

QUANTITATIVE ASSESSMENT OF HABITAT DIFFERENCES BETWEEN NORTHERN AND SOUTHERN MURIQUIS (PRIMATES, ATELIDAE) IN THE BRAZILIAN ATLANTIC FOREST

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INTRODUCTION

Habitat complexity and heterogeneity have been recognized as important variables affecting species richness in tropical forests worldwide (MacArthur & MacArthur 1961, MacArthur *et al.* 1962, August 1983, Schwarzkopf & Rylands 1989, Grelle 2003, Boubli *et al.* 2004). Primate species richness in particular appears to be directly correlated with these variables (Mittermeier & van Roosmalen 1981, Whitten 1982, Terborgh 1983, Medley 1993, Warner 2002). In addition, several studies point to the specificity of habitat requirements to certain primate taxa, especially in terms of habitat structure (complexity) (Schwarzkopf & Rylands 1989, Warner 2002). The two species of woolly spider monkey or miquiqui, *Brachyteles hypoxanthus* (northern miquiqui) and *B. arachnoides* (southern miquiqui) are endemic to the Atlantic Forest biome. Ecologically, both species seem to occupy similar niches where they occur; large, diurnal, arboreal, frugivore-folivore primates but their geographical ranges do not overlap (Rylands *et al.* 1995, Groves 2001, Melo *et al.* 2004, Koehler *et al.* 2005). To date, very few studies have attempted to contrast their ecology. To the best of our knowledge, the only studies that have compared northern and southern miquiquis in terms of differences in their

habitat requirements have done so by using tree diameter (diameter at breast height, DBH) as a surrogate for tree size and thus for habitat structure (Lemos de Sá & Strier 1992, Moraes *et al.* 1998). As a first attempt to contrast habitat requirements of these endangered species (IUCN 2008), we performed a systematic quantitative assessment of the habitat characteristics of eight of the 25 areas where miquiquis are known to occur (Melo & Dias 2005). Our objective was to investigate habitat differences between the two monkeys that would justify the elaboration of separate conservation action plans for the two species (Oliveira *et al.* 2005). Today, little more than 0.5% of miquiqui original numbers remain distributed throughout isolated, mostly small forest fragments (Aguirre 1971, Mittermeier *et al.* 1987, Strier 2000). The eradication of miquiquis from most of their original range was due to hunting (e.g. Lane 1990) and, even more importantly, to the decimation of their Atlantic forest habitat, to the extent that only 7.5% of this biome now remains (Morellato & Haddad 2000, Myers *et al.* 2000). Although miquiqui growth rate is quite slow (one birth every three years/female; Strier 1996), some populations have experienced significant increases in recent decades, much of it resulting from the capacity of miquiquis to successfully use secondary forests, even in relatively early successional stages (Strier 2000, Mendes *et al.* 2005). Understanding the processes allowing primates to

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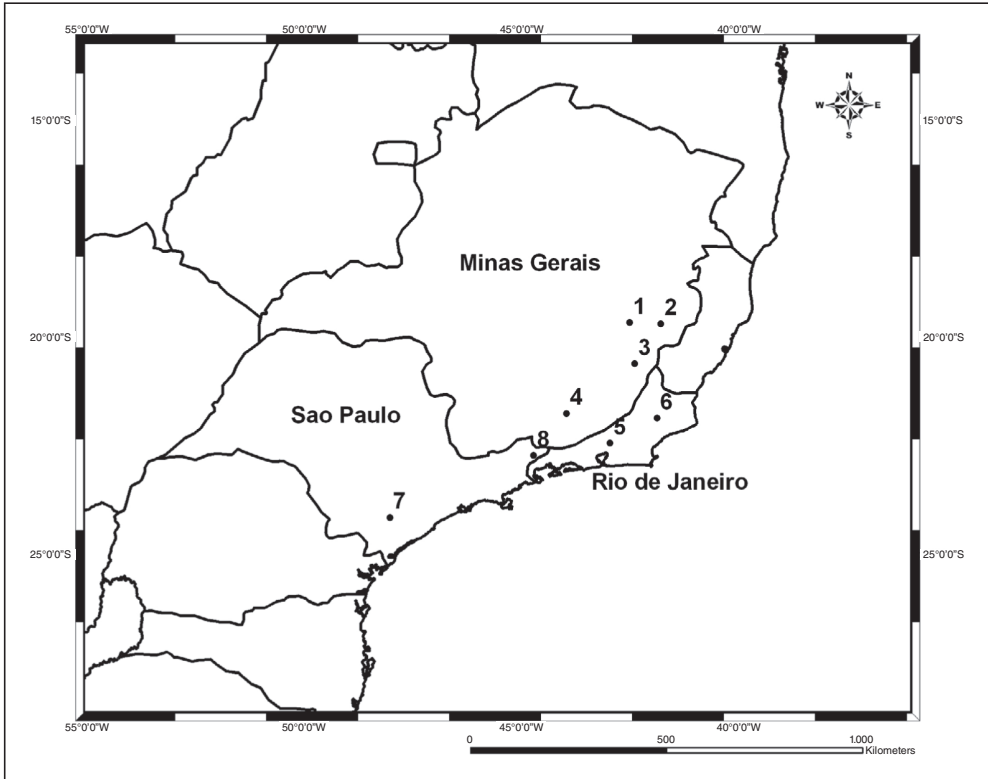


FIG. 1. Locations of data collection in the southeastern region of Brazil. *Brachyteles hypoxanthus* locations: 1) Parque Estadual do Rio Doce [PERD], 2) RPPN Feliciano Miguel Abdala [RPPN-FMA], 3) Parque Estadual Serra do Brigadeiro [PESB], 4) Parque Estadual do Ibitipoca [PEI]; *Brachyteles arachnoides* locations: 5) Parque Nacional da Serra dos Órgãos [PNSO], 6) Parque Estadual do Desengano [PED], 7) Parque Estadual Carlos Botelho [PECB], 8) Estação Ecológica de Bananal [EEB].

persist in fragmented environments is important to conservation and management of endangered species (Schwarzkopf & Rylands 1989). Thus, it is also our objective to describe the habitat characteristics of forests where muriquis persist in order to help identify other areas with similar characteristics that may be selected for future reintroductions in case managing these species with captive breeding and reintroduction becomes necessary for their long-term survival.

STUDY AREAS AND METHODS

The study was carried out in the early dry season (May-July) of 2005 at eight different locations (Figure 1). The choice of these areas was based on previous confirmation of the occurrence of *Brachyteles*. All

areas but the one sampled nearest to the PEI are under some degree of protection, such as national and state parks or privately owned reserves (RPPN). In fact PEI is a protected area, but most of this park is primarily composed of moorland vegetation and only some portions are forested; muriquis are known to be restricted to forest fragments adjacent to the park (Fontes *et al.* 1996). Habitat characterization was carried out following methods described in detail by August (1983). At each location we established up to 100 sampling stations spaced 50 m from each other and along a transect of up to 5 km on pre-existing trails. Sampling stations were positioned 10 m off the trail in an attempt to reduce a potential bias from the presence of the trail in the center of the sampling area (Warner 2002). There were 628 sam-

ples taken in total (319 for northern muriqui locations and 309 for southern muriqui locations). The number of sampling stations per location ranged from 55 to 101 with a mean of 78.5 ± 17.8 (\pm SD). The unequal number of sampling stations per site was due to differences in the length of pre-existing trails in sample locations. A total of 14 attributes was assessed within an imaginary square (with the observer positioned at the center) of 10-m sides encompassing the sample station. The location (flat, valley, bottom, hillside, and hilltop), soil type (clayey, loamy, and sandy), and presence/absence of potential water sources (occurrence within a 25-m radius) were determined visually. The topography was determined with a clinometer and divided into three classes: flat (<15 degrees), slope ($>15 <45$ degrees), and steep (>45 degrees). The geographic coordinates and altitudes (meters a.s.l.) were measured with the aid of a GPS device. Altitude was not measured at sampling stations in two locations associated with *B. hypoxanthus* because of equipment failure. Canopy, mid-story, and liana densities, canopy height, as well as canopy connectivity were subjectively estimated on a scale of 0–4, varying from low (0) to high (4) complexity (Boubli *et al.* 2004). These structural characteristics provided information related to the way both muriqui species (and other sympatric arboreal species) use their habitat (i.e. resting and sleeping sites, traveling routes; Whitten 1982). Density of epiphytes was calculated as the percentage of total coverage within the sampling stations. In order to minimize

bias due to personal subjectivity in the estimation of some attributes, they were all made by only one of us (IMCM). The occurrence of a few indicator taxa (e.g. palms, ferns, bamboo, *Cecropia* spp., and *Ficus* spp.) was recorded within the sampling station in order to determine maturation and degree of disturbance of the forest. Diameter at breast height (DBH) and the distance from each tree to the central sampling point were measured for the nearest tree ≥ 10 cm DBH in each quarter (Point-centered quarter method; Cottam & Curtis 1956). Values were combined at the species level (i.e. northern and southern muriquis) before performing a Wilcoxon Rank Sum test to verify habitat differences between species. Habitat differences within particular species locations were tested by means of Kruskal-Wallis Rank Sum tests (KW). However, those cases where significant differences were found in KW only indicate that at least one of the groups is different from at least one of the other without specifying which one. In these cases, a Multiple Comparison test was carried out to help determine which groups were different through pairwise comparisons adjusted appropriately (Siegel & Castellan 2008). Significance levels were set at $p < 0.05$.

RESULTS

In terms of altitude, northern muriqui locations are lower than southern muriqui locations. Excepting for PED, where 92% of sampling stations were located on flat areas, all other muriqui locations were pre-

TABLE 1. Summary (average \pm SD) of habitat complexity measures for *Brachyteles arachnoides* and *Brachyteles hypoxanthus* locations. Wilcoxon Rank Sum test statistics (W) and probabilities are given for combined data to compare habitat differences between species. NA indicates not applicable.

Habitat characteristics	<i>B. arachnoides</i>		<i>B. hypoxanthus</i>		W	p
	Mean	SD	Mean	SD		
Altitude (m)	1165.4	275.9	681.7	484.0	34158	< 0.001
Canopy height (m)	14.2	4.2	13.4	4.4	54217.5	0.020
Canopy density	3.3	0.8	2.6	0.9	70409	< 0.001
Canopy continuity	2.1	0.7	1.7	0.8	64122	< 0.001
Mid-story density	2.1	0.8	2.0	0.8	53619	0.026
Liana density	1.0	0.8	1.3	0.9	40187	< 0.001
Number of layers	0.4	0.8	0.4	0.9	48101	0.519
Epiphyte density	2.5	1.0	0.6	0.9	84773	< 0.001
DBH (cm)	22.1	14.1	20.5	14.5	811390	0.006
Density of trees (ind./ha)	980.33		669.27		NA	NA

dominantly dominated by slope ridges. However, the terrain was steeper in southern muriqui locations. Soil in all locations was predominantly silty. Based on the availability of fresh running water, northern muriqui locations were much drier than southern muriqui ones. The presence of emergent trees, fig trees, *Cecropia* spp., exotic grasses, and the fern *Pteridium aquilinum* was more abundant in northern muriqui locations, indicating a more disturbed habitat. These taxa can be easily found in areas subjected to anthropogenic disturbance. The palm *Euterpe edulis* as well as other palm species, tree ferns, bromeliads, epiphytes, ferns, and native bamboo species were, however, all more abundant in southern muriqui locations; all of these taxa are known to commonly occur in undisturbed forests. In terms of structural habitat characteristics (Table 1), only liana density was higher for northern muriqui locations than southern muriqui ones. Conversely, canopy height, canopy density, connectivity, density of mid-story, and density of epiphytes were all greater for southern muriqui locations. There was no difference in the number of forest layers across locations. In total, 2128 trees were measured; average DBH of trees was greater in southern muriqui locations (Table 1). There was a great variability in some attributes within both northern and southern muriqui locations (Tables S1 and S2, supplementary material on the Ecotropica homepage http://www.gtoe.de/?page_id=101).

DISCUSSION

Our results suggest that murequis have species-specific habitat requirements. In a general way, considering the structural characteristics of their habitat, northern muriqui locations are structurally simple, more disturbed, and present lower tree density than southern muriqui locations. Conversely, southern muriqui locations are structurally complex, more pristine, with a higher tree density, and a dense and more continuous canopy, as suggested by the high scores of habitat complexity measures. Thus, the forests where southern murequis (as well as other sympatric arboreal mammals) occur must present more travel routes compared with those where northern murequis occur. To the best of our knowledge, there are no records of southern murequis using the ground. Northern muriqui forests, however, are relatively lower and offer much less continuous forest strata (i.e. low canopy connectivity and density, and low mid-story density) which might partly explain the relatively frequent use of the ground for locomotion

in this species and other sympatric arboreal species (*Alouatta guariba*: Almeida-Silva *et al.* 2005, IMCM, pers. obs.; *B. hypoxanthus*: Mourthé *et al.* 2007; *Cebus nigritus* and *Callithrix flaviceps*: IMCM, pers. obs.). Frequent ground use for locomotion can have significant implications for the conservation of arboreal Atlantic forest wildlife, and much predation of arboreal animals is likely to occur when they were forced to descend trees to cross forest gaps (Galetti & Sazima 2006, Mourthé *et al.* 2007). We failed to identify forest layers (or strata) in this study. Irrespective of being a common concept in forest ecology, there is some debate on the existence and applicability of strata measurements (Richards 1996). Although a number of our sampling locations were placed in seasonal forests, we tried to reduce the effects of seasonality by sampling these areas in a relatively short space of time during the early dry season, so we are certain that seasonal differences did not affect our results. The higher density of epiphytes, as well as the greater number of sampling stations located close to water sources (i.e. streams, lakes, springs), show that southern muriqui locations are more humid than northern muriqui locations. In fact, the abundance of epiphytes was one of the most remarkable differences between muriqui species locations (Table 1) and it was possible to clearly perceive the difference by eye. The interaction between epiphytic aroids and animals is poorly understood but it is known that they serve as food for several arboreal mammals (Vieira & Izar 1999). Epiphytic aroids have occasionally been recorded as food in both northern and southern murequis (Strier 1991, Vieira & Izar 1999, Martins 2005). Although epiphytes have not been reported to be important as muriqui food items, they are strong indicators of overall humidity and low rainfall seasonality. According to Gentry and Dodson (1987), epiphytes decrease more drastically in drier areas than do any other plant-habit group, resulting in a difference in epiphyte density between wet and dry forest as high as 500-fold! Detailed studies are needed to look for more specific relationships between epiphytic aroids and arboreal mammals such as murequis. We were able to confirm the anecdotal reports that southern murequis live in higher and steeper locations than northern murequis (e.g. Cunha *et al.* 2009). It was not uncommon to have sampling stations located at places steeper than 45 degrees within southern murequis locations. However, the PESB, a northern muriqui location, could be easily assigned to be a

southern miquiqui location based on altitude only (Table 1). It is a highly mountainous area slightly less steep than PECB or PNSO. Although our crude visual soil analysis did not identify any differences between the locations, it is possible that a more detailed and refined true soil analysis (e.g. mechanical and chemical properties) might indicate significant differences that could help us to explain the occurrence and abundance of miquiqui species in those locations (e.g. Oates *et al.* 1990). The high density of lianas and the presence of several indicators of habitat disturbance in northern miquiqui locations, indicate a much more disturbed forest in these places. In addition, DBHs were higher in the southern miquiqui locations, indicating much more pristine forests than northern miquiqui locations. Both miquiqui species are known to prefer medium- to large-size trees according to their availability (Strier 1989, Moraes *et al.* 1998, Mourthé *et al.* in prep.). Despite the preference for larger trees, miquiquis are also known to rely successfully on secondary habitats, showing a great flexibility in using even small trees (Mourthé *et al.* in prep.). This type of behavioral plasticity has been cited to illustrate enhanced miquiqui capacity to deal with forest structural and floristic changes in recent decades (Martins 2005). Most northern miquiqui locations examined in this study have been highly exploited for agriculture, cattle ranches, and selective logging in the recent past (e.g. in the last 30–50 years) and were converted to conservation units only recently in some cases (e.g. RPPN-FMA, PESB). The locations of southern miquiquis are generally more pristine and the reserves were created a long time ago, though in some cases they have experienced problems related to illegal palm heart exploitation and hunting (e.g. EEB, PED, PNSO; pers. obs.). Thus, given the different conservation status of the parks and reserves sampled, the interpretation of our results should be approached with some care. In summary, this study shows that, in spite of morphological similarities between the two miquiqui species, there is a clear ecological distinction in terms of their forest structural characteristics (Table 1) justifying the elaboration of distinct management plans. This study represents the first attempt to quantitatively assess miquiqui forest characteristics and their differences across multiple sites. Further comparative studies on the ecology and behavior of these primates, as well as other arboreal animals, are needed to better understand the relationship between them and their habitats and to promote more effective conservation strategies for endangered species.

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