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Source: Primate Conservation, 24(1) : 59-64

Published By: Conservation International

URL: <https://doi.org/10.1896/052.024.0102>

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The Taxonomy and Conservation Status of *Saimiri sciureus albigena*: A Squirrel Monkey Endemic to Colombia

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Abstract: The Colombian squirrel monkey (*Saimiri sciureus albigena*), endemic to central Colombia, is classified as Near Threatened on the 2008 IUCN Red List of Threatened Species. Its geographic distribution is restricted to a small area of the Colombian Llanos, where there are major human impacts, involving the loss, fragmentation and degradation of its forests due particularly to agricultural conversion, and this species' persecution for the pet trade. Here we review its status, and argue that it is threatened and that it be considered as Vulnerable (VU) on future iterations of the IUCN Red List. We suggest the possibility, based on comparative studies of 1140 base pairs of the cytochrome b mitochondrial gene of 38 *Saimiri* specimens of nine different taxa, that the Colombian taxa could be considered subspecies of *Saimiri cassiquiarensis* (not *S. sciureus* as is currently believed), all showing similar haplotypes that are different from *Saimiri sciureus sciureus* of the eastern Amazon. An alternative arrangement could place the three Colombian taxa north of the Río Amazonas—*albigena*, *macrodon*, and *cassiquiarensis*—as full species.

Key Words: Colombian squirrel monkey *Saimiri sciureus albigena*, threatened status, genetics, Colombian Llanos, Colombia.

Introduction

Three squirrel monkeys occur in Colombia, all considered subspecies of the common squirrel monkey, *Saimiri sciureus* (see Groves 2001; Defler 2004). According to Hernández-Camacho and Cooper (1976) and Defler (2004), the Ecuadorian squirrel monkey, *S. s. macrodon* Elliot, 1907, occurs in the basins of the ríos Putumayo and Caquetá, south of the Río Apaporis (Fig. 1). Humboldt's squirrel monkey, *S. s. cassiquiarensis* (Lesson, 1840), occurs to the north of the Apaporis, populating the basins of the ríos Vaupés, Guainia and Inirida, northward as far as the southern (right) margin of the Río Vichada and west to the Andes, between the upper Apaporis and upper Río Guayabero. The Colombian squirrel monkey, *S. s. albigena* Pusch, 1942, has the northernmost distribution in Colombia, in the Llanos Orientales, eastern Andean piedmont and upper Río Magdalena (Defler 2004). The highest altitude recorded for the occurrence of this squirrel monkey is 1,500 m in Huila (Hernández-Camacho and Cooper 1976). The eastern limits in Arauca and Casanare are poorly defined (Defler 2004) (Fig. 1), but influenced by increasing grasslands, decreasing rainfall, and reduced extent of gallery forest as the limiting factors. *Saimiri s. albigena* occupies gallery forest with low canopy and sclerophyllous and hillside forest, palm

forest (associations of *Mauritia flexuosa*) and, extending to the south, the species occurs in the seasonally flooded and *terra firma* rain forests of the Amazon basin (Hernández-Camacho and Cooper 1976). *Saimiri s. cassiquiarensis* and *S. s. macrodon* were categorized as of Least Concern (LC) on the 2008 IUCN Red list of Threatened Species but *S. s. albigena* was considered to be Near Threatened (NT) because a sizeable part of its range has been heavily deforested, and population loss was estimated to be at least 20% in the past 25 years (based on a generation length of 8 years) due to continuing habitat loss and exploitation for pets (IUCN 2008). The IUCN Red List appraisal concluded that it almost qualified as Vulnerable (VU) under the criterion A2cd, that is, “an observed, estimated, inferred or suspected population size reduction of $\geq 30\%$ over the last 10 years or three generations, whichever is the longer, where the reduction or its causes may not have ceased or may not be understood or may not be reversible (A2), based on a decline in area of occupancy, extent of occurrence and/or quality of habitat (c) and actual or potential levels of exploitation (d)” (IUCN 2001). Here we review the status of *S. s. albigena* and its categorization on the IUCN Red List, specifically examining the latter proposition that it might in fact be better regarded as Vulnerable (VU) rather than Near Threatened. We also discuss the results of a molecular genetic study

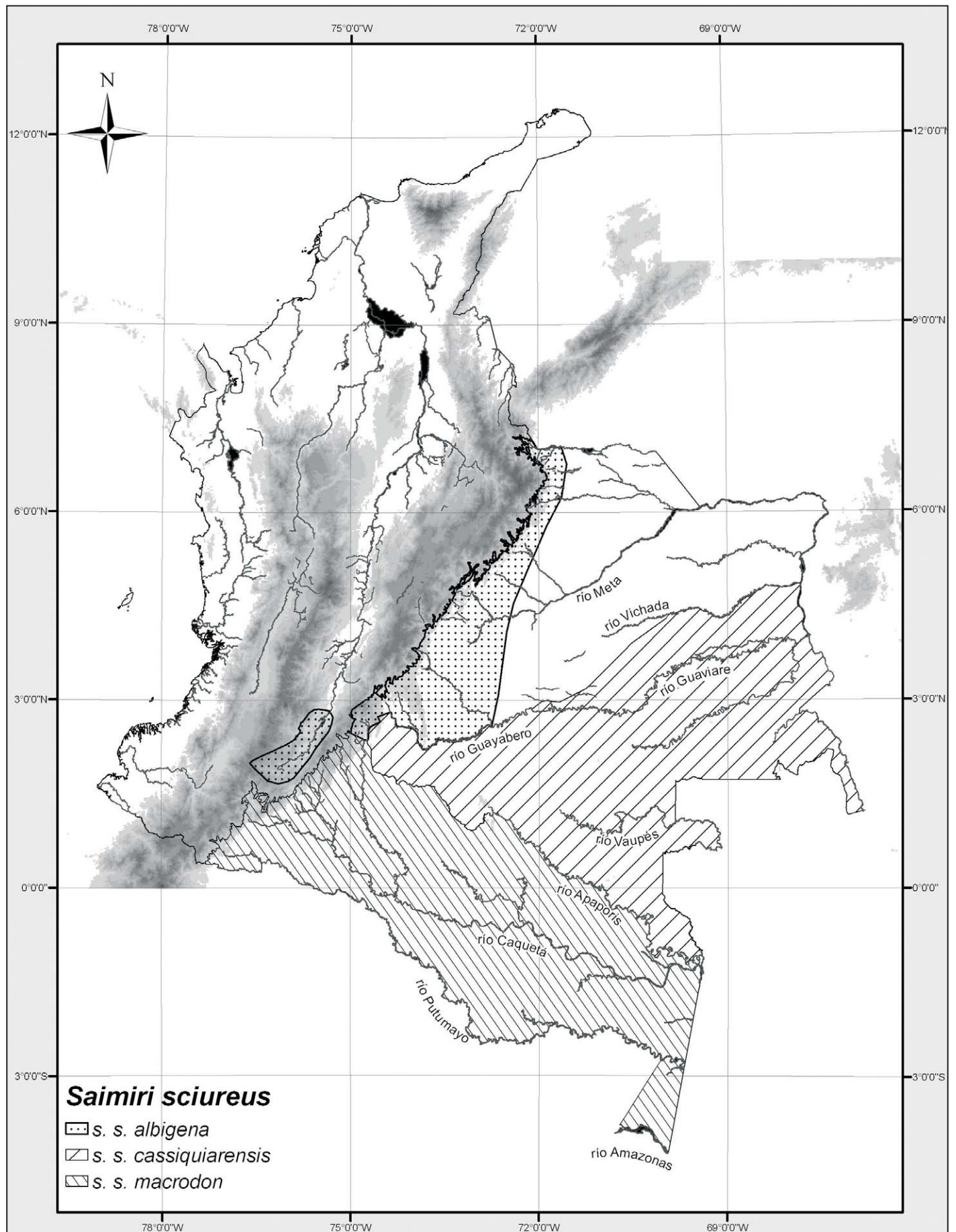


Figure 1. Confirmed distributions of *Saimiri* in Colombia (Hernández-Camacho and Cooper 1976; map from Defler 2004).

(mitochondrial cytochrome b gene) of nine different taxa of *Saimiri* and discuss their implications for the taxonomy of the three currently recognized Colombian forms.

Fragmentation and Habitat Loss

The area of the geographic range that has been confirmed for this endemic subspecies of *Saimiri* is 100,000 km². It comprises a mixture of pasture and gallery forest fragments of different sizes and differing extents of isolation, along with some continuous forest areas in the Department of Meta (Fig. 1). Taking into account the actual habitat available in the subspecies' range, there are about 60,000 km² of gallery forest fragments and continuous forest remaining: about half of the original distribution. The principal threats to this habitat are colonization, African oil palm plantations, pasture for livestock, and deforestation for other sundry reasons. During the last three years increasing governmental incentives for oil palm plantations have resulted in the loss of about 400 ha in a small area around San Martín de los Llanos, in Meta, and deforestation due to oil palm plantation still continues. Deforestation is occurring throughout the range of *Saimiri sciureus albigena*; the area that has been converted to oil palm plantations in the eastern part of the country (mainly in Meta Department) congruent to the distribution of *S. s. albigena* was 121,464 ha in 2008 with a suggested potential there of 1,933,382 ha of converted forest and savanna, all resulting in the destruction of nearby gallery forests (Colombia, Ministerio de Agricultura de Desarrollo Rural, Gobernación del

Meta 2007). This increase in forest conversion to oil palm has compromised fragments of gallery forest that undoubtedly harbored *S. s. albigena* groups and will continue to do so at an increased rate.

The use of fences as part of their home ranges and as corridors between forest patches is one of the reasons why these squirrel monkeys (which typically have large home ranges) have been able to persist in fragmented areas (Carretero-Pinzón *et al.* in prep.). In larger forests, squirrel monkeys can have home ranges of 240 ha or more (Terborgh 1983; Mitchell 1990; Carretero-Pinzón 2000), while in fragments *S. s. albigena* usually have home ranges of around 100 ha (Carretero-Pinzón 2008). In fragments assessed since 2004, *Saimiri* groups were found only in small and large fragments connected by fence rows, but they were absent from even the large fragments that were completely isolated (Fig. 2). Since we began our field research in 2004, one of the *S. s. albigena* groups we were monitoring disappeared from one of the fragments for no apparent reason in 2005 (Carretero-Pinzón pers. obs.). Their absence in larger fragments is evidence of localized extinctions due to deforestation and isolation. Data from environmental impact assessments carried out in the departments of Arauca, Meta, Boyacá and Casanare during 2008 have shown that for seven sites surveyed only one in Meta and one in Boyacá provided evidence that squirrel monkeys were still present. The impact assessments were made on behalf of oil companies, which mean that the forest of these two sites will probably eventually disappear (J. L. Barrera pers. comm.).

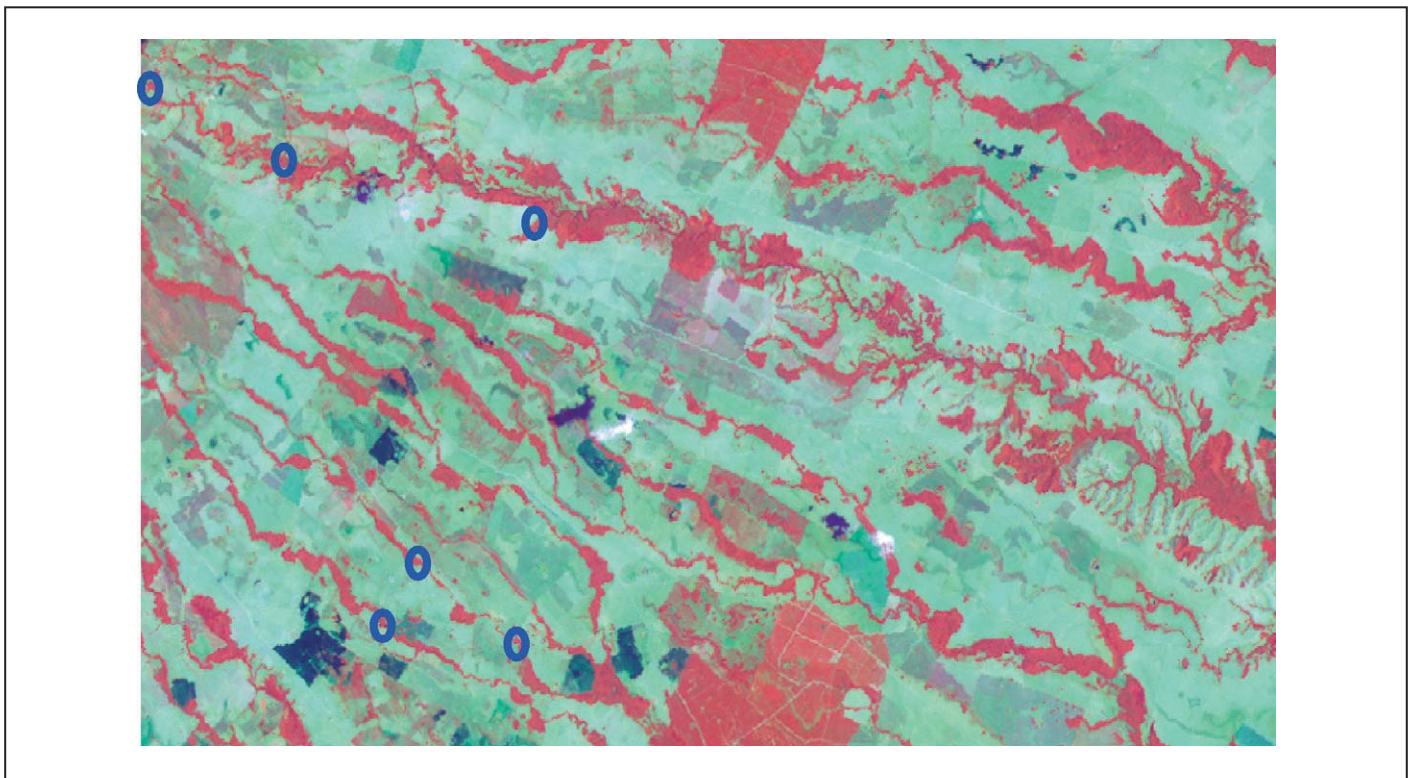


Figure 2. Six groups of *Saimiri sciureus albigena* (blue circles) located in 4,000 ha near San Martín, Department of Meta, Colombian Llanos (Red are forest fragments and oil palm plantations, brown and black parts are burnt areas, and the green marks pastures and open areas. (LANDSAT 0758 ETM EarthSat, Image, 2001).

Illegal Trade

Very large numbers of squirrel monkey were exported to the US and Europe during the 1960s and 1970's, largely from Iquitos (Peruvian Amazon), Leticia (Colombian Amazon), and Barranquilla on the Caribbean coast of northern Colombia (Cooper 1968; Cooper and Hernández-Camacho 1975; Mack and Eudey 1984). Although exports stopped in 1974, the illegal national trade continues, and *S. s. albigena* is one of the most common taxa found in rescue and rehabilitation centers (pers. obs.). They are common as pets in rural areas where often people kill many individuals of the group just to catch one.

Census Numbers

Data for a small portion of their distributional range show that in an area of 4,000 ha there are just 500 ha of gallery forest fragments sheltering only 70 individuals in two subpopulations of 30 and 40. The subpopulations were isolated from each other (three groups in each). We have observed behavioral differences in these isolated populations compared to populations in continuous forest. It is likely that the subpopulation of 30 individuals will go extinct if their particular fragments are not connected in the near future; no group size increase has been observed (from mid-2005 and January 2007) and we do not know the mortality rates in these groups (Carretero-Pinzón unpubl. data). It is possible that there are healthy large populations in the Tinigua National Natural Park (201,875 ha) and the Serranía de la Macarena Natural National Park (630,000 ha), but this needs to be confirmed. The population in Tinigua was secure until 2002, but then guerilla activity made it impossible to continue monitoring them (X. Carretero pers. obs.) and more recent information is lacking. There is much social unrest in the region where these parks are located, associated with guerilla activity and illegal crops such as coca. Another population is in a private reserve, Las Unamas Natural Reserve at San Martín, Meta department (Enciso 2006) that would appear to be well protected, and has a relatively large area of continuous forest (c. 1,300 ha). The first author began an assessment of this population in late 2008. These private reserves may be only safe, however, as long as their present owners live.

The Conservation Status of *Saimiri sciureus albigena*

Based on the information we have about the status of *Saimiri sciureus albigena* we consider that it should be categorized as Vulnerable (VU) following the IUCN Red List categories and criteria (IUCN 2001). The criteria for this are A2 (a, b) and B1 (a, b (ii,iii and iv)) as follows: 'A' is a reduction in population size based on (2) an observed and estimated population size reduction of 30% or more in the last 10 years that may not be reversible, based on (a) direct observation (during five years of work in the zone with this species by the first author) and (b) a diminishment of an index of abundance. The

evaluation is also based on (B) (geographic range), since we estimate the extent of occurrence to be less than 20,000 km² (1) since much of the range above the Río Guaviare consists only of forest fragments and both the findings that the range is severely fragmented (a) into remnant gallery forests that have not as yet been converted to agricultural use, and a directly observed continuing decline (b), in the area of occupancy (ii), area, extent and quality of habitat (iii) and in the number of locations or subpopulations (iv). The principal pressures driving the negative changes in the populations of this taxon are mainly agricultural activity and, especially, the rapid conversion of the land to oil palm plantations, and there seems to be high attrition from animals trying to disperse across roads and over open ground, judging from the frequent dead animals we have observed.

The Taxonomy of *Saimiri sciureus*: Molecular Genetics Data

In a series of recent molecular population genetic and phylogeographic studies, Lavergne *et al.* (in press) and M. Ruiz-García (unpubl. data) analyzed 1,140 base pairs of the cytochrome b mitochondrial gene of 38 *Saimiri* specimens representing nine taxa: *S. sciureus sciureus* (Linnaeus, 1758), *S. s. collinsi* Osgood, 1916 (from Marajó Island; recognized by Cruz Lima [1945], Cabrera [1957] and Hill [1960], but considered a synonym of *S. s. sciureus* by Hershkovitz [1984] and Groves [2001, 2005]), *S. s. macrodon*, *S. s. albigena*, *S. s. cassiquiarensis*, *S. ustus* (I. Geoffroy, 1844), *S. oerstedii* (Reinhardt, 1872), *S. boliviensis boliviensis* (d'Orbigny, 1834) and *S. b. peruviansis* Hershkovitz, 1984 (Fig. 3). *S. ustus* was quite clearly separated, confirming its classification as a distinct species by Elliot (1913), Cruz Lima (1945), Hill (1960), Hershkovitz (1984) and Groves' (2001, 2005). The results showed that *S. s. albigena* (two specimens from the Meta Department in Colombian Llanos) had two haplotypes for the cytochrome b gene that were not shared with other *Saimiri* taxa. These *albigena* haplotypes showed the lowest mean genetic divergence with *S. s. cassiquiarensis* (of 0.53, SD = 0.20), but no haplotypes were shared between the two neighboring squirrel monkeys *S. s. cassiquiarensis* and *S. s. macrodon*. A median joining haplotype network (Fig. 3) clearly showed that *albigena* represents an independent branch related to a group composed otherwise of *S. s. cassiquiarensis* and *S. s. macrodon* (and, more distantly, with *S. ustus*). The genetic differentiation in this *Saimiri* group from *S. sciureus sciureus* of French Guiana was conspicuously higher: *S. s. sciureus* differs by 45 nucleotide substitutions (ns) from *S. ustus* and 48 ns for *S. s. albigena*. In contrast, the number of substitutions within the above mentioned group, including *S. ustus*, was conspicuously lower. *S. ustus* presented 26 ns compared to *S. s. albigena*.

The Median Joining network (Fig. 3) was clearly useful for estimating divergence times between the haplotypes identified. The main *S. s. sciureus* haplotype diverged from the *S. s. albigena* haplotypes from 1 to 2.3 million years ago

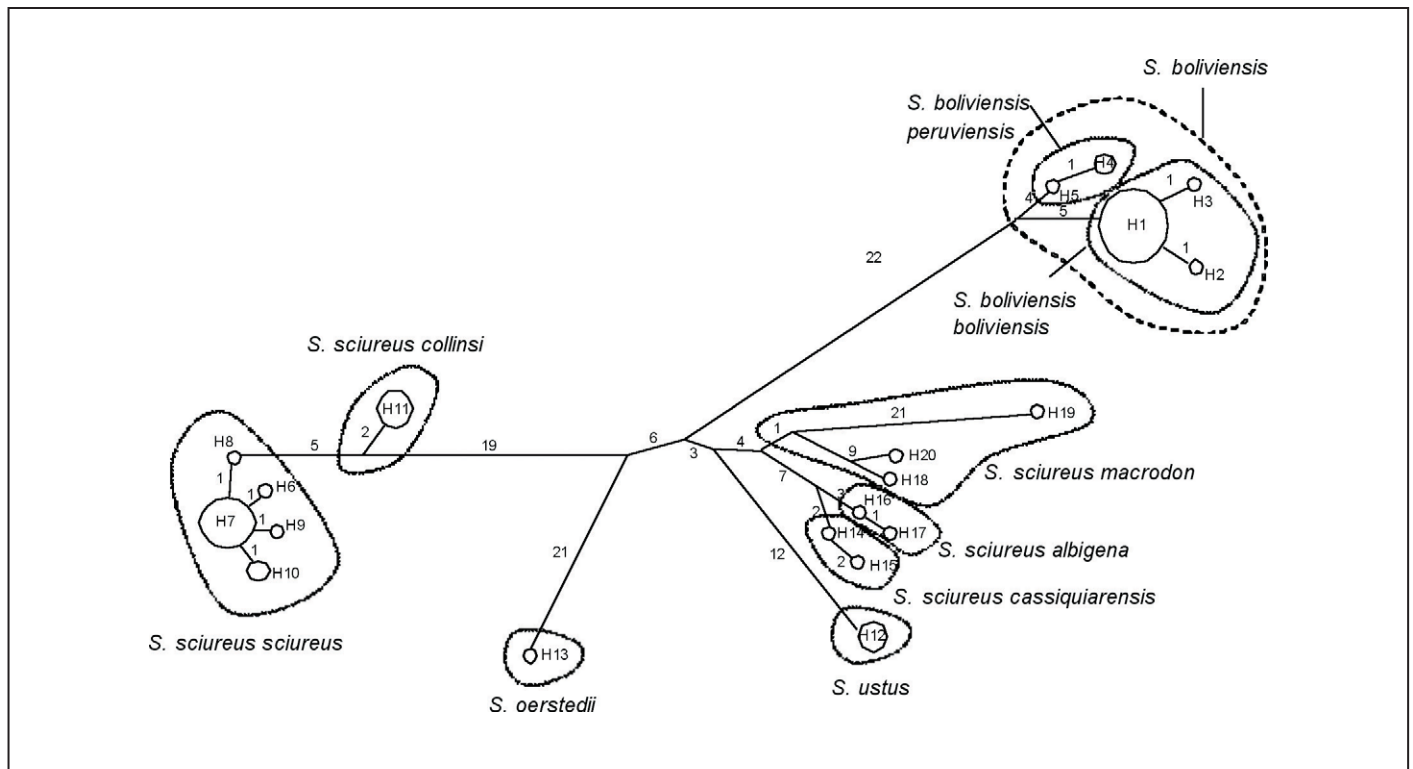


Figure 3. Median joining haplotype network for *Saimiri* taxa based on 1140 base pairs of the mitochondrial cytochrome b gene.

(mya), and *S. s. albigena* diverged from *S. oerstedii*, 2.7 to 6 mya. *Saimiri oerstedii* is closer, genetically, to *S. s. sciureus*, than is *S. s. albigena* (Fig. 3). The divergence between *S. s. macrodon* and *S. s. albigena* dates back to 1.1–1.9 mya, and the split of *S. s. albigena* from *S. s. cassiquiarensis* was more recent (0.28–0.63 mya), during the Quaternary (Pleistocene and Holocene, 1.6 mya to recent). The split between *S. sciureus sciureus* and *S. s. albigena* was in the beginning of the Pleistocene or in the last phase of the Pliocene during a period of heavy glacial advances and retreats with consequent dry periods, while that between *S. s. albigena* and *S. s. cassiquiarensis* could have corresponded to some period of the second and third Pleistocene glaciations. Pleistocene forest fragmentation could be responsible for the separation of the different haplotypes in *S. s. albigena* (Haffer 1997; Whitmore and Prance 1987). The separation of *albigena* from *cassiquiarensis* could be related to the presence of certain rivers or forest refuges related to cyclical climatic changes. For example, the Río Apaporis separates the distribution of *macrodon* and *cassiquiarensis*. Likewise, it is probable that *albigena* and *cassiquiarensis* were separated by expansion of the Eastern Llanos.

If we assume that *S. ustus*, *S. oerstedii* and *S. boliviensis* are distinct species, different from *S. sciureus* (see Hershkovitz 1984), and strictly follow the results obtained with the cytochrome b mitochondrial gene, then *S. s. sciureus* and *S. s. collinsi* of the eastern Amazon could be grouped. If *S. sciureus macrodon*, *S. s. albigena* and *S. s. cassiquiarensis* of the central and northwestern Amazon (Brazil, Colombia,

Ecuador, Peru and Venezuela) were to be considered a separate group but sufficiently closely related as to be considered subspecies, then *cassiquiarensis* Lesson, 1840 would be the oldest name of the three taxa, and hence the nominotypical species. However, following the Phylogenetic Species Concept (see Groves 2001, 2004), it would seem most appropriate that they be considered distinct but closely related species: *S. macrodon*, *S. albigena*, and *S. cassiquiarensis*. Further research using other molecular markers could confirm or modify the phylogeny of the squirrel monkeys that we have identified here, and would reinforce the need to modify the taxonomic arrangements as proposed by Hershkovitz (1984) and Groves (2001).

Acknowledgments

The first author is most grateful to the local farmers for their support in the last five years of work in the San Martín area, Colombian Llanos, and Dr. Martha Fandiño-Lozano for access to her satellite images. Erwin Palacios kindly provided useful comments on a prior draft of this article. Dr. Ruíz-García thanks the Pontificia Universidad Javeriana for its support to do this and other studies. We especially thank Colin P. Groves and Anthony Rylands for their comments and suggestions, and we are most grateful to Andrés Gonzalez and José Vicente Rodríguez of Conservación Internacional Colombia for their technical assistance in producing the map, Figure 1.

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Received for Publication: 25 February 2009

Revised: 12 May 2009