamos as marcas deixadas pelos dentes incisivos de roedores em frutos e sementes para a identificação desses consumidores. A largura das marcas dos incisivos, feitas em blocos Plasticine™ utilizando crânios de coleções de museus, foram comparadas com as marcas deixadas em frutos e sementes coletados em campo. Foi confirmada a existência de relação alométrica entre a largura dos incisivos e o tamanho do corpo. Além disso, frutos maiores e mais duros mostraram marcas de mordidas maiores em comparação com frutos/ sementes menores e macios, indicando a importância do tamanho do fruto e dureza na seleção do item pelo roedor. Baseado nas medidas de largura dos incisivos, os resultados também mostraram que os frutos/ sementes menores são usados por um menor número de espécies de roedores, em comparação com frutos de tamanho maior, sendo estes mais susceptíveis ao consumo. Devido à sobreposição no tamanho do corpo das espécies, este método não proporcionou identificações precisas dos roedores que consomem itens específicos, mas em média reduziu o conjunto das prováveis espécies em 46%. Quando utilizado paralelamente a outros métodos, esta técnica é viável devido ao fácil uso e baixo custo. No capítulo dois, utilizei armadilhas fotográficas em áreas com e sem a presença dos agregados de sementes, para avaliar a possível relação entre esses locais de acúmulo e a presença

de espécies de aves e mamíferos. Foi observado que a presença dos agregados não está relacionada com maior ocorrência da assembléia de vertebrados. No entanto, há uma relação positiva entre a ocorrência de predadores e a distribuição espacial da assembléia de vertebrados, demonstrando que esses predadores podem estar seguindo suas presas potenciais no igapó não inundado. A ocorrência generalizada destes animais pelo igapó, não apenas concentrando-se onde ocorrem altas densidades de recursos alimentares, parece ser a estratégia usada para selecionar os itens alimentares mais favoráveis, evitando o maior risco de predação ao forragear por períodos prolongados nos locais onde as sementes estão agregadas. Em conjunto, nossos resultados reforçam a importância potencial de florestas de igapó como um habitat-chave para uma variedade de taxas terrestres de terra firme, e abrem caminho para estudos adicionais.

INTERACTION BETWEEN VERTEBRATES AND FRUITS/SEEDS IN AN IGAPÓ FOREST IN CENTRAL AMAZON

Abstract

In igapó forests, water dynamics during river level recession is responsible for the seed patch formation. Animal-plant interactions that occur in that environment, as well as patches' influence on frugivorous and granivorous vertebrates' occurrence are unknown. This work is divided into two chapters and investigates i) the possible interaction between rodents and fruit/ seed, based on the bite sizes left in the fruits and ii) the role of seed patches in overall habitat use by vertebrate species in an igapó forest in Jaú National Park. Rodents have a highly specialized dentition, and incisor dimensions are very characteristic within each species. In chapter one, we field-tested a rarely-used methodology – using marks left by rodent incisors in fruits and seeds to identify the feeding species. The width of the incisors marks made in Plasticine™ blocks, using skulls in museum collections, were compared with the marks left on field-collected fruits and seeds. We confirmed the existence of an allometric relationship between incisors width and body size. Furthermore, larger and harder fruits showed larger bite marks compared with smaller and soft fruits/seeds, indicating the importance of fruit size and hardness in rodent food-plant selection. Based on tooth width measurements, the results also showed that smaller fruits/seeds are used by fewer rodent species, in comparison to fruits of larger size, these being more likely to be consumed and/or predicated. Due to an overlap in body size between species, the method did not provide precise identifications of the rodent species consuming particular items, although it does reduced the likely suite of species in 46%. However, when used in conjunction to other methods, this is highly viable field technique due to its easy use and low cost. In chapter two we report on the deployment of camera traps in areas with and without the seed patches to examine the relation between these accumulation sites and birds and mammals species presence. It was recorded that vertebrates assemblage occurrence is not related to patch presence. However, there is a positive relationship between predator occurrence and spatial distribution of the vertebrate assemblage, indicating that predator species may be following their potential prey in unflooded igapó, and so

possibly erasing granivore/seed associations that might otherwise occur. The widespread occurrence of these seed eaters animals throughout igapó, not only where are high density food resources, seems to be a compromise strategy that balances between selecting the most favorable food items with avoiding the higher predation risk of being foraging for prolonged periods at the seed patches. Our results underscore the potential importance of igapó forests as a key habitat for a variety of terra firme terrestrial taxa, and open the way for further studies.

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Introdução geral

Identificação de roedores

Roedores são um dos principais consumidores e dispersores de sementes e frutos em diversos ecossistemas, no entanto há pouca informação disponível, especialmente relacionada à sua história natural (IUCN, 2016). Esses animais possuem uma dentição altamente especializada, e a morfologia dos incisivos é característica dentro de cada grupo (Forget 1993; Jansen et al. 2004; Sunyer et al. 2013; ver Hulme 1998 para revisão). Mas de maneira em geral, o tamanho dos incisivos tende a variar alometricamente em relação às dimensões do corpo das espécies (Creighton, 1980; Creighton e Strauss, 1986). A variação de tamanho e características morfológicas dos incisivos dos roedores abre a possibilidade de identificar a presença e dieta das espécies a partir de marcas de mordida em restos de itens alimentares. No capítulo I, nós testamos a viabilidade de se utilizar a marca dos incisivos deixadas em frutos e sementes por roedores como indicador da identidade das espécies de consumidores em uma assembléia de roedores do Parque Nacional do Jaú. Essa metodologia consiste em comparar a largura das marcas dos incisivos feitas em blocos Plasticine™, utilizando crânios de coleções de museus identificados por especialistas, com as marcas deixadas em frutos e sementes coletados em campo.

Bancos de sementes de igapó

Cada vez mais as florestas de igapó vêm sendo reconhecidas como importante fonte de recursos alimentares para animais de florestas de terra firme adjacentes (Beja et al. 2010, Ramos Pereira et al. 2013, Barnett et al. 2012). Para árvores de florestas alagáveis da Amazônia, a hidrocoria e ictiocoria são modos de dispersão comuns, e a disponibilidade de frutos ocorre em pulsos sincronizados em grande parte da comunidade de plantas (Parolin et al. 2013). À medida que o nível da água baixa, os frutos e sementes flutuantes acumulam-se em obstáculos como troncos flutuantes, árvores caídas (Barnett et al. 2012) ou em áreas de relevo específico (especialmente os mais elevados) e de baixa correnteza da água. Estas “balsas” de sementes são então

depositadas no chão da floresta, e muitas germinam. A existência dos agregados de sementes e plântulas já foi descrita anteriormente (Piedade et al. 2010, Ferreira et al. 2010), porém não existem informações sobre como eles afetam o uso do habitat dos vertebrados que habitam a região. No capítulo II nós damos início a tais investigações, analisando como os agregados de sementes influenciam a ocorrência de vertebrados potenciais consumidores desses recursos disponíveis, em uma floresta de igapó no Parque Nacional do Jaú. Nós comparamos a ocorrência de vertebrados nos agregados de sementes e em áreas controle, além de apresentarmos uma lista das espécies registradas por armadilhas fotográficas para a região.

Objetivos

- Testar a viabilidade de marcas de mordida de roedores como indicadores da identidade das espécies consumidoras de frutos/sementes em uma assembléia de roedores de uma floresta de igapó.
- Avaliar se os agregados de sementes estão positivamente relacionados com a presença de espécies de mamíferos e aves na floresta de igapó do Parque Nacional do Jaú.

Capítulo I.

Antunes, A.C.; Baccaro, F. and Barnett, A.A. **What bite marks can tell us: use of on-fruit tooth impressions to study seed consumer identity and consumption patterns within an assemblage of terrestrial and scansorial Neotropical rodents.** Manuscrito em revisão na *Mammalian Biology*.

What bite marks can tell us: use of on-fruit tooth impressions to study seed consumer identity and consumption patterns within an assemblage of terrestrial and scansorial Neotropical rodents

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Abstract

Rodents have a highly specialized dentition, and incisor dimensions are very characteristic within each group. In this study we field-tested a rarely-used methodology – using marks left by rodent incisors in fruits and seeds to identify them. The width of the incisors marks made in Plasticine™ blocks, using skulls from museum collections, were compared with the marks left on field-collected fruits and seeds. We confirmed the existence of allometric relationship between incisors width and body size. Furthermore larger and harder fruits showed larger bite marks compared with smaller and soft fruits/seeds, indicating the importance of fruit size and hardness in rodent food-plant selection. Based on tooth width measurements, the results also showed that smaller fruits/seeds are used by fewer rodent species, in comparison to fruits of larger size, these being more likely to be consumed and/or predated. Due to an overlap in body size between species, the method did not provide precise identifications of the rodent species consuming particular items, although it does reduce the likely suite of species responsible. However, when used in conjunction to other tools, this method is highly

viable due to easy use and low cost. Future studies using bite marks images and a greater range of morphological features could increase the precision of this technique.

Keywords

Allometry . Fruit . Incisor . Rodentia . Tooth

Introduction

Rodent assemblages are often species rich, ranging from 4-6 sympatric species in temperate areas to 15 or more in the tropics (Glanz 1982). In the tropics it is common for rodents to range across an order of magnitude (e.g. *Mus minutoides* 3-12 g to *Cricetomys gambianus* 1–1.4 Kg: Barnett et al. 2000; *Oligoryzomys* spp. 10-25 g to *Cuniculus paca*, 6-14 Kg: Eisenberg and Redford 2000). Unlike other mammalian orders (e.g. Gittleman and Valkenburgh 1997 - canids; Plavcan and Key 1988 - primates; Shine 1989 for general review), rodent anterior dentition is used almost exclusively for food processing (see Rodrigues et al. 2011 for an exception). Consequently, incisor size is likely to scale allometrically with the body dimensions of a species (Creighton 1980; Creighton and Strauss 1986). Incisor dimensions are often highly characteristic for a given rodent species, and are considered key in the ecological structuring of species assemblages (Ben-Moshe et al. 2001). Their dimensions may distinguish sympatric congeners (Dayan and Simberloff 1994). In addition, within a sympatric rodent assemblage, there may be consistent variations between species of the same size class due to phylogeny or dietary specialization (Samuels 2009). In rodent assemblages where there is a range of sizes and ecological roles, this opens the possibility of identifying species' presence and diet from bite marks on food remnants alone.

The identification of rodent species from bite marks is of potential value as a field technique since determining their diets has generally involved analysis of faecal pellets (Pulliam and Brand 1975; Meserve 1981), stomach contents (Taylor and Green 1976; Barnett et al. 2000; Gebresilassie et al. 2004), or material obtained from stomach pumping (Kronfeld and Dyan 1998). However, all three methods suffer from problems with comminution, so that the material analyzed consists of small particles that are easier to assign to a food type, but often hard to assign taxonomically to a genus or

species (Hansson 1970; Barnett and Dutton 1995), especially when the ingested material is seed or fruit pulp (Barnett et al. 2000). This methodological shortfall is unfortunate since in many ecosystems, rodents are one of the major seed and fruit predators and dispersers (Forget 1993; Jansen et al. 2004; Sunyer et al. 2013; see Hulme 1998 for review).

Bite marks on seeds and fruits (Fig. 1) would allow a record of which rodent species were visiting an area, and, since the seeds and/or fruits of many plants groups are sufficiently well known for them to be identified to species (e.g. van Roosmalen 1985; Cornejo and Janovec 2010), exactly what they were eating. Also, it offers a way to gain additional information on rodent species distribution, abundance, habitat use and natural history. Using bite marks is simple and non-invasive, compared to other identification methods, which may require cytogenetic and molecular techniques (Aniskin and Volobouev 1999), besides the animal capture and handling. From a botanical perspective this technique is also advantageous as it would also allow the nature and extent of seed predation by rodents to be quantified with some precision. This technique has already proved efficient for identification of foods eaten by adult pacas (*Agouti paca*), which incisor marks are larger than 4 mm (Beck-King et al. 1999). To extend this application, we set out to test the viability of rodent bite marks as indicators of seed/fruit consumer species identity across an entire rodent assemblage.

Fig.1 The fruits of *Macrolobium acaciifolium* (A) and *Swartzia laevicarpa* (B) showing damage patterns rodents characteristic. The arrows indicate the marks left by the incisors and that can be used for species identification.

Methods

Study site

The study was undertaken in terra firme (non-flooded) and igapó (seasonally flooded) forests (sensu Prance 1979) in Jaú National Park (JNP), a 2,700,000-ha protected area in central Amazonian, Brazil. Major vegetation types at JNP include terra firme forest and igapó forest accounting for 70% and 12% of the park, respectively (Borges et al. 2004). The study site was located between Cachoeira do Jaú (01°53.21"S, 61°40.43"W) and Patuá village (01°53.16"S, 61°44.31"W) (Fig. 2)

Fig. 2 Location of Jaú National Park, Brazil, in relation to Manaus and Rio Negro.

Whenever seeds or fruits were found that bore rodent tooth marks (Fig. 3), they were collected and hardness (penetrability) measured. Only species for which we had more than four records of bitten fruit/seeds records were used in subsequent analysis. Plant species were identified by comparison with a photographic database compiled for general studies of *Cacajao ouakary* diet (Barnett 2010). The fruit length and width were measured to estimate the mean size of each fruit or seed. All fruits or seeds measurements were checked, whatever possible, with previous studies allowing a more precise fruit/seed identification (Parolin et al. 2010, for a review). All fruits and seeds with tooth marks were classified as soft, when penetrometer values were < 1 kg, and hard for values > 2 kg. Values between these were classified as intermediate (Barnett et al. 2015a). The width of the mark was measured to the nearest 0.1mm using SPI 2000 dial calipers (Swiss Precision Instruments, Garden Grove, CA, USA).

Fig. 3 Bite marks in a *Macrolobium acaciifolium* fruit. The width of the mark and the hardness (penetrability) of the fruit was measured.

From IUCN shapefiles and the Small Mammals of South America (Patton et al. 2015), a list of rodent species was created for the JNP (Table 1). We used this list to create a database for comparison and identification of rodent species consuming the fruits and seeds. Incisors in skulls of already-identified specimens from the mammal collections of the National Institute of Amazonian Research (INPA), the Zoology Museum of São Paulo University (USP) and the Natural History Museum, London (NHM) were pressed into 25 mm x 25 mm x 0.5 mm blocks of Plasticine (Mattel™) leaving an impression of the width and thickness of the cutting edge of the paired incisors. As Plasticine does not dry out (unlike Play-Dough and other alternatives), such blocks remain as a permanent reference collection of initial bite form. The bite mark widths on the Plasticine blocks were compared with the marks left by rodents on seeds/fruits collected at Jaú. Part of the body length data for rodent species was obtained directly in mammals INPA collection, and the remainder was taken from the literature (Bonvicino et al. 2008; Patton et al. 2015). Where needed, tail length was subtracted from total length to provide the body length data used for the analyses preparation.

Table 1. List of rodent species derived from the IUCN shapefiles for JNP, covering all groups potentially present in the study area.

Data analysis

We regressed tooth width against the body length to investigate whether the allometric relationship previously described for these two variables in rodents holds for the subset of species that occurs in JNP. As sources of metric data, we used measurements from the museum-derived tooth-marks in the Plasticine blocks and species body sizes reported in literature.

We used an Analysis of Covariance (ANCOVA) to investigate the relation between the mean width of incisor bite mark left by rodents in fruits/seeds at Jaú, and the mean sizes of fruits/seeds using fruit/seed hardness as a grouping factor. Both variables were log10 transformed to meet model assumptions. Fruit sizes were estimated considering the surface area of an ellipse, and using the formula: $A = \pi \cdot a \cdot b$. Where A is the fruit/seed area, a is the fruit/seed length and b the fruit/seed width.

We cross-matched the tooth widths from the Plasticine blocks with the bites marks left in the fruits/seeds found at JNP to create a possible list of rodent species interacting with each plant species. To investigate whether fruit/seed size has a role in rodent species diet selection, we used the total number of possible rodent species interacting with each plant species as an independent variable against the mean fruit/seed size in a generalized linear model with Poisson distribution. We used Poisson distribution in both models to account for residual variation from count data (number of possible rodent species interacting with each plant species). We also included the hardness of the fruit or seed as a covariate in the model. We compared the full model (fruit size and fruit/seed hardness) with a null model to test for model significance. We also reported the McFadden's pseudo r^2 as a measure of model fit (Long 1997). All analyses were done in R environment (R Core Team 2015).

Results

Of the 22 rodent species potentially present at JNP, two could not be found in the visited mammals collections (*Makalata macrura* and *Nectomys rattus*). *Hydrochoerus*

hydrochoeris was not included in the current study-since fruit and seeds do not form part of the *H. hydrochoeris* diet (Barreto and Quintara 2013). A new *Makalata* sp. from JNP, present in the INPA collections and in process of being described (Miranda CL, pers. comm.) was included in the analysis.

An allometric relation between tooth and body size holds for the assemblage of rodents from JNP (Fig.4). Rodent body length can explain ~76% of tooth width variation for this subset of species ($r^2 = 0.76$; $F_{1,32} = 101.9$; $p < 0.001$).

Fig.4 Tooth widths and body sizes of rodents present in JNP (see methods for details of data sources). Each point represents a species.

Fruit size and hardness have an important role for rodent plant selection (Fig. 5). Harder fruits/seeds possessed larger bite marks compared with soft ones (ANCOVA; $R^2 = 0.55$; $F_{2,30} = 18.92$; effect of fruit/seed size: $p = 0.002$; effect of fruit/seed hardness: $p < 0.001$).

Fig. 5 Bite marks and fruit/seeds area of plant species sampled in JNP. Each point represents one plant species.

The identity of the possible rodent species interacting with each plant species (based on incisor width) is given in the appendix. Though this is based only on incisor width measurements, the confirmed relationship between incisor size and body size (see Fig. 4), shows that larger species tend to eat larger, and harder, fruits (Fig. 5).

On average, the number of possible rodent species interacting with each plant species could be narrowed down in 46% using the incisor tooth marks left on fruits/seeds. Some plant species such as *Amanioua oblongifolia*, *Inga obidensis* and *Theobroma sylvestre* had bite marks ranging from 0.12 to 0.44 cm, which encompass the tooth width of 77% of all rodent species that occurs in the area. Conversely, *Casearia* sp. and *Chrysophyllum sanguinolentum*, had bite marks ranging between 0.12 to 0.15 cm and 0.68 to 0.72 cm encompassing the tooth width of only *Oecomys bicolor* and *Cuniculus paca* rodent species, respectively. At assemblage level (Fig. 6), smaller fruit/seeds tend to interact with fewer rodent species compared with larger ones, and the fruit or seed hardness have no effect (pseudo $r^2 = 0.22$; $p = 0.001$).

Fig. 6 Total number of possible rodent species (based on tooth width measurements) in relation to the mean fruit/seed size for plant species from JNP. Each point represents a plant species.

Discussion

There was a clear relation between the body length and incisor width within the known rodent assemblage for JNP. Our results corroborate previous studies (Lessa and Patton 1989; Mora et al. 2003; Samuels 2009; Vassallo et al. 2015), reinforcing the existence of this allometry in the rodents groups present at JNP. As expected, we found an increase in the width of the incisor teeth, increasing in direct proportion to the size of the animal for almost all species (Fig. 4).

Based on the allometric relationship between incisor width and body size, it is possible to relate the animal's size with the mean volume of each fruit that was bitten by that species. The results show that larger species appear to be biting larger and harder seeds, while the small species choose the smaller and softer ones (Fig. 5). Previous work has shown that seed dispersers of different sizes respond to different seed traits, such as size or mass (Yi and Wang 2015). Muñoz and Bonal (2008) found that seeds heavier than 70% of the mean mass of a rodent species are not removed by that species. Furthermore, it is known that the relation between the rodent mass and the seed mass is an important factor affecting the predation probability (Galetti et al. 2015).

The higher nutritional reward gained from consuming larger seeds (Kerley and Erasmus 1991) explains the patterns of seed consumption for the larger rodent species. However, for smaller species, manipulation of proportionately larger seeds is likely to be more physically difficult and costly in both terms of time and energy. Since seed size is frequently correlated to handling time, manipulation of larger fruits or seed by smaller rodent species likely decrease the efficiency of foraging (Stephens and Krebs 1986; Kerley and Erasmus 1991, Waite and Ydenberg 1994). This may also influence vigilance and hence increasing predation risk (Lima et al. 1986).

Although it is known that the morphological characteristics of incisors (protrusion, incisors cross-sectional area, muscles of the jaw) in rodent groups have positive

allometric relation with the animal's mass/body size (Lessa and Patton 1989, Mora et al. 2003, Samuels 2009), these are also directly correlated with the animal bite force (Becerra et al. 2011, 2012). Thus, the body size is related to the ability to eat hard items, with larger rodents being more easily able to consume items requiring greater bite force, as shown in our results (Fig. 5).

Our analysis did not achieve full separation of all species in the Jaú rodent assemblage purely on the basis of incisal width. This is, perhaps, not unsurprising, as there was also a concomitant overlap in body size between species (see Fig. 4), especially when juvenile individuals are included, as in the present study. Despite this, our data suggests that some fruits may be consumed by several rodent species while other by just a small proportion of the overall rodent assemblage. Overall, larger seeds and fruits tend to be more often attacked by rodents than smaller ones, independent of their hardness (Fig. 6), evidence that the size of a seed/ fruit influences the number of rodent species that will interact with it. There is also a considerable variation in the number of possible rodent species interacting with medium and larger fruit/seeds sizes. As discussed above, seed size is usually positively related to their overall energy content (Wall 1995; Castro et al. 2006), which explains the demand for these items by a greater number of species in the Jaú rodent assemblage. In our results, even for the hardest fruits, which may require more extensive handling, and hence enhances the risk of predation, energy reward appears to be the factor that best explains the result observed in Fig. 6. Wang and Chen (2009) found that, facing with seeds experimentally-manipulated to lack any energy content, rodents chose the larger ones, suggesting this feature functions as a proxy for others.

The methodology developed has some limitations; nevertheless this does not invalidate it as a simple useful tool that is, low-cost, non-invasive and easy to use under field conditions. Beck-King et al. (1999) found it is not possible to distinguish between subadult pacas (*Agouti paca*) and adult Central American agoutis (*Dasyprocta variegata*) using only bite marks. Similarly, it was not possible to separate the marks left by young or subadult and adult animals in this study. However, this may bring relevant information when the number of species occurring is reduced so that less overlap in the

body length and incisors width values occurs (e.g. Beck-King 1999; Barnett et al. 2015b). Further precision may be possible with a more nuanced approach that includes such features as incisor tooth thickness (which is known to vary between congeners: Samuels 2009), the curve of the teeth, the size of the space between them, and the presence of marks left by the grooves present (in some species) on the surface of the anterior enamel.

Conclusion

Using rodent bite marks on fruits and seeds clearly have ecological utility as it reveals at least which suite of species are attacking fruits and seeds, even if it does not always identify precisely which ones. The method is particularly relevant for studies that use bite marks to gain other ecological information, such as size-related foraging studies and data on the identity of plant species used by rodents. More generally, the seed size/rodent size ratios can help gain an understanding of the seed dispersal patterns, as well as which plant species are most consumed by rodents. It may be possible to improve the specificity of this technique by incorporating finer-scale features of inter-specific dental variation into the data set.

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Conflict of Interest The authors declare that they have no conflict of interest.

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SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article:

Appendix S1 Table listing the identity of the possible rodent species interacting with each plant species (based on incisor width). The list includes all species of plants found in the area, however only species for which we had more than four records of bitten fruit/seeds records were used in subsequent analysis.

Appendix S2 Table listing the rodent species measured in each collection, the incisors width (mm) based on the Plasticine blocks marks, the body length (mm) and the identification (ID) from its museum collections.

Appendix S3 Table listing the plant species with bite marks and the fruits size.

Family	Species
Caviidae	<i>Hydrochoerus hydrochaeris</i>
Cricetidae	<i>Euryoryzomys macconnelli, Holochilus sciureus, Hylaeamys megacephalus, Hylaeamys yunganus, Nectomys rattus, Oecomys bicolor, Oecomys concolor, Oecomys roberti, Rhipidomys leucodactylus</i>
Cuniculidae	<i>Cuniculus paca</i>
Dasyproctidae	<i>Myoprocta pratti</i>
Echimyidae	<i>Dactylomys dactylinus, Isothrix negrensis, Makalata macrura, Mesomys hispidus, Proechimys cuvieri, Proechimys echinothrix, Proechimys steerei</i>
Erethizontidae	<i>Coendou prehensilis</i>
Sciuridae	<i>Sciurus aestuans, Sciurus igniventris</i>

Table 1. List of rodent species derived from the IUCN shapefiles for JNP, covering all groups potentially present in the study area.

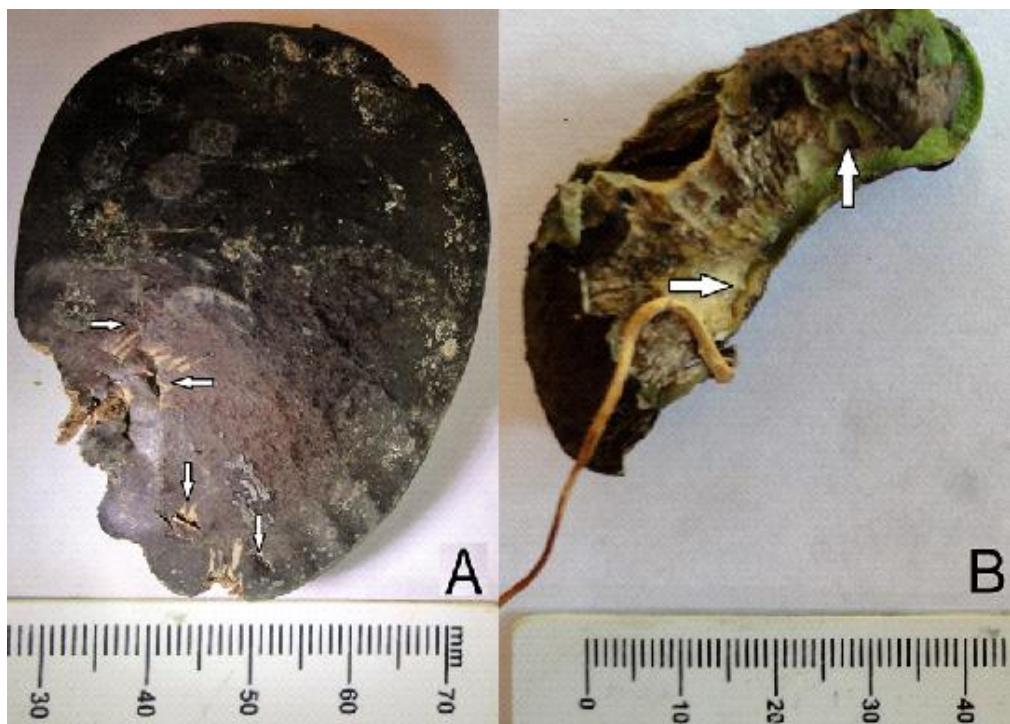


Fig.1 The fruits of *Macrolobium acaciifolium* (A) and *Swartzia laevicarpa* (B) showing damage patterns rodents characteristic. The arrows indicate the marks left by the incisors and that can be used for species identification.

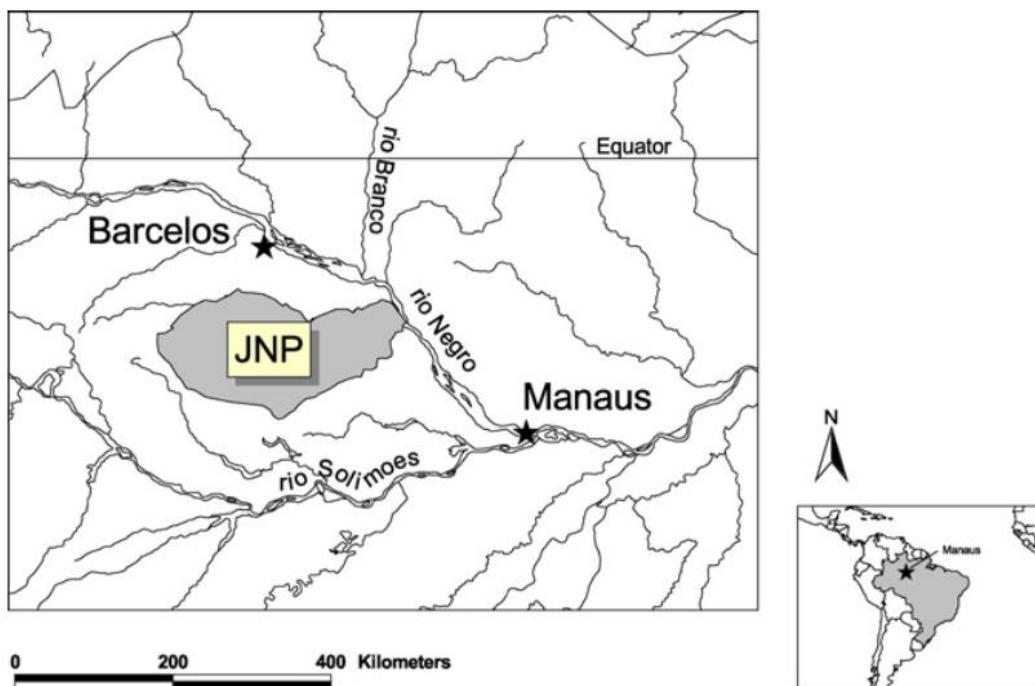


Fig. 2 Location of Jaú National Park, Brazil, in relation to Manaus and Rio Negro, Amazonas, Brazil.



Fig. 3 Bite marks in a *Macrolobium acaciifolium* fruit. The width of the mark and the hardness (penetrability) of the fruit was measured.

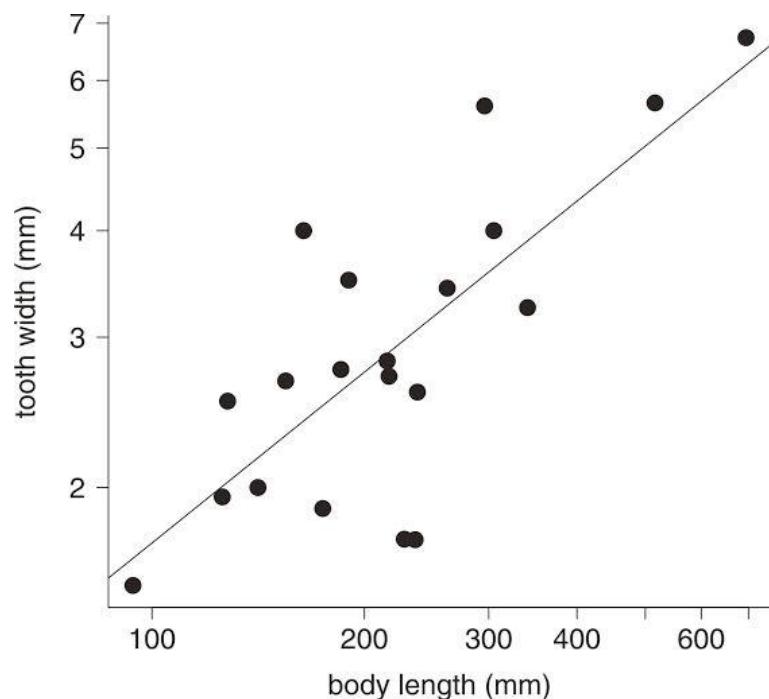


Fig.4 Tooth widths and body sizes of rodents present in JNP (see methods for details of data sources). Each point represents a species.

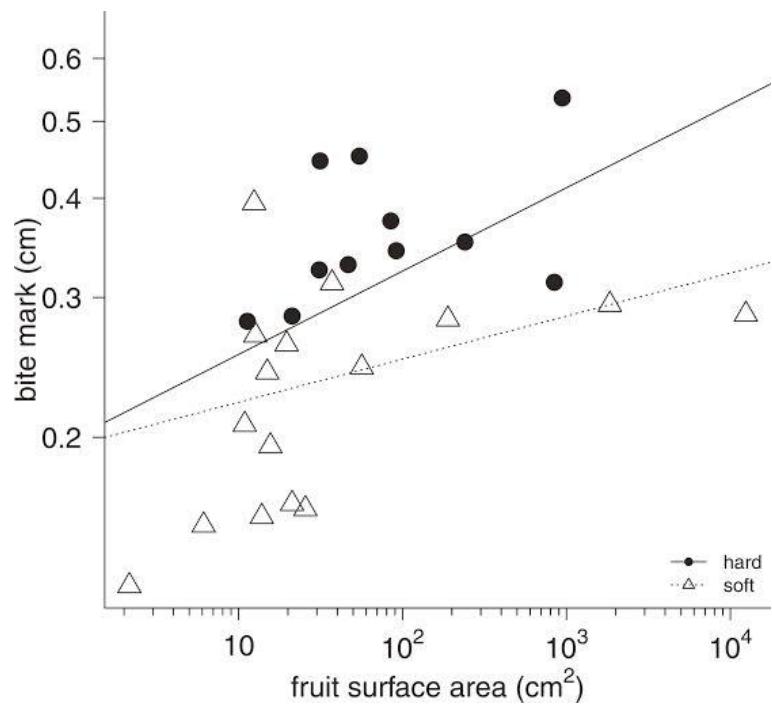


Fig. 5 Bite marks and fruit/seeds area of plant species sampled in JNP. Each point represents one plant species.

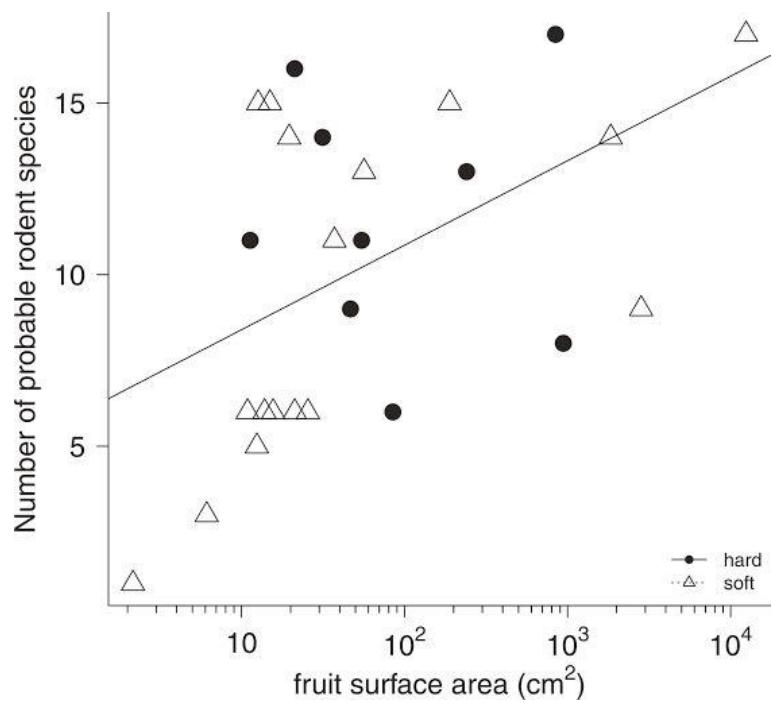


Fig. 6 Total number of possible rodent species (based on tooth width measurements) in relation to the mean fruit/seed size for plant species from JNP. Each point represents a plant species.

Capítulo II.

Antunes, A.C.; Baccaro, F.; Caetano, V.L., Ramos, J.F. and Barnett, A.A. **Igapó seed patches: An overlooked, but potentially key resource for a vertebrate assemblage in a seasonally flooded forest of Amazonian Brazil?** Manuscrito em preparação para *Journal of Ecology*.

Igapó seed patches: An overlooked, but potentially key resource for a vertebrate assemblage in a seasonally flooded forest of Amazonian Brazil?

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Abstract

In igapó forests, the water dynamics during the river's recession is responsible for the seed patch formation. Animal-plant interactions that occur in that environment, as well as the patches' influence on frugivorous and granivorous vertebrate occurrence are unknown. Using camera traps in areas with and without seed patches, we evaluated the relationship between these accumulation sites and birds and mammals species presence. Vertebrate occurrence was not related to patch presence. However, there is a positive relationship between predator's occurrence and spatial distribution of non-carnivore members of the vertebrate assemblage, indicating that predator species may be following their potential prey in unflooded igapó. The widespread occurrence of these animals throughout igapó, not only where density food resources are high, seems to be a compromise strategy between selecting the most favorable food items and avoiding the risk of being preyed upon when spending extended time foraging at food patches. Our results underscore the potential importance of igapó forests as a key habitat for a variety of terra firme terrestrial taxa, and open the way for further studies.

Keywords

Igapó forest . mammal . bird . interaction . Neotropical forest

Introduction

In the Amazon basin, blackwater floodplains along the Negro River and tributaries cover an area of approximately 119,000 km² (Melack and Hess 2010). In these areas, hereafter *igapós*, the annual flood pulse is one of the key determinants of plant species composition and diversity, and is one of the decisive factors influencing the spatial distribution of tree assemblage composition (Wittmann *et al.* 2010). Increasingly, igapó has been recognized as providing an important food resources for adjacent upland forests animals (Haugaasen and Peres 2007; Beja *et al.* 2010; Barnett *et al.* 2012; Ramos Pereira *et al.* 2013). The resource availability for fruit and seed eating species is marked seasonal, with two peaks of availability occurring annually: one at highest water levels, when most igapó trees produce fruits, and a second at the lowest water level, when many seeds that had been floating in the water lie exposed on the forest floor (Haugaasen and Peres 2005, 2007). Both periods coincide with times of reduced fruit availability in the adjacent unflooded (*terra firme*) forest (Haugaasen and Peres 2005). As a result of this fruiting asynchrony, arboreal and volant animals during the high water season, and the terrestrial animals during the dry season, move annually to the igapó forests to take advantage of these food resources (Bodmer 2009; Haugaasen and Peres 2007; Renton 2002).

For Amazon flooded forests trees, hydrochory and ichthyochory are common modes of dispersion (Kubitzki & Ziburski 1994). Consequently, fruit maturation, and hence availability to frugivores and granivores, occurs in synchronized pulses involving a large part of the plant community (Parolin *et al.* 2013). As the water level drops, seeds accumulate around obstacles such as floating logs, fallen trees (Barnett *et al.* 2012), or in areas with low water current velocity, often forming floating rafts of seeds (Fig. 1). When the river water recedes, these floating seeds are deposited on the forest floor, and many germinate (Barnett *et al.* 2012). Barnett *et al.* (2012) described that seed patch size vary from 0.4 to 3.8m², with densities of up to 594 seedlings per m², and noted that they contrast strongly with the rest of the understory vegetation, where seeds and seedlings are generally sparse (Fig. 2). These carpet-like, patches of varying size, density and species composition represent a food resource for golden-backed uacari

monkey (*Cacajao ouakary*, Pitheciidae), as well as peccaries and both arboreal and terrestrial rodents (Barnett *et al.* 2012).

The existence of these high density seed and seedling accumulations have been described previously (Ferreira *et al.* 2010; Piedade *et al.* 2010), however, the ecological importance of these seed patches, the animal-plant interactions that occur there (including seeds consumption and dispersion by animals), and which species (plant and animal) are involved, are all currently unknown. Haugaasen & Peres (2007) demonstrated that increasing availability of fruits and seeds deposited on the ground and new vegetative growth in igapó during the receding water level coincides with a migration of fruit and seed-eating vertebrates from the terra firme forest, while Bodmer (1990) found igapó to be seasonally important for ungulates. There is evidence that such activity also attracts predators, including jaguar (*Panthera onca*), puma (*Puma concolor*) and ocelot (*Leopardus pardalis*), probably because of the potential prey presence (Haugaasen *et al.* 2007).

The potential ecological importance of seed and seedling banks in the regeneration and long-term maintenance of tree populations has only recently been recognized (Ferreira *et al.* 2010; Piedade *et al.* 2010), but it has remained unknown how they affect the animals that inhabit the region. Here, we begin such investigations with a study of how seed patches influence vertebrate spatial patterning in igapó forests. This provides a baseline for future studies of the ecological dynamics of such seed patches: consumption and seed dispersal by animals, as well as the importance of floodplain forests in furnishing key resources for terra firme vertebrates.

Thus, this study has the main objective of evaluating whether areas of seed and seedling accumulation are positively related to increased mammal and bird species presence in unflooded igapó forest, as well as quantifying their feeding interactions. Specifically, we aimed to: (1) compare vertebrate visitation frequency at seed patches and areas of forest floor lacking these patches (control areas), (2) compare fruit and seed consumption frequencies at the patches and control areas, (3) evaluate whether (i) patch size, (ii) seed patch density, (iii) distance from patch to the edge of the nearest

terra firme forest and (iv) predator occurrence, influence vertebrate visitation frequency at such seed patches.

Methods

Study area

The study was conducted in Jaú National Park (JNP) ($01^{\circ}54' - 01^{\circ}57'$ S to $61^{\circ}27' - 61^{\circ}28'$ W) (Fig. 3), located between the cities of Barcelos and Novo Airão, on the southern bank of the Rio Negro, some 220 km northwest and upstream of Manaus, capital city of Amazonas State, Brazil. The average annual temperature is 26.7° C, with an annual average rainfall of approximately 2,400 mm. There are two distinct seasons: rainy (January to May) and dry (Borges *et al.* 2004). The hydrological regime has a monomodal flood pulse with average amplitude of 8.17 m (peld-maua.inpa.gov.br). The maximum flood level occurs during the second half of June and the minimum water level in early November [PELD MAUA (peld-maua.inpa.gov.br); values calculated from the hydrological station data of Moura, from the National Water Agency - ANA, located 70 km downstream from the Park]. Jaú National Park covers some 22,720 km² of igapó forests, terra firme and white sand forests, 12% of its area occupied by igapó forest, seasonally flooded by the Jaú River (Fundação Vitória Amazônica, 1988). The study was conduct between September and November 2015, during the low water season.

Sample design

We established 36 plots (50 X 20m) to study the interactions between vertebrates feeding at seed patches. These were always parallel to the river course, on the floor of unflooded igapó forest. Within each plot we: (I) recorded the size of all seed patches; (II) randomly selected one seed patch per plot (so that patches of a range of sizes were sampled), and (III) at each selected patch positioned a camera trap (Heconyx HC600 HyperFire). Camera traps were set to take five photos per event, without pause. Cameras remained in position, operating continuously for 15 days. Sequential photos of the same species from the same camera within 1 hour were considered a single record. To test if animals were selectively visiting those areas of forest floor with seed patches more often than random, an equal number of camera traps was positioned to provide

photographic coverage of areas where no seed patches were present, always following the same flood level of the camera installed on the patch (Fig. 4). Following day 15, the cameras were moved to a new location. New sites were at least 1.5 km away from each other along the river. Sampling at different elevations mean that, overall, the entire range of the flood-duration gradient was covered (IV). Using 1 m X 1 m sub-plots we determined density and identity of all seed/seedling in each seed patch and in all control areas where a camera trap was installed. Seedlings and seeds were identified at the Max Planck Institute herbarium, Manaus, with the assistance of the parataxonomist Ramos, J.F.

Density of patches per plot was calculated by adding the patch area of each plot and dividing by the total plot area (1000 m²). To measure the sampling points distances from the center point of each plot to the edge of the closest terra firme forest, we used a of Landsat TM sensor 8 image (orbital point 232/061 - date 06/02/2015, accuracy level 30 m), projection UTM 20, WGS 1984, and using Quantum GIS, version 2.10 and MISCELLANEOUS - MOSAIC tool, a color composite RGB (654 bands). Following this, the image was visually interpretation to identify vegetation types and linear measurements of distances in meters was manually performed using the tool MEASUREMENT (Quantum GIS, version 2.10).

Data analysis

We used a paired Student T-test to investigate whether the occurrence of vertebrates was higher at seed patches than at a comparable area of forest floor lacking such patches (control areas). The sample unit of this analysis was the total number of individual of frugivorous mammals and birds (potential direct consumers from the seed/seedling patches) recorded at patches and in control areas per plot. To compare the seed and seedling consumption within and outside the patches, we applied a paired Student T-test comparing the observed percentage of consumed individuals (both seeds and seedlings present inside the 1 m x 1 m sub-plot) patches vs. plot control areas.

We used a multiple regression analysis to test the effects of patch size, seed density per plot, distance between seed/seedling patch to the nearest edge terra firme

forest, and the occurrence of mammalian carnivores as a possible influence on seed-eater visitation frequency. For the latter, we defined “occurrence” as the total number of seed-eating mammals and birds or carnivores mammals recorded at the seed patches.

Results

In the 3.6 ha sampled, we found 89 seed patches, of which 36 were randomly selected for camera trap placement. Seeds and seedlings from 61 identified species were recorded from the seed patches (Table 1) (a further 11 remain unidentified). Total sampling effort was 540 camera-trap*days. We obtained 158 photographic records of: 8 rodent species (three of which it was not possible to identify), 11 other mammal species and 9 bird species (see Table 2 for list). There were higher numbers of seeds in patches than the control areas ($t = 4.06$, $df = 36$, $p < 0.01$), demonstrating that greater seed deposition actually occurs in some igapó locations compared to others (Fig. 5). However, there was no significant difference in mammal and bird visitation frequencies in areas with and without seed patches in the studied areas of igapó forest ($t=-0.35$, $df = 65$, $p = 0.72$) (Fig. 6).

The amount of seeds and seedlings individuals consumed at patches did not vary significantly compared to the control areas ($t = 1.15$, $df = 28$, $p = 0.12$) (Fig.7). Seed patch size and patch density per plot were positively correlated (Pearson $r = -0.80$), so we chose only patch density in subsequent linear models. Neither density of seed patches nor distance from the patch to terra firme forest was correlated with frequency of mammal and bird occurrence ($p > 0.05$) (Figs. 8a and 8b, respectively). However, a positive relation was observed between the presence of the seed-eating vertebrates and predators occurrence (Fig. 8c).

Discussion

Surveys of small mammals (rodents and marsupials < 3kg) show that terra firme forest areas have higher species richness than that in igapó forests (Fundação Vitória Amazônica 1988). Additionally, within the terra firme-inhabiting medium and large mammal assemblage from JNP, show higher densities of primates and non-flying mammals (predominantly fruit-eaters), compared to those in igapó (Iwanaga *et al.* 2004).

Similar results have been found in the bird assemblage at JNP, with species diversity and abundance lower in igapó than in terra firme Borges & Carvalhaes 2000).

The process of seed patch formation is still a largely unknown phenomenon, but it may be an important factor in explaining the patterns of seasonal occupation of unflooded igapó forest by mammal and bird assemblages. Seed patch formation, distribution and composition appear to be random, as their initiation depends largely of the presence of such impedimenta as fallen trunks and large palm fronds, around which floating seed rafts will form. Clearly, their size and position vary from year to year. None of these phenomena have yet been studied, but this appears to be related to the phenology of igapó plants, as well as their form of dispersion and the interaction between topography and the water dynamics as flood levels recede.

Although there was no difference in the studied vertebrate assemblage occurrence between the seed patches and control areas, it is unquestionable that large numbers of vertebrates' species and individuals are present in igapó when it is unflooded. For many vertebrate assemblages, the igapó forests provide, during the unflooded season, not only an abundant source of food resources, but also water (since many terra firme forest streams are dry at this time) (Haugaasen & Peres 2007) and refuges closest to water bodies. Our results show a high density of predators and therefore indicate a high risk of predation on site. In addition to the photographic records, other indications, such as rodent burrows, faeces, bitten seeds, and pawprints, also show this environment to be occupied or visited by a variety of mammal species. Our results, however, showed that these animals are not more commonly found where there are seed and seedling accumulations. Instead, the surveyed vertebrates seem to occupy the area more randomly, but being followed by carnivores. Furthermore, there were no differences in the number of seeds and seedlings consumed within and outside the seed banks.

Ungulate herbivores and small mammals are well known for a good spatial memory in relation to aggregations of food resources (Howery & Bailey 1999), and these can strongly influence their spatial use in an area (Fagan *et al.* 2013). However, the distribution of fruits and seeds on the igapó floor is likely to vary between years,

negating the value of any long-term spatial memory of resource locations an animal might deploy. Consequently, the fruit- and seed-eaters visiting unflooded igapó are probably exploring the area extensively and widely in search of resources that are unpredictable in size, composition and distribution.

There may, however, be others factors in play: in this study the camera-traps recorded a large number of carnivores ($n = 26$; 16% of records). The large numbers of pawprints also attested to the frequent occurrence of these animals in the study habitat. The species included those known to prey on small granivores, such as rats and mice (e.g. margay and ocelot), and those who prey on larger species such as a paca, peccary and deer (e.g. jaguar). The presence of such predators in an open landscape such as unflooded igapó, coupled with random distribution of most seeds and seedlings (and consequently requiring extensive travel by granivores to find them) may have an influence the way potential prey species are consuming the resources available at seed patches (Schmitz *et al.* 2004). The widespread occurrence of these animals throughout igapó area, not only where there are accumulated resources (seed and seedling patches), could well reflect a compromise foraging strategy: by *not* at seed and seedling accumulations foraging herbivores continue to gain access to desirable food items while avoiding sites like patches, at which prolonged foraging could be high-risk. For the golden-backed uacari monkey (*Cacajao ouakary*), landscape composition is one of the key factors influencing the foraging behavior at seed patches: this primate avoids seed patches close to dense ground-based vegetation, probably to reduce risk from ambush predators such as jaguar and ocelot (Barnett *et al.* 2012). Similarly, other animals using the resources available on the patches may have been influenced by the landscape (examples of landscape influencing on the animals occurrence: Adler 2000; Dueser & Shugart 1978; Jensen 1985), as does predation (da Fonseca & Robinson 1990). This vertebrate distribution pattern could explain the similarity in the frequency with which mammals and bird species were recorded at seed patches and in control areas.

Although the vertebrates recorded on the floor of unflooded igapó do not show pronounced occurrence at seed patches, some variables influence this assemblage on-site distribution in general. The fact that these animals appear to move randomly within igapó explains why, regardless of the distance from the terra firme forest, their

occurrence was recorded. During the driest months of the year, access to free-standing water is often restricted to the main river (Jaú), since most of the small streams dry up during the dry season (R.S. Moreira, pers. commm). Despite plots with higher patches densities did not influence birds and mammals occurrence, there was a positive relation between predator occurrence and this mammal and bird assemblage, so that predators may be tracking prey movements or positioning themselves in locations where encounter rate likelihoods are high. This result corroborates the assumption of Haugaasen and Peres (2007) that primary consumers presence in igapó forest has a positive domino effect on the predator's influx from terra firme. Furthermore, this positive relation between predator-prey can be explained by models that include fixed distribution of resources for prey, such as the seed patches in this study, which result in a predator aggregation associated to prey occurrence (Sih 2005).

Conclusion

The study found that terra firme vertebrates visit igapó during the dry period in search of food resources, shelter and water. Areas with high seed and fruit densities during the period when floodwaters receded resulted in the formation of seed and seedlings patches. Unexpectedly, herbivores are not specifically attracted to these high-density areas of potential food, and it appears that the animals move through the igapó in a more random pattern. This may be due to substantial carnivore presence, which could modify herbivore foraging strategies. The presence of large numbers of carnivores is further evidence that the area is not only important for primary consumers, but also or their predators. Future livetrap-based studies may find spatial differences in occupation of dry igapó by small rodents, the location and identify of it which is generally not possible to register with camera traps. Other studies (Haugaasen and Peres, 2007; Bodmer, 1990) indicated the potential importance of igapó forests as a key habitat for a variety of terrestrial taxa, nominally based in terra fime. Our results further reinforce this, and open the way for additional quantitative studies.

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Conflict of interest

The authors declare that they have no conflict of interest.

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Fig. 1 Seed patch accumulated around a floating log during the flooded season in igapó.



Fig. 2 High density of seedlings deposited in the unflooded igapó, contrasting with the rest of the forest floor.

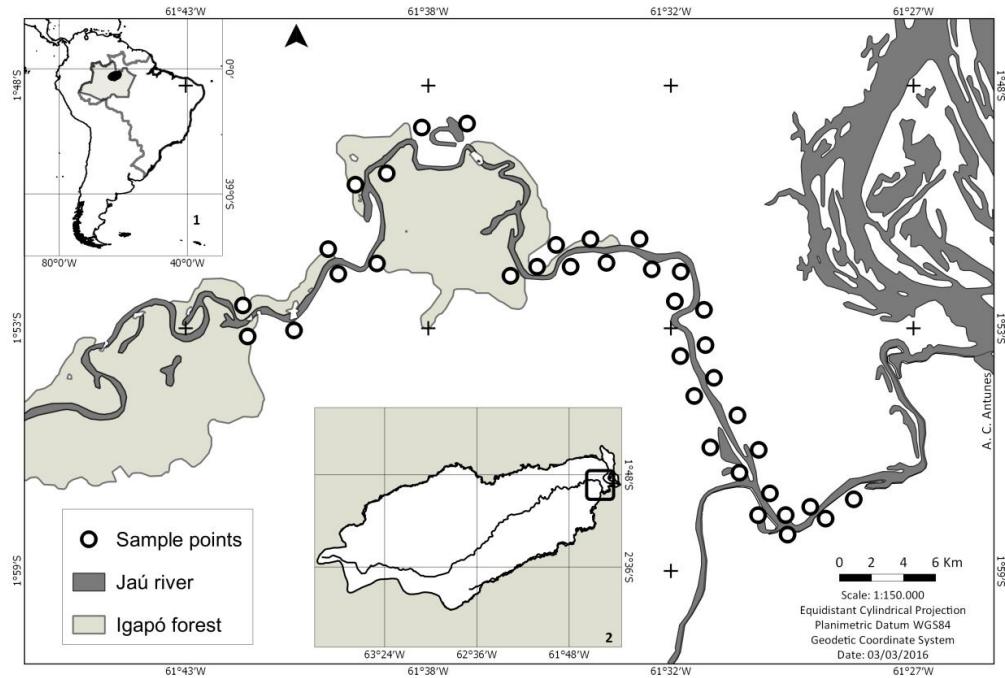


Fig. 3 Jaú National Park: Location of park and of study points within in.

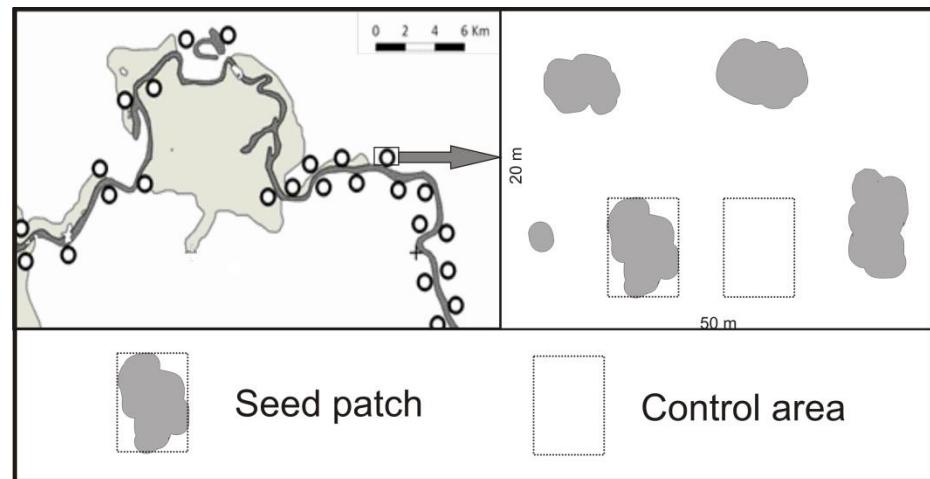


Fig. 4 Distribution of plot positions, habitat location and idealized seed patches and control areas within each plot.

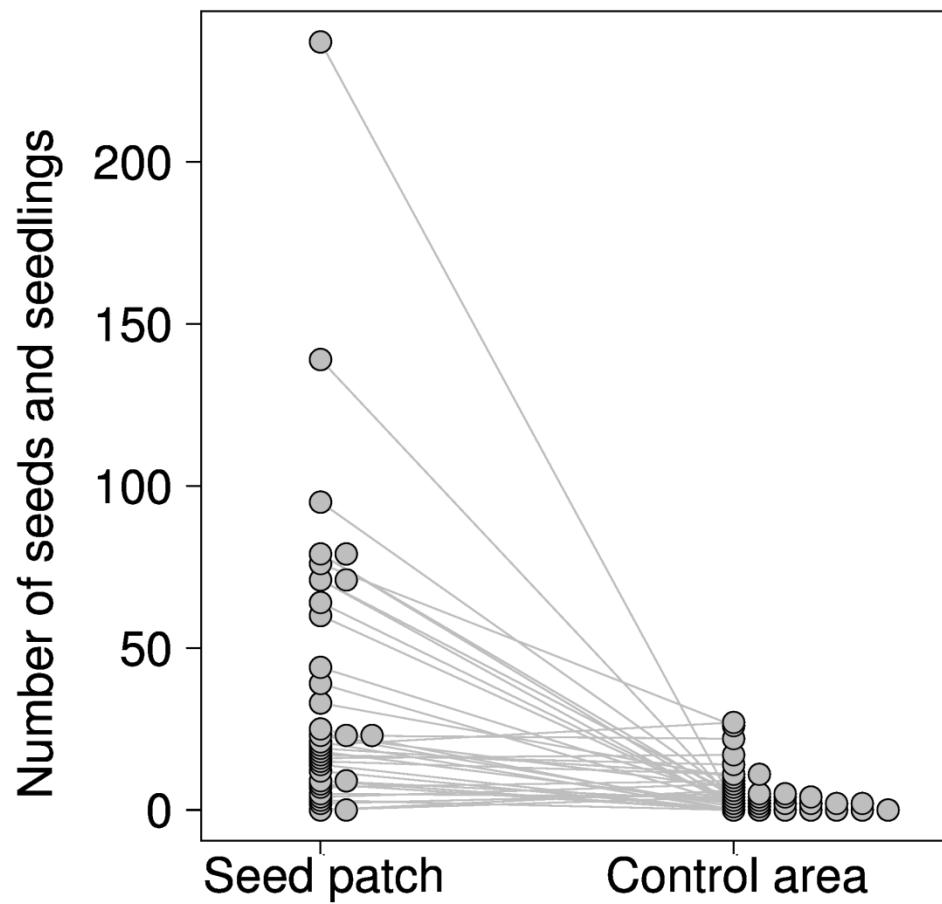


Fig.5 In unflooded igapó seeds are significantly more abundant in the seed patches than in the control areas.

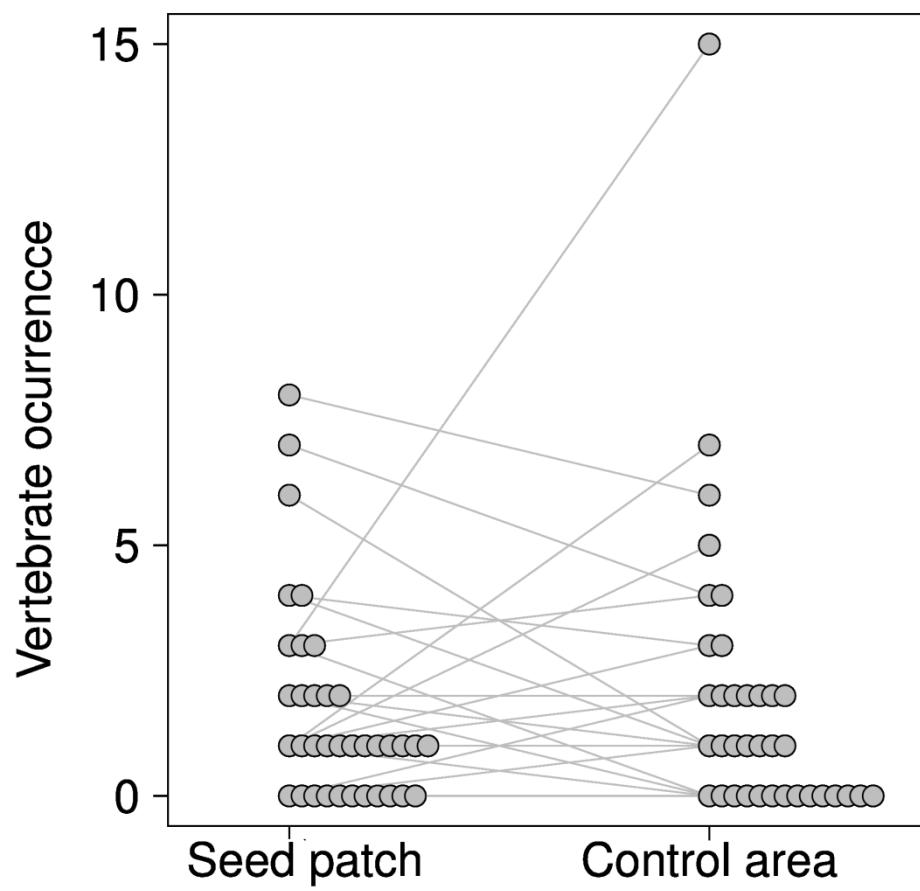


Fig.6 Number of non-carnivore mammals visitation between seed patches and control areas, at Igapó forest.

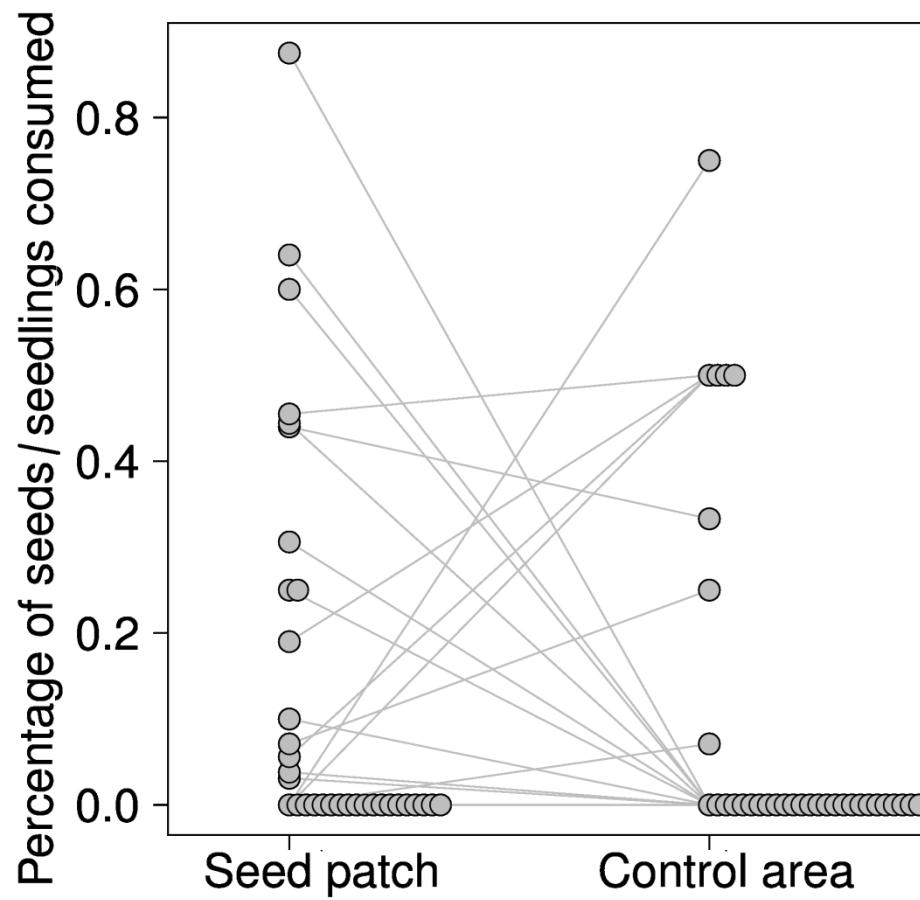


Fig.7 Plot showing that no difference exists between seed patches and control areas in the number of species of plants at the seedling stage consumed.

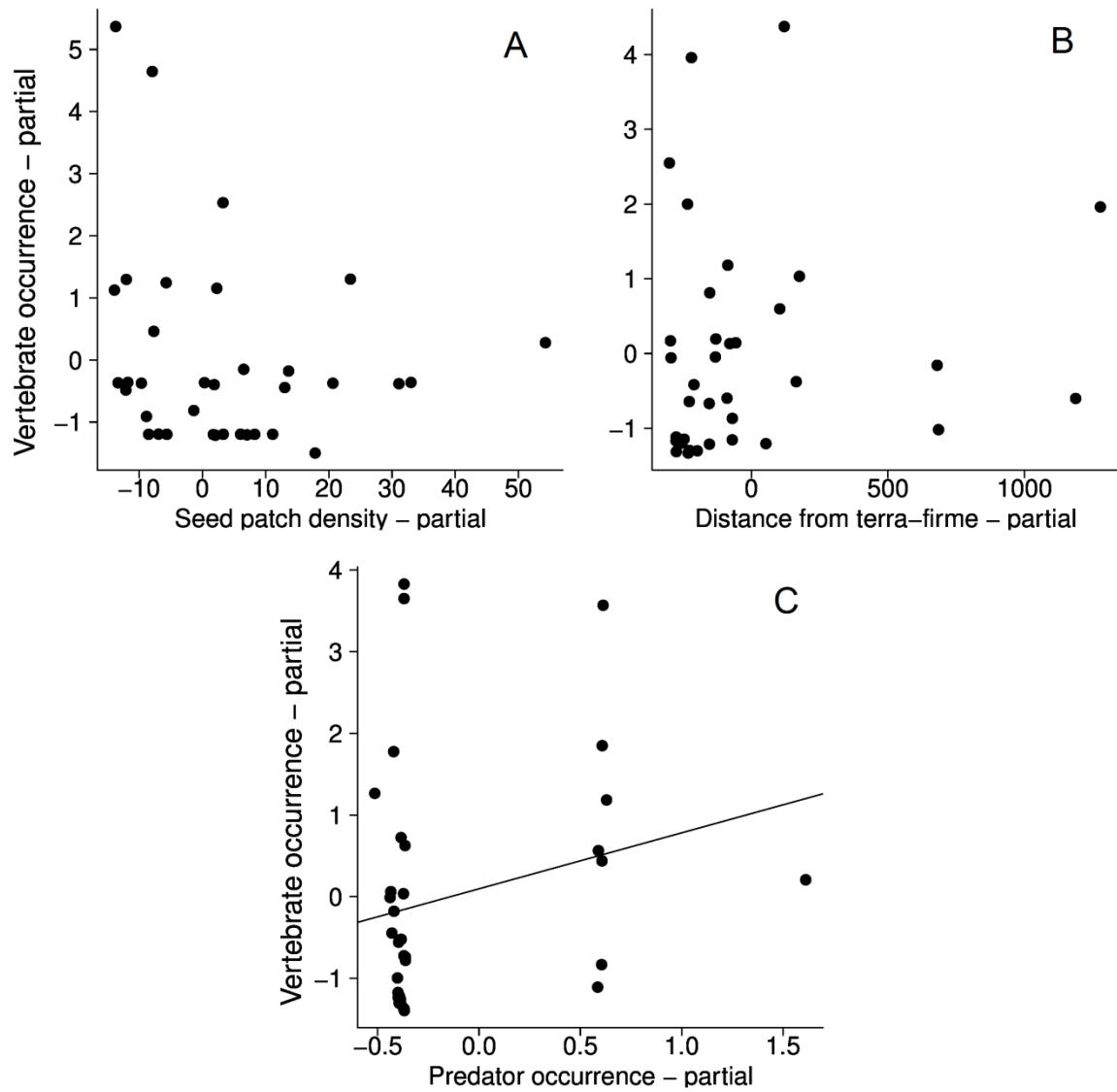


Fig.8 Linear regression with the three variables.

Family	Species/ Morphotypes
Arecaceae	cf. <i>Geonoma</i> sp. 1 <i>Iriartella setigera</i> <i>Leopoldina pulchra</i> <i>Mauritiella armata</i> <i>Oenocarpus mapora</i>
Bignoniaceae	<i>Tabebuia barbata</i>
Chrysobalanaceae	<i>Couepia paraense</i> <i>Hirtella</i> sp. 1 cf. <i>Hirtella</i> sp. 2 <i>Licania apetala</i> <i>Licania heterophyla</i> <i>Licania</i> sp. 1, 2, 3, 4 cf. <i>Licania</i> sp. 6
Clusiaceae	<i>Calophyllum brasiliense</i> <i>Garcinia</i> sp. 1
Combretaceae	<i>Buchenavia</i> sp. 1, 2 <i>Combretum</i> sp. 1, 2, 3 cf. <i>Combretum</i> sp. 4
Connaraceae	<i>Connarus</i> sp. 1 <i>Rourea</i> sp. 1
Ebenaceae	<i>Diospyros</i> sp. 1
Euphorbiaceae	<i>Alchornea</i> sp. 1 <i>Amaioa</i> sp. 1, 2 <i>Hevea spruceana</i> <i>Mabea nitida</i> <i>Mabea</i> sp. 1, 2
Elaeocarpaceae	<i>Sloanea</i> sp. 1
Fabaceae	<i>Acosmium</i> sp. 1 cf. <i>Cynometra bauhinifolia</i> <i>Cynometra</i> sp. 1

	cf. <i>Cynometra</i> sp.2
	<i>Dipytex odorata</i>
	<i>Dalbergia</i> sp. 1
	<i>Hydrocorea</i> sp.1, 2
	<i>Macrolobium acaciifolium</i>
	<i>Macrolobium</i> sp.1
	<i>Ormosea</i> sp.1, 2
	<i>Swartzia poliphyla</i>
	<i>Swartzia</i> sp. 1, 2, 3
	<i>Tachigalia</i> sp. 1, 2, 3
Gnetaceae	<i>Gnetum</i> sp.1
Humiriaceae	<i>Sacoglates</i> sp.1, 2
Lecythidaceae	<i>Eschweilera tenuifolia</i>
Lauraceae	<i>Ocotea cymbarum</i>
	<i>Ocotea</i> sp.1, 2
Loganaceae	<i>Strychnos</i> sp. 1
Malpighiaceae	<i>Byrsonima</i> sp.1
Menispermaceae	<i>Abuta</i> sp.1
Mimosoideae	<i>Abarema</i> sp.1
Myrtaceae	<i>Eugenia</i> sp. 1, 2
	<i>Myrciaria</i> sp.1
Passifloraceae	<i>Passiflora</i> sp.1
Polygalaceae	<i>Securidaca</i> sp.1
	<i>Symmeria paniculata</i>
Rubiaceae	<i>Coussarea</i> sp.1
Sapindaceae	<i>Allomphylus</i> sp.1
Sapotaceae	cf. <i>Elaeolyma</i> sp.1, 2
Morphotype	Morphotypes 1, 2, 3, 4

Table 1: Plant species and morphotypes present on seed patches and control areas at igapó unflooded forest, Jaú National Park.

Group/Species	Common name	n.reg
Mammals		
Carnivora		
<i>Leopardus pardalis</i>	Ocelot	11
<i>Leopardus wiedii</i>	Margay	8
cf. <i>Leopardus wiedii</i>		1
<i>Panthera onca</i>	Jaguar	4
<i>Pteronura brasiliensis</i>	Giant otter	2
Total	Carnivores	26
Rodentia		
<i>Cuniculus paca</i>	Lowland paca	10
<i>Dasyprocta leporina</i>	Red-rumped Agouti	1
<i>Hydrochoerus hydrochaeris</i>	Capybara	1
<i>Isothrix cf. bistriata</i>	Yellow-crowned Brush-tailed Rat	1
cf. <i>Makalata</i> sp.		9
cf. <i>Oecomys</i> sp.		3
<i>Proechimys</i> sp.		6
cf. <i>Proechimys</i> sp.		5
Didelphimorphia		
<i>Didelphis marsupialis</i>	Common opossum	15
<i>Philander</i> sp.	Four-eyed Opossum	20
Perissodactyla		
<i>Tapirus terrestris</i>	Lowland Tapir	1
Artiodactyla		
<i>Pecari tajacu</i>	Collared Peccary	4
<i>Mazama guazoubira</i>	Gray Brocket	1
<i>Mazama nemorivaga</i>	Brown Brocket	5
Primates		
<i>Cebus albifrons</i>		7
Birds		
Anseriformes		
<i>Cairina moschata</i>	Muscovy Duck	2
Struthioniformes		
<i>Crypturellus undulatus</i>	Undulated Tinamou	5
<i>Crypturellus</i> sp.		2
Columbiformes		
<i>Geotrygon montana</i>	Ruddy Quail-dove	2
<i>Leptotila rufaxilla</i>	Grey-fronted Dove	9
<i>Leptotila</i> sp		2
Galliformes		
<i>Pauxi tuberosa</i>		8

Gruiformes		
<i>Psophia leucoptera</i>	White-winged Trumpeter	1
Pelecaniformes		
<i>Tigrisoma lineatum</i>	Rufescent Tiger-heron	2
Struthioniformes		
<i>Tinamus guttatus</i>	White-throated Tinamou	1
<i>Tinamus cf. guttatus</i>		1
<i>Tinamus major</i>	Great Tinamou	3
<i>Tinamus cf. major</i>		1
<i>Tinamus</i> sp.		1
Total non-carnivores		129

Table 2. Vertebrates list of species recorded in igapó unflooded forest at Jaú National Park by camera traps

Síntese

Em florestas de igapó, a dinâmica da água durante a vazante dos rios atua na formação de agregados de sementes. São desconhecidas interações animal-planta que ocorrem nesse ambiente, bem como a influência dos agregados de sementes na ocorrência de vertebrados frugívoros e granívoros. Dentro desse contexto, nós exploramos as marcas de mordidas deixadas em frutos/ sementes por roedores para acessar quem consumiu esses itens. Além de simples, barata e não invasiva essa metodologia reduziu o conjunto das prováveis espécies que estão consumindo esses frutos/ sementes. Observamos também que os frutos/ sementes menores são usados por um menor número de espécies de roedores, em comparação com frutos de tamanho maior, sendo estes mais susceptíveis ao consumo. O método é particularmente relevante para estudos que procuram obter informações ecológicas, tais como forrageamento relacionado ao tamanho do animal ou dados sobre a identidade das espécies de plantas utilizadas pelos roedores. De modo mais geral, a razão tamanho do roedor/ semente, pode ajudar na compreensão dos padrões de dispersão de sementes, bem como das espécies de plantas mais consumidas pelos roedores.

Paralelamente também estudamos como uma assembléia de vertebrados interagem com os aglomerados de sementes formados durante a estação seca na floresta de igapó do PNJ. Registraramos uma variedade de espécies visitando a área, provavelmente em busca de recursos alimentares, refúgios e água. Embora os aglomerados de sementes em um primeiro momento pareçam um recurso que irá atrair animais herbívoros e granívoros, isso não acontece. Esses animais parecem se mover de forma aleatória pela área, independente da presença dos aglomerados de sementes. Esse resultado pode ser explicado pela substancial presença de carnívoros, que modificam as estratégias de forrageio de herbívoros. A presença de um grande número de carnívoros é mais um evidência de que essa área é importante não apenas para os consumidores primários, mas também para seus predadores. Esse trabalho reforça a importância das florestas de igapó como um habitat chave para uma variedade de vertebrados, além disso, abre portas para estudos adicionais.

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**APÊNDICE A - MATERIAL SUPLEMENTAR DO MANUSCRITO SUBMETIDO PARA
Mammalian Biology (Capítulo I)**

What bite marks can tell us: use of on-fruit tooth impressions to study seed consumer identity and consumption patterns within an assemblage of terrestrial and scansorial Neotropical rodents

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Appendix S1

Plant species	Rodent species
<i>Acosmium nitens</i>	<i>Euryoryzomys macconnelli</i> , <i>Hylaeamys megacephalus</i> , <i>Mesomys hispidus</i> , <i>Oecomys concolor</i> , <i>Oecomys roberti</i> , <i>Hylaeamys yunganus</i>
<i>Aldina heterophylla</i>	<i>Coendou prehensilis</i> , <i>Cuniculus paca</i> , <i>Dactylomys dactylinus</i> , <i>Holochilus sciureus</i> , <i>Isothrix negrensis</i> , New Makalata sp, <i>Myoprocta pratti</i> , <i>Scirius igniventris</i>
<i>Amanioua oblongifolia</i>	<i>Euryoryzomys macconnelli</i> , <i>Holochilus sciureus</i> , <i>Hylaeamys megacephalus</i> , <i>Hylaeamys yunganus</i> , <i>Isothrix negrensis</i> , New Makalata sp, <i>Mesomys hispidus</i> , <i>Myoprocta pratti</i> , <i>Oecomys bicolor</i> , <i>Oecomys concolor</i> , <i>Oecomys roberti</i> , <i>Proechimys cuvieri</i> , <i>Proechimys echonothrix</i> , <i>Proechimys steerei</i> , <i>Rhipidomys leucodactylus</i> , <i>Scirius aestuans</i> , <i>Scirius igniventris</i>
<i>Aniba</i> sp.	<i>Oecomys concolor</i> , <i>Proechimys echonothrix</i> , <i>Proechimys steerei</i> , <i>Rhipidomys leucodactylus</i>
<i>Astrocaryum aculeatum</i>	<i>Coendou prehensilis</i> , <i>Cuniculus paca</i> , <i>Dactylomys dactylinus</i> , <i>Holochilus sciureus</i> , <i>Isothrix negrensis</i> , New Makalata sp, <i>Myoprocta pratti</i> , <i>Oecomys concolor</i> , <i>Proechimys cuvieri</i> , <i>Proechimys echonothrix</i> , <i>Proechimys steerei</i> , <i>Rhipidomys leucodactylus</i> , <i>Scirius aestuans</i> , <i>Scirius igniventris</i>

<i>Astrocaryum jurua</i>	<i>Holochilus sciureus, Isothrix negrensis, new Makalata sp, Myoprocta pratti, Proechimys cuvieri, Proechimys echonothrix, Rhipidomys leucodactylus, Scirius igniventris</i>
<i>Attalea maripa</i>	<i>Coendou prehensilis, Cuniculus paca, Dactylomys dactylinus, Holochilus sciureus, Isothrix negrensis, Myoprocta pratti, Proechimys cuvieri, Proechimys echonothrix, Rhipidomys leucodactylus, Scirius aestuans, Scirius igniventris</i>
<i>Bellucia grossularioides</i>	<i>Euryoryzomys macconnelli, Hylaeamys megacephalus, Hylaeamys yunganus, Mesomys hispidus, Oecomys bicolor, Oecomys roberti</i>
<i>Brosimum sp.</i>	None of the species measured
<i>Calophyllum brasiliense</i>	<i>Euryoryzomys macconnelli, Hylaeamys megacephalus, Hylaeamys yunganus, Isothrix negrensis, New Makalata sp, Mesomys hispidus, Myoprocta pratti, Oecomys concolor, Oecomys roberti, Proechimys cuvieri, Proechimys echonothrix, Proechimys steerei, Rhipidomys leucodactylus, Scirius aestuans</i>
<i>Casearia sp.</i>	<i>Oecomys bicolor</i>
<i>Chrysophyllum sanguinolentum</i>	<i>Cuniculus paca</i>
<i>Couepia sp.</i>	<i>Euryoryzomys macconnelli, Mesomys hispidus, Oecomys concolor, Oecomys roberti, Proechimys cuvieri, Proechimys echonothrix, Proechimys steerei, Rhipidomys leucodactylus, Scirius aestuans</i>
<i>Duguetia sp.</i>	<i>Euryoryzomys macconnelli, Hylaeamys megacephalus, Hylaeamys yunganus, Mesomys hispidus, Oecomys bicolor, Oecomys concolor, Oecomys roberti, Proechimys cuvieri, Proechimys echonothrix, Proechimys steerei, Rhipidomys leucodactylus, Scirius aestuans</i>
<i>Duroia velutina</i>	<i>Euryoryzomys macconnelli, Holochilus sciureus, Isothrix negrensis, New Makalata sp, Mesomys hispidus, Myoprocta pratti, Oecomys concolor, Oecomys roberti, Proechimys cuvieri, Proechimys echonothrix, Proechimys steerei, Rhipidomys leucodactylus, Scirius aestuans, Scirius igniventris</i>
<i>Elaeoloma glabrescens</i>	<i>Euryoryzomys macconnelli, Hylaeamys megacephalus, Hylaeamys yunganus, Isothrix negrensis, New Makalata sp, Mesomys hispidus, Myoprocta pratti, Oecomys bicolor, Oecomys concolor, Oecomys roberti, Proechimys cuvieri, Proechimys echonothrix, Proechimys steerei, Rhipidomys leucodactylus, Scirius aestuans</i>
<i>Eschweilera albiflora</i>	<i>New Makalata sp</i>
<i>Eschweilera tenuifolia (fruit)</i>	<i>Coendou prehensilis, Dactylomys dactylinus, Holochilus sciureus, Isothrix negrensis, New Makalata sp, Myoprocta pratti, Oecomys concolor, Proechimys cuvieri, Proechimys echonothrix, Proechimys steerei, Rhipidomys leucodactylus, Scirius aestuans, Scirius igniventris</i>
<i>Eschweilera tenuifolia (seed)</i>	<i>Euryoryzomys macconnelli, Hylaeamys megacephalus, Hylaeamys yunganus, Isothrix negrensis, New Makalata sp, Mesomys hispidus, Myoprocta pratti, Oecomys bicolor, Oecomys concolor, Oecomys roberti, Proechimys cuvieri, Proechimys</i>

	<i>echonothrix</i> , <i>Proechimys steerei</i> , <i>Rhipidomys leucodactylus</i> , <i>Scirius aestuans</i>
<i>Eschweilera wachenheimii</i>	<i>Holochilus sciureus</i> , <i>Isothrix negrensis</i> , New Makalata sp, <i>Myoprocta pratti</i> , <i>Oecomys concolor</i> , <i>Proechimys cuvieri</i> , <i>Proechimys echonothrix</i> , <i>Proechimys steerei</i> , <i>Rhipidomys leucodactylus</i> , <i>Scirius aestuans</i> , <i>Scirius igniventris</i> <i>Hylaeamys megacephalus</i> , <i>Hylaeamys yunganus</i> , <i>Oecomys bicolor</i>
<i>Euterpe precatoria</i>	None of the species measured
<i>Gautteria foliosa</i>	<i>Holochilus sciureus</i> , <i>Isothrix negrensis</i> , New Makalata sp, <i>Myoprocta pratti</i> , <i>Scirius igniventris</i>
<i>Gustavia elliptica</i>	None of the species measured
<i>Heisteria barbata</i>	<i>Euryoryzomys macconnelli</i> , <i>Hylaeamys megacephalus</i> , <i>Hylaeamys yunganus</i> , <i>Mesomys hispidus</i> , <i>Oecomys bicolor</i> , <i>Oecomys roberti</i>
<i>Heisteria spruceana</i>	<i>Euryoryzomys macconnelli</i> , <i>Holochilus sciureus</i> , <i>Hylaeamys megacephalus</i> , <i>Hylaeamys yunganus</i> , <i>Isothrix negrensis</i> , New Makalata sp, <i>Mesomys hispidus</i> , <i>Myoprocta pratti</i> , <i>Oecomys bicolor</i> , <i>Oecomys concolor</i> , <i>Oecomys roberti</i> , <i>Proechimys cuvieri</i> , <i>Proechimys echonothrix</i> , <i>Proechimys steerei</i> , <i>Rhipidomys leucodactylus</i> , <i>Scirius aestuans</i> , <i>Scirius igniventris</i>
<i>Helicostylis scabra</i>	<i>Oecomys concolor</i> , <i>Proechimys cuvieri</i> , <i>Proechimys echonothrix</i> , <i>Proechimys steerei</i> , <i>Rhipidomys leucodactylus</i> , <i>Scirius aestuans</i> <i>Euryoryzomys macconnelli</i> , <i>Holochilus sciureus</i> , <i>Hylaeamys megacephalus</i> , <i>Hylaeamys yunganus</i> , <i>Isothrix negrensis</i> , New Makalata sp, <i>Mesomys hispidus</i> , <i>Myoprocta pratti</i> , <i>Oecomys bicolor</i> , <i>Oecomys concolor</i> , <i>Oecomys roberti</i> , <i>Proechimys cuvieri</i> , <i>Proechimys echonothrix</i> , <i>Proechimys steerei</i> , <i>Rhipidomys leucodactylus</i> , <i>Scirius aestuans</i> , <i>Scirius igniventris</i>
<i>Hydrochorea marginata</i>	<i>Oecomys concolor</i> , <i>Proechimys cuvieri</i> , <i>Proechimys echonothrix</i> , <i>Proechimys steerei</i> , <i>Rhipidomys leucodactylus</i> , <i>Scirius aestuans</i>
<i>Inga obidensis</i>	<i>Euryoryzomys macconnelli</i> , <i>Holochilus sciureus</i> , <i>Hylaeamys megacephalus</i> , <i>Hylaeamys yunganus</i> , <i>Isothrix negrensis</i> , New Makalata sp, <i>Mesomys hispidus</i> , <i>Myoprocta pratti</i> , <i>Oecomys bicolor</i> , <i>Oecomys concolor</i> , <i>Oecomys roberti</i> , <i>Proechimys cuvieri</i> , <i>Proechimys echonothrix</i> , <i>Proechimys steerei</i> , <i>Rhipidomys leucodactylus</i> , <i>Scirius aestuans</i> , <i>Scirius igniventris</i>
<i>Insertia</i> sp.	<i>Hylaeamys megacephalus</i> , <i>Hylaeamys yunganus</i> , <i>Mesomys hispidus</i> , <i>Oecomys bicolor</i>
<i>Iryanthera</i> sp.	<i>Holochilus sciureus</i> , <i>Isothrix negrensis</i> , New Makalata sp, <i>Myoprocta pratti</i> , <i>Proechimys cuvieri</i> , <i>Proechimys echonothrix</i> , <i>Rhipidomys leucodactylus</i> , <i>Scirius aestuans</i> , <i>Scirius igniventris</i>
<i>Leopoldinia pulcra</i>	<i>Holochilus sciureus</i> , <i>Isothrix negrensis</i> , New Makalata sp, <i>Myoprocta pratti</i> , <i>Scirius igniventris</i>
<i>Licania heteromorpha</i>	<i>Euryoryzomys macconnelli</i> , <i>Isothrix negrensis</i> , New Makalata sp, <i>Myoprocta pratti</i> , <i>Oecomys concolor</i> , <i>Oecomys roberti</i> , <i>Proechimys cuvieri</i> , <i>Proechimys echonothrix</i> , <i>Proechimys steerei</i> , <i>Rhipidomys leucodactylus</i> , <i>Scirius aestuans</i>
<i>Licania</i> sp.	<i>Holochilus sciureus</i> , <i>Isothrix negrensis</i> , New Makalata sp, <i>Myoprocta pratti</i> , <i>Scirius igniventris</i>
<i>Macrolobium acaciifolium</i>	<i>Coendou prehensilis</i> , <i>Dactylomys dactylinus</i> , <i>Holochilus sciureus</i> , <i>Isothrix negrensis</i> , New Makalata sp, <i>Scirius igniventris</i>
<i>Macrolobium limbatum</i>	<i>Holochilus sciureus</i> , <i>Isothrix negrensis</i> , New Makalata sp, <i>Myoprocta pratti</i> , <i>Scirius igniventris</i>
<i>Miconia</i> sp.	<i>Euryoryzomys macconnelli</i> , <i>Hylaeamys megacephalus</i> , <i>Hylaeamys yunganus</i> , <i>Mesomys hispidus</i> , <i>Oecomys bicolor</i> , <i>Oecomys roberti</i>
<i>Myrtaceae</i>	<i>Euryoryzomys macconnelli</i> , <i>Hylaeamys megacephalus</i> ,

	<i>Hylaeamys yunganus</i> , <i>Mesomys hispidus</i> , <i>Oecomys bicolor</i> , <i>Oecomys roberti</i>
<i>Oenocarpus bacaba</i>	<i>Euryoryzomys macconnelli</i> , <i>Hylaeamys megacephalus</i> , <i>Hylaeamys yunganus</i> , <i>Isothrix negrensis</i> , New Makalata sp, <i>Mesomys hispidus</i> , <i>Myoprocta pratti</i> , <i>Oecomys bicolor</i> , <i>Oecomys concolor</i> , <i>Oecomys roberti</i> , <i>Proechimys cuvieri</i> , <i>Proechimys echonothrix</i> , <i>Proechimys steerei</i> , <i>Rhipidomys leucodactylus</i> , <i>Scirius aestuans</i>
<i>Panopsis rubescens</i>	<i>Euryoryzomys macconnelli</i> , <i>Hylaeamys megacephalus</i> , <i>Hylaeamys yunganus</i> , <i>Mesomys hispidus</i> , <i>Myoprocta pratti</i> , <i>Oecomys bicolor</i> , <i>Oecomys concolor</i> , <i>Oecomys roberti</i> , <i>Proechimys cuvieri</i> , <i>Proechimys echonothrix</i> , <i>Proechimys steerei</i> , <i>Rhipidomys leucodactylus</i> , <i>Scirius aestuans</i>
<i>Parkia discolor</i>	<i>Holochilus sciureus</i> , <i>Isothrix negrensis</i> , New Makalata sp, <i>Myoprocta pratti</i> , <i>Oecomys concolor</i> , <i>Proechimys cuvieri</i> , <i>Proechimys echonothrix</i> , <i>Proechimys steerei</i> , <i>Rhipidomys leucodactylus</i> , <i>Scirius aestuans</i> , <i>Scirius igniventris</i>
<i>Parkia panurensis</i>	None of the species measured
<i>Philodendron</i> sp.	
1	<i>Isothrix negrensis</i> , New Makalata sp, <i>Myoprocta pratti</i>
<i>Philodendron</i> sp.	<i>Isothrix negrensis</i> , New Makalata sp, <i>Myoprocta pratti</i> , <i>Oecomys concolor</i> , <i>Proechimys cuvieri</i> , <i>Proechimys echonothrix</i> , <i>Proechimys steerei</i> , <i>Rhipidomys leucodactylus</i> , <i>Scirius aestuans</i>
2	
<i>Philodendron</i> sp.	
3	None of the species measured
<i>Philodendron</i> sp.	
4	None of the species measured
<i>Pouteria gomphifolia</i>	None of the species measured
<i>Protium</i> sp.	<i>Oecomys concolor</i> , <i>Proechimys echonothrix</i> , <i>Proechimys steerei</i> , <i>Rhipidomys leucodactylus</i>
<i>Sclerolobium hypoleucum</i>	<i>Holochilus sciureus</i> , <i>Isothrix negrensis</i> , New Makalata sp, <i>Myoprocta pratti</i> , <i>Proechimys cuvieri</i> , <i>Proechimys echonothrix</i> , <i>Rhipidomys leucodactylus</i> , <i>Scirius aestuans</i> , <i>Scirius igniventris</i>
<i>Sclerolobium</i> sp.	<i>Holochilus sciureus</i> , <i>Scirius igniventris</i>
<i>Socratea exorrhiza</i>	<i>Euryoryzomys macconnelli</i> , <i>Hylaeamys megacephalus</i> , <i>Hylaeamys yunganus</i> , <i>Mesomys hispidus</i> , <i>Oecomys bicolor</i> , <i>Oecomys concolor</i> , <i>Oecomys roberti</i>
<i>Swartzia polypylla</i> (seed)	<i>Coendou prehensilis</i> , <i>Cuniculus paca</i> , <i>Dactylomys dactylinus</i> , <i>Holochilus sciureus</i> , <i>Scirius igniventris</i>
<i>Tabebuia barbata</i>	<i>Euryoryzomys macconnelli</i> , <i>Hylaeamys megacephalus</i> , <i>Hylaeamys yunganus</i> , <i>Isothrix negrensis</i> , New Makalata sp, <i>Mesomys hispidus</i> , <i>Myoprocta pratti</i> , <i>Oecomys bicolor</i> , <i>Oecomys concolor</i> , <i>Oecomys roberti</i> , <i>Proechimys cuvieri</i> , <i>Proechimys echonothrix</i> , <i>Proechimys steerei</i> , <i>Rhipidomys leucodactylus</i> , <i>Scirius aestuans</i>
<i>Tabernaemontana</i> sp.	<i>Euryoryzomys macconnelli</i> , <i>Hylaeamys megacephalus</i> , <i>Hylaeamys yunganus</i> , <i>Mesomys hispidus</i> , <i>Oecomys concolor</i> , <i>Oecomys roberti</i>
<i>Ternstroemia</i>	<i>Euryoryzomys macconnelli</i> , <i>Hylaeamys megacephalus</i> ,

<i>candolleana</i>	<i>Hylaeamys yunganus, Mesomys hispidus, Oecomys bicolor, Oecomys concolor, Oecomys roberti, Proechimys echonothrix, Proechimys steerei, Rhipidomys leucodactylus</i>
<i>Theobroma sylvestre</i>	<i>Euryoryzomys macconnelli, Holochilus sciureus, Hylaeamys megacephalus, Hylaeamys yunganus, Isothrix negrensis, New Makalata sp, Mesomys hispidus, Myoprocta pratti, Oecomys concolor, Oecomys roberti, Proechimys cuvieri, Proechimys echonothrix, Proechimys steerei, Rhipidomys leucodactylus, Scirius aestuans, Scirius igniventris</i>
<i>Virola mollissima</i>	<i>Euryoryzomys macconnelli, Hylaeamys megacephalus, Hylaeamys yunganus, Mesomys hispidus, Oecomys bicolor, Oecomys roberti</i>

Table listing the identity of the possible rodent species interacting with each plant species (based on incisor width). The list includes all species of plants found in the area, however only species for which we had more than four records of bitten fruit/ seeds records were used in subsequent analysis.

Appendix S2

Table listing the rodent species measured in each collection, the incisors width (mm) based on the Plasticine blocks marks, the body length (mm) and the identification (ID) from its museum collections.

¹Mammal collection of the National Institute of Amazonian Research (INPA) ²Bonvicino et al 2008, ³ Patton et al. 2015

Species	Incisor width (mm)	Body length (mm)	Museum ID
Cricetidae			
<i>H. sciureus</i>	4	158 ³	INPA 2897, 2898
<i>H. megacephalus</i>	1.74	121.9 ³	INPA 5493, 5452, 5465, 5464, 4521, 4339, 4216, 5510
<i>H. yunganus</i>	1.74	132 ³	INPA 3386, 3387, 3385, 3895, 3388
<i>O. bicolor</i>	1.54	100 ³	INPA 6749, 6756, 6757, 6758, 6772, 6752, 6773
<i>O. concolor</i>	2.53	125 ³	BAL 1583, 1520, 1500, INPA 1667
<i>O. roberti</i>	1.95	123 ³	INPA 4207, 4199
<i>O. macconnelli</i>	2	143 ³	MZUSP 23142, 23332, 23184, 22950
<i>R. leucodactylus</i>	2.67	359 ¹	INPA 3875, 3874, 5058
Cuniculidae			
<i>C. paca</i>	6.73	9350 ²	76.685, 76.687, 77.99, 76.684, 73.1765, INPA 2856, 4025, 2855
Dasyproctidae			
<i>M. pratti</i>	3.25	362.5 ³	INPA 3921, 3923
Echimyidae			
<i>D. dactylinus</i>	5.6	315 ³	INPA 4123, 4124, 2878
<i>I. negrensis</i>	3.43	254.1 ³	INPA 4304, 4303, 4372
<i>New Makalata sp</i>	3.5		INPA 4135, 4374, 4425, 4305
<i>M. hispidus</i>	1.89	161 ³	INPA 4151, 4152
<i>P. cuvieri</i>	2.81	396.5 ¹	INPA 2966, 2764, 2771, 2733, 2769, 4470, 2765, 4471
<i>P. echinothrix</i>	2.7	193 ³	INPA 3486, 3491, 3503, 3487, 4468, 4543, 4540, 4541, 3482, 3481, 3499, 1723
<i>P. steerei</i>	2.59	393.25 ¹	INPA 3867, 3858, 3869, 3826, 3836, 3829, 3796
Erethizontidae			
<i>C. prehensilis</i>	5.65	797.25 ¹	4.7.4.82, 26.11.4.8, 27.8.11.48, 57.7.27.1, 26.11.4.7, 26.11.4.10, INPA 6730, 3919, 2875, 4566, 4073
Sciuridae			
<i>S. aestuans</i>	2.75	176 ³	MZUSP 5949, 2243, 3511, 5945
<i>S. igniventris</i>	4	255 ³	MZUSP 4208, 22348, 22347

Appendix S3

Plant species	Bite width Average (mm)	Fruit length Average (cm)	Fruit width Average (cm)	Reference
<i>Acosmium nitens</i>	1.80	1.24	2.8	Barnett, A. (N=17), pers comm.
<i>Aldina heterophylla</i>	5.35	25	12	Ziburski 1990. Waldhoff 1991. Parolin et al. 2003
<i>Amanioua oblongifolia</i>	3.14	17	15.8	Barnett, A. (N=10), pers comm.
<i>Aniba</i> sp.	2.55	2.5	1.7	(Aniba afinis) Ziburski 1990
<i>Astrocaryum jurua</i>	3.44	4	2.5	Ziburski 1990. Waldhoff et al. 1996. Maia 2001
<i>Astrocaryum aculeatum</i>	4.46	5.4	5.4	Barnett, A. (N=25), pers comm.
<i>Attalea maripa</i>	4.52	6.2	2.8	Barnett, A. (N=25), pers comm.
<i>Calophyllum brasiliense</i>	2.62	2.5	2.5	Waldhoff & Furch 1999
<i>Elaeoloma glabrescens</i>	2.77	-	-	-
<i>Eschweilera albiflora</i>	3.60	-	-	-
<i>Eschweilera tenuifolia</i> (fruit)	3.52	9	8.5	Ziburski 1990. Waldhoff et al. 1996. Maia 1997. 2001. Parolin et al. 2003
<i>Eschweilera tenuifolia</i> (seed)	2.69	3.1	1.3	Ziburski 1990. Waldhoff et al. 1996. Maia 1997. 2001. Parolin et al. 2003
<i>Eschweilera wachenheimii</i>	3.25	2.6	3.8	Barnett, A. (N=3), pers comm.

<i>Euterpe precatoria</i>	1.55	1.3	1.5	Barnett, A. (N=25), pers comm.
<i>Guatteria foliosa</i>	3.10	31	33.9	Barnett, A. (N=2), pers comm.
<i>Gustavia elliptica</i>	4.40	-	-	-
<i>Heisteria spruceana</i>	1.90	0.8	1.1	Barnett, A. (N=5), pers comm
<i>Helicostylis scabra</i>	2.74	-	-	-
<i>Hydrochorea marginata</i>	2.68	-	-	-
<i>Heisteria barbata</i>	1.20	-	-	-
<i>Inga obidensis</i>	2.86	20.7	191.3	Barnett, A. (N=7), pers comm.
<i>Insertia</i> sp.	1.70	-	-	-
<i>Iryanthera</i> sp.	3.55	-	-	-
<i>Leopoldinia pulcra</i>	3.95	1.8	2.2	Barnett, A. (N=10), pers comm.
<i>Licania heteromorpha</i>	2.80	2	1.8	Barnett, A. (N=24), pers comm.
<i>Licania</i> sp.	3.68	2.4	2.6	Present study (N=12), 8 spp
<i>Macrolobium acaciifolium</i>	3.75	6	4.5	Ziburski 1990. Waldhoff et al. 1996. Maia 2001. Maia & Chalco 2002. Parolin 2002. Parolin et al. 2003
<i>Miconia</i> sp.	1.59	2.1	2.1	Barnett, A. (N=7), pers comm.
<i>Myrtaceae</i>	1.53	-	-	-
<i>Oenocarpus bacaba</i>	2.42	1.7	2.8	Barnett, A. (N=25), pers comm.
<i>Panopsis rubescens</i>	2.45	5.8	3.1	Barnett, A. (N=17), pers comm.
<i>Parkia discolor</i>	3.13	16.9	0.7	Ziburski 1990. Parolin et al.

					2003
<i>Parkia panurensis</i>	3.00	-	-	-	
<i>Philodendron</i> sp. 1	3.40	13.6	38	Barnett, A. (N=1), pers comm.	
<i>Philodendron</i> sp. 2	3.27	-	-	-	
<i>Philodendron</i> sp. 3	3.70	-	-	-	
<i>Philodendron</i> sp. 4	3.70	-	-	-	
<i>Pouteria gomphiiifolia</i>	2.23	13.3	25.4	Barnett, A. (N=14), pers comm.	
<i>Protium</i> sp.	2.57	-	-	-	
<i>Sclerolobium hypoleucum</i>	3.30	5.3	2.8	Ziburski 1990	
<i>Sclerolobium</i> sp.	3.90	-	-	-	
<i>Socratea exorrhiza</i>	1.66	-	-	-	
<i>Swartzia polyphylla</i> (seed)	6.45	-	-	-	
<i>Tabebuia barbata</i>	2.82	1.98	30.43	Ziburski 1990. Maia 2001. Parolin et al. 2003. Conserva 2006	
<i>Tabernaemontana</i> sp.	1.95	1.46	3.41	(<i>Tabernaemontana juruana</i>) Waldhoff unpubl.	
<i>Ternstroemia candolleana</i>	2.33	11.3	14.1	Barnett, A. (N=10), pers comm.	
<i>Theobroma sylvestre</i>	2.84	1.5	4.5	Barnett, A. (N=6), pers comm.	
<i>Virola mollissima</i>	1.65	-	-	-	

Table listing the plant species with bite marks and the fruits size. The list includes all species of plants found in the area, however only species for which we had more than four records of bitten fruit/ seeds records were used in subsequent analysis.