INSTITUTO NACIONAL DE PESQUISAS DA AMAZÔNIA – INPA

PROGRAMA DE PÓS-GRADUAÇÃO EM ECOLOGIA

PADRÃO DE ATIVIDADE TEMPORAL E USO DO HABITAT POR *CRAX GLOBULOSA* E *PAUXI TUBEROSA* EM FLORESTA DE VÁRZEA E TERRA FIRME NA AMAZONIA BRASILEIRA

PRISCILLA RODRIGUES MADY PACIULLO

Manaus, Amazonas

Maio, 2019

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Orientador: Dr. William Ernest Magnusson

Emiliano Esterci Ramalho

Pedro Aurélio Costa Lima Pequeno

Dissertação apresentada a Coordenação do Programa de Pós-Graduação em Ecologia do Instituto Nacional de Pesquisas da Amazônia como parte dos requisitos para obtenção do título de Mestre em Ecologia

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

Aos 11 dias do mês de junho do ano de 2019, às 10h00min,no Auditório dos PPG's ATU/CFT/ECO, Campus III, INPA/V8.Reuniu-se a Comissão Examinadora de Defesa Pública, composta pelos seguintes membros: o(a) Prof(a). Dr(a). **Renato Cintra**,do Instituto Nacional de Pesquisas da Amazônia – INPA, o(a) Prof(a). Dr(a). **Gabriel Augusto Leite**, do Instituto Nacional de Pesquisas da Amazônia – INPA, e o(a) Prof(a). Dr(a).**Marina Anciães**, do Instituto Nacional de Pesquisas da Amazônia – INPA, tendo como suplentes o(a) Prof(a). Dr(a). Flávia Delgado Santana,do Instituto Nacional de Pesquisas da Amazônia – INPA, e o(a) Prof(a). Dr(a). Cintia Cornelius Frische, da Universidade Federal do Amazonas - UFAM soba presidência do(a) primeiro(a), a fim de proceder a argüição pública do trabalho de DISSERTAÇÃO DE MESTRADO de PRISCILLA RODRIGUES MADY PACIULLO, intitulado: "PADRÃO DE ATIVIDADE TEMPORAL E USO DO HABITAT POR CRAX GLOBULOSA E PAUXI TUBEROSA EM FLORESTA DE VÁRZEA E TERRA FIRME NA AMAZONIA BRASILEIRA",orientado(a) pelo(a) Prof(a).William Ernest Magnusson, do Instituto Nacional de Pesquisas da Amazônia – INPA e coorientado(a) pelos(as) profs(as) Emiliano Esterci Ramalho, do Instituto de Desenvolvimento Sustentável Mamirauá e Pedro Aurélio Costa Lima Pequeno, do Instituto Nacional de Pesquisas da Amazônia – INPA.

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

☒ APROVADO(A)   ☐ REPROVADO(A)

☒ POR UNANIMIDADE   ☐ POR MAIORIA

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

Prof(a).Dr(a). RENATO CINTRA
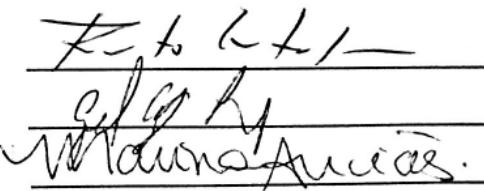
Prof(a).Dr(a). GABRIEL AUGUSTO LEITE
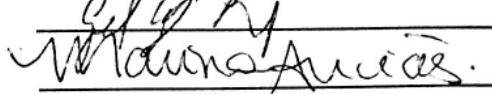
Prof(a).Dr(a). MARINA ANCIÃES
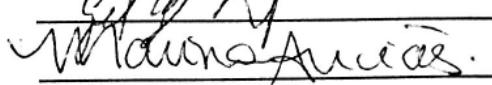
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Coordenação PPG-ECO/INPA

SINOPSE

   Este trabalho determinou o padrão de atividade temporal de *Crax globulosa* e *Pauxi tuberosa* em ambiente de várzea e terra firme e avaliou como o número de registro de felinos, a distância do corpo hídrico, altura da inundação e presença da isca associada a câmeras trap influenciaram o uso do habitat pelos cracídeos estudados.

Palavras-Chave: cracideos, atividade temporal, uso do habitat, várzea, terra firme.

AGRADECIMENTOS

RESUMO

A avaliação de como cracideos usam o habitat em áreas ainda bem conservadas é uma importante ferramenta para compreender sobre seu nicho ecológico. Neste estudo, objetivamos determinar o padrão de atividade temporal e como a altura da inundação, distancia de um corpo hidrico, registro de felideos e o uso de isca associadas a camera traps influenciam o uso do habitat por *Crax globulosa* e *Pauxi tuberosa* em áreas de várzea e terra firme. As armadilhas fotográficas foram instaladas no período de seca, durante cinco anos consecutivos na várzea e três anos na terra firme. O padrão de atividade temporal das espécies na várzea foram semelhantes, assim como entre varzea e terra firme. O numero de registro de felinos não afetou a distribuição de cracídeos nos ambientes estudados. No entanto, na floresta de terra firme, *P. tuberosa* utilizou locais com iscas com mais freqüência, enquanto na várzea, *C. globulosa* respondeu de forma negativa a altura da inundação. Além disso, na várzea ambas as espécies responderam à distância ao corpo hídrico mais próximo, mas de maneiras opostas: *C. globulosa* usou áreas mais próximas a corpos de água e *P. tuberosa* foi registrada mais frequentemente longe dos corpos de água. Os resultados sugerem que não há divisão temporal no uso do habitat entre as espécies de cracídeos estudadas. Em vez disso, as espécies tendem a segregar espacialmente em resposta à distância dos corpos d'água, possivelmente refletindo a variação na obtençao dos recursos disponíveis. Os achados deste estudo permitiram ampliar o conhecimento do nicho ecológico e uso do habitat por *C. globulosa* e *P. tuberosa* e forneceu as primeiras informções na Amazônia brasileira sobre a relação iterespecífica das espécie.

ABSTRACT

The evaluation of how species use habitat in areas well conserved is an important tool to understand their ecological niches. In this study, we aimed to determine the diel activity pattern and how inundation height, distance to the nearest water body, number of feline records and presence of baits influence habitat use by two curassow species, *Crax globulosa* and *Pauxi tuberosa*, in flooded and unflooded forests in Amazonia. Camera-trap stations were installed in the dry season, during five consecutive years in the flooded forest and three years in unflooded forest. The diel activity patterns of the species in the flooded forest were similar, as they were in flooded and unflooded forest. The number of feline records did not affect curassow distribution in any of the studied environments. However, in unflooded forest, *P. tuberosa* used sites with baits more often, whereas *C. globulosa* in flooded florest was more frequently recorded where inundation was shallow. Further, in flooded forest, both species responded to distance to the nearest water body, but in opposite ways: *C. globulosa* used more often sites near water bodies and *P. tuberosa* was recorded more often away from water bodies. These results suggest that there is no temporal partitioning in habitat use between the studied curassow species. Rather, the species tend to segregate spatially in response to the distribution of water bodies, possibly reflecting variation in available resources. This study allowed to increase the knowledge of the ecological niche and habitat use by *C. globulosa* and *P. tuberosa*, besides providing the first information about iterespecific relation of these species in the Brazilian Amazonian forest.

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INTRODUÇÃO GERAL

O habitat pode ser caracterizado como uma área em uma escala específica de espaço e tempo, composta por fatores bióticos e estruturais que propiciam recursos e condições necessárias para ocupação de um organismo (Block & Brennan, 1993; Kearney, 2006). A avaliação de como fatores bióticos e abióticos do habitat afetam a ocupação é uma importante ferramenta para compreender sobre as relações ecológicas e padrões de distribuição das espécies (Morris,1987).

O uso do habitat pode ser avaliado pela abundância, diversidade ou frequência de ocorrência das espécies ao longo de gradientes ambientais de ordem estrutural (Pearson,1975; Guerta & Cintra, 2014; Alvarenga et al. 2018), onde estes parâmetros podem variar conforme a capacidade de dispersão, tolerância a fatores abióticos e interações bióticas dos organismos (Brown, 1984; Cintra & Naka, 2012; Menger et al. 2017). Além disso, a avaliação temporal do uso diário do habitat pode fornecer informações sobre como cada organismo distribui seu tempo na busca por recursos alimentares, abrigo e reprodução (Halle, 2000), onde diferenças nas atividades diárias das espécies dentro de uma mesma área, pode ser fundamental para diminuir o risco de predação e competição (Kronfeld-Schor & Dayan, 2003).

As aves em específico, representam um grupo diverso que responde a variações sutis do ambiente (Bennet e Owens, 2002) permitindo determinar padrões de uso e seleção do habitat (MacArthur et al. 1966). Além disso, um mesmo habitat pode abrigar diversas espécies com certa proximidade filogenética, onde mecanismos ecológicos como a seleção natural, diferenças na composição da dieta, na distribuição espacial e temporal, permitem a co-ocorrencia das mesmas (Schoener, 1974; Estevo et al. 2017) por diminuir a sobreposição de nicho ecológico, reduzindo a competição (Pianka, 1973; Polechová & Storch, 2008; MacArthur & MacArthur, 1961).

Na Amazônia, aves de grande porte com hábitos de forrageio terrestre como cracídeos (Aves: Cracidae), têm sido registrados em florestas de várzea e terra firme (Michalski et al. 2015; Costa et al. 2018). Dentre elas, *Crax globulosa* especialista de florestas inundaveis, ocorre no Brazil onde é endêmico da bacia

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Amazônica (del Hoyo et al. 2017). Em certos locais, *Crax globulosa* é sintópico da especie *Pauxi tuberosa*, que possui distribuição mais ampla no Brasil, ocorrendo tanto em ambientes de várzea como terra firme (Haugaasen & Peres, 2008; del Hoyo, 2017), pertencendo a um gênero com hábitos mais generalistas (Santamaría & Franco, 2000; Hill et al. 2008) . Ambas espécies também ocorrem na Colômbia, Equador, Peru e Bolívia (del Hoyo, 2017), mas poucas são as informações disponíveis sobre o uso do habitat e relação ecologica interespecífica destes cracídeos.

Os ecossistemas de várzea e terra firme, diferem em densidade e riqueza de espécies da fauna, quanto ao grau de influencia da inundação e distribuição de corpos hidricos, que influenciam de diferentes formas o uso do habitat pelas espécies (Haugaasen & Peres, 2008; Alvarenga et al., 2018). Nas florestas inundaveis, a dinamica da inundação pode ter efeitos diretos sobre a detecção e distribuição das espécies (Ayres, 1993; Cintra, 2012), por modificar a estrutura física do habitat incluindo áreas de repouso, nidificação e fontes de alimento (González, 1996b, 1997; Arthur et al., 2012). A resposta a inundação ainda pode diferir conforme a espécie, onde a probabilidade de ocorrência de algumas aves pode diminuir em áreas de maior frequência de inundação, enquanto outras podem apresentar seleçao por areas com longos períodos de inundação (Royan et al., 2013; Leite et al., 2018).

As aves também podem responder de diferentes formas ao gradiente de distância do corpo hídrico, tendo preferência por áreas mais próximas ou distantes da água (Hill et al., 2008; Cintra & Cancelli, 2008). Em ambientes inundáveis, a proximidade de algumas espécies com a água pode ocorrer devido viabilizar a reprodução, alimentação e fuga contra predadores (Leite *et al,* 2018). Já em florestas de terra firme, maior abundancia de especies longe de corpos hidricos pode ser associada a mudança da disponibilidade de alimentos (Esclarski & Cintra, 2014).

Além disso, fatores bióticos como a presença de predadores podem interferir no uso do habitat por presas que tentam minimizar o risco de predação (Murphy et al., 2018). Aves de maior biomassa, como os mutuns, servem como fonte de alimento para alguns predadores carnívoros (Aranda & Sánchez-Cordero, 1996) que podem ser mais frequentes em áreas com maior disponibilidade da presa (Ávira-Nájera et al., 2018).

O uso de armadilhas fotográficas é atualmente um dos métodos frequentemente utilizados para obter dados sobre relações ecológicas entre espécies, padrão de atividade temporal (Frey et al., 2017) e como variaveis estruturais do ambiente influenciam a distribuição de vertebrados (O'brien & Kinnaird, 2008). Iscas tem sido associadas a armadilhas fotográficas para atrair vertebrados terrestres (Rocha, 2015), mas pouco se sabe sobre como o uso destes atrativos influencia a detecção de aves. Algumas aves possuem um sistema olfativo preciso (Steiger et al., 2008) e tem sido capturadas eventualmente em armadilhas com isca (Brennan, 2004). Dessa forma, a avaliação de como a isca influencia a detecção de espécies é uma questão metodologica importante a ser considerada em estudos que envolvam frequência de detecção.

Neste estudo, determinamos os padrões de atividade temporal de dois mutuns da Amazônia, *Crax globulosa* e *Pauxi tuberosa*, em florestas de várzea e terra firme, e testamos se o padrão diferia entre espécies e habitat. Também avaliamos como a altura da inundação, a distância até o corpo hídrico mais próximo, o número de registros de felinos e a presença de iscas influenciam o uso do habitat por essas espécies.

OBJETIVOS

Objetivo Geral

Determinar o padrão de atividade temporal e fatores bióticos e abióticos que influenciam no uso do habitat por *Crax globulosa* e *Pauxi tuberosa* em áreas de várzea e terra firme.

Objetivos específicos

- Determinar como a frequencia de registros de *Crax globulosa* e *Pauxi tuberosa* varia ao longo do dia na várzea e entre várzea e terra firme.
- Determinar se iscas associadas a armadilhas fotográficas influenciam o número de registro de *Crax globulosa* e *Pauxi tuberosa*.
- Determinar como a frequencia de registros de felinos afeta a de mutuns em área de várzea e terra firme
- Determinar como que a altura da inundação e a distância do corpo hídrico afetam o número de registros de *Crax globulosa* e *Pauxi tuberosa* em áreas de várzea e terra firme*.*

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Diel activity pattern and habitat use by *Crax globulosa* and *Pauxi tuberosa* in flooded and unflooded Amazonian forest

Priscilla Rodrigues Mady Paciullo[1]*, Emiliano Esterci Ramalho[2], Anelise Montanarin[2], Pedro Aurélio Costa Lima Pequeno[3], William Ernest Magnusson[1]

[1] Instituto Nacional de Pesquisas da Amazônia – INPA, Av. André Araújo 2936, 69067-375, Manaus/AM, Brazil.

[2] Instituto de Desenvolvimento Sustentável Mamirauá, Estrada do Bexiga 2584, 69553-225, Tefé/AM, Brazil.

[3] Universidade Federal de Roraima, Av. Cap. Ene Garcês, 2413 - Aeroporto, 69310-000, Boa Vista/RR, Brazil.

*E-mail: prisci.mady.rp@gmail.com (PRMP)

Abstract

The evaluation of how species use habitat in areas well conserved is an important tool to understand their ecological niches. In this study, we aimed to determine the diel activity pattern and how inundation height, distance to the nearest water body, number of feline records and presence of baits influence habitat use by two curassow species, *Crax globulosa* and *Pauxi tuberosa*, in flooded and unflooded forests in Amazonia. Camera trapping stations were installed in the dry season, during five consecutive years in the flooded forest and three years in unflooded forest. The diel activity patterns of species in the flooded forest were similar, as they were in flooded and unflooded forest. The number of feline records did not affect curassow distribution in any of the studied environments. However, in unflooded forest, *P. tuberosa* used sites with baits more often, whereas *C. globulosa* in flooded florest was more frequently recorded where inundation was shallow. Further, in flooded forest, both species responded to distance to the nearest water body, but in opposite ways: *C. globulosa* used more often sites near water bodies and *P. tuberosa* was recorded more often away from water bodies. These results suggest that there is no temporal partitioning in habitat use between the studied curassow species. Rather, species tend to segregate spatially in response to the distribution of water bodies, possibly reflecting variation in available resources.

Keywords: curassow**,** camera trapping, temporal activity, spatial organization, Amazonian ecosystems

Introduction

The evaluation of how species use habitat in well conserved areas is an important tool to understand their distribution and ecological niches [1]. Habitat use can be evaluated by a species response to biotic and abiotic environmental factors on an established spatial scale, as well by the temporal activity pattern [2,3,4,5].

Use of camera traps is currently one of the most frequently used methods to obtain data on ecological relationships between species, temporal activity

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patterns [4] and how the heterogeneity of the environment influences the distribution of vertebrates [6]. Baits have frequently been associated with camera traps to attract terrestrial vertebrates [7,8], but little is known about how the use of baits influences the detection of non-carnivorous birds. Some birds have an accurate olfactory system [9] and maybe attracted to baited traps [10]. In addition, in environments where the visual field is limited, some birds have prioritized olfaction [11].

Large terrestrial-foraging birds, such as curassows (Aves: Cracidae), have been recorded by camera traps in flooded and unflooded environments [12,13]. These ecosystems differ in density and species richness of the fauna and flora, the degree to which they are influenced by floods and fruit production, which influence habitat use by species in different ways [7,14,15]. Due to behavioral adaptation, the temporal activity of animals may also change according to the heterogeneity of the occupied environment [16,17].

At a small spatial scales, habitat heterogeneity can be represented by environmental gradients along which species densities provide clues as to habitat preferences of different species [2,3,18]. In flooded and unflooded forest, several species of birds have been shown to respond to the gradient of distance from water [19,20,21]. In flooded forests, flooding may also have direct effects on habitat use by birds [22,23]. Biotic factors, such as presence of predators, can also influence habitat use by prey in order to minimize the risk of predation [24,25]. Large birds, such as curassows, are a food source for some carnivore predators [26,27], which may influence the detection of birds [24].

Competition can also modulate co-occurrence of species [28,29]. Flooded forests can have high curassow densities, such as *Crax globulosa* a specialist of floodplain environments, and *Pauxi tuberosa* an ecologically similar species that occurs in flooded and unflooded forests [15]. Mechanisms that can reduce competition and facilitate the occurrence of similar species in the same environment may be related to temporal [4,5] or spatial segregation [30] of species in the occupied habitat, reducing the ecological niche overlap [1,3 , 28].

In this study, we determined the diel activity patterns of two Amazonian curassows, *Crax globulosa* and *Pauxi tuberosa,* in flooded and unflooded forest, and tested whether the pattern differed between species and habitats. We also

determined how inundation height, distance to the nearest water body, number of feline records and presence of baits influence habitat use by these species.

Materials and methods

Study area

This study was conducted in the 1,124,000 ha Mamirauá Sustainable Development Reserve (1°49' to 3°09' S, 64°45' to 67°23' W), which is mainly covered by forest flooded by two sediment-laden rivers and many large oxbow lakes, and Amanã (1°35' to 3°16' S, 62°44' to 65°23' W), a 2,350,000 ha reserve (Fig 1), covered mainly (84%) by non-flooded terra-firme rainforest. Both reserves are located near Tefé (03° 21' S, 64° 42' W), Amazonas State, Brazil. The climate in the region is tropical humid, with average monthly temperature around 26°C and average annual precipitation between 2300 [31] and 3000 mm [32]. The dry period in the region occurs from September to November, after which the rivers rise until May with the peak of the flood during two consecutive months followed by the ebb of the rivers until about September [33].
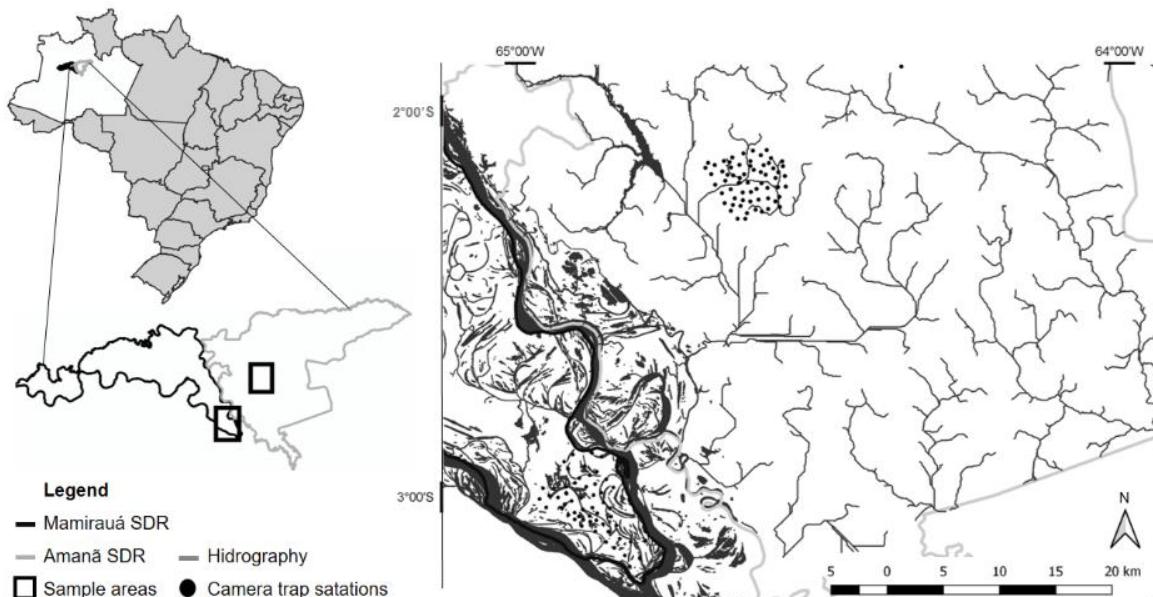
Fig 1. Map of the sample locations (black dots) in flooded forest of Mamirauá SDR and unflooded forest in Amanã SDR, Amazonas, Brazil.

Access to the Amanã and Mamirauá Sustainable Development Reserve was granted by the Instituto de Desenvolvimento Sustentável Mamirauá (IDSM). No ethical approval was required as this study did not involve animal handling, nor did it interfere with the animals' natural behavior.

Camera trapping

In Mamirauá SDR, sampling was carried out from September to January between 2012 and 2016, totalling 447 days of sampling. A total of 56 camera trapping stations were deployed, with 40 to 54 cameras separated by 1.1 to 5.5 km (2.3 ± 0.26 km) installed per year, covering a total area of 216.5 km².

In Amanã SDR, the study was conducted between December and May from 2013 to 2015, totalling 318 days. There, the sampling grid had 64 camera-trap stations spaced 1.7-2 km apart, covering an area of 140 km².

Each camera-trap station consisted of two camera-traps (model PC 800 Hyperfire, Reconyx Inc.) 4-5m apart facing each other, 40 cm above ground, configured to record 24 h/day, with no delay between consecutive triggers and 10 photos (one per second) per trigger. Detections of the same species at the same camera trap station separated by intervals of at least 30 minutes were considered independent.

Diel activity

Diel activity was evaluated by summing the number of records within each hour over the sampling periods, separated by species (*Crax globulosa* or *Pauxi tuberosa*) and study area (flooded or non-flooded florest), independent of the year.

Bait

The records of cracids obtained in this study were provided from camera traps originally installed to evaluate the population dynamics of *Panthera onca.* In some years and locations, a sardine and egg bait (~ 200 ml) was placed inside

a vented container fixed to the ground between each pair of cameras. At Amanã SDR, during 2013 and 2014, all the original grid of 50 camera-trap stations contained baits, but 14 extra points without baits were installed in the grid in 2014 and no stations had baits in 2015.

In Mamirarua, all câmera-trap stations contained baits from 2012 to 2014, but baits were placed in 26 camera-trap stations and the remainder (N= 28 and N=25) remained without bait in 2015 and 2016. Baits were renewed at 14-day intervals in both localities.

Feline records

The total number of records of felines (*Puma concolor*, *Panthera onca*, *Leopardus wiedii* and *Leopardus pardalis*) was used for data analyses for the non-flooded florest in campaigns with bait and without bait. In the flooded florest, only *Panthera onca* and *Leopardus wiedii* were recorded.

Environmental variables

The distance between each camera-trap station and the nearest permanent water body (stream, canal or lake) was obtained by measuring in the QGis 3.0 program the distance (in meters) on a map containing the latitudes and longitudes of the stations and the water resources shapefile. The shapefiles of permanent water bodies in Amanã and Mamirauá RDS were provided by Amazon Waters. In flooded florest, the inundation height was also obtained from the closest tree to the camera-trap station, in a similar topographical level, with a visible high-water mark on the trunk. The height of inundation was measured in each year with a measuring tape and the mean inundation height for each camera-trap station was used in analyses.

Analyses

To evaluate if diel activity patterns differed between species in flooded forest or between study areas for *Pauxi tuberosa*, we used the non-parametric Kolmogorov-Smirnov test for independent samples. The test evaluates the null

hypothesis that two variables (i.e. record times) have the same frequency distribution. To reduce the weight of stations with many records and avoid pseudoreplication, we also ran the analyses without possible records of the same individual at each station during a campaign. We considered images of same species at the same camera trapping station separated by intervals of at least 30 minutes as independent records when the individuals were not distinguishable by differences in sex or age. Results of the Kolmogorov-Smirnov test considering all the records (N= 456) were similar to those of the test which accounted for potential pseudoreplicates (N=272, S1 Table), so we present the results from the test with the larger sample size in the main text.

The effect of bait on the records of *P.tuberosa* in non-flooded florest was evaluated first by a Generalized Linear Model (GLM) assuming negative-binomial errors (for overdispersed count data) and log link for data from 2014. In this model, the dependent variable was the number of *P.tuberosa* and the predictors were the presence of bait (0,1), the number of feline records and distance to the nearest water body. The same was done for flooded-forest data from 2015 and 2016, separately. However, in this model, the dependent variable was the number of *P.tuberosa* or *C. Globulosa* and the predictors were the same as those used in non-flooded florest with the addition of average inundation height and the recorded number of the other species of curassow.

The effect of bait was also evaluated using the nonparametric Wilcoxon test for paired data to take into account a possible influence of the year on the recorded number of curassows at baits. This test was applied to determine if there was a difference in the detection of *P. tuberosa* between the 50 camera trap stations installed in 2013 and 2014 (mean of records) with the use of baits, and the 50 stations without bait in 2015 in non-flooded florest. The same was done for flooded-forest data considering the number of records of curassows from 37 camera trap stations without bait from 2015 and 2016 paired with the mean number of records at the same baited stations in other years.

To test the effect of number of feline records and the distance to nearest water body on the occurrence of *P.tuberosa* in non-flooded habitat, a GLM assuming negative-binomial errors was used, first considering the records from stations installed in campaigns using baits (n = 50), and then considering stations

without bait (N = 64). As no effect of bait on curassows record was detected in the flooded forest, the number of *C.globuosa*, *P. tuberosa* and feline records was counted for each of 56 camera trap-stations independent of the presence or absence of bait, a GLM assuming negative-binomial errors was used with the predictor variables number of feline records, distance to the nearest water body, inundation height and records of the species of curassow not used as the dependent variable. In all models, distance to nearest water body was log-transformed to account for its nonlinear effect.

We tested for spatial autocorrelation in the dependent and independent variables in all models using Moran's correlograms. In no case was spatial autocorrelation detected in both dependent and independent variables, so no adjustment for autocorrelation was included in the analyses [34]. All the analyses were undertaken in R, version 3.3.0.

Results

Diel activity

In unflooded forest, 70 records were obtained of *Pauxi tuberosa,* and none of *Crax globulosa*. In flooded forest, 220 records were obtained for *P. tuberosa* and 166 for *C. globulosa*. Curassows were photographed over 13 hours of the diel cycle beginning at 06:03 and ending at 18:22 (Fig 2). Both species had peak activity between 06:00 and 07:00 (Fig 2) in non-flooded and flooded rainforest.

The temporal activity patterns of *P.tuberosa* (Fig 2A) and *C. globulosa* (Fig 2B) in the flooded florest were similar (D = 0,05, p = 0,97), with constant activity after the morning peak and decrease to 18:00. In the non-flooded forest, the recorded number of *P. tuberosa* declined throughout most of the day after the morning peak activity, with a second peak between 16:00 and 18:00 (Fig 2A). Nevertheless, the distribution of record times of *P. tuberosa* also did not differ statisitcally (D = 0.15, p = 0.20) between flooded and unflooded forest.
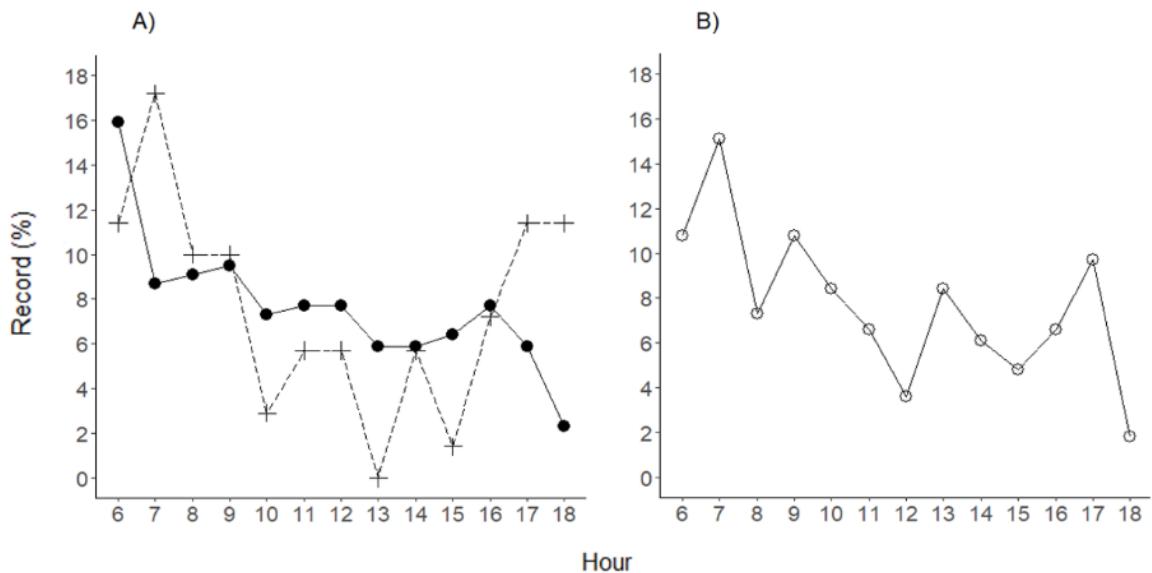
Fig 2. Percentage of records per hour of curassows. (A) *Pauxi tuberosa* in non-flooded (+) or flooded forest (●), and (B) *Crax globulosa* (○) in flooded forest.

Bait effect

There was evidence that the distribution of *P. tuberosa* records in non-flooded florest in 2014 was influenced positively (R^2 = 0.154) by the presence of bait (P = 0.06) in the camera-trap stations (Fig 3A), but not by the number of feline records (P = 0.53) or distance to the nearest water body (P = 0.12). Considering paired information among years, there was no difference (V = 248, p = 0.15) in the detection of *P. tuberosa* between stations with bait and without bait.

In flooded florest, controlling the effect of other predictor variables, bait did not influence the number of *P. tuberosa* (P = 0.702) or *C. globulosa* (P = 0.196) in 2015 or 2016. Over all years, more *P. tuberosa* were detected in the same stations (N = 37) when bait was present (V = 259, p = 0.002) (S3 Fig).
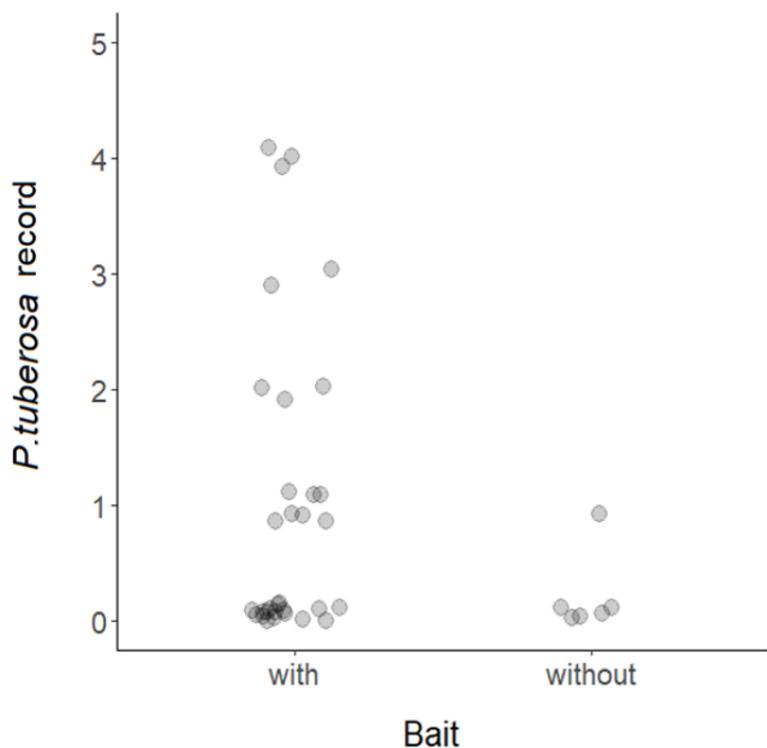
Fig 3. Number of *P. tuberosa* records at camera-trap stations with or without the presence of bait in 2014 in unflooded forest.

Effect of feline records and environmental variables

In unflooded forest, the distance from the stations with bait to the nearest water body varied from 141 to 3867 meters (1227 ± 883), similar to the stations without bait that ranged from 81 to 3867 (1204 ± 939) meters. Feline records and distance to the nearest water body were not related to *P. tuberosa* records in places with (R^2 = 0.054) or without (R^2 = 0.041) baits (Table 1).

Table 1. Generalized linear model relative to the effect of the the number of feline records and distance to nearest water body on the recorded number of *P. tuberosa* for stations with and without bait in unflooded forest.

With baits (N=50)			
Predictors	Coefficient	*z*	P
Intercept	-0.456		
Feline record number	0.149	1.629	0.103
Water body distance	0.0001	0.540	0.590

Without bait (N=64)			
Intercept	-1.482		
Feline record number	-0.179	-0.724	0.469
Water body distance	0.0003	1.015	0.310

As in non-flooded forest, the number of curassow records in the floodplain environment was not related to the number of records of felines (S2 Table). However, in flooded forest, the distance from the stations to the nearest water body, which varied from 1 m to 1380 meters (285 ± 305 meters), influenced positively the number of *P. tuberosa* recorded ($R^2 = 0.170$, P = 0,001) and negatively ($R^2 = 0.28$, P= 0.015) the number of *C. globulosa* (Fig 4) (S2 Table). The highest number of *C. globulosa* recorded was in areas closest to water (<250m) and the maximum distance at which *C. globulosa* was recorded was 890 meters, whereas *P.tuberosa* was recorded from 180 m to 1380 m from water.
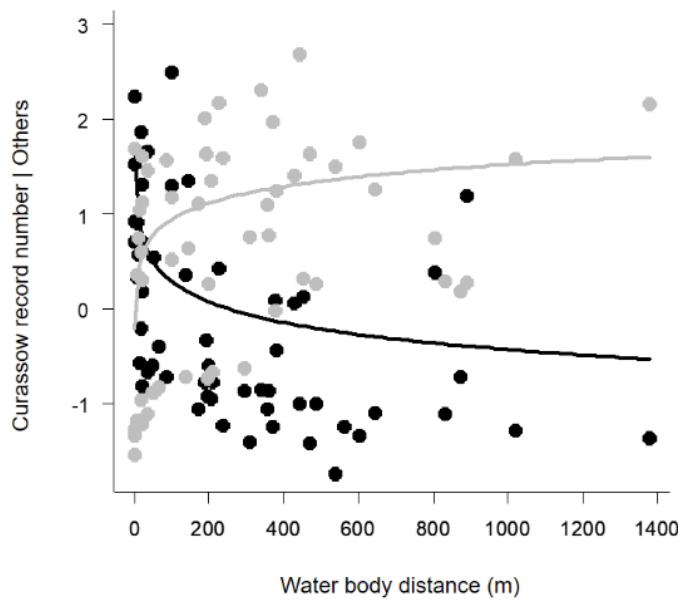
Fig 4. Partial regressions of the relationships between number of curassow records and water-body distance (m) in flooded forest. The line represents the negative (black) or positive (grey) relationship between records of *C. globulosa* (black points) or *P. tuberosa* (grey points) and the distance to the nearest water body. Some numbers in the y axe are negative because the partial regression represents the deviation of the expected results if all the other independent variables are kept in their observed means.

Only the recorded number of *C. globulosa* was negatively related to the mean flood height ($R^2 = 0.28$, P= < 0.001), which ranged from 2.1 to 7.1 meters (Fig 5). Also, in the studied area, the site closest to water body is not necessarily the area where the flood reaches a higher height, since this variable has a low positive correlation (0.107) with the water distance.
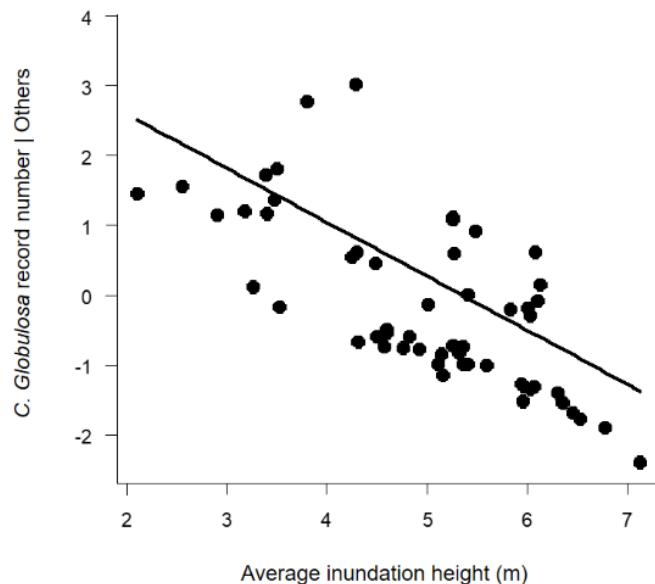
Fig 5. Partial regression of the relationship between number of records of *C. globulosa* and the average inundation height in flooded forest. Some numbers in the y axe are negative because the partial regression represents the deviation of the expected results if all the other independent variables are kept in their observed means.

Discussion

The trade-off between the risk of predation and starvation, the availability of food, the habitat type and the co-ocurrence of sympatric species are factors that may influence the temporal activity pattern of vertebrates in different environments [35,17,36,37]. Even though the diversity of predators, floristic characteristics, occurrence and density of curassow species and the seasonal availability of food are distinct between flooded and unflooded forest [7,38,15,14], in this study, the environmental differences did not cause statistically detectable

changes in the temporal activity range and patterns between *Pauxi tuberosa* populations.

Even in habitats with different structure and resources, such as natural forest and *Eucalyptus* reforestation, some species show high overlap in their activity patterns between studied areas [39]. In habitats where essential resources to survival are predictable, the temporal memory of habitat use can be maintained based on the behavioral and physiological adaptations acquired by species over generations [28]. In addition, the temporal activity of some species of birds is strongly linked to circadian rhythms and suffers non-perceptible influences from other factors [40]. Our evidence suggests that the temporal activity of *Pauxi tuberosa* may be more associated with acquired temporal behavior and the circadian rhythms than local variations in resources.

The temporal activity range found for the curassows in this study was similar to that reported for *Pauxi tuberosa* [41] and *Crax blumenbachi*, although the temporal activity range reported for latter species was slightly higher [42].

The similarity in temporal activity between *Crax globulosa* and *Pauxi tuberosa*, and the fact that the number of one species recorded did not influence the other, indicates that there is no niche partitioning in a temporal dimension and that there is no direct interference between species. Co-occurrence can be observed in species of tinamous [30] and curassows [29], possibly due to differences in spatial distribution and diet that decrease competition for resources.

Preference for areas closer to water bodies has been reported for *Crax fasciolata* [43], *Crax rubra* [44] and *C. globulosa* at distances less than 250m from water [45], similar to that found for *C. globulosa* in this study. The presence of *Crax* species near water and forest edge seems to be important for nest building [46,47], escape from predators and diet [19,47].

C. globulosa is considered a specialist in floodplain environments, where it remains even during high-water periods using the tree canopy for shelter [22]. Therefore, the negative relationship found in this study between the recorded number of *C. globulosa* and inundation height in flooded florest may be an adaptive response to survive the prolonged annual floods. The maximum inundation height where *C. globulosa* was recorded in this study was 6.1 m which, according to Wittman [48], corresponds to areas with inundation period of 168

days. However, in the flooded forest from Jurua River, *C. globulosa* showed positive association with areas that are inundated for six to eight months [22]. This difference in *C. globulosa* response to flooding may occur due to the different methodologies used in the studies, as well as differences in the topography and hydrology of the two flooded forest, where the study area of this work, has more large oxbow lakes that may favor negative association with flooding.

In contrast, *P.tuberosa* occurred more frequently far from water and was not influenced by inundation height in flooded forest. A similar result due to distance from water was observed for the same species in flooded Bolivian forest [19]. Co-occurrence of *P.tuberosa* with other species in flooded environments may be related to the need to range across large areas following fruiting or other preferred food [19,49,50] that may differ in presence and abundance along environmental gradients. Habitat partitioning by species in at least one dimension is thought to be important for the maintenance of bird communities [29]. In this study, the spatial segregation found for curassows along the water-distance gradient may allow the co-occurrence of the two species in flooded forest.

Although large birds are important prey for many mammalian predators [15] and curassows are preyed upon by felines [26], the number of feline records was not associated with records of curassows in the flooded or unflooded forest in this study. In Amapá National Forest, there was also no relationship between feline occurrence and large terrestrial birds, such as Cracidae and Psophiidae [12]. Species may not respond to the risk of predation by predators when resource availability is more important for survival [51].

Camera traps are commonly used in studies of felines and other mammals, and are useful to register large birds with terrestrial-foraging habits, which in most cases are not the principal targets of surveys [6,52]. The baits used in association with traps have little effect on feline records but negatively affect some frugivorous vertebrates in unflooded forest [8]. In contrast, *P. tuberosa* used sites with baits more often. Baited traps have resulted in the accidental capture of birds and have been used as a method to increase the chances of capture [10,53]. The attraction of birds by the bait may occur due to some species having a better developed olfactory system [9] or the habitat providing few visual cues [11]. Efficiency in attracting birds may also depend on the type of bait used [54].

Therefore the presence of bait should be taken into account in analysis of data from camera traps, especially in unflooded forests.

We conclude that diel-activity patterns of *Crax globulosa* and *Pauxi tuberosa* do not differ from each other, nor do they vary between flooded and unflooded forests for *P. tuberosa*, so there is no evidence of temporal partitioning between these species. The risk of feline predation does not appear to affect curassow activity in the forests we studied. Habitat segregation between species was observed only along the gradient of distance from water bodies, with *C. globulosa* being more common in habitats with lower flood height.

Supporting Information

S1 Table. **Kolmogorov-Smirnov (KS) test to evaluate possible differences between the diel activity pattern of curassows based on a total of 272 records.** (A) KS between record distributions per time interval of *Crax globulosa* (n=87) and *Pauxi tuberosa* (n=135) in flooded forest; and (B) *Pauxi tuberosa* between flooded and unflooded (n=50) forest.

Kolmogorov-Smirnov		
Test	D	p
A	0.037	0.994
B	0.057	0.431

S2 Table. Generalized linear model relative to the effect of the predictor variables on the recorded number of *P. tuberosa* or *C. globulosa* from 56 camera-trap stations in flooded forest.

P. tuberosa			
Predictors	Coefficient	*Z*	P
Intercept	0.156		
Crax-record number	0.044	1.601	0.109
Feline-record number	-0.010	-0.260	0.794
Water-body distance	0.255	3.167	0.001

Inundation height	-0.064	-0.504	0.614
	C. globulosa		
Intercept	5.207		
Pauxi-record number	0.050	0.768	0.442
Feline-record number	0.103	1.417	0.156
Water-body distance	-0.311	-2.413	0.015
Inundation height	-0.771	-3.674	0.0002
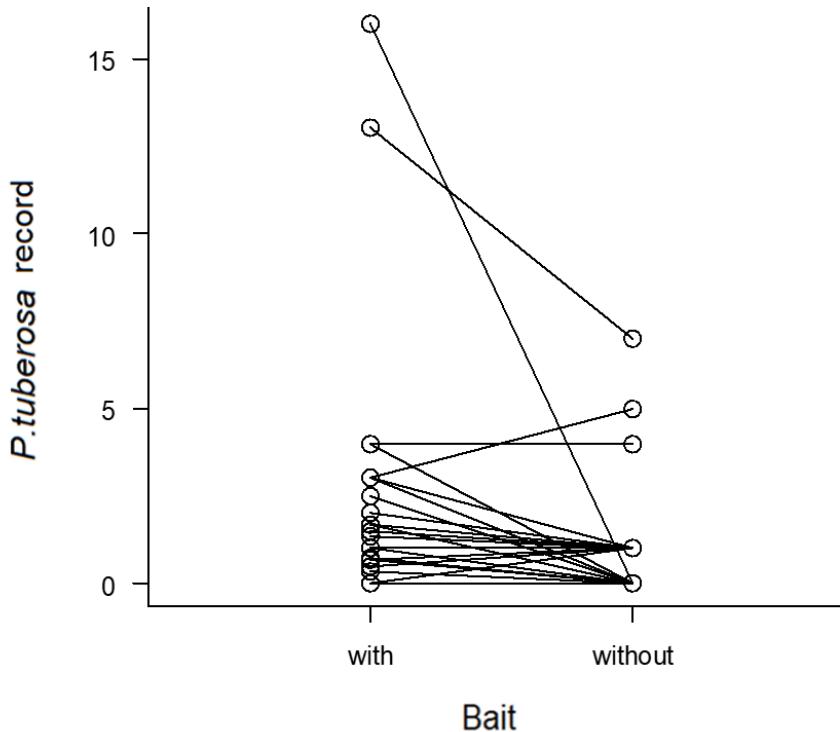
S3 Fig. **Number of *P. tuberosa* records at camera-trap stations with or without the presence of bait in flooded forest.** 37 paired camera trap stations.

Acknowledgments

Author Contributions

1. **Conceptualization:** PRMP WEM EER.

2. **Data curation:** PRMP AM EER.

3. **Formal analysis:** PRMP PACLP WEM.

4. **Funding acquisition:** EER.

5. **Investigation:** PRMP PACLP WEM.

6. **Methodology:** PRMP EER WEM.

7. **Project administration:** PRMP WEM.

8. **Resources:** EER WEM.

9. **Supervision:** EER PACLP WEM.

10. **Writing – original draft:** PRMP WEM.

11. **Writing – review & editing:** PRMP PACLP WEM.

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Conclusão

Os achados deste estudo permitiram ampliar o conhecimento sobre o nicho ecológico e fornece as primeiras informações na Amazônia brasileira sobre a relação iterespecífica das espécies estudadas. Também foram os primeiros relatos do uso do habitat por *Crax globulosa* e *Pauxi tuberosa* nas reservas de desenvolvimento sustentável estudadas, podendo servir de subsídeo para definição de áreas de monitoramento.

Além disso, concluimos por meio deste estudo que na floresta de várzea *P. tuberosa* não apresenta partição de nicho temporal com *C. gloulosa*. De acordo com a teoria da exclusão competitiva e de nicho ecológico a co-ocorrencia de especies pode ser viável quando a sobreposição do nicho ecológico é reduzida em pelo menos uma dimensão, como observado pela segregação espacial entre as espécies ao longo do gradiente de distância do corpo hídrico na várzea. Na floresta de várzea, *P. tuberosa* ocupou mais ambientes distantes da agua enquanto *C. globulosa* permaneceu mais proximo a corpos d'agua, expressando preferencias distintas de microhabitat em que a primeira espécie pode ainda ser mais generalista na obtenção de recursos que variam ao longo de distancias maiores dos corpos d'agua. Na floresta de terra firme a distância da água não afetou a distribuição de *P. tuberosa*.

Na várzea, *C. globulosa* foi mais abundante em habitats onde a altura da inundação foi menor. A altura da inundação não influenciou o uso do habitat por *P. tuberosa* na várzea, sendo importante a realização de futuros estudos de telemetria, tanto no período de seca quanto na cheia, para determinar os microhabitas mais usados pela espécie e se ocorre migraçao para áreas de terra firme, permitindo compreender melhor esta reposta. Em contraste à nossa hipótese inicial, o risco de predação por felinos não interferiu na atividade dos mutuns em florestas de várzea ou terra firme ainda bem conservadas.

A isca parece atrair *P. tuberosa* de forma mais evidente em área de terra firme, sugerindo que o olfato pode ser importante para o forrageio desta espécie principalmente em áreas de floresta mais densa onde o campo visual é diminuido. Este foi o primeiro estudo que testou o efeito da isca no registro de *C.globulosa* e *P. tuberosa,* sendo importante para base metodologica de estudos que envolvam o uso de camera trap e captura.

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