

## SHORT ARTICLES

### PLANT FEEDING PATCHES: PATTERNS OF USE BY ASSOCIATING *Callimico goeldii*, *Saguinus labiatus*, AND *S. fuscicollis*

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#### Introduction

Structural properties of feeding sites affect resource use in socially mediated ways in primates. Feeding patch characteristics (size, density, dispersion) relate to foraging efficiency and the ability to monopolize foods; for example, small or clustered patches may be more defensible than large, dispersed patches (e.g., Janson, 1988). Aspects of habitat use, such as vertical ranging, may also affect encounter rates of resources with varying structural properties. Thus, characteristics such as patch size are linked to interspecific dietary differences, and influence interactions at resources, including those of mixed species groups (Peres, 1996). Mixed species groups, or polyspecific associations (PSA), form when two or more species maintain proximity or coordinate activities, and often occur among closely-related taxa. Associating species may overlap substantially in their diets and share feeding sites, providing opportunities to more efficiently find and monitor resources, but also potentially increasing competition (Heymann and Buchanan-Smith, 2000; Peres, 1996).

The callitrichids *Callimico goeldii* (callimico), *Saguinus labiatus* (red-bellied tamarin), and *Saguinus fuscicollis* (saddle-back tamarin) form PSA in regions of sympatry in Amazonian Brazil and Bolivia (Pook and Pook, 1982; Porter, 2001b; Rehg, 2006b). All are small-bodied frugivore-insectivores, but differ in aspects of habitat use (Porter, 2001a; Rehg, 2006a). They tend to be vertically stratified, with *S. labiatus* more often in the mid to upper forest canopy, *S. fuscicollis* in lower to mid levels, and *C. goeldii* in forest understory (Porter, 2001b; Rehg, 2006a). However, there is notable overlap in their fruit diets. Data from the Fazenda Experimental Catuaba (FEC) in Brazil indicated 66% of plant food species were used by at least 2 of the primates, and 35% were used by all 3 (Rehg, 2006b). In Bolivia, of 95 fruit species consumed, 44 were eaten by *C. goeldii* and at least one of the tamarins (Porter, 2001a). Despite this diet overlap, aggression is infrequent in callitrichid PSA (Heymann, 1990). Porter and Garber (2007) reported only 16 instances of interspecific aggression in over 1300 observation hours of *C. goeldii*, *S. labiatus*, and *S. fuscicollis*.

Given differences in vertical ranging and infrequent aggression among *C. goeldii*, *S. labiatus*, and *S. fuscicollis*, but substantial overlap in fruit diets, I report on aspects of resource sharing related to a measure of patch size. Specifically, I provide data on the relationship of patch size to

use of feeding sites by each species, sharing of feeding sites during PSA, and frequency of interspecific aggression in relationship to food resources.

#### Methods

Data on *C. goeldii*, *S. labiatus*, and *S. fuscicollis* were collected at the FEC (S10°04', W067°36'), an 820 ha reserve managed by the Universidade Federal do Acre (UFAC), Brazil. The site is composed of *terra firme* forest of various successional stages in a region averaging ~2000 mm of rain annually, with a marked dry season June–August (IMAC, 1991; Rehg, 2006a). The research was approved by the Institutional Animal Care and Use Committee of the University of Illinois Urbana-Champaign, and permits granted by UFAAC and the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) of Brazil.

Data were collected primarily on a single group of each species (Stream Group) from Sept 1999 to Mar 2000, Dec 2000, June to Aug 2002, and June to Aug 2003. Other groups were observed opportunistically. Group sizes ranged from 7–12 individuals for *C. goeldii*, 6–10 individuals for *S. fuscicollis*, and 4–11 individuals for *S. labiatus*. In Stream Group, the same groups of each species associated — as defined by a distance of 25 m or less between group peripheries—throughout the study, and were not observed with other groups (Rehg, 2006a). The 3 species were in PSA 61% of observation time, and shared an identical home range of 48 ha through Mar 2000, which increased in 2003 to 56 ha for *Saguinus* and 59 ha for *C. goeldii* (Rehg, 2007). Thus, feeding sites available to one species would presumably be available to the others.

Data were collected using a modified instantaneous scan sampling method at 5 min intervals (Rehg, 2006b). Specific data collected varied among study periods due to changes in the research objectives; however, data were always collected on PSA status. There was an unequal number of scans of each species, with more recorded for *C. goeldii* (N=2741), but nearly comparable samples for the tamarins (N=1740 *S. fuscicollis*, N=1670 *S. labiatus*). I recorded all events of feeding (N=232 wet season, N=470 dry seasons), which was defined as manipulating or ingesting food. Sampled individuals were those readily visible, likely resulting in a bias for individuals that were close to one another, close to me, and active. Thus, observations of multiple individuals and species at feeding sites at the same time may be overrepresented. All occurrences of aggression (e.g., chasing, biting) were recorded, and when it involved feeding individuals it was considered food-related.

I collected data on structural features, such as DBH, of plant feeding sites, defined as individual trees and lianas with fruits, flowers, or exudates that were eaten. I used three grades of patch size (adapted from Peres, 1996): “Small” patches were trees with DBH ≤ 10 cm, and lianas with crowns of ≤ 5 m in diameter. “Medium” patches were

trees with DBH >10 cm and  $\leq 30$  cm, and lianas with a crown diameter > 5 m and  $\leq 10$  m. "Large" patches were trees with DBH  $\geq 30$  cm, and lianas with a crown diameter  $\geq 10$  m. Exudate patches on tree trunks are considered comparable to small patches in terms of access, and grouped with them. Structural properties such as DBH are not directly representative of food quality (Chapman et al., 2003), but patch size can represent space available to forage or feed, and is a way of evaluating ability to access or monopolize a resource. I calculated the number of plant feeding sites used by 1, 2, or 3 species at the same visit ("synchronous" use). Individuals were not marked, so determination of the specific individuals using feeding sites was not possible. A visit occurred when one or more individuals fed at a site, and lasted until all individuals left the site. As there was no attempt to quantify consumption rates, I cannot estimate food availability based on time at a site. I examined the relationship of patch size to the number of species that fed synchronously in the patch. Only samples in which 2 or more species were associated were included, as this assumes that multiple species could potentially "share" a site during a visit. I also tested the relationship of visit duration to patch sizes, and visit duration to the number of species using sites. Visit duration was approximated by number of sequential scans at a feeding site; visits recorded outside a scan and not lasting long enough to be included in a scan, were rounded to the nearest scan (counted as a 'single scan' visit).

Data were analyzed using SAS (Statistical Analysis System, Carey version 9.2, North Carolina). Given possible violations of random sampling, I used a resampling method, randomization, to analyze the data. Resampling methods allow the probability of results from a sample to be evaluated without assumptions about the population distribution (Crowley, 1992). Pearson chi-square goodness of fit tests were first conducted on the original data sets. For each randomization analysis, 1000 randomized data sets were constructed, and chi-square tests applied to each of these 1000 data sets. To determine if associations among variables in the original data set are significant, the distributions of chi-square values for the randomized data sets are compared to the value of that same statistical test on the original data set. If the value from the original data set is greater than 95% of the chi-square values from randomized data sets, the association among variables is significant (equivalent to  $\alpha = 0.05$ ). Here results are reported on the original chi-square tests as well as the proportion of chi-square values from randomized data sets that are below this value (see Rehg, 2006 for a similar application).

## Results

All 3 primates made use of a similar size range of feeding trees, from small (<8 cm DBH) to large trees (>150 cm DBH): for *C. goeldii*  $\bar{x} = 94.2 \pm 85.0$  cm (mean  $\pm$  standard deviation),  $N = 38$ ; for *S. fuscicollis*  $\bar{x} = 105.0 \pm 78.8$  cm,  $N = 43$ ; and for *S. labiatus*  $\bar{x} = 103.0 \pm 74.5$  cm,  $N = 69$ .

However, there were interspecific differences in the sizes of sites shared during visits versus those that were not shared. For *C. goeldii* and *S. fuscicollis*, sites visited alone included more small/trunk sites, while sites shared with heterospecifics (more than one species feeding at the same visit) included more medium and large sites ( $N = 49$ ,  $\chi^2 = 7.41$ ,  $p = 0.025$  for *C. goeldii*;  $N = 78$ ,  $\chi^2 = 15.84$ ,  $p = 0.0004$  for *S. fuscicollis*). In contrast, *S. labiatus* demonstrated no differences in patches visited alone or with heterospecifics ( $N = 92$ ,  $\chi^2 = 0.21$ ,  $p = 0.903$ ). Analyses on randomized data sets supported these results (96.2% for *C. goeldii*; 100% for *S. fuscicollis*; 0% for *S. labiatus*).

There were a total of 145 visits to 107 feeding sites when 2 or more species were in PSA. In 39% of these visits (57/145), more than 1 species fed during the visit, and in nearly all these instances (52/57) individuals of more than 1 species were in the site synchronously. In 22% of visits in which all 3 species were present, they all fed. On occasions when just one species used a site, it was primarily *S. labiatus* (50%). Visits made to sites by all 3 species were mainly to large patches (59%), with small/trunk patches accounting for 7% of visits (Fig. 1). Visits by any 2 species were mainly to large (58%) and medium patches (30%). Visits by just 1 species were predominately to large patches (45%), but included more medium (23%), and small/trunk (33%) patches. All sites that were jointly used by multiple species were also visited on multiple occasions. Visits to feeding sites by a single species or by multiple species were not independent of patch size ( $N = 145$ ,  $\chi^2 = 6.15$ ,  $p = 0.046$ ; greater than 95.5% of results on resampled data sets). Number of species visiting a site was not independent of visit duration by scans ( $N = 134$ ,  $\chi^2 = 31.43$ ,  $p = 0.0001$ ; 0% of randomized data sets were greater than original chi-square value). Visits in which two or more species used a feeding site were more likely to be recorded over multiple scans than visits by a single species. However, most visits to feeding sites were recorded only for a single scan, regardless of the patch size and there was no relationship between patch size and visit duration ( $N = 134$ ,  $\chi^2 = 3.55$ ,  $p = 0.470$ ).

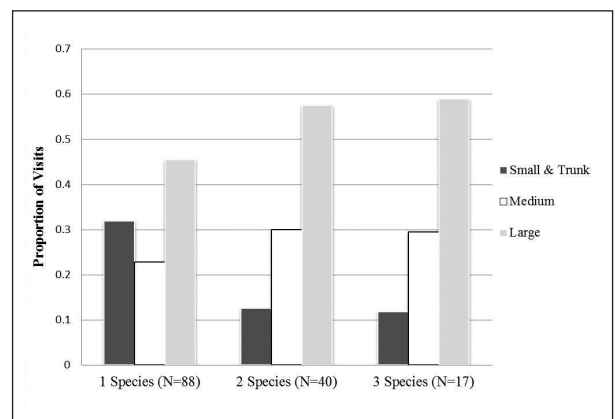


Figure 1. Proportion of visits to feeding sites of different patch sizes by 1, 2, or 3 species.

I observed food-related aggression a total of 33 times (1/13 hrs); 14 of these events were interspecific. All involved adult *S. labiatus* displacing or chasing adult *C. goeldii* or *S. fuscicollis* from a plant feeding “perch”, except once when *C. goeldii* displaced *S. fuscicollis*. Ten interactions occurred in the dry season and 4 in the wet season (1/31 hrs vs. 1/39 hrs); nine interactions occurred at small patches.

## Discussion

At the FEC *C. goeldii*, *S. fuscicollis*, and *S. labiatus* most often visited larger feeding sites while in PSA. However, *S. fuscicollis* and *C. goeldii* made proportionally more visits to small and medium patches than *S. labiatus*. Given vertical stratification among the species (Porter 2001a; Rehg 2006a), it is not surprising that *S. fuscicollis* and *C. goeldii* would more often encounter smaller sites in the low canopy or understory. However, closely-related *S. labiatus* and *S. fuscicollis* demonstrated greater plant diet overlap (Rehg 2006b), and jointly fed at more sites. Overall, the high frequency of shared visits to sites (over a third of all visits) and especially joint use of larger patches may support the suggestion by Porter and Garber (2007) that *S. fuscicollis* and *C. goeldii* take advantage of associations with *S. labiatus* to feed on fruit in the upper canopy. These observations also correspond with research on groups of *S. mystax* and *S. fuscicollis* in which Peres (1996) found greater interspecific dietary overlap on fruits found in large trees. Shared sites were more often medium or large patches, suggesting patch size was related to detectability of, or access to the resources. Although patch size is not a direct measure of resource abundance at any point in time, it may be correlated with potential productivity, and fallen fruit from larger sites would cover larger areas of the ground (making them more detectable from the understory). Patch size is also related to monopolizability. Bicca-Marques and Garber (2003) reported that at experimental feeding platforms *S. fuscicollis* acquired fewer food rewards visiting with *S. imperator* than alone, perhaps from deferring to (or being displaced by) the larger tamarin.

Duration of feeding visit was related to the number of species visiting a site, irrespective of patch size. This may be related to resource abundance, such that sites with more resources were fed at longer and by more species—irrespective of patch size. However, the precise data on resource abundance at the feeding sites needed to test this hypothesis were not collected at the time of the visits. In addition, a relationship between patch size and visit duration may be obscured by the crude duration measure of number of scans; most feeding visits on any size patch were recorded during a single scan only. It is of interest that callitrichid feeding bouts, even at large fruit resources, are typically short. Peres (1996) reported average feeding bout length of 2.3 mins at small patches, and an average length of 6.4 mins at large patches. This may indicate that even some large patches can be depleted of easily accessed

and ripe resources quickly, or it may be that other factors (exposure to predators, satiation) may cause the tamarins to limit feeding bouts.

Interspecific aggression was uncommon, and when it did occur *S. labiatus* was typically dominant, which is in agreement with previous studies (reviewed by Heymann and Buchanan-Smith, 2000) on dominance patterns in mixed tamarin groups. Although even infrequent aggression could be seen as a cost of PSA, direct interference competition would appear to be of minor consequence. The mixed groups at the FEC were often dispersed during foraging, and could encounter small, isolated food patches that could be quickly depleted. First access to these resources may affect food acquisition, although such scramble competition is difficult to evaluate as a PSA cost. Use of different vertical regions of the forest canopy by associating species may facilitate niche expansion (Porter and Garber, 2007). Such stratification, along with interspecific differences in diet and reduced association frequency in the dry season (Porter, 2001b; Rehg, 2006b), might also limit contest and scramble competition among *C. goeldii*, *S. labiatus*, and *S. fuscicollis*.

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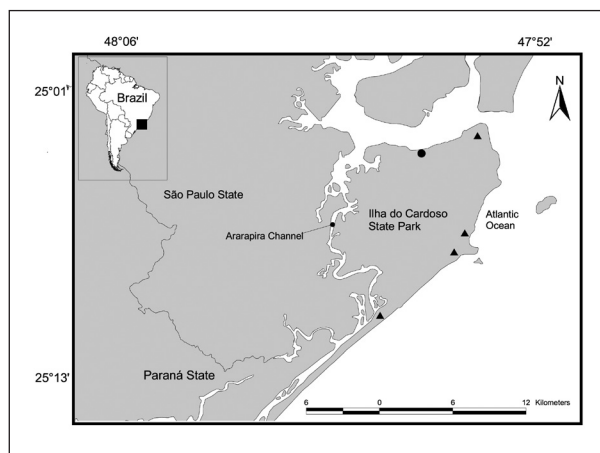
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## WAS THERE EVER A MURIQUI (*Brachyteles*) POPULATION IN THE ILHA DO CARDOSO STATE PARK IN SOUTHEASTERN BRAZIL?

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### Introduction

The muriqui, or woolly-spider monkey, (*Brachyteles*) is the largest of the New World primates (Nishimura *et al.*, 1988), and a flagship for the conservation of the Atlantic Forest in Brazil. They are endemic to the Brazilian Atlantic Forest (Aguirre, 1971; Nishimura *et al.*, 1988), which itself is threatened due to deforestation, with now only 8% remaining, scattered among innumerable fragments of different sizes. Of the 91,930 km<sup>2</sup> left, only 36% (33,084 km<sup>2</sup>)



**Figure 1.** Study area and location of the four villages (black triangles) and an isolated family (black circle) interviewed in the Ilha do Cardoso State Park, in São Paulo, southeastern Brazil.

is protected under federal law, despite the fact that it is a conservation hotspot due to its species richness and many endemic species (MMA and SBF, 2000; Myers *et al.*, 2000). Two species of muriqui are recognized: the southern (*Brachyteles arachnoides*) and the northern (*B. hypoxanthus*). Both are threatened from habitat loss and hunting—the southern muriqui is classified as Endangered and the northern muriqui as Critically Endangered (Nishimura *et al.*, 1988; Mendes *et al.*, 2008; Talebi, 2008). Research on primates in the Atlantic Forest has been ongoing since the late 1970s, and was stimulated mainly by Aguirre's (1971) pioneering monograph that generated interest in and concern for muriquis (Strier *et al.*, 2005). By 1971, the muriqui (only one species was recognized at the time) was believed to have occurred in forests extending south from the Rio Paraguaçu in Bahia to the Rio Ribeira valley in northern Paraná (Aguirre, 1971). Melo and Dias (2005) reviewed the numerous surveys and discoveries of further populations since the report by Aguirre (1971). This included the first report of a population in the Ilha do Cardoso State Park by Martuscelli *et al.* (1994). Martuscelli *et al.* (1994) reported that muriquis were seen twice in the northern part of the island (four adults in April 1989, two individuals in January 1991) during a four year study (1989–1992), but that they had since been extirpated (at least two monkeys were known to have been killed by local people). The occurrence of the muriqui on the island has never been independently confirmed. Here we report our findings concerning the presence of the muriqui in the Ilha do Cardoso State Park and discuss whether there ever was in fact a muriqui population there.

### Methods

#### Study Area

The Ilha do Cardoso State Park (151 km<sup>2</sup>) is on the southern coast of the state of São Paulo, in southeastern Brazil (25°10'015"S, 48°00'05"W; Sampaio *et al.*, 2005; Fig. 1). The island is part of the Iguape-Cananéia-Paraguá