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A History of Long-term Research and Conservation of Northern Muriquis (*Brachyteles hypoxanthus*) at the Estação Biológica de Caratinga/RPPN-FMA

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Abstract: Northern muriquis (*Brachyteles hypoxanthus*) are endemic to the Brazilian Atlantic forest, and rank among the most critically endangered primates in the world. The 957-ha forest at the Biological Station of Caratinga/Reserva Particular do Patrimônio Natural – Feliciano Miguel Abdalla (EBC/RPPN-FMA), in Minas Gerais, supports a population of more than 230 individuals, one of the highest population densities known. Long-term research and conservation efforts have been underway there since 1982, during which time the behavioral ecology, reproductive biology, and life histories of members of one of the two original groups (Matão) have been systematically monitored. These data, together with a census conducted in 1999, signaled the importance of expanding the project to include the entire population at this site. Since 2002, all four of the muriqui groups that now inhabit this forest have been monitored. While continuing to provide training and research opportunities for Brazilian students, our new research initiatives are focusing on understanding the demography and ecology of this population. Analyses of vegetation structure and composition indicate that the forest at EBC is relatively species-rich compared with other tropical rainforests worldwide. Tree mortality and recruitment are relatively high and overall primary productivity, as measured by litter fall, is average for tropical forests. Given that the forest at EBC has suffered the impact of selective logging, fire, and agriculture, we believe that its high rate of turnover may be a response to past disturbance regimes, and one of the reasons muriquis are doing so well here. It has been proposed that primates that include substantial amounts of leaves in their diet may be favored by habitat disturbance if that means an increase in the availability of more palatable and more nutritious leaves. In addition, in terms of fruits, muriquis are very opportunistic feeders, not appearing to select fruits of any particular, size, shape, or dispersion syndrome. This paper reviews the history of research and conservation activities on behalf of this critically endangered species at a critically important field site.
Key Words: Northern muriquis, *Brachyteles hypoxanthus*, population viability, demography, ecology, conservation

Introduction

Northern muriquis (*Brachyteles hypoxanthus)* are endemic to the Atlantic Forest of southeastern Brazil, and are ranked among the world's 25 most endangered primates (Mittermeier *et al*. 2000; Konstant *et al*. 2002; Strier *et al*. 2005). Previously, fewer than 500 individuals were estimated to survive in only a few dozen forest fragments in the states of Minas Gerais, Espírito Santos, and southern Bahia, with the largest population (more than 200 individuals) occurring in the 957-ha forest at the Estação Biológica de Caratinga (EBC)/RPPN-FMA (19°44′S, 41°49′W) in Minas Gerais (Fig. 1; Strier *et al*. 2002, in press). Results from recent surveys, however, show that there could be as many as 1,000 northern muriquis left in the wild, and important studies of some of these newly discovered populations have recently been initiated (Mendes 2004; Dias *et al*. 2005; Mendes *et al*. 2005).

The EBC muriquis have been the subjects of systematic research since 1982, and are continuing to provide important insights into the behavior, biology, and ecology of this species. Here, we describe the history of the EBC and the Muriqui Project of Caratinga, and some of the most significant new research and conservation initiatives underway as part of this project.

History of the EBC

Discovery

The EBC is a privately-owned forest surrounded by the coffee plantations and pastures of Fazenda Montes Claros.

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The forest at the EBC has long been recognized as one of the last remaining strongholds for muriquis. Both the EBC and the imperiled status of muriquis gained national attention in Brazil as a result of Aguirre's (1971) comprehensive monograph. Soon after, pioneering Brazilian conservationists, such as Adelmar F. Coimbra-Filho, then Director of the Centro de Primatologia de Rio de Janeiro (CPRJ), Almirante Ibsen de Gusmão Câmara, then President of Fundação Brasileira para a Conservação da Natureza (FBCN), and Célio Valle, then Professor of Zoology at the Universidade Federal de Minas Gerais (UFMG), attracted international attention to the plight of muriquis and the importance of the EBC by alerting Russell Mittermeier, then at World Wildlife Fund (WWF), to their status (Valle *et al*. 1982, 1983).

Zoology professors from UFMG, Ney Carnevalli and Célio Valle, first visited the EBC in 1974, establishing what became a critical collaborative relationship with the owner of the forest, Mr. Feliciano Miguel Abdalla (Valle 1992). Mr. Feliciano subsequently opened his lands to researchers and conservationists from around the world, beginning with Akisato Nishimura, from Japan, in 1977 (Nishimura 1979). In 1981, Russell Mittermeier brought Andrew Young, a Harvard University undergraduate and budding filmmaker, to the EBC to make the classic film "Cry of the Muriqui." Mittermeier's ex-graduate advisor from Harvard, Dr. Irven DeVore, narrated the film. DeVore was by that time serving as Karen B. Strier's (KBS hereafter) graduate advisor, and he encouraged her to consider studying muriquis at the EBC for her PhD dissertation. She conducted a pilot study there in 1982, and has continued her research at this site ever since.

Local infrastructure

Until 1983, researchers and conservationists visiting the EBC stayed in a small apartment adjacent to Mr. Feliciano's house, located about 2 km from the forest. Then, Mr. Feliciano donated a small abandoned house so that resident researchers could be more conveniently situated at the entrance to a dirt road that bisects one of the main valleys in the forest. FBCN and WWF renovated the house, which was inaugurated in May 1983, and inhabited, for the first time, in June of that year.

The research facilities have been improved and expanded over the last two decades. In 1992, electricity was brought in and the old veranda was converted to a third bedroom. An extension, known as the "Centro de Visitantes Célio Valle," was also built with support from Fundação Biodiversitas, an NGO based in Belo Horizonte, and the international nongovernmental organization (NGO), Conservation International (CI). In June 2002, "O Laboratório do Campo Dra. KBS," was constructed for the 20th anniversary of the muriqui project, with support from the Zoological Society of San Diego, California.

Initially, the EBC research house was administered by FBCN, then by Fundação Biodiversitas, and subsequently by the Brazil Program of CI (CI-Brasil). Eduardo Marcelino Veado, who had served as field assistant to KBS in 1983–84 when an undergraduate at UFMG, moved his family to the nearby town of Santo Antônio to become the director of the EBC in 1988, as an employee of the Fundação Biodiversitas. Subsequently, Eduardo established the Pró-Associação EBC, the NGO that now administers the EBC with support from CI-Brasil and, more recently, the Zoological Society of San Diego.



Figure 1. An adult male northern muriqui from the Jaó valley, with the town of Santo Antônio in the background. Photograph by Ítalo Mourthé, 2002.

The EBC muriquis were protected by Mr. Feliciano throughout his lifetime. In 2001, Mr. Feliciano's family transformed the forest into a Private Natural Heritage Reserve, the "Reserva Particular do Patrimônio Natural Feliciano Miguel Abdalla," or RPPN-FMA. The RPPN-FMA is administered by the Sociedade para a Preservação do Muriqui, the NGO that the Abdalla family established specifically for this purpose (Castro 2001).

Other research activities at the EBC

In addition to northern muriquis, the EBC forest supports significant populations of three other species of primates, two of which (the buffy-headed marmoset, *Callithrix flaviceps*, and the brown howler monkey, *Alouatta guariba clamitans*) are also endemic to the Atlantic forest and threatened with extinction. The third species, the black-horned capuchin monkey (*Cebus nigritus*), is also threatened and restricted to the Atlantic forest.

Systematic field studies resulting in undergraduate, Masters, and PhD theses have been conducted on all four of the primate species at the EBC (for example, Stephen F. Ferrari conducted his PhD thesis on buffy-headed marmosets [1988]; Sérgio L. Mendes his master's thesis on the brown howler monkeys [1985], and José Rímoli [2001] and Jessica W. Lynch [2001] their PhD theses on the black-horned capuchin monkeys). Together with other studies that have been carried out on the plants, birds, bats, and small mammals, the EBC has become a major research center for tropical field biology (Bernardes *et al*. 1988).

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The Muriqui Project of Caratinga (MPC)

Background

In 1982, two groups of muriquis were known to inhabit the EBC forest, with a total of about 50 individuals altogether (Valle *et al*. 1984). One group, known as the Matão group, occupied the central and southern part of the forest closest to the research house. The second group, known as the Jaó group, used the northern part of the forest. Until 2002, research efforts focused almost exclusively on the Matão group, nearer to the field station. Members of the Jaó group have been sighted opportunistically in about 40% of the Matão group's home range, which increased from 168 ha in 1983–1984 (Strier 1987) to 309 ha in 1988–1999 (Dias and Strier 2003). In 1988, six males from the Jaó group began making periodic incursions on their own into Matão forest, where they accounted for 10–12% of all observed copulations involving Matão females over a 5-year period (Strier 1994, 1997). By 1991, a third group, christened Matão 2 (M2), was established by some Jaó females and the transient Jaó males. The presence of the M2 group in what had originally been the northern part of the Matão group's home range may have stimulated the Matão group to shift its expanded home range into the southern part of the forest (Strier *et al*. 1993).

Since 1983, KBS has directed systematic studies of the Matão group, focusing on the behavioral ecology, reproductive ecology, and life histories and demography. In 2001, Jean Philippe Boubli (JPB hereafter) joined the project as KBS' post-doc, with the aim of extending the research to the Jaó muriquis and investigating the ecology of the species in greater detail. Most previous research had focused on the behavior of the animals, and questions about the forest's floristics, phenology, and primary productivity and detailed analyses of the muriquis' diets, including the occurrence of seeds in their feces, were still open. In 2003, Carla de Borba Possamai, currently a master's student at the Pontíficia Universidade Católica (PUC) of the state of Minas Gerais but who participated in the Matão project from June 2001–February 2003, initiated systematic research on the M2 group and, together with students working in Jaó, on what is now a fourth group (Nadir), composed of muriquis that broke off from the Jaó group in 2002 (Strier *et al*. 2004, in press).

From its onset, the MPC has maintained a tradition of providing research and training opportunities for outstanding Brazilian students. More than 30 have participated in the Matão project since 1983. Six students, including two from the Matão project, have participated in the Jaó project since 2002 (Table 1).

One of the keys to the long-term continuity of the Matão project has been the overlapping teams of students, who participate in the selection and training of their successors. This continuity has made it possible to follow all group members over the course of their lives, including all infants that were present in 1982 and have been born since. Muriquis have distinct facial markings that permit individual identification, and each team of students helps to train their successors to ensure that each muriqui can be followed from one year to the next.

Males stay in their natal groups for life (Strier 1991a), although exceptions may arise associated with unfavorable sex ratios. For example, in addition to the six males from Jaó that began to make incursions into the Matão in 1988 and ultimately helped to establish the M2 group (Strier *et al*. 1993/1994), a subset of males in Jaó now seem to be engaged in a similar process of transferring into the new Nadir group (Boubli *et al*. 2005).

Continuous observations of the Matão group have also made it possible to follow the life histories of females, which typically transfer out of their natal groups at about 6 years of age (for exceptions, see Strier 1991a; Martins and Strier 2004). Immigrant females are nulliparous and pre-pubescent (Strier 1991a; Printes and Strier 1999; Strier and Ziegler 2000). The first documentation of female immigration occurred in 1983, while the first case of a known natal female to emigrate occurred in 1987, when the first of the female infants present in 1982 transferred into the Jaó group. The continuity of the study has permitted us to document the complete reproductive careers of all nulliparous females in the Matão group since 1983, and the onset of the reproductive careers of natal Matão females of known age that have transferred into the other groups in this population (Strier *et al.* 2002; in press).

Female muriquis reproduce approximately every 3 years, with weaning typically beginning during an infant's second year of life (>12 months). Infants maintain close contact with their mothers (Odália-Rímoli 1998), and have experienced unusually high survivorship during their first year of life compared with that of sympatric brown howler monkeys (94% versus 74% in the same 4-year period; Strier *et al*. 2001, but see Strier *et al*. in press).

One of the main thrusts of the long-term study on the Matão group has been monitoring female reproductive condition using non-invasive fecal steroid assays. From these non-invasive methods, it has been possible to document gestation length, which is 7.2 months, and ovarian cycle intervals, which average 21 days (Strier and Ziegler 1997). We have also begun to document the hormonal conditions that appear to affect the resumption of ovarian cycling and conception (or conception failure) in females (Strier and Ziegler 2005).

The long-term study of the Matão group has focused on two major priorities: 1) monitoring the viability of the population, and 2) monitoring the habitat. Both the fecal hormone study and the demography study are contributing to the long-term priority of monitoring the viability of the population.

Population viability

The Matão study group has nearly quadrupled in size over the past 22 years, increasing from the 22 members present in July 1982 to 80 members as of July 2004. The importance of monitoring the population's viability was recognized in the early 1990s, following the first Population Viability Analysis (PVA) that Strier (1993/1994) conducted based on the demo-

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Table 1. Muriqui researchers at the EBC.

Year	Matão Project[a]	Jaó Project[b]	Matão-2 + Nadir Project[c]
2004–05	Danusa Guedes[31a] Janaína F. de Oliveira[30a]	Marcos Tokuda[5b] Ítalo M. Mourthé[4b] Fabiana Couto[3b]	Carla B. Possamai[1c—see 24a]
2003–04	Karynna T. de Souza[29a] Vagner de Souza[28a]	Ítalo M. Mourthé[4b] Fabiana Couto[3b] Janaína Mendonça[6b] Marcos Tokuda[5b]	Carla B. Possamai[1c—see 24a]
2002–03	Fernanda P. Paim[27a] Maria Fernanda F. F. Iurck[26a] Carla B. Possamai[24a]	Vanessa O. Guimarães[2b—see 21a] Ítalo M. Mourthé[4b] Fabiana Couto[3b]	
2001–02	Regiane R. de Oliviera[25a] Carla B. Possamai[24a]	Vanessa O. Guimãraes[2b—see 21a] Cláudio P. Nogueira[1b—see 9a]	
2000–01	José Cassimiro da Silva Jr.[23a] Waldney P. Martins[22a] Vanessa O. Guimarães[21a]		
1999–00	Waldney P. Martins[22a] Vanessa O. Guimarães[21a]		
1998–99	Luiz G. Dias[20a] Cristiane C. Coelho[19a] Cláudio P. Nogueira[9a]		
1997–98	Dennison Carvalho[18a] Nilcemar Bejar[17a]		
1996–97	Andréia S. de Olivera[16a] Laiena T. Dib[15a]		
1995–96	Cláudia G. Costa[14a] William A. Teixeira[11a]		
1994–95	Rodrigo Cambará Printes[13a] Maria Amélia F. Maciel[12a] William A. Teixeira[11a]		
1993–94	Lúcio P. de Oliveira[8a] Cláudio P. Nogueira[9a] Sebastião da Silva R. Neto[10a] Adriana Odália Rímoli[4a]		
1992–93	Cláudio P. Nogueira[9a] Lúcio P. de Oliveira[8a] Ana R. D. de Carvalho[7a]		
1991–92	Paulo Coutinho[6a] Fernanda Neri[5a]		
1990–91	Francisco D. Mendes[2a]		
1989–90	José Rímoli[3a] Adriana Odália Rímoli[4a]		
1988–90	José Rímoli[3a]		
1987–88	José Rímoli[3a]		
1986–87	Francisco D. Mendes[2a]		
1984–85	Karen B. Strier		
1983–84	Karen B. Strier Eduardo M.V. Veado[1a] Gustavo Fonseca		
1982	Karen B. Strier Andrew Young		
1974–81	Célio Valle and colleagues (UFMG)		

[a]Coordinated by KBS since 1985; sponsored by Célio Valle, César Ades, Gustavo Fonseca, and Sérgio L. Mendes.
[b]Coordinated by JPB since 2002; co-advised by KBS.
[c]Coordinated by Carla B. Possamai since 2003; co-advised by Robert J. Young (Professor, PUC-Minas) and KBS.
[1a]UFMG; [2a]USP; [3a]USP; [4a]USP; [5a]UF-Juiz de Fora, later UFMG; [6a]São Paulo, later UFPa; [7a]Taubaté, SP; [8a]UF-Juiz de Fora; [9a]U Guarulhos, later UFMG; [10a]UF-Viçosa; [11a]Belo Horizonte; [12a]UF-Viçosa; [13a]UFRS, later UFMG; [14a]PUC-Minas, later UFPa; [15a]UF-Uberlandia, later UFMG; [16a]Belo Horizonte; [17a]UFMG; [18a]UFMG; [19a]PUC-Minas; [20a]UFMG; [21a]UFRJ, later UFES; [22a]UFMG; [23a]UFMG; [24a]PUC-Curitiba, later PUC-Minas; [25a]UF-Viçosa, later PUC-Minas; [26a]PUC-Curitiba; [27a]UNISINOS-São Leopoldo, RS, later UFRS; [28a]UFES; [29a]PUC-Curitiba; [30a]PUC-Minas; [31a]PUC-Minas; [3b]UFMG; [4b]UFMG; [5b]USP; [6b]PUC-Minas.

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graphic and life history parameters from the first decade of the study.

One of the most important insights to emerge from the PVA was the influence of infant sex ratios on the growth of the Matão group. In fact, infant sex ratios in the Matão group were consistently female-biased in each of the annual birth cohorts from 1982 through 2000, when male births began to outnumber female births. The importance of female numbers to the group's increase in size was also evident from the cumulative number of females that have immigrated into the Matão group relative to natal Matão females that have emigrated. Until the early 1990s, the number of female emigrants was offset by a comparable number of immigrants. By the early 1990s, however, the number of female immigrants began to decline relative to the number of emigrants, raising questions about whether infant sex ratios and survivorship in the rest of the population at the EBC were consistent with those being documented in the Matão group (Strier in press).

The growing disparity between immigrants and emigrants also raised questions about whether the Matão group was serving as a "source" of females in the population, and conversely, whether Matão females were dispersing into a "sink." The need for more information about whether or not the demography of the Matão group was representative of the rest of the EBC population was a major motivating factor behind the census that Strier and Sérgio Mendes organized in 1999, which involved some 15 participants, all of whom were students and colleagues who had previously conducted research on muriquis and other primates at the EBC, and were therefore familiar with the forest (Strier *et al*. 1999).

The results of the census confirmed the persistence of three muriqui groups, and demonstrated that roughly half of the EBC muriqui population resided in Jaó. Several Matão females that had emigrated to Jaó were re-sighted, some carrying infants. These findings clearly demonstrated the importance of initiating research on the Jaó group.

Fortuitously, Dr. Alan Dixson, then Director of the Center of Research for Endangered Species (CRES) at the Zoological Society of San Diego, contacted KBS for recommendations for the Millennium Post-Doctoral program that he had been instrumental in establishing there. The program has been responsible for bringing JPB into the project, and thus providing both the funding and the expertise needed to expand the scope of the MPC. Initially, JPB began working with two recent students from the Matão project, both of whom could identify familiar Matão females that had recently transferred into Jaó, and could employ the methods of age classifications established from experience with the Matão group to provide informed estimates on the ages of all immature members of the Jaó group.

In 2003, with some initial support from KBS' funds, and then supported with her own grants from the Rufford Foundation, the Primate Action Fund of CI, and the Primate Society of Great Britain, Carla de Borba Possamai initiated systematic studies of the M2 group and what had by then become the fully established Nadir group. As a result, the entire population of northern muriquis is now being monitored, with all individuals recognized by their natural markings and demographic records maintained on a continuous basis.

Continued monitoring of all four of the muriqui groups at the EBC now permit us to obtain accurate counts of their size, which are updated on a monthly basis. As of 31 July 2004, there were 226 individuals known in this population, distributed across the four groups. All of the groups have similar age-sex class compositions, suggesting that the long-term demographic data from the Matão group is representative of the demographic history of the larger population before our population-wide monitoring began.

The population-wide demographic monitoring has also made it possible to evaluate the status of the entire population for the first time. For example, 80% of the 25 infants born in the population in 2003 survived to 12 months, and roughly one-third of all adult females were carrying infants as of July 2004. Although the population-wide rate of first year survivorship in 2003 is lower than rates documented in the Matão group in prior years (Strier *et al*. 2001), the percentage of adult females carrying yearlings in the population is consistent with predictions based on the 3-year birth interval documented in the Matão group since its onset (Strier *et al*. 2004, in press).

Available habitat

The second long-term priority of the MPC has been to study the relationship between the muriquis and their forest habitat at EBC. In Strier's (1993/1994) PVA simulations of the population based on the Matão group a decade ago, it was clear that increasing the habitat available to muriquis would have a positive impact on the size of the group, and by inference, on the population's size within about 20 years. The time lag in response is due to the late age (8–9 years) at which muriqui females give birth to their first infants (Strier 1991a). Indeed, the reliability of these simulations is implied by the fact that the size of the Matão group is now exactly what it was projected to be in the PVA simulations run a decade ago (Fig. 2).

The EBC muriqui population density is one of the highest reported for muriquis (Strier and Fonseca 1996/1997). High population density in a disturbed secondary forest such as the one at the EBC is, at first, a somewhat puzzling fact. By the early 1990s, however, it was clear that muriquis routinely exploited vegetation growing at the edges of the forest, and that higher densities of muriquis occurred in disturbed forests than in undisturbed forests (e.g., Stallings and Robinson 1991; Pinto *et al*. 1993; Strier and Fonseca 1996/1997). One of the reasons for this is that the largest part of the muriquis' annual diet is composed of mature and young leaves (51%; Strier 1991b). Leaves are particularly important food items at the beginning of the dry season, when fruits and flowers, which comprise 32% and 11% of the diet, respectively, are scarcer (Strier 1991b). It has been proposed that primates that include substantial amounts of leaves in their diet may be favored by habitat disturbance if that means an increase in

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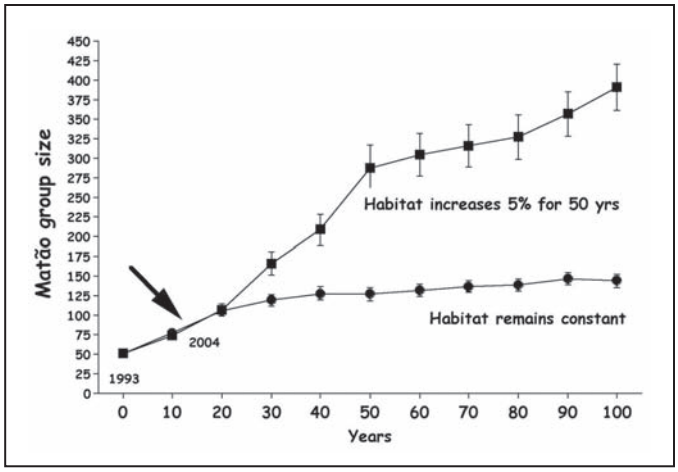


Figure 2. Effect of habitat availability on group size. From Strier (1993/1994), based on Vortex simulations conducted with input variables derived from the Matão group as of 1993, with no deleterious effects of inbreeding and female age at first reproduction = 11 years. Note that the size of the Matão group (arrow, as of 31 July 2004) is exactly what the simulations projected more than a decade ago, and that the effects of habitat availability on muriqui numbers were not expected to be evident until after 2013, or more than 20 years into the simulation. Accurate assessments of rates of habitat expansion are not presently available.

the availability of more palatable and more nutritious leaves (Johns and Skorupa 1987; Pinto *et al*. 1993; Ganzhorn 1995; Strier 2000). Rapidly growing pioneer plants, characteristic of secondary forests, may be more palatable because these plants contain fewer chemical and structural defenses (Coley *et al*. 1985; Ganzhorn 1995).

New ecological studies being conducted in the Jaó area indicate that the leaves of several *Miconia* species were among the top-ranking food items. *Miconia* is a typical plant of secondary growth and disturbed areas (Boubli *et al*. 2004, in prep.). However, as in Strier's (1991b) previous study on the Matão group, fruits, when available, are still the most sought after food items (Boubli *et al*. in prep.). Thus, we believe that one of the reasons muriquis are doing so well in the disturbed secondary forest at the EBC is that they are opportunistic in their diet, feeding on abundant food items such as the leaves of pioneer species in the genera *Miconia* and *Cecropia*. In terms of fruits, muriquis do not appear to select fruits of any particular dispersion syndrome. Instead, they consume a large variety of fruits, ranging from tiny seeded understorey fruits (e.g., *Psychotria* spp., *Miconia* spp.) that are usually preferred by birds or bats, to large seeded and hard-shelled fruits (e.g., *Spondias venulosa* and *Carpotroche brasiliensis*), usually preferred by parrots and large rodents (Boubli *et al*. in prep.).

A 15-year comparison of the Matão group's ranging patterns demonstrated an increase in the size of this group's home range corresponding to the increase in the size of the group, but no increase in the length of the group's day range (Dias and Strier 2003). This suggests that although larger groups use larger food supply areas, they do not travel farther each day to obtain sufficient food. However, there are other indications that we are now entering a critical period in terms of the estimated carrying capacity for muriquis at the EBC. Specifically, according to the original PVA estimates, the degree to which the area of suitable habitat can be increased will determine the degree to which the muriqui population can continue to grow (Strier 1993/1994). Thus, in addition to monitoring the demography of the entire muriqui population, documenting the ecology of the EBC forest and its capacity to sustain a viable population of muriquis has remained a priority.

The Forest of the EBC

With the initiation of the Jaó project, we have been carrying out a detailed ecological study of the EBC forest, which includes systematic monitoring of regeneration rates and plant part productivity. The main objective of this new endeavor has been to study the regeneration process in what is mostly secondary forest at the EBC, as well as to record any long-term changes in primary productivity that occur as the forest matures.

Floristic inventory

As a first step toward studying forest regeneration, we carried out a detailed floristic inventory of the area. In October 2001, six botanical plots measuring 500 × 10 m were laid out at randomly selected locations within the study area, totaling 3 ha. Within each plot, all trees ≥10 cm Diameter at Breast Height (DBH) were marked with aluminum numbered tags and had their DBH measured. In a subsample of the plots, totaling 1 ha, all trees ≤5 cm DBH were also tagged. Tagged trees were identified in the field by local experts and, to confirm field identification, voucher specimens were sent to specialists at the herbarium of the Federal University of Minas Gerais, Belo Horizonte.

Our data show that the EBC forest is relatively diverse in tree species, with an average of 150 species ≥10 cm DBH per ha and around 35 families represented. Data from several 1-ha plots throughout the neotropics reveal that the number of tree species ≥10 cm DBH varies from 60 to 150 and, in very rich areas such as western Amazonia, this figure goes up to 200–300 species (Richards 1996; Gentry 1990). In terms of floristic diversity, therefore, the EBC forest falls at the upper end throughout the Neotropics, although not matching the richest Amazonian areas, such as Pico de Neblina.

Leguminosae (mostly Mimosoideae) trees dominate the EBC sample, followed by Euphorbiaceae and Flacourtiaceae. The most abundant tree species in our sample is *Mabea fistulifera* (Euphorbiaceae), representing 12% of the marked trees in the plots. This species dominates the tops of the hills, forming monodominant patches of high stem density. Another abundant species is *Pseudopiptadenia contorta* (Mimosoideae), which contributes 6% of the individuals.

Average DBH for the 1,405 trees ≥10 cm DBH that had been tagged in the botanical plots in 2001 was 18 ± 13.24 cm, with most trees falling within the 10–20 cm DBH size class (Fig. 3). This DBH distribution at the EBC is comparable to several Amazonian sites (Gentry 1990). Average DBH was

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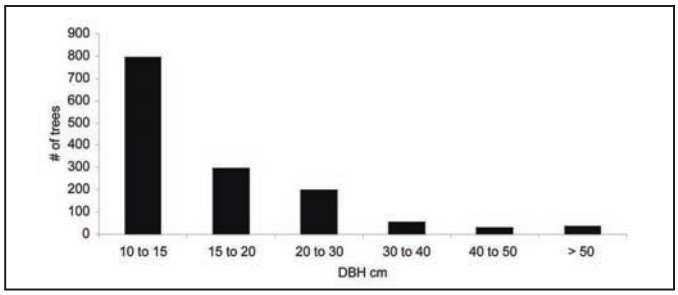


Figure 3. DBH distribution of trees ≥10 cm DBH in a 3 ha botanical sample of the EBC forest (Mean ± SD = 18.00 ± 13.24, N = 1,405).

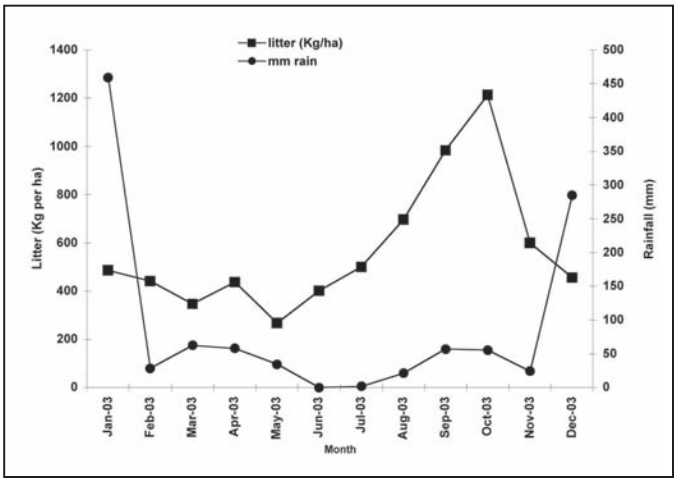


Figure 4. Primary productivity and rainfall. Productivity is measured by the amount of forest litter (leaves, flowers, fruits, twigs) collected in 100 × 1–m² litter traps in 2003.

smaller, however, due to the lack of large trees. There was no significant difference in the measured DBH of trees from 2001 to 2002 (t = 1.9, df = 1,370, $p = 0.06$), and the average DBH increment for the year was 0.4 ± 1.1 cm (n = 1,405).

Demography, phenology, and primary productivity

To understand the patterns of intra- and inter-annual variation in the availability of plant parts, we have also been gathering monthly phenological data on 1,753 of the 3,090 trees ≥10 cm DBH and their 1,253 associated lianas in the botanical plots, and on an additional 691 trees ≥5 cm DBH. Primary productivity has been measured by weighing forest litter collected in 100 × 1–m² litter traps placed at 20-m intervals in the botanical plots each month. We are also studying litter decomposition. In addition, since 2002, an annual census of all trees within the plots has been conducted to record mortality of marked trees, diameter increments, and finally to count and tag trees that recruited to the ≥5 and ≥10 cm DBH size classes.

In terms of primary productivity, we recorded a total of 6,828 kg of litter per ha in 2003 (Fig. 4). This is an intermediate value when compared with other tropical forests in the world (Proctor 1983; Boubli *et al*. 2004). The mortality rate for trees during the first 12-month study period was 2.4%, with 34 trees dying in the period of October 2001–October 2002 (Boubli *et al*. 2003).

Tree mortality rate at EBC is high when compared with other tropical rainforest sites around the globe (Phillips *et al*. 1994). In an analysis of 25 rainforest sites, Phillips *et al*. (1994) found that most sites had mortality rates of less than 2% per year, and only two floodplain areas had similar mortality rates to those found at the EBC. With 79 newly recruited trees (i.e., trees that grew to 10 cm DBH) in 2002 (or 5.6% of the total sample), the EBC forest showed a considerable recruitment rate when compared with other tropical rainforests, which usually range from about 1% to 3% per year (Phillips *et al.* 1994, Boubli *et al.* 2003).

Compared with other tropical rainforests worldwide, therefore, mortality and recruitment at the EBC have been found to be relatively high. Given that the forest at EBC has suffered the impact of selective logging, fire, and agriculture encroachment, we believe that its high rate of turnover may be a response to past disturbance regimes as it undergoes natural maturation, and not necessarily correlated with its high primary productivity. The continuation of this study will be necessary to distinguish between these two processes.

Seasonality

Rainfall at EBC has been monitored for more than 20 years, and the pattern recorded to date is of a highly uneven distribution of precipitation within the annual cycle, with most rainfall occuring between October and March, and a pronounced dry season from June through August (Strier *et al*. 2001). Interannual variation is not pronounced, although there have been years when rainfall exceeded the average by more than 50% (Strier 1999). The forest at EBC is semi-deciduous, and most trees shed their leaves toward the end of the dry season (Fig. 4). Consistent with earlier accounts (Strier 1991b), the production of reproductive plant parts appears to follow the seasonal rhythm with two peaks of flowering and fruiting a year, roughly 5 to 6 months apart (Fig. 5; Boubli *et al.* 2002, in prep.). Inter-annual variation in the height of flowering and fruiting peaks has also been recorded, but we are not expecting to correlate this with rainfall as we are investigating a long-term, supra-annual process. More data will tease apart the natural regeneration of a disturbed forest from the turnover rates of a mature forest.

Regeneration, connectivity, and community involvement

It was evident from the original PVA (Strier 1993/1994) that the continued growth and expansion of the EBC muriqui population, and thus, its long-term survival, is dependent on the availability of sufficient habitat. The EBC is an island surrounded by open pastures, and the muriquis' future here depends on the creation of new suitable forest habitat. In response to this need, the director of the field station, Eduardo Marcelino Veado, initiated a preliminary evaluation of the farming community surrounding the EBC forest in 1995. With the help of a consulting firm, interviews were conducted with neighboring landowners to begin to assess their interest in collaborating in the conservation of muriquis. Initially, priority focused on landowners whose forests were continuous

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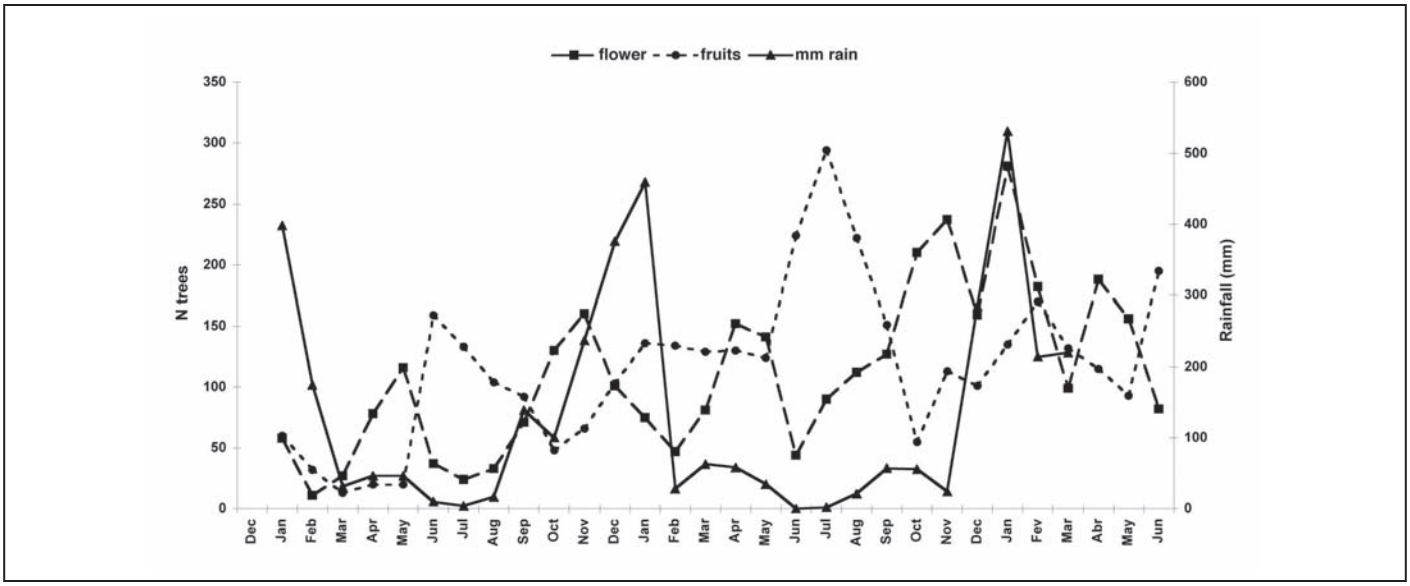


Figure 5. Multi-year (2002–2003–2004) phenology of trees ≥10 cm DBH in 3 ha at EBC.

with that of the EBC, and into which the Matão group was already making forays.

Efforts to develop reforestation projects have been underway ever since, with the ultimate goal of establishing a fauna corridor that will connect the EBC to neighboring forests and, ultimately, to a reserve near the city of Ipanema, Minas Gerais, some 20 km to the south. To achieve this goal, Eduardo Veado (2004) initiated a nursery project in 1997, which was expanded in 2003 as part of a new project, entitled 'Muriqui Conservação," funded by the Project for the Conservation and Sustainable Use of Brazilian Biological Diversity (*Projeto de Conservação e Utilização Sustentável de Diversidade Biológica Brasileira—PROBIO*) of the Brazilian Ministry of Environment and The Global Environment Fund (GEF), and coordinated by JPB. The plant nursery currently has the capacity to produce 200,000 saplings per year. In addition, to better understand the natural process of habitat recovery in the area, several regeneration experiments have been established to find the most effective way of bringing forest back into areas that had been converted to pasture. Experimental treatments include the placement of perches for birds that will bring seeds from surrounding forest, translocation of seed banks from surrounding forest fragments, and fences to exclude grazing by cattle. We know from long-term observations that pastures that had been allowed to regenerate through natural processes recovered sufficiently to be exploited by all four primates, including muriquis, within about 10 years (Strier and Mendes 2003). Our aim is to facilitate and accelerate the process.

A second major initiative to increase the extent of available habitat was also launched in 2003 under the Muriqui Conservação PROBIO project, and already it is showing promising signs of success. It focuses on the social environment for conservation, and has been executed by Francisco Pontual with assistance from Janaína Mendonça and Antônio Bragança. Following on from the initial survey of the attitudes of the neighboring landowners and their views concerning the conservation of the forest remnants within their properties, it was decided that the best way to approach the community on these matters was through a mechanism familiar to them, known as "mutirão," in which community members volunteer to work together on a project of communal interest, such as the building of a road, a bridge, or a chapel. Consistent with this practice, neighboring farmers were invited to attend technical courses on ranching and bovine nutrition provided by SENAR/MG, one of the project's partner institutions, and during these courses, also participate in our conservation "mutirão."

By the end of November 2004, more than 100 people had participated in 10 SENAR/MG courses, all with great enthusiasm and excellent community responsiveness. The relaxed group dynamics that characterized these courses provided unique opportunities to explain some important conservation goals, such as the fencing and recovery of the springs, creeks, and forests borders, which will help increase the standing water supply in the region as well. Many farmers had already noticed that local water sources are drying out, so they quickly understood that the immediate protection and recovery of degraded areas along the creeks could be of fundamental importance, not only for the expansion of habitat for the muriquis, but also for their own livelihoods. Once both the conservationists and farmers realized that they shared common goals such as these, the conservation "mutirão" could be conducted in a successful and mutually informative way. The Muriqui Conservação project is already fencing and protecting about 30 ha of private land owned by the local farmers that have joined the reforestation effort. Some 6,000 seedlings will be transplanted to help in the recovery pasture, and at least a dozen of the most influential local land owners are willing to protect more than just their water sources.

With their collaboration, we hope to not only to increase the habitat available for EBC muriquis but reduce as such the

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possibilities of their demise due to natural or human-induced disasters such as fires and disease. Although presently thriving, the EBC muriqui population is still small enough to be highly vulnerable to extinction due to these kinds of catastrophic events. Expanding the available habitat will permit this population to continue to grow and increase its long-term viability.

Future Directions

Until recently, the EBC muriqui population was thought to represent more than 40% of the species and was considered to be the largest and most viable population. Discoveries of other populations of northern muriquis in Minas Gerais include two that inhabit protected areas, and may be larger than the population at the EBC, and therefore promising for the future of the species (Dias *et al.* 2005). These discoveries have been accompanied by new research initiatives, which will soon be providing invaluable comparative perspectives on the behavior and ecology of the EBC muriquis. The long-term and ongoing research and conservation efforts at the EBC have been helping to provide training opportunities for young scientists, as well as insights into the basic biology and ecology of northern muriquis. The value of these efforts will continue to increase as comparative insights from other forests and populations become available, and we can pool our knowledge about muriquis and their habitats to ensure their future survival.

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