Articles

CALLITHRIX AURITA: A MARMOSET SPECIES ON ITS WAY TO EXTINCTION IN THE BRAZILIAN ATLANTIC FOREST

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Abstract

The buffy-tufted-ear marmoset (*Callithrix aurita*) is a small primate endemic to the montane regions of the southeastern Atlantic Forest in Brazil. The species was formerly listed as "Vulnerable" (VU) on the Brazilian Official National List of Threatened Fauna Species, but in December 2014 it was re-classified as "Endangered" (EN) as a result of habitat loss, forest fragmentation and, especially, competition and hybridization with invasive marmosets (*Callithrix* spp.). This article gives an overview of the current conservation status of and field research on *C. aurita* that includes the objectives set forth by the *C. aurita* Conservation Project (spearheaded in December 2014 by a group of *C. aurita* researchers), and the related set of integrated conservation actions. These actions include expanded geographical surveys of *C. aurita* populations, improvements to a captive *C. aurita* breeding program, and the establishment of new protected areas as part of a *C. aurita* metapopulation management program. Despite these current efforts, however, the strengthening and consolidation of urgent conservation actions to protect the buffy-tufted-ear marmoset still depend on a variety of factors, including increased institutional collaboration and augmented financial support. Enhancing institutional and financial backing for *C. aurita* conservation will improve our understanding of the various challenges involved and, facilitate the rapid development of alternative strategies to mitigate ongoing threats to the species.

Keywords: Callitrichids, invasive species, buffy-tufted-ear marmoset, primate conservation

Resumo

O sagui-da-serra-escuro (*Callithrix aurita*) é um pequeno primata endêmico das regiões montanhosas da Floresta Atlântica do sudeste brasileiro. Essa espécie foi considerada "Vulnerável" (VU) na Lista Vermelha do Brasil, mas desde dezembro de 2014, ela foi reclassificada como "Em perigo" pela Lista Nacional de Espécies de Fauna Ameaçadas, como consequência da perda de habitat, da fragmentação florestal e, especialmente, da competição e hibridação com espécies de saguis invasores (*Callithrix* spp.). Este artigo oferece uma visão geral do estado de conservação atual do *C. aurita* e resume as últimas pesquisas publicadas sobre a espécie. Também são descritos os esforços recentes direcionados para a conservação do *C. aurita*, que incluem os objetivos estabelecidos pelo Projeto de Conservação do *C. aurita* (projeto lançado em dezembro de 2014 por um amplo grupo de pesquisadores de *C. aurita*), e um conjunto de ações integradas que estão sendo realizadas para sua conservação. Entre estas ações estão a ampliação dos levantamentos das populações de *C. aurita*, o aperfeiçoamento do programa de criação de *C. aurita* em cativeiro, e o estabelecimento de novas áreas protegidas para servir como parte de um programa de manejo da metapopulação de *C. aurita*. No entanto, apesar dos esforços atuais, o fortalecimento e a consolidação dessas ações urgentes de conservação para proteger o sagui-da-serra-escuro ainda dependem de uma variedade de fatores, como o aumento de colaborações institucionais e o aumento de apoio financeiro. Aumentar o apoio institucional e financeiro para a conservação de *C. aurita* melhorará decisivamente a nossa compreensão dos vários desafios à conservação do *C. aurita* e viabilizará o desenvolvimento rápido e efetivo de estratégias alternativas para mitigar as ameaças em curso à sobrevivência dessa espécie.

Palavras-chave: Calitriquídeos, espécies invasoras, sagui-da-serra-escuro, conservação de primatas

Introduction

The buffy-tufted-ear marmoset (*Callithrix aurita,* Figure 1) is a small callitrichid 500–580 mm in head-body length (Vivo, 1991) and 400–450 g (Garber, 1992) in weight. It is endemic to montane regions of the Atlantic Forest in the Brazilian states of Rio de Janeiro, São Paulo (northeastern part), and Minas Gerais (southeastern part) (Coimbra-Filho, 1991; Brandão and Develey, 1998; Melo *et al*., 2015). The species was formerly listed as Vulnerable (VU) on the Official National List of Threatened Species (Melo and Rylands, 2008) and the IUCN Red List of Threatened Species (Rylands *et al*., 2008), as well as the Rio de Janeiro state list (Bergallo *et al*., 2000). In 2010, however, it was listed as Endangered (EN) in the state of Minas Gerais (Brazil, 2010). São Paulo state maintained it as Vulnerable until 2014 (Port-Carvalho and Kierulff, 2009), when it was also re-categorized as Endangered (Brazil, São Paulo, 2012). In December 2014, the species was classified as Endangered on the Brazilian national list (Brazil, MMA, 2014), and has been indicated for this category in the recent (2015) international reassessment of the IUCN Red List (IUCN SSC Primate Specialist Group, in prep.). The main reason for the reassessment was the inference of a population reduction of at least 50 % over three generations (18 years) resulting from habitat loss, forest fragmentation, and, especially, competition and hybridization with invasive marmosets (*Callithrix* spp.).

In 1982, the Rio de Janeiro Primatology Center (Centro de Primatologia do Rio de Janeiro – CPRJ) began a captive breeding program for the species due to concerns about its status in the wild (Coimbra-Filho, 1971, 1986, 1990). While there was rapid growth of the captive *C. aurita* population at CPRJ, reaching 40 individuals, maintaining them was challenging due to the occurrence of progressive wasting syndrome in the animals, as well as mortality due to apparent leukemia. Proper nutrition of *C. aurita* was also problematic due to the species' specialized diet resulting from adaptations to high-altitude habitats. A further challenge was finding proper housing for *C. aurita*, as the marmosets were placed into enclosures formerly occupied by Amazonian species of *Mico* (formerly *Callithrix*) and *Saguinus*. These accommodations could have facilitated virus transmission to *C. aurita* and led to the aforementioned cases of leukemia.

Figure 1. Buffy-tufted-ear marmoset, *Callithrix aurita*. Photo credit: R. Carvalho.

Due to its threatened status, *C. aurita* was included in the *National Action Plan for the Conservation of the Central*

Atlantic Forest Mammals (Escarlate-Tavares *et al.*, 2016). Research efforts focusing on the ecology and genetics of *C. aurita* were increased following the recommendations of this action plan, revealing that the threatened status of *C. aurita* was more worrisome than previously thought, and further justifying the reassessment of its conservation status.

Threats to conservation of wild *C. aurita* populations

Recent ecological research has shown that *C. aurita* faces competition from invasive marmosets (Pereira, 2006, 2010; Rylands *et al.*, 2008; Melo and Rylands, 2008; Pereira *et al.*, 2008, 2014; Port-Carvalho and Kierulff, 2009; Nogueira *et al.*, 2011; Bechara, 2012; Carvalho *et al.*, 2013; Carvalho, 2015; Melo *et al.*, 2015; Nunes, 2015; Gonçalves, 2016), and genetic research also demonstrates hybridization between *C. aurita* and their introduced congeners (Pereira, 2010; Nogueira *et al.*, 2011; Carvalho *et al.*, 2013; Carvalho, 2015). The invasive presence of exotic marmosets within the natural range of *C. aurita* is the result of the legal and illegal pet trade within Brazil. The species involved are black-tufted ear marmosets (*Callithrix penicillata*), occurring in the Cerrado and Caatinga of Central Brazil, and, predominantly, common marmosets (*Callithrix jacchus*), otherwise native to Northeast Brazil (Rylands *et al.*, 2009; L. Oliveira, A. Pissinatti, pers. obs.).

The common destinations of exotic *C. jacchus* and *C. penicillata* have been the rural areas and urban centers of Rio de Janeiro, São Paulo and Minas Gerais (Oliveira and Grelle, 2012). Pet marmosets are subsequently released by their "owners," and establish themselves in anthropogenically altered and disturbed habitats at forest-urban interfaces. They exhibit elevated adaptability to the highly-urbanized areas of Southeast Brazil and prosper; rapidly colonizing the native range of *C. aurita* throughout its range. This phenomenon is even observed in more preserved areas where native *C. aurita* are now commonly in contact with or close to these exotic populations of their congeners.

The growing invasion (here considered as the establishment of the breeding population of a non-native species with impacts on the local biodiversity) of exotic marmosets is rapidly affecting native populations of the buffy-tufted-ear marmoset. Indeed, groups of exotic and hybrid marmosets are physically replacing native *C. aurita* populations (Pereira, 2006, 2010; Bechara, 2012; Oliveira, 2012; Carvalho *et al.*, 2013; Carvalho, 2015; Melo *et al.*, 2015; Nunes, 2015). Besides physical replacement, hybridization undoubtedly affects the genetic integrity of pure *C. aurita* populations through genetic introgression. Genetic material from exotic *C. jacchus* and *C. penicillata* can introgress into the *C. aurita* genome through backcrossing of hybrid marmosets with pure *C. aurita,* although previous studies have shown that *C. aurita* and *C. jacchus*/*C. penicillata* belong to two distinct subgroups within the genus (see discussion in Malukiewicz *et al.*, 2017). This introgression of exotic marmoset genetic material into *C. aurita* carries serious, unknown evolutionary and conservation consequences.

The speed and potential consequences of this invasive process that *C. aurita* faces is well exemplified by the situation in the Serra dos Órgãos National Park in Rio de Janeiro State. Five years of observations of two pure *C. aurita* groups in the park indicated no contact of these native groups with any invasive marmosets. However, field data and film from 2015 demonstrated, for the first time, the presence of exotic marmosets near the monitored native groups. Further, the replacement of one of the pure *C. aurita* groups by a mixed group of exotic and native species was also observed in 2015. These sorts of mixed group are a threat to genetic integrity of *C. aurita* as they facilitate hybridization, backcrossing, and introgression. A recent genetic study has also evidenced ongoing hybridization within the Serra dos Órgãos National Park (Carvalho, 2015). This situation in the Serra dos Órgãos National Park is emblematic of the invasive process that is happening in other parts of *C. aurita*'s native range (C. Knogge, W. Lacerda, R. Carvalho, L. Oliveira, D. Pereira, J. Malukiewicz, pers. obs.). *Callithrix aurita* also hybridizes naturally with its parapatric neighbors *C. flaviceps* (Ferrari and Mendes, 1991; Melo, 1999) and probably *C. geoffroyi* (in the basin of the Rio Santo Antônio), including some natural contact areas in the vicinity of Rio Doce State Park, Minas Gerais (Coimbra-Filho, 1971; Mendes, 1989; F. R. Melo, pers. obs.). These appear to be stable hybrid zones (Coimbra-Filho *et al.*, 1993).

One limitation for conservation actions is that for many parts of the native *C. aurita* distribution, such as São Paulo State, up-to-date information on the occurrence of remaining *C. aurita* populations and the effects of invasive marmosets on *C. aurita* is still scarce. Moreover, there is not enough field information to identify the critical and key remaining populations of *C. aurita* that could be targeted for conservation action to reverse the population decline and protect viable populations. There are still a number of pure *C. aurita* populations living, but forest destruction is a major threat to this species (Rylands et al., 2008), and, consequently, remaining populations are frequently isolated in forest patches as small as 10 ha (R. Carvalho, pers. obs.) Such isolated populations may potentially suffer genetic, demographic and ecological problems of inbreeding, such as rare reproductive opportunities, limited food resources, and increased disease susceptibility (Keller and Waller, 2002). When close to human settlements, they also suffer from road kill and predation by dogs. These scenarios are frequently observed in several cities in São Paulo State,

including Mogi Guaçu, Mairiporã and Atibaia (M. Port-Carvalho, pers. comm.).

A conservation plan for *C. aurita* populations

The situation of *C. aurita* has now attracted the attention of a wider group of primatologists, conservationists and public agents, and has resulted in the preparation of a comprehensive conservation plan for the species. An inter-institutional meeting occurred on April 4, 2014, to prioritize urgent research and management measures for the conservation of *C. aurita*. It was held during the 1st Callitrichid Conservation Husbandry Workshop, sponsored by the Durrell Wildlife Conservation Trust, the National Center for Research and Conservation of Brazilian Primates (CPB) of the Instituto Chico Mendes de Conservação de Biodiversidade (ICMBio), and CPRJ. Institutions represented included ICMBio/CPB, CPRJ, UERJ (Universidade Estadual do Rio de Janeiro), Guarulhos Zoo, Sorocaba Zoo and Durrell. The group decided on the initial steps to establish the *Callithrix aurita* Conservation Project. Thereafter, eight other meetings were held at UERJ (July 31, 2014), Serra dos Órgãos National Park, (June 26, 2015) the São Paulo Forestry Institute (May 11, 2015; August 05, 2016), the Wildlife Department of the Environmental Secretary of São Paulo (June 10, 2016), during the XIV Brazilian Primatology Congress in Manaus (Nov 12, 2015), and at Guarulhos Zoo (October 21, 2015; March 03, 2016). They resulted in the prioritization of the following objectives: (1) to survey and determine areas of *C. aurita* occurrence under a standardized field protocol; (2) to enhance and expand a captive *C. aurita* breeding program; (3) to use field survey data to identify priority *C. aurita* conservation areas and establish protective refuges for wild *C. aurita* populations; (4) to create a specific decision tree for field work and management of introduced marmosets occurring inside *C. aurita*'s native range; and (5) to conduct the necessary scientific research to support an adaptive management plan for effective *C. aurita* conservation.

In March 2015, São Paulo State (SP) took the initiative of drafting its own conservation plan for *C. aurita.* The plan drafted by the Permanent Protection Committee of the Primates of the State of São Paulo (Brazil, São Paulo, 2014) embodied the general objectives above as well initiatives to: 1) develop a phenotypic identification key for *C. aurita* using published data and expertise of primate specialists; 2) elaborate an Action Plan for *C. aurita* conservation in São Paulo; 3) implement outreach and environmental education activities aimed at marmoset conservation; 4) implement management actions for *C. aurita* metapopulations *in situ*; 5) manage critical areas with introduced and/or hybrid marmoset populations; and 6) conduct research on *C. aurita* genetic diversity and hybridization with exotic congeners.

Current conservation actions to preserve remaining *C. aurita* populations

The first actions of the collaborative initiative for the *C. aurita* Conservation Project have started to be implemented, mainly through surveys to assess the species' current distribution and conservation threats. These surveys have been carried out since October 2015 by the NGO Muriqui Biodiversity Institute, the Environmental Secretariat of São Paulo, the research team and managers of the Serra dos Orgãos National Park, and the NGOs Instituto Bioma (Rio de Janeiro) and PREA (Minas Gerais). They have received the support of ICMBio, and three international institutions—Beauval Nature, Association Française des Parcs Zoologiques and the Margot Marsh Biodiversity Foundation. Another important initiative is a legislative proposal by the state of São Paulo, which has been under consideration by the office of the state's Environmental Secretary since 2016 to establish reproductive restrictions for allochthonous *Callithrix* legally held in captivity within São Paulo, in order to reduce surplus, legally-captive marmosets and reduce undue releases of exotic *Callithrix* into the wild.

Another important measure was the creation of a studbook for the captive population; a result of the 2nd Callitrichid Conservation Management Workshop, held in Manaus, in November 2015, and with the help of the Golden Lion Tamarin International Studbook keeper, Dr. Jennifer Mickelberg of Zoo Atlanta. There are very few currently in captivity; recent counting showed only about 33 (Studbook Keeper, C. Igayara, pers. comm.), and it is imperative that the growth of this small population is managed in such a way that its genetic diversity is maximized.

Preserving the diversity of *C. aurita* is especially important because wild *C. aurita* face a continued influx of invading marmoset species from the ongoing illegal wildlife trade, as well as from hybrid marmoset populations established in the surroundings areas (Moraes *et al.*, 2008). The ubiquitousness of introduced and hybrid marmosets is flagrant and widespread throughout the state of Rio de Janeiro, and the captive *C. aurita* population could be an important reservoir to ensure the species' survival and its reintroduction back into the wild.

Genetic and genomic studies have begun in order to assess levels of biodiversity with C. aurita. Carvalho (2015) conducted one of the first genetic studies of *C. aurita* that included individuals from within São Paulo and Rio de Janeiro states. Using the mitochondrial (mtDNA) cytochrome oxidase I (COI) locus, the genetic data showed 3 distinct haplotypes among 11 *C. aurita* genetic sequences. The *C. aurita* COI haplotypes had an average genetic p-distance of 5% in comparison to the COI haplotypes of *C. jacchus, C. penicillata, C. geoffroyi* and *C. kuhlii,* and, also formed

a sister clade with that of the latter set of species. Currently, a project is underway to assess genetic diversity of *C. aurita* over the entire mtDNA genome. Further, plans are being formulated to create a draft version of the nuclear *C. aurita* genome, and study introgression of *C. jacchus* and *C. penicillata* genomes into that of *C. aurita* (J. Malukiewicz and R. Carvalho, pers. comm.). Such genomic data will be important for future considerations of creating areas to preserve wild *C. aurita* populations and translocation of any such populations.

New reserves are being created and proposed in the states of São Paulo and Rio de Janeiro that we expect will benefit *C. aurita*. A new protected area is in the final stages of implementation in the Itapeti mountain range (1,763.45 ha) covering parts of the municipalities of Mogi das Cruzes, Guararema and Suzano (Brazil, São Paulo, Secretário do Meio Ambiente, 2017). An area adjoining the Ecological Station of Mogi Guaçu is being considered for a change in status from an experimental station to a state forest to extend the total protected area from 1,300 to 4,000 ha. This change would join together a mosaic of conservation units with the biological reserve administered by the Botanical Institute (in São Paulo), which is composed of over 470 hectares of a region formally called the Campininha farm (Barreto and Cabello de Brito, 2015). In Rio de Janeiro, the municipal government of Nova Friburgo is fast-tracking the creation of a local reserve for *C. aurita* with the support of the municipality's residents.

Conclusion and future outlook

Continued implementation of the objectives and actions of the *C. aurita* Conservation Project, as suggested and planned by the scientific community, requires direct participation of the personnel working in protected areas that have populations of *C. aurita*. Managers of these protected areas will be responsible for the implementation of scientific conservation measures. The supporting staff to whom this conservation work will subsequently be delegated possess indispensable experience and knowledge of the local flora and fauna. Thus, early and ongoing involvement of both managers and staff in the *C. aurita* Conservation Project is crucial to the project's success. Such participation is already happening at the Serra dos Órgãos National Park, the Mananciais do Rio Paraíba do Sul Environmental Protection Area, and protected areas in the urban district of São Paulo. There are many small populations of *C. aurita* on privately-owned land, which must also be integrated into the management plan by the willingness of landowners to transform this land into conservation units such as Brazilian Private Natural Heritage Reserves.

A crucial challenge to overcome is deciding control measures for invasive marmoset species that threaten *C. aurita*, in the face of the diverse opinions of the different stakeholders involved (scientists, NGOs, park managers, general public). Acceptance among stakeholders is essential for a set of effective management actions, as this agreement may give greater support to implement the actions. Even though there is a set of agreed upon principles to deal with the threat of invasive species towards conservation units, published in the national action plan (Escarlate-Tavares *et al.*, 2016), a decision stalemate exists as to the destination of marmosets that are captured, and this has been a major obstacle, because it has led to a lack of action and the permanence of introduced marmosets. These issues were recently broached at the "Integrative Actions for the Conservation of the Buffy-Tufted-Ear Marmoset and Resolving Threats from Invasive Congeners: Proposals and Alternatives" workshop, held at the Serra dos Órgãos National Park (June 26, 2015). This workshop highlighted the importance of implementing conservation strategies that draw from both scientific and applied expertise in order to achieve the conservation of *C. aurita*.

Besides the scientific and environmental communities, the general public will also play an indispensable role in the conservation of *C. aurita*. For example, we have received important records of the occurrence of *C. aurita* and introduced marmosets from the general public via social media, cell phone applications, and birdwatchers. Such information highlights the notion that efficient communication with the general public and the involvement of citizen-science strategies is an important conservation tool. Furthermore, all conservation measures taken by scientists, NGOs, public officials, and parks managers/staff are important for environmental education about *C. aurita* and the threats this species faces. Accordingly, one future priority of the *C. aurita* Conversation Plan will be to amplify our outreach efforts to educate and communicate with the public.

Of the many important issues that were highlighted at the XVI Brazilian Congress of Primatology, one has deserved special attention: the recent alarming indications that wild *Callithrix aurita* may be on an irreversible path to extinction. This issue raised concern that *C. aurita* is among the Neotropical primates at highest risk, particularly due to impacts from congeneric species. As such, urgent conservation actions to protect the buffy-tufted-ear marmoset must be implemented by better analyzing the various scenarios that threaten *C. aurita* conservation and by rapidly developing alternatives to mitigate ongoing threats to the species.

Special attention must also be given to licensing procedures involving urban development and construction ventures throughout the geographical distribution of *C. aurita*, especially in the larger municipalities of São Paulo and Rio de Janeiro. Licensing procedures include environmental

impact studies to investigate the possible occurrence of threatened species within forest fragments slated for development. Improper identification of threatened species under environmental licensing can lead to the mismanagement of both species conservation and legal requirements to offset the environmental impact of development. In addition to conservation measures and mitigation proposals in the areas of occurrence of the species, *in situ* information on ecology and behavior are needed for sound decision-making in licensing procedures to authorize major construction and development operations.

Current systematic surveys to identify regions with pure *C. aurita* populations, hybrid groups and invasive *Callithrix* spp., have already begun in some parts of the species' range (Pereira, 2010; Lacerda *et al*., 2015; Melo *et al*., 2015; Nunes, 2015), along with studies of ecology, population density, population genetics, and conservation medicine. Such work will make it possible to accurately evaluate the best strategies and chances for the species' recovery and survival. The first steps of raising awareness for *C. aurita*'s plight and mobilization of a conservation plan have been laid out, but our future conservation efforts will require partnerships with other researchers and institutions in order to synergize efforts to face the various challenges of saving *C. aurita* as an evolutionarily and ecologically unique Neotropical primate.

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