THE SOUTHERN MURIQUI, *BRACHYTELES ARACHNOIDES*: ECOLOGY OF A POPULATION IN A SEMIDECIDUOUS FOREST FRAGMENT

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Abstract

Southern muriquis (*Brachyteles arachnoides*) inhabit evergreen and semideciduous forest fragments in southeastern Brazil. Contrary to the broadleaf evergreen forests, the seasonal mesophytic forests experience a relatively severe dry season, which affects the muriquis' diet. Through behavioral sampling of feeding activity, I determined the diet of a group of muriquis in a semideciduous forest fragment. Leaves represented 55.3% of feeding records, flowers 16.1%, fruits 12.1%, and seeds 16.5%. Muriquis included 47 plant species in their diet. Leaf consumption was significantly higher in the dry season, but there was no evident difference between seasons in their feeding on either flowers, fruits, or seeds. Muriquis in this study shared only 11 taxa with groups in evergreen forests. The study group made consistent use of immature seeds. Dietary flexibility and the consumption of alternative resources may likely be advantageous where there are repeated lean periods and anthropogenic interference.

Key Words – southern muriqui, *Brachyteles arachnoides,* feeding ecology, São Paulo, Atlantic forest, Brazil

Introduction

The original range of the southern muriqui (*Brachyteles arachnoides*) extended through two forest types in the Atlantic forest: the broadleaf evergreen forests on the eastern slopes of the Serra do Mar in the states of Rio de Janeiro and São Paulo, and the mesophytic, semideciduous forests on the central plateau, in the interior of the states of São Paulo and Paraná. These seasonal forests were largely devastated because the flat terrain favored the development of farming and cattle-ranching. The ongoing process of habitat fragmentation drastically reduced the populations of southern muriquis, that now survive in only a few forest fragments.

The pattern of rainfall determines differences in the flora and climate of the two types of Atlantic forest. In the evergreen forests, annual rainfall is quite evenly distributed through the year, but in the semideciduous forests there is a relatively severe drought during part of the year (Morellato and Haddad, 2000). The occurrence of two distinct seasons leads to changes in food availability for the forest's folivores. As such, it is possible to suppose that muriquis in semideciduous forests face greater restrictions in relation to the availability of fleshy fruits, most especially at times of reduced rainfall, when fewer trees are fruiting. By contrast, the diet of muriquis in evergreen forests remains relatively unchanged through the year (Carvalho *et al*., 2004). In her long-term study of southern muriquis in a semideciduous forest fragment, Milton (1984a) found a high proportion of leaves in their diet, which also included flowers, and fleshy and dry fruits. However, Milton did not investigate whether the muriquis' diet changed between seasons.

The aim of this study was to determine the dietary composition of a group of *B. arachnoides* in a semideciduous forest fragment, examining particularly differences in food preference compared to groups in more humid forests, and the feeding strategies adopted during the dry season. The study area was in the Fazenda Barreiro Rico, in a forest fragment adjacent to that where Milton (1984a) carried out her study.

Methods

Study area

Most of the area of the Fazenda Barreiro Rico (22°41'S, 48°06'W; 450–586 m above sea level) is now split into several properties located in Anhembi and Santa Maria da Serra, in the eastern side of the central plateau of the state of São Paulo. Sandy quartzic soils of low fertility predominate in the region (Magalhães, 1999). Although the landscape is dominated by a mosaic of urban centers, farmland and pasture, the Fazenda Barreiro Rico maintains fragments of semideciduous submontane forest: 1,450 ha, 501 ha and 374 ha in size. All these forest fragments have been subjected to selective logging. As a result, they have broken canopies, clearings, and dense tangles of lianas in some parts. The predominant climate is mesothermic, with a dry season from April to September when monthly rainfall is below 70 mm. Sixty-year mean annual rainfall (1940–1999, data from a local weather station) is 1,284.5 ± 285.5 mm.

Further information on the area can be found in Martins (2005).

Study group
The study was carried out in the 1,450-ha forest fragment between June 2001 and May 2002. The muriqui group was completely habituated to the presence of observers. The lack of natural marks and unique attributes made it impossible to precisely identify all of the group members. It was easier to identify females with dependent infants than the males of any age category because the size and sex of the infants allowed me recognize them from one observation session to the next. The muriquis traveled alone or in subgroups with a mean size of 3.25 ± 1.65 individuals. A group size of 25–30 was estimated by counting the number of adult females with their young, summed with the largest grouping of males that I saw (11 at one time) (Martins, 2003).

Data collection
The observation and recording method used was instantaneous scan sampling (Altmann, 1974). I scanned the group every five minutes and registered the behavior of each individual I could see. The behavior categories I recorded were: moving, resting, ingesting food, and interacting socially. The foods were classified as leaves, flowers, fruits and seeds. Although separating fruits from seeds is not usual in studies of muriqui feeding ecology, I had to include it as a category due to the frequency with which I saw them eating the seeds of dry (non-succulent) fruits. As such, when I saw them eating fruits I noted especially the treatment they gave to the seeds, which I classified in one of three categories: seeds ingested (passive), seeds discarded, or seeds eaten (predated). When I saw them ingesting seeds passively while eating the entire fruit or parts of it, or discarding the seeds, I scored the individual as eating fruit, but when the muriqui was evidently targeting the seeds, chewing on them, I scored seed predation. I collected fecal samples from the adults to check whether the seeds were intact or chewed up and fragmented. The plants used in the muriqui's diet were marked, and herbarium samples were collected subsequently for identification. The muriquis were accompanied for three to four days each month, totaling 534 hours of observation, including 38 complete days. I made 5,984 scans which resulted in 2,532 feeding records.

Statistical analysis
The time spent eating different food items and species was calculated as a proportion of the total feeding records for each of the complete days of observation in each month, and expressed as monthly means (number of days varying from three to four). Proportions of different food items and species were also calculated as a proportion of the overall total feeding records. The seasons were determined according to the mean monthly rainfall for the area. Months when precipitation was below 100 mm were classified as dry season months (June to September 2001 and April to May 2002). Months with rainfall above 100 mm were considered to be rainy season months (October to December 2001 and January to March 2002). Seasonal differences in the amount of time spent eating leaves, flowers, fruits and seeds each day were tested with ANOVA. Homogeneity among variances was examined using the Levene test, the proportions being transformed to the arcsine of the square root when the variances were not homogeneous. I used the program STATISTICA 5.0 to carry out the test. Significance levels were pre-assigned to 0.05.

Results

Leaves took up 55.3% of the feeding records of the group, flowers 16.1%, fruits 12.1% and seeds 16.5%. The muriquis included 47 species of plants in their diet during the study (Table 1). Records for five of the species were incidental (seen outside of the formal observation sessions, or recorded through the presence of seeds in the fecal samples). Intact seeds of 18 species of plants were found in 117 fecal samples. Of the total of 31 food species recorded during observation sessions, *Aspidosperma polyneuron* (Apocynaceae) was most frequently registered, followed by *Duguetia lanceolata* (Annonaceae), *Hymenaea courbaril* (Caesalpinoideae) and *Esenbeckia leiocarpa* (Rutaceae) (Table 1). *Aspidosperma polyneuron* and *H. courbaril* supplied mainly leaves, while *D. lanceolata* and *E. leiocarpa* were important sources of immature seeds.

The consumption of leaves differed significantly between the seasons, but this was not so for flowers, fruits or seeds. The muriquis spent more time eating leaves in the dry season than in the wet ($F = 7.33$; $p = 0.01$). Variation in the daily contribution of flowers ($F = 0.31$; $p = 0.57$), fruits ($F = 1.11$; $p = 0.29$) and seeds ($F = 3.12$; $p = 0.08$) was higher between the months of each season than between seasons (Fig. 1). The muriquis made use of temporarily available resources. For example, flowers and nectar were eaten when *Mabea fistulifera* (Euphorbiaceae) was flowering in April (Fig. 1). Only four succulent fruits were included in the diet for the four months of the dry season; the liana *Pereskia aculeata* (Cactaceae), which fruited in June and July, was eaten most. Immature seeds were eaten in all months except October. There was an increase in seed consumption between January and March (Fig. 1) when *E. leiocarpa* was fruiting.

Discussion

The diet of the muriquis in this study showed some considerable differences to those recorded for groups in more humid forests. Of the 47 species of plants the muriquis ate, only 11 were also recorded in the studies of muriquis in the montane evergreen forests of the Carlos Botelho and Intervales state parks (Table 1). Ten of the species, members of the families Apocynaceae, Euphorbiaceae and Rutaceae, were eaten only by the muriquis at Barreiro Rico. In terms of their relative frequency, these three families are well represented in the area (Cesar and Leitão-

Table 1. Percentage of feeding records on each species (N = 2,532) by *Brachyteles arachnoides* in the Fazenda Barreiro Rico, and coincidence with records from two other study sites — Carlos Botelho State Park (PECB) and Intervales State Park (PEI), both of dense evergreen forest.

Species	Family	Percentage of records	PECB[1]	PEI[2]
Arrabidea sp.	Bignoniaceae	1.72		
Aspidosperma nemorale	Apocynaceae	2.47		
Aspidosperma polyneuron	Apocynaceae	12.47		
Astronium graveolens	Anacardiaceae	0.07		
Campomanesia sp.	Myrtaceae	0.11		
Cariniana estrellensis	Lecythidaceae	0.51	x	
Celtis spinosa	Ulmaceae	0.71		
Copaifera langsdorffii	Caesalpinoideae	0.51	x	
Cordia sellowiana	Boraginaceae	0.19		x
Croton floribundus	Euphorbiaceae	2.63		
Cryptocaria moschata	Lauraceae	IO	x	x
Diclidanthera sp.	Polygalaceae	1.81		
Dolichandra unguis-cati	Bignoniaceae	1.42		
Duguetia lanceolata	Annonaceae	6.5	x	
Esenbeckia leiocarpa	Rutaceae	5.84		
Eugenia ligustrina	Myrtaceae	2.48		
Eugenia pyriformis	Myrtaceae	0.77		
Eugenia sp.	Myrtaceae	0.27	x	x
Ficus sp.	Moraceae	SF	x	x
Fridericia samydoides	Bignoniaceae	0.11		
Gonatogyne brasiliensis	Euphorbiaceae	0.19		
Hymenaea courbaril	Caesalpinoideae	6.15		x
Inga striata	Mimosoideae	0.74		
Jacaratia spinosa	Caricaceae	0.46		
Lundia obliqua	Bignoniaceae	0.15		
Mabea fistulifera	Euphorbiaceae	1.3		
Metrodorea nigra	Rutaceae	0.7		
Mouriri glaziowiana	Melastomataceae	SF		
Myrciaria sp.[a]	Myrtaceae	—		
Neomithrantes obscura	Myrtaceae	0.55		
Ocotea catharinensis	Lauraceae	0.27	x	
Ocotea corymbosa	Lauraceae	0.81	x	
Ocotea velutina	Lauraceae	1.42		
Pachystroma ilicifolium	Euphorbiaceae	0.23		
Pereskia aculeata	Cactaceae	4.62		
Pithecoctenium sp.	Bignoniaceae	0.55		
Philodendron sp.	Araceae	0.42	x	
Psidium sp.	Myrtaceae	SF		
Qualea jundiahy	Vochysiaceae	4.69		
Rudgea sp.	Rubiaceae	1.45		
Savia dictyocarpa	Euphorbiaceae	2.84		
Sloanea monosperma	Elaeocarpaceae	0.07		
Styzophyllum riparium	Bignoniaceae	0.98		
Syagrus romanzoffiana	Arecaceae	SF		
Tanaecium seloi	Bignoniaceae	0.98		
Xylopia brasiliensis	Annonaceae	4.54		
Zanthoxylum rhoifolium	Rutaceae	0.19		

[a] = Recorded by Milton only (1984a). PECB = Carlos Botelho State Park, PEI = Intervales State Park. References: [1]Moraes (1992), Carvalho *et al.* (2004), Talebi *et al.* (2005); [2]Vieira and Izar (1999), Petroni (2000). IO = Incidental observation; SF = seeds in a fecal sample.

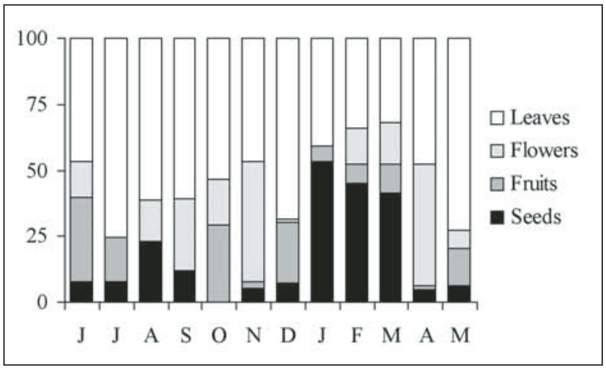

Figure 1. Monthly percentages of feeding records for four food items (leaves, flowers, fruits, and seeds) for *Brachyteles arachnoides* between June 2001 and May 2002 in the Fazenda Barreiro Rico, São Paulo.

Filho, 1990). The floristic composition of broadleaf evergreen and semideciduous forests in southeastern Brazil are distinct (Oliveira-Filho and Fontes, 2000), explaining the low overlap of food species between Barreiro Rico on the one hand and the Carlos Botelho and Intervales state parks on the other.

The consumption of immature seeds was seen frequently, and yet this food resource would appear to be rare or even absent from the diets of the muriquis in the broadleaf evergreen forests to the south (Moraes, 1992; Carvalho *et al.*, 2004; Talebi *et al.*, 2005). Milton (1984a) also recorded seed predation in the group she studied in the neighboring forest patch in Barreiro Rico. Milton (1984a) did not record the frequency of this behavior, however, which may indicate that it was less frequent. There are differences (to be expected) in the diets we recorded. For example, leaves of *Xylopia brasiliensis* accounted for 11% of the diet of Milton's (1984a) group, but only 4.5% of the records for the group I studied. Seeds ingested by primates contain non-structural carbohydrates and lipids (Maisels *et al.*, 1994; Norconk, 1996; Heiduck, 1997), but also nitrogen (Ayres, 1986). However, what it is that is attracting the Barreiro Rico muriquis to eat seeds is unclear. Acquisition of special skills to fracture or scrape the hard pericarps of, for example, *E. leiocarpa*, *D. lanceolata*, and *P. ilicifolium*, and the metabolic attributes to deal with the secondary compounds are interesting questions for further investigation.

The annual proportion of leaves in the diet recorded by Milton (1984a) for her study group and that which I found in my study group were similar (both more than 50%), and much higher than that recorded by Carvalho *et al.* (2004) (33%) and Talebi *et al.* (2005) (24%). The group at Barreiro Rico lives in a forest which, for a fragment, is quite large (1,450 ha), and it is relatively well conserved, despite the occasional logging. I would believe that the higher consumption of seeds and leaves may well be typical of muriquis occupying the more seasonal, semideciduous forests of the central plateau when compared to those in the less seasonal montane evergreen forests of the Serra da Paranapiacaba, for example. The behavioral strategy of *Brachyteles* is considered to be one of efficiency in exploiting dispersed and isolated patches of food resources such as fruits (Rosenberger and Strier, 1989), but the consumption of leaves, distributed more homogeneously, is still significant in the larger expanses of forest such as that at the Carlos Botelho State Park. Cecal fermentation (Milton, 1984b) and broad post-canine teeth (Rosenberger and Strier, 1989) allow these primates to process these low energy foods. Talebi *et al.* (2005) suggested an association between the higher contribution of leaves in the diet and the fact that animals are living in forest fragments. However, independent of and prior to any fragmentation, the muriquis would be selected to adapt to the lower diversity of zoochoric fruits and the greater seasonality in fruit availability that characterizes these semideciduous forests. A comparison of groups in fragmented and extensive semideciduous forests would be ideal, but unfortunately none of the latter remain in the range of the southern muriquis.

Muriquis at Barreiro Rico eat more leaves in the dry season, but although very variable between months, eat similar proportions of the other plant foods across seasons. The adaptive abilities of the muriqui are demonstrated by their increased consumption of leaves when succulent fruits are scarce. This pattern is not evident for the groups in the broadleaf evergreen forest, probably because of the larger number of species producing succulent fruits and a more uniform fruit abundance over the year. At Carlos Botelho, Carvalho *et al.* (2004) failed to detect any significant differences in the composition of the diet during the year.

The results suggest a greater variability in the diet of *Brachyteles arachnoides* than had been previously recognized. I have identified differences in the diet of the group in Barreiro Rico from those recorded for the groups in humid broadleaf forests, not only in the plant species eaten, but in the regular and considerable contribution of immature seeds. The predator-plant interaction deserves further research considering its effects on the recruitment of the plant species involved, and the influence of *Brachyteles* as a seed predator on the floristic communities of the forests where they live. Reliance on seeds and dietary flexibility were probably crucial aspects enhancing the southern muriqui's capacity to occupy seasonal semideciduous forests. This plasticity may well be allowing them to adapt to structural and floristic changes in the forests over recent decades. For example, the muriquis may well have developed or increased their capacity to eat ruderal invasives such as *Croton floribundus* (Euphorbiaceae) and *Inga striata* (Mimosoideae) or species which respond positively to fragmentation and disturbance such as lianas. It is possible that these feeding strategies provide an advantage for muriquis to tolerate not only repeated dry season conditions, but also anthropogenic effects over the remaining forests where they live.

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