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Effect of Seasonality on the Feeding Behavior of Martins' Bare-faced Tamarin *Saguinus martinsi martinsi* (Primates: Callitrichidae) in the Brazilian Amazon

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Abstract: Little is known of the ecology of *Saguinus martinsi martinsi* (Callitrichidae), native to the Brazilian Amazon. In this study, we present information on its diet, and investigate seasonal changes in the feeding ecology of a group at the core of its restricted range in the Saracá-Taquera National Forest in the municipality of Oriximiná, state of Pará, Brazil. We followed the group between May 2013 and April 2014 and collected data using scan sampling, with one-minute scans every 10 minutes. This resulted in 3,230 scans equivalent to 518 hours of observation. The group's diet was composed mainly of fruits (84.5%). Those of *Byrsonima crispa* were the most exploited in terms of time spent feeding (20%). An average of 10 trees in fruit were visited per day in the rainy season and eight per day in the dry season. The average time spent in any tree where they were feeding was seven minutes and 32 seconds (range 1–43 minutes) overall but was shorter in the dry season than in the rainy season. More plant species were included in the diet in the wet season (41) than in the dry season (24). The scarcity of fruit in the dry season affected the dietetic diversity of the group; they exploited fewer species for fruit (and principally *Byrsonima crispa* and *Cecropia* sp.) and turned to *Parkia* gum as a fallback.

Keywords: Ecology, diet, frugivory, primate, seasonal variation, tamarin

Introduction

Martins' bare-faced tamarin, *Saguinus martinsi martinsi*, is endemic to the Brazilian Amazon, with a restricted range in the west of the state of Pará (Oliveira *et al.* 2004; Rylands and Mittermeier 2013). Published studies regarding the species have assessed its occurrence and distribution (Oliveira *et al.* 2004, 2009; Andrade 2007), biogeography (Cropp *et al.* 1999), and phylogeny (Cunha *et al.* 2011) but its ecology and behavior are still poorly known (Oliveira *et al.* 2004). Even with this little information, the species was recently assessed as Near Threatened (NT) by the Chico Mendes Institute for Biodiversity (Melo *et al.* 2015). The diet of the genus *Saguinus* consists primarily of fruits and insects (Digby *et al.* 2007) but also includes exudates (Heymann and Smith 1999), nectar (Porter 2001) and small vertebrates (Heymann *et al.* 2000). They are frugivore-insectivores and also eat clay (geophagy) (Heymann and Hartmann 1991).

Peres (1994) described dietary strategies when food sources are limited, such as during the dry season. Among the frugivorous vertebrates, Neotropical primates are one of the main groups affected by local shortages of fruit at certain times of the year; they do not migrate and are little able to reduce their metabolic requirements (Hawes *et al.* 2013). Phenological studies in tropical forests have shown a reduction in the availability of fruits during the end of the rainy season and start of the dry season, and the primates meet their needs by including food items ignored at other times and by energy optimization through changes in their daily activities (Rylands 1986; Egler 1986; Peres 1994; Felton *et al.* 2008; Oliveira and Ferrari 2008; Mourthé 2014). Tamarins ingest seeds, even quite large ones, and are important seed dispersers (Knogge and Heymann, 2003; Peres *et al.* 2016; Heymann *et al.* 2019). An understanding of the diet allows us to identify their basic ecological requirements, supporting strategies for their conservation (Hawes *et al.* 2013) such as optimizing the management of reforested or restored areas

to increase carrying capacity through the availability of important plant species (Marshall *et al.* 2009). Likewise, it provides the wherewithal to evaluate their adaptability and resilience to environmental disturbance and climate change (Marshall *et al.* 2009; Mourthé 2014).

In this study, we present information on the diet of a group of free-ranging *Saguinus m. martinsi* at the Saracá-Taquera National Forest, specifically to see if the composition and proportions of food items in the diet showed significant variations between the dry and wet seasons, comparing as such the study group's feeding behavior between the two periods.

Methods

Study site

The Saracá-Taquera National Forest (01°20'–01°55'S, 56°00'–57°15'W) is in the municipality of Oriximiná, state of Pará, Brazil, 429,600 ha (Fig. 1). The predominant phytophysiognomy is Dense Ombrophilous Forest (STCP 2009). The region's climate is tropical wet, following the Köppen classification, with an average temperature of 26°C (Brazil, INMET 2015). There are distinct wet and dry seasons. Precipitation is highest from December to May (rainy season) with a monthly average of 268.8 mm, and lowest from June to November (dry season), when the monthly average is 72.3 mm (Brazil, INMET 2015). The average monthly temperature during the study period (May 2013 – April 2014), ranged from 26°C in February to 29°C in October, and the total precipitation was 1807 mm (Fig. 2).

Study group

We followed a group of *Saguinus m. martinsi*, habituated using the method of intensive pursuit (Williamson and Feistner 2003). The initial composition of the group, in May 2013, was of nine individuals: five males, three females and a juvenile of unknown sex. At the end of the study, the group was composed of seven individuals: three males (two adults and a subadult), two adult females and two juveniles (from a birth in December 2013).

Data collection and analysis

We observed the group of *Saguinus m. martinsi* in monthly campaigns of five consecutive days between May 2013 and April 2014. We used scan sampling, with scans of one minute carried out every 10 minutes (Altmann 1974). The total sampling effort was 60 days, corresponding to 518 hours of observation, with a total of 3,230 scans. We categorized the activities of the group in (i) feeding (including foraging), (ii) moving, (iii) resting and (iv) others (includes grooming, playing, vocalizing among group members and with neighboring groups, and copulation). Here we present only the data on feeding.

For each feeding record (defined as manipulation and ingestion of food) we used the focal tree method (Altmann 1974). We recorded the length of stay of individuals in the

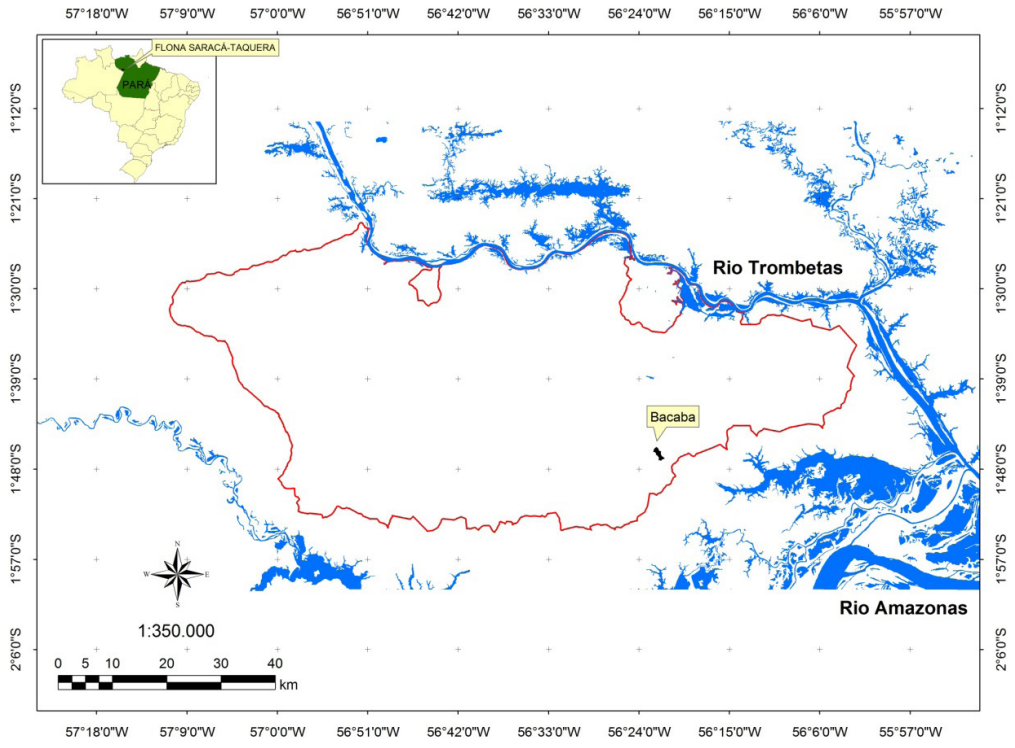

Figure 1. Location of the Saracá-Taquera National Forest in relation to Brazil, and the state of Pará. In green, the area studied (Bacaba).

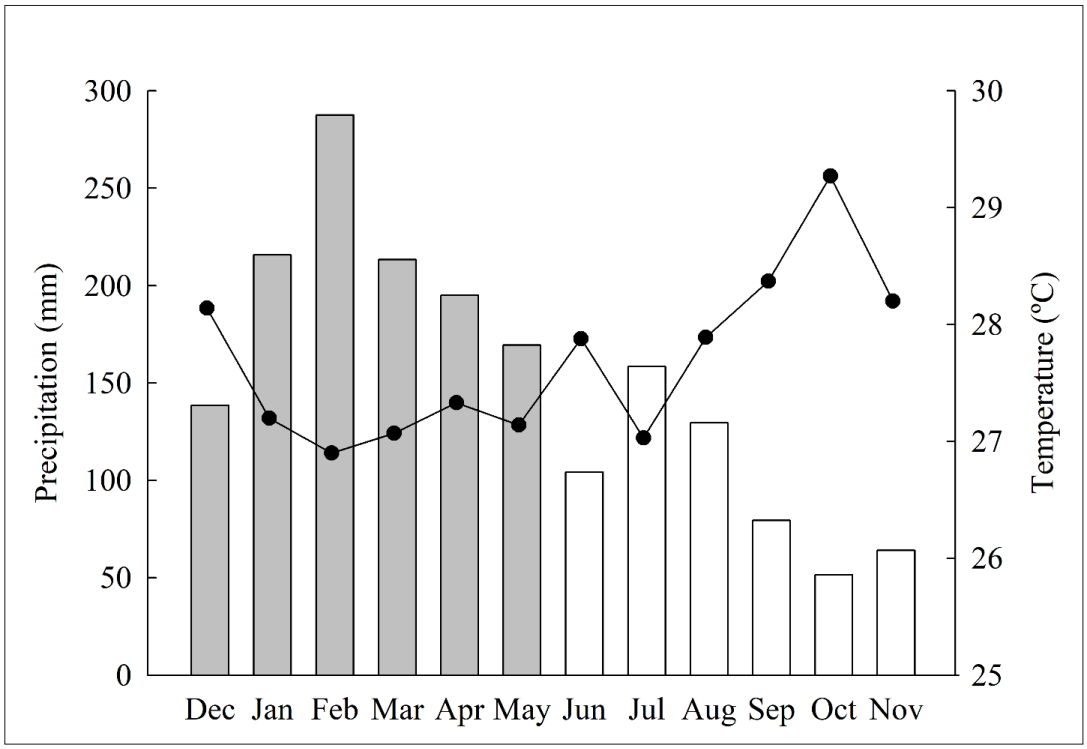

Figure 2. Monthly precipitation and temperature at the Saracá-Taquera National Forest during the study period (May 2013 – April 2014). Gray bars represent the rainy season, white bars the dry season. The line shows average monthly temperature.

feeding tree (starting with the first individual that entered and ending as soon as the last individual left the tree), the food item and, whenever possible, the species. We divided food items into four groups: fruits, invertebrates, exudates, and flowers. The fruits were collected and identified by a botanist at INPA (Instituto Nacional de Pesquisas da Amazônia). We obtained only five records for feeding on flowers and did not include them in the analysis.

To determine the contribution of each food item to the diet of the group, we calculated the relative frequency of records for each. For this, the number of records of a given food group was divided by the total number of feeding records in the study period. To assess whether there was a difference in the use of food items between the dry season (June–November) and the rainy season (December–May), we used the statistical test Z binomial (Rimolí *et al*. 2008), with an $\alpha = 0.01$, to prevent type I errors (Lima and Ferrari 2003). We used the same test to assess if there was a difference in the time spent feeding between seasons. We performed the tests in the Microsoft Excel program, and we obtained the p values in Calculators for Statistical Table Entries. We used the Wilcoxon signed-ranks test to see whether there were differences between the dry and rainy seasons regarding the time the groups spent in each feeding tree, and the number of trees visited per day. We also performed an ANOSIM similarity analysis to verify the similarity in the use of plant species as feeding trees between the two periods, and we used the coefficients of Bray-Curtis and Sorense to evaluate the proportion and composition, respectively. This last analysis was made using the R software, with $\alpha = 0.05$.

Results

With regard to time spent feeding, the diet of *Saguinus m. martinsi* was composed mainly of fruits—84.5% of records, followed by invertebrates (8%), exudates (7%) and flowers (0.5%). There was a clear predominance of fruit feeding in both seasons, above 50% of feeding records in all months (Fig. 3), but with differences in the composition and proportion of food items between the dry and wet seasons. Despite the consistency, there was a higher intake of fruits in the rainy season. Invertebrates were eaten throughout the year, but intake was higher in the dry season (Z in the dry season ($Z = 6.852$, $P < 0.01$). Gum-feeding was almost absent in the wet season.

On average, 21% of daily activity time was spent on feeding, including foraging, and there was no great difference between the two periods ($Z = 0.036$, $P = 0.485$). The group did not increase the time spent feeding during the dry season as we had thought it might. Of the 166 feeding trees used, an average of 10 trees were visited per day during the rainy season. This number of visits was significantly higher than in the dry season, where, on average, the group visited eight trees/day (Wilcoxon signed-ranks test: $Z = 2.572$, $P < 0.01$).

The time they stayed in each feeding tree averaged seven minutes and 32 seconds (range 1–43 min) but differed

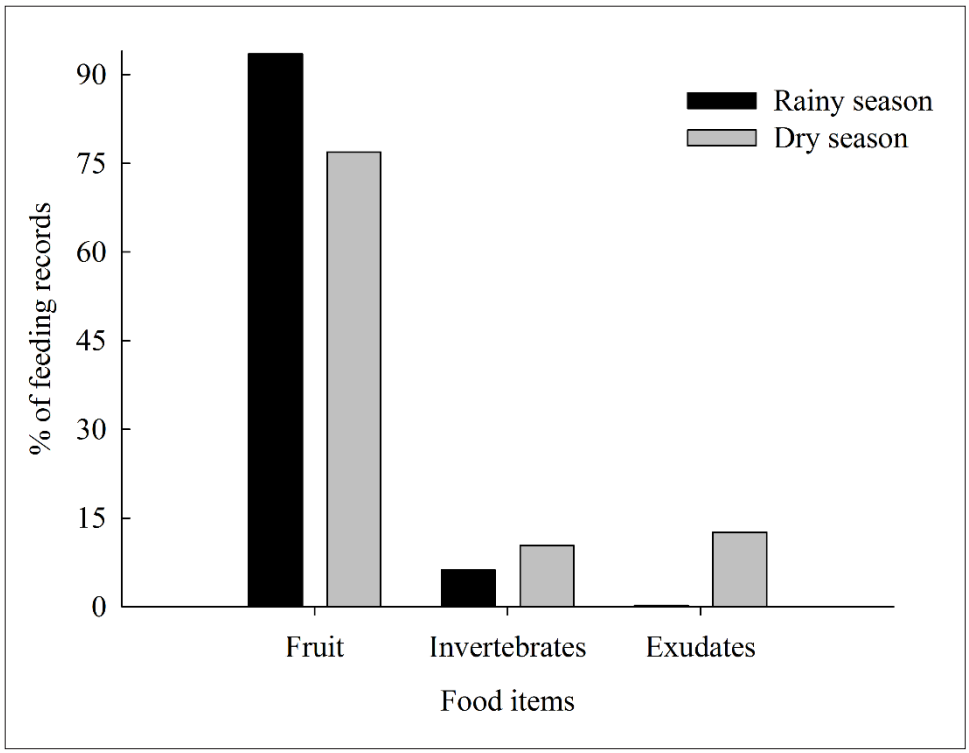

Figure 3. Percentage of records of feeding for the items in the diet of the group of *Saguinus m. martinsi* in the rainy and dry season at Saracá-Taquera National Forest. Notice the increase of food supply in the dry period.

significantly between the seasons (Wilcoxon signed-ranks test: Z = -4.395, P <0.01). In the dry season, the group spent more time, on average, in the feeding trees (nine minutes and 39 seconds), while in the rainy season it stayed for less time (average five minutes and 31 seconds) (Fig. 4).

We registered 50 species in the diet the tamarins (Table 1), 90% of them providing fruits. Forty-one were exploited during the rainy season, 26 of them exclusively so. Of the 24 species used in the dry season, nine were exclusive. Fifteen species provided fruit in both the dry and wet seasons. The ANOSIM analysis of similarity highlighted the difference in the composition of species used between the dry and rainy seasons (R^2 = 0.20, P <0.01) as well as the frequency of use (R^2 = 0.12, P< 0.01).

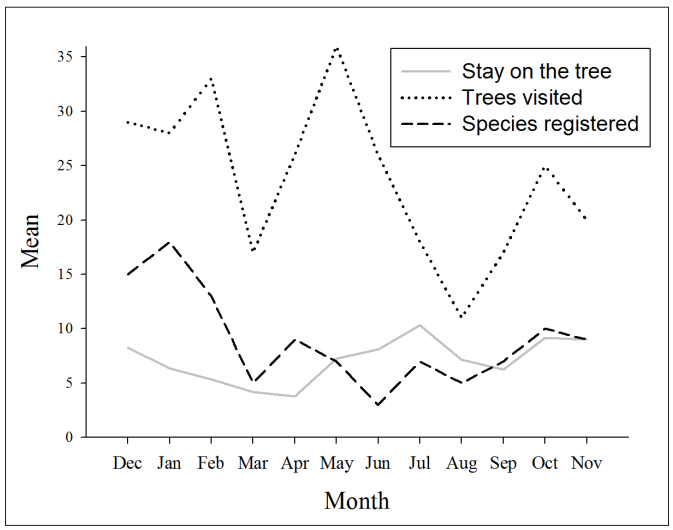

Figure 4. Monthly averages of species registered, number of trees visited per day, as well as the length of stay for the group of *Saguinus m. martinsi* at Saracá-Taquera National Forest.

Byrsonima crispa ("muruci" – Malpighiaceae) was the most important species providing fruit for the tamarins in terms of the number of trees providing fruit (N = 43; Table 2) and was, besides, the species in which the group spent more of its time feeding than any other. It was second highest in the number of visits (N = 131) (Table 2).

Prey recorded in the diet were all invertebrates of the orders Lepidoptera (caterpillars and adult moths), Orthoptera (grasshoppers) and Araneae (spiders). With respect to the time taken in eating invertebrates, 1.82% of the scans recorded eating caterpillars in the month of July, when the group was in *Hymenaea courbaril* trees ("Jatobá-da-mata" – Fabaceae), the most used plant species in this respect, with three trees and eight visits (Table 2). The second most used plant species as a source of invertebrates was *Oenocarpus bacaba* ("Bacabeira" – Arecaceae), 1.59%, having more trees recorded (eight) and 25 visits over six months for feeding on small spiders and other invertebrates (Table 2).

The group ate the exudates of two trees, *Parkia ulei* and *Byrsonima crispa*. They would bite into the dry *Parkia* seed pods and feed on the exudates inside. They were seen visiting one tree 28 times over five months, responsible for 73.68% of the exudate-feeding records. It was the fourth most used species for food (Table 2). The second tree used,

Table 1. Family, species, item explored and period of use of identified plants exploited by the group of *Saguinus m. martinsi* at the Saracá-Taquera National Forest, Pará, Brazil.

Family/Subfamily	Species	Item	Period
Annonaceae	*Guatteria schomburgkiana*	Fr[a]	December, February, March & April
	Guatteria sp.	Fr	December
Apocynaceae	*Couma guianensis*	Fr	February & April
	Geissospermum argenteum	Fr	February
Arecaceae	*Oenocarpus bacaba*	In[b]	August, September, October, November, December & January
Burseraceae	*Protium ferrugineum*	Fr	January
Caryocaraceae	*Caryocar villosum*	In	September
Cecropiaceae	*Cecropia* sp.	Fr	August, September, October, November, January, February, March & April
Combretaceae	*Buchenavia grandis*	Fr	January & February
Ebenaceae	*Diospyros cavalcantei*	Fr	July
Fabaceae	*Parkia ulei*	Ex[c]	May, July, August, September & October
	Hymenaea courbaril	Fr	October, November & January
	Inga stipularis	Fr	November & December
	Inga alba	Fr	December & January
	Inga macrophylla	In	July
	Inga paraensis	Fr	February
Goupiaceae	*Goupia glabra*	Fr	August
Lauraceae	*Mezilaurus itauba*	Fr	October, November & December
Malpighiaceae	*Byrsonima crispa*	Fr/Ex	May, June, July, August, September & October
	Byrsonima chrysophylla	Fr	July &February
Melastomataceae	*Miconia* sp.	Fr	October, November, December & January
	Miconia poeppigii	Fr	November, December, January & February
Myrtaceae	*Myrcia bracteata*	Fr	November & December
Moraceae	*Helicostylis tomentosa*	Fr	May, June, January, February, March & April
	Ficus gomelleira	Fr	December
Rutaceae	*Hortia coccinea*	Fl[d]	June
Salicaceae	*Laetia procera*	Fr	April
Sapotaceae	*Pouteria bilocularis*	Fr	May & November
	Pouteria anomala	Fr	December & January
	Manikara bidentata	Fr	December
	Micropholis cylindrocarpa	Fr	December
	Micropholis venulosa	Fr	January &April
Urticaceae	*Pourouma guianensis*	Fr	December

[a]Fr: fruits; [b]In: invertebrates; [c]Ex: exudates; [d]Fl: flowers

a *Byrsonima crispa*, had received the attentions of a woodpecker, *Celeus* sp., causing the trunk to produce gum. It was visited 10 times, corresponding to 26.31% of the exudate-eating records. We recorded them eating flowers only five times, and we did not include them in the analysis.

Discussion

We observed a mostly frugivorous diet (84.5% of feeding records) for the *Saguinus m. martinsi* group at the Saracá-Taquera National Forest. This is typical for the genus—for example, *Saguinus bicolor* 65% (Egler 1986), *Saguinus labiatus* 58% (Porter 2001), *Saguinus leucopus* 84% (Poveda and Sanchés-Palamino 2004), and *Saguinus niger* 87.5% (Oliveira and Ferrari 2008). A number of studies in tropical rainforests have shown that there are fruiting peaks during periods of higher precipitation, and a shortage of fruit in the driest periods (Peres 1994; Pinto and Setz 2004; Bentos *et al.* 2008; Cardoso 2011; Caselli and Setz 2011; Mourthé 2014). For our study group, there was indeed peak in fruit consumption and the diversity of species consumed during the rainy season. The high proportion of fruits used also in the dry period came mainly from two species which fruited in this period and were intensively exploited: *Byrsonima crispa* and *Cecropia* sp.

Byrsonima crispa and *Cecropia* sp. provided fruits over almost the entire dry season, at which time the number of fruiting species was reduced (Fig. 4), explaining thus the high consumption and number of visits to these trees (Table 2). The importance of *Cecropia* in months of drought has also been recorded in other studies of tamarins (*Leontocebus fuscicollis* – Yoneda 1984; Lopes and Ferrari 1994; *Saguinus labiatus* – Buchanan-Smith 1991), as well as marmosets (*Mico intermedius* – Rylands 1982, 1986). "Embauba" – Cecropiaceae is a family of pioneer species. Trees of the genus *Cecropia* were widely distributed and common in our study area. They fruit throughout the dry season (STCP 2009), their infructescences are eaten by a wide range of birds and mammals (Schoener 1971), and their abundance in successional forest patches and edge is implicated in the overall preference of tamarins and marmosets for these habitats (Rylands 1996). Poveda and Sánchez-Palamino (2004) also noted the importance of *Cecropia* in secondary forest in the diet of *Saguinus leucopus*.

The inclusion of new food items or the increasing use of otherwise secondary items are alternatives used by frugivorous primates to overcome periods of fruit scarcity (Schoener 1971; Egler 1986). *Leontocebus fuscicollis avilapiresi* and *Saguinus mystax pileatus*, studied by Peres (1994), showed a significant increase in the proportion of time feeding on exudates and nectar in the dry months (July–September). Goldizen *et al.* (1988) recorded nectar as the main item in the diet of *Saguinus fuscicollis weddelli* (now *Leontocebus weddelli*) between the months of July and August. Our *Saguinus m. martinsi* group turned to exudates, and increased its consumption of invertebrates in the dry season (Fig. 3).

Contrary to our expectations, the time spent feeding did not fluctuate significantly during the year. In the dry season, however, the group visited fewer trees per day and used fewer species, while they spent more time in each feeding tree compared to the rainy season (Fig. 4). This reflects the low availability of fruit and, as described earlier, the offer of fruits of *Byrsonima crispa* and the infructescences of *Cecropia* during the dry season were significant. The importance of *Cecropia* was clearly seen in July, when we recorded only three plant species providing fruits for the tamarins.

A reduction in the number of species in the diet during the dry season has also been recorded for *Saguinus niger*, which showed a higher permanence in feeding trees in this season (15–50 minutes), when it used only three plant species compared to the rainy season (5–20 minutes), when it used 16 species (Oliveira and Ferrari 2008). Despite the presence of exudate in the diet of a number of species of *Saguinus* and *Leontocebus* (the *nigricollis*, white-mouthed tamarin group, see Rylands *et al.* 2016), they do not have the morphological adaptations for gouging the trunks and

Table 2. Number of trees, number of visits and most representative species, in order of time spent (min), feeding, of a group of *Saguinus m. martinsi* at the Saracá-Taquera National Forest, Pará, Brazil.

Species	No. of trees	No of visits	Time (%)	Density (ind./ha)
Byrsonima crispa (NE) [a]	43	131	20.67	6.52
Miconea poeppigii (NE)	14	100	16.27	
Cecropia sp.	23	134	10.33	
Parkia ulei (NE)	1	28	8.13	2.87
Diospyros cavalcantei (NE)	3	24	5.76	
Mezilaurus itauba (VU)[c]	3	22	4.76	4.00
Helicostylis tomentosa (LC) [b]	6	43	3.88	
Inga stipularis (NE)	4	15	2.95	
Micropholis venulosa (NE)	4	25	2.95	1.22
Hymenaea coubaril (LC)	2	8	1.82	0.78
Pouteria anomala (NE)	3	13	1.76	
Miconea sp. (NE)	5	16	1.60	
Oenocarpus bacaba (NE)	8	24	1.59	100.43
Protium ferrugineum (NE)	5	15	1.39	
Guatteria schomburgkiana (NE)	4	16	1.32	

[a]NE, Not evaluated; [b]LC, Least concern; [c]VU, Vulnerable

branches to obtain gum that can be seen in the marmosets (Coimbra-Filho 1972; Rosenberger, 1978; Rylands, 1984). *Parkia* species have bunches of seed pods that produce exudate spontaneously obviating the need to gouge (Izawa 1978; Heymann and Smith 1999; Smith 2000; Oliveira and Ferrari 2008; Embrapa 2014). Oliveira and Ferrari (2008) recorded *Saguinus niger* exploiting the gum of *Parkia* (in this case *P. pendula*) to a greater extent than we found in our study, as did Buchanan-Smith (1991) studying *Saguinus labiatus*. Twenty-three *Parkia nitida* trees were used by a group of *Saguinus mystax* studied by Heymann and Smith (1999). *Leontocebus fuscicollis* and *Saguinus mystax* eat the gum of the seed pods of *P. nitida* and *P. pendula* (Peres 1994). The gum of *Parkia ulei* seed pods, the fourth most frequently exploited species is evidently a fallback food for the *S. m. martinsi* group (Marshall *et al.* 2009).

In summary, the *S. m. martinsi* group at Saracá-Taquera had a diet similar to those recorded for other tamarin species. The scarcity of fruit in the dry season affected the dietetic diversity of the group; they exploited fewer species for fruit (*Byrsonima crispa* and *Cecropia*) and turned to *Parkia* gum as a fallback.

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