

**NEW SOUTHERNMOST RECORDS OF *Callithrix geoffroyi*
(PRIMATES, CALLITRICHIDAE) EXPAND THE SPECIES KNOWN RANGE,
IN SOUTHEASTERN BRAZIL**

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The Geoffroy's marmoset, *Callithrix geoffroyi* (Humboldt, 1812), is a small sized primate common in southeastern Brazilian Atlantic Forest. It occurs predominantly in lowland forest of the state of Espírito Santo, but also in the southern portion of the state of Bahia and northeastern portion of the state of Minas Gerais (Figure 1, Rylands *et al.* 2009). In Minas Gerais, it occurs in the interfluvium of Jequitinhonha River and Doce River (Rylands *et al.* 1996, 2009). The westernmost and highest record of *C. geoffroyi* is at Serra do Cipó National Park at 1274 m of altitude in Minas Gerais state (Oliveira *et al.* 2003). Although rivers and mountains delimit the species range, today they are unlikely to be effective geographic barriers for dispersal - especially rivers, that nowadays do not have enough depth and width to prevent crossing (Hershkovitz 1977, Rylands *et al.* 1996, Mendes 1997). Climate conditions, topography, vegetation type, and interspecific competition with congeners are factors frequently pointed as determinants of *Callithrix* range limits (Rylands *et al.* 1996, Mendes 1997, Cerqueira *et al.* 1998, Grelle & Cerqueira 2006). Despite a relative well-known distribution, a definite delimitation of the species' southern geographic boundary is lacking, due to a gap of information about its occurrence and lack of surveys in southern Espírito Santo and northern Rio de Janeiro states. Disregarding introduced populations in Santa Catarina and São Paulo states (Rylands & Mendes 2008, Vivo *et al.* 2011), the southernmost historical record of *C. geoffroyi* is at the municipality of Guarapari, Espírito Santo state (specimen collected by M.

Martinelli and deposited at the Professor Mello Leitão Biology Museum, Espírito Santo (no. MBML 3011)). Mendes (1997) suggested that the southernmost geographic boundary of *C. geoffroyi* does not exceed the Itapemirim River, in southern Espírito Santo, while others suggested the boundary to be further south, near the border between Espírito Santo and Rio de Janeiro states (Rylands *et al.* 2009).

Here we present new records of *C. geoffroyi* and hybrids between that species and *C. penicillata* found in southern Espírito Santo and northern Rio de Janeiro states. We recorded *C. geoffroyi* in municipalities of Anchieta and Bom Jesus do Norte, in the state of Espírito Santo, and hybrids in municipalities of Mimoso do Sul, Espírito Santo, and Bom Jesus do Itabapoana, Rio de Janeiro state, all further south than the southernmost currently known record for the species (Table 1).

On December 2011, we recorded a group of five individuals of *C. geoffroyi*, opportunistically sighted out of the systematic survey described in the Material and Methods section, at Sítio Luma de Oliveira in Castelhanos, on the left bank of Benevente River, in the municipality of Anchieta, Espírito Santo state (20°49'31"S, 40°37'51"W, Figure 1). In January 2012, a second record was made in Espírito Santo. A couple of hybrids between *C. geoffroyi* and *C. penicillata* was found at Fazenda Independência, in a rural zone of the municipality of Mimoso do Sul (21°07'03"S, 41°24'52"W, Figure 1). No *Callithrix* group was found during the searches in these forest fragments. The couple was sighted nearby houses, where they

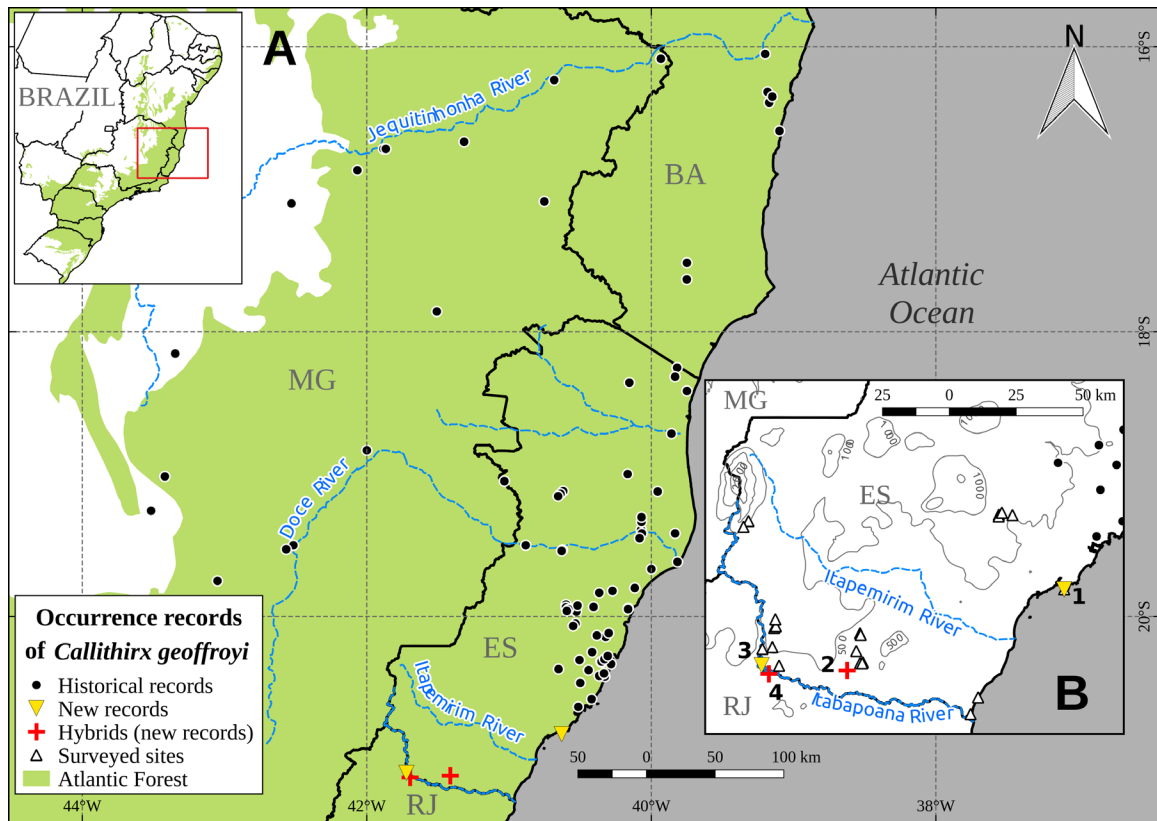


Figure 1. Occurrence records of *Callithrix geoffroyi*. A) Historical records compiled from literature and biological collections, and new records from sites surveyed in this study; Atlantic Forest boundaries according to Brasil (2006); Brazilian States: BA = Bahia, ES = Espírito Santo, MG = Minas Gerais, RJ = Rio de Janeiro. B) Zoom to study area. Altitude lines depicted in grey. Surveyed sites: 1 = Sítio Luma de Oliveira, Castelhanos, Anchieta, ES; 2 = Fazenda Independência, Mimoso do Sul, ES; 3 = Itabapoana River, Bom Jesus do Norte, ES; 4 = right bank of Itabapoana River, Bom Jesus do Itabapoana, RJ.

Table 1. Sites where the *Callithrix* individuals were recorded from July 2011 to January 2012. Brazilian states: ES = Espírito Santo, RJ = Rio de Janeiro.

Species	Coordinate	Locality
<i>C. geoffroyi</i>	20°49'31"S, 40°37'51"W	Sítio Luma de Oliveira, Castelhanos, Anchieta / ES
<i>C. geoffroyi</i> × <i>C. penicillata</i> (hybrids)	21°07'03"S, 41°24'52"W	Fazenda Independência, Mimoso do Sul / ES
<i>C. geoffroyi</i>	21°07'24"S, 41°42'59"W	Bom Jesus do Norte / ES
<i>C. geoffroyi</i> × <i>C. penicillata</i> (hybrids)	21°07'31"S, 41°42'45"W	Bom Jesus do Itabapoana / RJ

were often fed by locals. Both individuals had general pelage patterns similar to *C. geoffroyi*. The female, however, had a dark grey color around the head and dorsal pelage without orange stripes (Figure 2A), which is considered uncommon for

C. geoffroyi (Hershkovitz 1977, Mendes 1997). The male had orange stripes in the dorsal pelage but the head also had a grey color, lighter than the female (Figure 2A). A white spot in the forehead was evident in both, due to the greyish lighter

pelage around head, which is characteristic of *C. penicillata* (Herskovitz 1977, Fuzessy *et al.* 2014). The lighter pelage does not extend through the neck in both individuals observed, while in Geoffroy's marmosets the white pelage exceeds the throat (Mendes 1997, Fuzessy *et al.* 2014). Local residents said that the groups with white-headed individuals had recently been spotted in the region. These marmosets' pelage patterns meet the descriptions of wild hybrids between *C. geoffroyi* and *C. penicillata* (Fuzessy *et al.* 2014).

Additionally, in July 2011, a specimen of *C. geoffroyi* was accidentally captured in a tomahawk trap during a small mammal inventory in the left bank of Itabapoana River, a boundary between Espírito Santo and Rio de Janeiro states, in municipality of Bom Jesus do Norte, Espírito Santo (21°07'24"S, 41°42'59"W, Figure 1) (Figure 2B). This is the first record of *C. geoffroyi* to the south of Itapemirim River, expanding its known historical distribution to about 29' south (ca. 54 km). In a nearby locality, a group of hybrid individuals with the same pelage pattern of the specimens found at Fazenda Independência was sighted nearby houses in the right bank of the Itabapoana River, at municipality of Bom Jesus do Itabapoana, Rio de Janeiro state (21°07'31"S, 41°42'45"W, Figure 1) (Figure 2C).

Although we only report two new records to the south of the species range, this is the first record of *C. geoffroyi* south of Itapemirim River, allegedly the species' southernmost boundary (Figure 1). There are two hypotheses to explain this new finding: *C. geoffroyi* is native to the sites, but this has been ignored to date or *C. geoffroyi* has recently occupied these sites (i.e. at least over the last years), by human facilitation. We argue that the species' presence in southern Espírito Santo has been ignored. First, because southern Espírito Santo has relatively few mammalian biological inventories (Moreira *et al.* 2008). Second, because there are no efficient barriers to dispersal between these new sites and the previously known southern limit of the species' distribution (Guarapari), and these sites are not too far apart. Third, because distribution modeling reveals apparently adequate environmental conditions for *C. geoffroyi*'s occurrence in southern Espírito Santo and northern

Rio de Janeiro states (Nicolaevisky 2011). Fourth, there are no congeners, as potential competitors, native of northern Rio de Janeiro and southern Espírito Santo states lowlands, given that *C. aurita* and *C. flaviceps*, whose distributions could likely reach these regions, are predominantly higher altitude dwellers. This region, however, clearly represents the species' range limits, which in general sustain populations that are highly dynamic and with low density levels (Holt & Keitt 2000, Gaston 2003, Sexton *et al.* 2009). This may explain the absence or lack of detection of *C. geoffroyi* at the other surveyed localities. The data and arguments presented here, however, are not enough to completely discard the possibility that this species has been recently carried by humans to the south of Itapemirim River, as previously suggested for populations to the south of Jequitinhonha River (Coimbra-Filho 1986 *apud* Mendes 1997, Rylands & Mendes 2008). Only genetic studies could shed light on the origin of the individuals found in south of Itapemirim River.

In addition to the low population density expected at species' range limits, it is possible that these areas remain largely unoccupied today by *C. geoffroyi* because of the intense deforestation and fragmentation of the Brazilian Atlantic Forest (Ribeiro *et al.* 2009), which in Rio de Janeiro is particularly harsh in lowland forests (Jenkins *et al.* 2011). If that is the case, then deforestation may also have a role in defining the southern boundary of *C. geoffroyi*'s range.

The hybrids found in the Espírito Santo/Rio de Janeiro boundary also indicate the presence of non-native congeners in the region. Indeed, Mendes (1997) reported the presence of *C. penicillata* in the municipality of Itapemirim, in southern Espírito Santo. The introduction of exotic marmosets, usually associated with pet trade, is another threat to native *Callithrix* species. The transportation and release of marmosets outside their historical range may lead to the replacement of native marmosets by exotic congeners or by hybrids (Passamani *et al.* 1997, Pereira *et al.* 2008), changing the geographic distribution patterns of the genera. The presence of established populations of introduced *C. jacchus* and *C. penicillata* in the state of Rio de Janeiro is well documented in the literature (Oliveira & Grelle 2012, Rocha *et al.* 2004), being a cause



Figure 2. *Callithrix* individuals recorded. (A) A pair of hybrids between *Callithrix geoffroyi* and *C. penicillata* found at Fazenda Independência, Mimoso do Sul, Espírito Santo, with female in the left and male in the right. (B) *C. geoffroyi* captured in the left bank of Itabapoana River, Bom Jesus do Norte, Espírito Santo. (C) Hybrid specimen (*C. geoffroyi* × *C. penicillata*) found in the right bank of Itabapoana River, Bom Jesus do Itabapoana, Rio de Janeiro.

of concern for both marmosets and other native species (Alexandrino *et al.* 2012, Galetti *et al.* 2009, Oliveira & Grelle 2012, Pereira *et al.* 2008, Ruiz-Miranda *et al.* 2006). Therefore, human introductions of exotic marmosets, together with Atlantic Forest deforestation, may be precluding a predictable and steady expansion of the distribution of *C. geoffroyi*.

In 2008, the IUCN removed *Callithrix geoffroyi* from the Red List of threatened species. However, deforestation of Brazilian Atlantic Forest associated with illegal trade of marmosets and the release of exotic congeners within the range of *C.*

geoffroyi are major threats to the species (Rylands & Mendes 2008). Furthermore, predictions of global climate change impacts on Atlantic Forest species are worrisome (Colombo & Joly 2010, Loyola *et al.* 2012, 2013, Souza *et al.* 2011). Here we presented new records and considerations about the southern geographic boundary and distribution of *C. geoffroyi*. Considering these new records, the known geographic distribution of *C. geoffroyi* extends about 54 km to the south and the species' range reaches the Espírito Santo/Rio de Janeiro state border. Although climate, geographic barriers, and interspecific interactions

are proposed as common determinants of *Callithrix* species' geographic distributions, we suggest that deforestation should also be investigated as a possible range delimiter. We recommend the search of callitrichids to the south of Itabapoana River to better understand possible anthropic influences in the species' current distribution dynamics.

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MATERIAL AND METHODS

From January to September 2012, we sampled 21 localities at eight municipalities to the south of the known range boundary of *C. geoffroyi*, in Espírito Santo state. Fragments were chosen by size, using Google Earth, version 6.0 (<https://www.google.com/earth/>) or through indication of the presence of *Callithrix* by local residents. We conducted active searches for groups of *C. geoffroyi* using playback in these Atlantic Forest fragments. Playback recordings were granted by the sound collection of the Fonoteca Neotropical Jacques Viellard (<http://proj.lis.ic.unicamp.br/fnjv>) (ID numbers: 07726, 07728, 07857, 07858, 07859, and 07865). The audio files contained mainly long-call recordings of *C. geoffroyi* that group members use for intra-group cohesion and inter-group territorial defense (Snowdon 1993 *apud* Mendes 2009). Searches were taken daily in the early morning and late afternoon, which corresponds to the species' most activity hours (Passamani 1998), during four or five days with approximately one month interval between expeditions. Playback was conducted along previously open trails in fragments, in which linear transects were adopted whenever possible. However, when fragments were inaccessible, playback was used at the edges. We established playback points 150-200 m away from each other, and at each point playback was played in each direction. We waited about 40 s after playback for marmoset response. The number of playback points

in each fragment ranged from 6 to 10, depending on fragment size.

Additionally, we recorded *C. geoffroyi* individuals and hybrids opportunistically, in a small mammal inventory using tomahawk traps in July 2011, and by opportunistic sighting in Anchieta, Espírito Santo state, in December 2011.

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