Simian Malaria at Two Sites in the Brazilian Amazon. I - The Infection Rates of *Plasmodium brasilianum* in Non-human Primates

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The parasite that causes simian malaria in the Brazilian Amazon, Plasmodium brasilianum, *is infective to man. In this region, where humans live within and in close proximity to the forest, it was suspected that this parasite could be the cause of a zoonosis. A study was performed in the areas surrounding two hydroelectric plants in the Amazon, Balbina and Samuel, aiming at determining the zoonotic potential of this parasite.* P. brasilianum *was detected in, respectively, 15.8% and 9.9% of 126 and 252 primates belonging to seven and eight species examined from Balbina and Samuel. The highest malaria infection rates were found among the red-howler monkey* Alouatta seniculus straminea *(32.3%), the bearded-saki* Chiropotes satanas chiropotes *(50%) and the spider-monkey* Ateles paniscus paniscus *(2[1+]) from Balbina and in the squirrel-monkey* Saimiri ustus *(21%) and the black-faced-spider-monkey* Ateles paniscus chamek *(28.6%) from Samuel.*

Key words: simian malaria - *Plasmodium brasilianum* - *Plasmodium simium* - Primates - Cebiadae - Callithricidae

Simian malaria parasites have been described since the first decade of this century, when the practice of importing exotic animals, including primates, to be exhibited in circus and zoos in Europe was in vogue. The first New World's simian plasmodium, *Plasmodium brasilianum* Gonder and Berenberg-Gossler, 1908, was described from the blood of a bald-uakari (*Cacajao calvus*) acquired in the Brazilian Amazon. The other neotropical non-human malaria parasite, *P. simium* Fonseca, 1951, was identified from southern Brazil, in a howler-monkey (*Alouatta fusca*). These two simian parasites are very different, but both are infective to man. *P. brasilianum* is a quartan malaria parasite, practically indistinguishable from the human *P. malariae* (Garnham et al. 1963, Collins et al. 1969b, Cochrane et al. 1985, Lal et al. 1988), of which it may be synonimous (Coatney et al. 1972). *P. simium* is a tertian plasmodium, similar to *P. vivax* and *P. ovale* (Garnham 1966, Collins et al. 1969a). Goldman et al. (1993) argued that *P. simium* might be a strain of *P. vivax*. *P. brasilianum* is widely distributed among the simians (46 species) from Panama, Colombia, Peru, Venezuela and Brazil, while *P. simium* is restricted to two monkey species from southern and southeastern Brazil.

There has been early evidence that some simian malaria parasites could experimentally infect man. In 1960, humans were accidentally infected at a laboratory, by anopheline bite, with a strain of *P. cynomolgi*, an Asian malaria of *M. irus* (Eyles et al. 1960). Nevertheless, two episodes occured in nature, with two distinct simian parasites: one person infected in Malaysia, by *P. knowlesi*, a parasite of *M. irus* and *M. nemestrina* (Chin et al. 1965) and another in southeastern Brazil, by *P. simium* (Deane et al. 1966a). On other occasions, human infections by simian malaria were suspected (Coatney 1971, Sulzer et al. 1975, Kalra 1980).

No other human malaria cases of proved simian origin has been reported in Malaysia and southeastern Brazil. There was no evidence that monkey malaria demonstrated epidemiological importance to the indigenous population in those places since the simian and human malarias cycles are aparently independent (Warren & Wharton 1963, Deane et al. 1966b, Deane 1969, 1976, Warren et al. 1970, Coatney et al. 1972).

The place where that Brazilian episode of human infection of simian malaria was contracted, Cantareira forest, is highly enzootic (about 60% of howler-monkeys are infected with *Plasmodium*). The patient was a forest guard who used to conduct most of the anopheline captures at the tree canopy. There had never been human ma-

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laria in this area, where the guard was born and lived all of his life. This was an isolated event, like the Asian one, which occurred under special conditions, when a human introduced himself into the habitat of both mosquito and simian hosts of the malaria parasites.

Why did the individual living in a holoenzootic area acquire monkey malaria in that particular episode? The simian malaria vector in Cantareira forest well as in other areas in southeastern Brasil is *Anopheles cruzi*, an acrodendrophilic anopheline (99% collected at the tree canopy) (Deane 1967, Deane et al. 1970). This marked preference of *An. cruzi* for the upper forest canopy is certainly the barrier that restricts the malaria infection to monkeys in that area, even though simian malaria parasites are infective to man. The forest guard was infected only when he entered the holoenzootic upper forest canopy. It seems that the acrodendrophilic behaviour of *An. cruzi* does not allow for transmission of simian malaria to humans. If that behavioral barrier were surmountable, i.e., in case the vector attacked frequently in both environments - near the ground and at the tree canopy, could the simian malaria be transmitted to humans in Brazil?

P. brasilianum is widely disseminated in the Amazon Basin, where *An. cruzi* is absent and the vector remains unknown (Deane et al. 1968a, 1971, Almeida & Deane 1970, Ferreira Neto et al. 1970, Deane & Ferreira Neto 1973, Deane 1976). In the Amazon, where indians, miners, wood-choppers, rubber-gatherers and fishermen live in close proximity to or within the forest, it was suspected that *P. brasilianum* could be the cause of a zoonosis. This is dependent upon the simian malaria vector behavior, whether it activly feeds on monkeys, at the tree canopy, and also people on the ground.

These assumptions were emphasized when Arruda et al. (1989) verified that a high proportion of indians, miners and immigrants in the Amazon had antibodies against sporozoites and blood stages of *P. brasilianum/malariae*, although corresponding parasites were not detected in their blood films. Besides, Arruda et al. (1989) observed that all pets and wild monkeys examined in some of those tribes had antibodies against blood stages of *P. brasilianum/malariae*. Examining 755 *An. darlingi* Root, 1926 collected in some of the tribes, the same authors found three specimens positive for *P. brasilianum/malariae* circumsporozoite antigens. Based in this information it was speculated that *An. darlingi* is the vector of both the human and the simian quartan malarias in those settlements.

Nevertheless, it is necessary to determine the zoonotic potential of *P. brasilianum* in the Amazon, i.e., (1) to study mainly its sylvan cycle, (2) identify the vector, (3) determine vector blood feeding behaviour of biting regularly infected monkeys and humans inside the jungle or in the surrounding areas, (4) know the epidemiological importance of human transmission of this parasite and its threat to the anti-malaria campaigns and public health.

A study was performed in areas around two hydroelectric plants in the Brazilian Amazon aiming at to determine the potential for transmission of simian malaria caused by *P. brasilianum* to humans, based primarily on parasitological surveys among monkeys and on the distribution and behavior of the anopheline vectors.

The study comprised three phases: (1) determine malaria prevalence among the non-human primates in each area, (2) conduct mosquito captures and observations on the ecology and behavior of the potential vectors and (3) examine the caught anophelines for detection of natural infection of the quartan malaria parasites.

The present paper consists of the description of the studied areas and the search for simian malaria parasite infections. The anopheline survey will appear elsewhere.

METHODOLOGY

Studied areas - The study was carried out near two hydroelectric plants constructed on two rivers, on each side of the Amazon Basin: Balbina, on the Uatumã River, a tributary of the left margin of the Amazonas River, State of Amazonas (1°55'S 59°28'W) and Samuel, on the Jamari River, an affluent of the Madeira river, which flows into the right margin of the Amazonas River, State of Rondônia (8°10'S 62°29'W), Brazil (Fig. 1).

After the construction of the hydroelectric plants, a proportion of the jungle around each reservoir was selected as a forest reservation, where nearly all observations reported here and in the following papers on both the simian malaria and the anophelines, were performed.

The Balbina dam was built at a site where formerly there was a waterfall (Cachoeira Balbina), surrounded by dense forest. Only one person lived permanently at Cachoeira Balbina, while six rubber-tree tapers and nut collectors used to settle temporarily at the margins of Uatumã River nearby. During the construction these settlers were moved down-river (Chagas et al. 1982), while thousands of workers were settled a few kilometers from the dam site, starting the city of Balbina (9,300 inhabitants, 1985).

Balbina is at a low elevation: the dam and the city are located at 34m and 170m above sea level, respectively. The local relief is slightly undulated and the land is extremely poor, not favorable for agriculture. The Uatumã river and its tributaries are black water rivers, i.e. acidic and nutrient poor. The climate is tropical, warm and humid (annual rainfall near 2,262mm; mean temperature

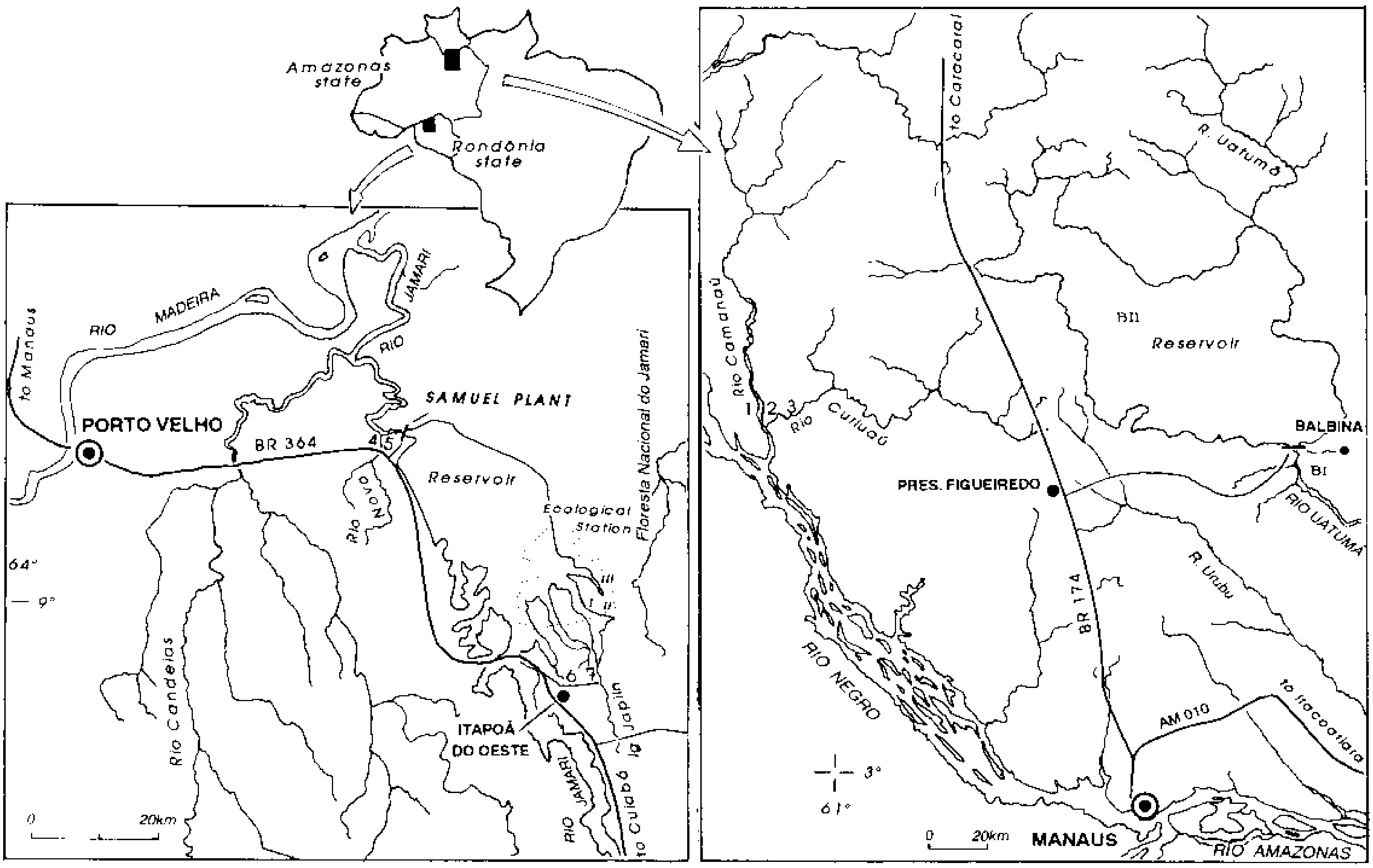

Fig. 1: localities visited and sites where simian malaria and anophelines were surveyed in the States of Amazonas and Rondônia, Brazil. Indian settlements: 1, Aldeia Maré; 2, Aldeia Cacau; 3, Aldeia Curiuaú. 4, Boca do Rio Novo. 5, Caboclo. 6,7, Estrada do Japiim, road. BI, Base I, platform. BII, Base II. I-III, platforms.

ranges from 22°C to 36°C; mean monthly RH around 82%) (Eletronorte 1989, 1992).

The territory of one indian tribe, Waimiri-Atroari, is located within the area of influence of the Balbina reservoir. Three settlements of these indians were visited in this survey: Cacau, Maré and Curiuaú, and the descriptions and data on malaria will appear elsewhere.

The Samuel hydroelectric plant was built on the rapids on the Jamari river, at the village of Cachoeira Samuel, whose inhabitants were subsequently moved 50km west. As opposed to Balbina, neither borough nor city was settled near the dam.

The Jamari valley elevations ranges between 80-200m above sea level. The land being very propitious for agriculture. The water of the Jamari river and its affluents is nutrient rich, carries a high sediment and has a neutral pH. In Samuel, the climate is equatorial, warm and humid, like Balbina. The annual rainfall ranges from 2,000mm to 2,900mm; the temperature usually varies from 20°C to 32°C and RH ranges from 74% to 90% (Lisboa 1990, Eletronorte 1990).

Almost 70% of the area around Balbina and Samuel are covered by a dense and tall humid forest, called "terra firme" forest. It is constituted mostly of medium-sized and tall leafy trees, with canopies at 5-15m and 25-30m, respectively.

Capture and examination of non-human primates - After the constructuion of both dams, primates were captured in the forests of the dam reservoir flooded plains and transferred to dry portions of the bordering jungle, i.e., to the forest reservations. Blood samples were obtained from some of these primates before their resettlement (from May 16 to 20 and September 6 to 30, 1988, in Balbina, and from February 17 to March, 28, 1989, in Samuel). In 1989, some of the squirrel-monkeys captured in both areas were transported to the Oswaldo Cruz Foundation, in Rio de Janeiro, for breeding purposes, where they were subsequently examined. Blood was obtained from a slight incision performed at the primates' ear and the exam carried out through Giemsa stained thick and thin blood smears. At least one whole thick blood film was examined before considering the animal negative. Parasitemia was not measured.

The nomenclature and systematics of the primates used here are those adopted by Coimbra Filho (1990), Hershkovitz (1983, 1984, 1985, 1987, 1988), Vivo (1985) and Konstant et al. (1985).

RESULTS

Primates from Balbina - A total of 1,919 non-human primates belonging to eight species were captured in Balbina. The most common species was the red-howler-monkey *A. s. straminea* (69.7%), followed by far by the bearded saki *C. s.*

chiropotes (9.3%), the capuchin *Cebus apella apella* (7.6%), the white-faced-saki *Pithecia pithecia pithecia* (6%), and the squirrel-monkey *Saimiri sciureus sciureus* (4%) (Fig. 2a).

The search for *Plasmodium* included 126 primates belonging to seven out of the eight species detected in Balbina (Table I; Fig. 2b). The squirrel-monkey *S. s. sciureus* and the red-howler-monkey *A. s. straminea* were the most frequently examined, respectively, 48% and 24.6% of the total. *P. brasilianum* was the only malaria parasite found infecting 20 monkeys (15.8%) distributed among five species (Table I). All infections were among Cebidae monkeys and high infection rates were obtained in *A. s. straminea* (32.3%), *A. p. paniscus* and *C. s. chiropotes* (50%). Only 8.2% and 12.5% of the squirrel-monkeys and sakis were positive, respectively.

Primates from Samuel - In Samuel, 1,806 non-human primates were captured. The most common species were the squirrel-monkey *S. ustus* (27.7%), the saki *P. irrorata irrorata* (20.4%), the titi *Callicebus brunneus* (19.3%) and the capuchin *C. a. apella* (11.5%). Four other species were caught less frequently at Samuel (Fig. 3a).

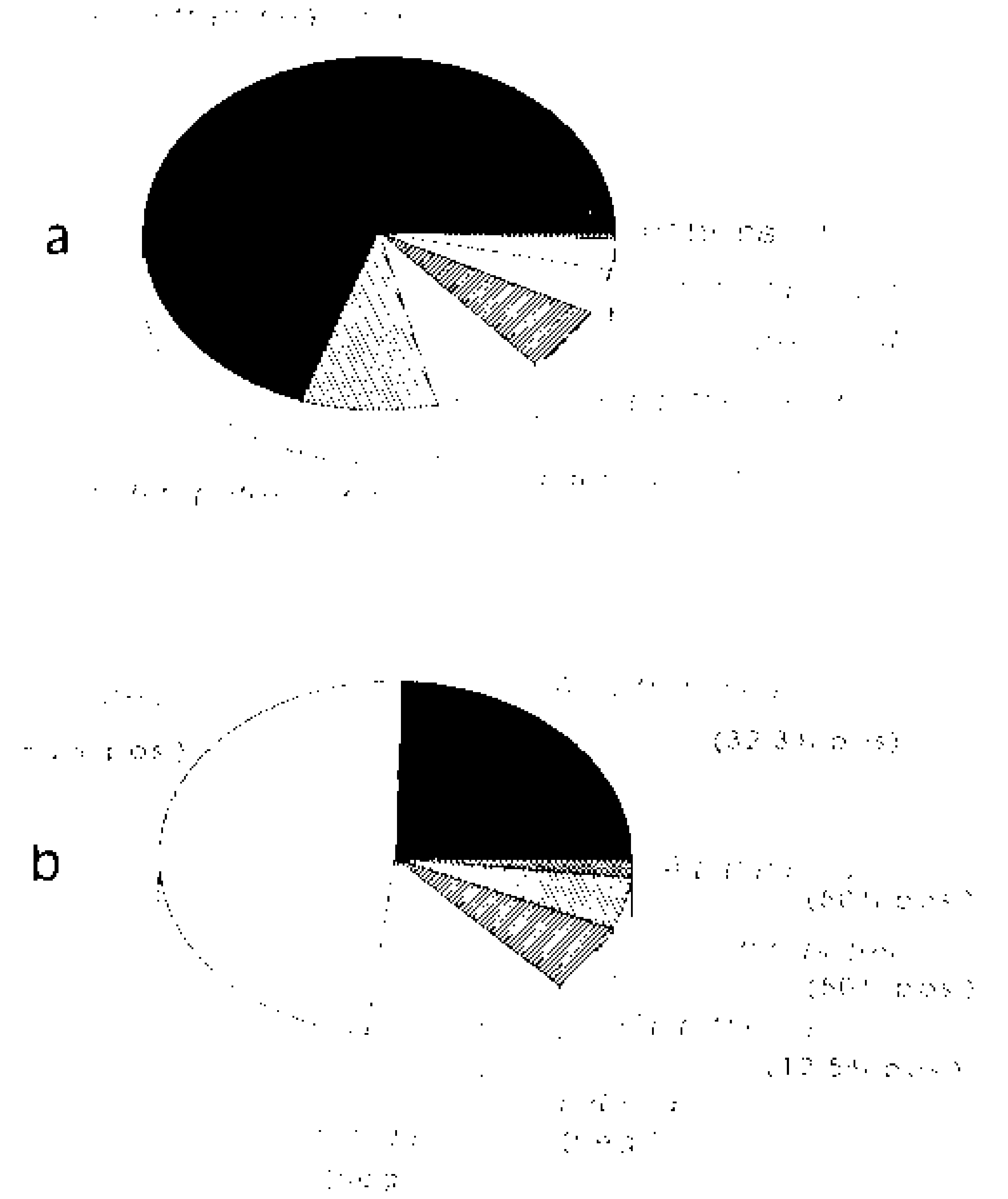

Fig. 2: percentage of primate species captured (a) in Balbina, and (b) examined for simian malaria parasites. Percentage of primates species examined positive for *Plasmodium brasilianum* in parenthesis.

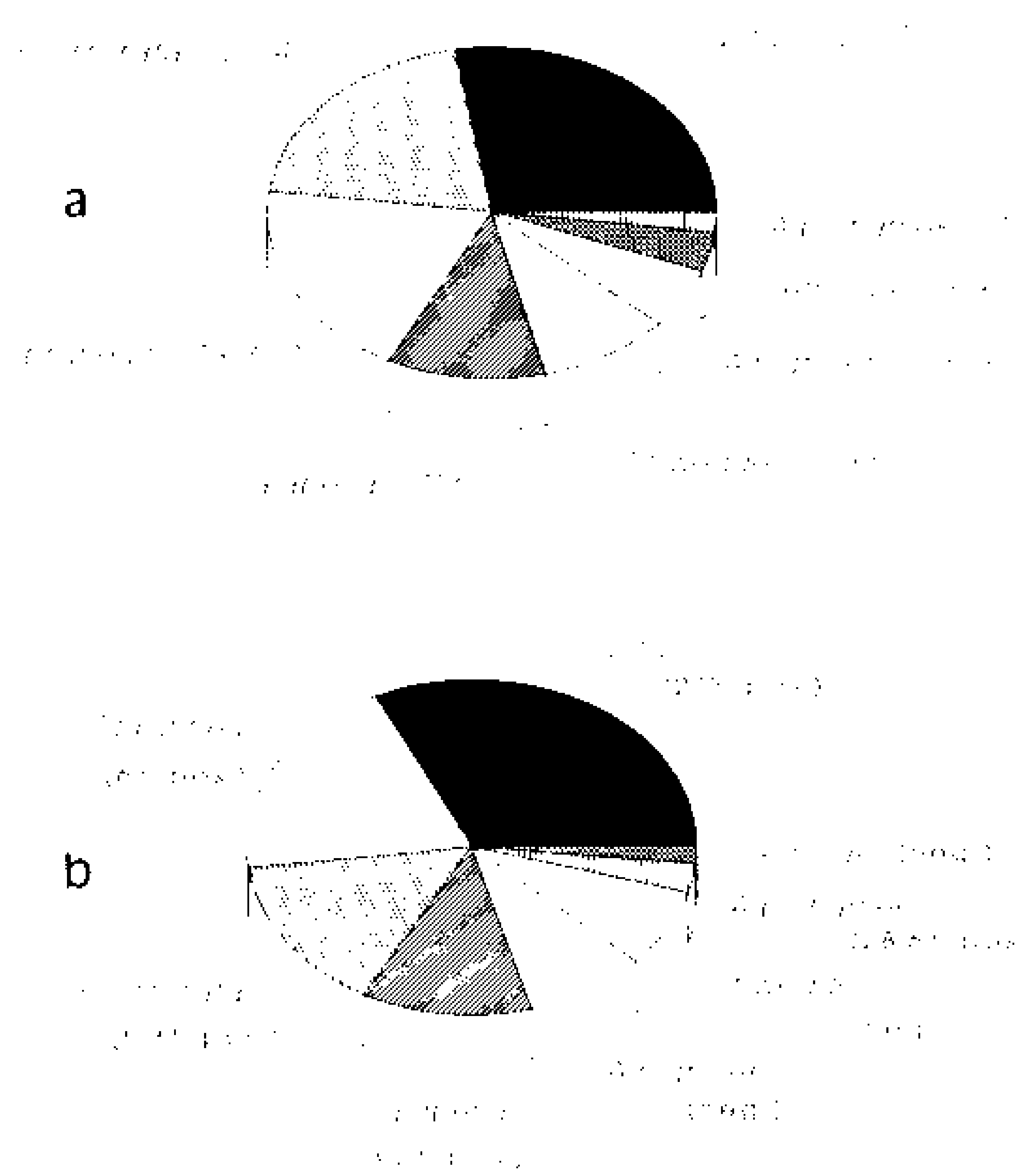

Fig. 3: percentage of primate species captured (a) in Samuel, and (b) examined for simian malaria parasites. Percentage of primates species examined positive for *Plasmodium brasilianum* in parenthesis.

TABLE I

Simian malaria in non-human primates captured in Balbina, State of Amazonas, in May and September, 1988. Number of primates examined and positive for *Plasmodium brasilianum*

Primate species	Common name	Number primates examined (positive)		Percent positive
Cebidae				
Alouatta seniculus straminea (Humboldt, 1812)	Red-howler-monkey	31	(10)	32.3
Ateles paniscus paniscus (Linnaeus, 1758)	Spider-monkey	2	(1)	50
Cebus apella apella (Linnaeus, 1758)	Capuchin	8		-
Chiropotes satanas chiropotes (Humboldt, 1811)	Bearded-saki	6	(3)	50
Pithecia pithecia pithecia (Linnaeus, 1766)	White-faced-saki	8	(1)	12.5
Saimiri sciureus sciureus (Linnaeus, 1758)	Squirrel-monkey	61	(5)	8.2
Callithricidae				
Saguinus midas midas (Linnaeus, 1758)	Tamarin	10		-
Total		126	(20)	15.8

The number of primates examined at Samuel was twice that of Balbina, i.e., 232 animals belonging to all eight species found in the local forest. *S. ustus*, *C. brunneus* and *P. i. irrorata* were the most frequently examined (Fig. 3b).

A total of 25 animals (9.9%) belonging to five species was found to be infected with *P. brasilianum* at Samuel (Table II). The parasite was most frequently detected in two species: *A. p. chamek* (26.6%) and *S. ustus* (21%) (Fig. 3b). Only 6% of the local titis, 5.3% of the sakis and 3% of the capuchins were infected. All examined tamarins and marmosets - *Saguinus fuscicollis weddelli* and *Callithrix emiliae* - and night-monkeys, provisionally called *Aotus nigriceps* (Pieckzarka et al. 1993) were negative.

DISCUSSION

According to Deane (1992) simian malaria in Brazil is present or more frequent in primary tall, humid forests, populated of susceptible Cebidae monkeys, especially those belonging to genera *Alouatta* and *Ateles*, while it is infrequently observed in drier, bushy regions, with secondary or low and little dense vegetation, propitious mostly to Callitrichidae and less susceptible Cebidae species. An example of the first situation is Horto da Cantareira, São Paulo, where more than 60% of the local primates are infected, thus making it a holoenzootic area. On the contrary, simian malaria was not found in numerous primates examined in the northeast States and southeast State of Minas Gerais, which are in the second situation. In intermediate situations, which may represent the majority, the infection rate is moderate or low, depending mostly on the constitution of the primate fauna and the existence of an efficient vector. If the primate fauna of such an area includes the susceptible species of genera *Alouatta* or *Ateles* besides the less susceptible ones, simian malaria should be more common there, and vice versa. Besides susceptibility, the considerable body weight and the group size in spider and howler-monkeys seem to favor their contact with the vectors (Davies et al. 1991). More than 30% of the primates have malaria in Guaíba, Joinvile, Santa Leopoldina, Altos das Guaribas and Cabeceira Grande, where species of *Alouatta* are abundant. As the proportion of howler and spider-monkeys decreases, the prevalence of simian malaria diminishes, as in Barreirinha, Porto Mauá, near the Manaus-Itacoatiara road, São José, Sooretama (Deane et al. 1969, Deane 1976), Balbina and Samuel.

The percentage of infected monkeys in Balbina (15.8%) is slightly above the average previously observed for Brazilian Amazon primates (9.7%, Deane 1976; 10.1%, Deane 1992). But it practically coincides with the rates found by the same author in State of Amazonas, i.e. 15-16%.

The red-howler-monkey *A. s. straminea* has been frequently found infected with *P. brasilianum* in the Brazilian Amazon (Deane & Almeida 1967, Deane et al. 1969, Deane & Ferreira-Neto 1969). But only one specimen was detected with *P. brasilianum* outside Brazil: Serrano (1967) examined four howlers from Venezuela, detecting the parasite in the blood of one animal. Our data demonstrate a higher percentage of simian malaria than observed by Deane (1992) in this *Alouatta* species and in the two *Ateles* species from both Balbina and Samuel.

The spider-monkeys were among the most commonly malaria- infected primates in the two studied areas. Other authors have also detected high infection rates in *A. p. paniscus* and *A. p.*

TABLE II

Simian malaria in non-human primates captured in Samuel, State of Rondônia, in February and March, 1989. Number of primates examined and positive for *Plasmodium brasilianum*

Primate species	Common name	Number primates examined	(positive)	Percent positive
Cebidae				
Aotus nigriceps (Dollman, 1909)	Night-monkey	22		-
Ateles paniscus chamek (Humboldt, 1812)	Black-faced-spider-monkey	7	(2)	28.6
Callicebus brunneus (Wagner, 1842)	Titi	50	(3)	6
Cebus apella apella (Linnaeus, 1758)	Capuchin	31	(1)	3.2
Pithecia irrorata irrorata (Gray, 1842)	Saki	38	(2)	5.3
Saimiri ustus (Geoffroy, 1843)	Squirrel-monkey	81	(17)	21
Callithricidae				
Callithrix emiliae (Thomas, 1820)	Marmoset	4		-
Saguinus fuscicollis weddelli (Deville, 1849)	Tamarin	19		-
Total		252	(25)	9.9

TABLE III

Neotropical primates naturally infected with *Plasmodium brasilianum and Plasmodium simium*, by country (BR: Brazil, CO: Colombia, PA: Panama, PE: Peru, VE: Venezuela)

Plasmodia/Primates	BR	CO	PA	PE	VE	References
Plasmodium brasilianum						
Cebidae						
Alouatta belzebuth belzebuth	+					Ferreira Neto et al. (1970), Deane (976), Arruda (1985)
Alouatta belzebuth nigerrima	+					Deane (1976), Arruda (1985)
Alouatta caraya	+					Deane (1976)
Alouatta fusca clamitans	+					Deane (1976)
Alouatta fusca fusca	+					Deane (1976)
Alouatta seniculus seniculus	+					Ferreira Neto and Deane (1973), Arruda (1985)
Alouatta seniculus straminea	+				+	Serrano (1967), Deane (1976), Lourenço-de-Oliveira (1988)
Alouatta villosa palliata			+			Clark (1931)
Alouatta villosa villosa			+			Galindo[a], Porter et al. (1966)
Aotus vociferans				+		Collins et al. (1985)
Ateles belzebuth belzebuth (?)[b]				+		Dunn and Lambrecht (1963)
Ateles fuscipes robustus		+	+			Clark(1931), Porter et al. (1966), Marinkelle and Grose (1968)
Ateles geoffroyi grisescens			+			Galindo[a]
Ateles geoffroyi panamensis			+			Clark (1931), Porter et al. (1966)
Ateles geoffroyi spp.[c]			+			Galindo[a]
Ateles paniscus chamek	+					Deane (1976), Deane et al. (1989)
Ateles paniscus paniscus	+					Deane (1976), Lourenço-de-Oliveira (in this paper)
Brachiteles arachinoides	+					Deane et al. (1968c)
Cacajao calvus	+					Gonder and Berenberg-Gossler(1908), Almeida and Deane(1970)
Cacajao rubicundus rubicundus	+					Ferreira Neto and Deane (1973)
Callicebus brunneus	+					Deane et al. (1989)
Callicebus moloch	+					Deane (1976), Arruda (1985)
Callicebus cupreus ornatus		+				Renjifo and Peidrahita (1949)[d]
Callicebus torquatus torquatus	+					Deane (1976)
Cebus albifrons		+				Dunn and Lambrecht (1963), Marinkelle and Grose (1968), Ayala (1978)
Cebus apella apella	+	+				Dunn and Lambrecht(1963), Marinkelle and Grose (1968), Deane (1976), Deane et al. (1989)
Cebus apella macrocephalus	+					Deane (1976)
Cebus capucinus capucinus		+	+			Clark (1931), Porter et al.(1966) , Marinkelle and Grose (1968)
Cebus capucinus imitator			+			Clark (1931), Galindo[a]
Chiropotes albinasus	+					Deane (1976)
Chiropotes satanas chiropotes	+					Deane (1976), Lourenço-de-Oliveira (in this paper)
Chiropotes satanas satanas	+					Deane (1976), Arruda (1985)
Lagothrix lagothrichia cana	+					Deane (1967)
Lagothrix lagothrichia lagothrichia	+	+		+		Dunn and Lambrecht (1963), Garnham et al. (1963), Deane (1976) Marinkelle and Grose (1968)
Lagothrix lagothrichia poeppigii	+					Ferreira Neto and Deane (1973)
Pithecia irrorata irrorata	+					Lourenço-de-Oliveira (in this paper)
Pithecia monachus spp.(?)[e]	+					Deane (1976)
Pithecia pithecia pithecia	+					Lourenço-de-Oliveira (1988)
Saimiri sciureus albigena		+				Renjifo et al. (1952), Garnham et al. (1963)
Saimiri sciureus macrodon (?)[f]				+		Dunn and Lambrecht (1963)
Saimiri sciureus sciureus	+					Deane (1976), Arruda (1985), Lourenço-de-Oliveira (1988)
Saimiri sciureus spp.(?)[g]		+				Marinkelle and Grose (1968)
Saimiri boliviensis peruviensis	+			+		Ferreira Neto and Deane (1973), Deane (1976), Collins et al. (1990)
Saimiri ustus	+					Deane et al. (1989)
Callithricidae						
Saguinus geoffroyi			+			Baerg (1971)
Saguinus midas niger	+					Arruda (1985)
Plasmodium simium						
Alouatta fusca clamitans	+					Fonseca (1951), Garnham (1966), Deane (1976)
Brachiteles arachinoides	+					Deane et al. (1968c)

[a]: *apud* Dunn and Lambrecht (1963); [b]: *Ateles paniscus* and *Ateles variegatus* of Dunn and Lambrecht(1963); [c]: *Ateles geoffroyi geoffroyi of Galindo* (loc. cit.); [d]: apud Marinkelle and Grose (1968); [e]: Pithecia monachus monachus of Deane (1976); [f]: *Saimiri sciura* of Dunn and Lambrecht(1963); [g]: *Saimiri sciureus* of Marinkelle and Grose (1968).

chameck in Brazil, generally ranging from 25-30% (Deane 1967, 1976, 1992, Deane et al. 1969, Deane & Ferreira-Neto 1969). In Samuel, *A. p. chameck* was mainly observed in dense and non-flooded portions of the forest, on flat or slightly undulated terrain, i.e. "terra firme".

On the other hand, the titis, *C. brunneus*, were most frequently seen in secondary forests, with natural felling of trees and tangled growth of lianas in Samuel. Only 6% of them had malaria (Table II), a percentage close to that found by Deane (1992) for titis in Brazil. Actually most of the titis examined in Latin America have been consistently negative or poorly positive (Marinkelle & Grose 1968, Deane et al. 1969, Arruda 1985). Almost nothing is known on the susceptibility of this primate species to the Old World simian and human plasmodia. Meanwhile, some *Aotus* species are very susceptible to the New World simian malarias and to the human ones (WHO 1987, Collins 1992). But they have always been negative in monkey malaria surveys, except for one exemplar of *A. vociferans* (Spix, 1823), from Peru, from which Collins et al. (1985) isolated the Peruvian I/CDC strain of *P. brasilianum*.

All marmosets and tamarins examined in the present study were negative for the malaria parasite (Tables I, II), similar to the finding of other authors. Malaria infection has been detected in only five out of more than 2,000 specimens examined in the Americas: one *Saguinus geoffroyi*, from Panamá and four *Saguinus midas niger*, Brazil, all infected with *P. brasilianum* (Porter et al. 1966, Baerg 1971, Arruda 1985). These findings seem to be exceptions, since 15 species of Callithrichidae have been examined in Brazil always with negative results (Deane 1976, 1992, Lourenço-de-Oliveira 1990). However, it is known that some tamarins and marmosets are experimentally susceptible to *P. simium* and to some of the human malarias (Deane 1967). The shelters used overnight for these animals, their low body weight and their small group size apparently do not favor their contact with the vectors (Davies et al. 1991).

High infection rate (50%) was observed in the bearded sakis *C. s. chiropotes* from Balbina (Table I). The geographical distribution of the genus *Chiropotes* includes the three Guianas and the Brazilian and Venezuelan Amazon Regions. However, this genus has only been examined in Brazil for malaria infection. Three out of the four bearded saki species or subspecies (Herskovitz 1985) have previously been found infected with *P. brasilianum* in Brazil: *C. albinasus* (33.3%, Deane 1976) and *C. s. satanas* (11.8%, Arruda 1985) and *C. s. chiropotes* (18.2%, Deane 1967 and 13.3%, Deane 1976, 1992). Adding our results to the findings of Deane (1992), the malaria infection rate in *C. s. chiropotes* in Brazil increases by 19.4%.

According to Deane (1992), the prevalence of malaria among the sakis, genus *Pithecia*, is generally low (2.4%), similar to that verified in *P. i. irrorata* from Samuel (5.3%), but less than in *P. p. pithecia* from Balbina (12.5%). The distribution of genus *Pithecia* includes other countries in the Northwestern and Western Amazon, but it has not been examined for malaria outside of Brazil.

Squirrel-monkeys are among the most utilized primates in malaria research, mainly because of their susceptibility to human and simian malaria parasites (Deane et al. 1966d, Collins et al. 1985, Gysin 1991). The percentage of *Saimiri* infected with *Plasmodium* in Brazil is low, i.e. 6.9% (Deane 1992), and is similar to our findings in *S. s. sciureus* from Balbina (Table I). Deane (1967) examined 110 *S. s. sciureus* from localities in the States of Amazonas and Pará, with negative results, while Almeida and Deane (1970) and Arruda (1985) found 26.1% and 1.3% malaria positive rates, respectively, in the above mentioned States. However, the infection rate in the squirrel-monkeys from Samuel, *S. ustus* (21%), was higher than those observed by Deane (1992) in *S. boliviensis peruviensis* (=*S. sciureus boliviensis* of Deane 1976, 1992) and *S. s. sciureus*.

The New World non-human primates detected with natural malaria infection are listed, by country, on Table III, updating the records of Dunn and Lambrecht (1963), Deane (1976), Brack (1987) and WHO (1987).

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