

SHORT COMMUNICATION

Extension of the geographic distribution of *Plecturocebus baptista* (Pitheciidae, Primates) and a possible hybrid zone with *Plecturocebus hoffmannsi*: evolutionary and conservation implications

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* Corresponding author: alessandrrocha.eco@gmail.com;  <https://orcid.org/0000-0001-7433-4933>**ABSTRACT**

Titi monkeys (family Pitheciidae) are Neotropical primates highly diversified in morphology, ecology and genetics, with a wide geographic distribution, including the Amazon, Atlantic Forest, Cerrado, Pantanal and Caatinga. This diversity, together with knowledge gaps, generates uncertainties in titi monkey taxonomy and distribution. An example is *Plecturocebus baptista*, with only 14 occurrence records and an ill-defined distribution based on untested geographical barriers. Here, we report the occurrence of this species at a new locality outside its known range, across the Paraná-Urariá River, which was considered a distributional limit for the species. The new record implies an overlap of *P. baptista* with the range of *P. hoffmannsi*. We document the sighting of an apparent hybrid animal. Our observations suggest that i) the distribution of *P. baptista* needs to be reviewed, and ii) the evolutionary relationships between *P. baptista* and *P. hoffmannsi* may be more complex than previously assumed. Since both species share contiguous areas of potential hybridization, we question whether the two species arose via allopatric speciation.

KEYWORDS: biogeography, titi monkeys, Amazon Forest, hybridization

Extensão da distribuição geográfica de *Plecturocebus baptista* (Pitheciidae, Primates) e uma possível zona híbrida com *Plecturocebus hoffmannsi*: implicações evolutivas e de conservação

RESUMO

Macacos zogue-zogue (família Pitheciidae) são primatas neotropicais altamente diversificados em morfologia, ecologia e genética, com distribuição geográfica abrangente, incluindo a Floresta Amazônica, Mata Atlântica, Cerrado, Pantanal e a Caatinga. Essa diversificação, juntamente com lacunas de conhecimento, gera incertezas na taxonomia e distribuição das espécies. Um exemplo é *Plecturocebus baptista*, com apenas 14 registros de ocorrência e distribuição indefinida, baseada em barreiras geográficas não testadas. Aqui nós relatamos a ocorrência da espécie em uma nova localidade, fora de sua área conhecida de distribuição, que transpõe uma suposta barreira geográfica, o Rio Paraná-Urariá. O novo registro de *P. baptista* se sobrepõe à distribuição de *P. hoffmannsi* e, neste contexto, observamos um indivíduo aparentemente híbrido entre as duas espécies. Nossas observações sugerem que i) a distribuição de *P. baptista* necessita ser revisada, e ii) a relação evolutiva entre *P. baptista* e *P. hoffmannsi* pode ser mais complexa do que se pensava. Como ambas espécies compartilham áreas contínuas de potencial hibridização, questionamos se as duas espécies resultaram de especiação alopátrica.

PALAVRAS-CHAVE: biogeografia, zogue-zogue, Floresta Amazônica, hibridização

Until recently, Neotropical primates of the family Pitheciidae, sub-family Callicebinae, popularly known as titis, all belonged to the genus *Callicebus*, Thomas 1903. However, a revision by Byrne *et al.* (2016) divided this genus into three. Accordingly, there are now two genera in Amazonia (*Cheracebus* and *Plecturocebus*), and one occurring in the Atlantic Forest, Cerrado, Pantanal, and Caatinga biomes (*Callicebus*). Titi

species are rarely sympatric and, in concordance with a widely agreed upon model (Ayres and Clutton-Brock 1992), are historically considered to be separated by discrete geographic barriers, such as rivers (Roosmalen *et al.* 2002). Collectively, the titis are the most specious group of Neotropical primates, with 35 known species (Byrne *et al.* 2016; Boubli *et al.* 2019). The large number of species, the remote areas of occurrence,

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poor representation in museum collections, combined with frequently complex intra- and inter-population variation (Serrano-Villavicencio *et al.* 2017), have led to a complex taxonomic history for this group (Hershkovitz 1990; Roosmalen *et al.* 2002), and new species continue to be described (Boubli *et al.* 2019). Therefore, it is essential to have well-defined geographical and taxonomic bases for effective conservation in this primate group (Carneiro *et al.* 2018).

Many titi species are poorly known both ecologically and biogeographically. Among these is *Plecturocebus baptista* (Lönnerberg 1939), for which only fourteen records exist, all from the Brazilian Amazon: twelve visual sightings, four by Roosmalen *et al.* (2002) on the Uirá-Curupá River (Amazonas state), and eight by Printes *et al.* (2018) on the Tapajós River (Pará). In addition, there are museum skins of specimens collected at Lago Baptista (03°18'S, 58°15'W) and Lago Tapaiúna (03°23'S, 58°18'W), along the Amazonas River (Gualda-Barros 2012; Hershkovitz 1990). Dedicated field studies on *P. baptista* have yet to occur.

Our objective was (i) to report the presence of *P. baptista* at a new locality, (ii) to highlight the existence of an area

of sympatry between *P. baptista* and *P. hoffmannsi* (Thomas 1908), and (iii) to discuss the implications for the evolution and conservation of the two species.

Field observations were made in November and December 2014 and January 2015, during field transect surveys in the municipality of Maués, Amazonas state (Brazil), between the Maués-Açu and Maués-Mirim rivers, at two sites 2.5 km apart near the urban area of Maués city (Figure 1). Both sites are secondary forest areas under continuing human impact. The first site (Site 1) is close to rural human habitations, and the second site (Site 2) is on a transect in the forest near guaraná (*Paullinia cupana* Kunth) and rosewood (*Aniba roseodora* Ducke) plantations.

Titis were sighted on three occasions, totalling five individuals. The first sighting was of a group of three adult *P. baptista*, foraging at a height of 1.5 m above the ground at Site 1 (3°23.704'S, 57°41.780'W). The second was of a single *P. hoffmannsi* individual, some 2 m from the ground at Site 2 (3°24.348'S, 57°42.403'W). The third sighting was of a single individual resting at the edge of the forest, at a height of 3 m, some 400 m from Site 1. The latter animal had an appearance intermediate in colour pattern between *P. baptista* and *P.*

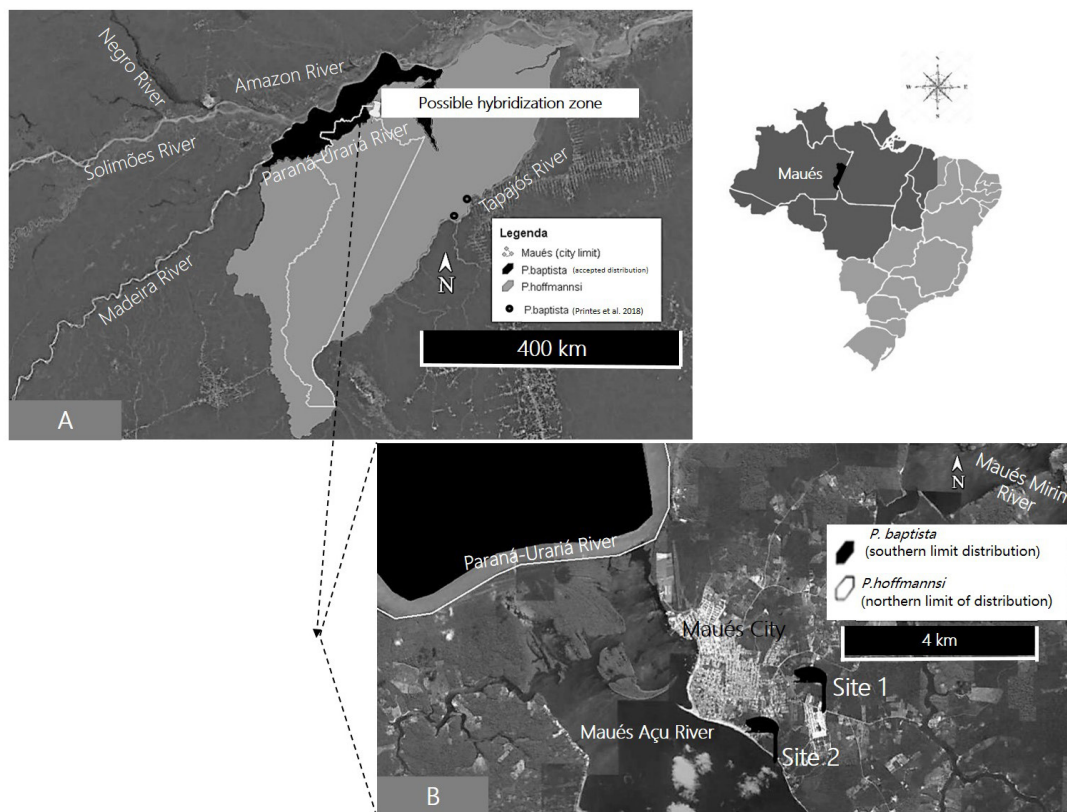


Figure 1. A – Known geographical range of *Plecturocebus baptista*, in black (Veiga 2008a) and *Plecturocebus hoffmannsi*, in gray (Veiga 2008b); indicating the potential hybridization zone in Maués, Amazonas state, Brazil; the map shows the location of the municipality of Maués in Brazil. B – Location of the two survey sites near the city of Maués, between the Maués-Açu and Maués-Mirim rivers, and the Paran-Uriariá River to the north. The historical distribution of *P. baptista* was bounded by the Paran-Uriariá River. At site 1, we found a hybrid of *Plecturocebus* (*P. hoffmannsi* x *P. baptista*) and a group of *Plecturocebus baptista*. At site 2 we observed a group of *Plecturocebus hoffmannsi*.

hoffmannsi, with crown, forehead, dorsum, flanks, hand, feet, outer limbs and tail exhibiting a blackish color; reddish-yellow sideburns and inner limbs; and dark reddish-brown chest, neck and belly (Figure 2). All sighting locations lie within the known distribution range of *P. hoffmannsi* (Veiga 2008b). The external appearance of *P. baptista* and *P. hoffmannsi* is distinct, and both species can be differentiated in the field by a series of pelage color pattern characteristics (Table 1). Although the observation is suggestive of a hybrid, molecular analyses would be necessary to confirm hybridization (Boubli *et al.* 2018).

The new *P. baptista* records show that the species is sympatric, not allopatric, with *P. hoffmannsi*. Roosmalen *et al.* (2002) proposed that some titi species could also be related, parapatric, and separated by an evolutionary process (possibly chromosomal inversion-linked incompatibility, Dumas *et al.* 2005) in a continuous geographical area, rather than being the result of allopatric speciation, as would be the case with *P. baptista* and *P. hoffmannsi* if the Paraná-Urariá River had acted as an effective geographical barrier. The occurrence of sympatric

titi species also supports the dispersal model proposed for *Cheracebus* and *Plecturocebus* through sequential, long distance events involving jump dispersal across rivers (Byrne *et al.* 2018).

Overlap in the distribution of *Plecturocebus* species is rare. Vermeer *et al.* (2001) reported a case for *P. discolor* and *P. oenanthe* in Peru. Printes *et al.* (2018) also reported an overlap between *P. baptista* and *P. hoffmannsi* on the left bank of the Tapajós River. In our study area, overlap may have occurred either by active dispersal across a river (Link *et al.* 2015), or by passive translocation via meander cut-offs (Jackson and Austin 2013).

It is also important to recognise that some recorded evolutionary phenomena may be recent (Rull 2011). Consequently, rather than being a long-established zone of contact between taxa, ours may be an example of a bridgehead population, newly established and integrating with existing forms, with whom they may still form viable offspring (Lombaert *et al.* 2010). Future studies should (i) confirm the occurrence of *P. baptista* x *P. hoffmannsi* hybrids in Maués, (ii) test whether they are fertile, (iii) determine the extent of the hybrid zone, and (iv) estimate the extent of genetic introgression, through non-invasive approaches such as satellite markers (Balloux *et al.* 2002) from fecal samples (Goossens *et al.* 2000). The areas where *P. baptista* is known to occur are subject to rapid habitat loss and fragmentation. Although titis are ecologically flexible and tolerant of human impacts (Chagas and Ferrari 2011), the speed and extent of habitat alteration should be cause for concern, specially since the species is not known to occur in any legally protected area. Within the municipality of Maués there are three protected areas in which the species could potentially occur (Maués State Forest, Pau-Rosa National Forest and Alto Maués Ecological Station), all connected to each other and with the Amaná National Forest, forming a conservation corridor with an area of 2,471,561 ha. Surveys and introgression studies of *P. baptista* and *P. hoffmannsi* should be conducted in these areas.

Our observations extend the limit of the historical distribution of *P. baptista* (Roosmalen, 2002), and support the evidence of its sympatry with *P. hoffmannsi* recently reported by Printes *et al.* (2018). According to our data, *Plecturocebus baptista* traversed the Paraná-Urariá River and probably dispersed in the interfluvium between the Amazonas (north), Madeira (southwest and west) and Tapajós (southeast and south) rivers to the left bank of the Tapajós (Printes *et al.* 2018). The interfluvium was formerly considered the area occupied exclusively by *P. hoffmannsi* (Veiga 2008b), therefore, populations of *P. baptista* and *P. hoffmannsi* occur in sympatry in the area.

Primate population surveys in the wider area of the Tapajós-Madeira interfluvium that aim to identify populations of *Plecturocebus* are necessary to understand the evolutionary history and ecology of the two species, as well as to ensure their preservation and that of their habitat. The dissemination of primological scientific knowledge is also key to promoting

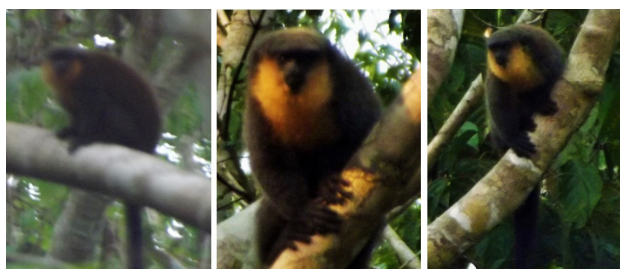


Figure 2. Images of a *Plecturocebus baptista* individual (left) and a potential *P. hoffmannsi* x *P. baptista* hybrid (centre and right) in Maués, Amazonas, Brazil.

Table 1. Comparison of color attributes of *Plecturocebus hoffmannsi* and *Plecturocebus baptista*, following Gualda-Barros *et al.* (2012). Illustrations from Reis *et al.* (2015).

Body part	<i>P. hoffmannsi</i>	<i>P. baptista</i>
Crown	grayish agouti	blackish to grayish agouti
Forehead	grayish agouti	blackish to grayish agouti
Sideburns	yellowish	dark reddish brown
Dorsum	grayish agouti	blackish to grayish agouti
Flanks	grayish agouti	blackish to grayish agouti
Neck, chest and belly	grayish agouti	dark reddish brown
Hands and feet	grayish agouti	blackish to grayish agouti
Limbs (outer)	grayish agouti	blackish to grayish agouti
Limbs (inner)	yellowish	dark reddish brown
Tail	dark grayish agouti	blackish to blackish agouti

awareness and appreciation of local biodiversity, and integration with sustainable economic activities such as primate-based tourism (Marsh 2002).

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