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Front cover: Adult male of Caquetá titi monkey (*Plecturocebus caquetensis*) at vereda La Leona, municipality of Valparaiso, Caquetá department, Colombia. Photo by Javier García.

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Articles

SEED PREDATION OF *ARAUCARIA ANGUSTIFOLIA* BY *SAPAJUS NIGRITUS*

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Abstract

In this study, we quantified seed predation of the Paraná Pine (*Araucaria angustifolia*) by black capuchin monkeys (*Sapajus nigritus*), in order to better understand their impact on forest regeneration. This study was conducted in an Araucaria forest fragment in the state of Paraná, Brazil. We marked 31 female Paraná pines and counted the seed cones, which ranged from 0 to 20 per tree (Mean = 5, SD ± 5.06). We recorded 88 predated cones, with an average of 2.35 ± 3.83 per tree. During the study period the monkeys only ate seeds from immature cones. The reason why the monkeys fed only on immature seeds may have been related to the scarcity of mature seeds and other resources. Comparing the seasons, we found a significant difference in the number of predation events between them. Cone predation on the top of each female Paraná pine was proportional to crop size, and totaled 57% of all cone production, which may have an impact on regeneration of this endangered gymnosperm. Thus, the ecological role played by the capuchin monkeys can be seen as going beyond seed dispersal, showing that this species may influence forest recruitment negatively through pre-dispersal seed predation.

Key Words: Araucaria forest, capuchin monkeys, pre-dispersal, Paraná pine.

Resumo

No presente estudo, objetivamos quantificar a predação de sementes de pinheiro-do-Paraná (*Araucaria angustifolia*) por macaco-prego (*Sapajus nigritus*), para melhor entender o impacto desses primatas sobre a regeneração florestal. Este estudo foi realizado em um fragmento de floresta Araucária no estado do Paraná, Brasil. Nós marcamos 31 fêmeas de pinheiro-do-Paraná e contamos as pinhas com sementes. Estas variaram de 0 à 20 por árvore (média = 5. EP ± 5.06). Nós registramos 88 pinhas predadas, com uma média de 2.35 ± 3.83 por árvore. Durante o período do estudo, os macacos-prego apenas consumiram pinhas imaturas. A razão pela qual os macacos-prego devem ter consumido apenas pinhas imaturas pode estar relacionada com a escassez de sementes maduras e também de outros recursos. Encontramos diferença significativa no número de eventos de predação de sementes entre estações do ano. A predação de pinha no topo de cada árvore fêmea de pinheiro-do-Paraná foi proporcional ao tamanho da copa, e totalizou 57% de toda produção de pinha, o que pode impactar na regeneração dessa gimnosperma ameaçada. Dessa forma, o papel ecológico desempenhado pelos macacos-prego pode ser visto como indo além da dispersão de sementes, mostrando que tal espécie pode influenciar negativamente no recrutamento florestal através da predação de sementes antes da dispersão.

Palavras-Chave: floresta de Araucária, macaco-prego, pré-dispersão, pinheiro-do-Paraná.

Introduction

Alteration and occupation of natural habitats by humans have caused biodiversity loss (Hansen *et al.,* 2004), although apparently certain species have benefited from this interference. Among them is *Sapajus nigritus* (Goldfuss, 1809 Primates, Cebidae), popularly known as the black capuchin monkey, which can adapt to altered environments (Rocha, 2000). Capuchin monkeys can utilize diverse habitats and their home range is usually large, between 150 and 293 ha, but they can also survive in smaller areas of approximately 12–80 ha, depending on the food distribution and its availability (Vilanova *et al.*, 2005; Bicca-Marques *et al.,* 2006). They are omnivores with a diet based on 60 to 70% of fruits and seeds, and 20 to 30% of animal matter, among other foods such as roots, flowers, leaves,

shoots and apical meristems (Galletti and Pedroni, 1994; Ludwig *et al.*, 2005; Ludwig *et al.,* 2006; Brocardo *et al.,* 2010). Combining a diverse diet and ease of adaptation, this species is considered a "problem" primate for many authors (Rocha, 2000; Santos *et al.*, 2007). In times of fruit scarcity, they increase their consumption of alternative resources from plantations located around the forest fragments, ranging from maize, cassava roots and even *Pinus* spp. (Galetti and Pedroni, 1994; Rocha, 2000; Ludwig *et al.,* 2006, Santos *et al.*, 2007). Within forest habitats they increase the consumption of *Euterpe edulis* and *Geonoma* spp. apical meristems in response to scarcity of other food sources (Souza and Martins, 2006; Brocardo *et al.,* 2010). Although widely known as a seed disperser (Galetti and Pedroni, 1994), monkeys of the genus *Sapajus* can cause some negative impacts on plant recruitment through herbivory of adult and young plants (Santos *et al.,* 2007; Brocardo *et al.,* 2010) and seed predation (Peres, 1991; Galetti and Pedroni, 1994). In fact, seed predation can be the only action performed by capuchin monkeys on particular plant species, as observed for *Cariniana micrantha* (Peres, 1991). And this also seems to be the case of relationship between black capuchin monkeys (*Sapajus nigritus*) and the Paraná pine trees (*Araucaria angustifolia*).

Paraná pine, which belongs to the Araucariaceae family, is a large dioecious gymnosperm (up to 50 m tall and 3 m in diameter at breast height - dbh) occurring in Brazil and Argentina, where it is limited to the Araucaria forest of subtropical and temperate climes (Hueck, 1953). In this forest, the Paraná pine is the dominant species; the mean adult density can reach 3,000 ind./km² (Mantovani et al*.,* 2004; Paludo et al., 2011). It is vulnerable due to logging (Mantovani et al*.,* 2004; Thomas, 2013). It takes about two years for the seed cone to become completely mature, reaching maturity generally between April and July (Mantovani et al., 2004). Its seeds, known as "pinhões" in Brazil, have a reddish-brown bark and are a valuable source of carbohydrates, proteins and lipids, for humans, domestic animals and wildlife. Seed predators include jays, parrots, agoutis, pacas, tapirs, deer, rats, porcupines, peccaries, and howler and capuchin monkeys. This plant is considered, therefore, a key resource for wildlife (Vieira and Iob, 2009). The dispersal of its seeds also depends on animals, such as agoutis (*Dasyprocta azarae*) (Brocardo and Galetti, 2014), squirrels (*Guerlinguetus ingrami*) (Bordignon and Monteiro-Filho, 2000), and plush-crested jays (*Cyanocorax chrysops*) (Brocardo and Galetti, 2014), which disperse the "pinhões" through scatter-hoarding behavior (synzoochory *sens*u Correa et al., 2015).

In spite of the intrinsic relationship between Paraná pine and animals, studies on the regeneration of this plant species have only given secondary focus to its interaction with seed dispersers and predators (Paludo *et al.*, 2011). Herein we present the first study to quantify the consumption of seeds of Paraná pine by black capuchin monkeys, which will help to better understand the impact of this primate on Araucaria forest regeneration.

Materials and Methods

We carried our study at the "Danilo Galafassi" Municipal Park (DGMP), located in Cascavel, Paraná state, Brazil (24º 57'21" S, 53º 27'19" W), comprising an area of 17.91 ha of Araucaria forest (Fig. 1). Despite the small area, the park is connected with another forest fragment, the "Paulo Gorski" Ecological Park (PGEP), comprising approximately 100 ha of both primary and secondary native forest. In these two areas, the population of capuchin monkeys must have been isolated for approximately 30–35 years ago, since urbanization, with no connection to other areas (Brocardo, 2013). The region is located 730–780 m.a.s.l., and a subtropical climate, Cfa according to the Köppen classification, with 1,800–2,000 mm annual rainfall, no dry season, and a mean annual temperature of 19 to 21°C (Castella and Britez, 2004).

Observations were carried out between March 2013 and March 2014, with at least three field surveys a month of a minimum of one hour each (no schedule on rainy days). In all, we sampled 71 days, with a total of 150 hours of observation. We monitored the behavior of monkey groups during seed consumption using 7×35 mm binoculars. We initially marked the bole (at 1.3 m off the ground) of productive female pines with metal plates (3.0 × 3.0 cm) to verify the seed consumption by monkeys. We quantified and recorded the cones on each marked pine tree canopy.

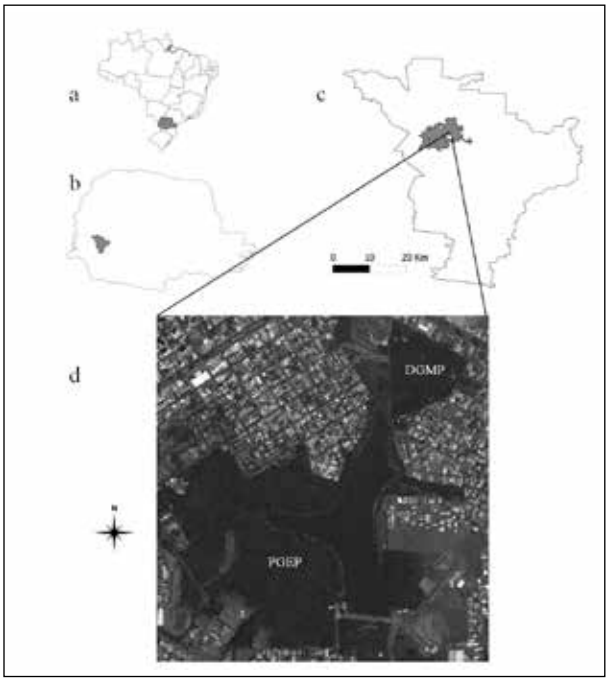

Figure 1. Study area. a) Paraná (gray) in Brazil, b) location of Cascavel municipality (gray) in Paraná state, c) emphasis on urban area (gray) of Cascavel and location of the sampled area; d) Danilo Galafassi Municipal Park (DGMP) and Paulo Gorski Ecological Park (PGEP). Image modified from Google Earth.

We considered all events of seed consumption or felling of immature pine cones caused by monkeys as predation events (negative impact on tree seed production), since immature seeds felled to the ground cannot be recruited. We analyzed the predation frequency between the seasons using the chi-square test, because capuchin monkeys can alter their diet in response to food scarcity (Ludwig et al., 2006; Brocardo et al., 2010).

Primates prefer trees with large crops (Janson et al., 1986, Stevenson, 2004), a fact related to foraging optimization, so when they act as seed predators, the impact will be proportional to seed production (Peres, 1991). We therefore expected that the impact of activities of the black capuchin monkeys on Paraná pine cones would be proportional to the crop size. Linear regression was used to test whether the predation events were related to crop size.

Results

The monkeys were observed for a total of 21 hours, and seed consumption was recorded for 3 h and 35 min. Thirty-four individuals were recorded in the largest group, which included an alpha male and some immature individuals. One to ten animals (subgroups) were recorded in other events. A density of 28 individuals/km² was estimated for the DGMP and PGEP areas combined (approximately 118 ha; see Fig. 1).

The capuchin monkeys eat the Paraná pine seeds by first removing the cone from the parent plant and then bite it open to get the seeds, which they bite open to access the endosperm (Fig. 2). When there is no endosperm, they just grab another seed and repeat the process. After having opened and consumed a pine cone, the monkeys eat another, and so on until their hunger is satiated or they give up. Also, pine cones sometimes end up falling from the top of the tree. Events of seed consumption typically lasted ten minutes on average.

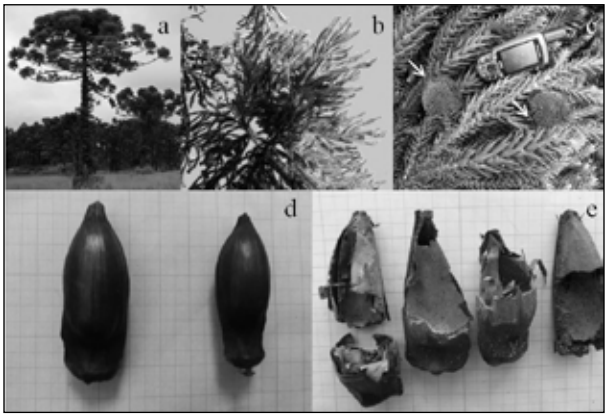

Figure 2. a) Adult Paraná pine b) seed cones in a branch c) Detail of immature seed cones between spiny leaves of *A. angustifolia*; d) intact mature "pinhões"; e) mature seed provided to captive black capuchin monkeys (d and e: scale is 1 cm)

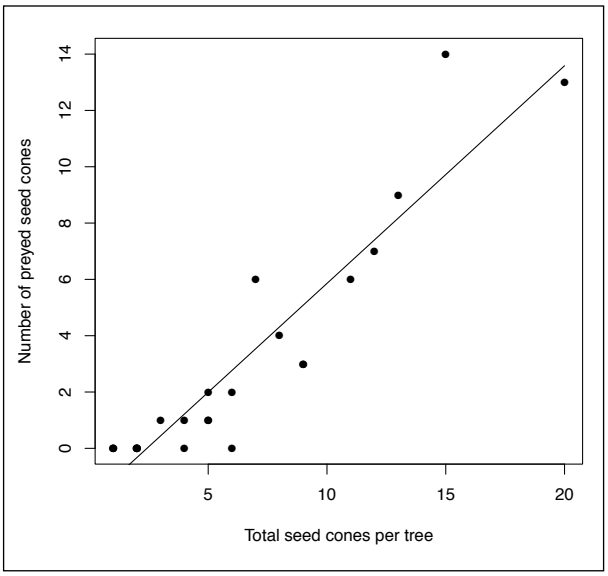

Figure 3. The relation between the number of Paraná pine cones in the canopy and the cones preyed upon by the capuchin monkeys.

We marked 31 female pines and the number of seed cones ranged from 0 to 20 per tree (mean = 5, SD ± 5.06). We counted 88 predated cones, an average of 2.35 ± 3.83 per tree. We did not record any consumption of mature cones, only immature seeds were consumed by the monkeys. The canopy with the largest number of cones also had the largest number of predated cones ($y = 0.772x - 1.87$, $R^2 = 0.87$) (Fig. 3).

According to the comparison between seasons (chi-square test), we found a significant difference in the number of depredation events between the four seasons ($X^2 = 89.72$, DF= 3, p-value < 0.01); 6 predated cones in the summer (December–March), 15 in the autumn (March–June), 60 in the winter (June–September), and 7 in the spring (September–December). In the winter, the consumption was greater than expected, while in the other seasons it was smaller. Considering the total number of cones counted (n=155), the capuchin monkeys impacted 57% of *Araucaria angustifolia* seed production in the study area.

Discussion

Paraná pine seeds are an important source in the diet of capuchin monkeys during autumn and winter in the Araucaria forest. In this forest, there is a reduced number of fruiting species during wintertime, when the "pinhões" are considered key resources for many frugivorous animals (Vieira and Iob, 2009). While *A. angustifolia* is often a dominant species where occurs, which disqualifies it as a keystone plant (*sensu* Power et al. 1996; Peres, 2000), its high importance for providing resources to several animal species in shortage periods may be used to classify it as a keystone plant (*sensu* Galetti et al. 1999; Stevenson, 2005).

Although the consumption of these seeds is more energetically advantageous when they are mature, apparently

monkeys prey upon seeds before maturation due to lack of other resources in the environment, especially during the winter period, when fruit production in the Araucaria forest is low (Vieira and Iob, 2009). Thus the consumption of immature "pinhões" by capuchin monkeys may be related to the use of alternative sources (Brocardo et al. 2010). Fragments such as our study site tend to present lower tree species richness, which in turn represent lower quantity and quality of resources for frugivorous species (Tabarelli et al., 1999, Chiarello, 2000), imposing behavioral and ecological adaptation pressure on capuchin monkeys (Ludwig et al., 2006; Pinto et al., 2009). In an Araucaria forest fragmented landscape, the increase in damage to *Pinus* trees caused by black capuchin monkeys was related to the food shortage period in the natural forest, mainly in winter (Mikich and Liebsch, 2014). The use of *Pinus* by *S. nigritus* in Araucaria forest region demonstrates how degraded the fragments of this forest currently are (Mikich and Liebsch 2014), because to obtain phloem sap and tissue from *Pinus* the monkeys suffer serious damage to their incisor teeth, that in turn affects their health and survival (Delgado, 2013).

The low cone production in our study site also may have influenced the consumption of immature seeds owing to the absence or low abundance of mature seeds. In another area located in São Paulo state, the "Carlos Botelho" State Park, an Atlantic Forest continuous area where stretches of planted *Araucaria angustifolia* are present (Brocardo et al. 2012), we observed *Sapajus nigritus* consuming only mature "pinhões" (CR Brocardo, pers. obs.). The Paraná pine seed production in our study area was lower than that found by Mantovani et al. (2004), who obtained 13 ± 7.6 and 19 ± 9.4, respectively in 2001 and 2002 in "Campos do Jordão" State Park , São Paulo state. We only recorded a mean of 5 ± 5.06 per tree. It is known that seed crop in *Araucaria angustifolia* varies between years (Souza et al., 2010), thus in years of greater seed production, the monkeys may prefer to prey on mature seeds. However, even large seed production can be proportionality impacted by monkeys. Our data demonstrated that predation of cones was related to crop size (Fig. 3). The green color of the cone seed can make the visual location by monkeys difficult when they are in other trees, but large crops are probably more conspicuous (Fig. 2 a–c). Even on a female Paraná pine, the capuchin monkeys may have difficulty locating cones due to the architecture of this tree, where the cones are inserted on tips of branches, between spiny leaves (Fig. 2 b–c).

For *Cariniana micrantha* (Lecythidaceae), an Amazonian tree, the seed predation impact exerted by capuchin monkeys was also related with crop size. The total damage on reproductive potential was 99.6% (69.5% predated seeds and 30.1% unviable seeds felled) (Peres, 1991). Although the impacts of capuchin monkeys are smaller on *A. angustifolia* seed production (57% of the cones) than on *C. micrantha*, they are still very high, affecting over half of the seed production. As capuchin monkeys are the most common monkey species within Araucaria forest fragments (Brocardo and Cândido-Jr, 2012), this primate may be contributing significantly to low Paraná pine recruitment (e.g., Paludo et al., 2011). Besides the impacts caused by monkeys, the extensive harvesting of "pinhões" for human consumption seriously affect Paraná pine regeneration (Souza et al., 2010). Furthermore, mature pine seeds fall directly below the parent plant, where they are eaten by mammals on the ground (Vieira and Iob, 2009; Brocardo and Galetti, 2014). Agoutis (*Dasyprocta azarae*) are abundant in the study area (Brocardo, unpubl. data) and, although they are seed dispersers (scatter-hoarding), in small forest patches they may also be the main terrestrial seed predators of these pines (Ribeiro and Vieira, 2013). Therefore, only a few seeds can escape predation and contribute to recruitment. Interventions are needed to ensure Paraná pine regeneration, such as collecting seeds for seedling production and subsequent transplantation in the area.

In conclusion, the ecological role played by capuchin monkeys goes beyond seed dispersal (positive influence on plant recruitment), demonstrating that primates may also affect forest recruitment negatively through pre-dispersal seed predation (Izawa, 1979; Peres, 1991; Stevenson et al., 2000; Stevenson, 2007).

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METHODS FOR CAPTURING WILD SQUIRREL MONKEYS IN A FLOODPLAIN FOREST: A COMPARISON OF TWO TECHNIQUES AND TWO SPECIES

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Abstract

Field studies of primates often require the capture and marking of individuals in order to monitor behavior, health and population parameters. However, there have been few field studies in which squirrel monkeys (genus *Saimiri*) have been successfully captured. Here we report results obtained using two different trapping methods to capture *Saimiri vanzolinii* and *S. cassiquiarensis* in Central Amazonia, Brazil. We constructed 20 trapping stations, each one consisting of a platform containing a pair of Tomahawk traps, which were monitored by camera traps and baited with half a bunch of bananas, daily (at 6:00h and removed at 17:00h), during three months preceding the capture. We captured eight individuals of *S. vanzolinii* in two stations during five days (capture rate of 1.6 individuals/day). We were unable to capture individuals of *S. cassiquiarensis* using the Tomahawk traps; thus, we manually captured the individuals while they were foraging on the ground. To capture them, these individuals were first corralled and then captured with dip nets and leather gloves. We captured twelve individuals in seven days (capture rate of 1.7 individuals/day). We believe that both of these methods can be used for trapping squirrel monkeys, since they take into account the foraging strategies of the species, use of space, the presence of other competitive species such as capuchin monkeys, and the ecological features of the study area.

Key Words: *Saimiri*, trapping methods, Tomahawk trap, primates.

Resumo

Estudos de campo com primatas frequentemente requerem a captura e marcação de indivíduos para monitoramento do comportamento, saúde e parâmetros populacionais. Entretanto, existem poucos estudos de campo em que os macacos-de-cheiro (Gênero *Saimiri*) foram capturados com sucesso. Aqui nós relatamos os resultados obtidos através de dois métodos usados para capturar *Saimiri vanzolinii* e *S. cassiquiarensis* na Amazônia Central, Brasil. Nós construímos 20 estações de captura, cada uma consistindo de uma plataforma contendo um par de armadilhas Tomahawk, as quais foram monitoradas por armadilhas fotográficas e provisionadas com metade de um cacho de bananas diariamente (o qual era colocado às 6:00h e removido às 17:00h), durante os três meses anteriores à captura. Nós capturamos oito indivíduos de *S. vanzolinii* em duas estações durante cinco dias (taxa de captura de 1.6 indivíduos/dia). Nós não conseguimos capturar indivíduos de *S. cassiquiarensis* usando as armadilhas Tomahawk; Portanto, nós manualmente capturamos os indivíduos enquanto eles forrageavam no chão. Para capturar os animais, eles foram encurralados e então contidos com puçás e luvas de couro. Nós capturamos 12 indivíduos em sete dias (taxa de captura de 1.7 indivíduos/dia). Acreditamos que ambos os métodos podem ser usados para capturar macacos-de-cheiro, desde que sejam consideradas as estratégias de forrageio das espécies, uso do espaço, presença de outras espécies competidoras como os macacos-prego, e as características ecológicas da área de estudo.

Palavras-Chave: *Saimiri*, métodos de captura, Tomahawk, Primatas.

Introduction

The trapping and immobilization of primates are sometimes necessary for the collection of biological material, which in turn can be useful to understand the population's health, genetics and behavior patterns. However, the literature contains little information regarding techniques and protocols used to capture wild Neotropical primates (Mitchell, 1990; Glander et al., 1991; Rocha et al., 2007; Stone et al., 2014). In Santa Rosa National Park, Costa Rica, Glander et al. (1991) captured *Alouatta palliata*, *Ateles geoffroyi* and *Cebus capucinus* using a blowpipe and CO_2 gun. The authors emphasized the issue of safety in relation to the capturing method employed, since the only safe body area for darting are the hindquarters. More recently, Rocha et al. (2007) described techniques and trap models for the capture of *Sapajus nigritus*, in three study sites in Paraná, southern Brazil. A large cage trap (2 × 2 ×

3m) was used, with bananas as bait to attract the primates. The process of baiting and habituating the animals to the traps lasted seven months.

Field studies involving the capture of wild squirrel monkeys are even rarer, due to their small body size and, especially, the lack of described and published trapping methods. Mitchell (1990) conducted the first successful trapping effort in Peru, where she trapped 39 individuals of *S. boliviensis*, within eight months. She utilized Tomahawk traps, anesthetic darts and a large cage (2 × 2 × 3 m). The first method, widely used for capturing small and medium-sized mammals, was not very successful because brown capuchins (*Sapajus apella*) would arrive first at the traps. Mitchell (1990) did not recommend the second method, due to the difficulty of aiming for animals high in the canopy and the risk of injury. The large-cage approach was the most adequate at the site, and yielded the highest capture rate. Recently, Stone et al. (2015) captured 21 individuals of *Saimiri collinsi*, with a new method developed by the authors. They implemented a large platform located in a 123.5 m² area enclosed by a green net (3 m high), where several individuals could be captured. However, this method is better suited to capture large groups, but not single individuals.

One of the areas in Brazil where wild squirrel monkeys are being studied is in the region of the middle Solimões River, state of Amazonas, within the Reserva de Desenvolvimento Sustentável Mamirauá (RDS Mamirauá) (Paim et al., 2013). Three *Saimiri* species occur within the reserve: *S. cassiquiarensis*, *S. macrodon* and *S. vanzolinii*. The first two are widely distributed in Amazon; however *S.vanzolinii* has the smallest geographic distribution of any Neotropical primate (approximately 870 km²) and is endemic to the reserve (Ayres, 1985; Paim et al., 2013). *S. vanzolinii* is listed as vulnerable in the IUCN Red List of Threatened Species (Boubli & Rylands, 2008) due to its high degree of endemism and its sympatric distribution with the other two species (Paim et al., 2103). The threats to this species led us to build a sample design to collect biological samples from these species, which would be used to conduct genetic studies and identify hybrids in the *S. vanzolinii* population. Thus, we would need to capture a few individuals of *S. vanzolinii* and *S. cassiquiarensis* from as many groups as possible, over a wide area. Here we describe two methods that were used to capture squirrel monkeys at RDS Mamirauá.

Methods

Study area

Trapping was conducted in the RDS Mamirauá, along the Jarauá river (2°51'7.4''S, 64°57'41.9"W), a channel that is considered the limit of the distribution of *S. vanzolinii* and *S. cassiquiarensis* (Paim et al., 2013). The RDS Mamirauá (1,124,000 ha; Ayres, 1993; Sociedade Civil Mamirauá, 1996) is a *várzea* ecosystem located at the junction of the rivers Solimões, Japurá, and Auatí-Paraná, and is one of the best-preserved regions in the Amazon. The reserve is influenced by variation in river levels between a dry (October to December) and a high water period (May to July) (Pires, 1973; Ramalho et al., 2009). Water level is likely the most important climactic factor in the region (Ayres, 1993), and its annual variation can surpass 12 meters (Junk et al., 1989; Ramalho et al., 2009).

Trapping methods

We constructed 20 trap stations along the Jarauá River: ten located in the range of *S. vanzolinii*, and ten in the range of *S. cassiquiarensis*. Capture stations on the same margin were spaced at least 2 km apart (Fig. 1). Each station consisted of a wooden platform (4–8 m high), each with two Tomahawk traps of 70 × 40 × 40 cm (Fig. 2A). Captures were carried out during the first week of November, 2012 (dry period). Each trap station was baited with five bananas for three months preceding the capture. Bait was placed daily starting at 06:00 h, and removed before sunset, at approximately 17:00 h. During the first month of habituation, the bananas were placed on top of the traps; in the second month, at the entrance of the traps; and in the last month, inside the traps, suspended by a metal hook. The traps were locked open during the habituation period.

We installed ten camera traps (model Reconyx PC800), on a rotational basis among the 20 platforms, in order to monitor primate visitation to the platforms and assess the success of the baiting. Camera trap images were used to determine the frequency of use of the feeding stations during the habituation period and to estimate the probability of capture. Each event detected by the camera was scored as a "visit" when the animal only visited the platform, and, "entry", when the animal visited the platform and entered the trap to obtain the bananas (Fig. 2B). We calculated the frequency of use of the stations during the monitoring period by dividing the number of "visits" by the number of days monitored in each station. In order to calculate the probability of capture at each station used, we divided the number of "entries" by the number of "visits" detected.

After three months of habituation, the traps were unlocked and we initiated the capture. As during the habituation period, we placed the bananas in the morning and removed them at dusk. We checked the stations twice a day (around 10:00 h and 14:00 h) to verify if any animals had been captured. At dusk, after the bait was removed, we closed each trap to avoid capturing nocturnal animals. Once a captured squirrel monkey was found, we removed the trap from the platform and the animal was restrained with a wooden board (Fig. 2C), so it could be anesthetized by a veterinarian. Males were anesthetized with an intramuscular mixture of ketamine+xylazine (15+1mg/kg), whereas the females were anesthetized with Zoletil50© (4.4mg/kg), both given to the lower limb (Araújo et al., 2009; Oliveira et al., 2010; Spolti et al., 2013). After sedation, we collected morphometric data and biological samples. Each animal received a microchip (Microchip Partners©) in the

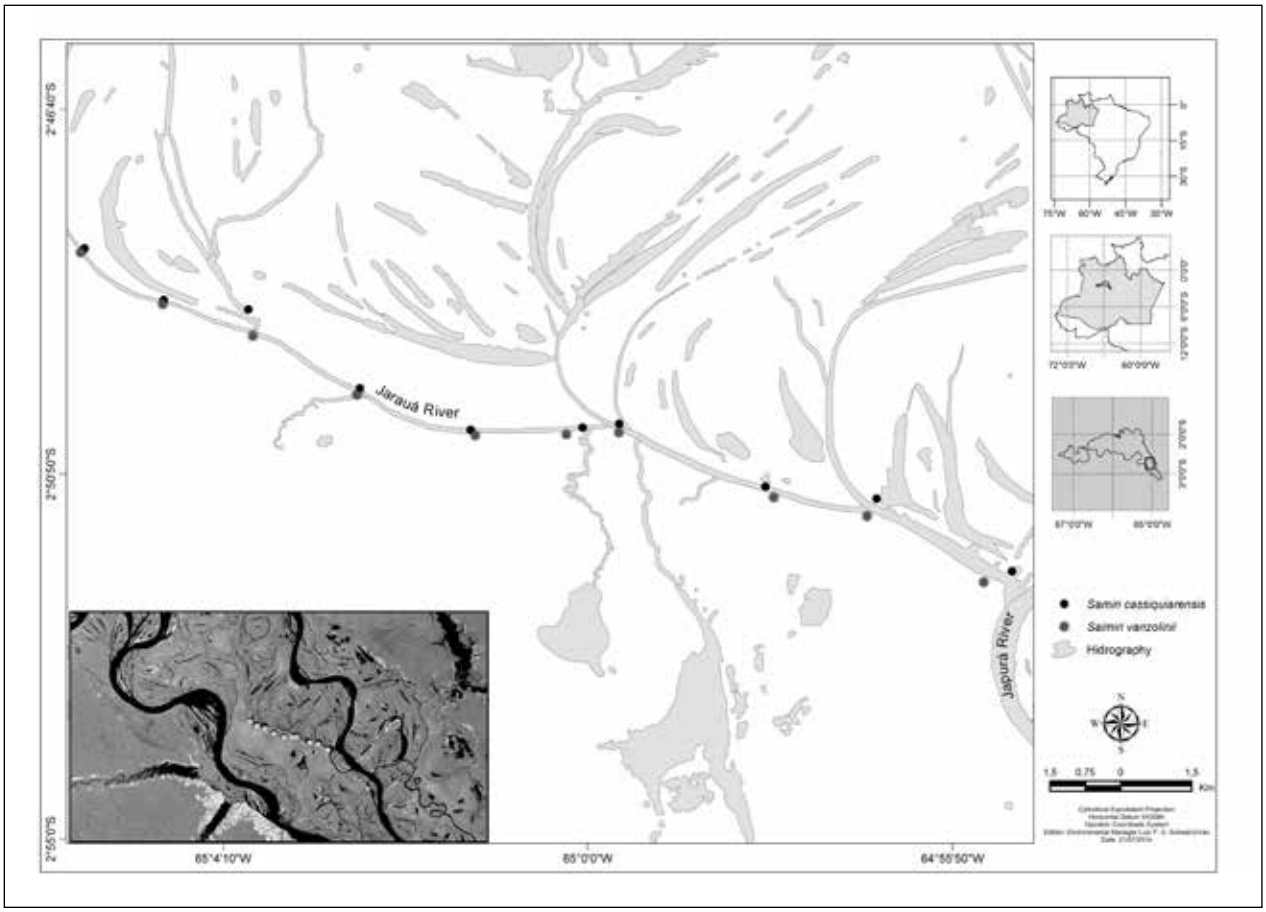

Figure 1. Distribution of trapping stations along the Jarauá River.

subcutaneous space between the shoulder blades. This was done with the purpose of identifying the individual in case we recaptured it. We also shaved the proximal end of the tail of each animal, in order to determine if trapped animals were re-visiting the trapping stations (as monitored by the camera traps). All procedures were conducted at the trapping site; once the animals had recovered, we released them at the same location of capture.

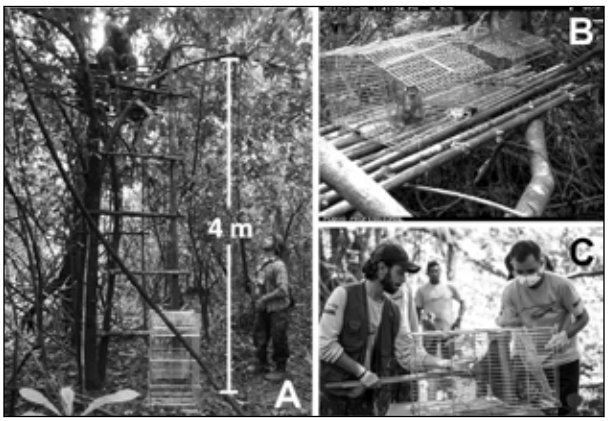

Figure 2. Capture of squirrel monkeys in RDS Mamirauá. (A) Construction of the trapping station; (B) "entry" event of *S. vanzolinii* registered by camera trap; (C) physical containment with the aid of a wooden board. Photos by: Fernanda Paim (A), Projeto Saimiri (B) and Sonia Vill (C).

Since the individuals of *S. cassiquiarensis* did not enter the Tomahawk traps (see Results and Discussion), we had to capture them manually, with the aid of a dip net and leather gloves. All captures were conducted on the margins of the river channels, between the forest edge and the river, while the animals foraged on the ground. Upon seeing a foraging subgroup, two researchers would corner the animals, until an individual was captured. Despite the fact that the animals showed an escape response, we did not observe any aggression toward the researchers. Captures were done as quickly as possible, in order to avoid stress to the other group members, but we avoided abrupt maneuvers that might stress the captured individual. The animals were immediately anesthetized and taken to the research base, near the capture area. The anesthetic protocol was the same as for *S. vanzolinii*. As soon as the animals had recovered from anesthesia, they were released at the capture site.

Results

As we had ten cameras to monitor the 20 stations on a rotational basis, each trapping station was monitored for 34 days with the camera traps. *S. vanzolinii* was detected at three of the stations and *S. cassiquiarensis* at four. However, the species differed in their frequency of use of the stations (Table 1). At the stations used by the species, *S. vanzolinii* visited on average 0.41 of the 34 days, while

Table 1. Capture stations used by *Saimiri* species. "Visit" refers to the events when the animals only visited the platforms without entering the traps. "Entry" refers to the number of events when the animals visited and entered the traps. No individuals of *S. cassiquiarensis* were captured in the trap stations.

Used stations	Visit	Entry	Frequency of use	Probability of capture	# of animals captured
S. cassiquiarensis					
SC2	3	0	0.09	0.00	0
SC4	1	0	0.03	0.00	0
SC9	3	1	0.09	0.33	0
SC10	3	0	0.09	0.00	0
S. vanzolinii					
SV1	29	28	0.85	0.97	4
SV6	12	7	0.35	0.58	4
SV8	1	0	0.03	0.00	0

S. cassiquiarensis visited on average 0.08 of the monitoring period. The probability of capture was calculated for each station and species. For *S. vanzolinii*, the probability was of 0.97 at one of the stations and 0.58 at another. At the third station at which this species was detected, it did not enter the trap. *S. cassiquiarensis* had a probability of 0.33 at one of the four stations used. At the remaining stations used by the individuals, only "visits" rather than "entries" were recorded.

In November 2012, we captured 20 squirrel monkeys: eight were *S. vanzolinii* and 12 were *S. cassiquiarensis*. The eight *S. vanzolinii* individuals were captured at two of the ten stations (four in each station): three adult males, three immature males and two adult females. The eight individuals were captured in five days, with a capture rate of 1.6 individuals/day. Despite the fact that platform construction, baiting and monitoring were conducted in the same manner on both margins of the Jarauá River (i. e. for both species), only *S. vanzolinii* were trapped in the Tomahawks, as predicted by the camera trap monitoring. Then, we manually captured twelve individuals of *S. cassiquiarensis* in seven days (capture rate of 1.7 individuals/day). The animals were captured near four of the ten trapping stations. We captured four adult males, four immature males and four adult females.

Discussion

This trapping effort is the first documented for squirrel monkeys in Central Amazonia. In our study area, both squirrel monkey species showed different patterns of trapping station usage, which could indicate they have different foraging strategies. During the dry season in the *várzea* forests, the ground margins of the river channels are colonized by annual and perennial grasses and terrestrial herbaceous vegetation (Junk et al., 2012). In an ecological study of *S. cassiquiarensis* at RDS Mamirauá, Araujo and Stone (in prep.) observed that the animals engaged in terrestrial activities during 8.6% of observations (5.9% of these were foraging and feeding activities). On the other hand, during six months of systematic data collection also during dry season, *S. vanzolinii* was never observed on the ground (F. Paim, pers. obs.).

Despite reaching our objectives with a satisfactory capture rate, it is possible that the visits of *Sapajus macrocephalus* to the stations (0.74 in the area of *S. vanzolinii* and 0.21 in the area of *S. cassiquiarensis*) led to a lower capture rate than expected. As discussed by Mitchell (1990), capuchin monkeys are a potential competitor for food, and their presence may have inhibited the use of the stations by squirrel monkeys. On the other hand, we highlight that this method may also be efficient for trapping capuchin monkeys in the future.

In October 2013, we replicated our methodology in another area of RDS Mamirauá, to capture *S. vanzolinii* and *S. macrodon* individuals, also within the limit of their geographic distributions. We captured nine individuals of *S. vanzolinii* and eight of *S. macrodon* in three days, with capture rates of 3 and 2.7 individuals/day, respectively. All animals were captured using Tomahawk traps. The capture rate for *S. vanzolinii* was almost double that of 2012. Both expeditions (in 2012 and 2013) were carried out during the dry season with different capture rates, which indicates that efficiency of the trapping techniques for congeneric species may vary among areas due to their particular ecological conditions.

Management implications

Trapping wild primates is essential to access information about population's health and genetics and has implications for conservation medicine. Efficient described methods are particularly important when the species of interest is endemic or prone to extinction, as *S. vanzolinii*, and require prompt management measures. We believe that our

Tomahawk trapping technique may be efficient, as long as certain factors are considered. Capture techniques for squirrel monkeys must be carefully evaluated, considering the risks to the animals, research objectives, and number of individuals and groups to be captured. Factors such as the species' foraging patterns, spatial use patterns, presence of competitor species and characteristics of the study area can affect the efficiency of the trapping methodology, and must be considered when planning a trapping expedition.

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SHORT-TERM LEARNING OF OLFACTORY DISCRIMINATION TASKS IN COTTON-TOP TAMARINS (*SAGUINUS OEDIPUS*)

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Abstract

After years of near absence from the literature, olfaction is finally beginning to be recognized to have an important role in primate feeding ecology. Yet even though it is already clear that primates' olfactory acuity is higher than previously thought, it is still unclear upon which parameters of the olfactory system selection pressures have worked to produce an efficient lineage-specific sense of smell. Here, we report experiments in which we presented a generalist primate, the cotton-top tamarin (*Saguinus oedipus*), with a series of olfactory discrimination tests in order to examine whether its generalist diet also yielded a general olfactory system. We show that tamarins are capable of discriminating between novel odors of several categories, learning to associate them with positive and negative rewards and use them as food selection cues. Although odors were from varying levels of ecological relevancy (fruity, herbal, and seafood), no differences in discrimination performance between were observed. Combined with partial learning and memorizing abilities, these results demonstrate a generalist olfactory system whose range of detectable compounds is not restricted to ecologically relevant odors and which relies on learning rather than innate responses.

Key Words: Food selection, foraging, frugivory, generalist diet, olfaction, sense of smell, sensory ecology.

Resumen

Después de años de casi total ausencia en la literatura, el olfato finalmente empieza a reconocerse que el olfato tiene un papel importante en la ecología alimentaria de los primates. Aun cuando es ya claro que la agudeza olfatoria de los primates es más alta de lo que antes se pensaba, no es aún claro sobre qué parámetros del sistema olfativo las presiones de selección han trabajado para producir un sentido del olfato eficiente específico al linaje. Aquí reportamos experimentos en los cuales sometimos a un primate generalista, el tití cabeza blanca (Saguinus oedipus), a una serie de pruebas de discriminación olfativa con el propósito de examinar si su dieta generalista también se correspondía con un sistema olfativo general. Mostramos que los titi cabeza blanca son capaces de discriminar entre olores nuevos de varias categorías, aprendiendo a asociarlos con recompensas positivas y negativas, y a usarlas como pistas para la selección del alimento. Aunque los olores fueron de variada relevancia ecológica (frutales, herbales y de comida de mar), no se observaron diferencias en el desempeño de discriminación entre ellos. Combinado con aprendizaje parcial y habilidades de memorizar, estos resultados demuestran un sistema olfatorio generalizado cuyo rango de compuestos detectable no está restringido a olores ecológicamente relevantes y el cual depende del aprendizaje más que de respuestas innatas.

Palabras Clave: Selección de alimento, forrajeo, frugivoría, dieta generalista, olfato, sentido del olfato, ecología sensorial.

Introduction

Primates are one of the most vision-oriented taxonomic groups (Fobes and King, 1982) and are the only eutherian mammal order which includes lineages with habitual or partial (polymorphic) trichromacy (Jacobs, 2009). This elaboration of visual capacities has long been considered to have come with a price – a continuous reduction in olfactory capacities which rendered them in effect "microsmats", whose olfactory capacities are reduced to almost negligible levels (Le Gros Clark, 1971). These notions begun shifting when social functions of olfaction were identified (Michael et al., 1976; Epple et al., 1993) but mostly after Laska and colleagues (e.g., Laska et al., 2000, 2004, 2005) demonstrated that primates of several lineages possess olfactory capacities that are in line with, and sometimes

even superior to, those of traditionally "macrosmats" such as dogs or rodents. This, in turn, led to a proliferation of studies that emphasized the roles of olfaction in primate feeding ecology. In frugivory – the main dietary modality of many primate species – few managed to demonstrate the ability of any species to locate fruiting trees from afar. In contrast, the majority of studies observed that primates tend to employ their sense of smell in the food selection phase, to assess the quality of individual fruits before ingestion (Nevo and Heymann, 2015). Whereas the importance of the sense of smell may be minor to vision when selecting fruits that provide clear visual signals, some fruit species are visually cryptic (i.e. their fruits do not change their color when ripening) and thus require reliance on olfactory cues (Hiramatsu et al., 2009; Melin et al., 2009). Here, the sense of smell may acquire the foremost position and provide crucial information otherwise unobtainable, regardless of color vision capacities.

In the food selection phase, the main challenge primates face is to quickly and accurately determine whether a fruit is ripe or unripe. Frugivorous primates are usually generalists: they may consume the fruits of up to hundreds of species (Van Roosmalen, 1985; Buzzard, 2006; Culot, 2009; Beaune et al., 2013), some of them providing fruits only every other year or even less (Chapman et al., 2005). Thus, primates may encounter certain fruits only at long intervals. Furthermore, the odor of ripe fruits of different species can be qualitatively and quantitatively different (Hodgkison et al., 2013) and even within species may change over the dial cycle (Borges et al., 2013) and according to the availability of nutrients (Mattheis and Fellman, 1999). As a result, it is unlikely that efficient recognition of ripe fruits can be based on a few compounds that characterize fruits of all, or many species. Therefore, along with some more general decision rules (e. g. ripe fruits tend to be softer, Dominy, 2004), this context strongly favors reliance on fast and accurate learning of the visual and olfactory cues associated with each consumed species (Schaefer et al., 2014). However, this stored information may be relevant only for few hours or days in which the species provides fruits, but possibly becomes obsolete fast when fruiting ceases and the primates shift their foraging effort to other species.

Thus, an efficient use of the olfactory system can be predicted to encompass discriminating between the odors of desired (ripe) and undesired (unripe) items, and based on trial-and-error, quickly learning to associate the positive and negative stimuli with their respected rewards to allow quicker and more correct choice during forthcoming encounters. Further, given that memory formation and its storing are not cost-free (Dukas, 1999), it is likely that they would take place only when the stimulus becomes regular. Indeed, previous studies demonstrated that continuous exposure to such challenges over many days allows primates to learn the tasks up to a point where their success rates are approaching 100% (Laska et al., 1996; Hübener and Laska, 1998). In addition, even if generalist frugivores are under selection to retain a generalist olfactory system which can allow response and quick learning of diverse stimuli, over time it can be expected to evolve to be more sensitive to odorants that are "ecologically relevant" – odorants or odorant classes that are common in their feeding items. The olfactory receptors of primates have experienced positive selection (Dong et al., 2009) and primates of several lineages possess high olfactory sensitivity to odorants common in fruits (e.g., Laska et al. 2006). Not surprisingly, capuchin monkeys (Cebus apella) have been shown to be better to discriminate between odors of ecologically-relevant fruits as opposed to ecologically-irrelevant seafood odors (Ueno, 1994).

Here, we report a short experiment which focused on the early stages of olfactory learning in food selection tasks in cotton-top tamarins (Saguinus oedipus), a generalist New World frugivorous-insectivorous primate (Neyman, 1978; Rylands and Mittermeier, 2013). We asked the following questions:

1. Can cotton-top tamarins quickly learn to associate novel odors with positive and negative rewards, and consequently learn to use the ability to discriminate between the odors in food-selection tasks?

2. Does olfactory memory form after short, abrupt, exposure to the stimuli?

3. Do tamarins perform better when the stimuli are ecologically-relevant?

To address these questions, we exposed captive cotton-top tamarins to a series of experiments that required them to discriminate between novel odor stimuli associated with positive or negative rewards, simulating an unfamiliar plant species that presents ripe and unripe fruits which carry different odors. In order to answer question (3), we repeated the experiments three times, using three sets of odorants of decreasing levels of ecological relevancy: fruity, herbal and seafood.

Methods

Study animals

Experiments were conducted on a group of 7 adult and subadult male cotton-top tamarins hosted at the German Primate Center, Göttingen, Germany in March 2012. The group lived in two connected cages, totaling at about 9 m^2. The tamarins were normally fed with a mash of rice flour, various fruits and vegetables, dried fruits such as raisins or apricots, rusk and boiled eggs. Once a week, mealworms or grasshoppers were provided.

Experimental procedure

Each of the four experiments was conducted over 2 h over 3 consecutive days in the following order: control, fruity, herbal, seafood odors (Table 1). For each experiment, on

Table 1. Odors used in all experiments

Conditions	Assigned odors	
	Odor indicating positive reward (S+)	Odor indicating negative reward (S-)
Control	-	-
Fruity	Cherry[1]	Grapefruit[1]
Herbal	Lavender[1]	Eucalyptus[1]
Seafood	Eel[2]	Shrimp[2]

[1] Pajoma Ingo Steyer KG, Hemmoor, Germany
[2] Behr Angelsport GmbH, Ladenburg, Germany

Figure 1. Experimental station.

each day, 4 identical experimental stations were placed in the enclosure at the same time. Each contained 2 familiar drinking bottles (Fig. 1). The bottles were filled with either sugar or salty water, which served as positive (S+) and negative (S-) rewards respectively. Next to the opening, each bottle was marked with a 1.5 ml Eppendorf vial containing 20 drops of commercially obtained aromatic oils (empty in the control experiment). Odors were assigned randomly in the beginning of the experiment and were not switched afterwards (i. e., a single odor was always associated with either a positive (S+) or a negative reward (S-). Preliminary experiments confirmed that the sugar water is a positive reward for the tamarins while salty water is never drank after an initial contact. The tamarins had not been exposed to these odors prior to the reported experiments. To ensure correct scoring, the bottles were marked with red and green markers. Male tamarins are dichromats (Jacobs, 2009) and could therefore not use this as a cue.

In each experimental session the tamarins were allowed to freely approach any of the four identical stations, examine the bottles and attempt drinking. Once an attempt was made (defined as physical contact of the tongue or lips with the bottle), the observer (E-M.R.) called individual's name, allowed the tamarin to drink or switch to the other bottle in case of an incorrect first choice, and then removed and re-placed the bottles in quasi-randomized order to annihilate location within the station as a cue. This also ensured that observing group members did not provide any useful cue in identifying the S+ bottle, and also that spatial preference of right or left could not affect the overall success rates. Thus, the chance level for correct choice was 50%. The experiments were recorded with a video camera. Scoring was conducted by the experimenter after all experiments were completed based on the color marks on the bottles. We recorded only the first choice (S+ or S-) in each interaction with the experimental station. To ensure that scoring was accurate, a second observer scored one of the video footages (150 datapoints). Inter-observer reliability was 96% (i.e. the second observer agreed with the experimenter in 96% of the scoring during analysis of one video).

Statistical analysis

Due to variation in the number of tamarin-bottle interactions between individuals and days and since no significant differences between days were found, we lumped all data points for each individual in each experiment (e. g., individual A, fruity) to a single figure depicting its success rate (share of correct decisions) in that experiment. One individual was excluded due to very low participation rate, thus reducing the sample size to N = 6. For the remaining individuals, the number of interactions with the experimental devices in any of the experiments ranged between 10 and 257. In each of the four experiments, we used one-tailed Wilcoxon tests to test whether the tamarins scored higher than the baseline chance level of 0.5. We used one-tailed tests because preliminary experiments showed that the tamarins avoid drinking salty water and thus the minimum theoretical success rate was 50% (Ruxton and Neuhäuser, 2010). To compare success rates between conditions we applied the Wilcoxon signed-rank test when comparing two groups and Friedman's test for more. We used paired tests to model the average within-individual difference in performance between treatments. Data were analyzed on R 3.0.1 (R Core Team 2013) and graphs were made using the package Plotrix (Lemon, 2006).

Results

Discrimination performance

Tamarins scored significantly above chance level in all experiments (Wilcoxon tests, one tailed, Fruity: N = 6, V = 15, p = 0.03; herbal: N = 6, V = 15, p = 0.03; seafood: N = 6, V = 24.5. p = 0.045), showing that, as a group, they could discriminate between the odors and choose

the correct drinking bottle above chance level (Table 2). Since we found no significant differences in discrimination performance between treatments, we further summed the scores of the three treatments (fruity, herbal, seafood) to a single "stimulus" figure, which increased the number of data points (79–257) per individual and substantially reduced inter-individual variation. This "stimulus" was also significantly larger than the 0.5 baseline (N = 6, V = 27, p = 0.017). Success rates in the control condition were not different than 0.5 (N = 6, V = 15, p = ns), indicating the subjects could not identify the S+ bottle based on cues other than the olfactory stimuli tested (Table 2, Fig. 2).

Short-term learning and memory formation

To examine memory formation of the stimuli we compared success rates between the 3 consecutive days of experiments, with the expectation that memorizing would result in increased success rates in days 2 and 3. Since performance in the three odor categories was indistinguishable, we lumped them to a stimulus to increase the number of observations per individual and the test's robustness. Success rates did not vary between days (N = 6, Friedman's X^2 = 4.33, df = 2, p = ns), indicating that a 2 h exposure was not sufficient for effective memory formation. Nonetheless, short-term learning was apparent: tamarins scored above chance level in both first and second halves of the sessions, but significantly more in the latter (stimulus, all days lumped – Wilcoxon test, two-tailed, N = 6, W = 2, p = 0.013) (Fig. 3).

Differences in discrimination performance between treatments

We found qualitative differences in discrimination performance between the three treatments. Performance was lowest for the fruity stimuli and highest for the herbal stimuli (Fig. 2). However, none of these differences are statistically significant (N = 6, Friedman's X^2 = 1.33, df = 2, p = ns).

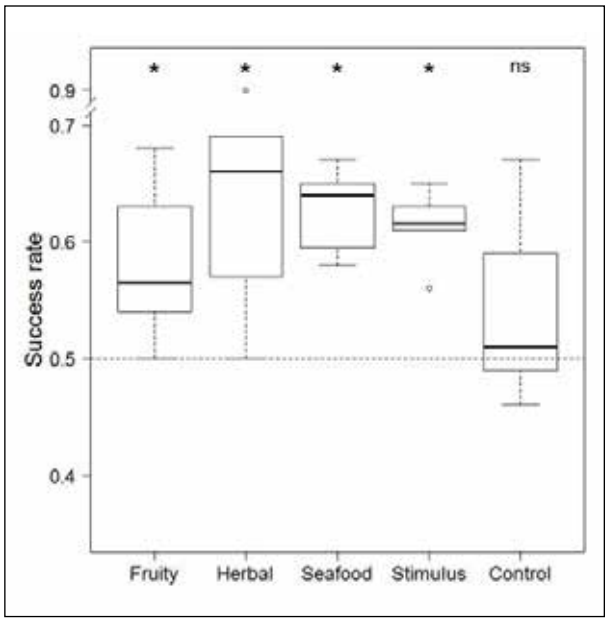

Figure 2. Success rates in all experiments. Stimulus is the success rates in all experimental conditions lumped (fruity, herbal, seafood). Asterisks denote significance at p < 0.05 in one-tailed Wilcoxon tests comparing success rates to the 0.5 chance level. N = 6 individuals in all experiments.

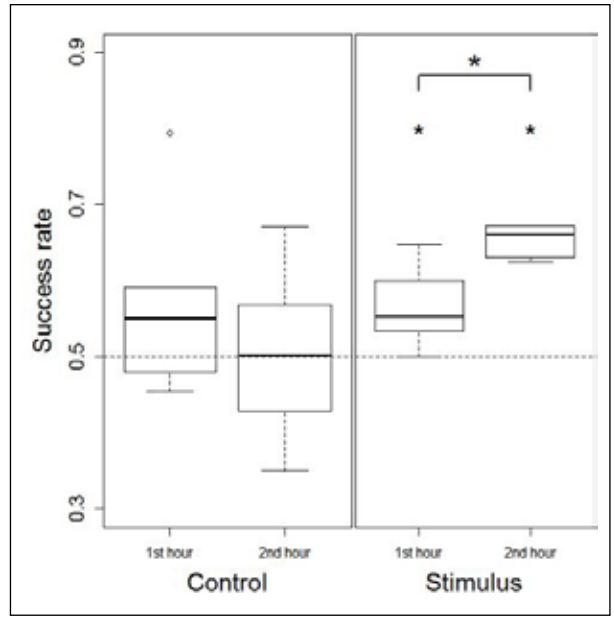

Figure 3. Success rates in early and late phases of the experiments. Results from all days are lumped. Stimulus is fruity, herbal and seafood lumped. Asterisks above boxes denote significance at p < 0.05 in one-tailed Wilcoxon tests comparing success rates to the 0.5 chance level. Asterisk above arch denotes significance at p < 0.05 in a two-tailed Wilcoxon paired test. N = 6 individuals in all experiments.

Table 2. Mean individual success rates (correct / total choices) in all conditions. Stimulus: fruity, herbal and seafood combined.

Individual	Conditions				
	Control	Fruity	Herbal	Seafood	Stimulus
B	0.59 (91/153)	0.68 (58/85)	0.67 (31/46)	0.63 (79/126)	0.65 (168/257)
G	0.46 (29/63)	0.54 (19/35)	0.91 (10/11)	0.57 (19/33)	0.61 (48/79)
J	0.51 (59/115)	0.63 (49/78)	0.65 (24/37)	0.59 (81/136)	0.61 (154/251)
L	0.49 (26/53)	0.58 (14/24)	0.5 (5/10)	0.67 (34/54)	0.62 (53/85)
O	0.67 (52/78)	0.5 (20/40)	0.57 (8/14)	0.65 (17/26)	0.56 (45/80)
R	0.51 (22/43)	0.55 (26/48)	0.68 (37/54)	0.65 (41/63)	0.63 (104/165)

Discussion

The first questions we asked were whether cotton-top tamarins, a generalist frugivore, can learn to use random novel odors as reliable cues in food selection tasks, and whether abrupt exposures would lead to memory formation. We focused on limited and fast exposure which mimics fruit species whose yield and fruiting time are relatively low and unpredictable. All three experiments (fruity, herbal, seafood) demonstrated this capacity. Within two hours the animals scored significantly above chance level in all conditions, and they clearly improved towards the end of each session. Thus, abrupt exposures of 2 h are sufficient for effective association of novel odors with positive and negative rewards, and the ability to discriminate between the odors allows cotton-top tamarins to identify desired feeding items and avoiding undesired items. In the wild, this ability is expected to translate into the ability to identify ripe fruits and avoiding unripe or overripe fruits. At the same time, the lack of difference in performance between experimental days indicates that this short-term learning process does not translate into effective memory formation. Although the tamarins systematically improved in solving the task within session, success rates in the following morning always decreased and indicate that the tamarins had to learn the task anew. So, it appears that while very short-term memory formation took place, it was not consolidated and could not be used after a day's break. However, it is likely that had the experiments been prolonged for more days or more hours per day, the tamarins would have begun storing the learned information rather than learning it every day anew, as demonstrated in previous studies (Laska and Hudson, 1993; Laska et al., 1996; Hübener and Laska, 1998).

Taken together, these results provide support for the validity of the characteristics we expected to find in the generalist's olfactory system – quick adjustment and ad hoc learning to deal with novel stimuli to make food acquisition more efficient, but lack of memory formation when the stimulus is irregular. This system is likely to be favored in generalist frugivores, which feed on hundreds of plant species whose fruit yield is irregular and unpredictable. On one hand, the frugivore would benefit from the ability to quickly learn to identify ripe over unripe or overripe fruits. On the other hand, when it is unknown whether or when and fruits of the same species would be encountered again, the costs of memorizing odors of ripe and unripe fruits of hundreds of species may exceed the benefits.

The third question at hand was whether tamarins would perform better when the challenge entails discrimination of ecologically relevant stimuli as opposed to irrelevant such as the seafood condition. We chose novel stimuli with which the tamarins had been unfamiliar in order to examine whether the ability to learn to associate novel odors with positive and negative rewards (question 1), increases when the stimuli are more ecologically relevant. Plant volatile compounds tend to be very different than those present in seafood (cf. Hiatt, 1983; Hodgkison et al., 2013; Knudsen et al., 2006). Therefore, if the tamarin olfactory system has been under selection to emphasize detection and discrimination of fruity/herbal volatile compounds, it was predicted that this should translate into higher ability to learn to use novel fruit or herbal odorants as food selection cues. This was intended to attempt to partially replicate a study which demonstrated that capuchin monkeys possess higher discrimination abilities when facing "fruity" rather than "fishy" odors (Ueno, 1994). Our results failed to record this pattern. In fact, fruity odors were qualitatively the most difficult to discriminate, although this trend was not supported by the statistical tests. This, however, should be taken with great care because it is practically impossible to standardize the "olfactory distance" between odor pairs in the experiments. There are genetic, neurological and ontogenetic factors which determine whether discrimination between two odor mixtures is easier or more difficult. As a result, it is possible that tamarins indeed possess higher olfactory discrimination capacities to "fruity" odor mixtures, but that the single odor pairs used here are not fully representative of odor mixtures from their respective categories. It is therefore likely that repeating these experiments with many different odor pairs would yield significant differences in discrimination performance between odors from categories of varying ecological relevance. Nonetheless, it is also possible that generalist species, and especially taxa such as tamarins, which rely on olfaction for intraspecific communication as well (Heymann, 2006), have retained a very general olfactory system which can respond to many different stimuli, even if ecologically less relevant.

In conclusion, these short experiments demonstrate two characteristics of the olfaction system of a frugivorous generalist primate: the ability to quickly learn to use arbitrary olfactory cues as food selection guides and the lack of clear specialization on odors strictly ecologically relevant. They further indicate that under abrupt and irregular exposure memory formation does not take place – a phenomenon that may be adaptive under such conditions. Time and budget limitations forced this to be an exploratory experiment which we hope would encourage other groups to examine similar questions using different settings and model species.

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adhered to the ASAB guidelines for the use of animals in research and teaching.

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GPS AS AN EFFECTIVE TOOL FOR STUDY OF THE HOME RANGE OF BLACK-AND-GOLD HOWLERS (*ALOUATTA CARAYA*) IN RIPARIAN FORESTS, SOUTHERN BRAZIL

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Abstract

The effectiveness of using Global Position Systems (GPS) to estimate primate home ranges in tropical forests has been questioned. The aim of this study was to test the efficacy of this tool by comparing quadrat methods with the help of a compass and tape measure (CT) and using GPS in estimating the size of the home range of two groups of *Alouatta caraya*; one group on a 1,050-ha, riparian-forest island, and the other on the mainland of the Upper Paraná River. They were monitored from October 2004 through September 2005, on two full days in each month per group, GPS readings (fixes) and tag marks were taken every 30 min. A 0.25-ha grid was used for the home range estimate. A home range of 4 ha was obtained for the island group by means of GPS, and 4.5 ha with CT. The mainland group used 14.75 ha, as estimated by both methods. However, some quadrats were incompatible in positioning between the methods in each environment. The annual and seasonal home ranges did not differ between the methods, showing that GPS was effective. The quadrats that were computed based on GPS and absent on CT indicated, however, a small error in the home range as defined by the GPS. Therefore, the greater the precision of the instrument when taking fixes, the better the result. The smaller the home range of the group, the more marked the error can become. For GPS to be even more effective in the study area or regions of similar vegetation, it is noted that the fixes should be taken at shorter intervals and the fixes should be taken with the best precision possible. We discuss the efficacy of the two methods as applied to studies of the spatial behavior of *A. caraya* in riparian environments.

Key Words: GIS; comparative methods; Neotropical primates; space use.

Resumo

A efetividade do uso de Sistemas de Posicionamento Global (GPS) para estimar a área de uso de primatas em florestas tropicais tem sido questionada. O objetivo do presente estudo foi testar a eficácia dessa ferramenta em comparação com o método quadrado com a ajuda de um compasso e fita métrica (CF) para estimar a área de uso de dois grupos de *Alouatta caraya*. Um grupo ocupava uma ilha de mata ciliar de 1.050 ha, e o outro terra firme no alto do Rio Paraná. De outubro de 2004 até setembro de 2005, pontos de GPS foram obtidos a cada 30 minutos para cada grupo, durante dois dias completos em cada mês por grupo. Um quadrante de 0,25 ha foi usado para estimar as áreas de uso dos animais. Uma área de uso de 4 ha foi obtida para o grupo da ilha com o auxílio do*GPS*, e de 4,5 ha com o método CF. O grupo de terra firme usou 14,75 ha, segundo ambos os métodos. Entretanto, alguns quadrantes foram incompatíveis em posicionamento quando comparados entre os dois métodos tanto na ilha como na terra firme. As áreas de uso anuais e sazonais não diferiram entre os métodos, mostrando que o uso de GPS foi eficiente. Para os quadrantes que foram computados de acordo com o GPS e sem considerar CF, observamos um pequeno erro na área de uso. Portanto, quanto maior a precisão do equipamento ao obter pontos fixos, melhor será o resultado. Quanto menor a área de uso do grupo, mais marcante o erro pode se tornar. Para o GPS ser ainda mais eficiente numa área de estudo ou regiões de vegetações semelhantes, é notado que: os pontos fixos deveriam ser obtidos em pequenos intervalos e com a melhor precisão possível. Nós discutimos a eficácia dos dois métodos usados em estudos de comportamento espacial em *A. caraya* em ambiente ribeirinho.

Palavras-Chave: GIS, métodos comparativos, primatas Neotropicais, uso do espaço.

Introduction

The Global Positioning System (GPS) technology can be a useful tool for collecting and plotting data (fixes and tracks, for example), which can be transferred to maps, providing a wide range of information for different ecological applications (Phillips et al., 1998; Burgman and Fox, 2003). Its efficacy varies according to the habitat and behavior of the

animal (Sprague et al., 2004). This method (GPS) is frequently used for studies of different species of mammals such as those mainly inhabiting open environments; artiodactyls, canids, and felines in North America (see review in Sprague et al., 2004; Haines et al., 2006; Burdett et al., 2007), canids and dolphins in South America (Juarez and Marinho-Filho, 2002; Wedekin et al., 2007), and elephants and primates in Africa (Blake et al., 2001; Doran-Sheehy et al., 2004; Markham and Altmann, 2008). However, its effectiveness is questionable in closed-canopy forests (Sigrist et al., 1999), such as for primate studies when estimating home range (Phillips et al., 1998; Blake et al., 2001; Marques 2006; Markham and Altmann, 2008; Nascimento et al., 2011). In these cases, the use of GPS is compromised by the loss of reception of satellite signals, thereby decreasing accuracy and making it impossible to mark accurate points, which leads to the use of other methods, such as compass and tape measure (CT method) to take the locations (Nascimento et al., 2011). Satellite reception, and hence location accuracy, determines whether GPS technology is a suitable tool (Ren et al., 2008).

Relatively few studies of the home range of primates have been conducted by means of the GPS method but its use is increasing, due to the recent advances GPS telemetry systems, like GPS radiocollars (Walter et al., 2011). Some examples of studies conducted in tropical closed-canopy forests are those of *Ateles geoffroyi yucatanensis* and *Alouatta pigra* in Mexico (Ostro et al., 1999; Valero and Byrne, 2007), *A. geoffroyi* and *Cebus capucinus* in Costa Rica (Campbell, 1994), *Alouatta clamitans* and *Sapajus nigritus* in southern and southeastern Brazil (Steinmetz, 2000; Aguiar et al., 2003; Ludwig et al., 2005), and *Rhinopithecus bieti* in China (Grueter et al., 2009; Ren et al., 2008). Home ranges of *Gorilla gorilla gorilla, Papio cynocephalus*, *Macaca fuscata,* and *Colobus angolensis ruwenzorii* were also studied using GPS, but the first two cases were conducted in open environments (African savannas), while the last two cases were developed in a "mixed habitat" formed by open and closed habitats (Doran-Sheehy et al., 2004; Sprague et al., 2004; Fashing et al., 2007; Markham and Altmann, 2008).

Marques (2006), in a review of home ranges of *Alouatta clamitans,* excluded results obtained by Steinmetz (2000), arguing that the data were obtained with the use of equipment (GPS) with a precision too low for this type of study. It was noted that the instrument bears an intentional error created by the United States Department of Defense to prevent military uses (at least 100 m off). However, selective availability was ended in 2000, improving the precision of civilian GPS. Still, the viable use of this instrument and the direct comparison between methods is also questionable. Therefore, the aim of this study was to compare the quadrat method with the help of a compass and tape measure (CT method) versus the use of GPS for calculating the home ranges of two groups of black-and-gold howler monkeys *Alouatta caraya* in riparian forests, and thereby the efficacy of GPS in determining primate home ranges in forested environments.

Material and Methods

Study sites

Black-and-gold howler monkeys live on an island and the opposite banks of the Upper Paraná River, in northwestern Paraná state near the town of Porto Rico (22º45'59"S, 53º18'58.4"W), southern Brazil (Aguiar et al., 2007a; 2009; 2011). For this study, howlers were studied in two riparian forests along the Upper Paraná River. One area was an island (Mutum Island) and the other extended along the adjacent left bank. The climate of the region is humid subtropical with 1,200–1,300 mm average annual rainfall (Romagnolo and Souza, 2000). The forests have relatively low tree species diversity (Romagnolo and Souza, 2000), with two types of vegetation: alluvial seasonal semideciduous forest (SSF) (flooded forest) present on the islands and plains (altitude of about 220 m), and a sub-montane SSF, mainly on the left bank of the river, on hillier ground (up to 250 m in altitude) (Campos and Souza, 1997). This stretch belongs to the Environmental Protection Area (APA) of Islands and Floodplains of the Upper Paraná River and has been the target of ecological and behavioral studies of primates (Aguiar et al., 2005, 2007a, 2007b, 2011; Ludwig et al., 2007; Rocha et al., 2007; Ludwig et al., 2008, Aguiar et al., 2009).

Mutum Island is the largest (1,050 ha) island near Porto Rico. The study area included a riparian forest that extends along the bank of the river and up to 160 m inland. The island has areas in various stages of regeneration, marshes, and lagoons and is dominated by the arboreal species *Cecropia pachystachya* Trec. (4 to 7 m in height). So, the canopy is relatively low with a height of 10 to 15 m and emergent trees with a maximum of 25 m, and is open with many clearings that can facilitate satellite signals reception. Along the left bank of the Paraná River is nearly extinct seasonally submontane SSF (Campos and Souza, 1997). This portion, where the study took place, comprises forest that most resembles the original state of this forest type (M. C. Souza, unpubl. data) despite human alterations in the region. The forest here extends inland up to 260 m from the river edge. In this area, the tree layer is higher than on the island, with a more closed canopy formed by trees 15 to 30 m tall. The arboreal species *Lonchocarpus guillemineanus* (Tul.) Malme dominates, with emergent trees reaching 30 m in height, which could impede the reception of satellite signals.

Data Collection

Howlers were observed from October 2004 to September 2005, after a five-month habituation period. Both the island and the mainland groups were observed from sunrise to sunset twice per month (306 h, $\overline{X}$: 12.45 ± 1.17 h per day; 288 h, $\overline{X}$: 12.63 ± 0.77 h per day, respectively). The composition of the group on Mutum Island (MG) varied

from 9 to 11 individuals (2–4 adult males, 5–6 adult females, 1–2 subadult males, 0–2 infants), and the mainland group (PG) included 11–13 individuals (1–3 adult males, 4–5 adult females, 1–2 subadult males, 2 juveniles, 1–3 infants (age classes following Rumiz 1990). The groups were approximately 2,600 m distant from each other.

Two methods for collecting home range data were used: marking locations with tags in the field to be measured later using a compass and tape measure (CT), as the control method, and GPS readings (fixes) (Garmin, model E-trex Venture; geographical coordinates obtained in UTM; South America 1969). Both are subject to errors, but here it is assumed that the CT method is the more precise. The use of a laser range finder or a clinometer can make maps potentially more accurate than compass and tape but at the cost of increased resources. The location was obtained from the center of the groups. Because black-and-gold howlers are relatively inactive for much of the day (Bicca-Marques, 1993; Bravo and Sallenave, 2003), markings (tags and GPS points) were standardized every 30 minutes (Fashing et al., 2007), to attempt to decrease the statistical dependence (Setz and Hoyos, 1986). In every location where a georeferenced point was marked by GPS, a tag with the same number was tied on a tree.

The points marked with tags in the field were measured with a compass and tape measure (50 m) from trails previously registered and plotted on a paper map on a 1:500 scale. The points and range used were analyzed seasonally. For GPS readings, we waited for the reception of the highest possible number of satellites (minimum of three) to minimize the estimated positional error, displayed with greatest precision of the instrument (which could vary from 5 to 19 m, depending on the density of the canopy), in order to obtain a reliable reading (Valero and Byrne, 2007). The fixes were loaded into the program GPS TrackMaker 11.8.

The grid cell method, by far the most commonly applied to studies on primates, was used, with quadrats of 0.25 ha for both methods (NRC, 1981; Ostro et al., 1999; Grueter et al., 2009). This method establishes that all quadrats visited by the animals are included in the home range. Next, the total home range size was obtained by summing the areas of all the grid cells where points occurred. The positioning of the grid plotted on the paper map was first established according to GPS TrackMaker 11.8. Ideally, this program could have continuously recorded the GPS readings; however, this procedure requires enormous storage and battery power, and satellite reception was often lost, which makes it inapplicable for the GPS model used in this study. To test for significant differences in home range results between the two methods, the number of quadrats used was compared by the nonparametric test of Friedman and Siegel's C table, considering a minimum significant difference (MSD) of 15 and alpha = 0.047.

Results

In summing all 594 h of monitoring of the animals (306 h for MG and 288 h for PG), the cumulative curve demonstrated that the home range size for both the island and mainland groups stabilized by the ninth month (CT method) (Fig. 1). The island group used an area of 4.5 ha based on CT and 4 ha based on the GPS method, a result that did not show any statistical difference ($0.001<p<0.01$) (Table 1). However, there were differences in the positioning of some quadrats (Fig. 2). The GPS method showed the use of one quadrat that was not computed, and three others that were absent when compared to the CT method.

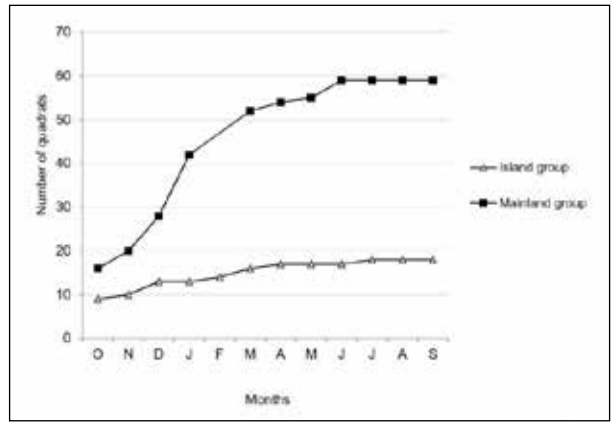

Figure 1. Cumulative curves of the use of quadrats for the island and mainland groups of *Alouatta caraya* over a period of 12 months of monitoring along the Upper Paraná River (October 2004 to September 2005) carried out by the scanning method with compass and tape measure (the month of February could not be sampled in the mainland group).

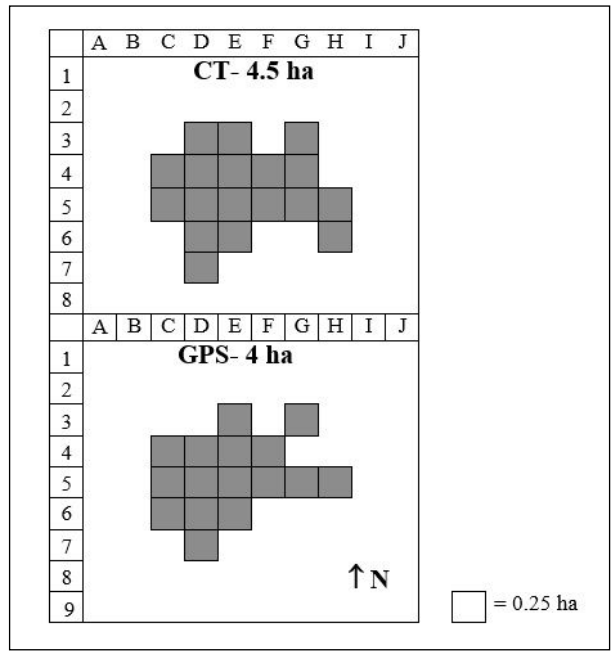

Figure 2. Total home range of island group of *A. caraya* on the Upper Paraná River obtained by the compass and tape measure (CT) method (gray quadrats, above) and by the GPS method (gray quadrats, below).

This resulted in four quadrats with incompatible positions. The mainland group indicated a home range of 14.75 ha with both methods (Table 1), and there was also no statistical difference (0.01<p<0.001). However, 12 quadrats (3 ha) showed different positions when the two methods were compared (Fig. 3). The seasonal analyses of both groups also indicated no significant differences between the two methods, showing a minimum difference of 0.25 ha in the spring for both groups and in the summer for the mainland group, a maximum difference of 0.5 ha in the summer and fall in the island group, and 1.5 ha for the mainland group in the winter (Table 1).

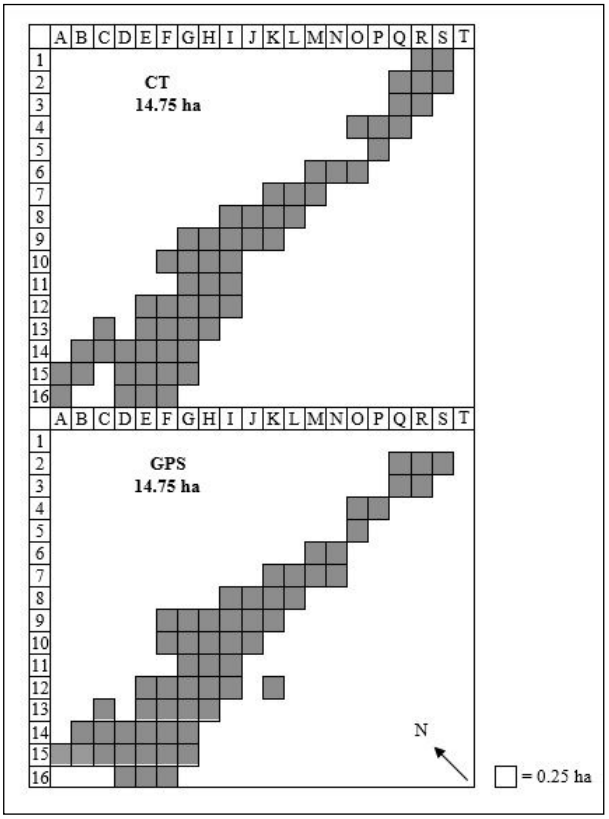

Figure 3. Total home range of mainland group of *A. caraya* on the Upper Paraná River, obtained by the compass and tape measure method (CT) (gray quadrats, above) and by the GPS method (gray quadrats, below).

Table 1. Seasonal and total home ranges of island and mainland groups of *Alouatta caraya* along the Upper Paraná River, based on two different methods (grid cell method by means of compass and tape measure, and by GPS).

Group	Season	Method / Home range (ha)	
		Compass and tape measure	GPS
Island	Spring	3.25	3.5
	Summer	3.0	2.5
	Fall	3.0	2.5
	Winter	2.75	2.75
	Total	**4.5**	**4.0**
Mainland	Spring	7.0	7.25
	Summer	10.25	10.0
	Fall	10.0	10.0
	Winter	8.0	9.5
	Total	**14.75**	**14.75**

Discussion

The results obtained through the use of a compass and tape measure and GPS in the groups studied did not differ significantly, showing that GPS is an efficacious technology for the analysis of home ranges of howlers and arboreal primates in general in forests of different physiognomies (sub-montane SSF and alluvial SSF). However, this method showed some inconsistencies with respect to the positioning of some quadrats when compared to the control method (CT). Quadrats that were computed by GPS and that were absent in the analysis with the compass and tape measure reflected the small error in the home range as defined by the GPS. However, this error did not compromise the results for the seasonal and total areas.

It can also be seen that the better the precision of the instrument in the location where the fixes are taken, the more precise is the estimate of the size of the area utilized by the animals. However, the smaller the home range of the group, the more evident this error can be, leading to a more representative result. For example, for the group with the smaller home range (MG), the positional incompatibility of the estimated quadrat was proportionally greater [approximately 1:1 (incompatible quadrat/ home range)], when compared to the mainland group with a larger home range (0.8:1), even though this group lives in a more mature forest. However, in the final summation, the numerical results obtained for the home range for the two methods were very similar, showing no significant difference for the two groups. This absence of statistical differences can be explained by the numerical compensation of the quadrats that appeared in different positions as estimated with the GPS. This error was probably due to the lower precision in fixes taken in the denser areas within the forest (personal observation) or satellite position. If the satellites are all directly overhead, the resulting error will be higher than if the three satellites are spread out (some on the horizon, for example). While canopy density is an important impediment to accuracy, satellite position may be also a key.

Therefore, for GPS to be considered even more effective for use in calculating the home range in this study or in areas with similar vegetation, in which the canopy allows for the use of this method, some important information is noted here: 1) the points should be taken as precisely as possible (preferentially down to 15 m), so that the error does not drastically affect the results, also attempting to diminish the positional incompatibilities of the quadrats; 2) the GPS readings should be taken at shorter intervals for more precise data collection, for example, every 15 min (for howler monkeys). The interval stipulated in this study (30 min)

did not allow the marking of all the quadrats that the animals utilized, since they passed through several different locations during the course of the day outside the marking time of the point. For example, in Figure 3 there is an isolated box, suggesting that the animals traveled quickly to and from there, presumably the monkeys passed through the uncolored space to arrive at this ¼ hectare. The collection rate should depend on primate speed, and the size of the quadrats: more frequent for faster moving animals, and for smaller quadrats. If large quadrats are used, data points can be collected less frequently.

Although the system using the CT method is more precise, it is extremely laborious, because it requires the help of others to measure the points (and later to collect the data) and calls for more trips to the field in addition to those for monitoring the animals. On the other hand, in relation to the cost/benefit of GPS, the work of the investigator is made easier. Also, it is very easy now to upload GPS points directly into a computer, which saves lots of time and transcription errors and facilitates analysis of points in computer programs. Burgman and Fox (2003) pointed out that this technology has improved the spatial accuracy of field sampling relative to traditional map-based methods. Furthermore, it is rapidly being improved with better batteries, antennas, and electrical efficiency, enhancing the acquisition and number of reliable positions (Sprague et al., 2004). Besides, the market cost of the equipment is becoming increasingly more accessible to the consumer, and computer programs that run their analyses can be obtained from the internet without charge. The results of this comparative methodological study revealed the importance of the cost/benefit ratio for the use of GPS in the analysis of home range studies of primates in riparian environments. Studies in similar fields can become easier using this equipment because these forests are naturally low [(e.g., the Brazilian "caatinga" or semiarid scrub forest, and the "cerrado" or savanna) or perturbed areas (e.g., riparian forests, mangroves, and secondary forests)]. The instrument can be considered, therefore, an efficacious tool for this type of ecological study in appropriate environments in the Neotropical domain, facilitating and providing important analyses that contribute to the conservation of primates and other mammals.

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PRIMATAS DO PARQUE ESTADUAL DA SERRA DO PAPAGAIO E RPPNS ADJACENTES, ESTADO DE MINAS GERAIS

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Resumo

No presente estudo reportamos sete espécies de primatas que ocorrem na área do Parque Estudual da Serra do Papagaio (PESP) e Reservas Particulares do Patrimônio Natural (RPPNs) localizadas no entorno do PESP: *Callicebus nigrifrons*, *Callithrix penicillata, Sapajus nigritus*, *Callithrix aurita, Alouatta guariba clamitans*, *Brachyteles arachnoides* e *B. hypoxanthus*. Dentre estas espécies, quatro encontram-se ameaçadas de extinção: *C. aurita*, *A. guariba clamitans*, *B. arachnoides* e *B. hypoxanthus*. A área do PESP e das RPPNs é de extrema importância para preservação de remanescentes de Floresta Atlântica e áreas de transição com o cerrado, abrigando as principais espécies de primatas endêmicas e ameaçadas de extinção da Floresta Atlântica. Além disso, a área compõe um grande corredor florestal dentro do Mosaico da Serra da Mantiqueira, fazendo divisa com o PARNA de Itatiaia (MG/RJ) e Parque Estadual da Pedra Selada (RJ).

Palavras-Chave: Primates, Unidades de Conservação, Serra da Mantiqueira, riqueza de espécies.

Abstract

We report on the occurrence of seven primate species in the Serra do Papagaio State Park (PESP) and the private reserves (RPPNs) loclated in the vicinity of the park: *Callicebus nigrifrons*, *Callithrix penicillata, Sapajus nigritus*, *Callithrix aurita, Alouatta guariba clamitans*, *Brachyteles arachnoides* and *B. hypoxanthus*. Four of these species are threatened: *C. aurita*, *A. guariba clamitans*, *B. arachnoides* and *B. hypoxanthus*. The park and the private reserves are extremely important for the preservation of the remnants of Atlantic forest and the transitional zone with the cerrado in this region, protecting endemic threatened species of the Atlantic forest. The forests there also form an important corridor in the forest mosaics of the Serra da Mantiqueira spanning the states of Rio de Janeiro and Minas Gerais: the Itatiaia National Park (MG/RJ) and the Pedra Selada State Park (RJ).

Key Words: Primates, conservation units, Serra da Mantiqueira, species richness.

Introdução

A Floresta Atlântica sofreu grande perda de sua extensão original, restando atualmente grandes extensões de floresta principalmente em cadeias de montanhas do Sudeste do Brasil, como as Serras do Mar e da Mantiqueira (Ribeiro et al., 2009; Colombo and Joly, 2010; Le Saout et al., 2013). A conservação destas cadeias de montanhas mostra-se essencial para a preservação de espécies de animais e vegetais, principalmente daquelas endêmicas e ameaçadas de extinção (Becker et al., 2013; Jenkins et al., 2013; Le Saout et al., 2013), como os primatas (Paglia et al., 2012; CPB/ICMBio, 2014).

Atualmente a Floresta Atlântica possui 7,5% de sua área original (Ribeiro et al., 2009), com cerca de 12,6 milhões de hectares protegidos no corredor da Serra do Mar, distribuídos em mais de 88 grandes Unidades de Conservação (UCs) (Ayres et al., 2005; Conservation International do Brasil, 2014; SOS Mata Atlântica, 2014), sendo uma das áreas mais ricas em biodiversidade dentro deste Bioma (Aguiar et al., 2005). Entretanto estas UCs mostram-se frágeis, devido a falta de técnicos, financiamento e conflito entre comunidades locais, governos e produtores rurais (Tabarelli et al., 2005), além de estarem isoladas uma das outras (Aguiar et al., 2005; Ayres et al., 2005; Tabarelli et al., 2005; Brasil, 2006). Uma das maiores dificuldades enfrentadas pelos parques e reservas naturais do Brasil reside no seu crescente isolamento de outras áreas naturais, protegidas ou não (Ayres et al., 2005), visto que a fragmentação e isolamento de remanescentes florestais aumentam ainda mais os efeitos da perda de habitat, com consequências diretas sobre a perda de espécies (Adren, 1994; Tabarelli et al., 2005, 2006). Apenas ¼ das áreas protegidas

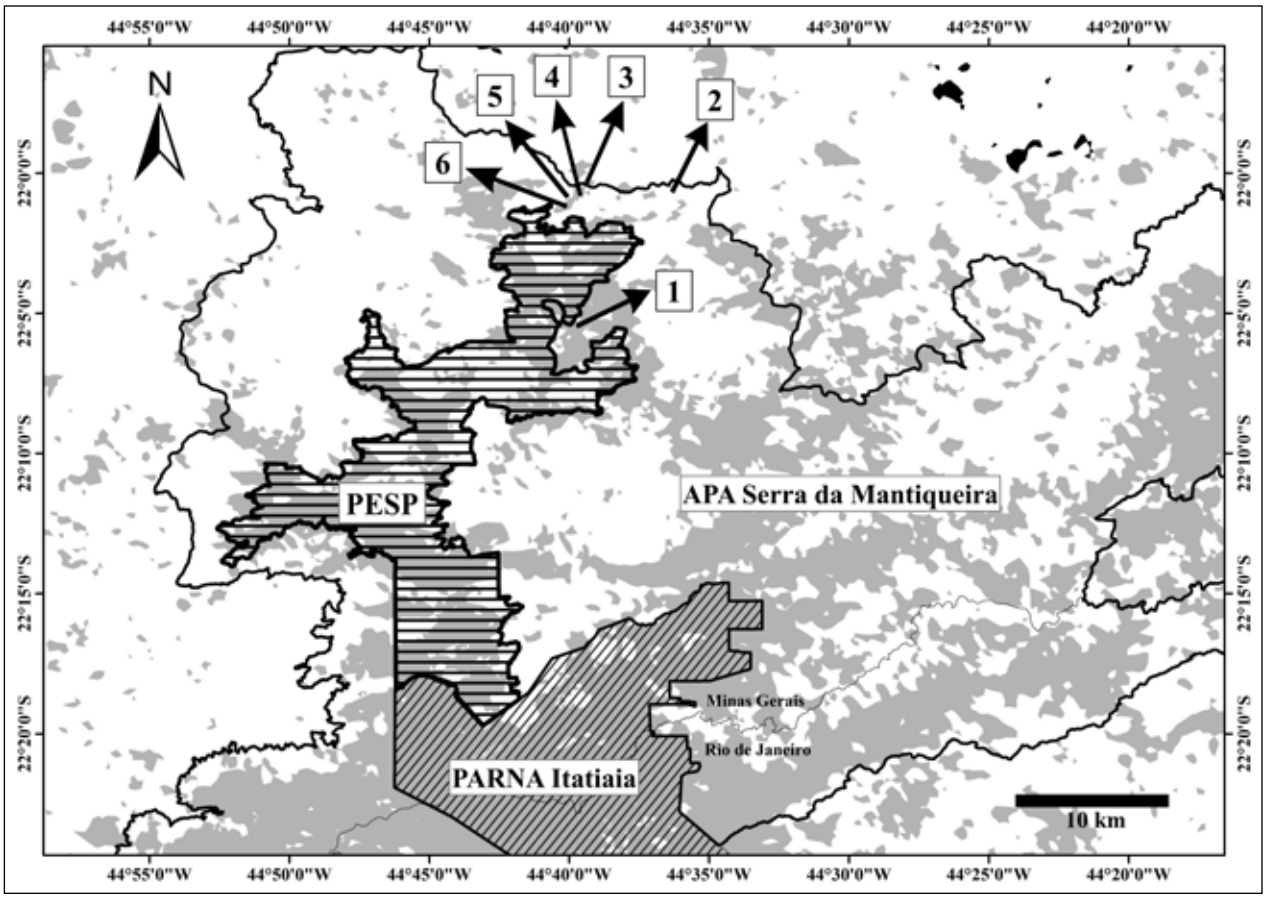

Figura 1. Localização das áreas consideradas no presente estudo ao longo da cadeia de montanhas da Serra da Mantiqueira, considerando o Parque Estadual da Serra do Papagaio (PESP), Parque Nacional do Itatiaia (PARNA Itatiaia), Área de Proteção Ambiental da Serra da Mantiqueira (APA Serra da Mantiqueira) e Reservas Particulares do Patrimônio Natural (RPPNs). 1 – RPPN Serra do Papagaio; 2 – RPPN Cachoeira do Tombo; 3 – RPPN Floresta do Pengá; 4 – RPPNs Furnas I e II; 5 – RPPN Nave da Esperança; 6 – RPPN Serra dos Garcias. Área cinza: remanescentes de Floresta Atlântica; Área negra: remanescentes de Cerrado.

da Floresta Atlântica provavelmente sustentam populações viáveis de Primatas (Chiarello et al., 2000) e pesquisadores em primatas tem dado cada vez mais atenção à fragmentação do habitat e seus impactos sobre a população destas espécies em florestas tropicais (e.g., Bicca-Marques, 2003; Ribeiro e Bicca-Marques, 2005; Silva e Codenotti, 2007; Arroyo-Rodriguez e Dias, 2010; Bicca-Marques e Freitas, 2010; Boyle et al., 2012). Devido à importância da Serra da Mantiqueira para o estabelecimento de corredores ecológicos para conservação da biodiversidade e à falta de estudos básicos nesta área, o presente estudo teve como objetivo reportar espécies de primatas que ocorrem no PESP e RPPNs do seu entorno.

Material e Métodos

O Parque Estadual da Serra do Papagaio (PESP) possui cerca de 23,000 ha e localiza-se entre os municípios de Aiuruoca, Alagoa, Baependi, Itamonte e Pouso Alto, estado de Minas Gerais (Fig. 1). O PESP integra o corredor da APA Serra da Mantiqueira (Conservation International do Brasil et al., 2000) e sua área pode ser considerada de extrema relevância para conservação dos mamíferos de Minas Gerais, juntamente com o PARNA Itatiaia (Fundação Biodiversitas, 2005). O PESP foi criado pelo decreto nº 39.793, de 5 de agosto de 1998 e faz divisa com o Parque Nacional (PARNA) do Itatiaia e cerca de 14 Reservas Particulares do Patrimônio Natural (RPPNs). Dentre os Municípios que integram o PESP, Aiuruoca é o Município de Minas Gerais que possui a maior quantidade de RPPNs (n = 12, IEF/MG, 2014), onde a maioria encontra-se na zona de amortecimento do PESP e dentro da APA Serra da Mantiqueira. Para o presente estudo consideramos o PESP e as RPPNs Cachoeira do Tombo, Nave da Esperança, Floresta do Pengá, Serra do Papagaio, Serra dos Garcias e Berço de Furnas I e II (Fig. 1 e Tabela 1).

A região do estudo é coberta por floresta semidecidual, floresta densa e fragmentos de Cerrado, além de ocorrer a Araucária (*Araucaria angustifolia* (Bertol.) Kuntze) em toda a área (Ururahy et al., 1983; IBGE, 2004). A característica de transição entre Floresta Atlântica e Cerrado é mais evidenciada na porção norte do PESP e na área das RPPNs. O clima, segundo a classificação de Köppen é do tipo Cwb, com temperatura média anual entre 18°C e 19°C e precipitação média anual de 1,400 milímetros. O período mais chuvoso vai de dezembro a fevereiro e as menores

Tabela 1. Unidades de Conservação consideradas, área e altitude aproximada e número de incursões realizadas entre os anos de 2009 e 2013. Unidade de Conservação: PESP – Parque Estadual da Serra do Papagaio; RPPN – Reserva Particular do Patrimônio Natural.

Unidade de Conservação	Área aproximada (ha)	Altitude aproximada (m)	N° de incursões realizadas
PESP	22.917	1.744 ± 615	75
RPPN Cachoeira do Tombo	12,02	1.076	24
RPPN Nave da Esperança	27,37	1.518	4
RPPN Floresta do Pengá	56,75	1.686	14
RPPN Serra do Papagaio	377,91	1.800	5
RPPN Serra dos Garcias	18,27	1.500	14
RPPN Berço de Furnas I e II	23,51	1.588	14

precipitações ocorrem entre junho e agosto (ver Carvalho et al., 2013).

Entre janeiro de 2009 e fevereiro de 2013 foram realizadas 75 incursões em trilhas dentro do PESP e 75 incursões em trilhas e no entorno das RPPNs (Tabela 1), totalizando 728 horas de censo visual, como parte de um projeto desenvolvido para inventariar os mamíferos que ocorrem dentro do PESP e no seu entorno. As trilhas das UCs foram percorridas no inverno, entre maio e agosto, e no verão, entre novembro e fevereiro, sendo que no ano de 2009 iniciamos as amostragens em janeiro. As trilhas percorridas dentro do PESP encontravam-se nos municípios de Aiuruoca, Alagoa e Itamonte e todas as RPPNs encontravam-se dentro do município de Aiuruoca. As incursões foram realizadas somente por um pesquisador, que apresentava conhecimento em relação ao grupo dos primatas, sendo iniciadas às 06h 00min e estendendo-se até às 19h 00min, em trilhas de até 18 km (média = 12,05 ± 6,69 km) com velocidade média de 2,5 km/h. Os primatas foram registrados por visualização, quando estavam em movimento ou parados, e/ou por vocalizações de longa distância, alimentação e contato (havendo aproximação do pesquisador em relação ao animal), sendo anotado o número de indivíduos sempre que possível. A altitude e as coordenadas do local do registro foram obtidas com GPS Garmin®, modelo Colorado. Calculamos o índice de abundância relativa (taxa de encontro), expresso em número de indivíduos avistados por 10 km percorridos. Testamos a diferença entre a ocorrência das espécies ao longo do perfil altitudinal da área, pelo teste de Kruskal-Wallis, desconsiderando aquelas com menos de três registros, ou seja, *Brachyteles hypoxanthus*.

Resultados e Discussão

Registramos sete espécies de primatas para o PESP e as RPPNs limítrofes: *Callicebus nigrifrons* (0,68 ind./10 km), *Callithrix penicillata* (0,35 ind./10 km), *Sapajus nigritus* (0,02 ind./10 km), *Callithrix aurita* (0,03 ind./10 km), *Alouatta guariba clamitans* (0,03 ind./10 km), *Brachyteles arachnoides* (0,06 ind./10 km) e *B. hypoxanthus* (0,02 ind./10 km) (Tabela 2). As espécies apresentaram distribuição altitudinal significativamente diferente ($H = 57,01$; $p < 0,01$; $N = 127$), com as espécies ameaçadas de extinção registradas nas zonas de maior altitude (Fig. 2), sendo também os locais onde encontramos os maiores fragmentos florestais.

No PESP, foram registradas sete espécies de primatas, das quais três são ameaçadas de extinção (Tabela 2). A riqueza registrada para o PESP é semelhante à riqueza de Unidades de Conservação próximas e que se localizam ao longo da cadeia de montanhas da Serra da Mantiqueira. No PARNA Itatiaia há ocorrência de sete espécies de primatas, sendo as mesmas registradas no PESP (Câmara, 1995; Marroig e Sant'Ana, 2001; Geise et al., 2004; Garcia, 2005; Loretto e Rajão, 2005). No Parque Estadual do Ibitipoca e em seu entorno há ocorrência de cinco espécies de primatas, todas elas registradas para o PESP, entretanto, não são registrados para o Parque Estadual do Ibitipoca, *B. arachnoides* e *C. aurita* (Nogueira et al., 2009, 2010).

Registramos *A. guariba clamitans*, *C. aurita*, e *B. hypoxanthus* entre os anos de 2009 e 2010 nas áreas mais elevadas do PESP (~1,900 m a.n.m.m.), próximo à divisa com o PARNA Itatiaia. *Brachyteles arachnoides* foi registrado em 2009 (entre 1,700 e 1,800 m a.n.m.m.) e como não há divisão física entre o PESP e o PARNA Itatiaia, esperava-se a ocorrência destas espécies dentro do PESP, assim como mencionado em seu plano de manejo (IEF/MG, 2008). Geise et al. (2004), avaliando a ocorrência de mamíferos terrestres ao longo de um gradiente altitudinal no PARNA Itatiaia, registraram espécies de primatas desde os 400 até os 1,720 metros de altitude. Para o PARNA Itatiaia as espécies que ocorrem em altitudes mais elevadas são: *C. nigrifrons* (1,720 m), *A. guariba* (1,700 m), *B. arachnoides* (1,305 m) e *S. nigritus* (1,250 m) (Geise et al., 2004). Possivelmente *S. nigritus* não ocorre em altitudes elevadas no PESP, pois a vegetação do parque apresenta-se mais fragmentada do que a do PARNA Itatiaia. No entanto, nosso esforço amostral foi menor quando comparado aos sete anos de estudos realizados no PARNA Itatiaia, com amostragens entre 1999 e 2005 (ver Câmara, 1995; Marroig e Sant›Ana, 2001; Geise et al., 2004; Garcia, 2005; Loretto e Rajão, 2005).

Brachyteles arachnoides, *B. hypoxanthus, A. guariba clamitans* e *C. aurita* são endêmicas da Floresta Atlântica (Paglia et al., 2012). *Brachyteles arachnoides* e *B. hypoxanthus*

apresentam distribuição restrita ao leste do Brasil no entorno das cadeias de montanhas da Serra do Mar, Serra da Mantiqueira e Serra do Espinhaço (Mittermeier et al., 1989; Melo et al., 2004; Cunha et al., 2009). A falta de registros de indivíduos de *B. arachnoides, B. hypoxanthus* e *C. aurita* após 2010 é preocupante, mesmo com o conhecimento da baixa densidade de *B. arachnoides* (Mittermeier et al., 1987) ou a grande pressão de caça sobre as espécies de Muriqui (*Brachyteles*) na Floresta Atlântica (Auricchio, 1997). *Callithrix aurita* é naturalmente rara, ocorre em baixa densidade (Coimbra-Filho, 1984; Brandão e Develey, 1998; Norris et al., 2011) e sua população está restrita as áreas de elevada altitude das montanhas do sudeste do Brasil, entre os estados de Minas Gerais, Rio de Janeiro e

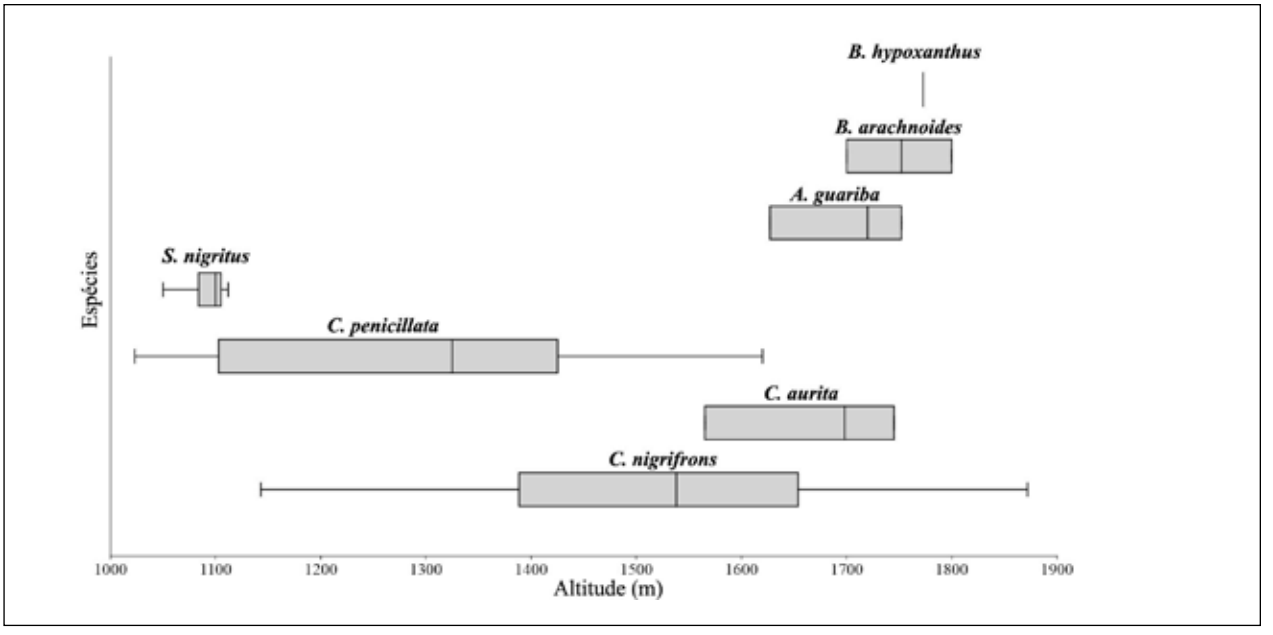

Figura 2. Variação no número de ocorrências de espécies de primatas no Parque Estadual da Serra do Papagaio e Reservas Particulares do Patrimônio Natural que ocorrem em seu entorno. As caixas do gráfico tipo BloxPlot representam 95% das ocorrências, a linha central representa o valor da mediana e as linhas horizontais nas extremidades das caixas representam os valores altitudinais máximos e mínimos para cada espécie.

Tabela 2. Espécies, número de ocorrências e total de indivíduos para as espécies registradas nas Unidades de Conservação considerada no presente estudo. Tipo de registro: Vis – Visualização; Voc – Vocalização. Grau de ameaça - 1 (IUCN, 2014) e 2 (ICMBio, 2014): VU – Vulnerável; EM – Em perigo; CR – Criticamente em Perigo.

Espécies	Tipo de Registro	PESP	Reservas Particulares do Patrimônio Natural (RPPNs)						Total de ocorrências	Total de Indivíduos	Grau de ameaça	
			Cachoeira do Tombo	Nave da Esperança	Floresta do Pengá	Serra do Papagaio	Serra dos Garcias	Berço de Furnas I e II			1	2
Callicebus nigrifrons	Vis, Voc	34	1	8	4	8	4	6	65	124	-	-
Callithrix aurita	Vis, Voc	3	-	-	-	-	-	-	3	6	VU	EN
Sapajus nigritus	Vis, Voc	2	4	-	-	-	-	-	6	5	-	-
Callithrix penicillata	Vis, Voc	8	20	3	4	5	3	4	47	65	-	-
Alouatta guariba clamitans	Vis, Voc	3	-	-	-	-	-	-	3	7	-	VU
Brachyteles arachnoides	Vis	3	-	-	-	-	-	-	3	11	EN	EN
Brachyteles hypoxanthus	Vis	1	-	-	-	-	-	-	1	4	CR	CR
Total		54	25	11	8	13	7	10	128	222	-	-

São Paulo, devido a fragmentação da Floresta Atlântica nas áreas mais baixas (Rylands e Faria, 1993; Auricchio, 1995; Rylands e Chiarello, 2003).

A RPPN Cachoeira do Tombo apresentou três espécies de primatas e teve maior riqueza dentre as RPPNs, além de ter elevado número de ocorrências de *C. penicillata*. As outras RPPNs apresentaram duas espécies cada uma, variando quanto ao número de ocorrências entre *C. penicillata* e *C. nigrifrons* (Tabela 2). O elevado número de ocorrências de *C. penicilatta* nas RPPNs e no entorno do PESP, principalmente nas altitudes inferiores a 1,200m, deve-se à fragmentação, antropização (principalmente na transformação de pastagens para criação de gado) (IEF, 2008; Viola et al., 2009) e presença de áreas com características vegetacionais de cerrado (IBGE, 2004; Viola et al., 2009). *Callithrix penicilatta* mostra-se com maior capacidade de adaptação do que *C. aurita*, é considerada invasora na Floresta Atlântica (Auricchio, 1995; Cerqueira et al., 1998) e tem elevado número de ocorrência em áreas abertas de Cerrado, Caatingas Arbóreas e áreas de transição com a Floresta Atlântica (Coimbra-Filho, 1984; Pontes et al., 2007; Ruiz-Miranda et al., 2011).

A localização do PESP é estratégica e de elevada importância para o Mosaico da Serra da Mantiqueira, integrando um grande corredor, juntamente com o PARNA Itatiaia e o recém-criado Parque Estadual da Pedra Selada, no estado do Rio de Janeiro. O mosaico da Serra da Mantiqueira desde 2008 vem sofrendo com a intensificação na construção de Hidrelétricas, linhas de transmissão de energia elétrica e abertura de lavras para mineração (Ferreira et al., 2014). A área da RPPN Cachoeira do Tombo, por exemplo, está inserida no mapa de conflitos ambientais do estado de Minas Gerais (Zhouri, 2014; GESTA, 2015) e atualmente (2014) passa pelo terceiro processo de licenciamento ambiental para construção de uma Pequena Central Hidrelétrica. Os licenciamentos anteriores foram indeferidos ou arquivados, devido à área estar inserida na zona de amortecimento do PESP, ser uma Área de Preservação Permanente, estar dentro da APA Serra da Mantiqueira e ser uma RPPN (GESTA, 2015). Além disso, dentre os principais problemas encontrados na área de estudo, temos: presença de gado bovino dentro das UCs, utilização de fogo para 'limpar pastagens' no entorno e dentro das UCs e inexistência de Plano de Manejo para as RPPNs. A criação de RPPNs mostra-se como uma alternativa aos proprietários de terras no entorno das grandes UCs, favorecendo a formação de corredores ecológicos. Por exemplo, Nogueira et al. (2009) descrevem que as áreas adjacentes ao Parque Estadual do Ibitipoca são muito importantes a preservação do *B. hypoxanthus*, visto que a espécie não foi encontrada dentro do Parque. Estudos específicos de longo prazo devem ser realizados na área do PESP e adjacências, principalmente para verificar as causas da baixa ocorrência e o desaparecimento das espécies de primatas ameaçadas de extinção.

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NEW RECORDS, RECONFIRMED SITES AND PROPOSALS FOR THE CONSERVATION OF BLACK LION TAMARIN (*LEONTOPITHECUS CHRYSOPYGUS*) IN THE MIDDLE AND UPPER PARANAPANEMA

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Abstract

The Black Lion Tamarin (BLT, *Leontopithecus chrysopygus*) is an endangered species, endemic to the State of Sao Paulo, Brazil. The conservation of the species depends on the effective management of the populations and forest conservation but also on the updated knowledge of its areas of occurrence. Here, we report the record of a new site of BLT occurrence in the municipality of Guareí and confirm the presence of this species in two municipalities, Taquarivaí and Borebi, which (Borebi) is the first record since the last two decades in the Middle Paranapanema basin. Direct observations of BLT groups occurred after the use of playbacks of BLT vocalizations (Guareí), during the prospection of the area (Taquarivaí) and the monitoring of the fauna (Borebi). These three sites are located close to known BLT populations. The occurrence of BLTs in anthropized landscapes with low forest cover, but with a considerable presence of riparian forests, gives evidence of the ecological resilience of the species and underlines the conservation value of such habitats. We are initiating scientific based projects and environmental education programs to increase the knowledge about the ecology and tolerance of BLTs in human altered landscapes. The confirmation of occurrence areas and new records of BLT populations is the starting point for the conservation success of the species.

Key Words: *Leontopithecus chrysopygus*, anthropized landscapes, riparian forests, conservation program.

Resumo

O Mico-leão-preto (MLP, *Leontopithecus chrysopygus*) é uma espécie ameaçada de extinção, endêmica do Estado de São Paulo, Brasil. A conservação da espécie depende não só do manejo eficaz das populações e da conservação das florestas, mas também do conhecimento atualizado das suas áreas de ocorrência. Neste artigo, reportamos o registro de uma nova área de ocorrência de MLP no município de Guareí e confirmamos a presença da espécie em dois outros municípios, Taquarivaí e Borebi, o qual (Borebi) é o primeiro registro da espécie nas duas últimas décadas na bacia do Médio Paranapanema. As observações diretas dos MLPs ocorreram após o uso de *playbacks* das vocalizações da espécie (Guareí), durante a prospecção da área (Taquarivaí) e durante trabalhos de monitoramento da fauna (Borebi). As três áreas são localizadas próximas de populações já conhecidas de MLPs. A ocorrência de MLPs em paisagens antropizadas com baixa porcentagem de cobertura vegetal, mas com a presença de matas ciliares, evidenciam certa flexibilidade e resiliência da espécie e enfatiza o valor que estes habitats têm para a conservação da espécie. Estamos iniciando projetos de pesquisa e programas de educação ambiental para melhorar o conhecimento sobre a ecologia e tolerância a paisagens antropizadas. A confirmação das áreas de ocorrência e novos registros de populações de MLPs são a base para o sucesso da conservação da espécie nestas localidades.

Palavras-Chave: *Leontopithecus chrysopygus*, paisagens antropizados, mata ripária, programa de conservação.

Introduction

Endemic to the State of São Paulo, with its geographical distribution restricted to the interfluve of the Tietê-Paranapanema (Hershkovitz, 1977; Mittermeier, 2013), a region that has suffered intense occupation and deforestation, the black lion tamarin (BLT, *Leontopithecus chrysopygus*) was considered to be extinct (not seen since 1905), but was rediscovered in the late 1960s in the Pontal do Paranapanema region (Coimbra-Filho, 1970). In 2000, the BLT was listed as one of the 25 most endangered primate species in the world (Mittermeier et al., 1985). Many studies on the ecology of this species, long-term conservation programs (Valladares-Padua, 1987; Valladares-Padua, 1993; Albernaz, 1997; Passos, 1998), and the finding of new populations in the basin of the upper Paranapanema River (Lima et al., 2003; Röhe et al., 2003; Rodrigues et al., 2014) brought new hope for its successful conservation. Because of the discovery of these additional populations, and the conservation efforts on behalf of this species, there was a proposal to downgrade the threat category from Critically Endangered in the updated list of threatened species in the state of São Paulo (São Paulo, 2008; Kierulff and Port-Carvalho, 2009). Currently, the BLT is classified as "Endangered" in all threatened species lists; state (São Paulo, 2014a), national (Brasil, 2014), and global (Kierulff et al., 2008).

Here we report on a newly found population of the BLT in the municipality of Guareí, and confirm its presence in two municipalities, Borebi and Taquarivaí. We discuss actions and joint projects that are underway that contribute to our understanding of the eoclogy of the BLT, and new local initiatives for its conservation.

Methods

In Guareí, we used playbacks of BLT vocalizations, following a method developed in other callitrichid census studies (Kierulff and Rylands, 2003; Neves, 2008), along the gallery forests of the Guareí River, from 27–31 October, 2014, and from 13–18 August, 2015. We found out about the presence of BLTs in Taquarivaí during an expedition to identify new sites for ecotourism. BLTs were fully habituated by the farm owner who simply called them to make them approach. They fed almost daily on fruits provided by the owner. The records in Borebi originate from monitoring studies on birds and mammals conducted by the Lwarcel Celulose Company. During the sightings, vocalizations of BLT were recorded, photographs taken and the geographic coordinates were noted.

Results

On 29 October 2014, in response to playback, two adults and one young BLT were sighted in a fragment of gallery forest along the Guareí River, about 100 m from a busy municipal road. On 3 August 2015, six individuals were seen crossing the road of the bridge over the Areia Branca River to feed on the palm (*Syagrus romanzoffiana*) while three other individuals passed under the bridge in the same direction. Finally, on 18 August 2015, three individuals (one adult male and one adult female were identified) responded to playback in the gallery forest along the Guareí River and were observed for 10 minutes and then were lost by the observers (Fig. 1, Table 1). We were unable to determine for certain whether the observations were from one or different groups. However, based on the location and the number of individuals observed, we think that the second observation in Guareí was of a different group than the first and third sightings.

In the same basin of the Upper Paranapanema River, in the region of Itapeva, on 22 May 2011, eight individuals were seen coming from the gallery forests of the Apiaí-Guaçu River in Taquarivaí to feed on fruits provided by the owner of the Farm, about 15 m from the forest (Fig. 2; Table 1). The sites in Borebi were on the property of the Lwarcel Celulose Company in the gallery forests along the Rio Claro River, in the middle Paranapanema River region. As the records were made during different field visits in 2007, 2010, 2013 and 2015, it was not possible to determine whether the sightings were from one or several BLT groups (Fig. 3; Table 1).

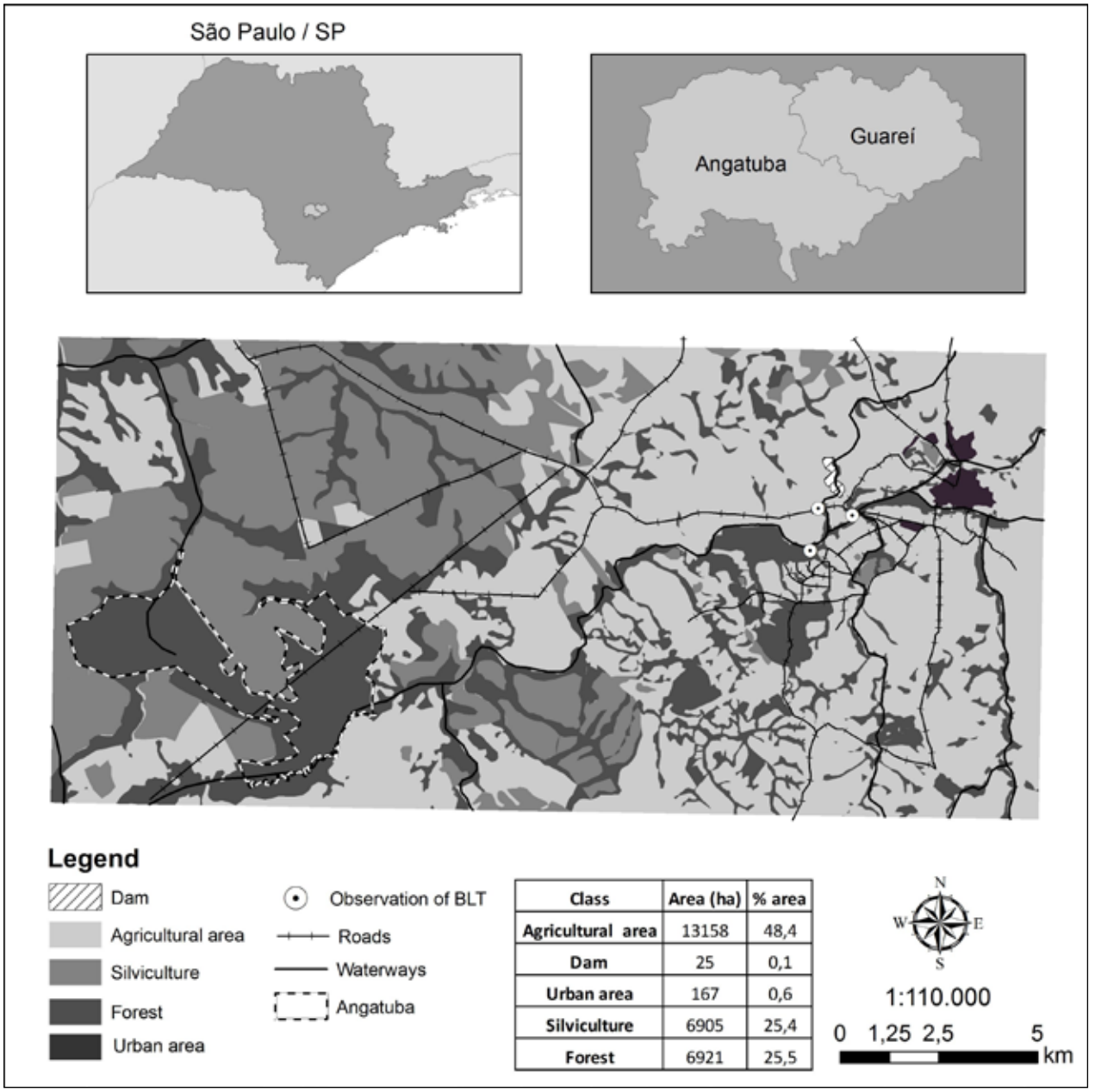
Discussion

There are already known occurrences of BLT populations close to the new or confirmed sites reported in this paper (Holst et al., 2006; Rylands et al., 2008; Rodrigues et al., 2014). The sightings of a BLT group in Guareí occurred in the riparian forest of the Guareí and Areia Branca rivers that connects to a population of the Angatuba Ecological Station 12 km away that was the focus of a recent population survey. At this specific location, local residents frequently observe BLTs crossing a busy road (the Domiciano de Souza municipal road, GRI 253), and road kills of three adult and 2 young BLTs were recorded in 2013. The busy municipal road connects the cities of Guareí and Angatuba and has a constant flow of heavy vehicles transporting timber. For this spot, emergency measures, such as speed reducing bumps, informative boards and, suspended walkways have been initiated to prevent further road kills in the BLT group's home range. Studies on the ecology of this population and more specifically on the group frequently seen crossing the road started in the second half of 2015.

The records in Taquarivaí were made in the gallery forests remaining along the Apiaí-Guaçu River already indicated with BLT sightings in the municipality of Buri (Lima et al., 2003). In the case of the record in Borebi, the nearest known population occurs in the gallery forests of the Rio Claro farm owned by Duratex SA, located in Lençóis Paulista, studied by Mamede-Costa and Gobbi (1998) and part of a BLT meta-population management project in the 1990s (Medici, 2001). Notably, this is the first record in

the last two decades of a population in the Middle Paranapanema basin, although there are other locations where the occurrence of BLTs have yet to be confirmed, such as the riparian forests of the Pardo River basin (Griese & Port-Carvalho pers. comm.).

The subpopulations of BLTs in these above mentioned regions are part of the extinction debt still to be paid with a loss of biodiversity as a consequence of natural habitat destruction and landscape conversion (Metzger et al., 2009; Lira et al., 2012). However, the records of BLTs in landscapes with low forest cover, few small remaining forest fragments, but with a considerable presence of riparian forests, give evidence of their notable resilience, allowing this species to persist in these remaining habitat settings, even in small groups with a low flux of individuals between them. The confirmation of still existing groups opens up promising opportunities for the conservation of this species. However, the threats of stochastic events (disease, predation and road kills) remain and may lead to local extinctions of small BLT subpopulations. There is already enough evidence for the severity of these threats as seen with the road kill reports in Guareí in 2013 and the sudden outbreak of yellow fever in municipalities within the geographic distribution of BLTs in the Middle and Upper Paranapanema River in 2009 (Mascheretti et al., 2013). Integrated programs on a local scale can mitigate the consequences of stochastic events whereas the development of regional landscape



Class	Area (ha)	% area
Agricultural area	13158	48,4
Dam	25	0,1
Urban area	167	0,6
Silviculture	6905	25,4
Forest	6921	25,5

Figure 1. Location of a new record for the occurrence of the black lion tamarin in the municipality of Guareí, Upper Paranapanema basin (Sao Paulo state) and percentages of different land use and forest cover in the landscape. The closest conservation unit where BLTs also occur is the Angatuba Ecological Station.

Table 1. Dates, geographic coordinates and details about the context of the observations of BLTs (River, basin, method, and number of individuals observed – N° ind) in the new (Guareí) and reconfirmed sites (Borebi and Taquarivaí) of BLT occurrence.

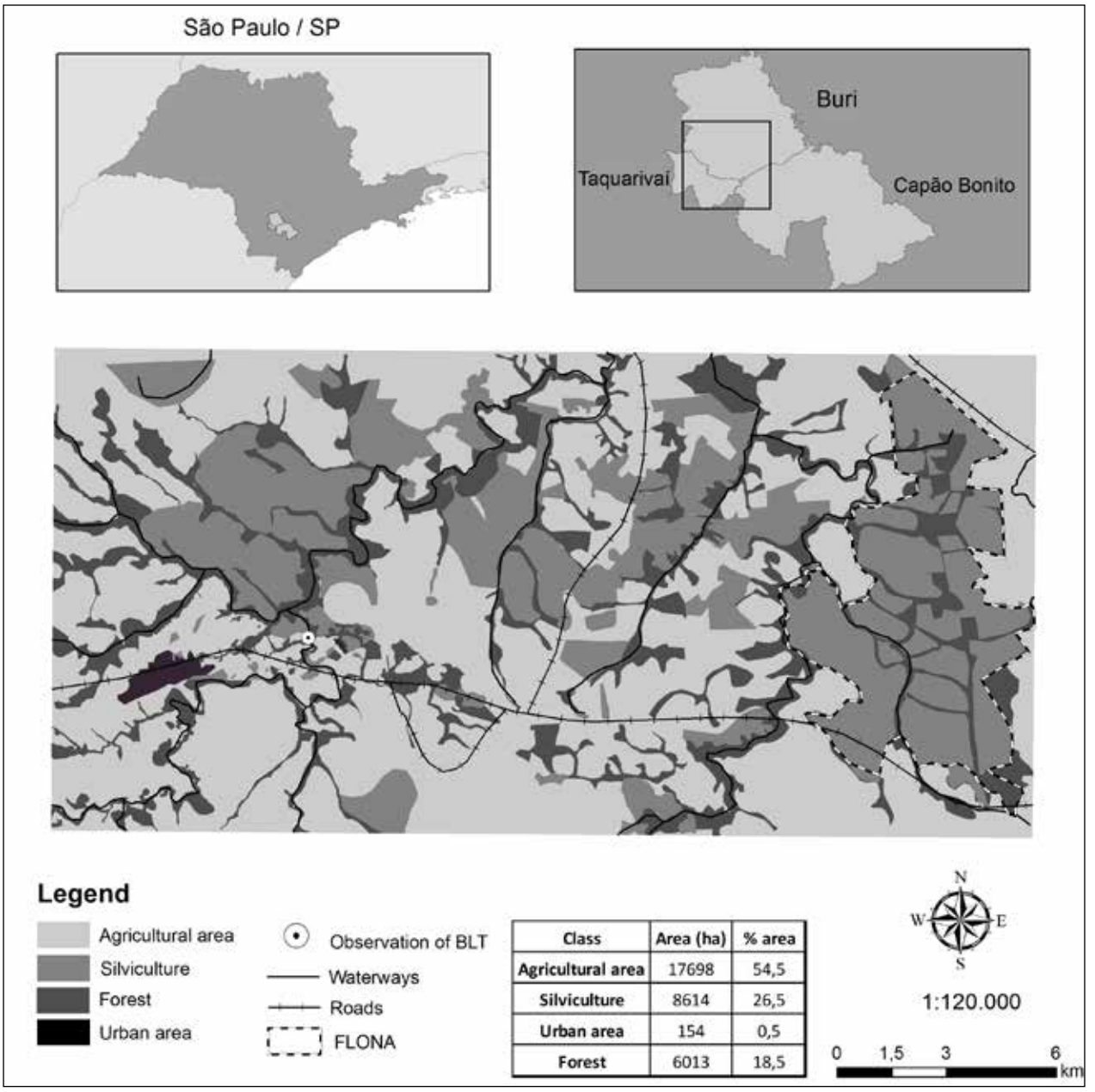
Municipality/Date	Coordinates	River/ Basin	Method	N° ind
Guareí/SP, 29/10/2014	23°22'37.20"S 48°12'24.85"W	Guareí / UP	*Playback*	3
03/08/2015	23°22'32.70"S 48°12'53.20"W	Areia Branca / UP	Oe[a]	9
18/08/2015	23°23'06.50"S 48°12'59.70"W	Guareí / UP	*Playback*	3
Taquarivaí/SP, 22/05/2011	23°54'59.12"S 48°39'56.34"W	Apiaí-Guaçu / UP	Regularly baited in a private property	8
Borebi/SP, 2007	22°45'41.22"S 49° 1'19.11"W	Rio Claro / MP	*Playback*	1
05/2010	22°45'31.56"S 49° 1'11.56"W	Rio Claro / MP	Oe[a]	4
03/2013	22°46'25.58"S 49° 4'33.33"W	Rio Claro / MP	Oe[a]	5
08/2013	22°45'47.79"S 49° 3'47.78"W	Rio Claro / MP	*Playback*	3
02/2015	22°45'29.79"S 48°59'32.48"W	Rio Claro / MP	Oe[a]	4

[a] Occasional encounters

management programs that promote the reconnection of isolated groups and ecological features may ensure the survival of BLTs in these disturbed cultural landscapes.

The landscapes sampled in this study have considerably less forest cover than the proposed threshold of 30% for conservation of the Atlantic Forest's biodiversity (Pardini et al., 2010; Martensen et al., 2012). Landscapes with less than 20% forest cover indicate a tendency to the extinction of a large part of the biodiversity, which may have already occurred. These landscapes are considered to have low resilience, and a huge investment demand for their restoration, and even then with little chance of success (Calmon et al., 2011; Tambosi et al., 2014). Conservation actions become more effective and efficient if they strengthen the resilience of endangered species and of the landscapes they inhabit. The recent alterations of the Brazilian forest code that reduce the width of legally protected riparian forests that should be restored when already destroyed implies a considerable reduction in habitat resilience (Metzger et al., 2010) and thus threatens the last remaining opportunities for the survival of BLTs in these landscapes.

The publication of new records of occurrence of endangered species is an important contribution to existing biological and biogeographical data on a small scale, but gains special relevance when incorporated in multiple-scale approaches and initiatives for new strategies for biodiversity conservation in the Atlantic Forest (Ribeiro et al., 2013). Over the past decades, there have been initiatives by various institutions and researchers on state, federal and international levels for the conservation of BLTs (Rylands et al., 2008; Rezende, 2014), overseen by the international management committee for the lion tamarins and ands evidenced by the population and habitat viability workshops (Holst et al., 2006), management plans for protected where BLTs occur (São Paulo, 2006; Brasil, 2007; São Paulo, 2008; Duratex, 2013), the creation of new protected areas, the development of a National Action Plan for the Conservation of the mammals of the Central Atlantic Forest (Brasil, 2010; Brasil, 2012; Brasil, 2014), the updated lists of endangered species (Brasil, 2014; Kierulff et al., 2008; São Paulo, 2014a), specific environmental education programs, the declaration of BLTs as an environmental heritage of the state of São Paulo and as a symbol of conservation (São Paulo, 2014b), the creation of the standing committee for the conservation of primates in the state of São Paulo (São Paulo, 2014b), the state programs with incentives for municipalities to protect natural resources, such as the program Blue Green Municipality and the environmental registry for rural properties (for details see:www.ambiente.sp.gov.br/), numerous meetings for fund-rasing and to integrate researchers and institutions involved, and the development and dissemination of research projects concerning the species (Instituto de Pesquisas Ecológicas,



Class	Area (ha)	% area
Agricultural area	17698	54,5
Silviculture	8614	26,5
Urban area	154	0,5
Forest	6013	18,5

Figure 2. Location of a reconfirmed site for the occurrecne of BLT in the municipality of Taquarivaí, Upper Paranapanema basin (São Paulo state), and percentages of different land use and forest cover in the landscape. The closest conservation unit where BLT also occur is the Capão Bonito National Forest (FLONA).

2013; Instituto de Pesquisas Ecológicas, 2014; Fundação Parque Zoológico de São Paulo, 2014).

In line with these actions, we are initiating research projects in Guareí and Borebi in order to better understand the ecology and resilience of BLTs in human-altered landscapes. Knowledge on resources, habitat, and matrix use is being integrated into impact and viability analysis to develop mitigation and landscape management measurements and incentives for the creation of private natural heritage reserves. Relevant stakeholders and local communities are being involved in democratic, bottom-up approaches in order to locally fulfill the agendas, proposals and guidelines of the current forums and working groups for the conservation of BLTs in their habitat.

Acknowledgments

We thank FAPESP for financial support to LC and MMS (process number: 2014/14739-0), and CNPq for the scholarship to ABS as part of the institutional scholarship program for scientific initiation (PIBIC-IF). Special thanks to the Prefeitura Municipal of Guareí for constant support and active collaboration during our research, especially to Neli Fidencio Rodrigues, Dileu Rodrigues Soares, Sabrina Priscila de Barros Oliveira, and the Mayor of Guareí João Batista Momberg. We also thank Lwarcel Celulose in

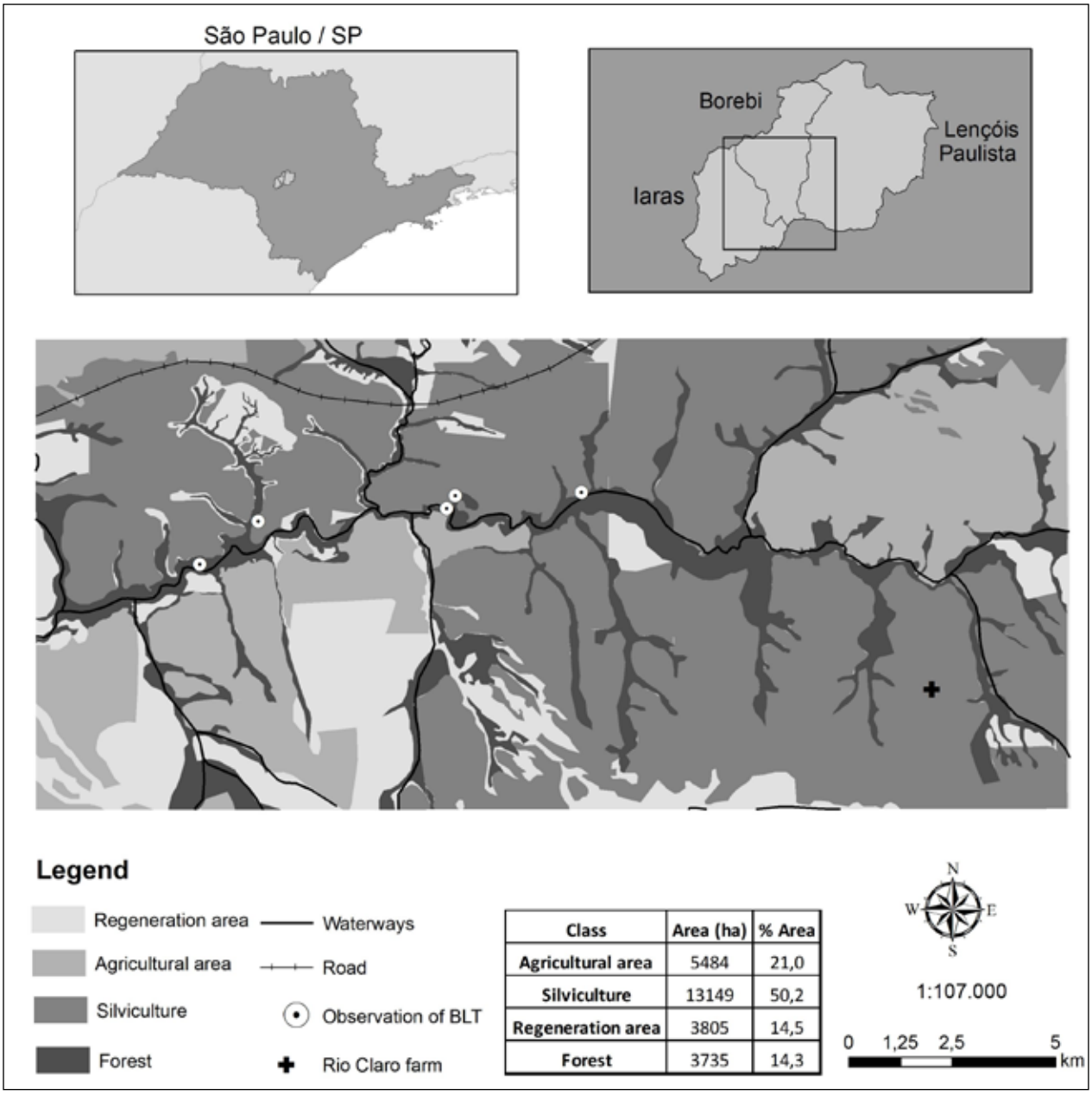


Figure 3. Location of a reconfirmed site for the occurrence of the black lion tamarin in the municipality of Borebi, Middle Paranapanema basin (São Paulo state) and percentages of different land use and forest cover in the landscape. The closest conservation unit where the BLT also occurs is the Fazenda Rio Claro, today protected as a private natural heritage reserve (RPPN Olavo Egydio Setubal).

allowing us to collect data in the Turvinho Farm (Borebi, SP).

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Erratum

ADDENDA AND CORRIGENDA TO MARSH, L. K. (2014). A TAXONOMIC REVISION OF THE SAKI MONKEYS, *PITHECIA* DESMAREST, 1804, *NEOTROPICAL PRIMATES* 21(1): 1–168.

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With the recent publication of *Neotropical Primates* 21(1): 1–168, we discovered the need to correct some taxonomic typos and errors, and wanted to address some taxonomic issues raised by a number of readers, as follows:

Page 12:
Royal Scottish Museum (RSM) should read National Museums of Scotland (NMS) (and throughout).

Page 15: *P. pithecia* synonomy
On *Pithecia rufibarbata*. Some discussion was raised about the synonymy for *Pithecia pithecia*, in particular regarding *P. rufibarbata*. A choice was made by Marsh, and corroborated by Groves, for the synonymy of *P. pithecia* that, since Hershkovitz (1987) had published an extended version (pp. 418–421), it was unnecessary to list all possible previous synonyms. If anyone requires the full list, they can refer to Hershkovitz (1987) directly, but with reference also to Marsh (2014).

The name *Pithecia rufibarbata* was attributed to a juvenile female from Suriname according to Hershkovitz (1987). However, Marsh did not see this holotype specimen in the Naturalis collection in Leiden, although all of Temminck's sakis were probably accounted for. Even though they have older labels, at some point in the past all of the mounted sakis in Leiden were renamed "*Pithecia nocturna*." One of the juvenile male mounts was noted as being determined in 1867. The juvenile male holotype for *P. ochrocephala* from the voyage of Temminck (RMNH 39097) is also labeled *P. nocturna*. Therefore, previous determinations as *rufibarbata* appear to have been replaced by *nocturna* for animals from Suriname. Kuhl (1820) described both *rufibarbata* and *ochrocephala* for the same specimens from Suriname (cf. Marsh 2014, Hershkovitz 1987).

Pithecia rufibarbata was apparently named twice in 1820 (J. P. Michel, pers. comm.). It will be difficult, if not impossible, however, to establish precise or relative publication dates to be certain of priority. This is of little consequence because both uses of *Pithecia rufibarba*[*ta*] are accredited to Kuhl based on specimens now in Naturalis, Leiden, so that both versions of the names are objective synonyms of each other, with nearly identical spelling (one a noun, the other an adjective). Kuhl appears to have adopted the name used in Temminck's collection, while Desmarest clearly considered Kuhl to be the original author of the name:

Pithecia rufibarbata "Mus. Temminkii" Kuhl, 1820 – *Beitr. Zool. vergl. Anat.*: 44 "*Pithecia rufibarbata* Mus. Temminkii. In Surinama. [...] In Museo Temminkiano."

Pithecia rufibarba"Kuhl" Desmarest, 1820 – *Mammalogie* 1: 90 "*pithecia rufibarba*. (Espèce nouvelle, non figurée.) *Pithecia rufibarba*, Kuhl. [...] Patrie. Surinam. (Museum de M. Temmink.)"

This suggests that Kuhl published before Desmarest, although he could have seen it in manuscript form. Similar comments apply to *Pithecia ochrocephala*, but in this case the names are identical:

Pithecia ochrocephala "Mus. Temminkii" Kuhl, 1820 – *Beitr. Zool. vergl. Anat.*: 44 "*Pithecia ochrocephala*. Mus. Temminkii. In Cayana. [...] In Museo Temminkiano."

Pithecia ochrocephala "Kuhl" Desmarest, 1820 – *Mammalogie* 1: 90 "*pithecia ochrocephala*. (Espèce nouvelle, non figurée.) *Pithecia ochrocephala*, Kuhl. [...] Patrie. Cayenne. (Museum de M. Temmink.)"

Page 15: *P. pithecia* synonymy
Marsh (2014) designated a neotype on page 15 for *Simia pithecia* Linnaeus, 1766, but, as indicated by J. P. Michels (pers. comm.), this was not done explicitly although the intention was clear from the text caption for Figure 5 (page 19). The current edition of the Code requires that a taxonomic necessity for designation of a neotype be stated, with Article 75.2 stating quite harshly that a neotype designation is otherwise invalid, but see Article 75.3 for the requirements (J. P. Michels, pers. comm.). Therefore, to clarify the situation, the neotype for *Simia pithecia* Linnaeus, (1766) is MNHN 452, mounted adult male skin from Cayenne, French Guiana, in the Muséum National d'Histoire Naturelle, Paris. A neotype is required

because of the long-standing confusion with the closely-related *Pithecia chrysocephala*, which has often been regarded as conspecific, and because the holotype of *Simia pithecia* Linnaeus, 1766, no longer exists.

Page 21: *P. chrysocephala* synonymy
Marsh (2014; 21) also designated a neotype for *Pithecia chrysocephala*, again not in strict accordance with the Code (J. P. Michels, pers. comm.). To clarify the situation, the neotype for *Pithecia chrysocephala* I. Geoffroy St-Hilaire, 1850, is RMNH 1845(a), a mounted adult male skin with skull inside from "Manacapurú, Amazonas, Brazil" in the collection of Naturalis, Leiden. This neotype replaces the missing cotypes in the Muséum National d'Histoire Naturelle, Paris, one of which was represented in plate XXIX of I. Geoffroy Saint-Hilaire (1850). A neotype is required because of the long-standing confusion with the closely-related *Pithecia pithecia*, which has often been regarded as conspecific.

Parentheses were placed erroneously around the author name at the top of the page. It should read: "*Pithecia chrysocephala* I. Geoffroy Saint-Hilaire, 1850."

Page 27: *P. hirsuta* types
It was pointed out by J. P. Michels (pers. comm.), that "*Pithecia hirsuta* was described by Spix (1823) based on three syntypes in the *Zoologische Staatssammlung*, München. Marsh (2014; 27) designated an adult male mounted skin (ZSM 19) as holotype. However, this should be designated as a lectotype for *Pithecia hirsuta*, with ZSM 14 and ZSM 15 as paratypes."

Spix (1823) used the ZSM No. 19 mounted specimen as the model for his holotype designation for *P. hirsuta* in his publication as Plate IX. However, through time and curation it remained a syntype on the label. Thus, we concur with Marsh (2014) that this specimen should remain as holotype. Thus, the other two specimens should be labeled as paratypes.

Groves adds background on the matter: Hershkovitz's statement that there was a syntype in Leiden is evidently based upon Jentink, F. A., 1892, *Museum d'Histoire Naturelle des Pays-Bas. Tome XI. Catalogue Systématique des Mammifères (Singes, Carnivores, Ruminants, Pachydermes, Sirènes et Cétacés*. Leiden: E. J.Brill. On p.49, under the heading "*Pithecia monacha* E. G. St. Hilaire", he says, against specimen *a*:

"Mâle adulte monté, un des types du *Pithecia hirsuta* Spix. Tabatinga, rive septentrionale du Solimoëns, près des confins du Pérou. Des collections de M. Spix. Schlegel, Cat.No 1. [Adult male mounted, one of the types of *Pithecia hirsuta* Spix. Tabatinga, Northern bank of the Solimões, near the borders of du Peru. From the collections of Mr. Spix. Schlegel, Cat.No 1]."

But this completely misquotes Schlegel, H., 1876. *Museum d'Histoire Naturelle des Pays-Bas. Les Singes. Simiae*. Leiden: E. J. Brill. First, on p. 222, lists under *Pithecia monacha*:

"Individus montés. – 1. Mâle adulte, voyage de Spix, Tabatinga, obtenu de Spix même sous le nom de *Pithecia inusta*. [Mounted individuals. – 1. Adult male, voyage of Spix, Tabatinga, obtained from Spix himself under the name of *Pithecia inusta*.]" (!)

Chris Smeenk is, or was, compiling a catalogue of the types of recent mammals in Naturalis, Leiden, and says that this agrees with what Schlegel wrote on the pedestal, and with the entry in the list of animals received from Von Spix in October 1824, which says just "*Pithecia inusta*."

Page 32: *P. milleri*
The rank of topotype does not have any special taxonomic role. It merely signifies that the specimen is from the same locality as the holotype. Technically, the topotype, Juvenile male, AMNH 33877, should be regarded as a paratype.

Parentheses were placed erroneously around the author name at the top of the page. It should read: "*Pithecia milleri* Allen, 1914."

Page 49: *P. inusta*
There is an inconsistency in the publication date in the synonymy. It should be 1823 not 1824 for the Spix publication.

Parentheses were placed erroneously around the author name at the top of the page. It should read: "*Pithecia inusta* Spix, 1823."

Page 63: *P. aequatorialis*
The rank of topotype does not have any special taxonomic role. It merely signifies that the specimen is from the same locality as the holotype. Technically, the topotype, adult female FMNH 86994, should be regarded as a paratype.

Parentheses were placed erroneously around the author name at the top of the page. It should read: "*Pithecia aequatorialis* Hershkovitz, 1987."

Page 64: Distribution of *P. aequatorialis*
While assembling the location data for the various species, Marsh misplaced an email from Diego Tirira in 2010 regarding a pet saki in a village in southeast Ecuador. This captive saki is clearly *P. aequatorialis* and was from Pastaza province, comunidad Enkerido, entre ríos Ácaro y Tarangaro, territorio Waorani: 01°23'S, 77°23'W, 430 m. This locality is south of the Curaray River. Tirira believed that the pet was from this area and not from further south across the Peruvian border along the same river. Therefore, it is important to note that it DOES appear that *P. aequatorialis*, and not just the overly grizzled *P. napensis,* occurs at least within this watershed. Thus, *P. aequatorialis* CAN be

considered to occur in Ecuador, although its confirmation in the wild state is required for a true "range extension" based on Marsh (2014).

Page 69: *P. napensis*
Parentheses were placed erroneously around the author name at the top of the page. It should read: "*Pithecia napensis* Lönnberg, 1938."

Page 69: Spelling correction
L. Soderstrom should be L. Söderström.

Page 70: Table correction
Table 18. The registration number of the holotype is RNHM A60-1921.

Page 75: Spelling correction
Bluntschili should be Bluntschli.

Page 83: *P. albicans* types
Gray (1860) clearly refers to at least one adult and a juvenile ("young") in his description of *P. albicans*, which would as such be syntypes. Napier (1976) lists an adult male (BMNH 1860.4.16.3) as holotype of *P. albicans*, but also an indeterminate adult (BMNH 1860.4.16.2) from the same locality. Hershkovitz (1987) mentions male, female and young syntypes. Therefore, BMNH 1860.4.16.3 is actually a lectotype and not a holotype for *P. albicans*.

Marsh (2014; 83) listed several specimens as paratypes, which were collected by W. Erhardt between 1925 and 1927. These specimens were collected long after Gray's (1860) original description and hence cannot possibly be considered syntypical material. These specimens were labeled erroneously as paratypes in the Natural History Museum, London. They should be listed as Key Specimens.

Parentheses were placed erroneously around the author name at the top of the page. It should read: "*Pithecia albicans* Gray, 1860."

Page 84: Table correction
Table 20. These are all Key Specimens – none are syntypes.

Page 91: *P. irrorata*
Hershkovitz (1987) does indeed give the holotype as BMNH 101a based on Napier (1976).

Parentheses were placed erroneously around the author name at the top of the page. It should read: "*Pithecia irrorata* Gray, 1842."

Page 92: Table correction
Table 22. None of these specimens are paratypes – only Key Specimens.

Page 101: *P. vanzolinii*
Parentheses were placed erroneously around the author name at the top of the page. It should read: "*Pithecia vanzolinii* Hershkovitz, 1987."

Page 105: *P. mittermeieri* holotype
Under "Type localities": The number for the holotype should be BMNH No. 27.8.5.9.1, not 28.8.5.9.1.

Page 113: *P. rylandsi* holotype
Marsh (2014; 113) designated as holotype for *P. rylandsi* AMNH 247669, subadult male skin and AMNH 248723 subadult male skull only. It is not possible for a holotype to comprise parts of two separate individuals. Given that most diagnostic characters for *Pithecia* spp. are based on skins, we designate AMNH 247669 as holotype for *P. rylandsi* and place AMNH 248723 as a paratype.

Page 114: Table correction
Table 25. AMNH 248723 should be redesignated as a paratype.

See comment above under p. 113.

Pages 137–143: Suggested missing references
Beolens, B., Watkins, M. and Grayson, M. 2009. *The Eponym Dictionary of Mammals*. The Johns Hopkins University Press, Baltimore, MD. xiii + 574 pp.

Desmarest, A. G. 1820. *Mammalogie ou description des espèces de mammifères. Première partie, contenant les ordres des bimanes, des quadrumanes et des carnassiers*. Mme Veuve Agasse, Paris. viij + 276 pp.

Matschie, P. 1915 (April). Ein anscheinend neues Krallenäffchen vom oberen Amazonas. *Sitzungsberichte der Gesellschaft naturforschender Freunde zu Berlin*, 1915(4): 95–96.

Page 150: Location correction
Tabolosos should be placed in San Martín, not Huánuco [-6.385674, -76.631259]. This was a mislabeling on a specimen collected in the region. The location is placed correctly on the map (p. 55, Map 6).

Short Articles

PREDATION BY COMMON MARMOSETS (*CALLITHRIX JACCHUS*) OF SMALL MAMMALS CAUGHT IN TRAPS

Antonio R. G. Freire-Filho
Thieres Pinto
Beatrice F. Menezes
Carlos André Lima Pimentel

Introduction

Studies describing predation of other mammalian taxa by primates are still scarce in the Neotropics and especially in Brazil. However, there are reports of bird's nest predation by *Leontopithecus chrysopygus* (see Passos, 1997) and *Callithrix jacchus* (see Lyra-Neves et al., 2007), or of small lizards and frogs by *Callithrix jacchus* (see Alonso and Langguth, 1989), *Callithrix geoffroyi* (see Passamani and Rylands, 2000), *Sapajus xanthosternos* (see Canale et al., 2013) and *Callithrix jacchus* (see Amora et al., 2014). *Callithrix jacchus* (Linnaeus, 1758), the white-tufted-ear-marmoset or common marmoset, is native to northeastern Brazil. These primates are arboreal and inhabit various kind of vegetation, including areas with disturbed and fragmented vegetation (Rylands and Farias, 1993; Castro and Araújo, 2006; Bicca-Marques et al., 2006). The diet of *Callithrix jacchus* is varied, including fruits, flower parts, plant exudates, fungi, seeds, invertebrates and vertebrates (Nash, 1986; Stevenson and Rylands, 1988; Caton et al., 1996; Digby and Barreto, 1993; Castro and Araújo, 2006; Bicca-Marques et al., 2006; Digby et al., 2011).

Methods

Here we report *C. jacchus* attacking small mammals caught in live traps. The data come from a study in a 13-ha patch of semi-deciduous forest (Mata de Tabuleiro), on the coast of the state of Ceará, northeastern Brazil. The forest is isolated, and the marmosets were often observed moving through gardens betweeen houses and along streets to reach other forest fragments. The study was based on observations of *C. jacchus* in a 1-ha area of the fragment, where "Tomahawk®" and "Shermann®" live traps were set in a grid (Auricchio and Salomão, 2002) to monitor populations of non-flying small mammals.

Results

The animals attacked by common marmoset were those caught in the traps being checked between 6:30 am and 9:30 am during the monthly trapping campaigns from November 2008 and December 2009: five consecutive days in each month. Four attacks were recorded, involving three small mammals captured in Tomahawk® traps: two attacks, one fatal, on Red-nosed armored tree rats *Makalata didelphoides* (Desmarest, 1817) (Fig. 1), an attack on a gray short-tailed opossum *Monodelphis domestica* (Wagner, 1842), and the predation of a woolly opossum *Micoureus demerarae* (Thomas, 1905) (Fig. 2). Three traps were on a tree and one on the ground.

Figure 1. *Makalata didelphoides* killed by *Callithrix jacchus*.

Figure 2. *Micoureus demerarae* after being attacked.

The first non-lethal record was of a female *M. domestica*, which suffered an open fracture of her right hind leg. In this case, we observed an adult individual of *C. jacchus* on a tree, about one meter above the ground, which then ran down from the tree and approached the trap. When on the ground, the marmoset pull on the short-tailed opossum by its hind legs and tail, but then saw us and desisted, climbing back into the tree and remainimg there vigilant and vocalizing until we approached the trap. The rest of the marmoset group stayed close, vigilant and vocalizing, in a radius of approximately three meters.

The second non-fatal record was of a male *M. didelphoides* who survived the attack, but was badly wounded and

had lost his tail, probably pulled out of the trap during the attack of *C. jacchus*. This rodent commonly and easily loses its tail, as an anti-predator strategy. For the other two, another red-nosed armored tree rat and the woolly oposum, their hind and front legs, as well as other body parts of were clearly pulled out of the trap and eaten (Figs. 1 and 2). Three of these episodes occurred in the dry season, and one in the beginning of the rainy season.

Discussion

The concentration of attacks in the dry season may be associated with differences in food availability, as was observed by Vilela and Faria (2002), Lyra-Neves et al. (2007) and Vilela and Del-Claro (2011). Low food availability in drier periods induces species to move into different environments and change their behavior, not only in spatial use patterns and social activities, but also in food preferences (Chapman, 1987). We cannot say that food availability influenced the concentration of the attacks in the drier period, because we did not assess the availability of resources during the monitoring years. The greater number of small mammals attacked may indicate the opposite; as the capture success in the dry season was higher and the probability of encountering a trap with a small mammal also increased. Groups of *C. jacchus* were observed in various situations lurking around traps containing captured animals. All of these events occurred during the morning hours, in agreement with the period of greatest activity of marmosets (Rylands and Farias, 1993; Schiel et al., 2010).

During the small mammal monitoring program we also captured white-eared opossums *Didelphis albiventris* Lund, 1841, but never observed *C. jacchus* to attack them, probably due to ther larger size; larger and heavier than *C. jacchus*. The opossums are also aggressive, as observed by Oliveira and Santori (1999) in predation events of *Bothrops jararaca* (Wied-Neuwied, 1824) by *D. albiventris*.

Few studies have reported predation of vertebrates by marmosets (Passos, 1997; Lyra-Neves et al., 2007; Vilela and Del-Claro, 2011; Amora et al., 2014). These primates usually prey on nests of small birds such as *Pachyramphus polychopterus* (Vieillot, 1818) and *Elaenia flavogaster* (Thunberg, 1822), because they offer less resistance to attacks. The marmosets are a food source for larger birds, such as *Rupornes magnirostris* (Gmelin, 1788) and *Cathartes aura* (Linnaeus, 1758), (Lyra-Neves et al., 2007).

Researchers have suggested that marmoset predation of small mammals was uncommon, because of their differences in activity periods. The marmosets are essentially diurnal and the small mammals are mostly nocturnal. This asynchrony can be the key factor promoting the exclusion of small mammals from the diet of *C. jacchus*. Birds, amphibians, and small lizards are the main vertebrate representatives in the diet of the genus *Callithrix* (Alonso and Langguth, 1989; Rylands and Farias, 1993; Lyra-Neves et al., 2007; Vilela and Del-Claro, 2011; Digby et al., 2011). The small mammals being attacked here were easy prey for *C. jacchus*; caught in the open and unable to flee. The marmosets were opportunistic in this case, and an important message is that those doing research monitoring small mammals in areas where marmosets are common should check the traps earleir in the day before the marmosets become active.

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CONSUMO DE EXSUDATOS POR *CEBUELLA PYGMAEA* E OUTROS MAMÍFEROS EM UM FRAGMENTO FLORESTAL NO SUDOESTE DA AMAZÔNIA

Rodrigo Canizo
Armando Muniz Calouro

Os exsudatos são um recurso altamente energético, composto principalmente por água, polissacarídeos complexos, cálcio e traços de minerais (ferro, alumínio, silício, magnésio e sódio) (Nash, 1986). Devido a sua composição, eles representam um importante componente da dieta (anual ou sazonal) de alguns primatas, principalmente espécies da família Callitrichidae (Soini, 1988; Peres, 2000). Contudo, apesar de sua disponibilidade em muitas espécies vegetais, seu consumo requer adaptações anatômicas e fisiológicas que viabilizam a sua exploração e digestão (Garber e Porter, 2010).

No Parque Zoobotânico da Universidade Federal do Acre (*ca.* 150 ha; 9º56"30"–67º52'08"S, 9º57'19"–67º53'00"O) em Rio Branco, Estado do Acre, Brasil, o micoleãozinho (*Cebuella pygmaea*, Callitrichidae) é um primata especialista na exploração de exsudatos. O Parque Zoobotânico é um fragmento florestal urbano caracterizado por uma cobertura de floresta secundária em diferentes estágios de regeneração (Meneses-Filho et al., 1995). Além do leãozinho, esse fragmento é habitado por seis espécies de primatas: soim-vermelho (*Saguinus weddelli*, Callitrichidae), bigodeiro (*Saguinus imperator*, Callitrichidae), macaco-de-cheiro (*Saimiri boliviensis*, Cebidae), parauacu (*Pithecia irrorata*, Pitheciidae), zogue-zogue (*Callicebus cupreus*, Pitheciidae) e macaco-da-noite (*Aotus nigriceps*, Aotidae).

Registros do consumo de exsudatos de oito espécies vegetais foram obtidos pelo método *ad libitum* (Altmann, 1974) durante um estudo do comportamento e ecologia de um grupo de leõezinhos composto por oito indivíduos (um casal de adultos, dois subadultos, dois juvenis e dois filhotes) no período de abril de 2011 a fevereiro de 2012, o qual totalizou 138 dias de observação (1656 horas), com uma média de 15 dias por mês. Três dessas espécies vegetais também foram exploradas por outros mamíferos: os callitriquídeos *Saguinus weddelli* e *Saguinus imperator* e o quatipuru-roxo *Guerlinguetus ignitus* (Sciuridae) (Tabela 1).

Concluímos que *Saguinus weddelli* e *S. imperator*, apesar de não apresentarem o nível de especialização dentária e digestiva encontrado nos leõezinhos (Terborgh, 1983; Garber, 1984, 1993; Ferrari, 1993; Heymann e Smith, 1999), podem ser considerados potenciais competidores diretos pelas fontes de exsudato disponibilizadas pela atividade de escarificação de *C. pygmaea* na área de estudo. Por outro lado, além do número de registros de consumo de exsudatos ter sido menor, a importância desse recurso para a dieta de *G. ignitus* tem sido considerada insignificante

Tabela 1. Espécies vegetais exploradas como fonte de exsudatos por *Cebuella pygmaea* e outros mamíferos no Parque Zoobotânico da Universidade Federal do Acre. Os valores representam o número de registros de consumo obtidos pelo método *ad libitum*.

Espécie vegetal (Família)	*C. pygmaea*	*S. weddelli*	*S. imperator*	*G. ignitus*
Cedrela fissilis (Meliaceae)	5851	15	19	2
Talisia racemosa (Sapindaceae)	2700	-	-	-
Vismia macrophylla (Clusiaceae)	1913	-	-	-
Qualea tessmanii (Vochysiaceae)	394	-	-	-
Inga marginata (Fabaceae)	281	-	-	-
Inga alba (Fabaceae)	84	1	1	5
Spondias mombin (Anacardiaceae)	28	8	-	-
Miconia sp. (Melastomataceae)	1	-	-	-
Total de registros	11252	24	20	7

(Moynihan, 1976; Soini, 1982, 1988). Pesquisas futuras visando estimar o grau de competição direta e indireta pelos exsudatos disponibilizados por *C. pygmaea* devem enfocar no monitoramento da visitação das árvores gomíferas durante os períodos diurno e noturno.

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OCORRÊNCIA DE PARAUACÚ *PITHECIA* CF. *MITTERMEIERI* MARSH, 2014 (PRIMATES, PLATYRRHINI) NA TRANSIÇÃO ENTRE OS BIOMAS PANTANAL, AMAZÔNIA E CERRADO, MATO GROSSO, BRASIL

Almério Câmara Gusmão
Manoel dos Santos-Silva

Introdução

Pithecia mittermeieri (Marsh 2014), (Primates, Pitheciidae) é um primata de médio porte conhecido regionalmente como parauacú ou macaco-velho (Sampaio et al., 2012; Marsh, 2014). Vive nas florestas tropicais do sul do rio Amazonas entre os rios Madeira e Tapajós, incluindo a drenagem do rio Aripuanã, limitando-se ao sul com o rio Guaporé (Marsh, 2014). Na recente revisão taxonômica deste gênero proposta por Marsh (2014), esta espécie foi descrita a partir das populações de *P. irrorata* (Gray, 1842) encontrada a leste do rio Madeira.

Pouco antes a esta revisão, Sampaio et al. (2012) haviam registrado a espécie em três fragmentos de floresta situado em torno da Central Hidrelétrica Bocaiuva, município de Brasnorte e em outro fragmento de floresta entre os município de Vila Bela da Santíssima Trindade e Pontes e Lacerda no estado de Mato Grosso. Estes registros estavam além da distribuição geográfica proposta por Hershkovitz (1987) e permitiram uma correção na distribuição da espécie *P. irrorata* no limite sudoeste da Amazônia brasileira (Sampaio et al., 2012). Entretanto, estes registros foram ignorados por Marsh (2014).

Marsh (2014) apresentou uma série de novas informações para as espécies deste gênero e citou a necessidade de mais estudos para dar mais compreensão sobre o grupo, e proporcionar estratégia de conservação para as espécies. No caso de *P. mittermeieri* a situação requer mais cuidados, pois a espécie está inserida em boa parte de sua distribuição geográfica no considerado "Arco do Desmatamento da Amazônia Brasileira" (Ferreira et al., 2005). Diante disso, o presente trabalho tem o objetivo apresentar dois novos registros de *Pithecia* cf. *mittermeieri* para a região de transição entre os biomas Pantanal, Amazônia e Cerrado no estado de Mato Grosso.

Material e Métodos

A região estudada está inserida em área de transição entre florestas dos Biomas Amazônica, Cerrado e Pantanal, bacia hidrográfica do rio Bugres, um dos afluentes a oeste do rio Paraguai. A fitofisionomia é caracterizada como floresta Estacional Semidecídual Submantana (RadamBrasil, 1978), a precipitação pluviométrica e de 1,500 mm (Köppen, 1948). As observações ocorreram durante estudos de censos em dois fragmentos de floresta um com 9,1 ha, tratados aqui como F1 e o outro com 45 ha, F2. Os dois fragmentos de floresta estão isolados em meio à pastagem e distantes entre si a 3.300 m. O esforço de amostragem foi de 22,2 km, sendo 9,5 em F1 e 12,7 em F2. Os fragmentos de floresta estudados apresentaram vestígio de corte seletivo de madeira e em F1 foi observado à presença de bovinos no interior da floresta.

O levantamento realizado na área foi baseado no método de transecção linear, complementado por observações qualitativas da fauna de primatas dentro da área de estudo. O método de censo tem sido aplicado amplamente na Amazônia brasileira para o estudo de populações de mamíferos (Peres, 1999; Buckland et al., 2010). Esta metodologia fornece dados sobre a diversidade primatas e sua abundância, além de alguns aspectos de sua ecologia. Para a identificação da espécie foram comparadas com as diagnoses e ilustrações disponíveis em Marsh (2014), além de consultas a especialistas. Apesar disso, a identificação específica ainda é provisória.

Resultados e Discussões

O primeiro registro de uma fêmea de *P.* cf. *mittermeieri* foi realizada no dia 28 de novembro de 2014 em um fragmento de floresta de 9,1 ha de floresta de terra firme, no sítio São João, sob as coordenadas 14°35'23"S, 57°24'27"O, 400 m a.n.n.m. no município de Tangará da Serra (Fig. 1). O mesmo animal foi novamente observado em janeiro de 2015. O segundo registro da espécie foi no dia 29 de novembro de 2014 nas coordenadas 14°37'18"S, 57°25'46"O, 396 m a.n.n.m., onde dois indivíduos foram observados deslocando-se entre os galhos no interior do único fragmento de floresta da fazenda Boa Vista. A baixa taxa de observação neste caso rejeita a confiabilidade de abundância relativa.

Estas observações de parauacus relatadas no presente estudo compreendem os registros mais a leste da distribuição geográfica da espécie, conforme observado nos mapas disponíveis em Sampaio et al. (2012) e Marsh (2014) (ver Figura 2). Sampaio et al. (2012) havia considerado que a espécie ocorre a leste do rio Juruena. Porém, uma série de fragmentos florestais foi inspecionado durante estudo de fauna de mamíferos no gradiente hidrográfico Guaporé/Paraguai e a espécie não haviam sido detectadas (Santos-Filho, 2000; Barbosa, 2012). Isto gera a hipótese de que atualmente a distribuição geográfica apresenta uma descontinuidade ocasionada pela ação humana.

O conhecimento sobre a ocorrência destas populações na região é de extrema importância para sua conservação, uma vez que é possível que se tome medidas específicas de preservação. Esta é mais uma espécie de primata conhecida para a região de influencia do bioma Pantanal. Por outro lado, as populações de parauacus existentes ali sofrem graves ameaças, pois a vegetação nativa foi quase totalmente modificada decorrente da ocupação humana nos últimos

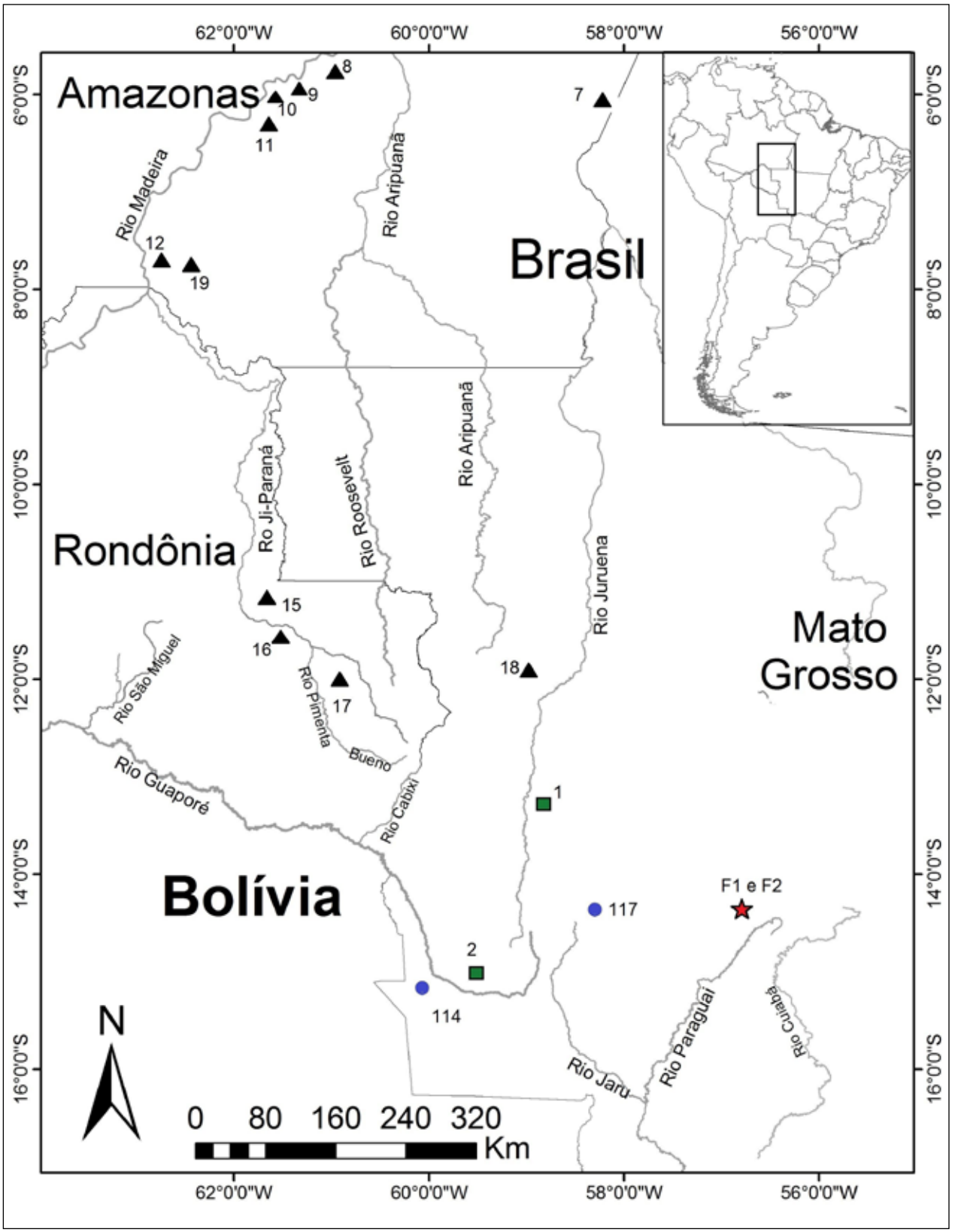

Figura 1. Mapa da distribuição geográfica de *P. mittermeieri.* Os pontos representados pelos quadrados verdes (1 e 2) são os Sampaio et al. (2012); triângulos pretos (7, 8, 9, 10, 11, 12, são de Marsh (2014); círculos azuis (114 e 117) são de Hershkovitz (1987) e a estrela vermelha indica os registros novos representado por F1 e F2.

Figura 1. Fêmea adulta de *Pithecia* cf *irrorata* fotografado no Sítio São José, Tamgará da Serra, MT.

55 anos. A vegetação natural foi substituída principalmente para a implantação da agropecuária, com predomínio de pastagem e lavoura de soja [*Glycine max* (L.) Merrill]. Além disso, nesta porção do estado de Mato Grosso, não existe Unidade de Conservação (UC). As evidentes ameaças conduzem a necessários que se priorizem estudos de identificação mais específicos como de análise genética para confirmar com maior segurança a identidade destas populações. Além disso é necessário a criação de UCs e corredores ecológicos conectando os fragmentos isolados proporcionando a dispersão e formação de novos grupos.

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FORMAÇÃO DE GRUPO MISTO ENTRE *MICO RONDONI* FERRARI ET AL., 2010, *SAGUINUS WEDDELLI* (DEVILLE, 1849) E *MICO MELANURUS* (É GEOFFROY, 1812) NA RESEX DO RIO CAUTÁRIO, RONDÔNIA, BRASIL

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As primeiras informações sobre os Platyrrhini de Rondônia foram obtidas durante a expedição da comissão Rondon (Miranda-Ribeiro, 1914) e a expedição Roosevelt (Allen, 1916). Bem mais tarde, Vivo (1985) revisou os sauins da região a partir de espécimes coletados durante o Projeto Polonoroeste. Este autor identificou o sauim-branco como *Mico emiliae* (Thomas, 1920), depois descrito por Ferrari et al. (2010) como *Mico rondoni*, e também o sauim-de-cara--suja como *Saguinus fuscicollis weddelli* (Deville, 1823). Já, o sauim-marrom (*Mico melanurus*) foi identificado por Ferrari et al. (1999) como a espécie encontrada na região sudoeste do estado de Rondônia. Casos de simpatria entre *S. weddelli* e *M. rondoni* já foram registrados por Martins et al. (1987), Lopes & Ferrari (1994) e Ferrari (2010) no norte do estado de Rondônia e entre *S. weddelli* e *M. melanurus* no sudoeste. Ferrari (2001) afirmou que a zona de contato entre *M. melanurus* e *M. rondoni* localiza-se no sudoeste do estado, porém, não era claro que elas ocorressem em simpatria. Locais com agrupamentos entre espécies de callitriquíneos em Rondônia têm sido pouco registrado cientificamente. Portanto, este trabalho trata da extensão da distribuição geográfica de *M. rondoni* e a formação de grupo misto com *S. weddelli* e *M. melanurus* na Reserva Extrativista (RESEX) do Rio Cautário, Rondônia, Brasil.

A RESEX do Rio Cautário está localizado no município de Costa Marques, RO, sudoeste da Amazônia brasileira. Essa Unidade de Conservação (UC) possui 146.400 ha e foi criada em 1995 (Rondônia, 2013). A fitofisionomia é do tipo Floresta Ombrófila Aberta (RadamBrasil, 1978) com predomínio de árvore de grande porte (>25m) como castanha da Amazônia (*Bertholletia excelsa*) e seringueira (*Hevea brasiliensis*). O clima é Tropical AW, segundo Alvares et al. (2014) com temperatura média 23°C, com estação de estiagem entre os meses de junho a outubro e chuvosa entre novembro e abril (Fig. 1). A observação de formação de grupo misto ocorreu de forma oportunista, durante caminhada nas trilhas existentes na UC, totalizando 16 h de esforço de amostragem. As identificações das espécies foram obtidas a partir dos registros fotográficos (Figs. 2, 3, 4), os quais foram comparados com as diagnoses e ilustrações disponíveis na literatura (Ferrari et al., 2008, 2010; Gusmão et al., 2013).

Foram observados 17 indivíduos de *S. weddelli*, 12 de *M. melanurus* e seis espécimes de *M. rondoni*. Os animais deslocavam-se num raio de 25 m, as margens do ramal principal de acesso a RESEX (11°57'05.5"S, 64°08'26.3"O, 185 m a.n.n.m.). Os sauins mantiveram em atividades de vocalização durante as observações, das quais eram indistinguíveis entre si. A presença das três espécies de sauim na região, também foi confirmada por moradores da RESEX durante entrevistas. A ocorrência de *M. rondoni*, também

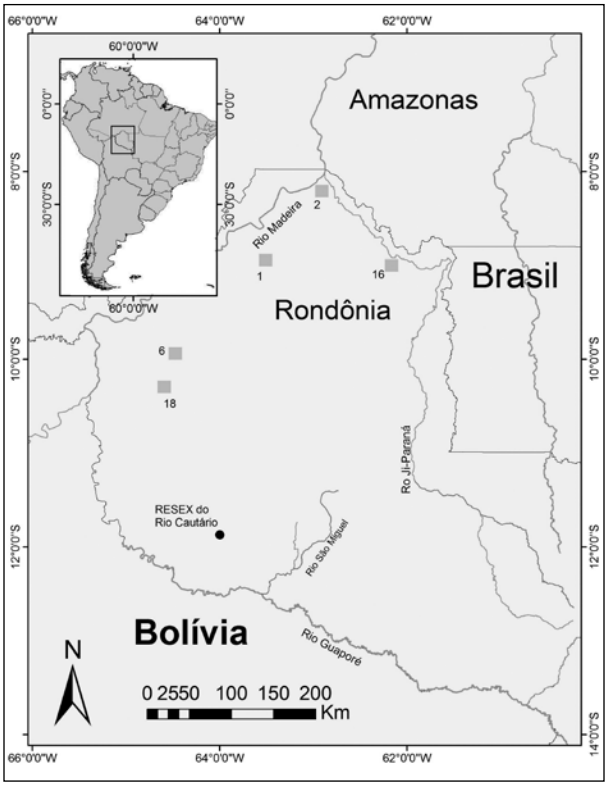

Figura 1. Mapa do estado de Rondônia com a localização da RESEX do Rio Cautário (circulo preto) e os pontos de registro de *M. rondoni* ordenado conforme em Ferrari et al. (2010) (quadrados cinzas).

Figura 2. Indivíduo de *M. melanurus* fotografado na RESEX do Rio Cautário. Foto: L. S. de Souza.

Figura 3. Indivíduo de *M. rondoni*, fotografado na RESEX do Rio Cautário, durante estudos do Plano de Manejo de Uso Múltiplo. Foto: Israel Vale Jr.

Figura 4. Indivíduo de *S. weddelli* fotografado na RESEX do Rio Cautário. Foto: A. C. Gusmão.

foi registrada durante a realização dos estudos de Mastofauna para o Plano de Manejo de Uso Múltiplo da RESEX (Ferronato, 2014). A observação de *M. rondoni* nesta localidade sugere uma extensão de mais de 150 km ao sul da distribuição geográfica conhecida. Ferrari et al. (1999) e Ferrari (2001) relatou que esta região é consistente com a zoogeografia das duas espécies de *Mico*, com este registro fica claro a simpatria entre elas. As duas espécies foram registrados em duas UCs relativamente próximas, a Reserva Biológica (REBIO) Traçadal (Ferrari e Lopes, 2001) e REBIO do Rio Ouro Preto (Messias, 2001). Essas observações de callitriquineos ocupando o mesmo habitat sugere uma complexidade ecológica na região e reforça a importância das UCs para a conservação da biodiversidade local.

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Recent Publications

BOOKS

Genome Mapping and Genomics in Human and Non-Human Primates, edited by Ravindranath Duggirala, Laura Almasy, Sarah Williams-Blangero, Solomon Paul, Chittaranjan Kole. 2015. Springer. 305pp. ISBN: 978-3662463055. This book provides an introduction to the latest gene mapping techniques and their applications in biomedical research and evolutionary biology. It especially highlights the advances made in large-scale genomic sequencing. Topics covered include linkage and association methods, gene expression, copy number variation, next-generation sequencing, comparative genomics, population structure, and a discussion of the Human Genome Project.

Dispersing Primate Females: Life History and Social Strategies in Male-Philopatric Species, edited by Takeshi Furuichi, Juichi Yamagiwa, Filippo Aureli. 2015. Springer. 299pp. ISBN: 978-4431554790. This book presents the latest knowledge about the dispersing females in male-philopatric non-human primates and in human societies. The non-human primates that are covered include muriquis, spider monkeys, woolly monkeys, gorillas, chimpanzees, bonobos, and some species of colobine monkeys. This volume provides new insights on evolution of female dispersal by describing factors influencing variations in the dispersal pattern across primates and a hypothesis for the formation of human families from the perspectives of female life history.

Parasite Diversity and Diversification: Evolutionary Ecology Meets Phylogenetics, edited by Serge Morand, Boris R. Krasnov, D. Timothy J. Littlewood, 2015. Cambridge University Press. 488pp. ISBN: 978-1107037656. Parasites (from viruses, bacteria and protists to arthropods and helminths) may constitute more than half of all livings species. Using the most recent molecular, phylogenetic and computational tools, Parasite Diversity and Diversification explores the latest advances in the processes explaining this considerable, yet cryptic, biodiversity. *Contents:* 1) Quantifying parasite diversity – Poulin R; 2) Relationships between parasite diversity and host diversity - Krasnov B & Poulin R; 3) Patterns of diversity and distribution of aquatic invertebrates and their parasites – Leung TLF, Mora C & Rohde K; 4) Under the changing climate: how shifting geographic distributions and sexual selection shape parasite diversification - Rózsa L, Tryjanowski P & Vas Z; 5) Impacts of parasite diversity on wild vertebrates: limited knowledge but important perspectives – Bordes F & Morand S; 6) Revealing parasite diversity using brute force molecular techniques and gently persuasive microscopy – Chambouvet A, Richards TA, Bass D & Neuhauser S; 7) Evolution of simian retroviruses - Ayouba A & Peeters M; 8) The diversity and phylogeny of *Rickettsia* - Weinert LA; 9) Advances in the classification of Acanthocephalans: evolutionary history and evolution of the parasitism - García-Varela M & Pérez-Ponce de León G; 10) The study of primate evolution from a lousy perspective – Reed DL, Allen JM, Toups MA, Boyd B & Ascunce M; 11) Host correlates of diversification in avian lice – Rózsa L & Vas Z; 12) Evolutionary history of Siphonaptera: fossils, origins, vectors – Dittmar K, Zhu Q, Hastriter MW & Whiting MF; 13) Bat fly evolution from the Eocene to the present (Hippoboscoidea, Streblidae and Nycteribiidae) – Dittmar K, Morse SF, Dick CW & Patterson BD; 14) The evolution of parasitism and host associations in mites – Dowling A; 15) Nematode life-traits diversity in the light of their phylogenetic diversification – Morand S, Nadler S & Skorping A; 16) Phylogenetic patterns of diversity in the cestodes and trematodes – Littlewood TJ, Bray RA & Waeschenbach A; 17) Patterns of diversification in the parasites of Caribbean *Anolis* lizards – Falk BG & Perkins SL; 18) Comparative analysis: recent developments and uses with parasites – Desdevises Y, Morand S, Krasnov BR & Claude J; 19) Phylogenetic signals in ecological properties of parasites – Krasnov BR, Morand S & Poulin R; 20) Parasite species coexistence and the evolution of the parasite niche – Šimková A & Morand S; 21) A community perspective on the evolution of virulence – Hawlena H & Ben-Ami F; 22) Host-specificity and species jumps in fish-parasite systems – Vanhove MPM & Huyse T; 23) When is cophylogeny evidence of coevolution? – Poisot T; 24) Bringing together phylogenies and behaviour in host-parasite interactions – Jenkins T & Christe P; 25) The evolutionary epidemiology of the Hepatitis C virus – Markov PV, Gray RR, Iles J & Pybus OGm; 26) Conclusion and perspectives – Kuris A.

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Meetings

V CONGRESO MEXICANO DE PRIMATOLOGÍA

La Asociación Mexicana de Primatología (AMP) y la Universidad Veracruzana (UV), se complacen en anunciar la realización del V Congreso Mexicano de Primatología, que se llevará cabo del 29 de Junio al 2 de Julio de 2015 en el Puerto de Veracruz. Convocamos a socios, estudiantes, investigadores, profesores, y público interesado en la primatología a participar en el congreso. Mayor información en www.primates-amp.org.mx

6TH EUROPEAN FEDERATION FOR PRIMATOLOGY MEETING

The 6th European Federation for Primatology Meeting will take place in Rome (Italy) from 25th to 28th August 2015, along with the XXII Congress of the Italian Association of Primatology. The conference will be organized by the Science Department of Roma Tre University, in association with the Institute of Cognitive Sciences and Technologies (National Research Council, Rome) and the Italian Primatological Association. For more information visit http://host.uniroma3.it/eventi/EFP2015/index.html

III SIMPOSIO DE PRIMATOLOGIA EN EL PERÚ

El III Simposio de primatología en el Perú tendrá lugar en la ciudad de Puerto Maldonado, entre el 20 – 23 de Octubre de 2015. Este simposio es organizado por Unkawasi, el Centro Alemán de Primates-DPZ, Field Projects International, Wildlife Shelter, la Asociación para la Conservación de la Cuenca Amazónica y la Universidad Nacional Amazónica de Madre de Dios. Para más detalles visitar http://www.monosperu.org/3er-simposio.html

5TH IBERIAN PRIMATOLOGICAL CONFERENCE

This congress will be hosted by the Portuguese Primatological Association (APP), at Évora, from 17th – 20th November 2015. The proposed format will allow congress participants to stay over the weekend for sightseeing and social events. This meeting gathers together the 6th Portuguese Primatological Conference and the 10th Spanish Primatological Conference. The main theme of the congress will be *"Extinction is forever"*. For more information go to www.apprimatologia.com/Actividades/IBERIAN2015.aspx

XVI CONGRESO BRASILEÑO DE PRIMATOLOGIA

El XVI Congreso Brasileño de Primatología se llevará a cabo en la Universidad Federal do Amazonas, en Manaus, entre los días 09–13 de Noviembre de 2015. Dentro de este congreso tendrá lugar el II Simposio de Primatología en America Latina organizado por la Sociedad Latinoamericana de Primatología (SLAPIM). Para mayores informes visitar: http://congresso2015.sbprimatologia.org.br/

PRIMATE SOCIETY OF GREAT BRITAIN WINTER MEETING 2015

The Primate Society of Great Britain 2015 winter meeting will be held in London, from December 2–4 2015, on the topic of "Social Learning and Culture". Further announcements of websites, registration and abstract submission will follow in due course, with abstract submission deadline in August. For more information visit: http://www.psgb.org/meetings.php

26TH CONGRESS OF THE INTERNATIONAL PRIMATOLOGICAL SOCIETY AND 39TH MEETING OF THE AMERICAN SOCIETY OF PRIMATOLOGISTS

The 39th meeting of the American Society of Primatologists will be held jointly with the 26th Congress of the International Primatological Society in Chicago, Illinois, August 21–27, 2016. All details, including submission deadlines, are available on the joint meeting website: http://www.IPSChicago.org.

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Notes to Contributors

Scope

The journal aims to provide a basis for conservation information relating to the primates of the Neotropics. We welcome texts on any aspect of primate conservation, including articles, thesis abstracts, news items, recent events, recent publications, primatological society information and suchlike.

Contributions

Manuscripts may be in English, Spanish or Portuguese, should be prepared with MS Word, and must use page and line numbering. The full name and address for each author should be included. Please avoid abbreviations and acronyms without the name in full. Authors whose first language is not English should have their manuscripts written in English carefully reviewed by a native speaker. Send all contributions to: Erwin Palacios, Conservación Internacional – Colombia, e-mail: epalacios@conservation.org. Manuscripts that do not conform to the formal requirements (formatting, style of references etc.) will be returned to authors without review. They can be resubmitted, provided all formal requirements are met.

Articles. Each issue of Neotropical Primates will include up to three full articles, limited to the following topics: Taxonomy, Systematics, Genetics (when relevant for systematics and conservation), Biogeography, Ecology and Conservation. Text for full articles should be typewritten, double-spaced with no less than 12 cpi font (preferably Times New Roman) and 3-cm margins throughout, and should not exceed 25 pages in length (including references). Please include an abstract in the same language as the rest of the text (English, Spanish or Portuguese) and (optional) one in Portuguese or Spanish (if the text is written in English) or English (if the text is written in Spanish or Portuguese). Tables and illustrations should be limited to six, except in cases where they are fundamental for the text (as in species descriptions, for example). Full articles will be sent out for peer-review. For articles that include protein or nucleic acid sequences, authors must deposit data in a publicly available database such as GenBank/EMBL/DNA Data Bank of Japan, Brookhaven, or Swiss-Prot, and provide an accession number for inclusion in the published paper.

Short articles. These manuscripts are usually reviewed only by the editors. A broader range of topics is encouraged, including such as behavioral research, in the interests of informing on general research activities that contribute to our understanding of platyrrhines. We encourage reports on projects and conservation and research programs (who, what, where, when, why, etc.) and most particularly information on geographical distributions, locality records, and protected areas and the primates that occur in them. Text should be typewritten, double-spaced with no less than 12 cpi (preferably Times New Roman) font and 3-cm margins throughout, and should not exceed 12 pages in length (including references).

Figures and maps. Articles may include small black-and-white photographs, high-quality figures, and high-quality maps. (Resolution: 300 dpi. Column widths: one-column = 8-cm wide; two-columns = 17- cm wide). Please keep these to a minimum. We stress the importance of providing maps that are publishable.

Tables. Tables should be double-spaced, using font size 10, and prepared with MS Word. Each table should have a brief title.

News items. Please send us information on projects, field sites, courses, Thesis or Dissertations recently defended, recent publications, awards, events, activities of Primate Societies, etc.

References. Examples of house style may be found throughout this journal. In-text citations should be first ordered chronologically and then in alphabetical order. For example, "…(Fritz, 1970; Albert, 1980, 2004; Oates, 1981; Roberts, 2000; Smith, 2000; Albert et al., 2001)…"

In the list of references, the title of the article, name of the journal, and editorial should be written in the same language as they were published. All conjunctions and prepositions (i.e., "and", "In") should be written in the same language as rest of the manuscript (i.e., "y" or "e", "En" or "Em"). This also applies for other text in references (such as "PhD thesis", "accessed" – see below). Please refer to these examples when listing references:

Journal article
Stallings, J. D. and Mittermeier, R. A. 1983. The black-tailed marmoset (*Callithrix argentata melanura*) recorded from Paraguay. *Am. J. Primatol*. 4: 159–163.

Chapter in book
Brockelman, W. Y. and Ali, R. 1987. Methods of surveying and sampling forest primate populations. In: *Primate Conservation in the Tropical Rain Forest*, C. W. Marsh and R. A. Mittermeier (eds.), pp.23–62. Alan R. Liss, New York.

Book
Napier, P. H. 1976. *Catalogue of Primates in the British Museum (Natural History)*. Part 1: Families Callitrichidae and Cebidae. British Museum (Natural History), London.

Thesis/Dissertation
Wallace, R. B. 1998. The behavioural ecology of black spider monkeys in north-eastern Bolivia. Doctoral thesis, University of Liverpool, Liverpool, UK.

Report
Muckenhirn, N. A., Mortensen, B. K., Vessey, S., Fraser, C. E. O. and Singh, B. 1975. Report on a primate survey in Guyana. Unpublished report, Pan American Health Organization, Washington, DC.

Website
UNESCO. 2005. UNESCO Man and the Biosphere Programme. United Nations Educational, Scientific, and Cultural Organisation (UNESCO), Paris. Website: http://www.unesco.org/mab/index.htm. Accessed 25 April 2005. ("Acessada em 25 de abril de 2005" and "Consultado el 25 de abril de 2005" for articles in Portuguese and Spanish respectively).

For references in Portuguese and Spanish:

"and" changes to "e" and "y" for articles in Portuguese and Spanish respectively. "In" changes to "Em" and "En" for articles in Portuguese and Spanish respectively.

"Doctoral thesis" changes to "Tese de Doutoramento" and "Tesis de Doctorado" for articles in Portuguese and Spanish respectively.

"MSc Thesis" changes to "Dissertação de Mestrado" and "Tesis de Maestría" for articles in Portuguese and Spanish respectively.

"Unpublished report" changes to "Relatório Técnico" and "Reporte no publicado" for articles in Portuguese and Spanish respectively.

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