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PADRÃO DE ATIVIDADE E FATORES QUE AFETAM A AMOSTRAGEM DE MAMÍFEROS DE MÉDIO E GRANDE PORTE NA AMAZÔNIA CENTRAL

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Manaus, Amazonas
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Sinopse

Estudou-se o período de atividades de espécies de mamíferos terrestre de médio e grande porte na Reserva de Desenvolvimento Sustentável Amanã. Também foi avaliado o efeito de trilhas e isca no número de registros de espécies de mamíferos carnívoros e não carnívoros. Adicionalmente, foi avaliado se o uso da isca aumenta a qualidade dos registros de animais com marcas naturais.

Palavras-Chave: ecologia, distribuição, comportamento, tendências de amostragem, armadilhas fotográficas.

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"O bom cientista se revela, se realiza no seu laboratório. Isso é lógico, ninguém escapa. Mas o cientista feliz é aquele que se integra na mata..."

Paulo Vanzolini

Resumo

Amostrar e monitorar animais elusivos, com densidades naturalmente baixas e grandes áreas de vida, como muitas espécies de mamíferos de médio e grande porte, é geralmente complexo. A distribuição e ecologia de muitas espécies amazônicas de mamíferos de médio e grande porte são pouco conhecidas. Além disto, baixas taxas de captura podem inviabilizar análises detalhadas. A carência dessas informações leva a ações de conservação e manejo pouco efetivas. Foram executadas duas campanhas de armadilhamento fotográfico durante duas estações de seca consecutivas na Reserva de Desenvolvimento Sustentável Amanã, Amazônia Central. O esforço de campo total foi de 4894 armadilhas fotográficas*dia. A grade de amostragem consistiu de 64 estações de armadilhas fotográficas, com ou sem isca. Neste estudo foram registradas 22 espécies de mamíferos terrestres de médio e grande porte, dos quais 11 estão categorizadas como ameaçadas ou deficientes de dados no Brasil ou globalmente. O padrão de atividade da maioria das 15 espécies de mamíferos terrestres de médio e grande porte analisadas é concordante com os relatos de história natural na literatura. Foram encontradas relações fracas entre os padrões de atividades dos predadores e suas potenciais presas e não há evidencias de segregação temporal entre os grandes carnívoros. O cachorro-vinagre *Speothos venaticus* foi uma das espécies registradas por armadilhas fotográficas na Reserva Amanã. Apesar de sua distribuição cobrir toda a bacia Amazônica, a ocorrência do cachorro-vinagre em vastas áreas da Amazônia permanece hipotética. Os registros de cachorro-vinagre apresentados neste trabalho diminuem uma grande lacuna na distribuição conhecida da espécie na Amazônia Central e inclui o primeiro registro da espécie em florestas sazonalmente alagas por água preta (Igapó). Também foi testada a eficiência do uso de trilhas e isca em aumentar a taxa de captura de espécies terrestres de mamíferos de médio e grande porte em amostragens com armadilhas fotográficas. Adicionalmente, foi testado se a qualidade dos registros fotográficos de animais com marcas naturais são melhores em armadilhas fotográficas com isca. Contrariamente ao recomendado na literatura, tanto as trilhas como as iscas não aumentaram o número de registros de carnívoros, e reduziram o número de registro de espécies não carnívoras. Entretanto, a qualidade das fotos para identificação individual de espécies com marcas naturais é melhor em armadilhas fotográficas com isca. Conclui-se que o uso de trilha e isca

deve ser avaliado com cuidado durante o planejamento de qualquer estudo, uma vez que eles podem influenciar as taxas de detecção das espécies de interesse.

Abstract

Surveying and monitoring of elusive animals with naturally low densities and large home ranges, such as many medium- and large-sized mammals, is challenging. The distribution and ecology of many species of medium- and large-sized Amazonian mammals remain poorly understood. Scarcity of reliable data on species' occurrence and ecology can lead to weak and inappropriate conservation actions. Additionally, low capture rates can preclude detailed analyses. We carried out two camera-trap surveys in the dry season of two consecutive years with an overall sampling effort of 4894 camera trap*days in Amanã Sustainable Development Reserve, Central Amazonia. The sampling grid consisted of up to 64 baited or unbaited camera trap stations. During the study, we recorded 22 species of medium- and large-sized terrestrial mammals, of which 11 are categorized as threatened or data deficient, either globally or in Brazil. The activity patters of most of the 15 medium- and large-sized terrestrial mammals species analyzed are largely concordant with existing natural history accounts. We found weak relationships among daily activity patterns of predators and their potential prey, and there was no evidence of temporal segregation among large carnivores. One of the recorded species was the bush dog (*Speothos venaticus*). Although its distribution covers the entire Amazon basin, the presence of *S. venaticus* remains hypothetical over vast areas of the Amazon. The records of bush dog presented in this study reduces a large gap in the known distribution of the species in Central Amazonia, and include the first documentation of the species from forest seasonally flooded by black water (Igapó). We tested the efficiency of the use of trails and bait in improving capture rates of medium- and large-sized terrestrial mammals in camera-trap surveys in the Amazon. We also tested if the quality of photographic records of naturally marked felids is enhanced by the use of bait. Contrary to reports in the literature, we found that neither bait nor trails increased the number of photographic records of carnivores, and that they reduced the number of records of non-carnivore species. However, the quality of photographs for individual identification of naturally marked felids was greater at baited camera-trap sites. We conclude that the use of bait and trails should be carefully considered at the planning stage of any camera-trap studies as they may influence detection rates of species of interest.

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Introdução geral

A Floresta Amazônica é a maior floresta tropical do mundo e o maior bioma do Brasil. Na Amazônia brasileira ocorrem 51 espécies de mamíferos terrestres de médio e grande porte (Paglia et al., 2012) e 16 (31,3%) delas estão classificadas como ameaçadas ou deficientes de dados no Brasil ou globalmente (Chiarello et al., 2008; IUCN, 2014). Apesar dos mamíferos terrestres de médio e grande porte ser um dos grupos mais bem conhecidos, poucos locais de floresta Neotropical foram adequadamente amostrados (Voss e Emmons, 1996). Além de muitos aspectos ecológicos que ainda são desconhecidos, existem incertezas sobre a distribuição de muitas espécies de mamíferos que ocorrem na Amazônia e até hoje novas espécies são descritas (Cozzuol et al., 2013; Helgen et al., 2013). A carência de informações confiáveis sobre ocorrência e ecologia das espécies leva a ações de conservações e manejo pouco efetivas.

No Capítulo I apresentei dados de padrão de atividade de 15 espécies de mamíferos terrestres de médio e grande porte que ocorrem na Reserva de Desenvolvimento Sustentável Amanã, bem como uma lista das espécies registradas por armadilhas fotográficas e observação direta.

O cachorro-vinagre *Speothos venaticus* foi uma das espécies registradas por armadilhas fotográficas na Reserva Amanã. Apesar de sua distribuição cobrir toda a bacia Amazônica, a ocorrência do cachorro-vinagre em vastas áreas da Amazônia permanece hipotética. Por sua raridade e ausência de registros confirmados na Amazônia Central (Jorge et al., 2013), a espécie recebe atenção especial neste trabalho. No Capítulo II apresentei dados de ocorrência da espécie na Reserva Amanã que diminuem uma grande lacuna na distribuição da espécie na Amazônia Central e inclui o primeiro registro da espécie em floresta de Igapó.

A amostragem e monitoramento de espécies elusivas, com densidades naturalmente baixas e grandes áreas de vida, como é o caso de algumas espécies de mamíferos de médio e grande porte, são tarefas geralmente difíceis. Baixas taxas de captura podem inviabilizar análises detalhadas. No Capítulo III eu testo a eficiência do uso de trilhas e isca para aumentar a taxa de captura de espécies terrestres de mamíferos de médio e grande porte em amostragens com armadilhas fotográficas. Eu também avaliei se o uso de isca melhora a qualidade dos registros fotográficos de felinos com marcas naturais, tendo em vista a identificação individual.

Objetivos

-Caracterizar o padrão de atividade de mamíferos de médio e grande porte registrados na Reserva Amanã.

-Testar se o uso de trilha e isca influencia a taxa de captura das espécies de mamíferos de médio e grande porte em amostragem com armadilhas fotográficas.

-Testar se o uso de isca aumenta o número de fotos de alta qualidade por registro de espécies com marcas naturais, visando à identificação individual.

Capítulo I.

Rocha, D.G; Ramalho, E.E; & Magnusson, W.E. **Activity pattern of medium- and large-sized terrestrial mammals of Amanã Sustainable Development Reserve.** Manuscrito em preparação para *Mammalia*

Activity pattern of medium- and large-sized terrestrial mammals of Amanã Sustainable Development Reserve

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Abstract

The distribution and ecology of many species of medium- and large-sized Amazonian mammals are poorly understood. Scarcity of reliable species' occurrence and ecological data lead to weak and inaccurate conservation actions. Information on species daily activity patterns helps to understand interactions between species, such as resource partitioning and hunting preferences. In this study, we present activity-pattern data of medium- and large-sized terrestrial mammals from Amanã Sustainable Development Reserve, in Brazilian Central Amazonia. We carried out two camera-trap surveys in the dry season of two consecutive years with an overall sampling effort of 4894 camera trap*days. We recorded 22 species of medium- and large-sized terrestrial mammals, of which 11 are categorized as threatened or data deficient in Brazil or globally. The activity patters of most of the species are largely concordant with accounts of natural history. We found weak relationships among daily activity patterns of predators and their potential prey and there was no evidence of temporal segregation among large carnivores.

Keywords: camera-trap, threatened species, Amazon, temporal partitioning, predator coexistence

Introduction

The distribution and basic ecological information of many species of medium- and large-sized Amazon terrestrial mammals is poorly understood and new species are still being discovered (Cozzuol et al., 2013; Helgen et al., 2013). This is in large part due to the continental size of the Amazon Forest and the great number of species and ecosystems that it holds. There are also large sampling gaps because of the challenging and expensive logistics in the Amazon Forest. All assessments of status of threatened species and further conservation planning are based on available information of the species' distributions, requirements, and habitat preferences. Scarcity of reliable species' occurrence and ecological data lead to weak and inaccurate conservation actions.

Camera-trapping is an efficient, non-invasive sampling method that is being extensively used to survey terrestrial medium- and large-sized mammals (O'Connell et al., 2011). It produces trustworthy records of species with relative low field effort. Many camera-trap devices also provide the date and time of each record, allowing study of activity patterns of multiple species using a single study design, with minimal interference of the observer on the animal behavior (Bridges and Noss, 2011).

Patterns of daily activity can indicate ecological interaction between species. Based in camera-trap data, many studies have proposed temporal partitioning between predators (Karanth and Sunquist, 2000; Palomares and Caro, 1999; Romero-Muñoz et al., 2010), as well as temporal synchronism of predator and prey activity patterns (Foster et al., 2013; Hernández-Saintmartín et al., 2013; Linkie and Ridout, 2011). Knowledge of activity patterns of target species is also important for the establishing sampling designs and may be useful on the conservation perspective, as species can change their behavior in response to human disturbance (Kitchen et al., 2000; Paviolo et al., 2009)

In this study, we present camera-trap data to evaluate species' activity patterns during the dry season in Amanã Sustainable Development Reserve, Amazonian

Brazil. Additionally, we present occurrence data on other species recorded by the camera traps.

Methods

The camera-trap surveys were conducted within the Amanã Sustainable Development Reserve (2°21'S, 64°16'W) located between the Negro and Amazon Rivers. The reserve covers 2,350,000ha of pristine habitat near the confluence of the Amazon and Japurá rivers. Together with the Jaú National Park (2,367,000ha) to the East and the Mamirauá Sustainable Development Reserve (1,124,000ha) to the West, it forms one of the largest continuous blocks of protected tropical forest in the world and the core of the Amazon Biosphere Reserve. The survey area was composed of a mosaic of terra firme and floodplain (Igapó) forest. The *terra firme* covers approximately 84% of the reserve, and includes all areas that are not seasonally flooded. *Igapó* forests are seasonally flooded by black-water rivers. The climate in the region is tropical humid, with average monthly temperature around 26°C and an average annual precipitation of 2373 mm (Ayres, 1993). The camera-trap surveys were conducted during the dry season (when the water level in the region is low) on the edges of Amanã Lake, along the Ubim creek (2°28'05"S/64°36'25W).

Surveys of terrestrial medium- and large-sized mammals were carried out from January to March 2013 and from December to April 2014. The sampling effort was of 1909 and 2985 camera-trap*day per survey, respectively. The surveys were originally designed to estimate jaguar density in Amanã Reserve. In the first survey, the sampling grid had 50 camera trap stations, covering an area of 140 km^2 (minimum convex polygon), divided in two contiguous sampling blocks. Each block contained 25 camera trap stations, 1.7-2 km apart. Each camera-trap station consisted of two camera-traps (model PC 800 Hyperfire, Reconyx Inc.) facing each other 4-5m apart, with a bait of sardine and eggs (~200ml) located in the center of the camera-trap station. The baits were placed inside a container, largely inaccessible for consumption and fixed to the ground (less than 3% removal rate). In the second survey, 14 camera-trap stations were added to the sampling grid, without the bait, making the camera-trap density higher, 1-2km apart, but not altering the sampled area (Figure 1). All camera-trap stations were installed on natural paths made by animals with the exception of three that were installed on man-made trails (about 5km long, 2-3m width and regularly maintained). Camera traps were set to take one photo per second without pause and were serviced every 14 days to change batteries, download photos and refresh the baits. Sequential photos of the same species within 30 minutes were considered a single record. To analyze the activity patterns, we used a subset of all photographs records including only medium- and large-sized terrestrial mammals (with average body mass > 1kg), hence excluding small rodent and arboreal species.

We followed the threat status of the International Union for the Conservation of Nature (IUCN) Red List and the Brazilian Red list of Species Threatened by Extinction (Chiarello et al. 2008). When available, we used the updated assessment published by the Brazilian Environment Ministry (Ministério do Meio Ambiente/MMA).

We categorized the activity pattern of all the species with at least 15 records. We calculated the proportion of independent records during the night (from 18:00 to 5:59) for each species and classified them as diurnal (< 10% of records at night), mostly diurnal (10–29% of records at night), cathemeral (30–69% of records at night), mostly nocturnal (70–89% of records at night) and nocturnal (≥ 90% of records at night) (Gómez et al., 2005; van Schaik and Griffiths, 1996).

We used Pearson correlations to evaluate if there was a positive relationship between the number of records per hour interval of predators and their potential prey. To evaluate if there was temporal partitioning amongst predators, we also looked for negative correlations of activity patterns of predators.

Results and Discussion

We obtained 2714 photographic records of 20 species of medium- and large-sized terrestrial mammals, belonging to 12 families and seven orders, at Amanã Reserve (Table 1). Although they were not detected by camera-traps, we added to the list direct sightings of the neotropical otter *Lontra longicaudis* and the giant otter *Pteronura brasiliensis*.

The total number species recorded in Amanã Reserve represents 43% of the medium- and large-sized terrestrial mammals known to occur in the Brazilian

Amazon (51 species in total, according to Paglia et al. 2012). The Order Carnivora had the highest number of recorded species (9). Nine (40.9%) of the 22 species were categorized as threatened (vulnerable) in Brazil and two were data deficient (Chiarello et al., 2008). The IUCN lists three species (18.2%) as vulnerable, the giant otter as endangered, and two species as data deficient (IUCN, 2014) (Table 1).

Of the 20 species of terrestrial medium- and large-sized mammals recorded by camera-traps, only 15 had at least 15 records (Table 2). Activity patterns of those species are presented in Figure 2. The black agouti *Dasyprocta fuliginosa*, the brown brocket deer *Mazama nemorivaga,* and the tayra *Eira barbara* are diurnal. The giant anteater *Myrmecophaga tridactyla* and the collared peccary *Pecari tajacu* are mostly diurnal. The ocelot *Leopardus pardalis* and the red brocket deer *Mazama americana* are mostly nocturnal. The lowland tapir *Tapirus terrestris*, the giant armadillo *Priodontes maximus*, the common opossum *Didelphis marsupialis*, the paca *Cuniculus paca,* and the nine-banded armadilho *Dasypus novemcinctus* are nocturnal. The jaguar *Panthera onca* and puma *Puma concolor* are cathemeral. The green acouchi *Myoprocta pratti* was classified as crepuscular for its distinct activity pattern with peaks of record events during the dawn and dusk (Figure 2).

Variations in behavior and daily activity patterns of a species may occur locally between habitats and over broader geographic scales (Blake et al., 2012; Iriarte et al., 1990). However, there are limitations when comparing activity patterns among studies, such as lack of standardization of activity-pattern classification criteria. Another problem is the differences in the seasons in which surveys were undertaken, this is important as species behavior can vary seasonally (Scognamillo et al., 2003). To conduct activity pattern analyses it is necessary to have sufficient records of a given species. The species composition and the abundance of species vary between studies sites. Consequently, the activity pattern of many species has been reported in one or only a few studies, especially those species belonging to highly-diverse genera (e.g. *Dasyprocta*).

In this study, recorded activity pattern for most non-carnivore species agreed with information already available in the literature, such as the diurnal collared peccary (Blake et al., 2012; Gómez et al., 2005; Harmsen et al., 2011; Hernández-Saintmartín et al., 2013; Maffei et al., 2002; Tobler et al., 2009), the nocturnal lowland tapir (Blake et al., 2012; Gómez et al., 2005; Harmsen et al., 2011; Maffei et al., 2002; Noss et al., 2003; Tobler et al., 2009), paca (Blake et al., 2012; Dubost and Henry, 2006; Gómez et al., 2005) and giant armadillo (Blake et al., 2012; Maffei et al., 2002; Noss et al., 2004). Although, the mostly nocturnal habit of the red brocket deer found in this study disagrees with the frequent assessment of the species as cathemeral (Blake et al., 2012; Gómez et al., 2005; Tobler et al., 2009) or diurnal patterns (Harmsen et al., 2011).

The nocturnal habit of the ocelot is well known (Blake et al., 2012; Gómez et al., 2005; Maffei et al., 2005, 2002; Tobler et al., 2009). The puma seems to have a flexible activity pattern, since studies have classified pumas as cathemeral (Gómez et al., 2005; Maffei et al., 2002), nocturnal (Blake et al., 2012; Harmsen et al., 2011) or diurnal (Romero-Muñoz et al., 2010). In the Amazon, jaguars are usually cathemeral (Blake et al., 2012; Emmons, 1987; Gómez et al., 2005; Hernández-Saintmartín et al., 2013) or nocturnal (Harmsen et al., 2011; Romero-Muñoz et al., 2010; Scognamillo et al., 2003).

There was a positive correlation between the activity pattern of the jaguar and the brown brocket deer; the puma and the collared peccary and green acouchi; and the ocelot and the nine-banded armadillo (Table 3). However, none of the significantly positive correlations were strong ($r<0.5$). Some studies imply that predator may be adjusting its activity pattern according to its prey when a high overlap of activity patterns is found (Emmons, 1987; Foster et al., 2013; Harmsen et al., 2009; Scognamillo et al., 2003). This adjust makes sense when the prey species become unavailable for the predator during the prey period of inactivity. This is the case of the paca, agouti, acouchi and armadillos that hide inside burrows, resting holes and excavations when not foraging. Felids may have a better hunting success when their prey are active (Harmsen et al., 2011), since cats rely on auditory and visual clues for hunting (Kitchener, 1991; Sunquist and Sunquist, 2002). Although non-borrowing prey are more vulnerable when they are not active (Sunquist et al., 1989), and hunting may also occur during those periods. Thus, absence of synchronization in activity patterns of predator and non-borrowing prey does not necessarily indicate low predation rates. Kamler et al. (2012) found that activity pattern of Dholes *Cuon* *alpinus* in northern Laos was significantly different to the activity pattern of their main prey species.

Although there is no available information about the diet of the felids in Amanã Reserve, the cathemeral habit of the big cats and the weak correlation of activity pattern of predator and their potential prey may indicate generalist food habits. While the jaguar and puma displayed cathemeral pattern, most of the prey species were restrained to either day or night. This indicates that jaguars and pumas are not following the daily schedule of any specific prey item (Romero-Muñoz et al., 2010).This strategy may allow use of a more diverse prey base. The low human disturbance in Amanã Reserve may also favor the activity of the big cats during the day (Paviolo et al., 2009).

Some studies have investigated temporal partitioning of sympatric species that have similar diets (e.g. Romero-Muñoz et al., 2010; Tobler et al., 2009). In this study, the families with more than one species recorded were represented both by nocturnal and diurnal species (Blake et al., 2012). The three species of rodents, the paca, the black agouti and the green acouchi have dissimilar activity patterns. The same is true of the cervid and felid species as well. This may be due to temporal partitioning, since overlap in diet tends to be higher in closely related species (Darwin, 1958). The exception to that tendency is the family Dasypodidae, in which the nine-banded armadillo and giant armadillo were both highly nocturnal.

Many authors have sought temporal segregation between jaguars and pumas (Estrada and Hernández, 2008; Foster et al., 2013; Harmsen et al., 2009; Scognamillo et al., 2003) and Schaller and Crawshaw (1980) suggested that pumas avoid encounters with jaguars. In this study, they both had cathemeral habits and there was no significant negative correlation between the number of records per hour of jaguar and puma ($r = 0.294$; $p = 0.16$). Thus, the evidence for temporal segregation between them is weak and coexistence may be possible due to food or spatial partitioning (Schoener, 1971).

Conclusion

This study recorded 22 species of medium- and large-sized terrestrial mammals in Amanã Reserve, of which 11 are categorized as threatened or data deficient in Brazil or globally. The activity patters of most of the species are largely concordant with accounts of natural history. We found weak relationships among daily activity patterns of predators and their potential prey, and there was no evidence of temporal segregation among large carnivores. It appears that, at least in the area that we studied, the daily activity pattern seems not to be the predominant factor to understand how species interact.

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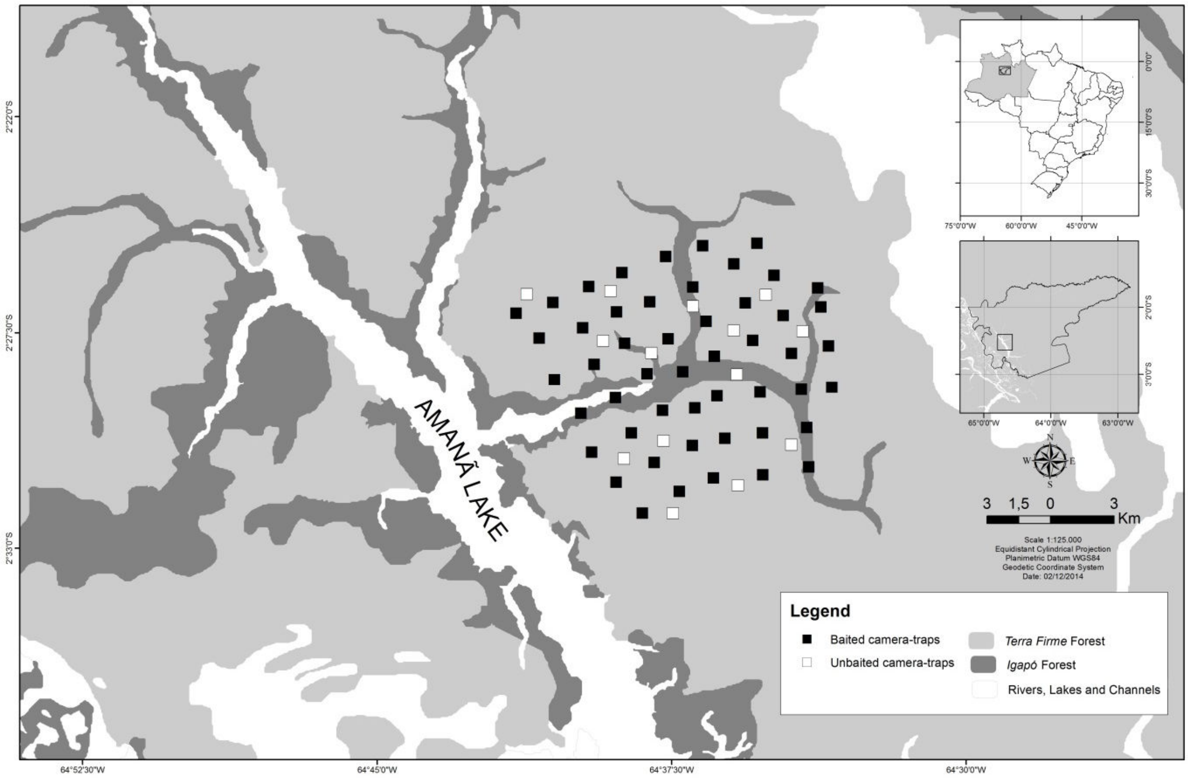
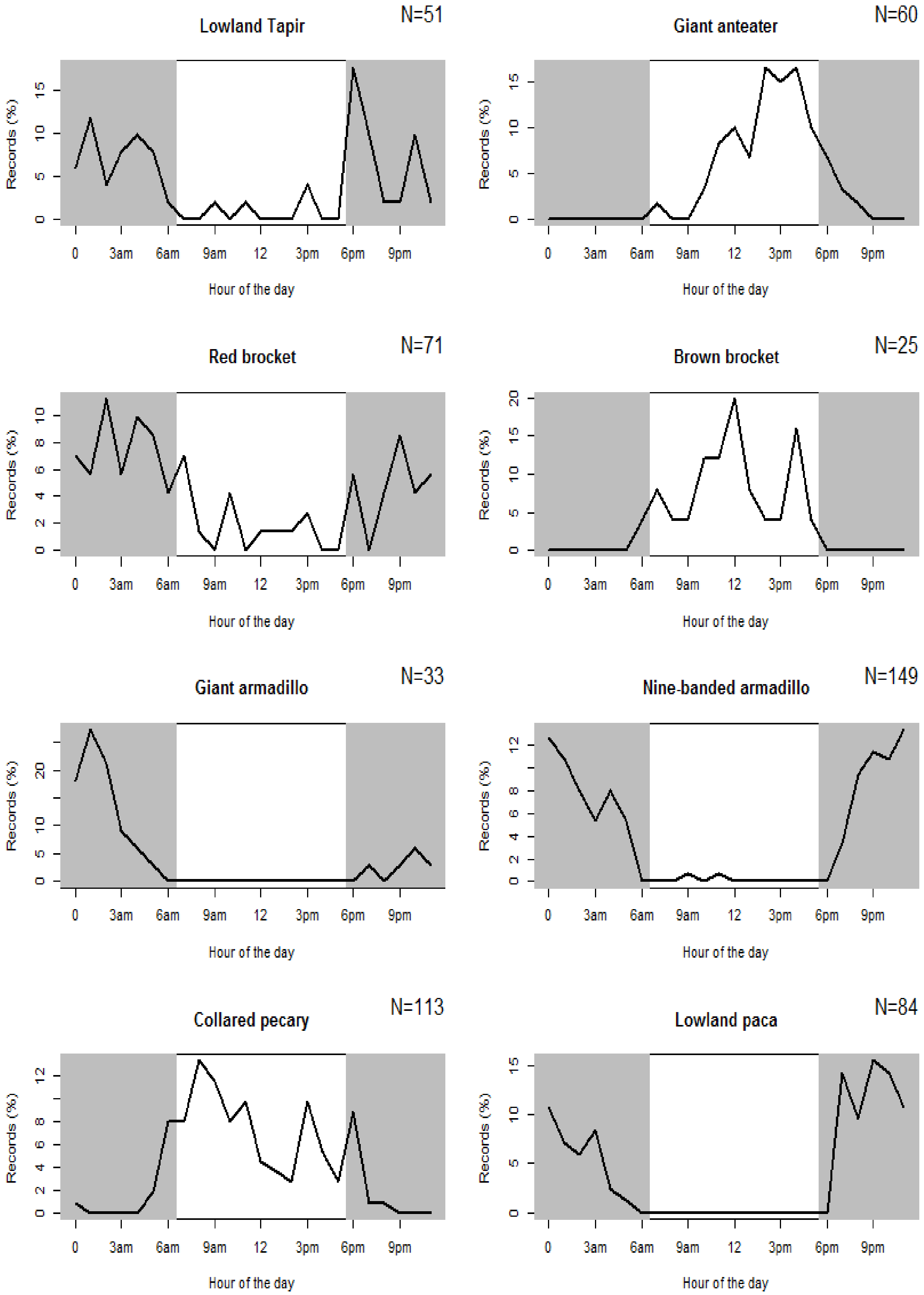


Figure 1. Map of the area surveyed with camera traps in Amanã Sustainable Development Reserve.


Lowland Tapir
N=51
Giant anteater
N=60
Red brocket
N=71
Brown brocket
N=25
Giant armadillo
N=33
Nine-banded armadillo
N=149
Collared pecary
N=113
Lowland paca
N=84
Records (%)
Hour of the day
0
3am
6am
9am
12
3pm
6pm
9pm

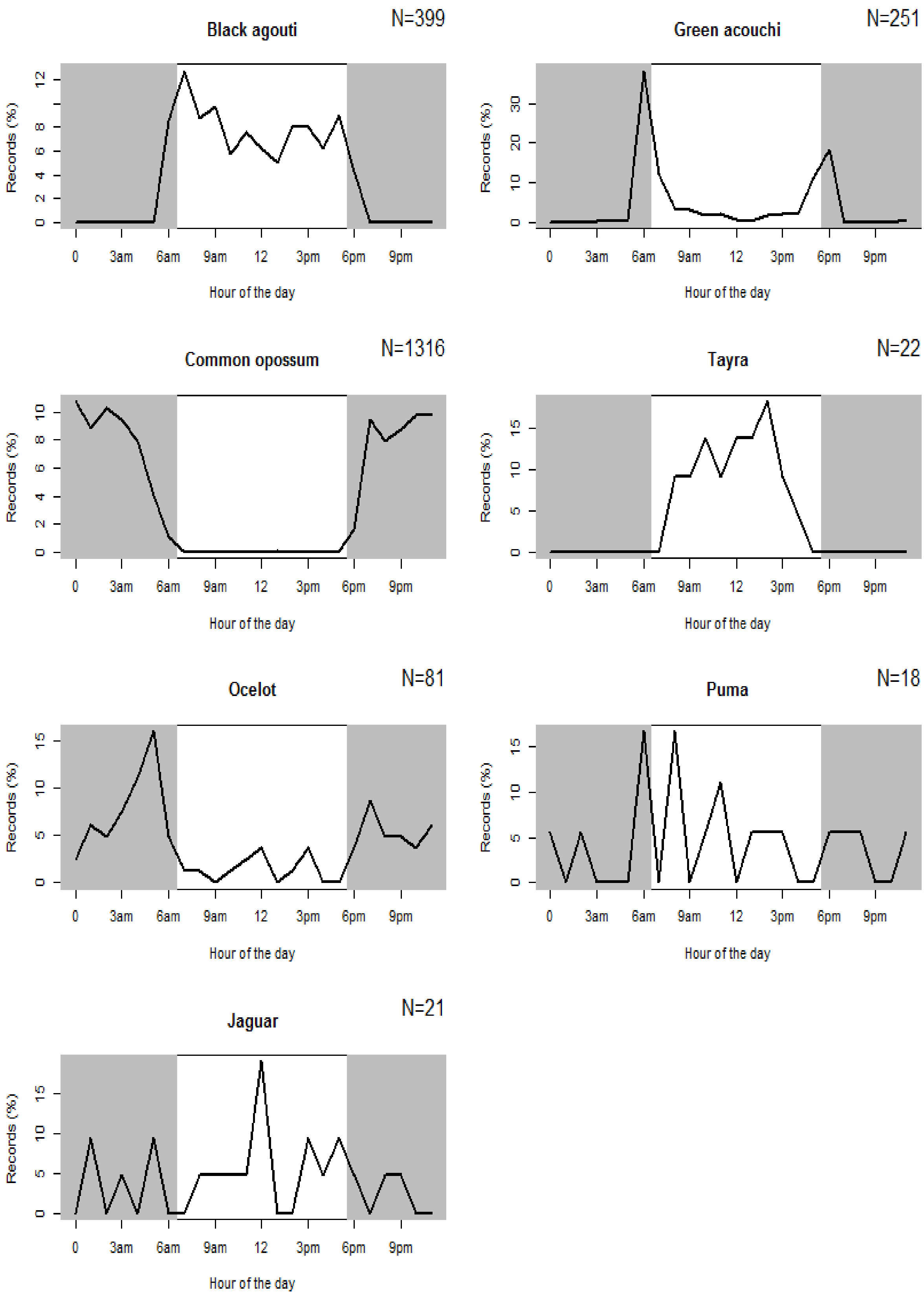


Figure 2. Hourly activity patterns for 15 medium- and large-sized terrestrial mammal species based on camera trapping data during two dry seasons in the Amanã Sustainable Development Reserve. Darker backgrounds represent night hours.

Table 1. List of species and conservation status of the medium- and large-sized terrestrial mammals recorded in Amanã Sustainable Development Reserve by camera traps. [1](Chiarello et al., 2008). [2](IUCN, 2014). [3](Barbanti et al., 2012a). [4](Barbanti et al., 2012b). [5](Desbiez et al., 2012). [6](Keuroghlian et al., 2012). [7](Medici et al., 2012). [8](Jorge et al., 2013). [9](Azevedo et al., 2013). [10](Oliveira et al., 2013). [11](Tortato et al., 2013). [12](Morato et al., 2013). [13](Rodrigues, Lívia de Almeida Pontes and Rocha-Campos, 2013). [14](Rodrigues et al., 2012). [15](Rodrigues et al., 2013). [16](Beisiegel and Campos, 2013). *Species recorded by direct sight only.

Order/Family	Species	Common Name	MMA Brazil[1]	IUCN[2]
Artiodactyla				
Cervidae	*Mazama americana* (Erxleben, 1777)	Red Brocket Deer	DD[3]	DD
	Mazama nemorivaga (F. Cuvier, 1817)	Brown Brocket Deer	DD[4]	LC
Tayassuidae	*Pecari tajacu* (Linnaeus, 1758)	Collared Peccary	LC[5]	LC
	Tayassu pecari (Link, 1795)	White-lipped Peccary	VU[6]	LC
Perissodactyla				
Tapiridae	*Tapirus terrestris* (Lennaeus, 1758)	Lowland Tapir	VU[7]	VU
Carnivora				
Canidae	*Speothos venaticus* (Lund, 1842)	Bush Dog	VU[8]	NT
Felidae	*Puma concolor* (Linnaeus, 1771)	Puma	VU[9]	LC
	Leopardus pardalis (Linnaeus, 1758)	Ocelot	LC[10]	LC
	Leopardus wiedii (Schinz, 1821)	Margay	VU[11]	NT
	Panthera onca (Linnaeus, 1758)	Jaguar	VU[12]	NT
Mustelidae	*Eira Barbara* (Linnaeus, 1758)	Tayra	LC[13]	LC
	Lontra longicaudis (Olfers, 1818)*	Neotropical Otter	NT[14]	DD
	Pteronura brasiliensis (Zimmermann, 1780)*	Giant Otter	VU[15]	EM
Procyonidae	*Nasua nasua* (Linnaeus, 1766)	South American Coati	LC[16]	LC
Cingulata				
Dasypodidae	*Dasypus novemcinctus* (Linnaeus, 1758)	Nine-banded Armadillo	-	LC
	Priodontes maximus (Kerr, 1792)	Giant Armadillo	VU	VU
Didelphimorphia				

Didelphidae	*Didelphis marsupialis* (Linnaeus, 1758)	Common Opossum	-	LC
Pilosa				
Myrmecophagidae	*Myrmecophaga tridactyla* (Linnaeus, 1758)	Giant Anteater	VU	VU
	Tamandua tetradactyla (Linnaeus, 1758)	Southern Tamandua	-	LC
Rodentia				
Dasyproctidae	*Dasyprocta fuliginosa* (Lichtenstein, 1823)	Black Agouti	-	LC
	Myoprocta pratti (Pocock, 1913)	Green Acouchi	-	LC
Cuniculidae	*Cuniculus paca* (Linnaeus, 1766)	Spotted Paca	-	LC

Table 2. Number of records, percentage of diurnal and nocturnal records and classification of daily activity patterns of medium- and large-sized terrestrial mammals recorded in Amanã Sustainable Development Reserve by camera traps.

Species	**Records**	**Nocturnal (%)**	**Activity**
Black Agouti	399	4.3	Diurnal
Tayra	22	0	Diurnal
Brown Brocket Deer	25	0	Diurnal
Giant Anteater	60	11.7	mostly diurnal
Collared Peccary	113	13.3	mostly diurnal
Green Acouchi	251	20.7	Crepuscular
Puma	18	33.3	Cathemeral
Jaguar	21	38.1	Cathemeral
Ocelot	81	80.2	mostly nocturnal
Red Brocket	71	76.1	mostly nocturnal
Lowland Tapir	51	90.2	Nocturnal
Giant Armadillo	33	100	Nocturnal
Common Opossum	1316	98.6	Nocturnal
Spotted Paca	84	100	Nocturnal

Nine-banded Armadillo	149	98.7	Nocturnal

Table 3. Pearson correlations (r value) of activity patterns of predators species and their potential prey speceis in Amanã Sustainable Development Reserve. Bold values indicate p<0.05.

Species	**Jaguar**	**Puma**	**Ocelot**
Lowland Tapir	-0.064	-0.202	-
Giant Anteater	0.300	-0.04	-
Giant armadillo	-0.08	-0.190	-
Collared peccary	0.162	***0.488***	-
Black agouti	0.144	0.262	***-0.649***
Green acouchi	-0.127	***0.446***	-0.125
Common opossum	-0.323	-0.231	***0.523***
Paca	-0.294	-0.207	0.317
Red brocket Deer	-0.239	-0.206	-
Brown brocket Deer	***0.433***	0.008	***-0.481***
Nine-banded armadillo	-0.24	-0.258	***0.434***
Tayra	0.224	0.202	***-0.490***
Jaguar	1	0.281	0.057
Puma	0.281	1	-0.182
Ocelot	0.057	-0.182	1

Capítulo II.

Rocha, D.G; Ramalho, E.E; Alvarenga G.C, Gräbin, D.M & Magnusson, W.E. **Records of the bush dog (*Speothos venaticus*) in Central Amazonia, Brazil.** Manuscrito aceito pela *Journal of Mammalogy*

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Records of the bush dog (*Speothos venaticus*) in Central Amazonia, Brazil.

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Abstract

The bush dog (*Speothos venaticus*) is a small Neotropical canid. Although its distribution covers the entire Amazon basin, the occurrence of bush dogs in vast areas of the Amazon remains hypothetical. The records of bush dogs presented in this study reduce a large gap in the known distribution of the species in Central Amazonia, and include the first documentation of the species from forest seasonally flooded by black water (*Igapó*).

Keywords: bush dog (*Speothus venaticus*), camera trap, Central Amazon, occurrence.

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Introduction

The bush dog (*Speothos venaticus*) is a small Neotropical canid, weighing 4–7 kg, that ranges from Panama to northern Argentina (Beisiegel and Zuercher, 2005). The species is currently categorized as Near Threatened on the IUCN Red List of Threatened Species (Dematteo et al., 2011). In Brazil, the bush dog is on the official list of threatened species (MMA, 2003), and was classified as Vulnerable in the most recent assessment on the species' status (Jorge et al., 2013). The main threats are habitat loss, reduction of prey abundance and the increasing risk of diseases transmitted by domestic dogs (Dematteo et al., 2011; DeMatteo and Loiselle, 2008; Oliveira, 2009). The bush dog's status, distribution and ecology are still poorly understood because of the species elusive behavior, natural low density, and large home range (Lima et al., 2009, 2015; Michalski, 2010; Zuercher and Villalba, 2002). However, there have been some important advances in the knowledge about the species over last few years (Fernandes-Ferreira et al., 2011; Lima et al., 2012, 2015).

Although the bush dog's distribution covers the entire Amazon, there are few records in this biome (DeMatteo and Loiselle, 2008; Oliveira, 2009). This is may be due in part to the ecological features of the species, such naturally low density and secretive behavior (Beisiegel, 2009; Lima et al., 2009; Zuercher and Villalba, 2002), but probably also reflects the logistic difficulties of sampling in the Amazon. Even though the Brazilian Amazon is in the middle of the bush dog's distribution, most reported locations for the species are on the borders of the biome (Barnett et al., 2001; DeMatteo and Loiselle, 2008; Oliveira, 2009). Therefore, most of the area of occurrence of the species remains hypothetical (Terborgh et al., 1984). The only reported records of the bush dog in Amazonas State are in the Amazônia National Park (Zuercher et al., 2004), Jaú National Park (Jorge et al., 2013) and Campos Amazônicos National Park (ICMBio, 2011). There are also some imprecise reports of bush dogs from the Negro (Coimbra-Filho, 1972), Juruá, Tefé, Urucu and Purús Rivers (Peres, 1991) (Figure 3).

Materials and methods

The records gathered in this study come from two camera-trap surveys conducted in Amanã Sustainable Development Reserve (2°21'S, 64°16'W) located between the

Negro and the Amazon rivers, in Central Amazonia (Figure 3). The reserve covers 2.350.000ha of pristine habitat and together with the Jaú National Park (2.367.000ha) to the East and the Mamirauá Sustainable Development Reserve (1.124.000ha) to the West, forms one of the largest continuous blocks of protected tropical forest in the world and the core of the Amazon Biosphere Reserve. The survey area was composed of a mosaic of *Terra Firme* Forest and *Igapó* Floodplain Forest. The *Terra Firme* is the predominant habitat, covering approximately 84% of the reserve, and includes all non-floodable habitats. *Igapó* forests are seasonally flooded by black-water rivers. The climate in the region is tropical humid, with average monthly temperature around 26°C and an average annual precipitation of 2373 mm (Ayres, 1993).

Data were collected in two consecutive camera trap surveys conducted during the dry season (when the water level in the region is low) on the edge of Amanã Lake. Surveys were carried out from January to March 2013 and from December to April 2014 in a combined sampling effort of 4894 camera traps*days. In the first year, the survey grid had 50 camera trap stations, 1.7-2 km apart, covering an area of 140 km^2 (minimum convex polygon). Each camera trap station was composed of 2 camera traps (model PC 800 Hyperfire, Reconyx Inc.), facing each other 4-5m apart with a lure of fresh sardine and eggs placed in the center. Lures were refreshed every 2 weeks. In the second year, 14 camera trap stations were added to the grid, without the lure, making the camera trap density higher, 1-2km apart, but not altering the sampled area (Figure 4). Camera trap stations were installed on natural paths made by animals with the exception of three that were installed on human trails (about 5km long, 2-3m width and regularly maintained).

Results

We recorded bush dogs in 3 independent events at 3 different camera trap stations (Figure 4). The first record was a pack of at least five individuals in February 2013 at 10:20h (2°27’46.116”S/64°38’42.180”W). The second was of one individual (other individuals were possibly present in the background due to movements of vegetation, but could not be confirmed) in December 2013, at 07:20h (2°26’42.576”S/64°38’03,804”W). These two records were made in the *Terra Firme* Forest close to small streams. The third record was of 2 males in the *Igapó* portion of the grid in January 2014, at 09:40h (2°29’09.528”S/64°38’56.184”W), 100m from a major tributary (80m wide) of Amanã Lake (Figure 5). All records were obtained in stations with lures, away from human trails and > 7km away from human settlements, and bush dogs spent less than 10 seconds in front of the cameras. Other mammalian carnivores photographed during this study were jaguar (*Panthera onca*), puma (*Puma concolor*), ocelot (*Leopardus pardalis*), margay (*L. wiedii*), tayra (*Eira barbara*), coati (*Nasua nasua*) and domestic dog (*Canis familiaris*). The bush dog was the only wild canid photographed.

Discussion

Although local people had already reported the occurrence of the bush dog in Amanã Reserve and a track that could have been from a bush dog was found during a line-transect survey of the area a few years ago (J.V. Amaral, pers. comm.), this is the first undeniable evidence of bush dog occurrence in the region. To our knowledge this is the first time the bush dog has been recorded in *Igapó* floodplain forest.

Our data corroborate bush dog behavior described in other studies. Records occurred in the morning indicating diurnal activity and bush dogs were moving in groups (Beisiegel and Zuercher, 2005; Kleiman, 1972; Lima et al., 2012). Lima *et al.* (2009) suggested that bush dogs avoid walking along roads. In this study none of the records occurred on camera traps placed on human trails. The large survey effort and low capture rate highlights the challenge of detecting bush dogs due to their natural low density. Similar efforts generated similar results in other studies in a fragmented landscape in southern Amazonia (Michalski, 2010) and in an area of continuous Atlantic forest in southwest Brazil (Beisiegel, 2009).

Information about bush dog distribution, habitat use and preferences are crucial to formulate conservation strategies for the species (Sillero-Zubiri et al., 2004). Since bush dogs are rarely seen or hunted in the Amazon (Dematteo, 2008), we consider that understanding their ecology and the impact of diseases transmitted from domestic dogs are research priorities in Central Amazonia.

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Resumo

O cachorro-vinagre (*Speothos venaticus*) é um canídeo Neotropical de pequeno porte. Apesar de sua distribuição cobrir toda a Bacia Amazônica, existem apenas alguns registros da espécie neste bioma. Portanto, a ocorrência do cachorro-vinagre permanece hipotética em vastas áreas da Amazônia. Os registros de cachorro-vinagre apresentados neste trabalho reduzem uma grande lacuna dentro da área de distribuição conhecida para a espécie na Amazônia Central, e inclui a primeira documentação da espécie em floresta sazonalmente alagada por águas pretas (Igapó).

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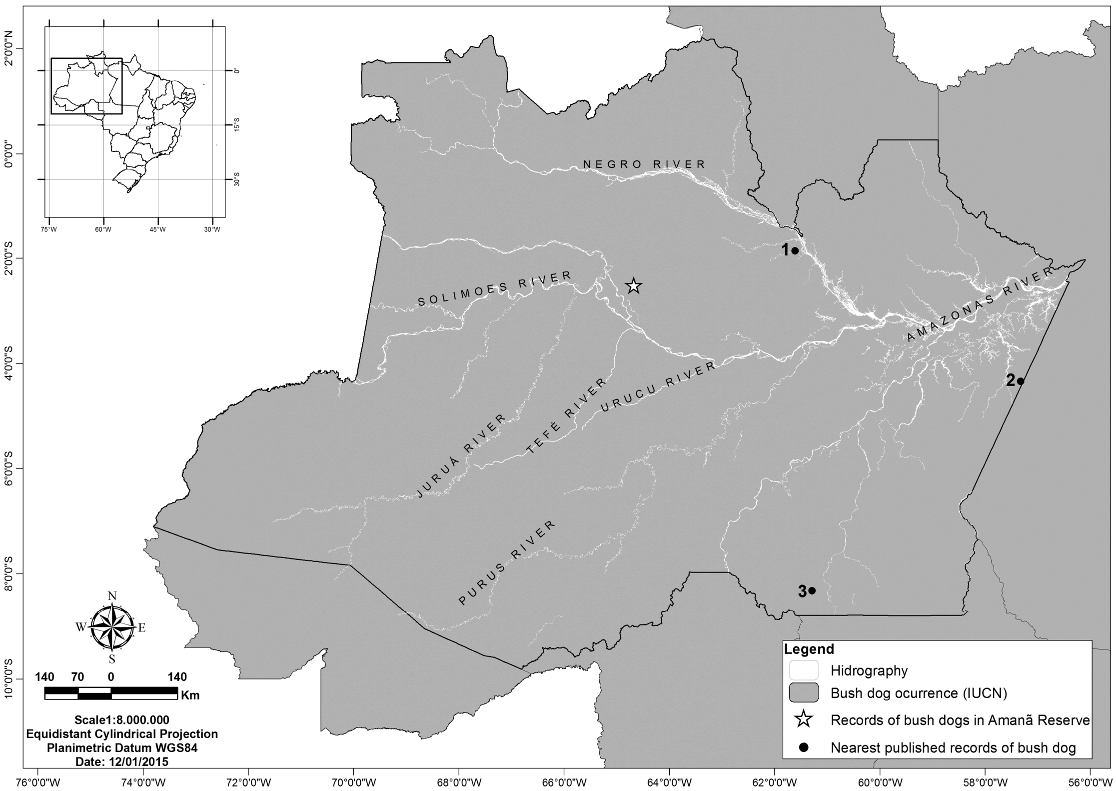

Figure 3. Map with records of bush dogs in the Amazonas State, Central Amazonia, Brazil. 1 - Jaú National Park (Jorge et al., 2013); 2 - Amazônia National Park (Zuercher et al., 2004); 3 - Campos Amazônicos National Park (ICMBio, 2011).

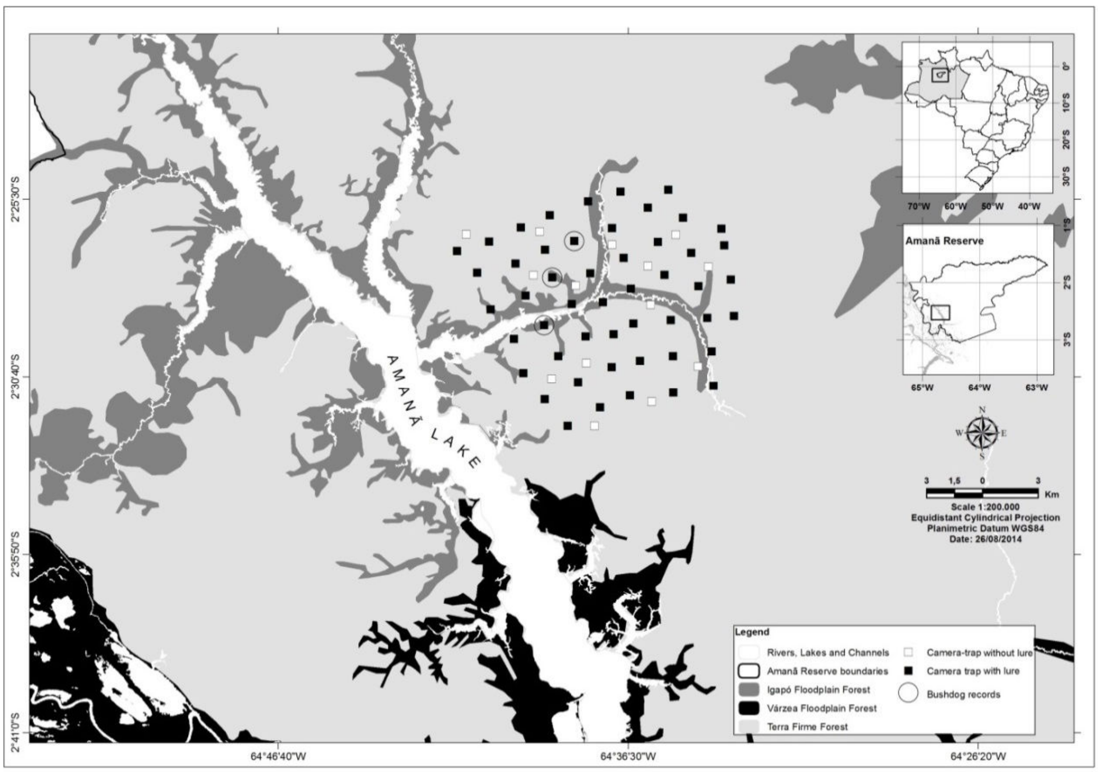

Figure 4. Map of the study site with camera trap stations, and locations of bush dog records in Amanã Sustainable Development Reserve.

Figure 5. Two male bush dogs photographed by camera traps in Amanã Sustainable Development Reserve, in January 2014.

Capítulo III.

Rocha, D.G; Ramalho, E.E & Magnusson, W.E. **Are we too focused on carnivores? Frequently used survey methods for predators bias estimates of density and relative abundance of prey species**. Manuscrito submetido para PLoS ONE

Are we too focused on carnivores? Frequently used survey methods for predators bias estimates of density and relative abundance of prey species

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Abstract

Surveying and monitoring of elusive animals with naturally low densities and large home ranges, such as many medium- and large-sized mammals, is challenging. Low capture rates can preclude detailed analyses. Here, we test the efficiency of the use of trails and bait in improving capture rates of medium- and large-sized terrestrial mammals in camera-trap surveys in the Amazon. We also test if the quality of photographic records of naturally marked felids is enhanced by the use of bait. We found that neither bait nor trails increased the number of photographic records of carnivores, and both reduced the number of records of non-carnivore species. However, the quality of photographs for individual identification of naturally marked felids was greater at baited camera-trap sites. The general consequence of not considering the effect of the use of bait and man-made trail systems is an underestimation of the density, relative abundance or detectability of non-carnivore species. We recommend that the use of bait and trails should be carefully considered at the planning stage of any camera-trap studies and we discuss the consequences

of our results for the interpretation of data from other most popular survey methods used to sample terrestrial mammals.

Keywords: sampling protocol, bias, capture rate, record quality, carnivore, non-carnivore

Introduction

Camera traps have become a popular method for the survey of medium- and large-sized terrestrial mammals in the last two decades (Karanth, 1995; Karanth et al., 2004; O'Connell et al., 2011; Sunarto et al., 2013; Tobler et al., 2008). They have been used for production of species lists (Lyra-Jorge et al., 2008), habitat use/preference (Linkie et al., 2007), estimative of relative abundance (O'Brien et al., 2003), species occupancy (O'Connell et al., 2006), activity patterns (Gómez et al., 2005) and resource use (Tobler et al., 2009).

Karanth et al. (1995) pioneered the use of camera-traps to study naturally-marked carnivore species, and several studies followed (du Preez et al., 2014; Gardner et al., 2010; Karanth et al., 2006; Kelly et al., 2008; Maffei et al., 2005; Rowcliffe et al., 2008; Silveira et al., 2010; Silver et al., 2004; Soisalo and Cavalcanti, 2006; Trolle and Kéry, 2005). Many medium- and large-sized mammals, especially carnivores, have low detection rates because of their naturally low density, large home ranges and secretive habits (Karanth et al., 2011; Lynam et al., 2009; Trolle and Kéry, 2005). Low capture rates can preclude detailed analysis and improving detection of such species is a concern (Nichols et al., 2008; O'Connell et al., 2006; Tobler et al., 2012), especially in the Amazon, where logistics are complex and expensive.

Although camera trapping does not require the use of trails and baits, those are two frequently recommended strategies to increase detection rates, especially of carnivores, in camera-trap surveys. Big cats, such as tigers *Panthera tigris*, jaguars *Panthera onca*, pumas *Puma concolor* and ocelots *Leopardus pardalis* are known to regularly use open trails as travel routes (Harmsen et al., 2010; Smith et al., 1989; Soisalo and Cavalcanti, 2006). Especially in dense vegetation, trails can funnel animals past a camera and increase capture rates. Use of trails is a common feature in the most popular survey methods for medium- and large-sized terrestrial mammals, such as distance sampling and track counts. The use of a wide variety of baits and lures has been reported in the literature (du Preez et al., 2014; Gerber et al., 2011; Hegglin et al., 2004; Long et al., 2003; Monterroso et al., 2011; Trolle and Kéry, 2005; Trolle, 2003). Baits are used in an attempt to increase the probability of detection (Karanth et al., 2011) by directing nearby animals to pass in front of camera-traps. There are potential sampling biases (attraction/aversion) caused by baits (Conover and Linder, 2009) and trails (Weckel et al., 2006), because not all species respond in the same way (Schlexer, 2008). However, studies addressing the effect of baits and trails are carnivore oriented (du Preez et al., 2014; Gerber et al., 2011; Harmsen et al., 2010; Long et al., 2003; Monterroso et al., 2011) and the effects on the detection of non-carnivores has been little studied (Harmsen et al., 2010; Weckel et al., 2006).

The most common purpose of camera traps studies has been to estimate population parameters of naturally marked felids, but approaches that include analysis of non-carnivore terrestrial species increase the value of camera trap studies (Rowcliffe and Carbone, 2008). Therefore, it is crucial to evaluate how much bias in the non-carnivore data may result from protocols designed to study naturally marked animals. This has consequences for the choice of future camera trap survey protocols, and for interpretation of the massive amount of data that has already been collected.

Besides potentially increasing carnivore detection rates in camera-trap studies (Gerber et al., 2011), baits can potentially improve individual identification of photographic records (du Preez et al., 2014). Based on individual recognition, several studies have estimated population parameters of naturally marked cat species, such as tigers (Karanth and Nichols, 1998), leopards *Panthera pardus* (Wang and Macdonald, 2009), jaguars (Soisalo and Cavalcanti, 2006), ocelots (Trolle and Kéry, 2003) and pumas (Kelly et al., 2008). To better identify individuals, the target animal has to be well positioned in front of the camera (ideally exposing its full flank). Baits can be used to improve individual identification by making the target animal stop at the right spot for enough time, allowing the cameras to take more photos at better angles. In this study, we compare the recording frequencies of medium- and large-sized terrestrial mammals at baited and unbaited camera-trap sites, and on-trail and off-trail camera-trap sites. We also tested if the quality of photographic records for individual identification of felids was better at baited sites.

Methods

Study area

The camera-trap surveys were conducted in Amanã Sustainable Development Reserve (2°21'S, 64°16'W) located between the Negro and Solimões Rivers. The reserve covers 2.350.000ha of pristine habitat near the confluence of the Amazon and Japurá Rivers. The surveyed area is composed of a mosaic of unflooded (terra firme) and floodplain (Igapó) forest. The terra firme covers approximately 84% of the reserve, and includes all areas that are not seasonally flooded. Igapó forests are seasonally flooded by black-water rivers. The climate in the region is tropical humid, with average monthly temperature around 26°C and average annual precipitation of 2373 mm (Ayres, 1993). The camera-trap surveys were conducted during the dry season, when the water level in the region is low, on the edges of Amanã Lake. Entry permission to the Amanã Reserva was granted by the Instituto de Desenvolvimento Sustentável Mamirauá.

Camera-trap surveys

The first survey was designed to evaluate the effect of the trails on the records of terrestrial mammals at camera-trap stations. We used seven research trails of 5km long, 2-3m width and regularly maintained, distributed in four regions around Amanã Lake. Eight single-camera-trap stations were installed on the research trails and eight were installed on natural paths made by animals at least 500m off the research trails (Figure 6). Camera-trap stations were at least 1.5km from any other camera-trap station and were simultaneously functional for 25 consecutive days between March and April 2012. The total sampling effort was 400 camera-traps*days. We used digital Tigrinus camera-traps (Tigrinus Inc., SC, Brazil), set to take one photo every 10 seconds without pause when triggered. Camera traps were serviced on the twelfth sampling day to change batteries and download photos.

The second survey was designed to evaluate the effect of bait on the records of terrestrial mammals at camera-trap stations. The survey was carried out from December 2013 to April 2014, in a total sampling effort of 2985 camera-traps*days. The surveyed area covered a polygon of 140 km^2 and was divided in two contiguous sampling blocks. The first block was operational during the first 57 days of the sampling period and the second block during the following 55 days. Each block contained a grid of 25 baited camera-trap stations, 1.7-2km apart and was composed of two camera-traps (model PC800 Hyperfire, Reconyx Inc.) facing each other 4-5m apart (Figure 7). The bait was a mixture of sardine and eggs (~200ml) which was placed in the center of the camera-trap stations inside a container, largely inaccessible for consumption and fixed to the ground (less than 3% removal rate). Camera-traps were set to take one photo per second without pause when triggered and were serviced every 14 days to change batteries, download photos and refresh baits. All camera-trap stations were installed on natural paths made by animals, with the exception of three that were installed on research trails. Within the sampling grid, we randomly placed 14 extra camera-traps stations without bait (7 in each block), distanced at least 1km from any other camera-trap station and following the same sampling protocol, except for the use of bait.

We used a subset of all photographs records including only medium- and large-sized terrestrial mammals (with average body mass > 1kg), hence excluding small rodent and arboreal species. For both surveys, sequential photos of the same species within 30 minutes were considered a single record.

Data analysis

We used general linear models (GLM) with Poisson distribution to evaluate the effect of the trail and bait on the number of records of carnivores, felids and non-carnivores for camera-trap data. We also evaluated the effect on every species that had at least five records. For the explanatory variables, we attributed the value 1 to baited or to on-trail stations and zero to unbaited or to off-trail stations. We did not include the common opossum *Didelphis marsupialis* in the non-carnivore group when analyzing the effect of the use of bait because the common opossum had more records than all other non-carnivore species altogether.

For operational reasons, the camera-trap stations varied in number of days active in the field during the bait survey. The shortest period that a camera-trap station worked in this study was 26 days. To make all stations comparable, we used only data collected during the last 26 sampling days of the first block and the first 26 sampling days of the second block.

For those species for which we detected an effect of bait on the number of photo records, we used Spearman correlation to test for a temporal effect of the bait on the number of records. Days were counted from the day we refreshed the baits, day 14 being the day before the next service. For this analysis, we did not limit the dataset to the 26 sampling days.

We also tested the effect of baits on the number of high-quality photos of naturally marked species. High-quality photos were considered those in which the target animal was between both cameras, with clear focus and that showed an entire side of the animal (Figure 8). We evaluated whether baits improved record quality for jaguar (*Panthera onca*), ocelot (*Leopardus pardalis*), margay (*Leopardus wiedii*) and puma (*Puma concolor*). Although pumas are not naturally marked, we included puma records because other studies have been successful using photo identification of this species (Kelly et al., 2008; Paviolo et al., 2009). We also tested if baited camera-trap stations had more records with high-quality photos of both sides of the target animal. For this analysis, we used all records of felids.

Results

Camera-trap stations on trails did not have significantly more records of carnivores than camera-traps off-trails (z=1.73, df=15, p=0.08, N=16), but had fewer records of non-carnivores (z=-2.10, df=15, p=0.03, N=16). Even though some species were recorded only at a few camera-trap stations, weakening species-specific analyses, most of the non-carnivore species had a negative relationship with the use of man-made trails. The species of carnivores had positive relationships with the use of man-made trails (Table 4). All species of carnivores recorded during the trail survey were felids (jaguar, puma, ocelot).

The bait had no statistically significant effect on the number of photo records of any species of carnivore taken separately (Table 5), nor for all felids (z=1.28, df=63, p=0.2, N=64) or all carnivores (z=1.65, df=63, p=0.09, N=64). Unbaited camera-traps had more records of non-carnivore species than baited ones (z=-6.97, df=63, p<0.01, N=64). Six species of non-carnivore (black agouti *Dasyprocta fuliginosa*, giant anteater *Myrmecophaga tridactyla*, green acouchi *Myoprocta pratti*, lowland tapir Tapirus *terrestris*, paca *Cuniculus paca* and red brocket deer *Mazama americana*) had their number of records negatively affected by the presence of bait. Of the non-carnivores, only the common opossum had higher number of records at baited camera-traps (Table 5).

Of the seven species affected by the use of baits in the camera-trap survey, there was a temporal effect only for common opossum. Days on which the bait was fresher had a higher number of photo records than days on which the bait was older (r_s= -0.73, N=772, p= 0.004).

There were 66 records of felids in the full dataset of the bait survey (46 of ocelots, 11 of pumas, seven of jaguars and two of margay). Records of the four species of felids at baited camera-trap stations had a higher number of high-quality photos than at unbaited stations (z=-2.77, df=65, p=0.005, N=66). The mean number of high-quality photos was 5.2 at baited camera-trap stations and 3.1 at unbaited ones. Nonetheless, the chance that a record had at least one high-quality photo was not related to the use of bait (x^2=0.707, df=1, p=0.40). The chance that a record had high-quality photos of both sides of the animal was also not related to the use of bait (x^2=0.735, df=2, p=0.69). There were 12 records of felids in the trail survey (seven of ocelots, two of pumas and three of jaguars). Ten of the 12 records had only one photo. Position of the station in relation to trail was independent of obtaining of high-quality photos (x^2=0.11, df=1, p=0.74).

Discussion

Placing camera-traps on trails is a common recommendation to maximize carnivore capture rates (Dillon and Kelly, 2007; Karanth et al., 2011; Rowcliffe et al., 2008). Many studies had higher success in recording felids with on-trail camera-traps (Harmsen et al., 2010; Soisalo and Cavalcanti, 2006; Trolle and Kéry, 2005), especially in dense-understory forests. The data reported here, even though not statistically significant, show the same tendency. In contrast, trails are not well suited as camera-trap locations for recording medium- to large-sized non-carnivore species. Trolle and Kéry (2005) also found higher recording rates of non-carnivore species on off-road camera trap sites. The cleaner understory and more open canopy of well establish trails may make cryptic species more exposed and represent higher depredation risk for them, resulting in avoidance behavior (Harmsen et al., 2010; Weckel et al., 2006).

Baited camera-traps often record more carnivores than unbaited ones. Du Preez and Macdonald (2013) and Gerber et al. (2012) had higher photo-detection rates of their target carnivore species using meat as bait (zebra and chicken respectively). Monterroso et al. (2011) also found valerian extract and lynx urine increased detection rates of carnivores. Bait with sardines are often used for camera-traps (Botelho et al., 2012; Trolle and Kéry, 2003), but it was not efficient in attracting carnivores to camera-trap stations in this study.

Non-carnivores avoided baited camera-trap stations in Amanã Reserve. Protein-rich baits are supposed to be more efficient in attracting carnivores, but the avoidance of non-carnivores species to this kind of bait was an unexpected result, and, to our knowledge, has not been reported before. Among the species that were affected negatively by the bait, the green acouchi, the black agouti and paca are mainly frugivorous (Beck-king et al., 2012; Dubost and Henry, 2006; Silvius et al., 2003), lowland tapir is a browser and grazer (Padilla and Dowler, 1994; Salas and Fuller, 1996), and the giant anteater and giant armadillo are insectivore specialists (Anacleto and Marinho-filho, 2001; Redford, 1985). It may be that the scent of rotting sardine and egg is similar to prey carcasses and is avoided by prey species. Other kinds of rich protein baits and lures made by macerated carnivore glands or synthetic pheromone–like chemicals may also have similar effects on non-carnivore detection rates.

The common opossum was the species most affected by the bait. It was by far the most recorded species and the only one attracted by the sardine and egg. This species also had the highest difference between means of number of records at baited and unbaited camera-trap stations (Table 4). The common opossum is an omnivorous and opportunistic forager, but was more attracted by fresher baits. The presence of bait seemed to interfere with the natural movements of the common opossums, and individuals investigated fresh baits for up to three hours. The fresh sardine and egg bait is a suitable choice for studies aiming to catch common opossums.

The efficiency of baits depends not only on their own characteristics and those of the target species (Schlexer, 2008), but also on environmental features. The Amazon forest is warm and humid, which quickens bait degradation. The frequent rains and dense vegetation understory also minimize the scent range of baits. The local availability of food may also be important as baits will have greater appeal in sites with little food availability. A large number of studies testing bait efficiency have been done in North America, aimed principally at carnivore monitoring, especially for the coyote *Canis latrans* (Hegglin et al., 2004; Howard et al., 2002; Martin and Fagre, 1988; Roughton, 1982). The importance of environmental features on the bait attractiveness makes comparison between studies in different regions limited.

The use of bait increased the quality of felid records by camera-traps. This indicates that baits may be useful in studies with the principle aim of estimating population parameters with methods based on individual identification. Poor-quality identifications results in fewer new target animals recorded and fewer recaptures, and consequently less-robust population-parameter estimation (Maffei et al., 2011). Difficulty in identification often results from photos that show the target animal from a distance or only part of its body (usually face or tail shots). This can be caused either by chance or the slow trigger system of the camera trap employed. Even when the animal is well positioned, photos may be blurry, unfocused or overexposed. These usually result from animals passing quickly in front of the camera, heavy rain or mist, malfunction or wrong set up of camera traps. The use of bait has the potential to reduce problems by inducing the target animal to stop at the right spot for longer. Even though a significantly higher number of high-quality photos per record at baited stations is an improvement for individual identification, the mean increment due to the use of bait was only two high-quality photos per felid record event. Use of baits also did not increase the chances of obtaining at least one high-quality photo of one or both sides of the target animal. Therefore, the overall advantage of the use of bait for the improvement of individual identification was slight. Possibly, baits will have a superior contribution to photo quality in studies using outdated equipment. Although it is more expensive to replace outdated equipment, new models of camera, with faster triggers, better focus systems and shorter photo intervals reduce the bad-quality-record problem, and have the advantage of not requiring baits that repel non-carnivore species.

Sampling protocols should be chosen based on research objectives and method applicability (Foresman and Pearson, 1998). Although, the use of bait and man-made trail systems are two widespread recommendations to increase carnivore capture rates in camera-trap surveys targeting felids, they were not effective in this study. We highlight the need to consider such recommendations with caution, since they may reduce the detection of some species. We recommend running pilot studies to test for such complications in multispecies approaches. Studies of felids often produce surveys of many other medium- and large-sized mammals as a by-product (Tobler et al 2008). However, the use of baits and trails may bias or reduce the efficiency of such supplementary studies. Balme et al. (2014) pointed out other complications associated with the use of bait, such as violation of the assumption of geographic closure in closed capture-recapture sampling, increasing of mortality by inflating inter- and intraspecific carnivore interactions and negative consequences to species conservation caused by habituation of carnivores to bait.

The results presented here have implications for the interpretation of data from camera-trap and other methods for surveying medium- and large-sized mammals. Comparisons between capture rates from studies with different camera-trap protocols should take into consideration effects of the use of trail and bait on different species. Most survey methods for medium- and large-sized terrestrial mammals are trail dependent. Relative species indices based on track counts on trails presume similar species-detection probabilities, which is not true if non-carnivore species are avoiding the trails. The use of these indices to compare relative abundance among species should add a correction factor to those species that avoid the trials, and comparisons across sites should be made with caution, since trail features can differ greatly among sites. Data from distance-sampling surveys that assume homogeneous distribution in the sampled area and perfect detection on the trails, should also consider the trail avoidance effect on the detection curve.

The general consequence of not considering the effect of the use of bait and man-made trail systems is an underestimation of the density, relative abundance or detectability of non-carnivore species. The availability of prey is one of the main factors believed to influence carnivore movements, distributions and densities (Carrillo et al., 2009; Karanth et al., 2004; Mendes Pontes and Chivers, 2007;

Rabinowitz and Nottingham, 1986). However, the survey methods for medium- and large-sized mammals are biased toward the carnivores. This might lead to misunderstanding of predator-prey interactions. Underestimation of the numbers of non-carnivore species may also lead to poor species-management decisions or inaccurate evaluations of species conservation status.

Conclusion

The use of bait and man-made trail systems are two common recommendations to increase capture rates in camera-trap surveys targeting carnivores. However, we emphasize the need to consider such recommendations with caution, since those techniques can bias recording rates of prey species. If the aim of the camera-trap survey is exclusively to estimate felid population parameters, the use of bait might be helpful to improve individual identification, although in our study it did not significantly increase carnivore detection rate. The use of bait and trails may bias studies focused on multispecies ecology by repelling or attracting specific non-carnivore species, and in some cases could lead to poor conservation decisions.

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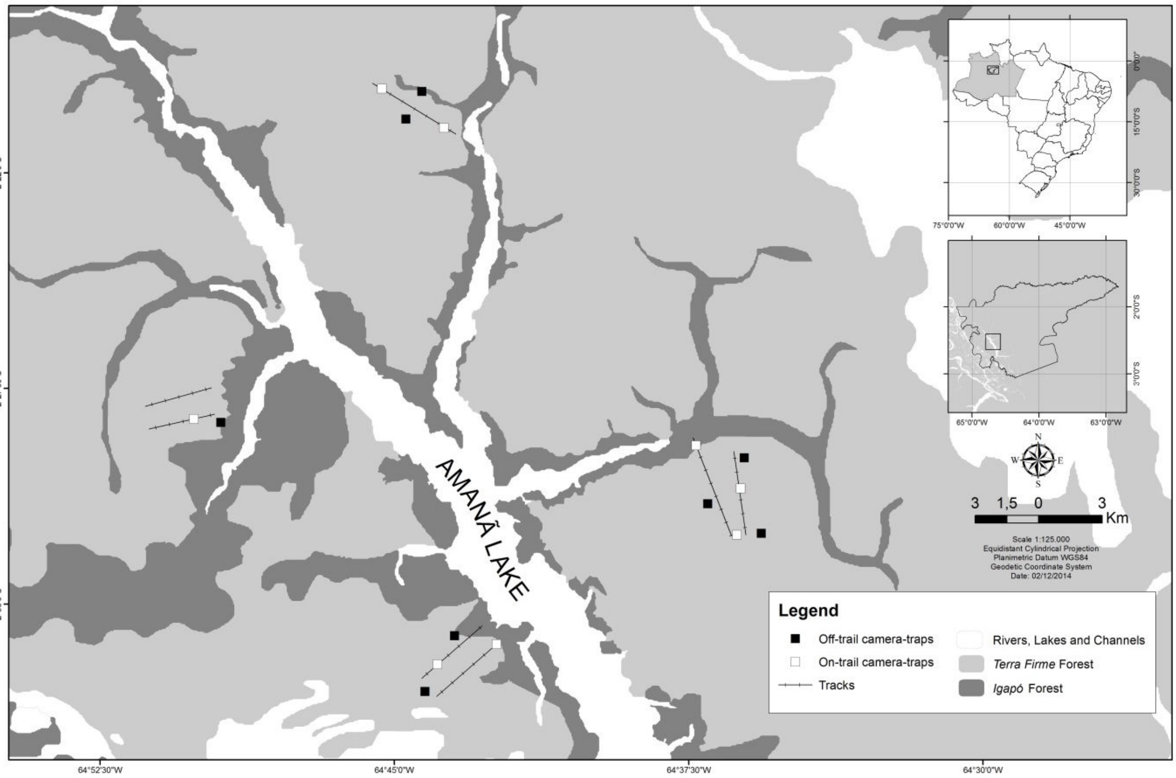

Figure 6. Map of the area surveyed to test the effect of man-made trails on records of medium- and large-sized terrestrial mammals in Amanã Sustainable Development Reserve.

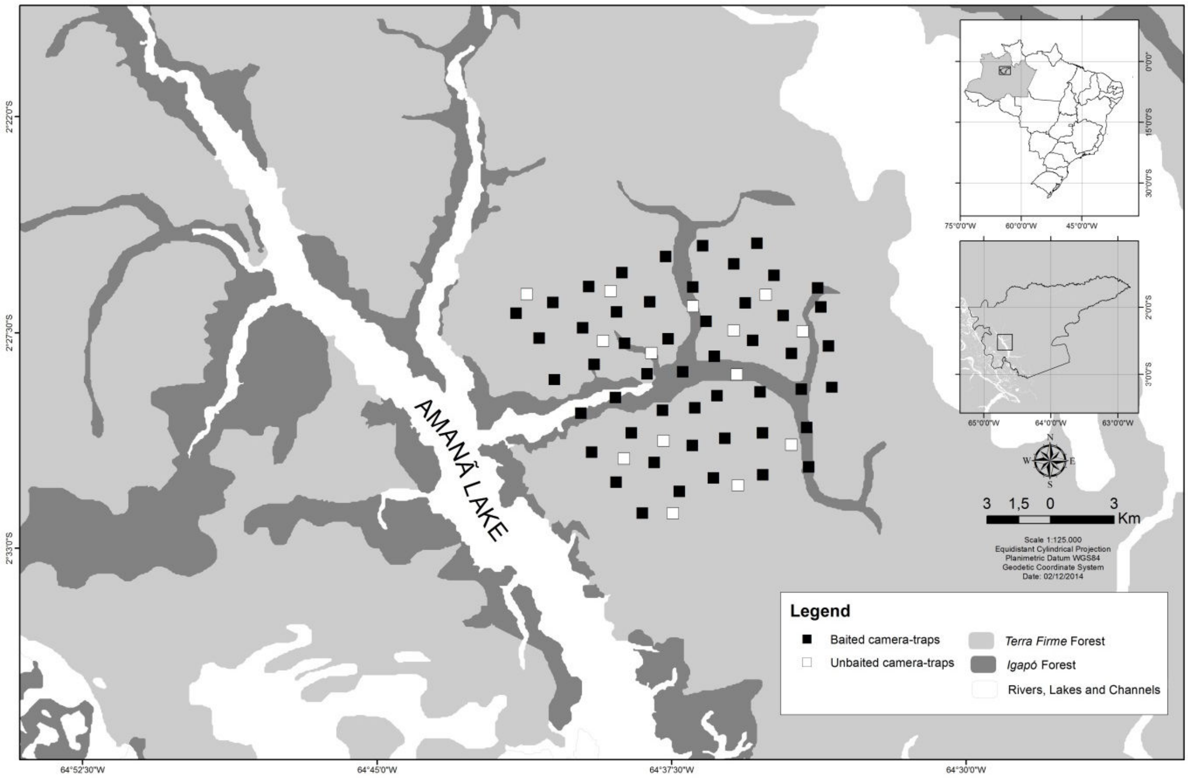

Figure 7. Map of the area surveyed to test the effect of baits on records of medium- and large-sized terrestrial mammals in Amanã Sustainable Development Reserve.

Figure 8. Camera-trap photo of an ocelot *Leopardus pardalis* as an example of a high-quality record, in which the target animal was between both cameras, with clear focus and showing an entire side of the animal.

Table 4. List of species recorded in a camera trap survey at Amanã Sustainable Development Reserve in 2012, with number of records and recorded sites, mean values of number of captures at on- and off-trail stations and GLM (Poisson distribution) result.

Group/*Species*	**Common name**	**n.reg**	**n.sites**	**mean on trail**	**mean off trail**	**estimate**	**p.value**
Carnivores							
Leopardus pardalis	Ocleot	9	5	0.75	0.37	0.693	0.326
Panthera onca	Jaguar	4	4	0.37	0.12	-	-
Puma concolor	Puma	2	2	0.25	0.00	-	-
Total	Carnivores	15	8	1.37	0.5	1.733	0.082
Non-carnivores							
Cuniculus paca	lowland paca	3	2	0.12	0.25	-	-
Dasyprocta fuliginosa	black agouti	18	8	1.12	1.12	0	1
Didelphis marsupialis	common opossum	7	4	0.50	0.75	0.288	0.706
Mazama americana	red brocket deer	5	4	0.00	0.62	-19.833	0.997
Mazama nemorivaga	brown brocket deer	1	1	0.00	0.12	-	-
Myoprocta pratti	green acouchi	5	5	0.12	0.12	-1.946	0.128
Myrmecophaga tridactyla	giant anteater	7	6	0.25	0.62	-0.916	0.273
Pecari tajacu	collared peccary	3	3	0.12	0.25	-	-
Priodontes maximus	giant armadillo	3	2	0.25	0.12	-	-
Tapirus terrestris	lowland tapir	3	3	0.00	0.37	-	-
Tayassu pecari	white-lipped peccary	1	1	0.00	1.12	-	-
Total	non-carnivores	56	14	2.50	4.50	-2.108	**0.035**

Table 5. List of species recorded in a camera-trap survey in Amanã Sustainable Development Reserve in 2013-2014, with number of records and recorded sites, mean values of number of captures at baited and unbaited stations and GLM (Poisson distribution) results.

Group/*Species*	**Common name**	**n.reg**	**n.sites**	**mean baited**	**mean unbaited**	**estimate**	**p.value**
Carnivores							
Eira Barbara	Tayra	9	7	0.16	0.07	0.806	0.447
Leopardus pardalis	Ocleot	27	21	0.48	0.21	0.806	0.187
Leopardus wiedii	Margay	2	2	0.04	0.00	-	-
Nausa Nasua	Coati	2	2	0.04	0.00	-	-
Panthera onca	Jaguar	5	5	0.08	0.07	0.123	0.915
Puma concolor	Puma	4	4	0.06	0.07	-	-
Speothos venaticus	bush dog	1	1	0.02	0.00	-	-
Total	Carnivores	50	29	0.88	0.42	1.653	0.09
Non-carnivores							
Cuniculus paca	lowland paca	31	21	0.38	0.86	-0.813	***0.027***
Dasyprocta fuliginosa	black agouti	139	40	1.94	3.00	-0.436	***0.018***
Dasypus novemcinctus	nine-banded armadillo	42	26	0.70	0.50	0.336	0.416
Didelphis marsupialis	common opossum	579	49	11.4	0.64	2.875	***<0.001***
Mazama americana	red brocket deer	21	15	0.28	0.50	-0.58	0.21
Mazama nemorivaga	brown brocket deer	7	6	0.10	0.14	-0.357	0.669
Myoprocta pratti	green acouchi	76	30	0.66	3.07	-1.538	***<0.001***
Myrmecophaga tridactyla	giant anteater	20	14	0.16	0.86	-1.678	***<0.001***
Pecari tajacu	collared peccary	36	28	0.60	0.43	0.336	0.451
Priodontes maximus	giant armadillo	14	12	0.14	0.50	-1.273	***0.017***
Tamandua tetradactyla	southern tamandua	3	3	0.04	0.07	-	-
Tapirus terrestres	lowland tapir	20	15	0.20	0.71	-1.273	***0.004***
Total	Non-carnivores	409	61	5.20	10.6	-6.971	***<0.001***

Síntese

Existe uma grande carência de informações ecológicas de espécies de mamíferos de médio e grande porte na Amazônia. Este trabalho contribui com dados de ocorrência e padrão de atividades de espécies de mamíferos terrestres de médio e grande porte na Amazônia Central, bem como testou protocolos visando tornar mais eficientes amostragens com armadilhas fotográficas. Em comparação com outros estudos feitos na Amazônia, o padrão de atividade da maioria das espécies analisadas foi concordante com os relatos de história natural na literatura, mostrando que esse é um aspecto bastante constante na ecologia e comportamento das espécies. Foram encontradas relações fracas entre os padrões de atividades dos predadores e suas potenciais presas e não foram encontradas evidências de segregação temporal entre os grandes carnívoros. Isto indica que o âmbito temporal explicou pouco como as espécies interagem. Cerca de metade das 22 espécies de mamíferos registrados na Reserva Amanã estão listadas como ameaçadas ou deficientes de dados no Brasil ou globalmente. Os registros de ocorrência de cachorro-vinagre (*Speothos venaticus*) apresentados neste estudo, diminuindo uma grande lacuna na distribuição conhecida da espécie na Amazônia Central brasileira e incluindo o primeiro registro da espécie em florestas sazonalmente alagadas por água preta (Igapó). Quanto aos fatores relacionados à amostragem, constatou-se que o uso de trilhas e iscas não aumentou o número de registros de carnívoros como era esperado segundo, a literatura. Além disto, o uso de trilhas e iscas reduziu o número de registro de espécies não carnívoras. Este resultado tem implicações importantes não apenas para comparações entre estudos com diferentes protocolos de amostragem com armadilhas fotográficas, mas também tem implicações em relação a premissas de outros métodos amplamente usados na amostragem e monitoramento de mamíferos. A qualidade das fotos para identificação individual de espécies com marcas naturais foi melhor em armadilhas fotográficas com isca. Entretanto essa melhora pode ser custosa em estudos interessados em várias espécies. Concluiu-se que o uso de trilha e isca deve ser avaliado com cuidado durante o planejamento de qualquer estudo utilizando armadilhas fotográficas.

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