185-198.
Le Houerou, H. N. and Popov, G. F. 1981. An ecoclimatic classification of intertropical Africa. *Plant. Prod. Protec. Pap.* (31). F.A.O., Rome.
Lindstedt, S and Boyce, M. 1985. Seasonality, fasting endurance, and body size in mammals. *Am. Nat.* 125: 873-878.
MacArthur, R. H. and Wilson, E. O. 1967. *The Theory of Island Biogeography*. Princeton University Press, Princeton, NJ.
Magurran, A. E. 1988. *Ecological Diversity and its Measurement.* Princeton University Press, Princeton, NJ.
MacNab, B. 1990. The physiological significance of body size. In: *Body Size in Mammalian Paleobiology: Estimation and Biological Implications,* J. Damuth and B. J. MacFadden (eds.), pp.11-23. Cambridge University Press, Cambridge.
Murphy, P. G. 1975. Net primary productivity in tropical terrestrial ecosystems. In: *Primary Productivity of the Biosphere*, H. Leith and R. H. Whittaker (eds.), pp.217-231. Springer Verlag, Berlin.
Pagel, M. D., May, R. D. and Collie, A. R. 1991. Ecological aspects of the geographical distribution and diversity of mammalian species. *Am. Nat.* 137: 791-815.
Peet, R. K. 1974. The measurement of diversity. *Ann. Rev. Ecol. Syst.* 5: 285-307.
Peres, C. A. 1989. Exudate-eating by wild golden lion tamarins, *Leonopithecus rosalia. Biotropica,* 21: 287-288.
Peters, R. H. 1983. *The Ecological Implications of Body Size*. Cambridge University Press, Cambridge.
Poulin, B., Lefebvre, G. And MacNeil, R. 1992. Tropical avian phenology in relation to abundance and exploitation of food resources. *Ecology* 73: 2295-2309.
Reed, K. E. and Fleagle, J. G. 1995. Geographic and climatic control of primate diversity. *Proc. Natl. Acad. Sci. USA.* 92: 7874-7876.
Ross, C. 1992. Environmental correlates of the intrinsic rate of natural increase in primates. *Oecologia* 90: 383-390.
Rosenberger, A. L. 1992. Evolution of feeding niches in New World monkeys. *Am. J. Phys. Anthropol.* 88: 525-562.
Rosenberger, A. L. and Strier, K. B. 1992. Adaptive radiation of ateline primates. *J. Hum. Evol.* 18: 717-750.
Rylands, A. B., Mittermeier, R. A. and Rodríguez-Luna, E. 1995. A species list for the New World primates (Platyrrhini): Distribution by country, endemism, and conservation status according to the Mace-Lande system. *Neotropical Primates* 3 (suppl.): 113-164.
Schmidt-Nielsen, K. 1990. *Animal Physiology: Adaptation and Environment.* 4th ed. Cambridge University Press, Cambridge.
Sokal, R. R. and Rohlf, F. J. 1981. *Biometry: The Principles and Practice of Statistics in Biological Research*, 2nd ed. W. H. Freeman, New York.
Strier, K. B. 1992. Ateline adaptations: behavioral strategies and ecological constraints. *Am. J. Phys. Anthropol.* 88: 515-524.
Temerin, L. A., Wheatley, B. P. and Rodman, P. S. 1984. Body size and foraging in primates. In: *Adaptations for Foraging in Non-Human Primates*, P. S. Rodman and J. G. H. Cant (ed.), pp.215-248. Columbia University Press, New York.
Terborgh, J. 1983. *Five New World Primates: A Study in Comparative Ecology.* Princeton University Press, Princeton, NJ.
Terborgh, J. and Stern, M. 1987. The surreptitious life of the saddle-backed tamarin. *Am. Sci.* 75: 260-269.
Walter, H. and Leith, H. 1967. *Climate Diagram World Atlas.* Gustav Fischer, Jena.
Wernstedt, F. L. 1972. *World Climatic Data.* Climatic Data Press, Lemont.
Williamson, D. K. 1997. Primate Socioecology: Development of a Conceptual Model for the Early Hominids. Unpublished Ph.D. thesis, University College London, London.
Williamson, D. K. and Dunbar R. I. M. In press. Energetics, time budgets and group size. In: *Comparative Primate Socioecology*, P. C. Lee (ed.). Cambridge University Press, Cambridge.
Wolda, H. 1978. Seasonal fluctuation in rainfall, food and abundance of tropical insects. *J. Anim. Ecol.* 47: 369-381.
Wolfheim, J. 1983. *Primates of the World.* University of Washington Press, Seattle.

The Squirrel Monkey Breeding Colony of The Pasteur Institute, Cayenne, French Guiana

Benoît de Thoisy
Hugues Contamin

Introduction

Squirrel monkeys, especially *Saimiri sciureus* and *S. boliviensis*, are animal models widely used in biomedical research; mainly in pharmacology, toxicology, cancerology, nutrition, cardiovascular diseases and neurology (Mittermeier *et al.*, 1994). Numerous captive breeding colonies have been established in different parts of the world. However, reproduction of captive squirrel monkeys is often inconsistent, giving rise to disappointing breeding results. The aim of this article is to briefly present the 15-year-old colony of the Pasteur Institute of French Guiana, emphasizing efforts to ensure the well-being of the monkeys and, being a biomedical research institution, the results obtained using this non-human primate model.

In 1978, The Pasteur Institute of French Guiana, belonging to a network of international Pasteur Institutes, decided to initiate a long-term research program on human malaria. Although not the natural host of either *Plasmodium vivax* or *P. falciparum, Saimiri sciureus* was chosen as a model because it is sensitive to experimental infection (Gysin, 1991). Moreover, squirrel monkeys naturally

occur in French Guiana, and a captive colony maintained under natural climate conditions appeared to have better chances of obtaining good reproductive rates.

Establishment of the Colony

Three phenotypes, belonging to two squirrel monkey species (Hershkovitz, 1984), were acquired for the establishment of the colony: two phenotypes of *Saimiri s. sciureus* (Gothic type), one from Guianas and the other from Brazil, and the Bolivian squirrel monkey, *Saimiri boliviensis* (Roman type). Most of them were wild caught from Guyana, Surinam, French Guiana and northeastern Brazil, although a few were bought in the USA.

The colony is organized into three areas in two distinct locations: inside the confines of the Pasteur Institute in Cayenne, where the main captive breeding colony is maintained, and on the "Ilet-La-Mère", a 56-ha, wooded island just offshore from Cayenne. On the island, a part of the monkey population is held in captivity in a supplementary breeding colony, whilst the rest are free-ranging. Three factors determined the use of the island. The "Ilet-La-Mère" permitted the establishment of a semi-wild colony, where animals for experimentation or reproduction needs could be obtained by trapping. The isolation from wild monkey populations and animal dealers is today considered to be fundamental, both for conservation and health reasons. The island should also give the opportunity to release into a controlled environment post-experiment monkeys and old breeders. This isolated colony could also represent a reserve in case of a dramatic epidemic in Cayenne, and would permit the re-establishment of the captive colony within a few years without recourse to the capture of wild monkeys and a consequent long-term disruption of research programs.

Current Situation

At the end of 1996, the entire colony was comprised of 1,060 squirrel monkeys: 770 and 110 in the Cayenne and island colonies, respectively, and 180 free-ranging. Today all captive monkeys are *S. s. sciureus* from the Guianas due to their much better breeding performance, and the two other types of squirrel monkeys have been progressively released onto the island. The infrastructure at Cayenne consists of large outside cages where breeding mothers and young are kept. There are indoor cages for monkeys destined for experimental purposes, and monkeys used in the various malaria protocols are maintained in individual cages in a separate room. Three airtight rooms are reserved for HTLV and Hepatitis C-infected monkeys. On the island, the infrastructure is restricted to large outside cages for breeders and young.

The Breeding Colony

The French Guianan colony of *S. sciureus* is today probably one of the largest in the world. The colony was established 18 years ago, and records from 1986, 1991 and 1996 highlight its growth and the overall improvement in breeding (Tables 1 and 2). Most of the monkeys are now captive-born, 65% of births in 1996 produced F2 infants (born from captive-born parents, parents of wich were caught in the wild), and for the first time a small number (3%) of F3 births. Interestingly, a birth peak (observed in free-ranging squirrel monkeys) was noticeable during the first ten years of the Cayenne colony, but has gradually disappeared. In 1991, a birth peak was still evident (Moisson and Gysin, 1992), but has not been observed in recent years. Seasonality is recorded, however, in the captive squirrel monkeys on the island, and is the only difference in the breeding performances of the two captive colonies (Cayenne and Ilet). In general, there has been an overall decrease in mortality, with a change in the causes of death. Infection-related deaths decreased from 22% in 1991 to 4% in 1996. In 1991, 11% of deaths were related to experimentation, whereas by 1996 this proportion had increased to 18%. It should be noted that this slight increase reflects a better control of other causes of mortality, mainly infections, rather than an increase in death related to experimentation. At present, infant mortality (new-born, <1 week old), is the major contributor to the mortality statistics (40%). Deaths are otherwise the results of accidental injuries, reproductive pathologies and old age.

The Wild Population on the "Ilet-La-Mère"

This island was colonized during XVIIIth and XIXth centuries by Jesuits, and later was the site of the famous French Guianan convict prison. Jesuits deforested most of the island and introduced fruit trees, such as *Spondias mombin* (Anacardiaceae), mangos (*Mangifera indica*, Anacardiaceae), and guavas (*Psidium goyava*, Myrtaceae). Today with the exception of two small *Schizachyrium* savanna areas, the vegetation is characterized by a mixed community of non-deciduous trees with a high floristic diversity (Alexandre, 1983), thus providing fruits year-round. Since 1981, the island has been legally protected by local decrees prohibiting hunting and restricting access. Initially there were no mammals on the island. Some rodents, rats, agoutis (*Dasyprocta agouti*) and acouchis (*Myoprocta acouchi*) were introduced and have since thrived. The primate population includes mostly squirrel monkeys together with some pairs of night monkeys (*Aotus*

Table 1. Main characteristics of the captive population of the captive squirrel monkey colony of the Pasteur Institute in Cayenne, French Guiana.

	n	Male:Female	Young[1]:Adult	Captive-born	Mortality
1986	475	2:3	4.5:10	17%	75 (16%)
1991[2]	701	1:2	4.1:10	29%	91 (13%)
1996[3]	879	1:1	4.2:10	87%	49 (5.52%)

[1] < 3 year-old.
[2] 60 wild monkeys were introduced in the colony in 1987.
[3] 60 monkeys were sold and left the colony in 1992.

Table 2. Breeding results of the captive squirrel monkey colony.

	Reproductive females	Viable births	Fecundity	Fertility	Young still alive at weaning
1986	164	46	28%	32%	65%
1991	266	125	47%	53%	93%
1996	272	149	55%	61%	87%

trivirgatus) released by the Pasteur Institute in the early 1980s. Observations of the night monkey groups are infrequent, but they are estimated to number less than 20 or 30 individuals, including young. There is an absence of competitors of the squirrel monkeys. A total of 170 were introduced in 1981 and more than 150 were released during the following years. From this population, 60 animals were captured and taken back to Cayenne. A recent survey (Louguet *et al.*, 1997) indicated that 180 squirrel monkeys currently inhabit the island. This is not a single population, however. It is divided into two distinct subpopulations which interact very infrequently. Half of the squirrel monkeys, although free-ranging are not wild. They are completely dependent on the provision of artificial dietary supplements twice a day, and their home range is restricted to 2-3 ha around the site of the captive colony. The other monkeys live in four groups occupying the forested area. Most of the adult females are breeding and we believe that the population may now have reached a numerical threshold due to limited food resources. The population density is, however, comparable to those observed in natural habitats on the continent. The main eco-ethological patterns of the free-ranging population are comparable to those observed in secondary forests elsewhere (Louguet *et al.*, 1997).

The Role of *Saimiri sciureus* at the Pasteur Institute of French Guiana

Research

The aim of the colony is to maintain squirrel monkeys for biomedical research, especially as a model for human malaria. In general, the females are kept for reproduction, and it is mostly the four-year-old males which are used in the research programs. Sixty to 70 naive monkeys are available for experimentation each year. Ninety-five percent of the monkeys are involved in the various human malaria research protocols, and are not sacrificed. Anti-*Plasmodium* treatments, when required, are efficient, and as a consequence the monkeys recover fully. After varying periods of experimental use, the monkeys are re-integrated into the colonies as breeders. Programs studying the physiology and physiopathology of squirrel monkeys are receiving increasing importance (Contamin *et al.*, submitted). Some other research programs have also been initiated recently. They include the use of the squirrel monkeys as a model for HTLV (Kazanji *et al.*, 1997) and Hepatitis-C. Scientific collaboration in vaccinology, pathology, parasitology, genetic and cytogenetic studies are ongoing or planned with other Pasteur Institutes and biomedical research institutions.

Education

Once or twice a year, the Pasteur Institute opens its doors for public visitation, including even part of the island. This represents a valuable means by which the Pasteur Institute can explain its various biomedical research programs to the local people, many of whom are strongly concerned with the problems of malaria in French Guiana. Lectures are given about the colony, squirrel monkey biology, and the importance of biomedical research.

Conclusion

It is important to emphasize some of the difficulties in maintaining the colonies. The large, outdoor colony reduces cost, but renders difficult the strict application of recommendations and guidelines proposed for the keeping of monkeys for biomedical research. Nevertheless, the success of this colony is shown by its good breeding record, its importance internationally in its contributions to research on malaria, and the increasing role of squirrel monkeys as a primate model for retroviral studies.

Acknowledgments

The preliminary results on the performance of the Pasteur Institute breeding colony could not have been highlighted without the important work carried out by the successive veterinarians who have contributed so much to the well-being of the monkeys and the improvement of their living conditions, most especially: J. Gysin, J.-M. Postal, P. Moisson, J.-C. Vié, and B. Bonnemains. We also thank Gordon Langsley for help with the English version of this text.

Benoît de Thoisy and **Hugues Contamin**, Institut Pasteur de Guyane, Service de Primatologie, BP 6010, 97306 Cayenne cedex, French Guiana.

References

Alexandre, D.-Y. 1983. Premiers aperçus sur la végétation de l'Ilet-La-Mère. Unpublished report, ORSTOM, Cayenne.

Contamin, H., Behr, C., Puijalon, O. and Michel, J.-C. Submitted. The Guyanan squirrel monkey (*Saimiri sciureus*): a model for studying some clinic pathological changes associated with human *falciparum*-malaria.

Gysin, J. 1991. Relevance of the squirrel monkey as a model for experimental human malaria. *Res. Immunol.* 142:649-654.

Hershkovitz, P. 1984. Taxonomy of squirrel monkeys genus *Saimiri* (Cebidae, Platyrrhini): A preliminary report with description of a hitherto unnamed form. *Am. J. Primatol.* 7:155-210.

Kazanji, M., Moreau, J-P., Mahieux, R., Bonnemains, B., Bomford, R., A. Gressain and de Thé, G. 1997. HTLV-A infection in squirrel monkeys (*Saimiri sciureus*) using autologous, homologous, or heterologous HTLV-1-transformed cell lines. *Virology* 231(2):258-266.

Louguet O., Bayart, F. and de Thoisy, B. 1997. Adaptations écologiques et comportementales d'une population de singes-écureuils sur I'Ilet-la-Mère en Guyane Française. Congress Société Francophone de Primatologie, Lyon, France.

Mittermeier R. A., Konstant, W. R. and Mast, R. B. 1994. Use of Neotropical and Malagasy primate species in biomedical research. *Am. J. Primatol.* 34:73-80.

Moisson P. and J. Gysin, J. 1992. Reproductive perfor-

mances and pathologies statements in a breeding colony of squirrel monkey (*Saimiri sciureus*). In: *Abstracts. XIVth Congress of the International Primatological Society*, pp.296-297. Strasbourg, France, 16-21 August, 1992.

First Detailed Field Data on *Chiropotes satanas utahicki* Hershkovitz, 1985

Urbano L. Bobadilla
Stephen F. Ferrari

The Xingu-Tocantins interfluvium has been the principal focus of development in eastern Amazonia over the past three decades, with the building of the TransAmazon highway, the Carajás mining project, construction of the Tucuruí hydroelectric dam, and the establishment of cattle ranching in its southern half, currently the principal location of land conflicts in Brazilian Amazonia. Endemic to this interfluvium (Hershkovitz, 1985), Uta Hick's bearded saki, *Chiropotes satanas utahicki*, was assigned the Mace-Lande category of 'vulnerable' by Rylands *et al.* (1996), based on criterion A1(c): a decline in area of occupancy, extent of occurrence and/or quality of habitat. This clearly reflects the overall situation within this primate's distribution, but, with the exception of a small number of more general surveys (see Ferrari and Lopes, 1996), there are no specific data on the status of wild populations.

With this in mind, *C. s. utahicki* was the focus of a study at two locations, the Ferreira Penna Scientific Station (ECFPn) (01°42'S, 51°28'W) in the Caxiuanã National Forest, and the Fazenda Arataú (03°50'S, 50°20'W) (Fig. 1). They were chosen in order to assess the effects of human colonisation on *C. s. utahicki* populations. Surveys were carried out at these sites between January and October, 1996. While primary *terra firme* forest predominates at both, the 33,000 ha ECFPn is contiguous with the remaining 300,000 ha of the Caxiunã National Forest, a protected area that suffers only very low levels of human encroachment, while in contrast the 7,000 ha forest reserve on the Fazenda Arataú has not only been isolated from surrounding forest for some twenty years, but has also been selectively logged.

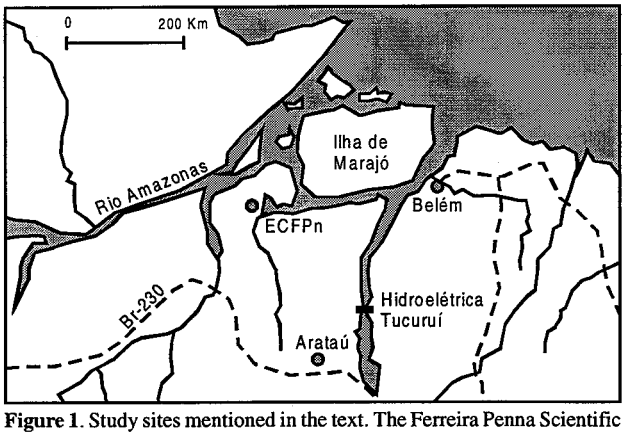

Figure 1. Study sites mentioned in the text. The Ferreira Penna Scientific Station (ECFPn) in the Caxiuanã National Forest, municipality of Melgaço, and the Fazenda Arataú, municipality of Novo Repartimento, Pará, Brazil.

Data were collected using standard line-transect survey methods (Brockelman and Ali, 1986). A total of 532.9 km were surveyed at the ECFPn, covering both rainy (January to April) and dry seasons (September and October), whereas 101.3 km were surveyed at the Fazenda Arataú during the late wet/early dry season (May to August).

The two surveys revealed some surprising contrasts between the two study sites (Table 1) which, in many respects, were the opposite of the pattern that would be expected according to the ecological characteristics of each species. Black-handed tamarins (*S. m. niger*) normally prefer disturbed and/or secondary forest, for example (Oliveira, 1996), even at Caxiuanã (Ferrari and Lopes, 1996), but they were nevertheless sighted more than twice as frequently at ECFPn than at the Fazenda Arataú. While bearded sakis are thought to be highly intolerant of habitat disturbance (Johns and Ayres, 1987), on the other hand, the sighting rate for *C. s. utahicki* at the Fazenda Arataú was almost twenty times higher than that at Caxiuanã.

C. s. utahicki groups were slightly larger at the ECFPn (mean size 9.3 individuals, $n = 7$ sightings) in comparison with the Fazenda Arataú (mean size 6.9 individuals, $n = 24$), but both values fall within the range for *Chiropotes* recorded in previous studies (Ayres, 1981; Branch, 1983; Lopes, 1993), and there is little to suggest any significant tendency with regard to this variable, especially given the sample size.

The ECFPn survey not only covered the longest total distance of any carried out so far in an area inhabited by bearded sakis, but also encompassed a range of different months. It thus seems reasonable to conclude that the number of sightings recorded is a reliable indication of an enigmatically low density of *C. s. utahicki* at this site. While the survey at the Fazenda Arataú was much shorter, a similar study carried out in January 1996 also indicated that bearded sakis were relatively abundant there (A. F. P. Nunes, pers. comm.).

The reasons for such a striking difference in the apparent abundance of *C. s. utahicki* at the two sites remain unclear, but one factor may be the high density of babaçu (*Orbignya martiana*) palms at the Fazenda Arataú, the fruits of which were regularly eaten by the sakis. Although the forest at the ECFPn may be among the most floristically diverse of eastern Amazonia (Almeida *et al.*, 1983),

Table 1. Sightings of primates at the two study sites.

Species	Sightings (per 10 km) at	
	ECFPN[1]	Fazenda Arataú[2]
Alouatta belzebul belzebul	111(2.08)	10 (1.00)
Cebus apella apella	25 (0.47)	18 (1.78)
Chiropotes satanas utahicki	6 (0.11)	21 (2,07)
Saguinus midas niger	59 (1.11)	5 (0.50)
Saimiri sciureus sciureus	-	4 (0.40)
Total	201 (3.77)	58 (5.73)

[1] Total transect length = 532.9 km;
[2] Total transect length = 101.3 km.