ISSN 2317-6237

BOLETIM
MUSEU PARAENSE EMÍLIO GOELDI

# CIÊNCIAS NATURAIS

v. 15 n. 3 setembro/dezembro de 2020

## A Tour in the South American Mammalogy
Editor: Alexandra Maria Ramos Bezerra

# Boletim do Museu Paraense Emílio Goeldi

## Ciências Naturais

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v. 15, n. 3
setembro-dezembro
2020

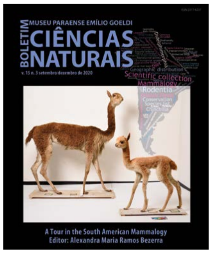

IMAGEM DA CAPA
Dois espécimes de *Vicugna vicugna* (Molina, 1782) coletados por J. J. von Tschudi no Peru e depositados no *Muséum d'Histoire Naturelle de Neuchâtel*. Números de tombo 94.1565C (esquerda) e 94.1565B (direita). Autor: Louise Robert.

BOLETIM DO MUSEU PARAENSE EMÍLIO GOELDI.
CIÊNCIAS NATURAIS (ISSN 2317-6237)

O Boletim do Museu Paraense de História Natural e Ethnographia foi criado por Emílio Goeldi e o primeiro fascículo surgiu em 1894. O atual Boletim é sucedâneo daquele.

The *Boletim do Museu Paraense de História Natural e Ethnographia* was created by Emilio Goeldi, and the first number was issued in 1894. The present one is the successor to this publication.

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Museu Paraense Emílio Goeldi

# Boletim do Museu Paraense Emílio Goeldi
## Ciências Naturais

ISSN 2317-6237

| Bol. Mus. Para. Emílio Goeldi | Cienc. Nat. | Belém | v. 15 | n. 3 | p. 523-931 | setembro-dezembro 2020 |
|---|---|---|---|---|---|---|

ENDEREÇO PARA CORRESPONDÊNCIA:
Museu Paraense Emílio Goeldi
Núcleo Editorial - Boletim do Museu Paraense Emílio Goeldi
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Belém - PA - Brasil
Telefone: 55-91-3075-6186
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VERSÃO ONLINE DA REVISTA:
http://editora.museu-goeldi.br/naturais/index.html
http://issuu.com/bgoeldi_cn

SUBMISSÃO DE TRABALHOS:
https://boletimcn.museu-goeldi.br/ojs/?journal=bcnaturais&page=login

AQUISIÇÃO:
Permuta: mgdoc@museu-goeldi.br
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INDEXADORES
CAB Abstracts
IBSS - International Bibliography of the Social Sciences
LATINDEX - Sistema Regional de Información en Línea para Revistas Científicas de América Latina, el Caribe, Espanã y Portugal
Zoological Record

Dados Internacionais de Catalogação na Publicação CIP

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Boletim do Museu Paraense Emílio Goeldi. Ciências Naturais. 2020. – Belém: MPEG, 2020. v. 15 n. 3., v. il.
Semestral: 1984-2002
Interrompida: 2003-2004
Quadrimestral a partir do v. 1, 2005.

Títulos anteriores: Boletim Museu Paraense de História Natural e Ethnographia 1894-98; Boletim Museu Paraense de História Natural e Ethnographia (Museu Goeldi) 1902; Boletim do Museu Goeldi (Museu Paraense) de História Natural e Ethnographia 1906-1914; Boletim do Museu Paraense Emílio Goeldi de História Natural e Etnografia 1933; Boletim do Museu Paraense Emílio Goeldi 1949-2002, série Zoologia, série Botânica e série Ciências da Terra; Boletim do Museu Paraense Emílio Goeldi, série Ciências Naturais, em 2005. A partir de 2006, Boletim do Museu Paraense Emílio Goeldi. Ciências Naturais.

ISSN 2317-6237

1. Zoologia. 2. Mammalia. 3. Rodentia. 4. Morfologia. 5. Coleções Científicas. 6. Conservação. I. Museu Paraense Emílio Goeldi.

CDD-21ª.ed. 500

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# CARTA DO EDITOR

É com grande satisfação que informo que o sumário do último número de 2020 do **Boletim do Museu Paraense Emílio Goeldi. Ciências Naturais** é composto por manuscritos do dossiê intitulado "Um *tour* pela mastozoologia na América do Sul", que foi idealizado e cuidadosamente editorado pela Dra. Alexandra Maria Ramos Bezerra, a quem sou profundamente grato. O dossiê é composto por 23 contribuições originais escritas por pesquisadores de vários países das Américas e da Europa. Os manuscritos tratam sobre vários aspectos da fauna atual e pretérita de mamíferos da América do Sul, revelando a complexidade e a riqueza desse grupo taxonômico no referido continente. Informações adicionais sobre o dossiê e sobre os artigos foram apresentadas na Carta da Editora, escrita pela Dra. Alexandra.

Ao fechar esta carta, renovo meus agradecimentos à Rafaele Lima da Silva e à Talita do Vale, que mais uma vez trabalharam com empenho e profissionalismo na finalização de mais uma edição.

**Fernando da Silva Carvalho Filho**
Editor Científico

# CARTA DA EDITORA

Nascido de uma ideia de colaborar na divulgação do **Boletim do Museu Paraense Emílio Goeldi. Ciências Naturais**, e com o apoio do editor-chefe Fernando S. Carvalho Filho, o presente número especial, intitulado "Um *tour* pela Mastozoologia na América do Sul", reúne um importante conjunto de estudos sobre a fauna de mamíferos na América do Sul. São 23 artigos escritos por pesquisadores do Brasil (16 estados e todas as regiões representadas), de quatro países da América do Sul (Argentina, Colômbia, Paraguai, Peru), três da Europa (Itália, Portugal, Suíça) e dos Estados Unidos, incluindo estudos realizados em diversas ecorregiões, dos Andes até a Amazônia oriental e a Caatinga, do sul da Mata Atlântica ao mar Atlântico no norte do continente. A maior parte dos artigos foi liderada por pesquisadoras, sendo 13 (56%) como primeiras autoras (incluindo um com autoria única) e 11 como últimas autoras (48%; ou 52%, se considerarmos a autoria única).

Não restringimos temas ou grupos-alvo. Assim, o presente número traz contribuições sobre etnoecologia e interação comportamental entre espécies; estudos de fragmentos fósseis e de egagrópilos; ecologia de comunidades em pequenos e em grandes e médios mamíferos; listas de espécies e novos registros de distribuição; revisão taxonômica e filogeografia; divulgação de acervos históricos e coleções científicas; assim como discussões sobre conservação e tomadas de decisão para a preservação das espécies.

Abrimos esse número com o ensaio sobre o efeito dos incêndios, ocorridos nos últimos dois anos principalmente, na Amazônia e no Pantanal, sobre a fauna de xenartros – grupo de mamíferos endêmico do continente americano (1º artigo, Silva & colaboradores). O *status* de conservação para as espécies de roedores do Brasil, em nível mundial (*i.e.*, a Lista Vermelha da IUCN), é explicado em seu processo de elaboração e os resultados discutidos quanto aos padrões geográficos das espécies ameaçadas (2º artigo, Lacher & colaboradores). Dois estudos que tentam compreender padrões de distribuição para três espécies ameaçadas, a chinchila (3º artigo, Stuhler & colaboradores) e os peixes-bois sul-americanos (4º artigo, Bonvicino & colaboradores), são imprescindíveis para compreender as lacunas e traçar estratégias de tomadas de decisão em conservação.

Comportamento e interação entre homem e animal são abordados em estudos sobre a baleia-franca-austral em colônias de pescadores no Sul do Brasil (5º artigo, Zappes & colaboradoras), e em uma população de saguis-de-tufos-brancos em uma área urbana com remanescente de mangue no Nordeste do país (6º artigo, Albuquerque & Oliveira). Interações ecológicas em ambientes antropizados norteiam o estudo parasitológico no morcego insetívoro *Myotis nigricans* (7º artigo, Oliveira & colaboradoras), onde as autoras propõem mais investigações para compreender a relação dos índices parasitológicos com a presença da espécie em áreas modificadas da Mata Atlântica; enquanto na Amazônia, no médio rio Xingu, os primeiros resultados em investigações por ectoparasitas em uma comunidade de morcegos são divulgados (19° artigo, Silva & colaboradores). Os efeitos da urbanização e possíveis transmissões de parasitas entre espécies são também discutidos na observação de protocooperação entre capivaras e quatis *Nasua nasua* na cidade de Campo Grande, Centro-Oeste do Brasil (20° artigo, Rucco & colaboradores). A investigação da bioacumulação de metais pesados em tecidos de uma espécie de pequeno marsupial (*Gracilinanus microtarsus*) estimula mais investigações nessa linha de pesquisa (17º artigo, Machado & colaboradores).

Duas diferentes abordagens, sobre a diversidade de pequenos mamíferos não voadores da Mata Atlântica, trazem à luz: novos cariótipos para duas espécies de roedores em um isolado da Serra da Mantiqueira no Sudeste do Brasil (8º artigo, Faria & colaboradores); e a probabilidade do efeito El Niño sobre a variação temporal no uso do microhabitat em espécies mais abundantes no alto rio Paraná, no Paraguai, sugerindo mais estudos ao longo da distribuição dessas espécies (9º artigo, Owen). Mamíferos de médio e grande portes são investigados quanto à sua riqueza em uma área de tensão ecológica entre Amazônia e Cerrado, no estado do Tocantins, Brasil central (10º artigo, Mercês & colaboradores); e os mesocarnívoros quanto à probabilidade de ocorrência e uso do habitat nas sazonais florestas secas tropicais do norte da Colômbia (11º artigo, Gómez-Ruiz & colaboradores).

Os roedores são destaques exclusivos em três estudos com abordagens em taxonomia, morfologia e história natural: a proposição de que o complexo de espécies de ratos-chinchila *Abrocoma cinerea* inclua menos espécies do que as atualmente reconhecidas (14º artigo, Teta); uma lista taxonômica comentada de espécies na Amazônia peruana, a partir de dados obtidos em três anos de inventários em Iquitos (13º artigo, Díaz); e a composição taxonômica de uma lista de espécies, obtida a partir da identificação de fragmentos de crânios e mandíbulas encontrados na Toca dos Ossos, um sítio paleontológico na Caatinga, é discutida à luz do recorte temporal desses achados (15º artigo, Gomes & colaboradores). Assim como os roedores da Toca dos Ossos, os lagomorfos são exclusivos em um estudo revisando os registros de ocorrência em depósitos do Quaternário no Brasil (16º artigo, Chahud & colaboradores - um estudo editado principalmente pelo colega Adriano Maciel).

A diversidade genética do furão *Galictis cuja* é investigada em um estudo de filogeografia e descrição de cariótipo, com amostras obtidas principalmente a partir de espécimes atropelados (12º artigo, Bontempo & colaboradores). A revisão em coleções científicas e a coleta de novos espécimes levaram à reidentificação e a mudanças nos limites de distribuição de duas espécies de morcegos do gênero *Thyroptera*, na Amazônia e no Cerrado (18º artigo, Semedo & colaboradores).

Finalizando o número, temos a divulgação de espécimes históricos e acervos científicos. No Brasil, com um catálogo de todos os mamíferos de médio e grande portes do estado do Pará depositados no Museu de Zoologia da Universidade de São Paulo (22º artigo, Nascimento & Vendramel). Na Suíça, *Muséum d'Histoire Naturelle de Neuchâtel*, com os mamíferos coletados por Johann Jakob von Tschudi em sua expedição ao Peru, incluindo importante discussão sobre seus tipos nomenclaturais depositados na instituição (23º artigo, Serrano-Villavicencio & colaboradores). Espécimes coletados na América do Sul, principalmente nos séculos XIX e XX, e enviados a alguns museus de zoologia em Roma, Itália, são apresentados, inclusive um espécime do tatu-peludo *Dasypus pilosus*, pouco representado em coleções (21º artigo, Gippoliti & Castiglia).

Registro aqui meu enorme agradecimento aos autores, que acreditaram na proposta e submeteram os resultados de seus estudos, além de aguentarem firmes todas as rodadas de revisões e de terem compreendido o atraso na programação de lançamento do especial. Um agradecimento tão importante quanto também aos 55 revisores (28 pesquisadoras e 27 pesquisadores), que usaram o seu tempo e tanto contribuíram (alguns deles mais de uma vez) para aprimorar os estudos submetidos a este número especial, nominalmente: Ada Sánchez-Mercado, Adarene G. Motta, Adriana Bocchiglieri, Adrielle M. Cezar, Aldo Caccavo, Alexandre Portella, Ana Claudia Delciellos, Ana Cristina Mendes-Oliveira, Ana Lazar, Anderson Feijó, André F. Mendonça, Andrea Presotto, Bernardo R. Teixeira, Bruce D. Patterson, Caryne Braga, Cibele R. Bonvicino, Daniela Kalthoff, Diogo Loretto, Eldianne Lima, Elisandra Chiquito, Fernanda S. Santos, Filipe S. Gudinho, Giovanni Amori, Gisele Lessa, Guilherme S. T. Garbino, Gustavo Graciolli, Joana Macedo, João Carlos G. Borges, Jorge J. Cherem, Laura H. O. Côrtes, Lena Geise, Leonardo Kerber, Leonardo S. Miranda, Leonardo Trevelin, Marcus V. Brandão, M. Mónica Díaz, Maria Victoria Vadell, Michelle Mercês, Naiara de Araújo, Natalie Olifiers, Pablo Teta, Paúl M. Velazco, Ricardo Moratelli, Riccardo Castiglia, Salvatore Siciliano, Sergio Solari, Shirley P. da Silva, Stella M. Malcher, Susi M. Pacheco, Thiago B. F. Semedo, Thomas E. Lacher Jr., Tulio Dornas, Waleska Gravena, Wanderley J. Silveira Jr, Yamil di Blanco.

Esse número também não seria possível sem o trabalho contínuo e dedicado das editoras de formatação e design Rafaele Silva e Talita do Vale, respectivamente.

Dedico ao meu pai.

**Alexandra Maria Ramos Bezerra**
Editora do número especial

* * *

## EDITOR'S NOTE

Born from an idea to collaborate with the **Boletim do Museu Paraense Emílio Goeldi. Ciências Naturais**, and with the support of the editor-in-chief Fernando S. Carvalho-Filho, this issue, entitled "A *tour* in the South American Mammalogy" brings together an important set of studies on the mammalian fauna of South America. Herein 23 articles written by researchers from Brazil (16 states and all regions represented), from four South American countries (Argentina, Colombia, Paraguay, Peru), three from Europe (Italy, Portugal, Switzerland) and from the United States. These studies were carried out in several ecoregions, from the Andes to the eastern Amazon and the Caatinga, from the southern Atlantic Forest to the Atlantic Sea on the north continent. Most of the articles were led by women researchers, with 13 (56%) as first authors (including one with single authorship) and 11 as last authors (48%; or 52% if we consider single authorship).

We did not restrict themes or specific taxonomic groups. Thus, this volume brings contributions on ethnoecology and behavioral interaction between species; studies on fossil remains and egagropils; community ecology of small nonvolant mammals and of large and medium-sized species; species lists and new distribution records; taxonomic revision and phylogeography; dissemination of historical collections and scientific collections; as well as discussions about conservation and decision-making for the preservation of species.

We opened this issue with the essay on wildfires, mainly the occurred in the last two years in Amazon and Pantanal, on the xenarthrans, a group of Western Hemisphere endemic mammals (1st article, Silva & collaborators). The worldwide conservation status (*i.e.*, IUCN Red List) for rodent species in Brazil is explained on its list elaboration process, and the results discussed regarding the geographic patterns of threatened species (2nd article, Lacher & collaborators). Two studies uncovering the distribution patterns of three endangered species, the short-tailed chinchilla

(3rd article, Stuhler & collaborators) and the two South American manatees (4th article, Bonvicino & collaborators), which are essential to understand the gaps and outline strategies conservation decision-making.

Human and animal behavior and interaction are addressed in a study on the Southern Right Whale and the fisheries colonies in southern Brazil (5th article, Zappes & collaborators), and in a population of Common marmosets in an urban area with mangrove remnant in the Brazilian northeast (6th article, Albuquerque & Oliveira). Ecological interactions in anthropized environments guide the parasitological study in the insectivorous bat *Myotis nigricans* (7th article, Oliveira & collaborators), where the authors propose further investigations to understand the relationship of parasitological indexes with the presence of the species in converted areas of the Atlantic Forest; while in the Amazon, in the Middle Rio Xingu, the first results in investigations by ectoparasitic flies in a community of bats are disclosed (19th article, Silva & collaborators). Urbanization effects and the possible transmission of parasites between species are also discussed in an observation of protocooperation between capybaras and coatis *Nasua nasua* in Campo Grande city, Central Brazil (20th article, Rucco & collaborators). The investigation of the bioaccumulation of heavy metals in tissues of small marsupial species (*Gracilinanus microtarsus*), encourages further investigations in this research field (17th article, Machado & collaborators).

Two different approaches on the small nonvolant mammals diversity from Atlantic Forest reveal: new karyotypes for two species of rodents from Serra da Mantiqueira, in Southeast Brazil (8th article, Faria & collaborators); while the El Niño effect on the temporal variation in the microhabitat use by abundant species from the Upper Paraná River, in Paraguay, suggest further studies their whole geographic distribution (9th article, Owen). Medium- and large-sized mammals are investigated for their richness in an area of ecological tension between the Amazon and Cerrado domains, in Tocantins state, central Brazil (10th article, Mercês & collaborators), while the mesocarnivores are analyzed for both occurrence and habitat use in a seasonally dry tropical forests of northern Colombia (11th article, Gómez-Ruiz & collaborators).

Rodents are the exclusive highlights in three studies approaching taxonomy, morphology and natural history: a propose that chinchilla rats of the *Abrocoma cinerea* complex include fewer species than those currently recognized (14th article, Teta); a commented taxonomic list of species from a Peruvian Amazon, based on data obtained from three years of inventories in Iquitos (13th article, Díaz); and the taxonomic composition of a species list obtained from the identification of skulls and jaws fragments found at Toca dos Ossos, a paleontological site in the Caatinga of Bahia state, is discussed regards the temporal frame of these findings (15th article, Gomes & collaborators). Such as the rodents from Toca dos Ossos, lagomorphs are protagonists in a study reviewing the occurrence records in Quaternary deposits of Brazil (16th article, Chahud & collaborators - a study mainly edited by colleague Adriano Maciel).

The genetic diversity of the ferret *Galictis cuja* is investigated in a study of phylogeography and description of karyotype, with samples obtained mainly from roadkill animals (12th article, Bontempo & collaborators). While reviewing scientific collections and collecting new specimens led to reidentification and changes in the distribution limits of two bat species of the genus *Thyroptera*, in the Amazon and the Cerrado (18th article, Semedo & collaborators).

Finishing the volume, we have the dissemination of historical specimens and scientific collections. In Brazil, with a catalog of all medium- and large-sized mammals from Pará state deposited at the *Museu de Zoologia da Universidade de* São Paulo (22nd article, Nascimento & Vendramel). In Switzerland, in the *Muséum d'Histoire Naturelle de Neuchâtel*, with the mammals collected by Johann Jakob von Tschudi on his expedition to the Peru, including an important discussion of their nomenclatural types housed in this museum (23rd article, Serrano-Villavicencio & collaborators). Specimens collected in South America, mainly during the 19th and 20th centuries, and sent to some museums of zoology in Rome, Italy, are presented, including a specimen of the hairy armadillo *Dasypus pilosus*, a few specimens in scientific collections (21st article, Gippoliti & Castiglia).

I am truly grateful to the authors, who believed in the proposal and submitted the results of their studies, in addition to standing firm throughout all rounds of reviews and having understood the delay in the schedule for launching the special issue. I am also indebted to the 55 reviewers (28 female researchers and 27 male researchers), who spent their time and contributed (some of them more than once) to improve the studies submitted to this special volume, namely: Ada Sánchez-Mercado, Adarene G. Motta, Adriana Bocchiglieri, Adrielle M. Cezar, Aldo Caccavo, Alexandre Portella, Ana Claudia Delciellos, Ana Cristina Mendes-Oliveira, Ana Lazar, Anderson Feijó, André F. Mendonça, Andrea Presotto, Bernardo R. Teixeira, Bruce D. Patterson, Caryne Braga, Cibele R. Bonvicino, Daniela Kalthoff, Diogo Loretto, Eldianne Lima, Elisandra Chiquito, Fernanda S. Santos, Filipe S. Gudinho, Giovanni Amori, Gisele Lessa, Guilherme S. T. Garbino, Gustavo Graciolli, Joana Macedo, João Carlos G. Borges, Jorge J. Cherem, Laura H. O. Côrtes, Lena Geise, Leonardo Kerber, Leonardo S. Miranda, Leonardo Trevelin, Marcus V. Brandão, M. Mónica Díaz, Maria Victoria Vadell, Michelle Mercês, Naiara de Araújo, Natalie Olifiers, Pablo Teta, Paúl M. Velazco, Ricardo Moratelli, Riccardo Castiglia, Salvatore Siciliano, Sergio Solari, Shirley P. da Silva, Stella M. Malcher, Susi M. Pacheco, Thiago B.F. Semedo, Thomas E. Lacher Jr., Tulio Dornas, Waleska Gravena, Wanderley J. Silveira Jr, Yamil di Blanco.

This number would also not be possible without the continuous and dedicated work of both copy editor Rafaele Silva and design editor Talita do Vale.

I dedicate it to my father.

**Alexandra Maria Ramos Bezerra**
Editor for special issue

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# OPINIÃO/ENSAIO

# Wildfire against the survival of Xenarthra: anteaters, armadillos, and sloths

# Incêndios contra a sobrevivência de Xenarthra: tamanduás, tatus e preguiças

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Alexandre Martins Costa Lopes[I, V] | Fernanda Góss Braga[I, VI] | Abílio Ohana[I, VII] |
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**Abstract:** During 2019 and 2020, Amazon and Pantanal wildfires were news all over the world, followed by shocking images of burnt landscapes and animals. Fires within rainforests and wetlands are seldom related to natural causes. Instead, these are human-driven events, often caused by illegal actions associated with deforestation and land conversion to sustain intensive agriculture and farming, among other impacts. The loss of native vegetation, not only causes habitat loss, fragmentation and degradation, but also increases the risk of natural fires creating a vicious circle. Among the animals mostly threatened by fire are the xenarthrans. Here, we bring attention to this group of mammals, which have several biological adaptations that make them particularly vulnerable to fire events. We present sloths, armadillos and anteaters as valuable components of biodiversity, being relicts of a vast diversity of South American endemics, and comprising many endangered, unique and poorly known species. Last, we conclude that 2019/2020 fires in the Amazon forest and Pantanal wetland, added to a multitude of other threats, are seriously menacing regional diversity components of these emblematic mammals.

**Keywords:** Agribusiness. Amazon rainforest. Cerrado. Deforestation. Habitat conversion. Pantanal.

**Resumo:** Durante 2019 e 2020, incêndios em áreas selvagens na Amazônia e no Pantanal foram notícia pelo mundo afora, acompanhados por imagens chocantes de paisagens e animais queimados. Fogos em florestas úmidas tropicais e planícies alagáveis raramente se relacionam a causas naturais. Ao invés, estes são eventos antrópicos, frequentemente causados por ações ilegais, associadas com desmatamento e conversão de uso da terra para sustentar atividades de agricultura e pecuária intensivas, entre outras. A devastação de vegetação nativa não só causa perda, fragmentação e degradação de habitat, mas também aumenta o risco de ocorrência de fogos naturais, gerando um ciclo vicioso. Entre os animais mais ameaçados pelo fogo, estão os xenartros. Aqui, atentamos para este grupo de mamíferos, que possui inúmeras adaptações biológicas as quais o tornam particularmente vulnerável. Nós apresentamos preguiças, tatus e tamanduás como valiosos componentes da biodiversidade, sendo relíquias de uma vasta diversidade de endemismos sul-americanos e compreendendo várias espécies ameaçadas, únicas e pouco conhecidas. Por fim, concluímos que os incêndios de 2019/2020 na floresta amazônica e no Pantanal, adicionados a uma multitude de outros impactos, estão ameaçando severamente a diversidade regional destes mamíferos emblemáticos.

**Palavras-chave:** Agronegócio. Floresta úmida amazônica. Cerrado. Desmatamento. Conversão de habitat. Pantanal.

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SILVA, S. M., P. M. SANTOS, K. T. MOLINA, A. M. C. LOPES, F. G. BRAGA, A. OHANA, F. R. MIRANDA & A. BERTASSONI, 2020. Wildfire against the survival of Xenarthra: anteaters, armadillos, and sloths. **Boletim do Museu Paraense Emílio Goeldi. Ciências Naturais** 15(3): 523-532. DOI: http://doi.org/10.46357/bcnaturais.v15i3.214.

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Recebido em 25/11/2019
Aprovado em 03/10/2020
Responsabilidade editorial: Alexandra Maria Ramos Bezerra

Recently, particularly during the second semester of 2019 and 2020, fires devastating the Amazon rainforest and Pantanal wetland, the biggest floodplain in the world, captured the attention of the international media and public worldwide (*e.g.*, Hughes, 2019; Kelly *et al.*, 2019; Krauss, 2019; Lusa & Público, 2019; Mendes, 2019; Watts, 2019; Carvalho, 2020; La Croix & AFP, 2020; Lemos, 2020; Lusa, 2020; Ramsay, 2020). These events revived discussions on climate change, loss of ecosystem services, and on sociopolitical and religious issues (Orr, 2005 and subsequent replies).

The environmental repercussions of tropical fires have been extensively investigated (*e.g.*, Ramos-Neto & Pivello, 2000; Cochrane, 2003; Bowman *et al.*, 2009; Morton *et al.*, 2013). These fires are usually intentional, human-driven, and have been frequent and devastating all over the world (*e.g.*, Cochrane, 2003; Bowman *et al.*, 2009; Dwomoh *et al.*, 2019; Clark & Williams, 2020). Huge wildfire events are so drastic that discussions are often regional- or global-scaled, mostly ignoring the most directly affected elements, the local flora and fauna. Disturbing photographs of burnt landscapes and animals have been recently shared in social media networks (*e.g.*, AFP, 2019; Kelly *et al.*, 2019; Lemos, 2020). Among other, a picture of a carbonized giant anteater (*Myrmecophaga tridactyla* Linnaeus, 1758), has powerfully illustrated to public opinion the immediate losses resulting from fire.

Rainforests, like the Amazon, are characterized by high humidity levels and dense vegetation (Corlett & Primack, 2011), which hinder the occurrence of natural wildfires (*e.g.*, Cochrane, 2003). Thus, the risk of natural fire in South American rainforests is low even during the dry season (INPE, 2019). Conversely, in open-vegetation phytophysiognomies, like savannas and Cerrado in Brazil, fires do naturally occur during the dry season, giving rise to the latent biodiversity during the subsequent rainy season (Abreu *et al.*, 2017; Arruda *et al.*, 2018). Also, managed human-driven fires in such open-vegetation ecosystems might even be beneficial to avoid excessive accumulation of biomass and disproportionate wildfires during dry seasons (*e.g.*, Coutinho, 1982; Arruda *et al.*, 2018). Similarly, cycles of flood and fire in Pantanal can be beneficial for vegetation regeneration (Oliveira *et al.*, 2014). Nonetheless, contrary to Cerrado, naturally occurring fires are not frequent in the region, and occur in well-defined periods (Macedo *et al.*, 2009), since Pantanal is recognized as a seasonal floodplain, with two known flooding periods: dry (June to September) and full (October to May) (Santos, S. *et al.*, 2007; Oliveira *et al.*, 2014).

In the last decade (2009-2019), a stabilizing trend for the burnt area in the three biomes, Amazon, Pantanal and Cerrado (the latter is here mentioned for comparison purposes only) is observed, particularly during 2014-2017 (Figure 1A). For the Brazilian Amazon and Pantanal, for which public records are available, a mean burnt area of 67,300.8 km$^2$/year (± 18,368.9 km$^2$/year) and 10,311.7 km$^2$/year (± 4607.1 km$^2$/year) were respectively registered between 2009 and 2019 (Figure 1A) (INPE, 2020a). The area burnt in the Amazon in 2019 surpassed the amount loss during the whole previous year, even after 2019 as ended (Figures 1A and 1B) (INPE, 2020a). In Pantanal, the amount of burnt area has raised in 2019; more than doubled the decade mean (20,835 km$^2$), and a worse scenario is expected for 2020 (Figure 1A), where the number of fires has increased by 78% in August and September 2020 (Figure 2), compared to the same period of the former year (Figure 2; INPE, 2020a). Fire outbreaks were more expressive during August and September, corresponding to 58% and 52% of the area burnt between January 2019 and August 2020 both in the Amazon and Pantanal, respectively (Figure 1B). August/September 2019/2020 fires were also numerous in Bolivia, Peru and Paraguay (INPE, 2020a). Moreover, in March 2019 and February 2020, during the rainy season, more than 80% of the burnt territory in Brazil was in the Amazon (Figure 1B). These evidences exemplify and reinforce both that recent fires in the Amazon and Pantanal are not natural events and the loss of pristine habitats has not halted yet.

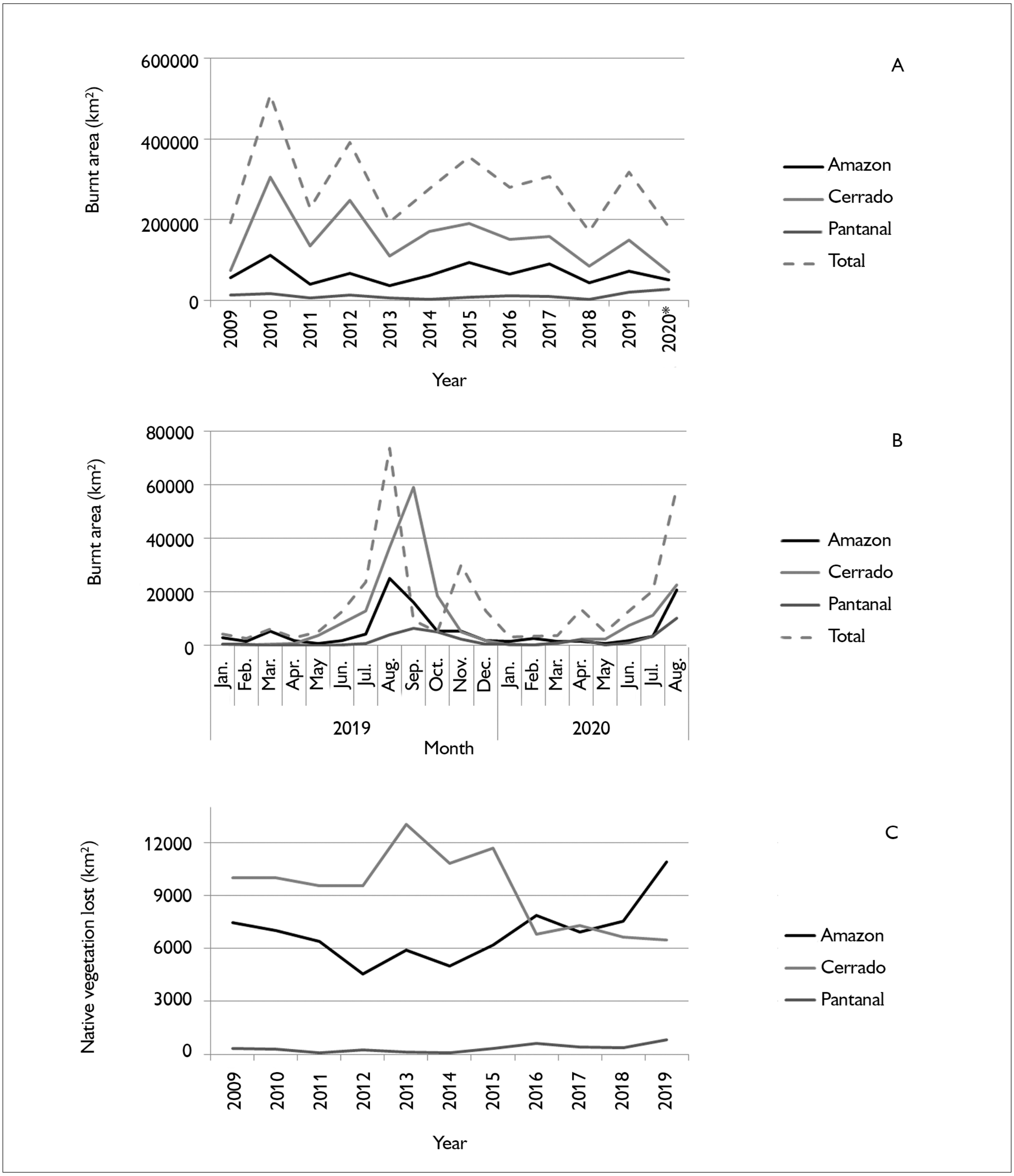

Figure 1. Loss of native vegetation in Brazilian biomes (INPE, 2020a, 2020b; Souza Jr. *et al.*, 2020). Total area burnt in Brazil during (A) the last decade and (B) last year (2019) in the Amazon forest, Pantanal, Cerrado and Brazil (Total); C) deforestation in the Amazon and Pantanal has been increasing during recent years, particularly in 2019.

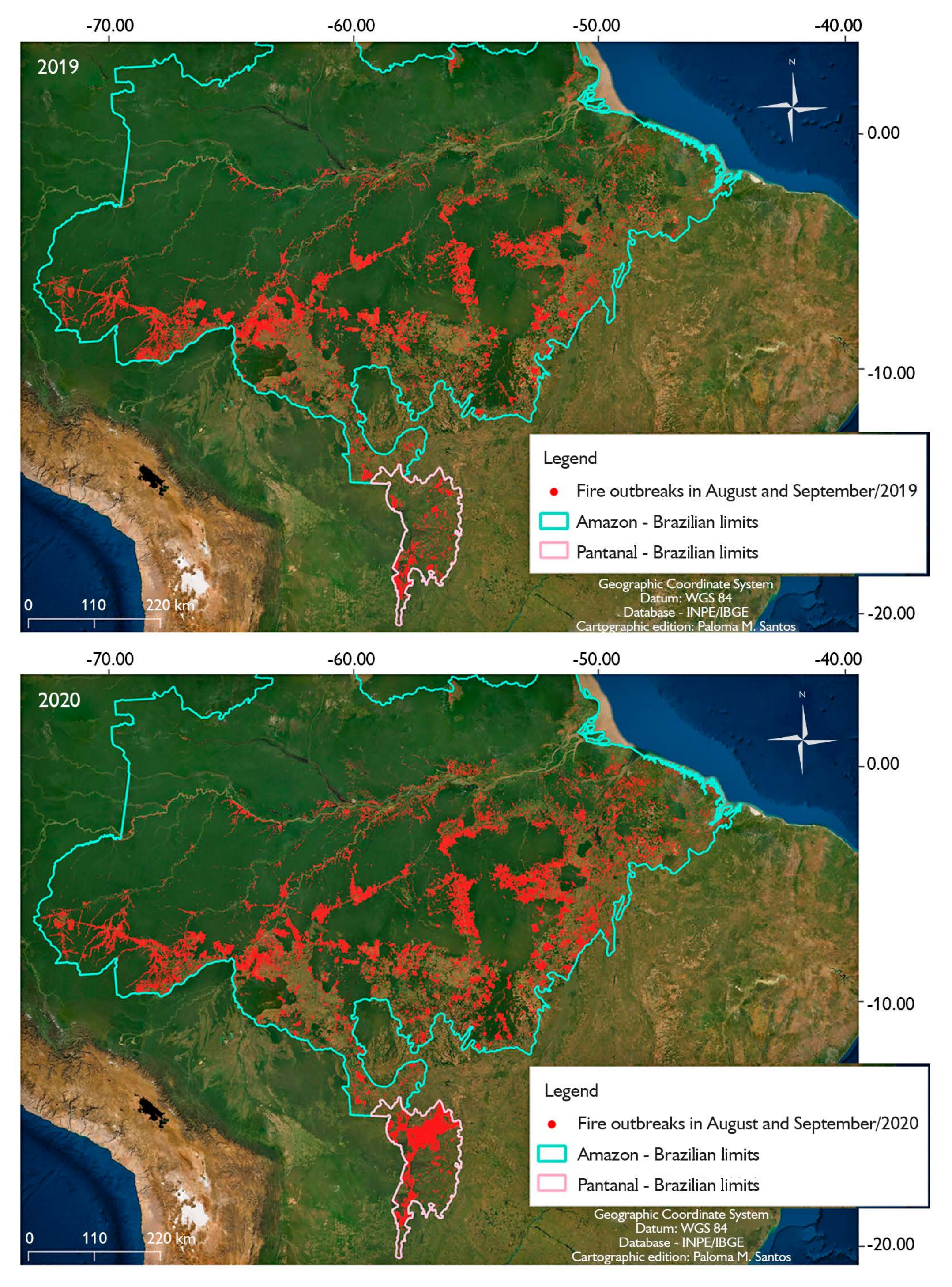

Figure 2. Fire outbreaks in the Amazon and Pantanal biomes during August and September 2019 (upper map) and 2020 (lower map) (INPE, 2020a).

The location of August/September 2019/2020 wildfires, in southern Amazon and northern Pantanal (Figure 2), is not a coincidence. Fires in tropical wild environments have been correlated with deforestation (Ramos-Neto & Pivello, 2000; Morton *et al.*, 2013; Silva Junior *et al.*, 2020). Today, deforested areas present similar risk of natural fire as open dry vegetation regions (INPE, 2020a); showing that the loss of native vegetation increases the risk of fire (Silva, S. S. *et al.*, 2018), as observed also in western Brazilian Amazon. Although *c.* 80% of the Brazilian Amazon and Pantanal native vegetation still stand, deforestation rates remain high (reviewed by Alho *et al.*, 2019 and Guerra *et al.*, 2020 for Pantanal; INPE, 2020b for the Amazon; Souza Jr. *et al.*, 2020), particularly during 2019 (Figure 1C), and their road-oriented pattern results in intense fragmentation and profound transformation of the natural landscape (INPE, 2020b). Deforestation combined with the establishment of agro-silvo-pastoral systems, logging, hydroelectric dam construction, mineral prospection and urbanization have been causing chronic land use conversion in South America (Ribeiro, M. *et al.*, 2009; Ribeiro, E. *et al.*, 2015; Lees *et al.*, 2016; Alamgir *et al.*, 2017; Alho *et al.*, 2019; Guerra *et al.*, 2020; Silva Junior *et al.*, 2020).

Among the wild species affected by August/September 2019/2020 wildfires are mammals of the superorder Xenarthra; 50 million-year old representatives of the South American endemic fauna (Gibb *et al.*, 2016). Anteaters, sloths and armadillos are seriously threatened by fire (Silveira *et al.*, 1999). The Brazilian action plan for the giant anteater and giant armadillo, *Priodontes maximus* (Kerr, 1792), has the specific aim to "decrease the impact of fire on the target species" (MMA/ICMBio, 2019). Xenarthrans have specialized diets, insectivorous (anteaters and armadillos) and folivorous (sloths), resulting in low metabolic rates and body temperatures (McNab, 1992). To maintain their temperature, most xenarthrans are highly dependent on covered areas, as forest-like habitats (*e.g.*, Medri & Mourão, 2005; Cassano *et al.*, 2011; Attias *et al.*, 2018; Bertassoni & Ribeiro, M., 2019), and have several layers of hair (for Pilosa, Shaw & Carter, 1980; Gilmore *et al.*, 2001), making a highly inflammable fur, rapidly set on and spreading a fire. Additionally, in an adaptation to save energy, some of these animals maintain slow movements (Gilmore *et al.*, 2001; Nagya & Montgomery, 2012; Lewton & Dingwall, 2013; Bertassoni & Ribeiro, M., 2019). Most of them are incapable to run fast in the face of some threat (*e.g.*, Ribeiro, P. R. *et al.*, 2016). This inability hinders the escape of xenarthrans from an advancing fire front. Roadkills are another variable that must be considered during fire outbreaks (Diniz & Brito, 2013), since four species of armadillos and anteaters are among the top 10 of the most road-killed animals in Brazil (Ribeiro, P. *et al.*, 2017); arboreal mammals, such as sloths, also might be impacted by roadkill, although this is a threat mainly disregarded (Srbek-Araujo *et al.*, 2018). After long wildfires, even when burrows may act as protection against direct fires, the warmth soil and the smoke and particulates in the air might be fatal for fossorial animals as armadillos, by causing overheating and accumulation of toxic gases within their burrows (Silveira *et al.*, 1999). Smoke inhalation has been recorded as a direct cause of death for giant armadillos, and indirectly due to consequent bacterial and fungal infections (Arenales *et al.*, 2020).

The superorder Xenarthra comprises over 30 extant species (Burgin *et al.*, 2018, but see also Miranda *et al.*, 2018; Feijó *et al.*, 2019; Santos, P. *et al.*, 2019a). The group is phylogenetically relevant not only due to its even wider extinct diversity (hundreds of extinct species described) (McKenna & Bell, 1997), but mostly because of its basal position in the evolutionary history of placental mammals and especially for the morphological and ecological uniqueness of the extant species of the group (Isaac *et al.*, 2007; Tarver *et al.*, 2016). Half of the present diversity of xenarthrans is considered globally Near Threatened, Threatened or Data Deficient (DD) (Santos, P. *et al.*, 2019a; Superina & Abba, 2020), but most of it is endangered and poorly known at a regional scale (Smith, 2012; Anacleto *et al.*, 2013; Rodríguez *et al.*, 2015; ICMBio/MMA, 2018). Moreover, at regional and local levels, molecular and morphological evidences have been revealing high differentiation among brown-throated sloth (*Bradypus variegatus* Schinz, 1825) (Silva, S. M. *et al*., 2018), maned sloth (*Bradypus torquatus* Illiger, 1811) (Lara-Ruiz *et al*., 2008) and giant anteater (Clozato *et al*., 2017) populations, respectively; describing new species of the genus *Cyclopes* Gray, 1821 in the Amazon (Coimbra *et al*., 2017; Miranda *et al*., 2018) and of the genus *Dasypus* Linnaeus, 1758 across its range (Feijó *et al*., 2019); and detecting different local adaptations for pathogen resistance within distinct populations of the lesser anteater (*Tamandua tetradactyla* Linnaeus, 1758) (Clozato *et al*., 2015). These results have clear implications for the conservation *status* and management practices of xenarthrans. Distinct areas, and therefore different taxa, are facing dissimilar types and degrees of pressure. Local defaunation in tropical deforested areas is well documented, resulting mostly from habitat loss and soil conversion (Canale *et al*., 2012; Jorge *et al*., 2013; De Marco *et al*., 2020). For example, areas with less than 20% of forest cover no longer can sustain populations of maned sloths (*B. torquatus*) in the Atlantic forest (Santos, P. *et al*., 2019b). Thus, at local-scales, armadillos, sloths and anteaters are seriously threatened; and might be rapidly disappearing, population by population. Under current scenarios of fire and anthropogenic changes in land-use, the xenarthrans are more threatened than ever.

In this context, more dialogue and mutual understanding among the segments of the government and environmental agencies are urgent (reviewed by Laurance, 2019). A step for this integration might be the Environmental Rural Registry (ERR), a mandatory digital registration, which aims to integrate environmental information regarding private rural properties (Brazilian Environmental Law 12,651/2012) (Brancalion *et al*., 2016). However, agribusiness sectors have generally been more successful in imposing their interests and suppressing popular demands for environmental protection and more sustainable-friendly development strategies (*e.g*., Lees *et al*., 2016; Alamgir *et al*., 2017; Alho *et al*., 2019; Guerra *et al*., 2020). It is our role, as wildlife researchers and conservationists, to produce the relevant information and disseminate it to the public and stakeholders. We must continue applying our expertise to point out appropriate strategies for the socioeconomic development of our countries and the protection and sustainable use of their unique and exuberant natural resources and biodiversity.

## ACKNOWLEDGEMENTS

We acknowledge the comments of Thomas E. Lacher, one anonym reviewer, and editor Alexandra Bezerra that helped to improve this manuscript. We also acknowledge the institutions and NGOs in South America battling for wildlife conservation and socio-environmental sustainability.

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# ARTIGOS


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Bol. Mus. Para. Emílio Goeldi. Cienc. Nat., Belém, v. 15, n. 3, p. 535-556, set.-dez. 2020

# Conservation status of the order Rodentia of Brazil: taxonomic and biogeographical patterns

## Estado de conservação da ordem Rodentia do Brasil: padrões taxonômicos e biogeográficos

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**Abstract:** The Global Mammal Assessment (GMA) evaluates the risk of extinction for all species of mammals, providing important data on their status to national and global conservation agencies and conventions. We assessed all of the species of Brazilian rodents as part of the GMA activities of the International Union for the Conservation of Nature Species Survival Commission (IUCN SSC) Small Mammal Specialist Group. A total of 234 species were evaluated against the IUCN Red List Criteria and placed into one of eight categories. Although rodents do not have elevated extinction risk compared to mammals as a whole, several families of caviomorph rodents have high levels of either threat, data deficiency, or both. The family Echimyidae has a large number of species and one-third of those either are species of conservation concern or data deficient. The family Ctenomyidae also is of concern in this regard. There are also strong geographic patterns to threat and poor knowledge. The focal areas for conservation effort are the Atlantic Forest and the Cerrado, and for Data Deficient species Atlantic Forest, Cerrado, and Amazonia, in particular the eastern Amazon. The results highlight the need for targeted field research and the application of ecological and spatial data to the development of conservation actions.

**Keywords:** Atlantic Forest. Biodiversity. Extinction risk. IUCN. Red list.

**Resumo:** A Avaliação Global de Mamíferos (GMA) é uma iniciativa da IUCN que gera informações sobre o risco de extinção para todas as espécies de mamíferos, fornecendo dados importantes às agências e convenções nacionais e globais de conservação. A partir da recente GMA, o Grupo de Especialistas em Pequenos Mamíferos da IUCN SSC (*Species Survival Comission*) avaliou todas as 234 espécies de roedores brasileiros em relação aos critérios da lista vermelha da IUCN, colocando-as em uma das oito categorias. Embora a ordem Rodentia não apresente risco elevado de extinção em comparação com os mamíferos como um todo, várias famílias de caviomorfos demonstram altos níveis de ameaça e/ou deficiência de dados. Para a família Echimyidae, que possui elevado número de espécies, um terço delas são preocupantes quanto à conservação ou com dados insuficientes. Ctenomyidae também é motivo de preocupação a esse respeito. Ademais, existem padrões geográficos consistentes de ameaças e pouco conhecimento. As áreas focais para os esforços de conservação são a Mata Atlântica e o Cerrado, e para as espécies com deficiência de dados, a Mata Atlântica, o Cerrado e a Amazônia, em particular o leste da Amazônia. Os resultados destacam a necessidade de pesquisas de campo direcionadas e a aplicação de dados ecológicos e espaciais no desenvolvimento de ações de conservação.

**Palavras-chave:** Mata Atlântica. Biodiversidade. Risco de extinção. IUCN. Lista vermelha.

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LACHER, T. E., S. D. MCCAY, G. V. BIANCONI, L. K. WOLF, N. S. ROACH & A. R. PERCEQUILLO, 2020. Conservation status of the order Rodentia of Brazil: taxonomic and biogeographical patterns. **Boletim do Museu Paraense Emílio Goeldi. Ciências Naturais** 15(3): 535-556. DOI: http://doi.org/10.46357/bcnaturais.v15i3.234.

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Recebido em 10/12/2019
Aprovado em 30/10/2020
Responsabilidade editorial: Alexandra Maria Ramos Bezerra

## INTRODUCTION

Rodents represent about 40% of all living mammal species, comprising close to 2,500 species divided into 34 families (Lacher *et al.*, 2016). However, things such as access to large datasets of species, and advances in phylogenetic methodology and molecular techniques have led to frequent taxonomic revisions, and the number of scientifically recognized species is in constant flux (Wilson & Reeder, 2005; Chiquito *et al.*, 2014; Burgin *et al*., 2018; Chiquito & Percequillo, 2019). In Brazil, rodents are represented by about 257 species in nine families, and, in total, rodents make up approximately 34% of all Brazilian mammals (755 species) (Paglia *et al.*, 2012; Percequillo *et al.*, 2017; Abreu-Jr. *et al*., 2020).

In addition to the large number of taxa, rodents are diverse in their morphology, physiology and behavior. Their life histories are directly influenced by their diet, and rodent diets are diverse, encompassing carnivory, insectivory, omnivory, granivory, generalist herbivory and specialist herbivory (Nowak, 1999; Samuels, 2009). Their diversity allows them to occupy different ecological niches and play vital roles in the functioning of ecosystems (Asquith *et al.*, 1999; Keesing, 2000; Zeng *et al.*, 2019).

Like other mammalian groups, rodents face conservation challenges through the threats of global habitat loss and degradation, including impacts such as fragmentation, defaunation, climate change, and their synergistic effects. These threats to conservation are particularly pronounced in tropical ecosystems (Galetti *et al.*, 2013; Dirzo *et al.*, 2014; Peres *et al.*, 2016; ICMBio, 2018; Bovendorp *et al.*, 2019). Increased extinction threats facing rodents are especially concerning since they are among the least well researched group of all Brazilian vertebrates (Cassano *et al.*, 2017; Percequillo *et al.*, 2017). These gaps in available data are a problem, as they impair the development of species conservation plans (Jetz & Freckleton, 2015).

The IUCN Red List was established in 1964 and the first two volumes of Red Data Book by the International Union for the Conservation of Nature (IUCN) were published in 1966 on global assessments of mammals and birds. Following these initial records, country-led initiatives for national list making became increasingly common (Scott *et al.*, 1987; Vié *et al.*, 2008). The first Brazilian initiatives to protect mammalian species by categorizing them under a conservation priority status began with Carvalho (1968) and Coimbra-Filho & Magnanini (1968). Carvalho's list (1968) grounded the protection of species through the first federal ordinance (Brasil, 1968) which listed 18 species, with the absence of only one land mammal initially listed by Carvalho, the Short-eared Dog *Atelocynus microtis* (Sclater, 1883) (Machado, 2008). The IUCN threat categories that describe extinction risk were first adopted in Brazil in 1971 (Machado, 2008; Souza *et al.*, 2018). On that occasion Coimbra-Filho (1972) presented a list of 27 mammals included in two threat categories as recommended by Species Survival Commission: species in imminent danger and vulnerable. Also, this was the first time Brazil cited rodents as threatened (vulnerable) including the Pacarana *Dinomys branickii* Peters, 1873, and the Bristle-spined Rat *Chaetomys subspinosus* (Olfers, 1818), with the latter considered by Coimbra-Filho (1972) as the most sensitive. Along with R. A. Mittermeier, Coimbra-Filho was responsible for the Brazilian mammal dataset delivered to the IUCN Global Red List of Threatened Species, in 1974 (see Mittermeier *et al.*, 2005).

Five national assessments of threatened species have been published in Brazil by the federal agencies the Brazilian Institute for Forestry Development (IBDF), that later gave origin to the Brazilian Institute of Environment and Natural Resources (IBAMA), and the Ministry of the Environment (MMA) (Brasil, 1968, 1973, 1989, 2003, 2014) and the country's last two assessments (2003 and 2014) were based on "The 2001 IUCN Red List Categories and Criteria: Version 3.1" (IUCN, 2001). The 2014 Brazilian report assessed a total of 244 rodents with eight species categorized as Vulnerable, 19 as Endangered, three as Critically Endangered, and 29 as Data Deficient (Brasil, 2014;

ICMBio, 2018). The Brazilian lists through every iteration exhibited an increasing quality of assessments involving hundreds of specialists and institutions in the evaluation process. There were 28 specialists involved with rodents alone in the 2014 list. They were decidedly very useful in guiding conservation work at sub-global levels.

IUCN, through its Global Species Program (IUCN, n. d.a) and the Species Survival Commission (IUCN, n. d.b), assesses the risk of extinction of animal, plant and fungi taxa at the global level. After the launch of "The 2001 IUCN Red List: Categories and Criteria: Version 3.1" (IUCN, 2020a), all global assessments have been based on the rules outlined in this document. Five quantitative criteria are used to assess the extinction risk of a given species classifying it into one of nine risk categories. Every species of mammals, including 2,255 rodent species, were first assessed and classified according to these categories and criteria (Version 3.1) in 2008 (Schipper *et al.*, 2008). This study showed that 15.8% (258 species) of rodents assessed were in one of the IUCN categories of threat (Vulnerable, Endangered, or Critically Endangered) and 16% (368 species) had insufficient information for a proper assessment of their conservation status, and were therefore classified as Data Deficient.

Red List assessment data are one of the main biodiversity indicators used by the signatories of the Convention on Biological Diversity (CBD), Brazil among them, and other international conventions in order to monitor progress towards national and global biodiversity conservation goals. Successive global assessments are used in the calculation the Red List Index (Butchart *et al*., 2005) to track trends risk of extinction these species face over time. The IUCN SSC Small Mammal Specialist Group (SMSG) led by four of the authors of this manuscript (SDM, NSR, ARP, TEL) assessed all New World species of orders Rodentia and Eulipotyphyla. Here, we present the results of our status assessments for Brazilian rodent species, including spatial patterns of threat and data deficiency in relation to the principal Brazilian biomes.

## METHODS

### IUCN RED LIST ASSESSMENTS

We conducted our assessments following the guidelines of the International Union for the Conservation of Nature Red List (IUCN Red List) Categories and Criteria: Version 3.1 (IUCN, 2001). We assessed 1,138 New World species of which 1,031 were rodents. The total number of rodents assessed for Brazil was 234 from nine families (*sensu* Wilson & Reeder, 2005; Wilson *et al.*, 2016, 2017).

The steps to conduct a single species assessment following IUCN Red List guidelines are as follows (Figure 1).

1) Pre-assessment: the specialist group identifies Red List Authorities to assist in the assessments and the timeline is agreed upon for assessment review. Data source review and data compiled in the Species Information Service (SIS) by project staff, expert consultants, and project participants (SIS, n. d.). When assessments are completed, the information is downloaded into the species accounts and is made publically available on the IUCN Red List website (IUCN, 2020b);

2) Assessment: draft assessments are prepared in SIS through workshops, review, and consistency checks. Post-workshop review and consistency checks are also carried out;

3) Review: draft assessments in SIS are referred to Red List Authorities for assessment review;

4) Submission: all assessments from Red List Authorities, Global Species Programme, and Partner projects are submitted via SIS. The Red List Unit in Cambridge, UK (IUCN, 2020c), scans assessments submitted for obvious errors and checks consistency between projects. The Red List Unit checks criteria use, supporting documentation and consistency, proofreading, and formatting for: - reviewed assessments for Red List Authorities; - unreviewed assessments from outside IUCN SSC network;

5) Publication: assessments are then added to the SIS database and appear on the appropriate IUCN Red List website update (IUCN, 2020b), accessible to the public.

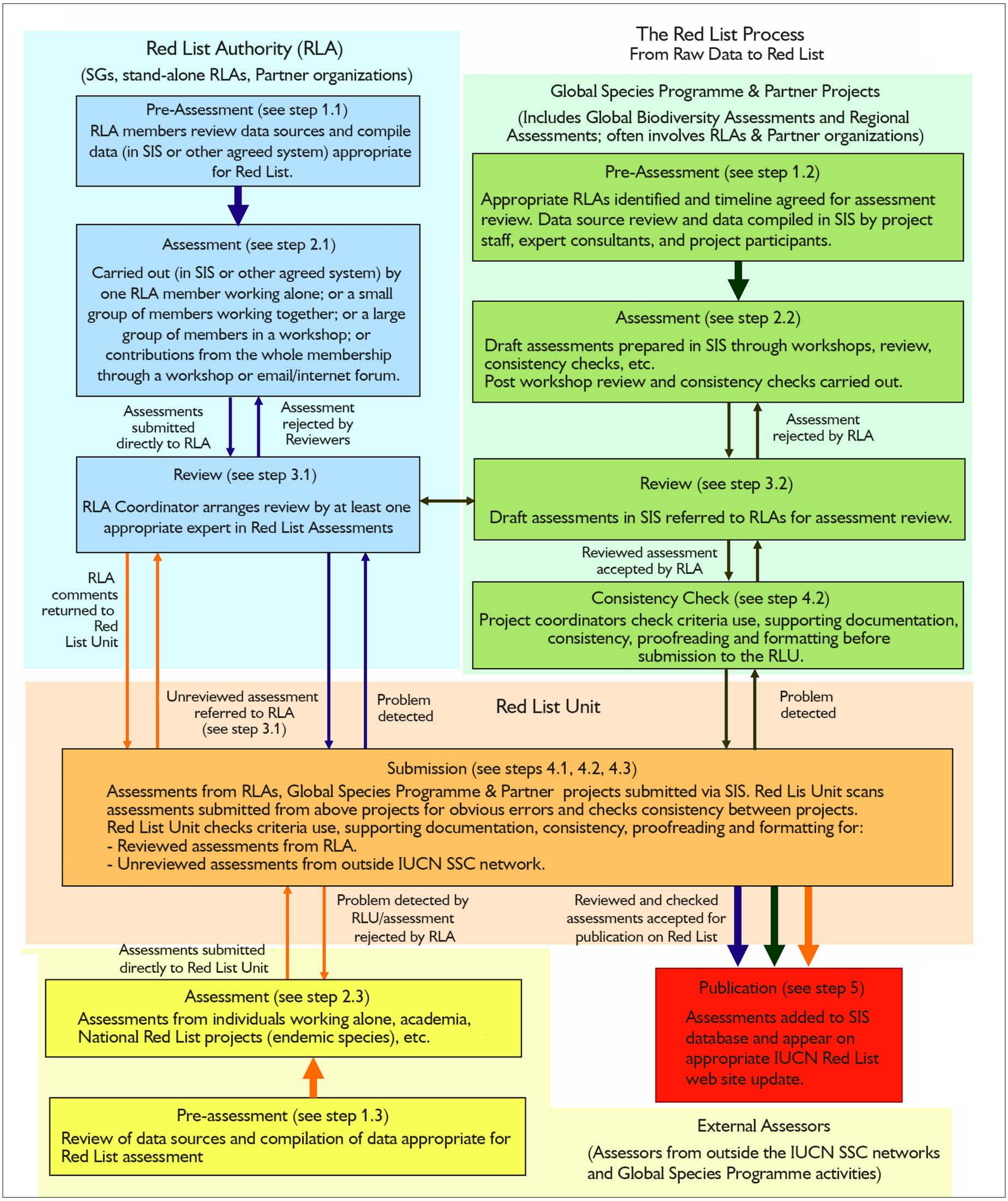

Figure 1. The IUCN Red List Species Assessment Process. The primary pathway used by the SMSG followed as outlined in the blue box. Used with permission of the IUCN Red List Unit, Cambridge, UK.

In preparation for publication, assessed species are ranked on a scale according to their threat of extinction (Figure 2). The species of highest concern of being at risk of extinction are listed in the 'Threatened' subcategory. Within the 'Threatened' subcategory there are three assignations of increasing conservation concern: 'Vulnerable', 'Endangered', and 'Critically Endangered'. The 'Near Threatened' category consists of species that are assessed to be on the brink of being assessed under a Threatened subcategory. For the purposes of this paper, we also considered the 'Near Threatened' category as part of our species of conservation concern.

## BRAZILIAN SMALL MAMMAL SPECIES ASSESSMENTS

We coordinated and conducted assessments individually for each species of Brazilian Rodentia by IUCN Red List trained assessors in the Texas A&M University Unit of the IUCN SSC Small Mammal Specialist Group. All assessors were required to pass the on-line training course available at the website The Nature Conservancy (2019). In the past, assessments were frequently conducted collaboratively in organized workshops, however, the 2019 assessments lacked the funds necessary for assessment workshops and assessors instead contributed their work via the SMSG team using the Species Information Service (SIS) online toolkit. The SIS toolkit is a collaborative database used for species assessments. Trained participating assessors are granted access to the interface by the Global Mammal Assessment (GMA) housed at Sapienza University of Rome, Italy. These assessors are then assigned species for which to gather information and then draft a report of an assessment in collaboration with the Small Mammal Specialist Group (SMSG) at Texas A&M University. Final assessment report drafts are then sent to the

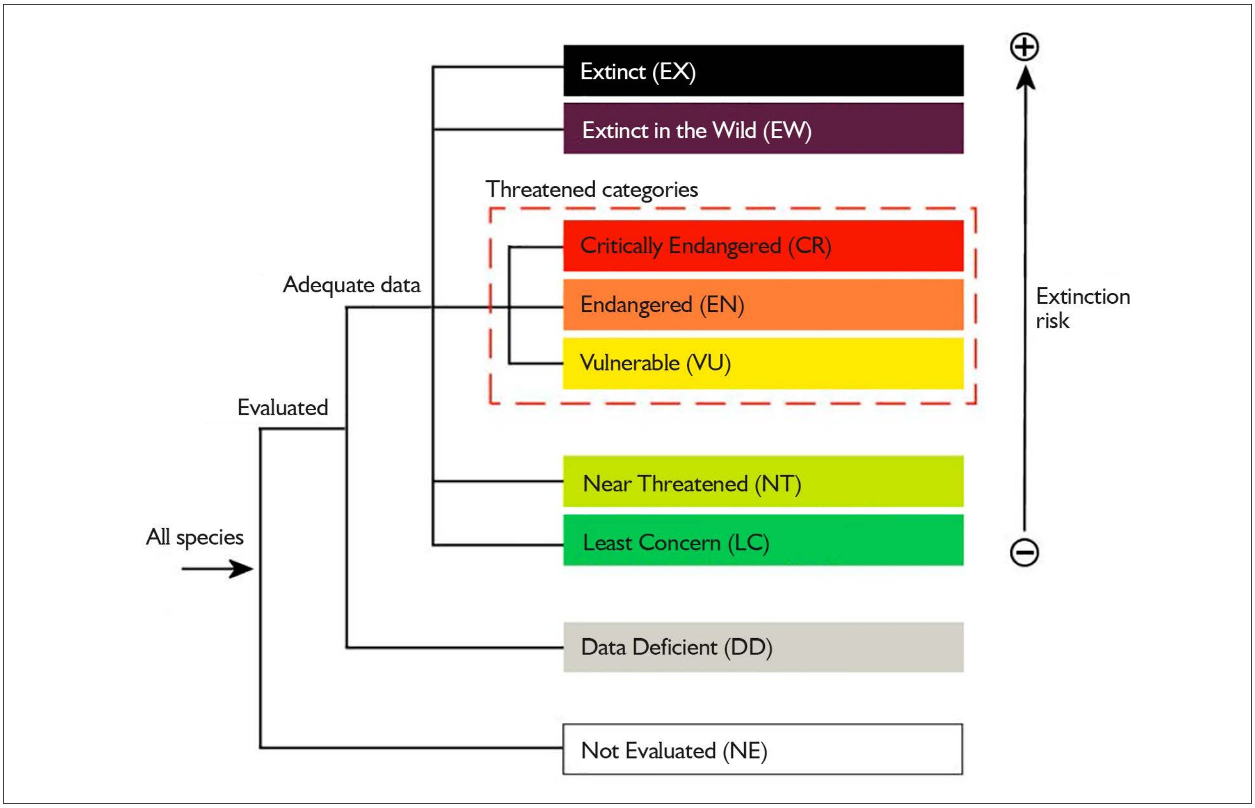

Figure 2. The IUCN Red List Categories. Used with permission of the IUCN Red List Unit, Cambridge, UK.

GMA, who reviews reports and provides edits. These are often returned to the SMSG team for additional changes or research. The assessments are then sent to the IUCN Red List Unit in Cambridge for final review and approval before being published on the IUCN Red List website.

Organizing assessors electronically was often difficult. Few Brazilian assessors were certified through the IUCN Red List training and subsequent examination and therefore had no access to the SIS system, and instead had to collaborate with colleagues who had access and were able to complete and consolidate reports. A large portion of the effort to complete these assessments was spent organizing assessors and their data, and connecting them to colleagues who consolidated their reports within the SIS system.

The Texas A&M Small Mammal Specialist Group Assessment Team (SMSG) consolidated information for all Brazilian Rodentia species included in this assessment. The SMSG then took the collection of reports and made range maps of most assessed species in this report – some range maps were provided from Mammals of South America (Patton *et al*., 2015), others from Volumes 6 and 7 of the Handbook of Mammals of the World (Wilson *et al.*, 2016, 2017), as well as other regional treatises on mammals and the primary literature. Brazilian assessors also provided point locality data and revisions to previous published range maps.

Heat maps of the density of species of conservation concern and data deficiency were generated in ArcGIS using the spatial data from the IUCN Red List website.

## RESULTS

### ASSESSMENT OF ALL SPECIES OF RODENTIA IN BRAZIL

We conducted assessments of all species of Brazilian rodents documented between 2015 and 2019. As a consequence, recently described species are not included in the data compiled for this analysis. There were 80 species assessed in the present study that were not assessed in the 2008 Global Mammal Assessment (Table 1 and supplemental material[1]; Schipper *et al.*, 2008). The 80 new species were assessed using Red List criteria by the SMSG. The relative distribution of species among categories remained fairly consistent with the exception of a 40%, but numerically small, drop in Vulnerable (VU) species. The greatest increase was in the number of Least Concern (LC) species, as most of the 80 newly assessed species fell into this category. There was a total of 24 species we considered of conservation concern: 20 in one of the three threatened categories and four listed as Near Threatened.

We evaluated the current status of all rodents by family, both for species of conservation concern and Data Deficiency (Table 2). The families Caviidae, Ctenomyidae, Echimyidae, and Erethizontidade have a higher percentage of species of conservation concern than the percentage for rodents as a whole, and these same four families have a higher than expected percentage of Data Deficient (DD) species than for rodents as a whole. The family Echimyidae,

Table 1. Number of species of rodents by IUCN Category in 2008 and the present study with percentage of change in each category. There were 80 new assessments in the present study. Legends: NE = not evaluated; DD = data deficient; LC = least concern; NT = near threatened; VU = vulnerable; EN = endangered; CR = critically endangered; EX = extinct.

| Category | 2008 | Present | % Change |
|---|---|---|---|
| NE | 80 | 0 | - |
| DD | 35 | 40 | 14.3 |
| LC | 92 | 168 | 82.6 |
| NT | 2 | 4 | 100.0 |
| VU | 10 | 6 | -40.0 |
| EN | 10 | 11 | 10.0 |
| CR | 3 | 3 | 0.0 |
| EX | 2 | 2 | 0.0 |
| Total | 234 | 234 | - |

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[1] See complementary material to this article, in a table available at link: http://editora.museu-goeldi.br/bn/artigos/cnv15n3_2020/Lacher et al_suppl.xlsx

Table 2. The number of species of rodents by family in each IUCN Red List Category in the present reassessment. Families with superscript 1 indicate an elevated number of species of conservation concern (NT, VU, EN, CR); families with superscript 2 indicate an elevated percentage of DD; and families with superscript 3 an elevated number of species both of conservation concern and DD species. Legends: NE = not evaluated; DD = data deficient; LC = least concern; NT = near threatened; VU = vulnerable; EN = endangered; CR = critically endangered; EX = extinct; * = there are also two Least Concern species of Muridae, not native to Brazil.

| Family | DD | LC | NT | VU | EN | CR | EX | Species number |
|---|---|---|---|---|---|---|---|---|
| Caviidae[1] | 1 | 7 | 0 | 0 | 0 | 1 | 0 | 9 |
| Cricetidae | 17 | 97 | 3 | 4 | 3 | 0 | 2 | 126 |
| Ctenomyidae[3] | 2 | 2 | 0 | 1 | 1 | 0 | 0 | 6 |
| Cuniculidae | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Dasyproctidae[2] | 4 | 5 | 0 | 0 | 0 | 0 | 0 | 9 |
| Dinomyidae | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Echimyidae[3] | 12 | 42 | 1 | 0 | 6 | 2 | 0 | 63 |
| Erethizontidae | 3 | 5 | 0 | 1 | 1 | 0 | 0 | 10 |
| Sciuridae | 1 | 6 | 0 | 0 | 0 | 0 | 0 | 7 |
| Total | 40 | 168 | 4 | 6 | 11 | 3 | 2 | 232* |

with 19% DD species and 14.3% species of conservation concern is of particular importance of additional basic research and conservation action.

## SPECIES OF CONSERVATION CONCERN ACCOUNTS

Of the 24 species of conservation concern, 16 are restricted to the Atlantic Forest and two more occur both there and in the Cerrado. Two other species are restricted to the Cerrado, and two others in the Pampas region of southern Brazil (Table 3). This highlights the need for concerted conservation efforts in the Brazilian Atlantic Forest. Detailed accounts for all 24 species follow. Common names are those presented on the IUCN Red List accounts.

### Caviidae

### *Cavia intermedia* Cherem, Olimpio & Ximenez, 1999 – Santa Catarina's Guinea Pig

IUCN Red List: CR D / Brazil: CR B1ab(iii)+2ab(iii); D / Santa Catarina: CR.

Description: this species is only found only on Ilhas Moleques do Sul, a continental island that is part of the *Parque Estadual da Serra do Tabuleiro*, a large conservation unit that includes hills, coastal lowlands, and several coastal islands. Its total distribution is only 4 hectares – the smallest area of occurrence of any known mammal in the world. It has an average estimated population size of 42 individuals (Salvador & Fernandez, 2008; Lacher, 2016; Roach, 2016).

Major threats: hunting is presumed to be a threat to Santa Catarina's Guinea Pig, but fire and species introductions may also represent major threats. Given its extremely small population size and restricted distribution, it is highly vulnerable to natural disasters.

Current conservation efforts: the species is monitored, and the population appears stable. The Park and all available habitats have been designated as a Preservation Zone where entry is prohibited. Nevertheless, management and enforcement are ineffective; the most urgent conservation need is to guarantee full protection and enforcement of restricted access and possible monitoring and restoration of its key herbaceous and grassland food base (Lacher, 2016; Roach, 2016). Species listed as CR in Brazil (Brasil, 2014); included in the Santa Catarina's List of Threatened Species in category CR (São Paulo, 2011); and recently addressed in the "Plano de Ação Estadual para a Conservação do Preá-de Moleques-do-Sul" (Santa Catarina, 2019).

Table 3. Summary of the 24 Species of Conservation Concern, with data of distribution, conservation status, and threats. Brazil and State List columns marked '-' had no federal or state evaluation. Occurrence and federative unit codes: AL = Alagoas; BA = Bahia; DF = Distrito Federal; ES = Espírito Santo; GO = Goiás; MG = Minas Gerais; PE = Pernambuco; PB = Paraíba; PR = Paraná; RJ = Rio de Janeiro; RO = Roraima; RS = Rio Grande do Sul; SC = Santa Catarina; SE = Sergipe; SP = São Paulo. Biomes: AF = Atlantic Forest; AM = Amazon; CA = Caatinga; CE = Cerrado; PA = Pampa. Categories of Threat: VU = Vulnerable; EN = Endangered; CR = Critically Endangered; PE = Possibly Extinct.

(Continue)

| Taxon | Occurrence | Biome | Endemic | Brazil list | State list | Principal threats |
|---|---|---|---|---|---|---|
| CAVIIDAE | | | | | | |
| *Cavia intermedia* | SC (island) | AF | Yes | CR | SC (CR) | Small and restricted population |
| CRICETIDAE | | | | | | |
| *Drymoreomys albimaculatus* | SP to SC | AF | Yes | - | - | Habitat degradation, forest fragmentation |
| *Euryoryzomys lamia* | MG, GO | CE | Yes | EN | MG (CR) | Agriculture and extraction of timber |
| *Hylaeamys laticeps* | BA to RJ | AF | Yes | - | - | Agriculture, forest degradation, urbanization |
| *Hylaeamys oniscus* | AL, PE, PB | AF | Yes | - | - | Sugar cane, other agriculture, fragmentation |
| *Juliomys rimofrons* | RJ, MG, SP | AF | Yes | - | - | Habitat degradation, forest fragmentation |
| *Microakodontomys transitorius* | DF | CE | Yes | EN | - | Urban expansion, population isolation |
| *Phaenomys ferrugineus* | MG, RJ, SP | AF | Yes | - | SP (VU) | Decline in the quality or extension of habitat |
| *Podoxymys roraimae* | RO | AM | No | - | - | Tourism and extraction of timber |
| *Rhagomys rufescens* | MG, ES, RJ, SP, SC | AF | Yes | - | RJ (PE) | Habitat degradation forest fragmentation |
| *Wilfredomys oenax* | SP, PR, RS | AF | No | EN | PR (CR),<br>RS (EN) | Habitat degradation forest fragmentation |
| CTENOMYIDAE | | | | | | |
| *Ctenomys flamarioni* | RS | PA | Yes | EN | RS (EN) | Domestic animals, urbanization, extraction of sand |
| *Ctenomys lami* | RS | PA | Yes | EN | RS (EN) | Urbanization, agriculture |
| ECHIMYIDAE | | | | | | |
| *Callistomys pictus* | BA | AF | Yes | EN | BA (EN) | Disturbance of native forest, mixed agroforestry, *cabruca* |
| *Phyllomys brasiliensis* | MG | AF/CE | Yes | EN | MG (EN) | Decline in the quality or extension of habitat |
| *Phyllomys lundi* | MG, RJ | AF | Yes | EN | MG (EN) | Decline in the quality or extension of habitat |
| *Phyllomys mantiqueirensis* | MG | AF | Yes | - | - | Restricted and decline in quality or extension of habitat |
| *Phyllomys thomasi* | SP (island) | AF | Yes | EN | SP (EN) | Restricted habitat, urbanization, domestic animals |
| *Phyllomys unicolor* | BA | AF | Yes | CR | BA (CR) | Agriculture, decline in quality or extension of habitat |
| *Trinomys eliasi* | RJ | AF | Yes | VU | RJ (EN) | Human pressure, habitat alteration, extraction of sand |

Table 3. (Conclusion)

| Taxon | Occurrence | Biome | Endemic | Brazil list | State list | Principal threats |
|---|---|---|---|---|---|---|
| *Trinomys moojeni* | MG | AF/CE | Yes | EN | MG (VU) | Decline in the quality or extension of habitat, fire |
| *Trinomys yonenagae* | BA | CA | Yes | EN | BA (EN) | Loss of habitat, especially extraction of sand |
| ERETHIZONTIDAE | | | | | | |
| *Chaetomys subspinosus* | SE to RJ | AF | YES | VU | BA (VU),<br>ES (VU) | Decline in the quality or extension of habitat |
| *Coendou speratus* | PE, AL | AF | YES | EN | - | Forest fragmentation, restricted to small fragments |

## Cricetidae

### *Drymoreomys albimaculatus* Percequillo, Weksler & Costa, 2011 – White-throated Montane Forest Rat

IUCN Red List: NT B1ab(iii)+2ab(iii).

Description: this species is a specialist of premontane forests in the coastal Brazilian Atlantic Rainforest from São Paulo and Rio de Janeiro to Santa Catarina states, in altitudes ranging between 650 and 1,200 meters including a register for the Serra da Bocaína National Park in a mixed habitat of forest and bamboo (Percequillo *et al.*, 2011; Delciellos *et al.*, 2015). While found to inhabit secondary and disturbed forests, literature suggests it needs access to pristine forest to sustain its population (Percequillo & Weksler, 2015).

Major threats: as with all inhabitants of the Atlantic Forest biome, this species is vulnerable to the effects of habitat loss (Engelbrektsson, 2019).

Current conservation efforts: while this species occurs in protected areas (Engelbrektsson, 2019), there are no existing conservation plans specific for it.

### *Euryoryzomys lamia* (Thomas, 1901) – Buffy-sided Euryoryzomys

IUCN Red List: VU B2ab(i,iii) / Brazil: EN B1ab(iii) / Minas Gerais: CR.

Description: this forest-dwelling species is only recorded existing in four localities in the states of western Minas Gerais and southern Goiás. Of these four localities, two no longer support viable habitat, as their forest has been completely destroyed by agricultural land use change (Percequillo, 2015a; Percequillo & Weksler, 2018).

Major threats: this species faces threats from habitat destruction due to agriculture and logging activities.

Current conservation efforts: while this species occurs in the protected area *Parque Nacional da Chapada dos Veadeiros* (Bonvicino *et al*., 2005), there are no existing conservation plans specific to this species. Species is listed as EN in Brazil (Brasil, 2014) and included in the state of Minas Gerais List of Threatened Species in category CR (Minas Gerais, 2010).

### *Hylaeamys laticeps* (Lund, 1840) - Atlantic Forest Hylaeamys

IUCN Red List: VU B2ab(i,ii,iii).

Description: this species occurs in the lowlands of the Atlantic Rainforest, from Bahia to Rio de Janeiro (Weksler *et al*., 1999; Percequillo & Weksler, 2019).

Major threats: this species faces threats from deforestation, urbanization, and agriculture (Percequillo, 2015b; Percequillo & Weksler, 2019).

Current conservation efforts: while this species occurs in protected areas including the Rio Doce State Park in Minas Gerais (Percequillo, 2015b; Percequillo & Weksler, 2019), there are no existing conservation plans specific for it. Note that Percequillo (2015b) considers *Hylaeamys seuanezi* (Weksler, Geise & Cerqueira, 1999) to be synonymous with *H. laticeps*, disputed by Brennand *et al*. (2013). In fact, Brennand *et al*. (2013) are correct in their decision and the appropriate the name for this species is *H. seuanezi*, with *H. laticeps* currently under the synonymy of *H. megacephalus* Fischer, 1814.

### *Hylaeamys oniscus* (Thomas, 1904) – Northern Atlantic Forest Hylaeamys

IUCN Red List: NT B2ab(iii).

Description: this species only exists in the northeastern part of the Atlantic Rainforest, north of the Rio São Fransciso in the states of Alagoas, Pernambuco, and Paraíba (Percequillo, 2015b). The remaining habitat for this species is highly fragmented. The species has only been captured in the forest, and not in surrounding developed areas, suggesting that this species is entirely reliant on dense forest habitat (Percequillo & Roach, 2017).

Major threats: the majority of this species' habitat has been developed and converted for sugar cane, ranching, and other agricultural activities. What is left of this species's habitat is severely fragmented (T. Lacher Jr., personal communication).

Current conservation efforts: while this species occurs in protected areas, including the *Estação Ecologia de Murici*, Alagoas state, and *Reserva Biológica de Saltinho*, Pernambuco state (Percequillo & Roach, 2017), there are no existing conservation plans specific for it.

### *Juliomys rimofrons* Oliveira & Bonvicino, 2002 – Cleft-headed Juliomys

IUCN Red List: NT B1a+2a.

Description: this rare, arboreal species is believed to be endemic to high altitude areas connecting along the borders of the states of Rio de Janeiro, Minas Gerais, and São Paulo. This species has only been observed in the wild thrice over the course of an eight-year survey project – although, this could be the result of misguided trapping methodology (Bonvicino & Geise, 2008; Fonseca *et al*., 2013).

Major threats: although this species faces no immediate threats, its restricted range in few remaining protected areas suggest that it was likely more widespread in the past, and the remaining populations need protection (Naylor & Roach, 2019).

Current conservation efforts: records of these species show them mainly occurring in protected national parks, however, there are no existing conservation plans specific for it.

### *Microakodontomys transitorius* Hershkovitz, 1993 - Transitional Colilargo

IUCN Red List: EN B2ab(iii) / Brazil: EN B1ab(iii)+2ab(iii).

Description: it is endemic to Brazil and was known only from the type locality: Brazil, Federal District, *Parque Nacional de Brasília*, 1,100 m (Eisenberg & Redford, 1999; Paresque & Hanson, 2015). Another four individuals were collected in the Área Alfa da Marinha, ca. 170 km NW *Parque Nacional de Brasília*, near to the *Área de Proteção Ambiental* (APA) *das Bacias do Gama e Cabeça de Veado* (ICMBio, 2018).

Major threats: it is assumed that *M. transitorius* is a rare species and its population is severely fragmented because the landscape between its two registration sites includes habitat degraded by urban growth (Paresque & Hanson, 2015; ICMBio, 2018). Environmental and ecological impacts may to be larger than acceptable.

Current conservation efforts: although the landscape of its territory is affected by human activities, where the quality of the habitat is decreasing, *M. transitorius* occurs in one protected area: *Parque Nacional de Brasília*. *Microakodontomys transitorius* is listed as EN in Brazil (Brasil, 2014).

### *Phaenomys ferrugineus* (Thomas, 1894) - Rio de Janeiro Arboreal Rat

IUCN Red List: EN B2ab(ii,iii) / São Paulo: VU.

Description: this species appears to be endemic to Atlantic Forest of southeastern Brazil and it is known only from restricted areas in the states of Minas Gerais, Rio de Janeiro and São Paulo, mainly of montane forest (Passamani *et al.*, 2011; Percequillo, 2015c).

Major threats: it may be restricted to the region of the Serra da Mantiqueira and Serra da Bocaina range and surrounding areas (Passamani *et al.*, 2011). The major threat to this species is continuing decline in the extent and quality of its habitat.

Current conservation efforts: *Phaenomys ferrugineus* occurs in six protected areas: *Parque Nacional de Itatiaia*, *Estação Ecológica de Bananal*, *Parque Estadual dos Três Picos*, *Área de Proteção Ambiental Floresta do Jacarandá*, *Parque Nacional da Serra dos Órgãos*, and *Parque Nacional da Serra da Bocaina*. The species has been included in the Conservation Action Planning of Central Atlantic Forest Mammals (Escarlate-Tavares *et al.*, 2016) and it is included in the São Paulo's List of Threatened Species in category VU (São Paulo, 2018).

### *Podoxymys roraimae* Anthony, 1929 – Roraima Akodont

IUCN Red List: VU D2.

Description: this species is only documented on the Venezuelan side of Mount Roraima, but its range likely extends across the Brazilian border in the northern part of the state of Roraima. All specimens of this species have been documented in areas with growth of *Bonnettia* trees (Patton, 2018).

Major threats: timber extraction and tourism threatens this species' habitat (Linares, 1998).

Current conservation efforts: this species likely occurs in the *Parque Nacional do Monte Roraima* (Paglia *et al.*, 2012).

### *Rhagomys rufescens* (Thomas, 1886) – Rufescent Rhagomys

IUCN Red List: VU B2ab(i,ii,iii) / Rio de Janeiro: Possibly Extinct.

Description: this species occurs in the Atlantic Rainforest in Minas Gerais, Espírito Santo, part of Rio de Janeiro, São Paulo, and Santa Catarina states in Brazil (Patton *et al*., 2015; Bergallo & Percequillo, 2019). Little is known of this species' ecology and life history.

Major threats: like many species endemic to the Atlantic Rainforest, this species faces major threats from habitat destruction and fragmentation.

Current conservation efforts: this species occurs in protected areas (*Núcleo Picinguaba of the Parque Estadual da Serra do Mar*, *Estação Ecológica do Bananal* in São Paulo state) and has been included in the Conservation Action Planning of Central Atlantic Forest Mammals (Escarlate-Tavares *et al.*, 2016). It is cited as probably extinct in Rio de Janeiro, its type locality (Bergallo *et al.*, 2000).

### *Wilfredomys oenax* (Thomas, 1928) - Red-nosed Tree Mouse

IUCN Red List: EN B2ab(ii,iii,iv) / Brazil: EN B2ab(ii,iii) / Paraná: CR / Rio Grande do Sul: EN.

Description: this species occurs from Brazil to north and central Uruguay (Musser & Carleton, 2005). In Brazil, it is known only from restricted areas in the states of Paraná, Rio Grande do Sul (ICMBio, 2018) and São Paulo (Brandão, 2015), without new records in Paraná and São Paulo states for over 38 and 70 years, respectively, even with significant rodent sampling (Brandão, 2015; ICMBio, 2018).

Major threats: the species is rare and very little is known about its status and habitat requirements. There is continuing decline in the extent and quality of its habitat across the entire distributional range.

Current conservation efforts: the species has been included in the Conservation Action Planning of Lake and Lagoon Systems of Southern Brazil (ICMBio, 2018). It is listed as EN in Brazil (Brasil, 2014) and included in the Paraná's List of Threatened Species in category CR (Paraná, 2010) and Rio Grande do Sul in EN (Rio Grande do Sul, 2014).

## Ctenomyidae

### *Ctenomys flamarioni* Travi, 1981 – Flamarion's Tuco-tuco

IUCN Red List: EN B2ab(i,ii,iii,iv) / Brazil: EN B1ab(i,iii) / Rio Grande do Sul: EN.

Description: it is endemic to Brazil occurring exclusively along the first coastal dune strip in Rio Grande do Sul state, an environment that has a high degree of salinity and poor vegetation cover (Freitas, 1995).

Major threats: its habitat has been altered by urbanization, sand mining and other activities. Human and domestic animal populations are also a threat to *C. flamarioni* (ICMBio, 2018).

Current conservation efforts: the species has been included in the Conservation Action Planning of Lake and Lagoon Systems of Southern Brazil (ICMBio, 2018). It is listed as EN in Brazil (Brasil, 2014) and included in the Rio Grande do Sul's List of Threatened Species in category EN (Rio Grande do Sul, 2014).

**_Ctenomys lami_ Freitas, 2001 - Lami Tuco-tuco**

IUCN Red List: VU B1ab (i,ii,iii) / Brazil: EN B1ab (ii,iii) / Rio Grande do Sul: EN.

Description: this species occurs in multiple localities in the state of Rio Grande do Sul, especially on Lami beach in the Guaíba River. Most localities where this species is present have experienced anthropogenic development (Bidau, 2015).

Major threats: deforestation has resulted in the degradation of a previous natural barrier between *Ctenomys lami* and *Ctenomys minutus* Nehring, 1887. As such, a hybrid zone has opened up and threatens the integrity of the species *Ctenomys lami* (Gava & Freitas, 2003). This species is also threatened by increased urbanization and agricultural development in its limited territory.

Current conservation efforts: it is listed as EN in Brazil (Brasil, 2014) and included in the Rio Grande do Sul's List of Threatened Species in category EN (Rio Grande do Sul, 2014).

### Echimyidae

**_Callistomys pictus_ (Pictet, 1843) - Painted Tree Rat**

IUCN Red List: EN B2ab (i,ii,iii) / Brazil: EN B1ab (ii,iii) / Bahia: EN.

Description: it is endemic to the Atlantic Forest of coastal Bahia, where it is known for only four locations (Emmons *et al*., 2015; Fabre *et al.*, 2016; ICMBio, 2018).

Major threats: the landscape is a mosaic inhabited by this species composed mainly of small forest fragments immersed in a matrix of shaded cocoa plantations (Saatchi *et al.*, 2001). Disturbances of native forests and cocoa agroforestry still occur, and it represents a serious threat to the survival of *Callistomys pictus*.

Current conservation efforts: the species has been included in the Conservation Action Planning of Central Atlantic Forest Mammals (Escarlate-Tavares *et al.*, 2016) and most recently has been included in the Bahia's List of Threatened Species in category EN (Cassano *et al.*, 2017). It is listed as EN in Brazil (Brasil, 2014).

**_Phyllomys brasiliensis_ Lund, 1840 – Brazilian Atlantic Tree Rat**

IUCN Red List: EN B2ab(i,ii,iii) / Brazil: EN B2ab(iii,iv) / Minas Gerais: EN.

Description: it is endemic to Brazil and extremely rare, occurring only in Minas Gerais (type locality is *Lapa das Quatro Bocas*, Lagoa Santa). Since the 19th century there are few records (only five) in regions of the Minas Gerais state, in the valleys of Paraopeba and das Velhas rivers (Fabre *et al.*, 2016; Leite & Loss, 2015; ICMBio, 2018).

Major threats: the major threat to this species is continuing decline in the extent and quality of its habitat. Species is not found in any protected areas.

Current conservation efforts: it is listed as EN in Brazil (Brasil, 2014) and included in the Minas Gerais' List of Threatened Species in category EN (Minas Gerais, 2010). The species has been included in the Conservation Action Planning of Central Atlantic Forest Mammals (Escarlate-Tavares *et al.*, 2016).

**_Phyllomys lundi_ Leite, 2003 - Lund's Atlantic Tree Rat**

IUCN Red List: EN B1ab(iii) / Brazil: EN B2ab(iii,iv) / Minas Gerais: EN.

Description: it is endemic to southeastern Brazil and known only from two localities 200 km apart in the Minas Gerais and Rio de Janeiro states (Fabre *et al.*, 2016; Leite & Loss, 2015).

Major threats: the major threat to this species is continuing decline in the extent and quality of its habitat. An area of occupancy of the species was reduced by fire, so the species was classified as EN in Brazil (ICMBio, 2018).

Current conservation efforts: it is listed as EN in Brazil (Brasil, 2014) and included in the Minas Gerais' List of Threatened Species in category EN (Minas Gerais, 2010). One of the locations where the species was found is a protected area: *Reserva Biológica de Poços das Antas*, Rio de Janeiro.

### *Phyllomys mantiqueirensis* Leite, 2003 – Serra da Mantiqueira Atlantic Tree Rat

IUCN Red List: CR B1ab(iii).

Description: it is only found in a single area from mixed montane rainforest at 1,800 m altitude in limits of the *Área de Proteção Ambiental* (APA) *da Mantiqueira*, Minas Gerais, that belongs to the Brazilian Army (Leite, 2003).

Major threats: it may be restricted to high-elevation forests in the Serra da Mantiqueira, a very specific and naturally restricted habitat that has been continuing decline in area, extent and quality of habitat.

Current conservation efforts: the species' habitat is owned by the army for field training, this provides some degree of protection (Loss & Leite, 2016a).

### *Phyllomys thomasi* (Ihering, 1897) - Thomas's Atlantic Tree Rat

IUCN Red List: EN B1ab(iii)+2ab(iii) / Brazil: EN B1ab(iii) / São Paulo: EN.

Description: it is endemic to the *Ilha de São Sebastião*, São Paulo state, Brazil, a continental island where 80% is Atlantic Forest; the extent of occurrence is approximately 348 km$^2$ – based on the area of the island (Eisenberg & Redford, 1999; Fabre *et al.*, 2016; ICMBio, 2018).

Major threats: the island, where the municipality of Ilhabela is inserted, has been severely urbanized with rapid and unordered population growth, occupation of forest areas, illegal burning, introduction of domestic animals, and tourism (ICMBio, 2018).

Current conservation efforts: it is listed as EN in Brazil (Brasil, 2014) and included in the São Paulo's List of Threatened Species in category EN (São Paulo, 2018). *Phyllomys thomasi* has been included in the Conservation Action Planning of Central Atlantic Forest Mammals (Escarlate-Tavares *et al.*, 2016). Approximately 83% of the total area of the Island represents a protected area: *Parque Estadual de Ilhabela*.

### *Phyllomys unicolor* (Wagner, 1842) - Unicolored Atlantic Tree Rat

IUCN Red List: CR B2ab(ii,iii) / Brazil: CR B1ab / Bahia: CR PEX.

Description: it is endemic to Brazil and known only from the type specimen recorded in 1824. The type locality is Helvética, ca. 50 km SW Caravelas, Bahia, at elevation 59 meters (Emmons *et al*., 2002; Loss & Leite, 2016b).

Major threats: it is known only from the holotype in only one locality that almost entirely represents an agriculture mosaic. This is a landscape that inevitably leads to localized declines in biodiversity (ICMBio, 2018).

Current conservation efforts: it was recently included in the Bahia's List of Threatened Species in category CR (Cassano *et al.*, 2017) and is listed as CR in Brazil (Brasil, 2014). The species has been included in the Conservation Action Planning of Central Atlantic Forest Mammals (Escarlate-Tavares *et al.*, 2016).

### *Trinomys eliasi* (Pessôa & Reis, 1993) – Elias's Atlantic Spiny Rat

IUCN Red List: NT / Brazil: VU B1ab(ii,iii) / Rio de Janeiro: EN.

Description: this species occurs in the northeastern region of the state of Rio de Janeiro. The population is fragmented into multiple small populations within a restricted range (Brito & Figueiredo, 2003; Pessôa *et al.*, 2015). This solitary terrestrial species lives in semi-deciduous and evergreen forests (Pessôa *et al.*, 2015).

Major threats: this species is vulnerable to human pressure from habitat destruction, especially in areas where its habitat is affected by sand extraction, and in areas where this species occurs in *Barra de Maricá*, which is used as a landfill for waste disposal (Brito & Figueiredo, 2003).

Current conservation efforts: this species occurs in national parks, including *Reserva Biológica Poço das Antas*, *Parque Nacional da Restinga de Jurubatiba*, *Reserva Particular do Patrimônio Natural Fazenda Santa Helena*, and several others (ICMBio, 2018). The species is listed as VU in Brazil (Brasil, 2014) and included in the Rio de Janeiro's List of Threatened Species in category EN (Bergallo *et al.*, 2000). *Trinomys eliasi* has been included in the Conservation Action Planning of Central Atlantic Forest Mammals (Escarlate-Tavares *et al.*, 2016).

### *Trinomys moojeni* (Pessôa, Oliveira & Reis, 1992) – Moojen's Atlantic Spiny Rat

IUCN Red List: EN B1ab(i,iii) / Brazil: EN B1ab(iii) / Minas Gerais: VU.

Description: it is endemic to Brazil restricted to the east-central Minas Gerais, in the southern Espinhaço massif. *Trinomys moojeni* occurs in forest lands above 1,000 m and is present at the border between the Cerrado and Atlantic Forest (Roach & Naylor, 2016). It has been reported from the *Parque Nacional da Serra do Cipó* and *Reserva Particular do Patrimônio Natural Serra do Caraça* (Cordeiro Jr. & Talamoni, 2006; Pessôa *et al.*, 2015).

Major threats: the major threat to this species is continuing decline in the extent and quality of its habitat; also, there are frequent fires in its range.

Current conservation efforts: it is listed as EN in Brazil (Brasil, 2014) and included in the Minas Gerais List of Threatened Species in category VU (Minas Gerais, 2010). *Trinomys moojeni* is included in the Conservation Action Planning of Central Atlantic Forest Mammals (Escarlate-Tavares *et al.*, 2016). *Trinomys moojeni* occurs in two protected areas.

### *Trinomys yonenagae* Rocha, 1996 - Yonenaga's Atlantic Spiny Rat

IUCN Red List: EN B2ab(i,ii,iii) / Brazil: EN B1ab(ii,iii) / Bahia: EN.

Description: this species occurs in semiarid dune habitats in Caatinga biome of Brazil. It is known from middle *Rio São Francisco* in northwestern Bahia state where it lives a gregarious, semi-fossorial lifestyle in self-dug burrow systems (Santos & Lacey, 2011; Pessôa *et al.*, 2015).

Major threats: this species is threatened by habitat loss, especially due to commercial sand mining (Luchesi *et al.*, 2019).

Current conservation efforts: it was recently included in the Bahia's List of Threatened Species in category EN (Cassano *et al.*, 2017) and listed as EN in Brazil (Brasil, 2014).

## Erethizontidae

### *Chaetomys subspinosus* (Olfers, 1818) – Bristle-spined Rat

IUCN Red List: VU B2ab(ii,iii,iv) / Brazil: VU B2ab(ii,iii) / Bahia: VU / Espírito Santo: VU.

Description: it is endemic to Brazil and occurs in fragments of Atlantic coastal plains and mountains, from Sergipe to northern Rio de Janeiro (Voss, 2011). This species is nocturnal and arboreal, and prefers habitat with high levels of vertical complexity (Barthelmess, 2016). Male individuals of this species utilize a range almost triple the size of their female counterparts (Giné *et al.*, 2015).

Major threats: this species is threatened by deforestation, and many populations are now extinct from forest lost (Barthelmess, 2016). Less than 17% of previous forest cover remains within this species' current geographic range (Barthelmess, 2016).

Current conservation efforts: there are currently conservation efforts in action to protect this species, mainly undertaken by the group or researchers from the Graduate Program in Ecology and Biodiversity Conservation, State University of Santa Cruz, Bahia. *Chaetomys subspinosus* has a National Action Plan (Faria *et al.*, 2011), is listed as VU in Brazil (Brasil, 2014) and included in the Bahia and Espírito Santo's List of Threatened Species in category VU (Cassano *et al.*, 2017; Espírito Santo, 2005).

### *Coendou speratus* Mendes Pontes, Gadelha, Melo de Sá Loss, Caldara Junior, Costa & Leite, 2013 – Pernambuco Dwarf Porcupine

IUCN Red List: EN B1ab(i,ii,iii,iv,v)+2ab(i,ii,iii,iv,v) / Brazil: EN B1ab(iii).

Description: this species is found in fragmented lowland evergreen forest habitat and remnant patches of sub montane Atlantic Forest in the states of Pernambuco and Alagoas in Brazil (Leal *et al.*, 2017; Mendes Pontes *et al.*, 2013). This species lives in dens in hollow trees and is likely nocturnal, as all observations have occurred at night (Mendes Pontes *et al.*, 2013; Voss, 2011).

Major threats: it is found in forest fragments that face anthropogenic pressure in the form of logging, hunting, and general development. Remaining forest fragments are small and in poor condition (ICMBio, 2018).

Current conservation efforts: This species occurs in one protected area (*Estação Ecológica Murici*, *Área de Proteção Ambiental Estadual de Murici*, state of Alagoas); there are no existing conservation plans specific to it (ICMBio, 2018). It is listed as EN in Brazil (Brasil, 2014).

## DISCUSSION

There were 20 species in one of the Threatened Categories out of the 194 actually assessed for this study (234 less 40 DD species), or 10.3%. This is far less than the number of threatened species for mammals as a whole, which was 25% in Schipper *et al.* (2008). This paper also speculated on the impact of species classified as DD on overall conservation status as a group. If all DD species were considered under no threat of extinction, adding them to the total would reduce the percent of rodents actually in an IUCN Category of threat, whereas if all were threatened then this would raise the percentage. There are currently 40 DD species of rodents, and using the same approach as Schipper *et al.* (2008) the percentage of threatened rodents could range from to 8.5% to 25.6%, approaching the number for the class Mammalia. Most studies have shown that a relatively high percentage of DD species are at risk once sufficient data are obtained. Jetz & Freckleton (2015) used a combination of phylogenetic and spatial models to predict threat data for 483 species of DD mammals. These models predicted that 69% of these species would have an elevated risk of extinction and that an estimated 21.5% of rodent species would be potentially in a Threatened Category. One of the highest priorities in the IUCN Red List Unit is to reduce the number of species currently assessed as DD. In many cases this can only be completed with additional field research, but using a combination of expert opinion coupled with modeling approaches (application of Criterion E) as above can also provide valid assessments.

Another concern is the very high percentage of LC species, 87% of those species assessed (n = 194). Although this could reflect the adaptability and tolerance of rodents, it could also reflect application of poor spatial data (in fact, the gaps on the distribution of samples are immense; see for instance, Prado & Percequillo, 2013). Of all the species assessed as threatened or of concern, 21 used criterion B and one used D2 (*Podoxymys roraimae*). Only *Cavia intermedia* (D) had population data, because its distribution on a small oceanic island had allowed for a direct census (Salvador & Fernandez, 2008). Assessments of Brazilian rodents are almost completely lacking in any kind of population data that would allow for an assessment of trends. The reliance on Criterion B, in particular EOO, can result in an overestimate of the dispersion of risk when there is use of historical point locality data. Many peripheral populations could have been exterminated and a failure to attempt to estimate available habitat can create a sense of complacency regarding the status of many species. A novel alternative approach, estimation of Area of Habitat (AOH) is not equivalent to either EOO or AOO, but can provide insights on refining survey and assessment methods that would yield better estimates of EOO or the development of an AOO given additional data collection (Brooks *et al*., 2019). More fieldwork will invariably improve assessments for both DD and LC species.

The break-down of threat and Data Deficiency shows that some families are of elevated concern. The percent of species of concern for the caviomorph family Echimyidae is 14.3% and the percent DD species is also high for Echimyidae (19%) but also for Dasyproctidae (44.4%). The sum of concern and DD for echimyids is 33.3%. These two families need additional ecological, behavioral, and phylogenetic research and should be priorities for funding at the state and federal level. Although the family Ctenomyidae has low overall richness in Brazil, two-thirds of the species are either Threatened or Data Deficient. In addition to their unique morphological, behavioral, and ecological characteristics, they provide valuable ecosystem function roles in aerating and mixing soils. Most species also have very restricted ranges and merit a stronger conservation focus.

In addition to the patterns for family there were also strong spatial patterns for both species of concern and DD species, as revealed in the heat maps (Figures 3 and 4) and the distribution of the 24 species of concern (Table 3). The Atlantic Forest is clearly the highest priority for the implementation of conservation action. It is the most important region for a high concentration of threatened species, followed by the Cerrado. The Atlantic Forest and Cerrado also harbor high densities of DD species, as does the Amazon, in particular the eastern Amazonian Basin. There has been significant prior emphasis on the conservation of Atlantic Forest mammals (Galetti *et al*., 2009) and habitats (Tabarelli *et al.*, 2010), but clearly the need remains high.

Given the increasing threats to biodiversity of habitat alteration, climate change, invasive species, and diseases, we would expect a convergence of efforts among institutions and agencies to unite research and conservation policy and action in the most efficient manner possible. Unfortunately, there remains a disconnect in the research and conservation rewards and priorities especially between academic institutions and conservation agencies and organizations. These represent

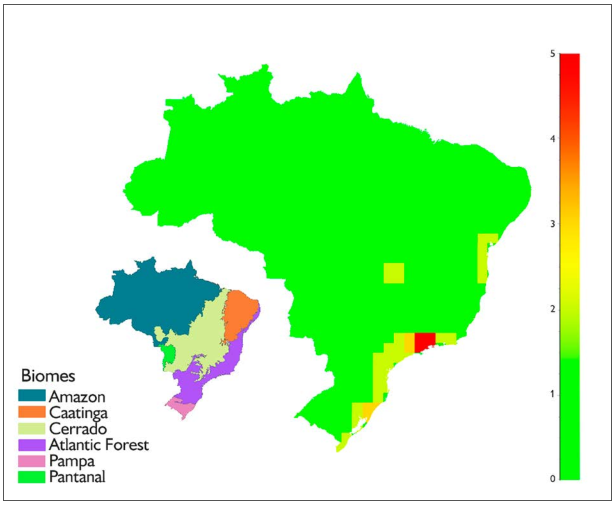

Figure 3. A heat map of the density of species of conservation concern, highlighting the Atlantic Forest and parts of the Cerrado. Map: crested by authors, insert of biomes modified from from https://data.globalforestwatch.org/datasets/54ec099791644be4b273d9d8a853d452_4

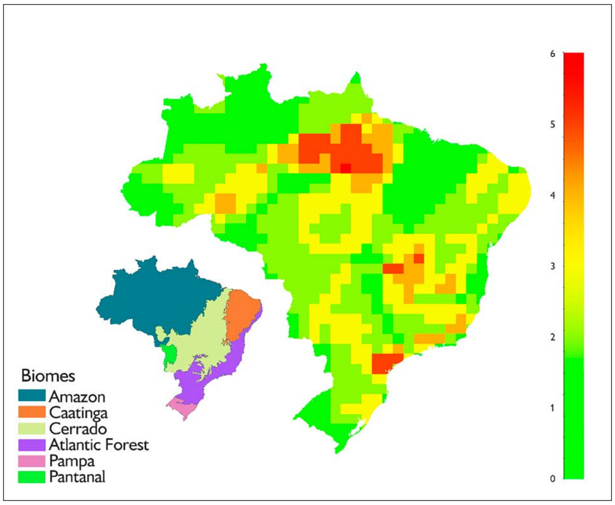

Figure 4. A heat map of the density of Data Deficient species, highlighting the Atlantic Forest, the Cerrado, and the eastern Amazon. Map: crested by authors, insert of biomes modified from from https://data.globalforestwatch.org/datasets/54ec099791644be4b273d9d8a853d452_4

natural partners, where universities gather and prioritize research data that can best address our biodiversity crisis. Better collaborations between universities and conservation NGOs are urgent to improve our knowledge of DD and LC species (Lacher *et al*., 2012) and the implementation of conservation actions (Hoffmann *et al*., 2010), where we can clearly demonstrate conservation successes.

## ACKNOWLEDGEMENTS

We thank Texas A&M University for logistical assistance and student financial support (specifically to N. Roach, S. McCay, and L. Wolf), the IUCN Red List Unit, Cambridge, UK for permission to use figures one and two, and to all of the Latin American and US assessors who contributed to the New World Red List assessment process for the IUCN SSC Small Mammal Specialist Group. Also, to M. Miretzki for his help in obtaining Brazilian scientific literature not available on the web. Two anonymous reviewers for valuable suggestions and comments in a previous version of this manuscript.

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# Updated habitat suitability estimates and conservation implications for the short-tailed chinchilla *Chinchilla chinchilla* (Lichtenstein, 1830) (Rodentia: Chinchillidae)

## Estimaciones actualizadas de la idoneidad de habitat e implicaciones para la conservación de la chinchilla de cola corta *Chinchilla chinchilla* (Lichtenstein, 1830) (Rodentia: Chinchillidae)

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**Abstract:** The short-tailed chinchilla (*Chinchilla chinchilla*) is a species classified as endangered throughout its distribution and for which neither a conservation nor management plan exists. Ecological niche models (ENMs) allow detection of potential areas of occurrence for species that are rare and/or of conservation interest. Here, we built and evaluated a suite of ENMs that incorporated new records for the species in Bolivia and removed those whose veracity could not be confirmed to provide an updated estimate of the extent of suitable habitat for *C. chinchilla*. Following model selection based on partial ROC, omission rate, and AICc, we then projected our top models across the historical distribution of *C. chinchilla* to identify locations of potentially suitable habitat. An ensemble of top models highlighted suitable habitat in Argentina, Bolivia, Chile, and Peru, with values of probability of suitable habitat up to 0.72. Together, these results demonstrate that suitable habitat still exists across the historical range of this species, provide insight into the climatic niche of this species, and highlight areas across the four countries for which future surveys of wild populations may be worthwhile.

**Keywords:** Andes. Ecological niche model. Maxent. Short-tailed chinchilla. South America

**Resumen:** La chinchilla de cola corta (*Chinchilla chinchilla*) es una especie clasificada como críticamente amenazada a lo largo de su distribución y para la cual no existen planes de manejo ni de conservación. Los modelos de nichos ecológicos (MNEs) permiten detectar áreas de probable ocurrencia para especies que son consideradas raras y/o de interés para la conservación. En este estudio, construimos y evaluamos un conjunto de MNEs que incorporaron nuevos registros para la especie en Bolivia y eliminaron aquellos cuya veracidad no pudo ser confirmada, para proporcionar una estimación actualizada de la extensión del hábitat adecuado para *C. chinchilla*. Después de seleccionar los mejores modelos basados en ROC parcial, tasa de omisión y AICc, los resultados de los mismos fueron proyectados a lo largo de la distribución histórica de *C. chinchilla* para identificar localidades con hábitat potencialmente adecuado. Un conjunto de los mejores modelos destacaron hábitat adecuado en Argentina, Bolivia, Chile y Perú, con valores de probabilidad de hasta 0.72. En conjunto, estos resultados demuestran que todavía existen hábitats idóneos en todo el rango histórico de la especie, proporcionan información sobre su nicho climático, y resaltan áreas en los cuatro países para las cuales valdría la pena organizar búsquedas de poblaciones silvestres en el futuro.

**Palabras clave:** Andes. Modelo de nicho ecológico. Maxent. Chinchilla de cola corta. Sur América.

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STUHLER, J., D. ARENAS-VIVEROS & J. SALAZAR-BRAVO, 2020. Updated habitat suitability estimates and conservation implications for the short-tailed chinchilla *Chinchilla chinchilla* (Lichtenstein, 1830) (Rodentia: Chinchillidae). **Boletim do Museu Paraense Emílio Goeldi. Ciências Naturais** 15(3): 557-572. DOI: http://doi.org/10.46357/bcnaturais.v15i3.273.

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Recebido em 08/02/2020
Aprovado em 14/11/2020
Responsabilidade editorial: Alexandra Maria Ramos Bezerra

## INTRODUCTION

Natural ecosystems are experiencing human-induced changes of significant magnitude over an unprecedently short timescale (Pimm *et al.*, 2014; Diaz *et al.*, 2019). These effects are being felt across the globe and are thought to be responsible for major changes to human welfare, ecosystem services, and wildlife populations (Hooper *et al.*, 2012; Faurby & Svenning, 2015; Rapacciuolo *et al.*, 2017). The most pernicious effects are those that have resulted in local extirpation or which have brought populations to the brink of extinction, as in the case of the short-tailed chinchilla *Chinchilla chinchilla* (Lichtenstein, 1830).

The short-tailed chinchilla is one of the most emblematic rodents native to the Andes. Overexploitation of wild chinchilla populations for their valuable pelts in the 19th and early 20th century was responsible for the species' population decline across its former range. Consequently, the short-tailed chinchilla was classified as Endangered by the International Union for Conservation of Nature (IUCN) (Roach & Kennerley, 2016), in Appendix I of the Convention on International Trade in Endangered Species (CITES), and as threatened or critically endangered in Peru, Bolivia, and Argentina (Valladares *et al.*, 2014a, 2018). Because of uncertainties about its historical distribution, the extent and stability of the full range of this species is currently unclear. Historically, the species was known from the coast and Andes of central Peru south through the highlands of west-central Bolivia (Anderson, S., 1997), northern Chile (Spotorno *et al.*, 2004), and adjacent northwestern Argentina (Osgood, 1943; Barquez *et al.*, 2006).

Chilean populations, thought to be extinct due to overexploitation by 1953 (Jiménez, 1996), were rediscovered in the highlands of northern Chile above 3,400 m (Spotorno *et al.*, 1998, 2004; Tirado *et al.*, 2012). In Peru, before most populations were exterminated by overexploitation, short-tailed chinchillas were reported as abundant, ranging from the coast near Lima to elevations over 3,300 m (Osgood, 1943 quoting from von Tschudi, 1845); similar observations about Bolivian populations in La Paz, Oruro, and Potosí departments were reported by Walle (1914). This author noted, however, that "the extinction of the species will only be a matter of time if measures are not taken to preserve it" (Walle, 1914, p. 371). Bolivian populations were thought to be extinct (Anderson, S., 1997; Salazar-Bravo *et al.*, 2002), but have since been rediscovered in the highlands of Potosí Department (Delgado *et al.*, 2018a, 2018b).

The conservation of endangered species requires accurate information about their distributions, so that conservation practitioners and decision-makers can best identify and safeguard habitats based on recognized priorities (Guisan *et al*., 2013; Sánchez-Mercado *et al*., 2014). Surveys for rare and threatened species are essential for monitoring populations and supporting conservation outcomes (Guisan *et al.*, 2006). However, knowing where to direct survey effort is often hampered by a paucity of data regarding species' distributions, biology, and ecology (Thompson, 2013). Ecological niche models (ENMs) provide an approach to mapping potentially suitable habitat to guide field surveys (Pearson *et al.*, 2007; Aizpurua *et al*., 2015) and have been used in this manner for a variety of taxa, including mammals (Anderson, R. & Martinez-Meyer, 2004; Gerstner *et al.*, 2018). The application of ENMs is appealing because it is efficient (*e.g.*, relative to random sampling; Guisan *et al.*, 2006), and research has demonstrated that the detection of rare species is greatly improved when surveys are guided by ENMs (*e.g.*, Raxworthy *et al*., 2003; Bourg *et al.*, 2005). ENMs employ quantitative methods that allow inferring ecological requirements of a species based on the conditions of areas where its presence is known, and then calculating the probability of habitat suitability in other areas (Wisz *et al*., 2008; Peterson *et al*., 2011). Thus, it is not surprising that in recent decades, ENMs have become a fundamental tool in ecology, conservation and natural resource management (Guillera-Arroita *et al*., 2015).

In the context of the short-tailed chinchilla, the only attempt at using ENMs to guide field work of conservation importance was presented by Copa Alvaro *et al.* (2014). These investigators developed an ENM of suitable areas for the potential presence of the species in Bolivia, based on anecdotal trapping records in the counry (provided by local interviewees), verified records of the presence of the species in Chile, and museum records from Argentina and Bolivia. The potential suitability map produced by these authors was fairly effective. In fact, independently from their work, our team verified the presence of wild populations of the species in a locality that their model identified with the second-highest suitability level (*i.e.*, between 52.4-66.8 percent; Delgado *et al.*, 2018b). Since the publication of Copa Alvaro *et al.* (2014), new information has emerged about the presence of the short-tailed chinchilla in Bolivia. For example, at least one wild population is now known to be present in the southern portion of the country and a critical review of historical and museum records of Bolivian origin demonstrated that the veracity of a locality used by Copa Alvaro *et al.* (2014) could not be confirmed (Delgado *et al.*, 2018b). In light of these changes in knowledge of the distribution of the short-tailed chinchilla in Bolivia, and in order to provide an updated map of habitat suitability for the species in Bolivia and neighboring countries, we developed a new model that includes the new records, removes those of dubious origin, and was constructed attending to best-practice standards and ecological principles that are known to affect the performance of these types of models (Barve *et al.*, 2011; Boria *et al.*, 2014; Cobos *et al.*, 2019; Araújo *et al.*, 2019).

## MATERIALS AND METHODS

### OCCURRENCE RECORDS

The localities used in this study are distributed across three countries in the region: Argentina, Bolivia, and Chile between -19° and -27° latitude. All locations are located on the western side of the Andes at altitudes between 3,500 and 5,000m (Table 1). We obtained the Argentinean localities from the Global Biodiversity Information Facility (GBIF) (Teta & Rodríguez, 2020) and the works of Ortiz *et al.* (2010), near the Socompa volcano, and Walker *et al.* (2007) in the northern region of Catamarca province. The Chilean localities come from environmental impact studies conducted by Salares de Atacama SCM (2011) and Minera Gold Fields Salares Norte Ltda. (2013), as well as records published by Lagos *et al.* (2012) and Valladares *et al.* (2012, 2014b). The location reported by Tirado *et al.* (2012) was not included because a specific coordinate could not be obtained. Bolivian occurrences were obtained from the map published by Copa Alvaro *et al.* (2014), as well as the record published by Delgado *et al.* (2018a), and from a skull found by Nuria Bernal (personal communication) in or near the Eduardo Avaroa Reserve. Based on discussion of the reported locations of *C. chinchilla* in Bolivia by Delgado *et al.* (2018b), we did not include the Cochabamba location associated with a specimen in the Museum of Vertebrate Zoology [MVZ M-97361] due to questions concerning the accuracy of its locality data. Similarly, we omitted a Peruvian locality from the Royal Ontario Museum [ROM 91301] because of uncertainty over the location and source of the record (Spotorno & Patton, 2015). Thus, we ultimately compiled 24 total localities for consideration in the modelling process.

However, sampling bias that produces geographic clusters of localities can artificially increase spatial autocorrelation of localities used in ENMs, potentially leading to model overfitting and inflated values of performance used for model evaluation (Veloz, 2009; Hijmans, 2012). Spatial filtering of occurrence data (*i.e.*, removing spatial clusters of occurrence records in a way that retains the greatest amount of information) can therefore improve predictions of ENMs by reducing overfitting and improving model performance (Anderson, R. & Raza, 2010; Boria *et al.*, 2014). Thus, we spatially filtered our data using SDMtoolbox version 2.2 (Brown *et al*., 2017) in ArcMap 10.6.1. Given environmental heterogeneity and likely degree of sampling bias in the region, we chose a thinning distance of 10 km, which has previously been used for Andean mammals (Gerstner *et al.*, 2018). Spatial filtering ultimately reduced the overall occurrence data set from the 24 described above to 19 localities (*i.e.*, two in Argentina, nine in Bolivia, and eight in Chile; Table 1), which we ultimately used in our modeling efforts.

Table 1. Occurrences records of *Chinchilla chinchilla* considered for modeling efforts.

| Record | Country | Department/ Province | Elevation | Reference | Used |
|---|---|---|---|---|---|
| 1 | Argentina | Salta | 3974 | Teta & Rodríguez (2020) | No |
| 2 | Argentina | Salta | 3946 | Ortiz *et al.* (2010) | Yes |
| 3 | Argentina | Catamarca | 4091 | Walker *et al.* (2007) | Yes |
| 4 | Bolivia | Potosí | 4400 | Copa Alvaro *et al.* (2014) | Yes |
| 5 | Bolivia | Potosí | 4268 | Copa Alvaro *et al.* (2014) | Yes |
| 6 | Bolivia | Potosí | 4531 | Copa Alvaro *et al.* (2014) | Yes |
| 7 | Bolivia | Oruro | 4484 | Copa Alvaro *et al.* (2014) | Yes |
| 8 | Bolivia | Oruro | 4048 | Copa Alvaro *et al.* (2014) | Yes |
| 9 | Bolivia | Oruro | 4531 | Copa Alvaro *et al.* (2014) | Yes |
| 10 | Bolivia | Oruro | 4825 | Copa Alvaro *et al.* (2014) | Yes |
| 11 | Bolivia | Potosí | 4363 | Delgado *et al.* (2018a) | Yes |
| 12 | Bolivia | Potosí | 4497 | Nuria Bernal (personal communication) | Yes |
| 13 | Chile | Antofagasta | 4939 | Valladares *et al.* (2012) | Yes |
| 14 | Chile | Atacama | 4732 | Valladares *et al.* (2014b) | Yes |
| 15 | Chile | Atacama | 3783 | Valladares *et al.* (2014b) | Yes |
| 16 | Chile | Atacama | 4007 | Lagos *et al.* (2012) | Yes |
| 17 | Chile | Atacama | 3979 | Lagos *et al.* (2012) | Yes |
| 18 | Chile | Atacama | 4143 | Lagos *et al.* (2012) | No |
| 19 | Chile | Atacama | 4057 | Lagos *et al.* (2012) | No |
| 20 | Chile | Atacama | 4386 | Lagos *et al.* (2012) | Yes |
| 21 | Chile | Atacama | 3985 | Salares de Atacama SCM (2011) | Yes |
| 22 | Chile | Atacama | 4661 | Minera Gold Fields Salares Norte Ltda. (2013) | Yes |
| 23 | Chile | Atacama | 4566 | Minera Gold Fields Salares Norte Ltda. (2013) | No |
| 24 | Chile | Atacama | 4383 | Minera Gold Fields Salares Norte Ltda. (2013) | No |

Furthermore, the choice of study extent can have a significant effect on model output. Including areas with suitable environments that lack records (*e.g.*, due to dispersal limitations or biotic interactions) can cause a model's algorithm to recognize spurious environmental differences and indicate these regions as unsuitable (Anderson, R. & Raza, 2010; Barve *et al.*, 2011). Thus, we defined a species-specific study region by creating circular buffers of 1° around each occurrence and merging each buffer into a single polygon. The resulting area was then used to define the region used for building candidate models.

## ENVIRONMENTAL DATA

We considered 15 climatic variables from WorldClim (Fick & Hijmans, 2017) in our analyses at a resolution of ~1 $km^2$, excluding the four layers that combine precipitation and temperature into the same layer, due to spatial anomalies (Escobar *et al.*, 2014). We also considered land cover data for 2015 from the Climate Change Initiative Global Land Cover database (ESA, 2017). All environmental layers had the same extent and resolution. To reduce redundancy among environmental variables, we used correlation analyses on the 15 climatic variables for the study region by identifying variable pairs with correlations of r ≥ 0.8 and retaining the variable that we considered more biologically relevant for the species (Appendix 1). Ultimately, we included annual mean temperature (BIO1), isothermality (BIO3), temperature seasonality (BIO4), temperature annual range (BIO7), annual precipitation (BIO12), precipitation of driest month (BIO14), precipitation seasonality (BIO15) and land cover.

## MODEL BUILDING

We modeled the potential distribution of *C. chinchilla* using Maxent, a presence-background model that uses a maximum entropy approach to estimate the most uniform distribution of a species' occurrence across the study area, minimally constrained by the provided environmental data (Phillips *et al.*, 2006). Importantly, Elith *et al*. (2011) showed that Maxent performs well with sparse datasets (*e.g.*, rare species). We randomly sampled 10,000 background localities from the study area.

Estimating optimal levels of model complexity is a challenging but necessary enterprise to generate realistic geographic predictions, especially for rare species (Galante *et al*., 2018; Gerstner *et al.*, 2018). Thus, we generated a suite of candidate models with different levels of complexity by varying two key parameters in Maxent: feature classes (FCs) and regularization multiplier (RM) (Phillips & Dudík, 2008; Elith *et al*., 2011; Anderson, R. & Gonzalez, 2011; Warren & Seifert, 2011). The FCs available in Maxent control the flexibility of the modeled response to each predictor variable, whereas the regularization multiplier determines the degree to which model complexity (*i.e.*, number of parameters) is penalized. We built a suite of 64 candidate models of varying complexity. Specifically, we considered linear (l), quadratic (q), product (p), and hinge (h) feature classes (l, h, q, lh, lq, lp, qp, lqp) and a range of regularization multipliers from 0.5-4.0 in 0.5 increments.

## MODEL SELECTION

We assessed performance across the candidate models by using the common approach of randomly dividing the data into training and test sets, thus creating a semi-independent dataset for model evaluation (Guisan & Thuiller, 2005). We used 80% of the points to build the model and the remaining 20% for model validation. Model selection was based on recent advances in niche modeling and followed guidelines provided by Cobos *et al.* (2019). Specifically, we first removed non-significant candidate models based on partial ROC tests (Peterson *et al*., 2008), with 500 iterations and 50% of data for bootstrapping. We then filtered by omission rates (*E* = 5%; Anderson, R. *et al*., 2003) and model complexity (AICc; Warren & Seifert, 2011). Thus, best models were identified as those within 2 AICc units of the minimum from the significant, low-omission candidate models.

Following model selection, we created final models using the full set of occurrences and the selected parameterizations. We produced 10 replicates by bootstrap, with logistic outputs, and then transferred the final models to a larger study region bounded between -10.5° and -32.5° latitude (Figure 1), based on the historical distribution of the species (Valladares *et al*., 2018), in order to identify areas in the greater region worth surveying for the species (Raxworthy *et al*., 2003; Pearson *et al.*, 2007). We used the mobility-oriented parity and metric (MOP; Owens *et al*., 2013) to assess areas where strict extrapolation (*i.e.*, transfer areas with values outside the range of climates in the calibration area) occurs. All model building, selection, and extrapolation steps were performed in the kuenm package in R (Cobos *et al.*, 2019).

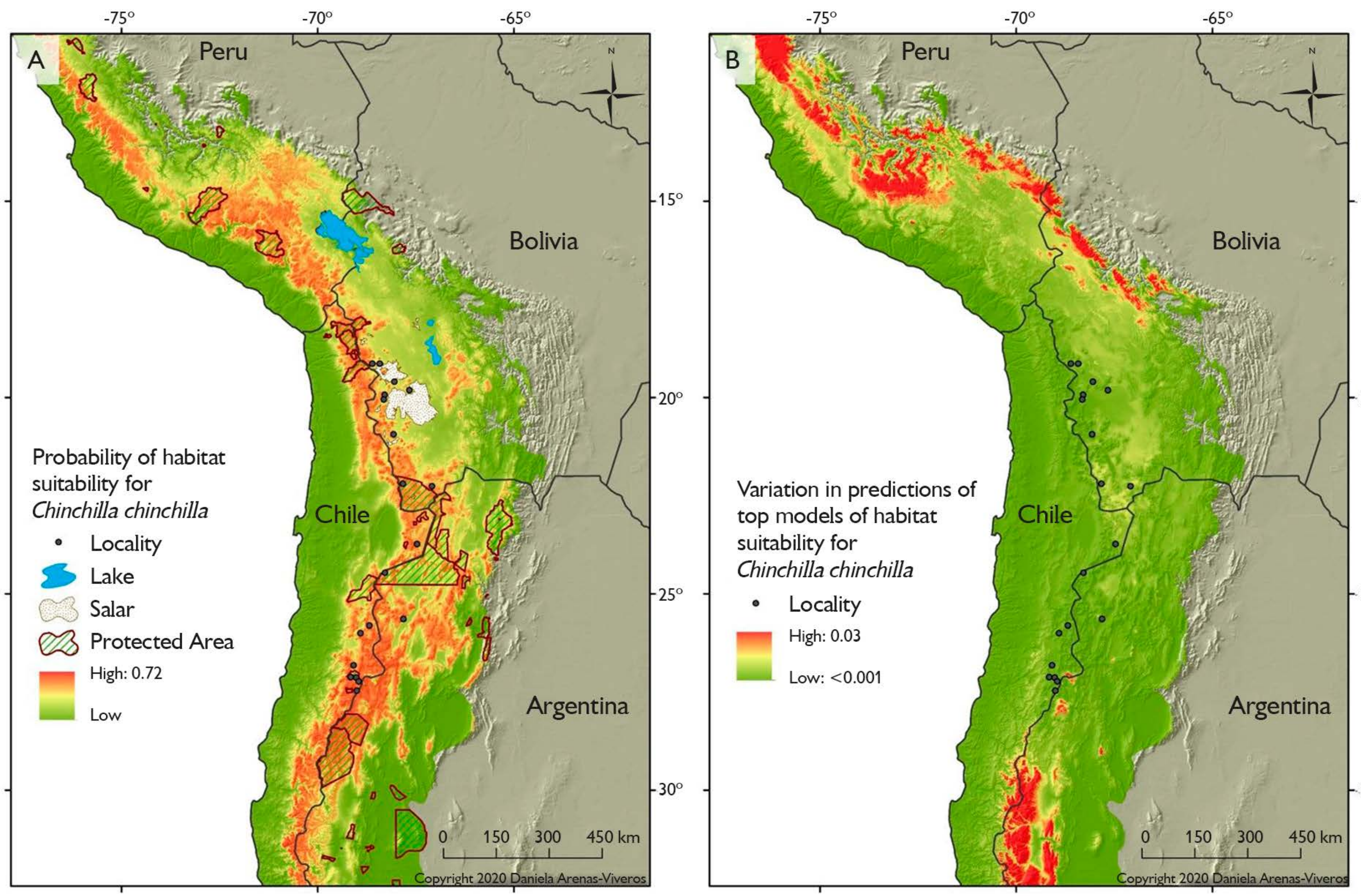

Figure 1. A) Geographical prediction of suitable habitat across the historical distribution of *C. chinchilla* based on the top models. Warmer colors (*e.g.*, red) represent areas with higher probability of habitat suitability, whereas cooler colors (*e.g.*, green) represent areas with lower probability; B) variation in habitat suitability predictions among the top models.

## RESULTS

Model building in kuenm (Cobos *et al.*, 2019) resulted in 64 candidate models with different feature class and regularization multiplier combinations. Out of the 64 candidate models, 12 models satisfied all criteria (i.e., statistically significant and met the omission rate and AICc criteria; Table 2). Because we had multiple top models that satisfied all criteria, we used the average of all replicates across parameters to consolidate results for the species (Figure 1).

Table 2. Summary of the 64 models considered during the model building process. Following evaluation based on significance (*i.e.*, partial ROC), omission rate, and AICc criteria, 12 final models, in bold, were used for interpretation of habitat suitability across the historical range of the species. 'RM' refers to the regularization multiplier used, whereas 'FC' refers to the feature class (h: hinge, l: linear, p: product, q: quadratic).

(Continue)

| RM | FC | Partial ROC | Omission rate | AICc | Delta AICc | Weight AICc | Number of parameters |
|---|---|---|---|---|---|---|---|
| **2.0** | **qp** | **0** | **0** | **474.39** | **0.00** | **0.73** | **3** |
| **2.0** | **lqp** | **0** | **0** | **474.39** | **0.00** | **0.43** | **3** |
| **3.5** | **lq** | **0** | **0** | **474.42** | **0.03** | **0.17** | **3** |
| **3.5** | **q** | **0** | **0** | **474.42** | **0.03** | **0.15** | **3** |
| **2.5** | **qp** | **0** | **0** | **474.61** | **0.22** | **0.28** | **2** |
| **2.5** | **lqp** | **0** | **0** | **474.61** | **0.22** | **0.22** | **2** |
| **3.5** | **qp** | **0** | **0** | **474.94** | **0.55** | **0.10** | **1** |
| **3.5** | **lqp** | **0** | **0** | **474.94** | **0.55** | **0.09** | **1** |
| **4.0** | **qp** | **0** | **0** | **475.53** | **1.14** | **0.06** | **1** |
| **4.0** | **lqp** | **0** | **0** | **475.53** | **1.14** | **0.06** | **1** |
| **4.0** | **lq** | **0** | **0** | **476.16** | **1.77** | **0.05** | **3** |
| **4.0** | **q** | **0** | **0** | **476.16** | **1.77** | **0.05** | **3** |
| 3.0 | qp | 0 | 0 | 476.49 | 8.69 | 0.00 | 2 |
| 3.0 | lqp | 0 | 0 | 476.49 | 8.69 | 0.00 | 2 |
| 3.5 | l | 0 | 0 | 480.52 | 12.72 | 0.00 | 1 |
| 4.0 | l | 0 | 0 | 480.89 | 13.10 | 0.00 | 1 |
| 4.0 | h | 0 | 0 | 481.25 | 13.45 | 0.00 | 3 |
| 2.5 | l | 0 | 0 | 481.55 | 13.75 | 0.00 | 2 |
| 2.5 | lp | 0 | 0 | 481.77 | 13.97 | 0.00 | 2 |
| 3.0 | lp | 0 | 0 | 482.23 | 14.44 | 0.00 | 2 |
| 3.0 | l | 0 | 0 | 482.54 | 14.74 | 0.00 | 2 |
| 3.5 | lp | 0 | 0 | 482.79 | 14.99 | 0.00 | 2 |
| 2.0 | l | 0 | 0 | 483.25 | 15.45 | 0.00 | 3 |
| 4.0 | lp | 0 | 0 | 483.44 | 15.64 | 0.00 | 2 |
| 2.0 | lp | 0 | 0 | 484.15 | 16.35 | 0.00 | 3 |
| 4.0 | lh | 0 | 0 | 486.11 | 18.31 | 0.00 | 4 |
| 1.5 | lp | 0 | 0 | 486.14 | 18.34 | 0.00 | 4 |
| 1.5 | q | 0 | 0.25 | 467.80 | 0.00 | 0.02 | 3 |

Table 2. (Conclusion)

| RM | FC | Partial ROC | Omission rate | AICc | Delta AICc | Weight AICc | Number of parameters |
|---|---|---|---|---|---|---|---|
| 1.0 | qp | 0 | 0.25 | 468.42 | 0.62 | 0.02 | 3 |
| 1.0 | lqp | 0 | 0.25 | 468.42 | 0.62 | 0.02 | 3 |
| 2.0 | lq | 0 | 0.25 | 469.22 | 1.42 | 0.01 | 3 |
| 2.0 | q | 0 | 0.25 | 469.22 | 1.42 | 0.01 | 3 |
| 2.5 | lq | 0 | 0.25 | 470.84 | 3.04 | 0.01 | 3 |
| 2.5 | q | 0 | 0.25 | 470.84 | 3.04 | 0.01 | 3 |
| 1.5 | lq | 0 | 0.25 | 471.05 | 3.25 | 0.00 | 4 |
| 1.5 | qp | 0 | 0.25 | 471.20 | 3.40 | 0.00 | 3 |
| 1.5 | lqp | 0 | 0.25 | 471.20 | 3.40 | 0.00 | 3 |
| 3.0 | lq | 0 | 0.25 | 472.59 | 4.80 | 0.00 | 3 |
| 3.0 | q | 0 | 0.25 | 472.59 | 4.80 | 0.00 | 3 |
| 1.0 | q | 0 | 0.25 | 473.50 | 5.70 | 0.00 | 5 |
| 2.5 | h | 0 | 0.25 | 473.92 | 6.12 | 0.00 | 4 |
| 2.5 | lh | 0 | 0.25 | 473.92 | 6.12 | 0.00 | 4 |
| 3.0 | h | 0 | 0.25 | 474.60 | 6.80 | 0.00 | 3 |
| 3.0 | lh | 0 | 0.25 | 474.85 | 7.05 | 0.00 | 3 |
| 1.0 | lq | 0 | 0.25 | 475.84 | 8.04 | 0.00 | 6 |
| 3.5 | h | 0 | 0.25 | 477.82 | 10.02 | 0.00 | 3 |
| 0.5 | lq | 0 | 0.25 | 480.63 | 12.83 | 0.00 | 8 |
| 1.0 | l | 0 | 0.25 | 481.87 | 14.07 | 0.00 | 4 |
| 3.5 | lh | 0 | 0.25 | 481.99 | 14.19 | 0.00 | 4 |
| 1.5 | l | 0 | 0.25 | 484.33 | 16.54 | 0.00 | 4 |
| 0.5 | l | 0 | 0.25 | 487.38 | 19.58 | 0.00 | 7 |
| 2.0 | h | 0 | 0.25 | 488.33 | 20.53 | 0.00 | 8 |
| 2.0 | lh | 0 | 0.25 | 488.33 | 20.53 | 0.00 | 8 |
| 1.0 | lp | 0 | 0.25 | 491.30 | 23.50 | 0.00 | 6 |
| 0.5 | lp | 0 | 0.25 | 509.16 | 41.36 | 0.00 | 10 |
| 1.0 | h | 0 | 0.25 | NA | NA | NA | 22 |
| 1.0 | lh | 0 | 0.25 | NA | NA | NA | 20 |
| 1.5 | h | 0 | 0.25 | NA | NA | NA | 22 |
| 1.5 | lh | 0 | 0.25 | NA | NA | NA | 23 |
| 0.5 | q | 0 | 0.5 | 476.31 | 8.51 | 0.00 | 7 |
| 0.5 | lqp | 0 | 0.5 | 483.63 | 15.83 | 0.00 | 8 |
| 0.5 | qp | 0 | 0.5 | 484.11 | 16.31 | 0.00 | 8 |
| 0.5 | h | 0 | 0.5 | NA | NA | NA | 49 |
| 0.5 | lh | 0 | 0.5 | NA | NA | NA | 50 |

The ensemble of top models shows suitable habitat in all four countries from the historical range of *C. chinchilla* (*i.e.*, Argentina, Bolivia, Chile, and Peru; Figure 1A), with a probability of suitable habitat up to 0.72. Medium to high suitable habitat was constrained to areas above 3,000 m along the Andes, with areas as high as 5,000 m in Chile and Argentina considered suitable by our analyses (with the exception of the Altiplano region above 3,800 m). Importantly, there was generally low variation among model predictions, except for areas in the northern and southern portions of the study region (Figure 1B), which were both outside of the calibration area. Annual mean temperature (BIO1) consistently had the highest percent contribution and permutation importance across replicates of all top models. Furthermore, the ensemble indicated relatively high probability of suitable habitat across a number of protected areas within Chile, Bolivia, and Argentina (Figure 2).

## DISCUSSION

Identifying potential distributions and areas of suitable habitat is essential for conservation and management planning for endangered species (Hoffman *et al.*, 2008). Ecological niche models can be useful for predicting the probability of habitat suitability across a region of interest (Peterson *et al*., 2011). This can, in turn, inform decisions about future biological surveys (Raxworthy *et al*., 2003) or highlight areas that may yield successful reintroductions (D'Elía *et al.*, 2015), albeit after considering a number of other important ecological factors. The short-tailed chinchilla was considered extinct in Bolivia until Delgado *et al.* (2018a) reported the existence of a population in areas neighboring the Laguna Colorada. Adding this record and the one reported by N. Bernal (personal communication), we developed a new estimate of the potential distribution of *C. chinchilla* that expands upon the work of Copa Alvaro *et al.* (2014) in Bolivia and provides estimates of suitable habitat across the historical range of *C. chinchilla*. Below, we discuss the implications of our findings.

### GEOGRAPHIC DISTRIBUTION OF SUITABLE HABITAT

Our suite of models identified a number of areas of apparently suitable habitat. First, the area with the most extensive amount of predicted suitable habitat occurred along the Argentina-Chile border between -25° and -32° latitude (Figure 1A), although the area below -30° latitude was somewhat variable among models (Figure 1B). Moving north, areas of suitable habitat appear to follow the western range of the Andes into Peru. These results indicate several areas to prioritize for conducting new surveys for the species. For example, there were a number of areas in central Argentina (*e.g.*, Serrania de San Luis and Serrania de Cordoba) and southern Peru that had suitability values similar to that of areas where our group verified presence of wild chinchilla populations in Bolivia, suggesting that these areas should be high priority for future survey efforts. Furthermore, although *C. chinchilla* is believed to be extirpated from Peru (Pacheco, 2002), our model also highlighted areas of potentially suitable habitat in southern and western Peru. While we ultimately excluded a GBIF record from Peru (see Methods), we note that our model highlights Cerro de Pasco, which suggests that the record may be representative of a wild population.

The estimates from our modeling efforts may also signal important aspects of the ecology of the short-tailed chinchilla. In particular, we found that annual mean temperature (BIO1) was the most important predictor variable, even though we considered a number of temperature and precipitation variables that represented both average climatic conditions (*e.g.*, BIO1 and BIO12) as well as climatic variability (*e.g.*, BIO4 and BIO15). From a geographical perspective, we found that many high elevation areas, such as mountain peaks, were frequently predicted to be areas of suitable habitat. Together, this suggests a strong influence of average temperature, particularly over any measure of precipitation, on distribution patterns of this species. This is important given the susceptibility of montane mammals to climate change (Rubidge *et al*., 2012;

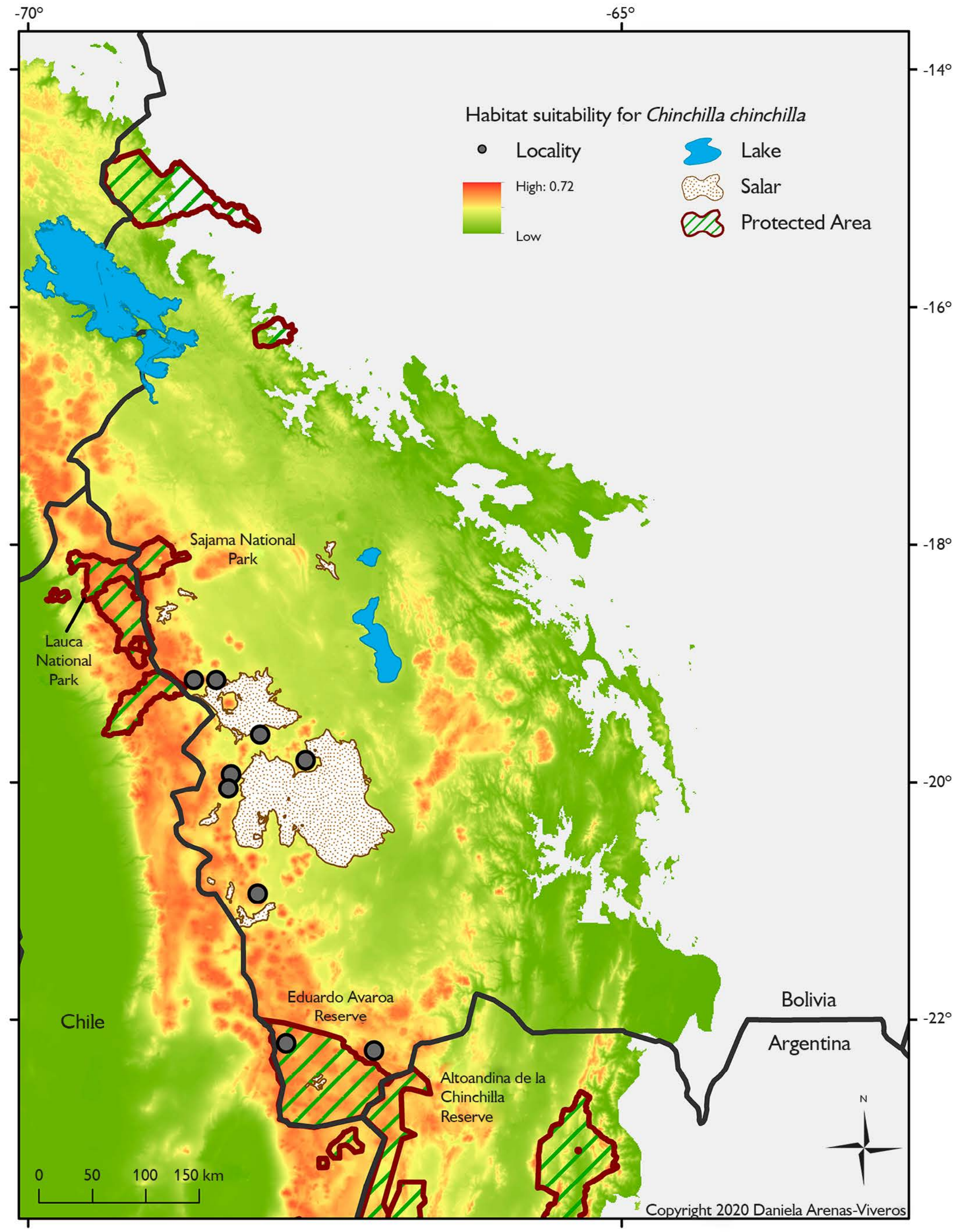

Figure 2. Habitat suitability predictions for *C. chinchilla* in Bolivia. Protected areas, including the Eduardo Avaroa Reserve (bottom left) are indicated with maroon outlines and green hashes.

McCain, 2019), and further demonstrates that climate change likely constitutes an added threat to this species as temperatures continue to increase. This suggests that the species could ultimately run out of suitable habitat over time if it is indeed tracking temperature changes by moving upslope. This discovery, in combination with the impact that overexploitation has had on wild populations, highlights the urgency for developing conservation and/or management plans for the short-tailed chinchilla.

## COMPARISONS TO PRIOR DISTRIBUTIONAL ESTIMATES

There are a number of important discussion points concerning the results of our range-wide estimate compared to the estimate of suitable habitat in Bolivia by Copa Alvaro *et al.* (2014), which represents the most recent distributional estimate of any kind for this species. When comparing the potential distributions in Bolivia from the two models, there are important similarities and differences. One important difference is the lack, in our model, of highly suitable areas in the eastern cordillera in the departments of La Paz and Cochabamba (Figure 2). This difference is undoubtedly due to the decision to exclude a record from Cochabamba associated with a specimen in the Museum of Vertebrate Zoology; this supposed record represented the only locality for the species in the Puna Mesophytic province (figure 1 in Copa Alvaro *et al*., 2014). That our model ensemble did not identify suitable habitat in this region provides further support that this record may be faulty. However, we did find high levels of agreement between the two studies in terms of suitable habitat within the Eduardo Avaroa Reserve (EAR) in southern Bolivia (Figure 2), which is not surprising given the two new records from this region following the publication of Copa Alvaro *et al.* (2014). Moreover, the high degree of agreement between the two studies with regard to suitable habitat in the EAR further demonstrates the need to conduct surveys for the species in this reserve, and also points to this reserve as a potentially important area from which to launch conservation initiatives for the species. Similarly, Sajama National Park, located in the Oruro department, is indicated as an area of suitable habitat for the species in Bolivia.

## CONSERVATION OF WILD CHINCHILLA POPULATIONS

Given the conservation status of *C. chinchilla* and its history of being overharvested, protected areas across the region may represent important locations for future conservation efforts geared towards the species. Importantly, a series of protected areas are distributed across the historical distribution of this species, and many of them overlap with predicted areas of high suitability. Reserves along the Argentina-Chile border coincide with some of the largest expanses of predicted suitable habitat in our models. In addition, protected areas along country borders represent a unique opportunity for joint conservation initiatives. For example, Sajama National Park in Bolivia borders protected areas in Chile (*e.g*., Lauca National Park), and the EAR shares a boundary with the *Reserva Provincial Alto Andina de la Chinchilla* in the Jujuy department in Argentina (Figure 2). These protected areas should be surveyed to confirm the species' presence and assess the status of any extant populations.

In 2014, Valladares and collaborators lamented that at the time of publication there was an almost complete lack of basic information on the biology of *C. chinchilla*. Unfortunately, this situation has changed very little in the intervening years. With the confirmation of the presence of wild populations in Bolivia and Chile, and the interest of several groups of dedicated biologists, this knowledge gap should start to close, at least with respect to these populations. As the second decade of the new millennium starts, it becomes imperative to agree upon a conservation and management plan for a species that is endangered, not only because of the isolation of its potential habitats, but also because of the low genetic diversity found in its populations (Spotorno *et al.*, 2004).

Our results highlight the need to conduct systematic sampling and to search for remaining populations in the historical distribution of *C. chinchilla*. While this work represents an updated, operational estimate of suitable habitat, more information is needed to effectively conserve habitat for this species. Additional records of this species will have multiple benefits, one of which will be to help improve the models analyzed herein and thus improve our capacity to predict areas where additional populations of *C. chinchilla* can be found. In that regard, we want to highlight the potential for citizen science to achieve new records across the region. For example, Gerstner *et al*. (2018) benefited immensely from nine additional records provided by citizens (i.e., an increase of 60% of the records used in the model) to update distributional estimates for the olinguito *Bassaricyon neblina* Helgen, Pinto, Kays, Hekgen, Tsuchiya, Quinn, Wilson & Maldonado, 2013. We believe that this is a route worth exploring with citizens and researchers across the four South American countries from which this species has been documented.

## CONCLUSION

The present contribution represents updated habitat suitability estimates for the short-tailed chinchilla (*C. chinchilla*) across its historical range by including new records of the species from Bolivia. This new prediction presents areas of relatively high probability of habitat suitability in all four countries from the historical geographic range. The need for systematic sampling in areas with the potential for high habitat suitability in both historical and contemporary areas of the species' distribution is highlighted, as well as the potential for citizen science as a tool to uncover additional localities that will permit the construction of updated models that are better informed for estimating the potential distribution of this species.

## ACKNOWLEDGEMENTS

We extend our sincere thanks to the following individuals and institutions: *Servicio Nacional de Areas Protegidas* (SERNAP) for their unconditional support and interest in this work. To N. Bernal, for sharing information on an unpublished record of the species in the Laguna Colorada region (skull to be deposited in the Colección Boliviana de Fauna) and for her comments on a previous version of this manuscript. To W.T. Bean (California Polytechnic State University, San Luis Obispo) for helpful dialogue on modeling decisions and M. Cobos (University of Kansas) for assistance working with the kuenm package in R. To E. Delgado (SERNAP) and O. Rocha (BIOTA Bolivia) for their efforts on the conservation of the wildlife of southern Potosi Department in Bolivia. To L. Pacheco (Institute of Ecology, *Universidad Mayor de San Andrés*) for his comments on a previous version of this contribution. Finally, we thank two anonymous reviewers for comments that improved the overall quality of the manuscript.

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Appendix 1. Correlation matrix of candidate climate variables across the study region. Final variables were selected by retaining the variable that we considered more biologically relevant for the species among variable pairs with correlations ≥ 0.8. Selected climate variables for consideration during the modeling process included annual mean temperature (BIO1), isothermality (BIO3), temperature seasonality (BIO4), temperature annual range (BIO7), annual precipitation (BIO12), precipitation of driest month (BIO14), and precipitation seasonality (BIO15).

| Variables | BIO1 | BIO2 | BIO3 | BIO4 | BIO5 | BIO6 | BIO7 | BIO10 | BIO11 | BIO12 | BIO13 | BIO14 | BIO15 | BIO16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BIO1 | - | | | | | | | | | | | | | |
| BIO2 | -0.444 | - | | | | | | | | | | | | |
| BIO3 | -0.443 | 0.704 | - | | | | | | | | | | | |
| BIO4 | -0.008 | 0.324 | -0.387 | - | | | | | | | | | | |
| BIO5 | 0.868 | 0.038 | -0.217 | 0.282 | - | | | | | | | | | |
| BIO6 | 0.901 | -0.758 | -0.515 | -0.296 | 0.571 | - | | | | | | | | |
| BIO7 | -0.342 | 0.944 | 0.434 | 0.596 | 0.166 | -0.714 | - | | | | | | | |
| BIO10 | 0.995 | -0.434 | -0.496 | 0.080 | 0.881 | 0.880 | -0.306 | - | | | | | | |
| BIO11 | 0.982 | -0.509 | -0.376 | -0.195 | 0.793 | 0.945 | -0.459 | 0.962 | - | | | | | |
| BIO12 | -0.292 | 0.325 | 0.055 | 0.303 | -0.120 | -0.406 | 0.385 | -0.284 | -0.344 | - | | | | |
| BIO13 | -0.209 | 0.378 | 0.111 | 0.320 | -0.013 | -0.366 | 0.429 | -0.206 | -0.272 | 0.950 | - | | | |
| BIO14 | -0.428 | -0.168 | -0.058 | -0.227 | -0.542 | -0.220 | -0.198 | -0.428 | -0.359 | 0.267 | 0.060 | - | | |
| BIO15 | -0.020 | 0.435 | 0.068 | 0.549 | 0.232 | -0.273 | 0.526 | 0.006 | -0.138 | 0.289 | 0.511 | -0.486 | - | |
| BIO16 | -0.216 | 0.392 | 0.109 | 0.343 | -0.012 | -0.381 | 0.447 | -0.211 | -0.283 | 0.959 | 0.994 | 0.056 | 0.499 | - |
| BIO17 | -0.505 | -0.142 | 0.005 | -0.251 | -0.618 | -0.281 | -0.189 | -0.507 | -0.432 | 0.223 | -0.004 | 0.917 | -0.573 | -0.009 |

Bol. Mus. Para. Emílio Goeldi. Cienc. Nat., Belém, v. 15, n. 3, p. 573-599, set.-dez. 2020

# Distribution of South American manatees, *Trichechus manatus* Linnaeus, 1758 and *T. inunguis* (Natterer, 1883) (Sirenia: Trichechidae)

# Distribuição dos peixes-boi sul-americanos, *Trichechus manatus* Linnaeus, 1758 e *T. inunguis* (Natterer, 1883) (Sirenia: Trichechidae)

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**Abstract:** South America is unique as it is home of two species of manatees: the West Indian manatee, *Trichechus manatus*, and the Amazonian manatee, *T. inunguis*. These species are easily identified by the belly skin coloration, the first is entirely gray whereas *T. inunguis* has a white mark pattern in the belly, and presence of nails in *T. manatus*, absent in *T. inunguis*. The morphology and the range of *Trichechus* species have been clearly established. However, we show that the belly skin coloration and the presence of nails on the pectoral flipper may be polymorphic. These findings prompted us to check all available information about the manatee. In view of lack of accurate data on manatee locations, we produced a gazetteer and a map of *Trichechus* spp. in South America using records obtained by regular monitoring of aquatic mammal strandings conducted by the *Grupo de Estudos de Mamíferos Aquáticos da Amazônia* of the *Museu Paraense Emílio Goeldi*, all available peer-reviewed data, reports, thesis, and newspaper files with photos showing diagnostic characters. These findings showed the need of improving the identification of these species before implementing conservation strategies. Finally, we present a complete report on the extant distribution of these species in South America.

**Keywords:** Amazonas river basin. Amazonian manatee. Aquatic mammals. Atlantic Ocean. Conservation. West Indian manatee.

**Resumo:** A América do Sul é única em registrar duas espécies de peixes-bois: o peixe-boi-marinho, *Trichechus manatus*, e o peixe-boi-da-amazônia, *T. inunguis*. Essas espécies podem ser distinguidas pela coloração ventral; totalmente cinza na primeira, enquanto *T. inunguis* tem um padrão de manchas brancas no ventre, e a presença de unhas nas nadadeiras peitorais, ausentes em *T. inunguis*. A morfologia e a distribuição das espécies de *Trichechus* são claramente estabelecidas. No entanto, mostramos aqui que a mancha do ventre e a presença de unhas na nadadeira peitoral podem ser polimórficas. Esses achados nos instigaram a verificar toda informação disponível a respeito dos registros de peixes-bois. Em vista da falta de dados precisos sobre a localização dos peixes-bois em publicações anteriores, produzimos um *gazetteer* e um mapa de *Trichechus* spp. na América do Sul, utilizamos registros originais coletados pelo Grupo de Estudos de Mamíferos Aquáticos da Amazônia (GEMAM) do Museu Paraense Emílio Goeldi, todos os dados revisados por pares, incluindo dissertações, teses e arquivos de jornais com fotos evidenciando caracteres diagnósticos. Finalmente, apresentamos um relato completo sobre a distribuição das espécies de peixes-bois na América do Sul e a necessidade de melhorar a identificação dessas espécies, para uma efetiva implementação de estratégias de conservação.

**Palavras-chave:** Bacia do rio Amazonas. Peixe-boi-da-Amazônia. Mamíferos aquáticos. Oceano Atlântico. Conservação. Peixe-boi-marinho.

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BONVICINO, C. R., M. C. VIANA, E. H. C. OLIVEIRA, R. EMIN-LIMA, J. S. SILVA JÚNIOR, M. E. M. SOUSA & S. SICILIANO, 2020. Distribution of South American manatees, *Trichechus manatus* Linnaeus, 1758 and *T. inunguis* (Natterer, 1883) (Sirenia: Trichechidae). **Boletim do Museu Paraense Emílio Goeldi. Ciências Naturais** 15(3): 573-599. DOI: http://doi.org/10.46357/bcnaturais.v15i3.246.

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Recebido em 20/12/2019
Aprovado em 03/12/2020
Responsabilidade editorial: Alexandra Maria Ramos Bezerra

## INTRODUCTION

South America is unique in hosting two trichechid species: the West Indian manatee, *Trichechus manatus* Linnaeus, 1758, and the Amazonian manatee, *T. inunguis* (Husar, 1977). These species have been easily identified by their belly coloration, the former being entirely gray and the latter with white pattern. Moreover, *T. manatus* has nails on the pectoral and a diploid number (2n) of 48 chromosomes (Gray *et al.*, 2002; Barros *et al.*, 2016), while *T. inunguis* has nailless pectoral and show 2n = 56 (Loughman *et al.*, 1970; Assis *et al.*, 1988).

Two subspecies have been proposed to the West Indian manatee: the Florida manatee, *T. m. latirostris* (Harlan, 1824), mostly restricted to the Florida peninsula (United States) and the Antillean manatee (*T. m. manatus*), distributed throughout the Caribbean, Central and South America (Hatt, 1934; Domning & Hayek, 1986; Garcia-Rodriguez *et al*., 1988; Vianna *et al*., 2006; Meirelles *et al*., 2018). The Florida and the Antillean subspecies are remarkably similar in external morphology but can be distinguished by morphometric analysis of cranial characters (Domning & Hayek, 1986). In recent decades, West Indian manatee populations have been affected by habitat degradation (O'Shea & Ackerman, 1995), exceptional cold weather (O'Shea *et al.*, 1985), red tide outbreaks (Buergelt *et al.*, 1984; O'Shea *et al.*, 1991), hunting and incidental catch (Thornback & Jenkins, 1982; Mignucci-Giannoni, 1990; Meirelles, 2008) and collisions with boats (O'Shea *et al.*, 1985). The manatee is a specialized feeder and reduction of seagrass beds due to coastal development poses a serious threat (Best, 1981; Reynolds, 1981).

*Trichechus inunguis* is distributed throughout the major rivers of the Amazon basin, although it is rare in the Tocantins, Xingu and Tapajós rivers in Brazil (Bertram & Bertram, 1973). Information on its distribution in eastern Pará state, including the large Marajó Island, is deficient, imprecise, and limited to a few historical records (*e.g.*, Edwards, 1847; Ferreira, 1903; Domning, 1981). Thousands of manatees have been hunted for centuries in Brazil (Domning, 1982) and, in some regions, they continue to be hunted at a local scale. Due to their murky water habitat added to the cryptic behavior of the species, accurate population estimates are difficult.

The International Union for Conservation of Nature and Natural Resources (IUCN) presently recognizes *T. manatus* and *T. inunguis* as vulnerable taxa (Marmontel *et al.*, 2016). At present, key accounts of the distribution of the Amazonian manatee fail to provide a clear picture of the precise range of these elusive species (*e.g*., Husar, 1977; Reeves *et al.*, 1992; Jefferson *et al.*, 1993; Emmons & Feer, 1997).

In this study we present (a) a gazetteer of published and unpublished records of *Trichechus* spp. in South America, including our own unpublished records, these findings prompted us to check all available information about the manatee; (b) a review of former and current records of manatees (*Trichechus* spp.) in South America, mainly along Marajó Island, on the eastern Amazon coast; (c) a discussion on the conservation status of these species on the Eastern Amazon coast.

## MATERIALS AND METHODS

### DATA SURVEY

In view of lack of accurate data on manatee locations in previous published records, we produced a gazetteer of *Trichechus* spp. in South America (Appendix 1, Figure 1). We used all available peer-reviewed data, theses and newspaper files with good photos showing diagnostic characters, for generating a map of manatee distribution in South America.

### SAMPLING COLLECTION

In order to investigate the presence of manatees in rivers in eastern Amazon and the Marajó Bay area, the *Grupo de Estudos de Mamíferos Aquáticos da Amazônia* (GEMAM) of the *Museu Paraense Emílio Goeldi* (MPEG), Belém, Pará state, Brazil, established a collaborative network of investigators and volunteers to search for stranded and live-rescued manatees in November 2005. A toll-free phone number

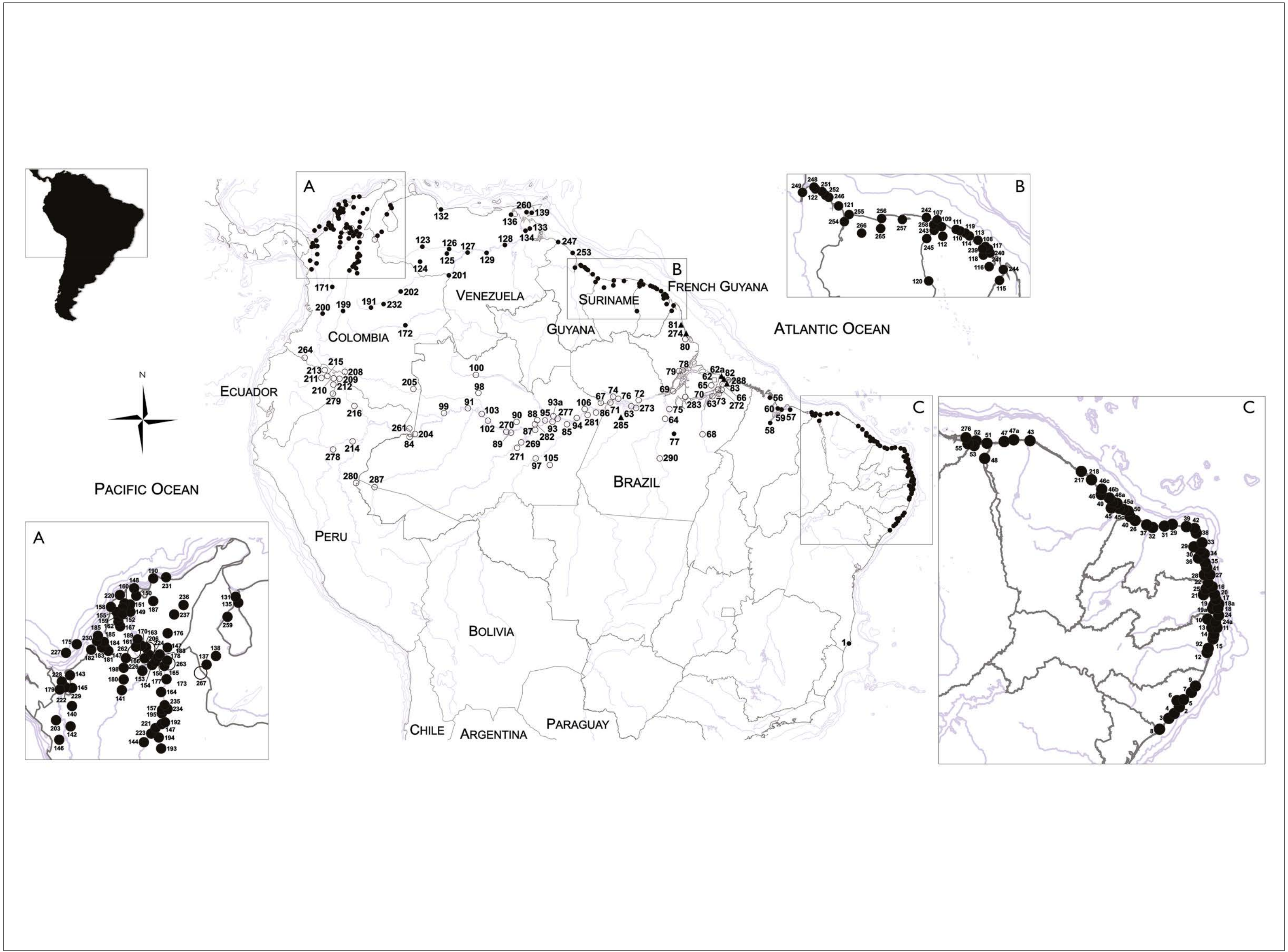

Figure 1. South America map showing all available records of manatees: A) detail of north Colombia and northwestern Venezuela; B) north of Guyana, Suriname, and French Guiana; C) northern Brazil. Black circles indicate *Trichechus manatus* localities, open circles *T. inunguis*, open square sympatry between them, and black triangles *Trichechus* sp. localities. Numbers refer to names of localities listed in Appendix 1.

and additional social media were available for reporting manatee strandings (Bicho D'água, n. d.). These events were regularly monitored between 2005 and 2018. Every two weeks, a coastline stretch of approximately 300 km, including the Marajó Bay area and eastern Pará state coast, were accessed by boat and a four-wheel vehicle or, alternatively, monitored on foot. At least three field assistants took part in surveys. Findings were validated with voucher samples, photographs, and other sources of original information. Field works were conducted under licenses SISBIO/ICMBio to GEMAM, under the numbers 30327-1 and 54305-1. The gazetteer (Appendix 1), with all published records of South American manatees, also includes new records of *Trichechus* vouchers deposited in the mammal collection of the *Museu Paraense Emílio Goeldi* (MPEG).

### MORPHOLOGY

We examined external morphology, including coloration, of *Trichechus* specimens of all available photographs and *in loco* observations during stranding events along eastern Amazon coast. Taxonomic identification was carried out based on external morphological characters as described in Domning & Hayek (1986). Stranded specimens were checked for (a) presence of nails, (b) body coloration (black or grey), (c) skin texture, and (d) presence of white (or pinkish) patch(es) on breast, belly, fluke and/or flippers. We examined all available specimens of *Trichechus* spp. deposited in MPEG (Table 1).

## RESULTS

### GEOGRAPHIC DISTRIBUTION

The most complete map of the geographic distribution of South American manatees (*Trichechus* spp.) is herein presented, including Brazil, French Guiana, Suriname, Guyana, Venezuela, Colombia, Peru, and Ecuador (Figure 1). Appendix 1 shows localities in detail.

In this study, *T. inunguis* has been recorded along the eastern Amazon coast, in the Marajó Bay area, nearby inlets and channels in sympatry with *T. manatus* in several localities (Table 1). Amazonian manatees have also been reported along the eastern coast of Marajó Island (Table 1, records 21, 22, 24, 32, 39, 40, 41, 42) and adjacent eastern coastline (Table 1, records 26, 35). Presently, 33 specimens of *T. inunguis*, and nine *T. m. manatus* have been deposited in the MPEG (Table 1). In the field work between November 2005 and January 2018 along Eastern Pará, a total of 35 stranded manatees were observed.

### MORPHOLOGY

A total of 15 specimens, stranded, live-captured, or photographed, were examined. Twelve specimens presented typical *T. inunguis* or *T. manatus* morphological attributes (Table 1, Figure 2), including two live specimens with a *T. inunguis* characteristic phenotype (Figures 2A-2C), with whitish/pinkish patches on chest and belly, black body coloration, and nailless flippers. This was the case of MPEG42157 recovered in Colares, Marajó Bay, on 31 July 2012, with a large white patch on the chest and belly and rounded paddle, and Tito (GEMAM748) – a rescued and released orphan, from Furo das Marinhas, Santa Bárbara do Pará, eastern Marajó Bay. Another specimen showed the typical *T. manatus* phenotype, like Udi (MPEG44496) (Figure 2B). However, three other specimens with nails (characteristic of *T. manatus*) showed white belly patches (characteristic of *T. inunguis*). This was the case of one male manatee (Omar, MPEG42229) with the characteristic presence of nails as in *T. manatus*, but with atypical coloration. This calf is held in captivity in Salvaterra, Marajó Island since 20 July 2013. Although it has nails the general appearance resembles a more typical Amazonian phenotype, including a white narrow belly patch and another small one in the caudal fluke. Another specimen, Leleco (MPEG44491), a calf rescued December 13, 2014, in Vila do Pesqueiro, Soure, Marajó Island, also showed an Amazonian phenotype, including a round paddle, large pinkish patch on chest and belly, and pinkish patches on the flippers. A third specimen with nails and an Amazonian phenotype, was stranded alive on Soure, Marajó Island (Figures 2D-2F).

Table 1. Specimens of *Trichechus* deposited in the collection of *Museu Paraense Emílio Goeldi* (MPEG), Belém, Pará state (PA), Brazil, with record number (Rec), species identification, voucher museum number, collecting localities, name of captive animals, sex (S), type of preserved material, and remarks. Legend: F = female, M = male, I = unsexed, GEMAM = *Grupo de Estudos de Mamíferos Aquáticos da Amazônia*, specimen housed at MPEG. (Continue)

| Rec | Species | Voucher | Localities | Coordinates | Name | S | Material | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1 | *Trichechus inunguis* | MPEG1518 | Brazil, Pará, Belém, Icoaraci | -1.2985, -48.4755 | - | M | Skeleton | - |
| 2 | *Trichechus inunguis* | MPEG4636 | Brazil, Pará, Santarém, Taperinha, rio Ayaya | -2.4865, -54.3127 | - | I | Skull, mandible | - |
| 3 | *Trichechus inunguis* | MPEG4637 | Brazil, Pará, Santarém, Taperinha | -2.4865, -54.3127 | - | F | Skull, mandible | - |
| 4 | *Trichechus inunguis* | MPEG4638 | Brazil, Pará, Santarém, Taperinha, rio Ayaya | -2.4865, -54.3127 | - | F | Skull, mandible | - |
| 5 | *Trichechus inunguis* | MPEG4639 | Brazil, Pará, Santarém, Taperinha, rio Ayaya | -2.4865, -54.3127 | - | F | Skull, mandible | - |
| 6 | *Trichechus inunguis* | MPEG4640 | Pará, rio Curuá | -6.4056, -54.7287 | - | F | Skull, mandible | - |
| 7 | *Trichechus inunguis* | MPEG4641 | Brazil, Pará, Monte Alegre, Lago Grande de Maycurú | - | - | I | Skull, mandible | - |
| 8 | *Trichechus inunguis* | MPEG6491 | Brazil, captive specimen from *Jardim Zoológico de Belém* | - | - | F | Skull, mandible | - |
| 9 | *Trichechus manatus* | MPEG6492 | Brazil, captive specimen from *Jardim Zoológico do MPEG* | - | - | F | Skull, mandible | - |
| 10 | *Trichechus inunguis* | MPEG6493 | Brazil | - | - | M | Skull, skeleton | - |
| 11 | *Trichechus inunguis* | MPEG6494 | Brazil, captive specimen from *Jardim Zoológico do MPEG* | - | - | M | Skull, skeleton | - |
| 12 | *Trichechus inunguis* | MPEG6495 | Brazil | - | - | F | Skull | - |
| 13 | *Trichechus inunguis* | MPEG7959 | Brazil, Pará, Oriximiná, rio Trombetas | - | - | F | Skull | - |
| 14 | *Trichechus inunguis* | MPEG8845 | Brazil, captive specimen from *Jardim Zoológico de Belém* | - | - | F | Skull | - |
| 15 | *Trichechus inunguis* | MPEG9138 | Brazil, captive specimen from *Jardim Zoológico do MPEG* | - | - | I | Skeleton | - |
| 16 | *Trichechus inunguis* | MPEG11298 | Brazil, Pará, Rio Guamá, mouth of igarapé Tucunduba | -1.4770, -48.4685 | - | F | Skeleton | |
| 17 | *Trichechus inunguis* | MPEG11838 | Brazil, Pará, Cametá, rio Tocantins | -3.3026, -55.3079 | - | I | Skin | |
| 18 | *Trichechus inunguis* | MPEG12755 | Brazil, captive specimen from *Parque Zoobotânico do MPEG* | - | - | M | Skeleton | - |
| 19 | *Trichechus inunguis* | MPEG22428 | Brazil, unknown locality | - | - | M | Skull, mandible | - |
| 20 | *Trichechus manatus* | MPEG37815 | Brazil, Pará, Marajó Island, Salvaterra, Porto dos Pescadores | -0.7667, -48.5167 | - | I | Skull | - |
| 21 | *Trichechus inunguis* | MPEG44485 | Brazil, Pará, Marajó Island, Cachoeira do Arari (GEMAM216) | -1.0167, -48.9667 | - | F | Pectoral | Female with fetus |

Table 1. (Conclusion)

| Rec | Species | Voucher | Localities | Coordinates | Name | S | Material | Remarks |
|---|---|---|---|---|---|---|---|---|
| 22 | *Trichechus inunguis* | MPEG44486 | Brazil, Pará, Marajó Island, Salvaterra, Ponta do Pilão | - | Vitória | F | Tissue | Rehabilitation |
| 23 | *Trichechus manatus* | MPEG42043 | Brazil, Pará, Marajó Island, Soure, vila Caju-una | -0.6248, -48.4804 | - | F | Skeleton | Stranded dead |
| 24 | *Trichechus inunguis* | MPEG42148 | Brazil, Pará, Abaetetuba (GEMAM419) | -1.7247, -48.8813 | - | I | Skeleton | Hunted and confiscated |
| 25 | *Trichechus inunguis* | MPEG42156 | Brazil, captive specimen from *Jardim Zoológico de Belém* | - | - | F | Skeleton | - |
| 26 | *Trichechus inunguis* | MPEG42157 | Brazil, Pará, Colares, igarapé do Cedro (GEMAM380) | -0.9401, -48.2901 | - | F | Tissue | Stranded |
| 27 | *Trichechus manatus* | MPEG42229 | Brazil, Pará, Salvaterra, praia do Salazar (GEMAM585) | -0.9232, -48.5304 | Omar | M | Tissue | Alive, in rehabilitation |
| 28 | *Trichechus manatus* | MPEG44487 | Brazil, Pará, Santo Antônio do Tauá, vila Jutaí (GEMAM581) | -1.1516, -48.1329 | Jutaí | M | Tissue | Died in rehabilitation |
| 29 | *Trichechus manatus* | MPEG44488 | Brazil, Pará, Salvaterra, praia do Salazar | -0.9232, -48.5304 | | | Tissue | |
| 30 | *Trichechus inunguis* | MPEG44489 | Brazil, Pará, Gurupá (GEMAM586) | -1.3985, -51.6465 | Gurupá | M | Tissue | Died in rehabilitation |
| 31 | *Trichechus manatus* | MPEG44478 | Brazil, Pará, Salvaterra, praia de Joanes | -0.8796, -48.5063 | | | Tissue | Carcass |
| 32 | *Trichechus inunguis* | MPEG44490 | Brazil, Pará, Salvaterra, praia de Joanes (GEMAM617) | -0.8554, -48.5368 | | | Tissue | Carcass |
| 33 | *Trichechus manatus* | MPEG44491 | Brazil, Pará, Soure, vila do Pesqueiro (GEMAM645) | -0.6616, -48.4821 | Leleco | M | Skeleton | Died in rehabilitation |
| 34 | *Trichechus inunguis* | MPEG44492 | Brazil, Pará, Melgaço, *Floresta Nacional* (FLONA) Caxiuanã, Vila Brabo, Rio Anapú | - | | | Tissue | |
| 35 | *Trichechus inunguis* | MPEG44493 | Brazil, Pará, Vigia (GEMAM671) | -0.7799, -48.1622 | | | Tissue | Stranded dead |
| 36 | *Trichechus inunguis* | MPEG44494 | Brazil, Pará, Goianésia do Pará | -3.9653, -48.9008 | Vitória | F | Skeleton | |
| 37 | *Trichechus inunguis* | MPEG44495 | Brazil, Pará, Melgaço, FLONA Caxiuanã (GEMAM649) | - | Kaluanã | F | Tissue | Alive, in rehabilitation |
| 38 | *Trichechus manatus* | MPEG44496 | Brazil, Pará, Salvaterra, vila Água Boa (GEMAM741) | -0.71867, -48.5022 | Udi | F | Skeleton | Hydrocephalus |
| 39 | *Trichechus inunguis* | MPEG44497 | Brazil, Pará, Salvaterra, praia de Joanes | -0.8796, -48.5063 | Joeny | F | Tissue | Alive, in rehabilitation |
| 40 | *Trichechus inunguis* | MPEG44498 | Brazil, Pará, Salvaterra, Ponta do Pilão | -0.8832, -48.5144 | - | | Skeleton | - |
| 41 | *Trichechus inunguis* | MPEG44499 | Brazil, Pará, Salvaterra, praia de Joanes (GEMAM746) | -0.8796, -48.5063 | - | M | Skeleton | - |
| 42 | *Trichechus inunguis* | GEMAM748 | Brazil, Pará, Santa Bárbara do Pará, Furo das Marinhas | -1.1995, -48.3297 | Tito | M | Tissue | Rescued and released |

Figure 2. Variation in coloration of *Trichechus* spp. along the eastern coast of Marajó: A) typical *T. inunguis* live rescued in Joanes, Salvaterra, Marajó Is. (B) in Caxiuanã National Forest in lower Amazon region, and (C) in Soure, Marajó Is., (D-F) typical *T. manatus* rescued in Marajó Is., note the greyish coloration and the presence of nails, (G) Omar (MPEG42229), a live rescued *T. manatus* in rehabilitation in Salvaterra, Marajó Is., note the black coloration, presence of white spots in the belly and tail, round paddle tail, and the presence of nails, (H-I) rescued *T. manatus* in Marajó Is., note the blackish coloration, the presence of white coloration in the belly and flippers and also presence of nails. Photos: (A) Bicho D'água, (B) Janine Valente, (C) Leonardo Silva, (D-F) Renata Emin, (G) Salvatore Siciliano, (H-I) Jacqueline Vieira.

## DISCUSSION

### GEOGRAPHIC DISTRIBUTION

The map and gazetteer provide insights on the distribution of manatees (*Trichechus* spp.) in South America, pointing to Brazil and Colombia as the only two countries with both *T. inunguis* (Amazonian manatees) and *T. m. manatus* (Antillean manatees). The occurrence of two trichechid species within the boundaries of these countries represents a unique situation worldwide and deserves special attention for conservation strategies. According to two reviews (Reeves *et al.*, 1992; Jefferson *et al.*, 1993), Antillean manatees in mainland South America are presently distributed from Alagoas state (10° S), in the Northeast of Brazil, to the Colombian coastline and major inland rivers. Their former southern range in South America having extended further south to the mouth of Rio Doce (19° 37' S), Espírito Santo state, in the southeastern Brazil (Whitehead, 1977). More recently, a manatee rib found amid a pile of weathered bones of humpback whales in Barra de Caravelas (17° 43' S), Bahia state, in September 1990, posed the intriguing possibility that manatees have been recently present at this latitude (Siciliano & Barbosa-Filho, 2016). The Caravelas record has been included in our map and gazetteer, accounting for the likely southern limit of *T. manatus* in South America.

Detailed examination of the map indicates two gaps in the distribution of *T. m. manatus* in South America, one along the Venezuelan coastline, in accordance with Lefebvre *et al.* (1989) and Luna (2013) who proposed that this major discontinuity was likely due to unsuitable habitats. One gap, herein reported, was found along vast stretches of the northern coast of Brazil, known as '*Reentrâncias Maranhenses*', or simply '*Lençóis Maranhenses*', stablished as a National Park in 1981. The *Lençóis Maranhenses* represents an open sandy dune environment spread over 75 km of coastline very unsuitable as a habitat for manatees, located in the coast, near and south São Luis do Maranhão, between -2.35693, -43.27116 and -2.56476, -42.7880.

Our findings also provided compelling evidence of recent recolonization around Marajó Island, in agreement with a previous report on the mouths of the Amazon and the vicinity of Belém where *T. inunguis* and *T. manatus* had apparently been heavily hunted to the verge of extinction (Domning, 1981).

Our review indicated that *Trichechus inunguis* is widely distributed in the Amazon basin, following the main course of the Amazon River and its major tributaries to Colombia, Peru, and Ecuador. Records of *T. inunguis* in French Guiana, Suriname, Guyana, and Venezuela are presently unavailable, although Amazonian manatees have been found to occasionally penetrate southern Guyana close to the boundary with Brazil (Bertram & Bertram, 1973; Lima, C. *et al*., 2019). This finding has been confirmed by a recent manatee rescue in the Takutu river (= Tacutu), on the border of Brazil and Guyana (Marmontel *et al.*, 2016).

As above stated, previous reports on the potential distribution of Amazonian manatees in eastern Pará state have been incomplete because several authors restricted their potential occurrence in eastern Amazonia to a vast geographic area frequently referred as 'Marajó Island', failing to define the actual range of these elusive species. Along the eastern Amazon coast, *T. inunguis* has been herein confirmed in the Marajó Bay area and nearby inlets and channels (Table 1). The influx of abundant freshwater during the rainy season (December-June) may favor the spreading of Amazonian manatees throughout this vast territory, when the mixed waters in Marajó Bay undergo reduced salinity as attested by recent regular records in Furo das Marinhas (1° 21' 4" S, 47° 34' 20" W), Mosqueiro (1° 9' 49" S, 48° 28' 15" W), and Ourém (1° 33' 0" S, 47° 6' 0" W) localities (Rosário & Santos, 2014; Prestes *et al.*, 2020). These findings are in accordance with previous work that reported the presence of *T. inunguis* in the coast of French Guiana (Vilaça & Santos, 2019), with strong influence of fresh water, and then with low salinity. The records herein presented revise the distribution map of Amazonian manatees in Brazil (Figure 1).

Eastwards Pará state coastline there is a vast coastline with numerous large bays bordered by mangrove ecosystem, referred as the '*Salgado Paraense*', offer a potentially suitable habitat to Antillean manatees although it has remained poorly surveyed for decades.

We found *Trichechus inunguis* throughout the lower Amazon and its tributaries, including Marajó Island and its Atlantic coast and coastal islands, and from the northern (Amapá state, Brazil) to the southern shore of the Amazon estuaries (Pará state, Brazil). These findings contradicted Domning's (1981) assertion that *Trichechus inunguis* would not inhabit regions with a high inflow of saltwater. Domning (1981) stated that *Trichechus manatus* apparently was 'exterminated from the Atlantic coast of Pará', assuming that this species, and not *T. inunguis*, formerly occurred in this region. This author concluded that any zone of sympatry between *T. manatus* and *T. inunguis* was highly restricted, if ever present, and that these species had mutually exclusive distributions (*i.e.*, parapatric). However, both manatee species are presently common and have been recorded by us in a wide area of sympatry on the eastern cost of Marajó Island, providing the first evidence that *T. inunguis* and *T. manatus* were syntopic. Although some populations have been reduced with respect to historical levels (Lefebvre *et al*., 1989), these findings suggest that manatee populations are recovering, as was the case of other marine species like the humpback whale and the northern elephant seal (Stewart *et al.*, 1994; Thomas *et al.*, 2016; Zerbini *et al.*, 2019). Similar findings were also reported for *T. inunguis* (Cantanhede *et al.*, 2005) in disagreement with a previous postulation that a low reproductive rate imposed a limit to the ability of manatees to recover from population reduction (Thornback & Jenkins, 1982; Marmontel, 1995).

## MORPHOLOGY

In this study, external morphology, and coloration in live *Trichechus* specimens examined in the field and the Salvaterra (Marajó Isl.) rehabilitation center revealed that these traits were variable. Domning & Hayek (1986) stated that nails represented primitive mammalian traits, and that their loss in *T. inunguis* was a derived trait, in accordance with findings of vestigial nails in *T. inunguis* newborns which were subsequently absent in adults (Luna, 2013). Noteworthily, Domning & Hayek (1986) described an atypical ventral coloration in a female manatee from Rio Arari, Marajó Island, together with a detailed and comparative description of *Trichechus* spp. coloration, "*T. senegalensis* Link, 1795 and *T. manatus* normally are uniformly dark in color without distinct markings [...] *T. inunguis*, in contrast to the other species, is said to be constantly characterized by [...] a white breast patch" (Domning & Hayek, 1986, p. 91). This description, however, was only valid for the majority of individuals rather than for all; in fact, unmarked specimens had been reported by Stannius (1845, p. 2), Edwards (1847, p. 149) and Pereira (1944, p. 39), as well as two of the three specimens in Natterer's original type-series (von Pelzeln, 1883, p. 91-92). Domning & Hayek (1986) further stated that

> Of 23 individuals examined by one of us (DPD), three were completely unmarked, three had only a tiny and inconspicuous belly patch, ten had a single, "normal" patch or a pair of patches confined to the chest and/or abdomen, and seven had multiple ventral patches extending onto the throat and/or tail. In one of the later, the patches consisted of white mottling on broad areas of the belly and tail, and in one of the second category there was also some gray speckling on the belly and indistinct pinkish areas on the throat and chest (figure 1 in Domning & Hayek, 1986). The belly patches may be either white or bright pink, possibly depending on the visibility of vascularized layers through the skin. When referring to nails, these authors mentioned: "Small nails on the lateral surfaces of the tips of one or more digits normally characterize *T. manatus* and *T. senegalensis* Link, 1795; their absence gave Behavior patterns in the west Indian manatee, with emphasis on feeding and diving its name. However, Stannius (1845, p. 2) found a single nail on each flipper in a young Amazonian manatee from Para [sic Pará]".

Generally, conventional descriptions of *Trichechus* spp. coloration are vague, stating that Amazonian manatees were grey to black, while most of them showed white or pink belly and chest patches (Jefferson *et al.*, 1993, 2008). In West Indian manatees "the colour of the skin is generally grey to brown, sometimes with a green, red, white, or black tinge caused by algal and/or barnacle growth. The short hairs are colourless. Calves appear to be a darker shade of grey, almost black" (Jefferson *et al.*, 1993, p. 524). According to Emmons & Feer (1997), *T. manatus* was "similar to Amazonian manatee except larger; flippers with large, flat nails on their tips; underparts gray or with pink blotches, without white patches".

Our data on the coloration and external morphology of recovered *T. manatus* along the eastern coast of Pará contradicted these previous reports and provided strong evidence of color polymorphism. We noted that some *T. manatus* specimens had nails but also whitish or pinkish patches on the chest and/or belly, including flippers, with typical coloration of *T. inunguis*. It has been postulated that colored body patches in mammals might be useful for intraspecific signaling (Caro, 2005) in mate selection, which can lead to reproductive isolation, even in sympatry (White & Kemp, 2016). It is notable that *T. inunguis* also showed an apparent polymorphism with respect to nails, which were detected in at least two specimens (Luna, 2013; Domning & Hayek, 1986).

## THREATS TO MANATEES ON EASTERN AMAZON COAST

Throughout our field studies along the Amazon coastline we identified several threats to manatees since 2005, as the 35 stranded manatees between November 2005 and January 2018 along eastern Pará. Other threats included incidental catches in gillnets and fixed trap nets as well as illegal hunting, mainly of calves, and water contamination (GEMAM, unpublished data). The use of fishing corrals built in submerged aquatic vegetation beds in Pará accounted for serious threats to manatees. Recently, in the spring of 2018, an intentional killing of a stranded manatee was reported in Joanes, Marajó Island. Necropsy and histopathologic findings in a newborn *T. inunguis* from Goianésia do Pará, Pará state confirmed chronic systemic bacterial infection caused by *Salmonella enterica* subsp. *enterica* (Correa Neto, 2017).

Moreover, one large Amazonian manatee incidentally caught in gillnets in Rio Arari, Cachoeira do Arari, Marajó Island on 16 July 2007 was killed for food consumption and later recovered for genetic analysis (MPEG44485, Table 1). A young male *T. inunguis* named Tito (GEMAM748) was caught by a small gillnet set off Furo das Marinhas, in Santa Bárbara do Pará, on 23 June 2017. It was disentangled alive and rescued by our team and forwarded to the MPEG rehabilitation center in Belém. Being in good health, it was released at the same spot a week later.

## CONCLUSIONS

In conclusion, the Amazonian manatee is widely distributed in the Amazon River basin and all major tributaries, limited only by rapids. It is also found in the mouth of the Amazon River as far as the influence of the plume, reaching the French Guiana. In Marajó Bay, the Amazonian manatee is sympatric with the Antillean manatee. The current distribution of the Antillean manatee comprises the Sergipe state, in Northeastern Brazil and up north along the South American coastline. Two gaps in the distribution were detected: one along the Lençóis Maranhenses, in Maranhão, Brazil and another along the coast of Venezuela.

## ACKNOWLEDGMENTS

We are grateful to the IBAMA office in Pará for logistical support during rescue operations. Héctor N. Seuánez kindly revised early drafts of the manuscript. Field and laboratory work were supported by grants from the *Projeto Piatam Mar* and *Piatam Oceano/Petrobras*, *Projeto Bicho D'água/Petrobras*, *Vale/Fundação de Amparo à Pesquisa do Estado de São Paulo/Fundação de Amparo à Pesquisa do Estado do Pará/Fundação de Amparo à Pesquisa do Estado de Minas Gerais* (FAPESP/FAPESPA/FAPEMIG) (Grant no. 038/2011), *Conselho Nacional de Desenvolvimento Científico e Tecnológico* (CNPq), and *Fundação de Amparo à Pesquisa do Estado do Rio de Janeiro* (FAPERJ) to C.R. Bonvicino

(CNPq 304498/2014-9 and FAPERJ E26/201.200/2014, in *Instituto Oswaldo Cruz*), CNPq to S. Siciliano (306076/2019-5), CNPq to Renata Emin-Lima (313356/2015-7). Waleska Gravena, an anonymous reviewer, and the editor A. Bezerra made insightful comments on the manuscript.

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Appendix 1. List of localities of *Trichechus* specimens in South America. Number before localities refers to Figure 1. Acronyms: AMNH = American Museum of Natural History, New York, NY, USA; Aquasis = *Associação de Pesquisa e Preservação de Ecossistemas Aquáticos*, Caucaia, Ceará state, Brazil; IDSM = *Instituto de Desenvolvimento Sustentável Mamirauá,* Tefé, Amazonas state, Brazil; CMA = *Centro Mamíferos Aquáticos do ICMBio*, Itamaracá, Pernambuco state, Brazil; MN = *Museu Nacional*, UFRJ, Rio de Janeiro, Brazil; MPEG = *Museu Paraense Emílio Goeldi,* Belém, Pará state, Brazil.

*Trichechus* sp.

**BRAZIL**

**Amapá state**

(274): Rio Amapá Grande: Domning (1981),
(81) Calçoene: Cunaní - incidental capture in Domning (1981),
(80) Maracá: Ilha de Maracá - incidental capture in Domning (1981),
**Pará state** (82) Soure: Ilha de Marajó, Vila do Pesqueiro – this study,
(62a) Salvaterra: Ilha de Marajó, Vila de Monsarás – this study.

*Trichechus manatus manatus* Linnaeus, 1758

**BRAZIL**

**Alagoas state**

(not located): Pescana and Tabuia - interview in Lima, R. (1997),
(2) Barra de São Miguel: interview in Lima, R. (1997),
(3) Coruripe: Praia da Lagoa do Pau, Praia de Miaí, and Distrito de Poxim - interview in Lima, R. (1997),
(4) Jequiá da Praia: Praia Barra de Jequiá and Praia de Lagoa Azeda - interview in Lima, R. (1997),
(5) Maceió: Praia de Cruz das Almas - incidental capture in nets in Borobia & Lodi (1992), Praia da Garça Torta, Praia de Guaxuma, Praia de Ipióca, Praia de Jacarecica, Praia de Jatiúca, Praia de Riacho Doce, and Praia de Sahuaçuí - interview in Lima, R. (1997),
(6) Marechal Deodoro: Praia do Francês and Prainha de Barra Nova - interview in Lima, R. (1997),
(7) Paripueira: interview in Lima, R. (1997),
(8) Piaçabuçu: Praia do Peba - interview in Lima, R. (1997),
(9) Passo de Camaragibe: Barra de Camaragibe and Praia dos Morros - interview in Lima, R. (1997),

**Amapá state**

(275) Mouth of Rio Uaçá: incidental capture in Silva *et al.* (2013),
(77) Oiapoque: Taperebá, Rio Oiapoque - Domning (1981),

**Bahia state**

(1) Caravelas: MN 30493 - Siciliano & Barbosa-Filho (2016),

**Ceará state**

(217): Cascavel: Praia de Balbino - incidental capture in Meirelles (2008),
(218) Caucaia: Praia de Icaraí - incidental capture in Meirelles (2008),
(43) Acaraú: Praia da Volta do Rio - incidental capture in Meirelles (2008),
(44) Aquiraz: Praia do Barro Preto and Praia de Porto das Dunas - incidental captures in Meirelles (2008),

Appendix 1. (Continue)

(45) ARACATI: incidental capture in Meirelles (2008), (45a) Praia de Quixaba - Aquasis 10 in Meirelles (2008), (45b) Praia de Canoa Quebrada, S0112/114 in Meirelles (2008), (45c) Praia Fontainha - interview in Lima, R. (1997), Praia de Majorlândia, Retirinhos, and Praia Quitérias - interview in Lima, R. (1997), Praia do Retiro Grande - incidental capture in Meirelles (2008),

(46) BEBERIBE: Barra de Sucatinga and district Parajuru - incidental capture in Meirelles (2008) and interview in Lima, R. (1997), Lagoa de Dentro - incidental capture in Meirelles (2008), Praia Cabo Verde - interview in Lima, R. (1997), reserva extrativista Prainha do Canto Verde and Praia do Diogo - incidental captures in Meirelles (2008), Praia de Parajuru - Aquasis 2 in Meirelles (2008), Praia Uruaú - interview in Lima, R. (1997), (46a) Praia de Morro Branco - interview in Lima, R. (1997),

(47) CAMOCIM: Praia de Bitupitá - interview in Lima, R. (1997), (47a) district Guriú - interview in Lima, R. (1997),

(48) FORTALEZA: incidental captured in Borobia & Lodi (1992),

(49) FORTIN: Praia de Pontal do Maceió - interview in Lima, R. (1997),

(50) ICAPUÍ: Aquasis 36 in Alves *et al.* (2013), Praia de Ponta Grossa and Praia de Tremembé - interview in Lima, R. (1997), Praia da Redonda - incidental capture in Meirelles (2008),

**Maranhão state**

(58) RIO MEARIM - incidental capture in Domning (1981),

(54) ALCÂNTARA: Ponta das Pedras – hunted, Siciliano (1991), Rio Pericumã - stranded in present study,

(55) ARAIOSES: Barra das Canárias - sighting in present study,

(56) CURURUPU: sightings in present study,

(57) HUMBERTO DE CAMPOS: Baía de Tubarão - found dead in present study, Rio Maparí - sightings in present study,

(59) SÃO JOSÉ DE RIBAMAR: Praia de Guarapiranga, - sightings in present study, rescued in Parente *et al.* (2004), Praia de Panaquatira - Conceição *et al.* (2020),

(60) SÃO LUÍS: sighting in Domning (1981),

(61) VILLAGE OF COIVARA = Boqueirão: incidental capture in Domning (1981),

**Pará state**

(62) SALVATERRA: Ilha de Marajó, Porto dos Pescadores,

(83) SANTO ANTÔNIO DO TAUÁ: present study,

**Paraíba state**

(16) BAÍA DA TRAIÇÃO: Praia Tramataia - interview in Lima, R. (1997),

(17) CABEDELO: UFPB550,

(18) CONDE: Barra do Abiaí - incidental capture in Borobia & Lodi (1992),

(18a) PRAIA DE COQUEIRINHO - CMA 0150111/13 - sighting in Borobia & Lodi (1992) and interview in Lima, R. (1997), Praia de Jacumã - interview in Lima, R. (1997),

(19) JOÃO PESSOA: Barra de Gramame and Praia do Poço - interview in Lima, R. (1997), Praia de Tambaú - UFPB545, Praia do Bessa - UFPB546,

(19a) Praia da Penha - interview in Lima, R. (1997),

(20) LUCENA: Barra do Rio Miriri - interview in Lima, R. (1997),

Appendix 1. (Continue)

(21) Mamanguape: interview in Lima, R. (1997),
(22) Mataraca: Barra de Camaratuba - interview in Lima, R. (1997),
(23) Parnamirim: mouth of Rio Pitimbú - sighting in Borobia & Lodi (1992),
(24) Pitimbú: Rio Abiaí - live capture in Borobia & Lodi (1992), Praia de Acaú - interview in Lima, R. (1997) and incidental capture in nets in Borobia & Lodi (1992), Ponta dos Coqueiros, INPA150, INPA151,
(24a) Praia de Pontinha - interview in Lima, R. (1997),
(25) Rio Tinto: mouth of Rio Mamanguape - sighting in Borobia & Lodi (1992),

**Pernambuco state**

(92) Cabo de Santo Agostinho: Praia de Gaibu - interview in Lima, R. (1997),
(10) Goiana: Banks da Rocha (1971), Rio Goiana - incidental capture in Borobia & Lodi (1992), Praia de Atapuz, Praia Carne de Vaca, and district of Ponta de Pedras - interview in Lima, R. (1997),
(11) Ilha de Itamaracá: Canal de Santa Cruz estuary – sightings in Borobia & Lodi (1992),
(12) Ipojuca: Praia de Nossa Senhora do Ó - live capture in Borobia & Lodi (1992),
(13) Itapissuma: interview in Lima, R. (1997),
(14) Paulista: Praia de Pau Amarelo - interview in Lima, R. (1997),
(15) Recife: Maria Farinha - interview in Lima, R. (1997),

**Piauí state**

(276) Porto dos Tatus: Ilha Grande - interview in Lima, R. (1997),
(51) Cajueiro da Praia: Praia de Barra Grande - interview in Lima, R. (1997),
(52) Luís Correia: Praia do Coqueiro - interview in Lima, R. (1997),
(53) Parnaíba: Praia da Pedra do Sal - interview in Lima, R. (1997),

**Rio Grande do Norte state**

(219) Caiçaras: Rio Fundo, and São José do Gostoso - interview in Lima, R. (1997),
(26) Areia Branca: Praia de Caraúbas, Praia Upanema, and Praia da Ponta do Mel - interview in Lima, R. (1997),
(27) Baia Formosa: Praia de Sagi, CMA 0150111/14,
(28) Canguaretama: Barra do Cunhaú and Sibaúma - interview in Lima, R. (1997),
(29) Ceará-Mirim: Praia de Muriú - interview in Lima, R. (1997),
(30) Extremoz: Barra do Rio, Graçandu, and Genipabu - interview in Lima, R. (1997),
(31) Galinhos: interview in Lima, R. (1997),
(32) Macau: interview in Lima, R. (1997),
(33) Maxaranguape: Barra de Maxaranguape and Praia de Maracajaú - interview in Lima, R. (1997), (34) Natal: Praia de Areia Preta, stranded in Borobia & Lodi (1992), Praia de Pitangui, Praia de Ponta Negra, Redinha, and Praia do Rosado - interview in Lima, R. (1997),
(35) Nísia Floresta: Praia de Barreta, Praia da Barra de Tabatinga, Praia de Búzios, Praia de Pirangi do Norte, and Praia de Pirangi do Sul - interview in Lima, R. (1997),
(36) Parnamirim: Cotovelo and Praia de Cotovelo - interview in Lima, R. (1997),
(37) Porto do Mangue: interview in Lima, R. (1997),

Appendix 1. (Continue)

(38) Rio do Fogo: Praia de Pititinga, and Praia de Zumbi - interview in Lima, R. (1997),
(39) São Miguel do Gostoso: Tourinhos Praia dos Morros - interview in Lima, R. (1997),
(40) Tibau: interview in Lima, R. (1997),
(41) Tibau do Sul: Praia da Pipa - interview in Lima, R. (1997),
(42) Touros: Praia de Perobas, Praia do Cajueiro, and Lagoa do Sal - interview in Lima, R. (1997).

## COLOMBIA

(Not Located) Atrato river, Ciénaga La Grande - sightings in Caicedo-Herrera *et al.* (2004),

**Santander and Cesar departments**

(Not Located) Río Lebrija - sightings in Caicedo-Herrera *et al.* (2004),

**Atlantico and Bolivar departments**

(Not Located) Tapacomocho in Río Magdalena - incidental capture in Montoya-Ospina *et al.* (2001),
(220) Ciénaga del Totumo: Río Magdalena - sightings in Caicedo-Herrera *et al.* (2004),

**Antioquia department**

(Not Located) El Retiro - sightings in Caicedo-Herrera *et al.* (2004),
(221) Ciénaga Sardinata: Río Magdalena - sightings in Caicedo-Herrera *et al.* (2004),
(222) Bahía Candelaria: Río Atrato and Río Cauca - incidental captures in Montoya-Ospina *et al.* (2001),
(223) Ciénaga de Barbacoas: Río Magdalena - sightings in Caicedo-Herrera *et al.* (2004),
(140) Barranquilla: Río Magdalena, Bocas de Ceniza - incidental capture in Montoya-Ospina *et al.* (2001),
(141) Caucasia: sightings in Caicedo-Herrera *et al.* (2004),
(142) Murindó: sightings in Caicedo-Herrera *et al.* (2004),
(143) Necoclí: sightings in Caicedo-Herrera *et al.* (2004), Río Atrato - incidental capture in Montoya-Ospina *et al.* (2001),
(144) Puerto Berrío: sightings in Caicedo-Herrera *et al.* (2004),
(145) Turbo: sightings in Caicedo-Herrera *et al.* (2004),
(146) Vigía del Fuerte: sightings in Caicedo-Herrera *et al.* (2004),
(147) Yondó: sightings in Caicedo-Herrera *et al.* (2004),

**Armenia department** sightings in Caicedo-Herrera *et al.* (2004),

**Atlantíco department**

(Not Located) Del Banco - sightings in Caicedo-Herrera *et al.* (2004),
(148) Barranquilla: sightings in Caicedo-Herrera *et al.* (2004),
(149) Manatí: sightings in Caicedo-Herrera *et al.* (2004),
(151) Repelón: sightings in Caicedo-Herrera *et al.* (2004),
(152) Santa Lucia: sightings in Caicedo-Herrera *et al.* (2004),
(150) Palmar de Varela: sightings in Caicedo-Herrera *et al.* (2004),

**Bolivar department**

(Not Located) Canal del Dique - incidental captures in Montoya-Ospina *et al.* (2001),
Bahia Barbacoas: Río Magdalena - incidental captures in Montoya-Ospina *et al.* (2001),

Appendix 1. (Continue)

(224) Isla de Mompós: Río Magdalena - incidental captures in Montoya-Ospina *et al.* (2001),
(225) Corregimiento de San Antonio – sightings in Caicedo-Herrera *et al.* (2004),
(226) Altillo de Loba - sightings in Caicedo-Herrera *et al.* (2004),
(154) Altos del Rosario: Sightings in Caicedo-Herrera *et al.* (2004),
(153) Achí: Corregimiento de Achí, sightings in Caicedo-Herrera *et al.* (2004), Río Cauca - incidental capture in Montoya-Ospina *et al.* (2001),
(155) Arjona: sightings in Caicedo-Herrera *et al.* (2004),
(156) Calamar: sightings in Caicedo-Herrera *et al.* (2004), Río Magdalena - incidental capture in Montoya-Ospina *et al.* (2001),
(157) Cantagallo: sightings in Caicedo-Herrera *et al.* (2004),
(158) Cartagena: corregimiento Pasacaballos - sightings in Caicedo-Herrera *et al.* (2004), Córdoba, Corregimientos de Tacamocho - sightings in Caicedo-Herrera *et al.* (2004),
(159) Gambote: sightings in Caicedo-Herrera *et al.* (2004),
(161) Magangué: Coyongal – sightings in Caicedo-Herrera *et al.* (2004), corregimiento in Tacaloa Río Magdalena - incidental capture in Montoya-Ospina *et al.* (2001), Tacasaluma – sightings in Caicedo-Herrera *et al.* (2004),
(160) Mahates: sightings in Caicedo-Herrera *et al.* (2004),
(163) Mompos: La Peña, sightings in Caicedo-Herrera *et al.* (2004),
(162) Maria la Baja: sightings in Caicedo-Herrera *et al.* (2004),
(165) Regidor: sightings in Caicedo-Herrera *et al.* (2004),
(164) Morales: sightings in Caicedo-Herrera *et al.* (2004), Río Magdalena, El Dique - incidental capture in Montoya-Ospina *et al.* (2001),
(166) Pinillos: sightings in Caicedo-Herrera *et al.* (2004), Río Cauca - incidental capture in Montoya-Ospina *et al.* (2001),
(167) San Cristóbal: sightings in Caicedo-Herrera *et al.* (2004),
(168) San Estanislao: sightings in Caicedo-Herrera *et al.* (2004), San Pablo - sightings in Caicedo-Herrera *et al.* (2004),
(169) Simití: sightings in Caicedo-Herrera *et al.* (2004),
(170) Talaigua Nuevo: Río Magdalena - incidental capture in Montoya-Ospina *et al.* (2001),

**Caldas department**

(171) Riosucio: sightings in Caicedo-Herrera *et al.* (2004),

**Casanare department**

(172) La Poyata: Río Meta - incidental capture in Montoya-Ospina *et al.* (2001),

**Cesar department**

(Not Located) Río Cesar, Arroyo El Delirio - incidental capture in Montoya-Ospina *et al.* (2001),
(173) Aguachica: sightings in Caicedo-Herrera *et al.* (2004),
(174) Chimichagua: sightings in Caicedo-Herrera *et al.* (2004),
(175) Chiriguana: sightings in Caicedo-Herrera *et al.* (2004),
(176) El Paso: sightings in Caicedo-Herrera *et al.* (2004),
(177) Gamarra: sightings in Caicedo-Herrera *et al.* (2004), La Gloria, Río Magdalena - incidental capture in Montoya-Ospina *et al.* (2001),

Appendix 1. (Continue)

(178) TAMALAMEQUE: sightings in Caicedo-Herrera *et al.* (2004),

**Chocó department**

(NOT LOCATED) Momil - sightings, Caicedo-Herrera *et al.* (2004),

(227) BRAZO LEON: Río Atrato - incidental captures in Montoya-Ospina *et al.* (2001),

(228) GOLFO DE URABÁ: Río Atrato - incidental captures in Montoya-Ospina *et al.* (2001),

(229) CIÉNAGA MARRIAGA: Río Atrato - incidental captures in Montoya-Ospina *et al.* (2001), (203) RÍO TRUANDÓ: incidental capture in Montoya-Ospina *et al.* (2001),

(179) UNGÍA: sghtings in Caicedo-Herrera *et al.* (2004),

**Córdoba department**

(NOT LOCATED) sightings in Caicedo-Herrera *et al.* (2004), mouth of Río Sinu, Playa del Viento in Río Sinú, Tierralta in Río Sinú, and Ciena Grade de Lorica in Río Sinú - incidental captures in Montoya-Ospina *et al.* (2001),

(230) BOCA DE TINAJONES: Río Sinú - incidental captures in Montoya-Ospina *et al.* (2001),

(180) AYAPEL: sightings in Caicedo-Herrera *et al.* (2004), Río San Jorge, Ciénaga de Ayapel - incidental capture in Montoya-Ospina *et al.* (2001),

(181) CHIMÁ: sightings in Caicedo-Herrera *et al.* (2004),

(182) CULEBRA: Río Meta - incidental capture in Montoya-Ospina *et al.* (2001),

(183) LORICA: sightings in Caicedo-Herrera *et al.* (2004),

(184) PURÍSIMA: sightings in Caicedo-Herrera *et al.* (2004),

(185) SAN ANTERO: Río Sinú - incidental capture in Montoya-Ospina *et al.* (2001),

(186) SAN BERNARDO DEL VIENTO: sightings in Caicedo-Herrera *et al.* (2004),

**Magdalena department**

(NOT LOCATED) San Sebastian in Río Magdalena, Don Diego River, Río Sevilla, Fundación River, Río Frió - incidental captures in Montoya-Ospina *et al.* (2001),

(231) BURITACA RIVER: incidental captures in Montoya-Ospina *et al.* (2001),

(187) ARACATACA: Ciénega Grande de Santa Marta: incidental capture in Montoya-Ospina *et al.* (2001),

(188) EL BANCO: Río Magdalena - incidental capture in Montoya-Ospina *et al.* (2001),

(189) PINTO: Río Magdalena - incidental capture in Montoya-Ospina *et al.* (2001),

(190) SANTA MARTA: Ciénega Grande de Santa Marta, Tagangaba - incidental capture in Montoya-Ospina *et al.* (2001),

**Meta department**

(NOT LOCATED) Corregimiento Caño Chicagua, Curumaní el Banco, – sightings in Caicedo-Herrera *et al.* (2004), La Hermosa in Río Meta, Piñalitos in Río San Jorge, Aguas Pietras in Río Sinú, Bugre in Río Sinú - incidental captures in Montoya-Ospina *et al.* (2001),

(232) PUERTO GAITAN: Río Meta - incidental captures in Montoya-Ospina *et al.* (2001),

(233) PUERTO KENNEDY: sightings in Caicedo-Herrera *et al.* (2004),

(191) PUERTO LÓPEZ: Río Meta - incidental capture in Montoya-Ospina *et al.* (2001),

**Sucre department**

(NOT LOCATED) Corregimiento Ciénaga de Santiago Apóstol, and Santa Cruz y Tolú - sightings in Caicedo-Herrera *et al.* (2004),

Appendix 1. (Continue)

(197) San Benito Abad: sightings in Caicedo-Herrera *et al.* (2004),

(198) San Marcos: Río San Jorge - incidental capture in Montoya-Ospina *et al.* (2001),

**Santander department**

(Not Located) Sabana de Torres - sightings in Caicedo-Herrera *et al.* (2004),

(234) Ciénaga de Paredes: Río Magdalena - incidental captures in Montoya-Ospina *et al.* (2001),

(235) Ciénega de Colorado: Río Magdalena - incidental captures in Montoya-Ospina *et al.* (2001),

(236) Valledupar: sightings in Caicedo-Herrera *et al.* (2004),

(237) Villa Rosa: sightings in Caicedo-Herrera *et al.* (2004),

(192) Barrancabermeja: sightings in Caicedo-Herrera *et al.* (2004),

(193) Cimitarra: sightings in Caicedo-Herrera *et al.* (2004),

(194) Puerto Parra: sightings in Caicedo-Herrera *et al.* (2004),

(195) Puerto Wilches: sightings in Caicedo-Herrera *et al.* (2004),

**Tolima department**

(199) Purificación: sightings in Caicedo-Herrera *et al.* (2004),

**Valle del Cauca department**

(200) El Cerrito: Corregimiento El Cerrito, sightings in Caicedo-Herrera *et al.* (2004),

**Vichada department**

(Not Located) Isla el Pañuelo in Río Meta - incidental capture in Montoya-Ospina *et al.* (2001),

(201) Puero Carreño: Río Meta - incidental capture in Montoya-Ospina *et al.* (2001),

(202) Santa Rosalía: Río Meta, El Bordereño - incidental capture in Montoya-Ospina *et al.* (2001).

FRENCH GUIANA

(Not Located) Approuagé river and Mana River- interview in Thoisy *et al.* (2003), Mahury river, Cayenne - Castelblanco-Martínez (2015),

(238) Awala-Yalimapo: sighting in Thoisy *et al.* (2003),

(108) Bourda: sighting in Thoisy *et al.* (2003),

(239) Cayenne River: interview in Thoisy *et al.* (2003),

(109) Coswine: sighting in Thoisy *et al.* (2003),

(110) Counamama: interview in Thoisy *et al.* (2003),

(240) Ilet la Mère: interview in Thoisy *et al.* (2003),

(111) Iracoubo: interview in Thoisy *et al.* (2003),

(112) Javouhey: sighting in Thoisy *et al.* (2003),

(241) Kaw River: sighting in Thoisy *et al.* (2003),

(113) Kourou: sighting in Thoisy *et al.* (2003),

(242) Les Hattes: interview in Thoisy *et al.* (2003),

(114) Malmamoury: sighting in Thoisy *et al.* (2003),

(243) Maroni River: interview in Thoisy *et al.* (2003),

Appendix 1. (Continue)

(244) OUANARY RIVER - interview in Thoisy *et al.* (2003),
(115) OYAPOCK: sighting in Thoisy *et al.* (2003),
(116) RÉGINA: sighting in Thoisy *et al.* (2003),
(117) RÉMIRE-MONTJOLY: sighting in Thoisy *et al.* (2003),
(118) ROURA: sighting in Thoisy *et al.* (2003),
(119) SINNAMARY: interview in Thoisy *et al.* (2003),
(245) ST LAURENT: interview in Thoisy *et al.* (2003).

## GUYANA

(NOT LOCATED) Akawini river, Arapiaco river, Berbice river, Canje river - Bertram & Bertram (1973), Nanniekrek, Sebai river, and Wuini river - Bertram & Bertram (1973),
(246) ABARY RIVER: Bertram & Bertram (1973),
(246) BARIMA RIVER: Bertram & Bertram (1973),
(121) COURANTYNE: Bertram & Bertram (1973),
(248) DEMERARA RIVER: Bertram & Bertram (1973),
(249) ESSEQUIBO RIVER: Bertram & Bertram (1973),
(122) GEORGETOWN: UNEP (1995),
(250) KIATUNA RIVER: Bertram & Bertram (1973),
(251) MAHAICA RIVER: Bertram & Bertram (1973),
(252) MAHAICONY RIVER: Bertram & Bertram (1973),
(253) POMERROM RIVER: Bertram & Bertram (1973).

## SURINAME

(NOT LOCATED) Nanni Crrek - Duplaix & Reichard (1978), Cottica river and its tributaries Perica river and the small stream Koopmans and Barbakoeba - Duplaix & Reichard (1978), Coesewijne river, tributary of Coppename river - Duplaix & Reichard (1978), Wayombo river, tributary of Coppename river - Duplaix & Reichard (1978),
(254) COURANTYNE RIVER: Bertram & Bertram (1973),
(256) SARAMACCA RIVER: Duplaix & Reichard (1978),
(257) SURINAME RIVER: Duplaix & Reichard (1978),

### Marowijne district

(258) WANE KREEK - UNEP (1995),

### Nickerie district

(255) NICKERIE RIVER: and its tributaries Maratakka and Paraíso rivers - Duplaix & Reichard (1978),

### Saramacca district

(265) TABITI RIVER: tributary of Coppename river - Duplaix & Reichard (1978),
(266) TAPOERIPA KREEK: UNEP (1995),

### Sipaliwini district

Appendix 1. (Continue)

(120) Cottica river: Dekker (1974).

**TRINIDAD and TOBAGO**

(139) Gran Laguna, Oropouche Norte, Charamel and Otoire rivers - UNEP (1995), Pantano de Nariva and Río Oropouche Norte - UNEP (1995), Río L'Embranche, Manzanilla Norte - sighting in UNEP (1995).

**VENEZUELA**

(260) Golfo de Pária: in Sucre and Monagas - Boede *et al.* (2013),
(259) Northeastern Lago Maracaibo – Montiel-Villalobos & Barrios-Garrido (2005),

**Anzoátegui state**

(Not Located) mouth of Neveri river - UNEP (1995),

**Apure state**

(123) Brusual: interview in O'Shea *et al.* (1988),
(125) El Saman: interview in O'Shea *et al.* (1988),
(124) Elorza: interview in O'Shea *et al.* (1988),
(126) San Fernando de Apure: interview in O'Shea *et al.* (1988),

**Bolivar state**

(Not Located) Maripa - interview in O'Shea *et al.* (1988),
(127) Caicara: interview in O'Shea *et al.* (1988),
(128) Ciudad Bolivar: interview in O'Shea *et al.* (1988),
(129) Las Majadas: interview in O'Shea *et al.* (1988),

**Carabobo state**

(132) Puerto Cabello: sighting, UNEP (1995), Costa Barlovento - Boede *et al.* (2013),

**Delta Amacuro state**

(133) Pueblo Palo Blanco: interview in O'Shea *et al.* (1988),
(134) Tucupita: interview in O'Shea *et al.* (1988), Caño Manamo,

**Monagas state**

(Not Located) El Silencio - interview in O'Shea *et al.* (1988),
(135) Barrancas: interview in O'Shea *et al.* (1988),
(136) Caripito: interview in O'Shea *et al.* (1988),

**Sucre state**

(Not Located) Caño La Brea - UNEP (1995), Turuépano - Boede *et al.* (2013),

**Zulia state**

(137) Casigua: interview in O'Shea *et al.* (1988),
(131) Capitán Chico, Maracaibo: Santa Rosa de Agua Parque Ecoturístico "Tierra de Sueños" - Fundación Azul Ambientalistas, 2014, Lago de Maracaibo - interview in O'Shea *et al.* (1988),
(138) Encontrados: interview in O'Shea *et al.* (1988).

Appendix 1. (Continue)

*Trichechus inunguis* (Natterer, 1883)

**BRAZIL**

**Amazonas state**

(not located) RDS Piagaçu-Purus - sighting in Best (1983), Lago Aranucú - IDSM00/01, Lago Anuã - interview in Franzini *et al.* (2013), Paranã do Castanho - IDSM97/07, Rio Japurá - IDSM98/02L, *Reserva de Desenvolvimento Sustentável Piagaçu-Purus* (Caua-Cuiuanã - sighting in Souza (2015), Itapuru - interview in Best (1983), sightings in present study, incidental capture in Best (1983), Poço do Varela (Beabá) – recorded in Rosas *et al.* (2003), Jaruá, comunidade Arapari in IDSM93/01,

(282) Anamã: rescued in present study,

(84) Atalaia do Norte: rescued, Mundo Animal,

(85) Autazes: rescue in present study,

(90) Badajós: Codajás municipality – hunted, present study,

(86) Barreirinha: sightings, present study,

(87) Beruri: rescued in present study,

(88) Caapiranga: rescued in present study,

(89) Coari: rescued in present study, Coari Grande - interview in Franzini *et al.* (2013),

(91) Fonte Boa: Rio Panauã, Lago Guedes - IDSM01/47,

(281) Guajará: Marmotel (2019),

(104) Ilha dos Machado: IDSM00/04 in Barros *et al.* (2016),

(93) Iranduba: lago do Baixio in Ilha do Baixio – rescued in present study,

(93a) Cacau-Pirêra district: Porto das Balsas - rescued in present study,

(94) Itacoatiara: hunted, present study,

(268) Lago Aiapua: sighting in Best (1983),

(269) Lago Arapari: recorded in Rosas *et al.* (2003),

(270) lago Coari: interview in Franzini *et al.* (2013),

(271) Lago Jari: recorded in Rosas *et al.* (2003),

(273) Lago do Piorini: Codajás municipality – hunted, present study,

(96) Lago Mamori: rescued in present study,

(277) Careiro da Várzea: rescued in present study,

(95) Manacapuru: rescued in present study, Balneário do Miriti, km 75 on the road to Manuel Urbano - rescued in present study, Comunidade Betel and Comunidade São Sebastião - rescued in present study, Costa do Botija, Comunidade Jesus de Nazaré - incidental capture in nets in present study,

(97) Manicoré: rescued in present study,

(98) Maraã: Panauã, upstream mouth of Lago do Guedes - IDSM01/01, São Francisco do Boia, Rio Aranapú, mouth of Lago Gigante - IDSM00/09,

(99) Parintins: Villa Bella Imperatriz, Santa Clara, Rio Amazonas - AMNH93124,

(105) Rio Arauazinho: tributary of Rio Aripuanã – INPA_CCM81,

Appendix 1. (Continue)

(287) Rio Urucu: Coari municipality - interview in Franzini *et al.* (2013),
(100) Santa Isabel do Rio Negro: Rio Negro - rescued in present study,
(101) Silves: Comunidades Jacu, Taperebatuba e Igarapé-Açu – hunted, present study,
(102) Tefé: mouth of Lago Tefé - AMNH76813,
(103) Uarini: Lago do Cipó - IDSM01/13, São Raimundo do Jarauá, comunidade Jarauá: IDSM00/06,
(106) Uatumã: hunted, present study,

**Amapá state**

(not located) Ilha do Juruá, South of Cabo Norte - incidental capture in Domning (1981),
(78) Macapá: incidental capture in Domning (1981),
(80) Maracá: Ilha de Maracá, Jipioca Ecological Station - Marmontel *et al.* (2016),
(79) Santana: Rio Pirativa – rescued in present study,

**Pará state**

(Not Located) Rio Paru - INPA29, Ilha de Marajó, Canal Perigoso - INPA178-180,
(63) Abaetetuba: MPEG42148,
(64) Altamira: Rio Curuá,
(73) Belém do Pará: mouth of Igarapé Tucunduba, Rio Guamá - MPEG11298,
(65) Cachoeira do Arari: Rio Arari – MPEG 44485, Ilha de Marajó - INPA182,
(286) Cametá: Rio Tocantins: this study,
(66) Colares: Igarapé do Cedro - MPEG42157,
(284) Comunidade Pixuna do Tapará: Santarém municipality - rescued in present study,
(67) Faro: Rio Amazonas, Rio Inhamundá - AMNH96167,
(68) Goianésia do Pará: Rio Capim - MPEG44494,
(69) Gurupá: MPEG44489,
(70) Icoaraci: Ilha do Arapiranga - MPEG1518,
(71) Juruti: hunted, present study,
(72) Monte Alegre: Rio Mayairú, Lago Grande - MPEG04641,
(76) Óbidos: Lago Pauxis - rescued in present study,
(74) Oriximiná: Rio Trombetas - MPEG07959,
(283) Portel: Ilha de Marajó, Rio Acuti-Pereira,
(62) Salvaterra: Ilha de Marajó, Joanes - GEMAM 604 in Sousa (2011),
(272) Santa Bárbara: rescued in present study,
(75) Senador José Porfírio: Tabuleiro do Embaubau - Paschoalini *et al.* (2016),
(285) Taperinha: MPEG4635, MPEG4637, Taperinha in Rio Ayaya - MPEG4636, MPEG4638-4639.

**COLOMBIA**

(Not Located) Isla Charal, Isla Chimborazo, Isla El Indio, Isla Playa Caimanes, and La Angela – Castelblanco-Martínez *et al.* (2009),

Appendix 1. (Continue)

**Amazonas department**

(Not Located) Río Cotuhé – sightings in Caicedo-Herrera *et al.* (2004),
(261) Loreto Mocagua: sightings in Caicedo-Herrera *et al.* (2004),
(204) Leticia: Evans & Herald (1970),
(205) Mirití-Paraná: sightings in Caicedo-Herrera *et al.* (2004),

**Bolívar department**

(262) Magangué, Puerto Nariño – sightings in Caicedo-Herrera *et al.* (2004),

**Caqueta department**

(Not Located) Husar (1977), Boca Meta - Castelblanco-Martínez *et al.* (2009),

**Caldas department**

(Not Located) San Jose - Castelblanco-Martínez *et al.* (2009),

**Cesar department**

(263) El Burro: Castelblanco-Martínez *et al.* (2009),

**Guainía department**

(Not Located) Isla Santa Helena - Castelblanco-Martínez *et al.* (2009),

**Magdalena department**

(206) Tronconal: Castelblanco-Martínez *et al.* (2009),

**Nariño department**

(264) Punta Lajas: Castelblanco-Martínez *et al.* (2009),

**Norte de Santander department**

(207) Tres Bocas: Castelblanco-Martínez *et al.* (2009),

**Putumayo department**

(Not Located) Río Igará-Paraná, affluent of Rio Putumayo - sightings in Caicedo-Herrera *et al.* (2004),
(208) Puerto Leguízamo: sightings in Caicedo-Herrera *et al.* (2004),

**Sucre department**

(Not Located) Puerto Sucre – Castelblanco-Martínez *et al.* (2009),

**Vaupés department**

(Not Located) Apoporis - Husar (1977),

**Vichada department**

(Not Located) Raudal Bachaco – Castelblanco-Martínez *et al.* (2009).

## ECUADOR

(Not Located) Río Anãngu, tributary of Río Napo, and Río Lagarto Cocha, tributary of Río Aguarico - sightings in Timm *et al.* (1986),
(209) Laguna Cocha: near the mouth of Río Aguarico - sighting Timm *et al.* (1986),
(213) Laguna Grande: upper Río Cuyabeno - sighting in Timm *et al.* (1986),
(210) Laguna Zancudo Coch: Río Aguarico - sighting in Timm *et al.* (1986),

Appendix 1. (Conclusion)

(211) Río Napo: near San Francisco - sighting in Timm *et al.* (1986),
(212) Río Yasuní: near confluence with Río Napo - sighting in Timm *et al.* (1986).

**PERU**, **Amazonas region**
(Not Located) Lagoa El Dorado - interview in Landeo-Yauri *et al.* (2013),
**Ucayali region**
(280) Tapiche River: AMNH8691,
**Loreto region**
(215) Napo: Río Napo, near San Roque - sighting in Timm *et al.* (1986),
(278) Pacaya Samiria National Reserve: interview in Landeo-Yauri *et al.* (2013),
(214) Río Samiria: sighting in Timm *et al.* (1986),
(216) Río Curaray: AMNH73594,
(279) Río Curaray mouth: Maynas province - AMNH 73594.

# Etnoecologia comportamental da baleia-franca-austral *Eubalaena australis* (Desmoulins, 1822) por meio do conhecimento ecológico local de pescadores artesanais na Área de Proteção Ambiental da Baleia Franca, Sul do Brasil

# Ethnoecology behavioral of Southern Right Whale *Eubalaena australis* (Desmoulins, 1822) through the local ecological knowledge of artisanal fishermen in Southern Right Whale Area of Environmental Protection, southern Brazil

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**Resumo:** O objetivo deste estudo foi caracterizar o conhecimento ecológico local dos pescadores artesanais do município de Garopaba, Santa Catarina, Sul do Brasil, em relação ao comportamento da baleia-franca-austral, *Eubalaena australis*, na Área de Proteção Ambiental (APA) da Baleia Franca. Em outubro de 2010, foram realizadas 33 entrevistas etnográficas com pescadores em que 81,8% (n = 27) dos entrevistados identificam a espécie por meio da sua área de ocorrência, coloração e tamanho corporal. As análises das entrevistas foram baseadas nestes 27 pescadores selecionados, com a descrição de mais de uma etnocategoria por entrevistado. Os pescadores indicaram dez etnocategorias comportamentais comuns a adultos e infantes, e a categoria 'não faz nada' frente a embarcações (n = 13; 26,0%) foi a mais frequente. Para comportamentos específicos de adultos, foram descritas 25 etnocategorias e a mais frequente foi 'brincar' (n = 13; 18,1%). Quatro etnocategorias foram descritas para infantes (n = 18) e estão relacionadas à alimentação/amamentação (n = 15; 83,3%) e à vocalização/eventos de interação com a fêmea adulta (n = 3; 16,7%). A partir das experiências empíricas proporcionadas pela prática pesqueira artesanal, os entrevistados foram capazes de reconhecer a espécie, distinguir indivíduos adultos e infantes e descrever suas principais características comportamentais.

**Palavras-chave:** Cetáceos. Comportamento. Conhecimento ecológico local. Estado de Santa Catarina.

**Abstract:** The aim of this study is to characterize the local knowledge displayed by the fishermen at Garopaba Municipality, Santa Catarina state, Brazil, regarding the behavior of Southern Right Whale, *Eubalaena australis*, in the region of the Southern Right Whale Area of Environmental Protection (AEP). In October of 2010 there were performed 33 interviews with local fishermen and found that 81.8% (n = 27) of the interviewed were able to identify the species by its area of occurrence, coloration, and body size. The analyses were based on interviews of 27 selected fishermen. Were described 10 common behavioral ethnocategories adults and infants, in which the most frequent was 'do nothing' to vessels (n = 13; 26.0%). For the specific behaviors of the adult were described 25 ethnocategories (n = 72) and the most frequent was 'playing' (n = 13, 18.1%). Four ethnocategories been described for infants (n = 18) and are relate to feeding/breastfeeding (n = 15, 83.3%) and the calling/interaction events with the adult female (n = 3, 16.7%). From the empirical offered by artisanal fishing, the interviewed were able to recognize the species, to distinguish between adults and infants and to describe its main behavioral characteristics.

**Keywords:** Cetacean. Behavior. Local traditional knowledge. Santa Catarina state.

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ZAPPES, C. A., M. L. DANIELSKI & A. P. M. DI BENEDITTO, 2020. Etnoecologia comportamental da baleia-franca-austral *Eubalaena australis* (Desmoulins, 1822) por meio do conhecimento ecológico local de pescadores artesanais na Área de Proteção Ambiental da Baleia Franca, Sul do Brasil. **Boletim do Museu Paraense Emílio Goeldi. Ciências Naturais** 15(3): 601-616. DOI: http://doi.org/10.46357/bcnaturais.v15i3.183.

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Recebido em 05/09/2019
Aprovado em 08/09/2020
Responsabilidade editorial: Alexandra Maria Ramos Bezerra

## INTRODUÇÃO

A Etnociência é o estudo do conhecimento de populações humanas sobre o mundo natural, as taxonomias e classificações. Esta ciência descreve práticas e crenças de comunidades tradicionais e pode, ainda, realizar comparações entre o conhecimento praticado pelas comunidades humanas e o descrito pelo meio acadêmico (Farias & Alves, 2007; Roué, 2000). O termo Etnoecologia permite a integração entre o saber acadêmico e o saber social na área da Ecologia, já que é uma ciência voltada para o estudo do conhecimento dos grupos tradicionais, bem como suas práticas e crenças em relação ao ecossistema (Diegues, 2000). A partir dessa proposta, pesquisadores que estudam a Etnoecologia trabalham com pescadores artesanais, a fim de compreender o modo como estes atores se relacionam com o ambiente (Diegues, 2000).

Pescadores artesanais são definidos como um grupo tradicional que utiliza a mão de obra familiar durante a prática da pesca e cuja subsistência é baseada nesta atividade (Diegues, 2002). Essas comunidades apresentam vasto conhecimento pesqueiro empírico, já que exploram hábitats costeiros e de águas interiores há várias gerações. Esses atores locais, por meio de suas observações, são capazes de fornecer informações relevantes sobre a biologia e a ecologia das espécies que se distribuem nos campos de pesca (Costa-Neto, 2000). O conhecimento ecológico local (CEL) pode ser definido como aquele adquirido por uma comunidade por meio do contato do homem com o ambiente, sendo transmitido ao longo de gerações (Berkes, 1999; Clauzet *et al*., 2005).

No município de Garopaba, litoral do estado de Santa Catarina (SC), Sul do Brasil, a pesca artesanal é importante na economia das populações tradicionais. Parte deste município está inserida na Área de Proteção Ambiental (APA) da Baleia Franca e há sobreposição sazonal de áreas de uso entre os pescadores artesanais e as baleias-francas-austrais *Eubalaena australis* (Desmoulins, 1822) (IWC/Brasil, 1999). Essa espécie se distribui no Hemisfério Sul, entre 20º S e 64º S (IWC/Brasil, 1999; Jefferson *et al*., 2015), e na região de Garopaba é registrada uma população semirresidente nos meses de inverno e na primavera (julho a novembro). Neste período, as baleias migram para o litoral da América do Sul para o nascimento e a amamentação dos filhotes, assim como para a atividade reprodutiva (Danielski, 2008; Groch, 2000; Jefferson *et al*., 2015). Nos últimos quinze anos, o número de baleias que migram sazonalmente para o litoral do país tem aumentado a cada ano (Groch *et al*., 2005).

Interações entre a pesca artesanal e a baleia-franca-austral são descritas por pescadores, as quais indicam conflitos entre a espécie e a atividade pesqueira, como colisões com embarcações e captura acidental por redes de pesca, que causam ferimentos aos animais e danos aos petrechos de pesca (Zappes *et al*., 2013a, 2013b). Ainda, a cada estação de migração da baleia-franca-austral para a costa brasileira, aumentam as avistagens desses organismos pelos pescadores, já que as rotas das baleias coincidem com as principais áreas de pesca artesanal (Bueloni, 2012; Zappes *et al*., 2013a, 2013b).

Apesar destas informações, estudos relacionados ao conhecimento ecológico local de pescadores artesanais sobre baleias são escassos e ainda incipientes no litoral brasileiro (Bueloni, 2012; Zappes *et al*., 2013a, 2013b), o que indica a necessidade da realização de trabalhos que envolvam esta questão. Compreender a etnoecologia de cetáceos marinhos pode facilitar o diálogo e a integração entre os conhecimentos tradicional e científico e, desta forma, aplicar medidas eficazes para a conservação dessas espécies, por meio da cogestão da pesca artesanal (Huntington *et al*., 2002; Zappes *et al*., 2016).

O presente estudo descreve, pela primeira vez para a espécie, o etnoconhecimento dos pescadores artesanais sobre os comportamentos exibidos pela baleia-franca-austral na APA da Baleia Franca e compara as informações obtidas com dados da literatura, de modo a avaliar o conhecimento ecológico local desta comunidade.

## MATERIAL E MÉTODOS

### ÁREA DE ESTUDO

O município de Garopaba (28° 01' S, 48° 36' O), localizado no litoral do estado de Santa Catarina (SC), Brasil, apresenta área costeira de 108 km² e está inserido na APA da Baleia Franca (Figura 1). Nesta região está sediada a Colônia de Pescadores Z-12, que reúne 11 núcleos pesqueiros em atividade (Rebouças, 2008). Os núcleos são frequentados por pescadores das comunidades de Garopaba e dos municípios vizinhos, com 1.500 pescadores cadastrados (Capellesso & Cazella, 2011), sendo que nas comunidades da Praia de Gamboa existem 30 pescadores registrados, e da Praia de Garopaba, 50 registrados.

### PROCEDIMENTOS

As informações foram obtidas em outubro de 2010, a partir de 33 entrevistas etnográficas realizadas nas comunidades de Gamboa (n = 14) e Garopaba (n = 19). Estudos relacionados à Etnociência indicam que o tamanho ideal de amostragem varia de 30 a 60 entrevistas (Bernard, 2000; Mason, 2010; Morse, 1994). O número de entrevistas aplicadas no presente trabalho justifica-se pelo fato de que, em cada embarcação, trabalham de dois a quatro pescadores, os quais podem atuar em mais de uma embarcação; além disso, a partir da décima entrevista houve o mesmo padrão de resposta entre os pescadores (ponto de saturação) (Thiry-Cherques, 2009).

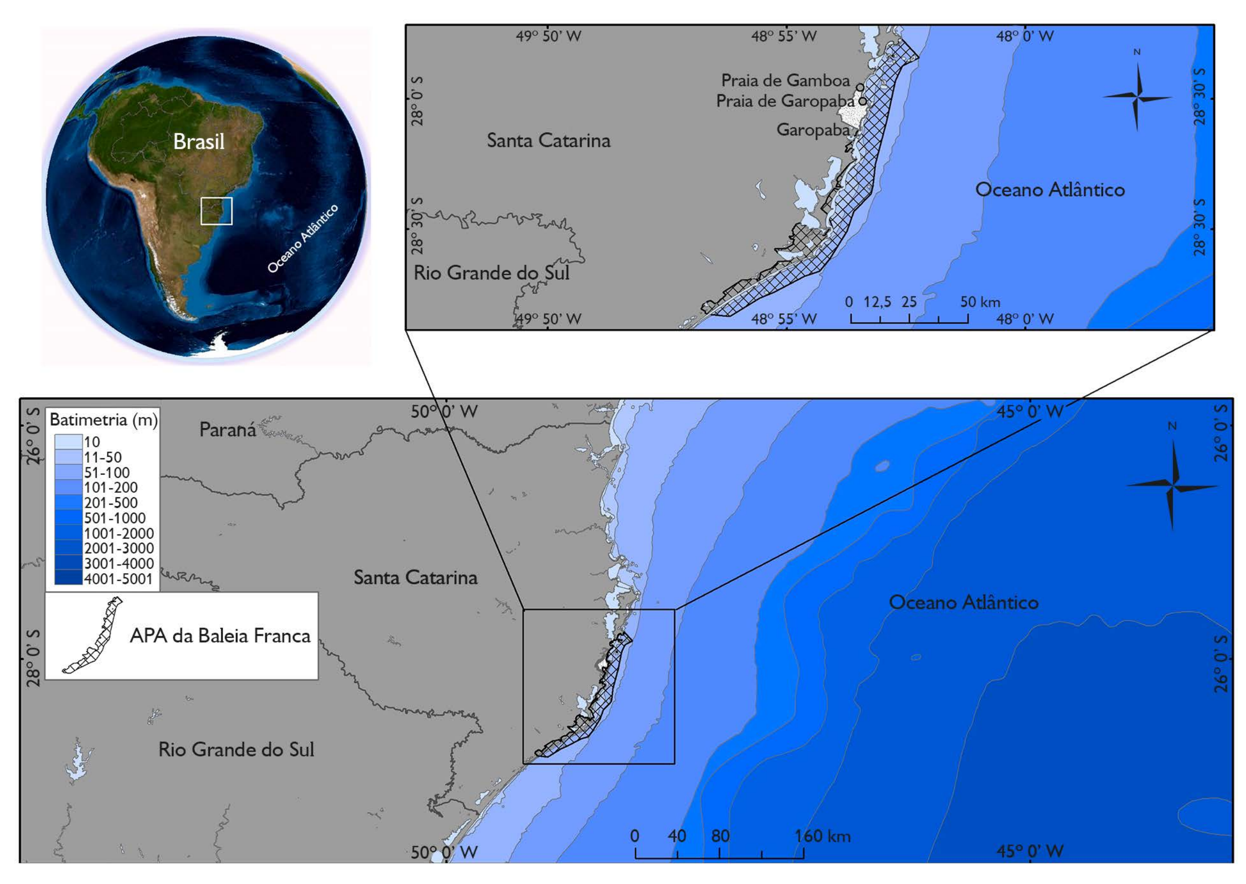

Figura 1. Localização da Área de Preservação Ambiental (APA) da Baleia Franca e do município de Garopaba (área delimitada em branco no mapa menor, detalhado), estado de Santa Catarina, Sul do Brasil. Mapa: Sérgio Carvalho Moreira (2019).

As entrevistas foram orientadas por um questionário-padrão previamente elaborado (Schensul *et al*., 1999) com questões semiestruturadas abertas (n = 49) e fechadas (n = 19). Antes de cada entrevista, foram explicados os objetivos do estudo e fornecida a garantia de preservação da identidade a cada entrevistado (Librett & Perrone, 2010). Apenas o primeiro nome do pescador era solicitado pelo pesquisador, de modo a facilitar a comunicação. O projeto também foi cadastrado no Sistema de Gestão Nacional do Patrimônio Genético e do Conhecimento Tradicional Associado (SISGEN) (número do cadastro AE2CAEC) e recebeu anuência para sua realização do representante legal dos entrevistados, que é o presidente da Colônias de Pescadores Z-12 (Brasil, 2015).

Todas as entrevistas foram conduzidas por meio de diálogos (entrevista 'pessoal' ou 'face a face'), em formato de pergunta-resposta, a fim de gerar confiança entre entrevistador e entrevistado e aumentar a confiabilidade dos dados (Zappes *et al*., 2011a). O estabelecimento de diálogo entre pesquisador e entrevistado garante a liberdade do informante durante os relatos e desenvolve uma visão compartilhada da realidade local (Kvale, 1996). O questionário foi dividido nas seguintes categorias: (1) perfil dos entrevistados (sexo, idade, período de atuação na pesca); (2) descrição da atividade pesqueira (tecnologia dos artefatos, embarcações e espécies-alvo) (Begossi, 2001); (3) e características morfológicas e comportamentais da espécie em estudo, no caso a baleia-franca-austral *E. australis* (Tabela 1). Inicialmente, as perguntas se relacionaram às baleias adultas e, posteriormente, aos indivíduos infantes (neonatos e juvenis). A fim de distinguir indivíduos adultos de infantes, os pescadores informaram que 'adulto' apresentava maior tamanho corporal quando comparado ao infante, além de descreverem que 'infantes' não apresentam todas as calosidades no dorso. Deste modo, foi possível que os entrevistados descrevessem com clareza cada uma das duas faixas etárias abordadas. Algumas perguntas tiveram respostas fechadas, seguidas de uma justificativa ou explicação aberta para que o entrevistado pudesse expor o seu raciocínio.

Para o primeiro contato com o presidente da Colônia de Pescadores Z-12, foi utilizada uma agente intermediária, que desempenhou a função de guia durante o trabalho de campo (Santos, 2006). A seleção do primeiro entrevistado ocorreu por meio do auxílio do presidente da instituição de pesca, já que, geralmente, é aquele que melhor conhece os demais (Sanches, 2004). O método bola-de-neve, ou método de rede, foi empregado a partir da segunda entrevista, em que foi solicitado a cada entrevistado que indicasse outro potencial entrevistado (Bailey, 1994; Biernacki & Waldorf, 1981). Ainda, era aplicada a aleatoriedade, por meio de encontros oportunísticos com os pescadores (Paes & Zappes, 2016).

Os termos utilizados no questionário (Anexo 1) estavam em conformidade com o vocabulário usual dos entrevistados, a fim de evitar dúvida sobre as questões formuladas. A equipe se apresentou como membro de instituição de ensino e pesquisa, para não haver associação com autoridades ou órgãos de fiscalização. Todos os pescadores entrevistados foram escolhidos por meio dos seguintes critérios: (1) ser pescador artesanal; (2) ter a pesca

Tabela 1. Tópicos das questões abordadas no questionário semiestruturado.

| 1. Perfil dos entrevistados |
|---|
| Sexo |
| Idade |
| Período de atuação na pesca |
| 2. Descrição da atividade pesqueira artesanal |
| Tecnologia dos artefatos |
| Embarcações (comprimento e potência do motor) |
| Espécies-alvo |
| 3. Características de *Eubalaena australis* |
| Comprimento corporal |
| Coloração |
| Área de ocorrência<br>Ecologia comportamental |

como principal atividade econômica; (3) praticar a pesca artesanal na APA da Baleia Franca. Para evitar a interferência de um informante sobre os outros, cada entrevista foi conduzida em caráter individual (Zappes *et al*., 2013a, 2013b). Ao final de cada entrevista, foi apresentada ao entrevistado uma prancha ilustrativa (Anexo 2) contendo fotos de espécies de cetáceos com registro na região e que são classificadas pela cultura popular como 'baleias' [A - orca (*Orcinus orca* Linnaeus, 1758), B - baleia-franca-austral (*E. australis*), C - baleia-de-bryde (*Balaenoptera edeni* Anderson, 1879), D - baleia-jubarte (*Megaptera novaeangliae* Borowski, 1871)]. A estimulação visual ajuda na análise dos relatos e facilita a identificação das espécies pelos entrevistados (Miranda *et al*., 2007).

Após as entrevistas, as informações foram agrupadas por categorias de temas, para esclarecer a relação entre a linguagem e a interação social, por meio da aplicação da análise do discurso para o desenvolvimento da percepção dos pescadores sobre os comportamentos da baleia-franca-austral (Rocha & Deusdará, 2005). A certeza do reconhecimento da espécie por parte dos entrevistados foi obtida por meio da seleção dos relatos que estavam de acordo com o padrão de distribuição da espécie na região (indivíduos avistados entre 100 e 1.500 m da costa e grupos de fêmeas com filhotes avistados após a arrebentação, em profundidades de 5 a 10 m) (Bottini, 2014; Groch, 2000; Payne, 1986), coloração do corpo (preta com manchas brancas e presença de calosidades na cabeça), comprimento corporal máximo (17 m) e comportamento descrito na literatura (Jefferson *et al*., 2015). Para as análises, foram considerados somente os relatos dos pescadores que identificaram a espécie por meio das características ora indicadas.

## RESULTADOS E DISCUSSÃO

Dos 33 pescadores entrevistados, 27 (82%) identificaram a baleia que ocorre na região como pertencente à espécie *E. australis* – Praia de Gamboa (n = 10) e Praia de Garopaba (n = 17) –, sendo que os relatos destes pescadores referentes ao item 3 da Tabela 1 coincidiram com as características descritas pela literatura para a espécie. Desta forma, os dados fornecidos pelos pescadores mostram-se confiáveis, ao serem comparados com a literatura sobre essa espécie. A categoria 'ecologia comportamental' foi descrita com menor grau de coincidência, provavelmente devido à complexidade em se observar a etologia de grandes baleias que pouco emergem para a superfície da água. O conhecimento empírico sobre os cetáceos adquirido por comunidades pesqueiras, por meio da prática da pesca artesanal, também foi abordado em alguns estudos ao longo da costa do Brasil. Os resultados revelaram que pescadores artesanais são capazes de identificar as espécies que se distribuem nos seus campos de pesca preferenciais (Souza & Begossi, 2007; Freitas-Netto & Di Beneditto, 2008; Zappes *et al*., 2011a, 2011b, 2013a, 2013b, 2016).

## PERFIL DOS ENTREVISTADOS

Os pescadores selecionados, todos do sexo masculino, apresentaram idade entre 24 e 94 anos, e a faixa etária mais frequente para as duas áreas foi entre 41 e 60 anos. Em relação ao tempo de pesca na região, as respostas foram: 14 trabalham entre 11 e 30 anos (52%), nove há mais de 31 anos (33%) e quatro até dez anos (15%). Para a escolaridade, 15 entrevistados (56%) responderam ter cursado apenas o Ensino Fundamental, oito (30%) o Ensino Médio, dois (7%) o Ensino Superior e dois (7%) relataram não ter estudado. Tais características são semelhantes entre outras comunidades de pescadores artesanais localizadas no Brasil (Alencar & Maia, 2011; Oliveira *et al*., 2016; Silva, C. *et al*., 2014; Zappes *et al*., 2016). Devido ao fato de a pesca artesanal permitir o sustento imediato da família, pescadores se dedicam a esta atividade, cuja rotina dificulta a dedicação aos estudos (Silva, C. *et al*., 2014). Dessa forma, há o abandono da escola por estes trabalhadores, o que afeta sua situação socioeconômica e, ainda, pode interferir na capacidade de organização da colônia e em associações de pescadores (Silva, M. *et al*., 2007).

## DESCRIÇÃO DA ATIVIDADE PESQUEIRA ARTESANAL

Os artefatos de pesca utilizados são a rede de espera/caceio (n = 21, 88,9%), espinhel (n = 14, 51,9%), rede de arrastão de praia (n = 5, 18,5%), tarrafa (n = 4, 14,8%), rede de arrasto/rede de camarão (n = 1, 3,7%) e rede de cerco (n = 1, 3,7%). Com relação às embarcações, um entrevistado (3,7%) relatou utilizar mais de um tipo de barco (barco de arrasto, bateira e canoa). Treze pescadores (48,1%) utilizam a bateira, que pode medir entre 7,5 e 15 m de comprimento e com potência do motor variando de 24 a 250 HP; canoa (n = 4, 14,8%), que varia de 6 a 10 m de comprimento; baleeira (n = 2, 7,4%), que varia entre 9 e 14 m de comprimento, com motor entre 24 e 115 HP; lancha (n = 1, 3,7%), com 9 m de comprimento e motor de 24 HP; e bote (n = 1, 3,7%), com 8 m de comprimento e motor entre 25 e 45 HP. Dois pescadores (7,4%) relataram pescar andando pela orla da praia e cinco (18,5%) não souberam identificar o tipo de embarcação utilizada na pescaria. Os dois pescadores que atuam na orla já tiveram experiência de prática de pesca embarcados, por isso identificaram a baleia-franca-austral como *E. australis.*

## CARACTERÍSTICAS DA *EUBALEANA AUSTRALIS* E COMPORTAMENTOS COMUNS A INDIVÍDUOS ADULTOS E INFANTES

Os comportamentos descritos para *E. australis* se relacionaram àqueles exibidos durante o dia e a noite, durante a alimentação, a vocalização e frente às embarcações. A ordenação em etnocategorias considerou as classes de maturidade 'adultos e infantes' (Tabela 2), 'adultos' (Tabela 3) e 'infantes' (Tabela 4). Durante a entrevista, o mesmo pescador descreveu mais de um comportamento para cada uma destas questões, o que explica o número de relatos maior do que o número de entrevistados.

Os pescadores descreveram dez etnocategorias comportamentais comuns a ambas as classes de maturidade (n = 50) que se relacionaram às categorias reportadas pela literatura como pertencentes a alimentação, respiração, vocalização/eventos de

Tabela 2. Etnocategorias comportamentais comuns aos indivíduos adultos e infantes de *Eubalaena australis* descritas pelos pescadores do município de Garopaba, Santa Catarina, e comparação com dados da literatura. Etnoclassificação de comportamento: A = exibido durante a alimentação, V = exibido durante a vocalização, E = frente a embarcações; classe de maturidade: A = adulto, I = infante; categorias comportamentais descritas na literatura: 1 = IWC/Brasil (1999), 2 = Jefferson *et al*. (2015), 3 = Clark (1983), 4 = Elwen & Best (2004), 5 = Groch (2005), 6 = Lundquist (2007), 7 = Danielski (2008), 8 = Dombroski *et al.* (2016).

| Etnocategorias comportamentais | Etnoclassificação | Classe de maturidade | Número de relatos | Categorias comportamentais descritas na literatura |
|---|---|---|---|---|
| Segue o cardume, abre a boca e come um peixe por vez | A | A/I | 5 | Alimentação[1, 2] |
| Assobiar | V | A/I | 2 | Respiração[1] |
| Respirar | V | A/I | 3 | |
| Gritar | V | A/I | 3 | Vocalização/eventos de interação (repertório acústico)[3, 4, 8] |
| Berrar | V | A/I | 9 | |
| Não faz nada | E | A/I | 13 | Desinteresse, indiferença[5, 6] |
| Afastar | E | A/I | 6 | Afastamento[1, 5] |
| Se o motor estiver ligado, foge | E | A/I | 3 | |
| Quando chega perto do barco, afunda | E | A/I | 3 | Imersão e posterior emersão[5] |
| Se aproxima da embarcação | E | A/I | 3 | Aproximação à embarcação[5, 6, 7] |

interação, desinteresse/indiferença, afastamento, imersão e posterior emersão e aproximação à embarcação (Tabela 2). A etnocategoria 'não faz nada' foi relatada com maior frequência (n = 13, 26,0%) e se inseria na questão referente aos comportamentos exibidos pela baleia frente à embarcação.

Tabela 3. Etnocategorias comportamentais exclusivas de indivíduos adultos de *Eubalaena australis* descritas pelos pescadores do município de Garopaba, Santa Catarina, e comparação com dados da literatura. Etnoclassificação de comportamento: D = exibido durante o dia, N = exibido durante a noite, A = exibido durante a alimentação, V = exibido durante a vocalização; classe de maturidade: A = adulto; categorias comportamentais descritas na literatura: 1 = Groch (2000), 2 = Danielski (2008), 3 = Thomas & Taber (1984), 4 = IWC/Brasil (1999), 5 = Lyamin *et al*. (2007), 6 = Groch (2005), 7 = Payne (1986), 8 = Clutton-Brock (1991), 9 = Jefferson *et al*. (2015), 10 = Clark (1983), 11 = Ford & Kraus (1992) e 12 = Dombroski *et al*. (2016).

| Etnocategorias comportamentais | Etnoclassificação | Classe de maturidade | Número de relatos | Categorias comportamentais descritas na literatura |
|---|---|---|---|---|
| Nadar | D/N | A | 6 | Deslocamento/natação[1, 2] |
| Passear | D/N | A | 7 | |
| Viajar | N | A | 2 | Viajar (migração)[3, 4] |
| Mergulhar | D/N | A | 2 | Mergulho/não definido[4] |
| Ficar parada | D/N | A | 4 | Repouso[1, 2, 3, 5] |
| Descansar | D/N | A | 2 | |
| Dormir | D/N | A | 3 | Dormir/sono/deslocamento lento[2, 4] |
| Aconchegar com o filhote no litoral | D | A | 1 | Área de reprodução/área de preferência[1, 4, 6, 11] |
| Vir procriar | D | A | 1 | |
| Cuidar e ensinar a cria | D/N | A | 2 | Aprendizado e desenvolvimento do filhote/imitação do comportamento das mães pelo filhote[2, 3, 7] |
| Pular | D/N | A | 4 | Comportamento aéreo/exibição/brincadeiras[1, 2, 3, 4] |
| Brincar | D/N/V | A | 13 | |
| Colocar a nadadeira para fora | D | A | 1 | |
| Bater a cauda | N | A | 2 | |
| Comer | D/N | A | 3 | Alimentação[4, 8] |
| Mergulhar e dar o bote | A | A | 1 | |
| Encher a boca d'água, soltar a água pela barbatana, a comida fica presa na barbatana | A | A | 3 | |
| Embocar o cardume | A | A | 6 | |
| Gemer | V | A | 2 | Vocalização/eventos de interação[9, 10, 12] |
| Comunicar-se com o filhote e com os outros | V | A | 2 | |
| Assoprar | V | A | 1 | Respiração[4] |
| Suspirar | V | A | 1 | |
| Apitar | V | A | 1 | |
| Levantar a cabeça para emitir som | V | A | 1 | |
| Jogar os animais para cima e os agarrar com a boca | A | A | 1 | Não encontrado registro na literatura |

Tabela 4. Etnocategorias comportamentais exclusivas de indivíduos infantes de *Eubalaena australis* descritas pelos pescadores do município de Garopaba, Santa Catarina, e comparação com dados da literatura. Etnoclassificação de comportamento: A = exibido durante a alimentação, V = exibido durante a vocalização; classe de maturidade: I = infante; categorias comportamentais descritas na literatura: 1 = Clark (1983), 2 = Elwen & Best (2004), 3 = Thomas & Taber (1984), 4 = IWC/Brasil (1999) e 5 = Dombroski *et al.* (2016).

| Etnocategorias comportamentais | Etnoclassificação | Classe de maturidade | Número de relatos | Categorias comportamentais descritas na literatura |
|---|---|---|---|---|
| Chama a mãe para perto | V | I | 3 | Eventos de interação[1, 2, 5] |
| Pega o leite que é solto na água | A | I | 8 | |
| Bate na baleia e ela solta o leite na água | A | I | 2 | Amamentação[3, 4] |
| Suga o leite com a boca | A | I | 5 | |

Na Península de Valdés, Argentina, foram realizados testes com embarcações de observação de baleias em geral, indicando que esses organismos podem assumir diferentes comportamentos em relação às embarcações, como evitar a aproximação, ser indiferentes à sua presença ou, em alguns casos, nadar em direção aos barcos (Lundquist, 2007). Groch (2005) aponta que o comportamento de indiferença da baleia-franca-austral em relação à embarcação pode estar relacionado com a propagação do som das embarcações nas enseadas, o que poderia inibir suas atividades.

Oito pescadores descreveram características humanas para a baleia como: mansa (n = 3, 37,5%), dócil (n = 3, 37,5%), curiosa (n = 1, 12,5%) e sensível (n = 1, 12,5%). A atribuição das características 'mansa' e 'dócil' pode se relacionar ao seu comportamento de natação lenta na superfície por longos períodos (Danielski, 2008; Groch, 2000), onde raramente executa comportamentos aéreos. A característica 'curiosa' pode se relacionar aos infantes que se aproximam da embarcação, e 'sensível', por perceber de longe a presença de embarcações. Relatos de características humanas para os cetáceos são apontados em outros estudos etnobiológicos envolvendo comunidades de pescadores artesanais no litoral brasileiro. Zappes (2007) relata a atribuição da característica 'manso' para o boto-cinza [*Sotalia guianensis* (van Bénéden, 1864)], na costa nordeste e sudeste, e Zappes *et al*. (2016) descrevem a mesma característica para a toninha (*Pontoporia blainvillei* Gervais & D'Orbigny, 1844), no Complexo Estuarino de Paranaguá, estado do Paraná, Sul do Brasil. Peterson *et al*. (2008) e Zappes *et al.* (2011a), em estudos realizados em Laguna, em Santa Catarina, e Imbé/Tramandaí, no estado do Rio Grande do Sul, registraram relatos de características antropomórficas para o golfinho-nariz-de-garrafa (*Tursiops truncatus* Montagu, 1821). O antropomorfismo de comportamentos de baleia-franca-austral faz com que pescadores percebam 'qualidades' nestes animais, tornando as baleias carismáticas, o que, consequentemente, pode reduzir possíveis conflitos entre a pesca artesanal e os cetáceos.

## COMPORTAMENTOS EXCLUSIVOS DE INDIVÍDUOS ADULTOS

Um total de 25 etnocategorias comportamentais foi descrito para indivíduos adultos de baleia-franca-austral (n = 72). A categoria 'brincar' (n = 13, 18,1%), com a maior frequência de relatos, está relacionada aos períodos diurno e noturno e com a vocalização dos animais (Tabela 3). O termo 'brincar' é reportado na literatura para *E. australis*, a fim de caracterizar atividades realizadas entre mães e filhotes, em que o adulto exibe vários padrões comportamentais, desde boiar na superfície com o ventre parcialmente exposto até saltos e batidas de nadadeira caudal. Estes comportamentos podem ter significado social (aprendizado do filhote) e fisiológico (fortalecimento dos músculos para movimentos migratórios) (Groch, 2000; IWC/Brasil, 1999; Thomas & Taber, 1984).

Para os comportamentos exibidos durante o período noturno, as etnocategorias 'brincar' (n = 3, 13,6%) e 'passear' (n = 3, 13,6%) foram as mais relatadas. Durante a noite, torna-se difícil visualizar os animais e, dessa forma, ao ouvirem os ruídos produzidos pela movimentação das baleias na água, os pescadores provavelmente fazem associação com os sons produzidos durante o dia, a partir de atividades de brincadeira ou deslocamento. O etnocomportamento 'passear' está relacionado à natação do animal, que pode ser observada pelos pescadores quando a baleia emerge. Baleias-francas-austrais, durante a época de reprodução e nascimento dos filhotes, migram para águas costeiras e calmas, executando movimentos lentos na superfície, com menor gasto de energia (Elwen & Best, 2004; Payne, 1986).

Entre os entrevistados que identificaram *E. australis*, 26 relataram ouvir a vocalização dos animais. Os sons foram classificados pelos pescadores em 11 etnocategorias (n = 20) e o comportamento mais frequente foi 'berrar' (n = 6, 30%). Além disso, foram identificados os seguintes comportamentos de vocalização: 'levantar a cabeça para emitir som' (n = 2), 'gritar' (n = 2), 'assoprar' (n = 1), 'suspirar' (n = 1), 'apitar' (n = 1), 'assobiar' (n = 1) e 'respirar' (n = 1). Vocalização de baleias tem sido amplamente estudada nos últimos anos (Dombroski *et al*., 2016, 2017; Hofmeyr-Juritz, 2010; Parks & Tyack, 2005; Parks *et al*., 2011; Tyack & Clark, 2000), entretanto, devido à dificuldade de se observar o comportamento do animal no momento em que vocaliza, pouco se sabe sobre a relação desses sons com suas atividades (Dombroski *et al*., 2016, 2017; Parks *et al*., 2011).

Quanto aos eventos 'levantar a cabeça para emitir som', 'assoprar', 'suspirar', 'apitar', 'assobiar', 'respirar' e 'gritar', estes parecem estar mais associados com a atividade respiratória da espécie do que com a comunicação propriamente dita. Ao emergir para respirar, *E. australis* produz um 'esguicho' ou 'borrifo' em formato de 'V', que pode atingir de 5 a 8 m de atura, resultante do ar quente expelido e da vaporização de gotículas de água contidas nos dois orifícios respiratórios (Jefferson *et al*., 2015). O som provocado pelo ar expelido pode ser ouvido a centenas de metros, o que justifica os relatos desses eventos serem descritos pelos pescadores como pertencentes à vocalização.

Para a questão relacionada com a alimentação, foram descritas quatro etnocategorias (n = 11), entre as quais 'embocar o cardume' (n = 6, 54,5%) foi a mais frequente. A alimentação das baleias-francas-austrais nas regiões subpolares é constituída de zooplânctons, principalmente de pequenos copépodes e eufausídeos (Goodall & Galeazzi, 1986; IWC/Brasil, 1999; Jefferson *et al*., 2015; Moore *et al*., 1999). Entretanto, não há registro de atividade alimentar da espécie, ao migrar para áreas de baixas latitudes relacionadas à reprodução, como a APA da Baleia Franca. O fato de os pescadores de Garopaba e Gamboa relatarem a ocorrência da alimentação da baleia-franca-austral para a costa do estado de Santa Catarina pode ser justificado pela observação do comportamento de superfície, na qual a baleia abre a boca. Este comportamento, apesar de ser pouco comum em áreas costeiras de reprodução, está relacionado com a termorregulação corporal, e não com a alimentação (Ford & Kraus, 1992).

## COMPORTAMENTOS EXCLUSIVOS DE INDIVÍDUOS INFANTES

Quando questionados sobre os indivíduos infantes, os pescadores relataram quatro etnocategorias comportamentais (n = 18), duas relacionadas à alimentação/amamentação (n = 15, 83,3%) e duas à vocalização com eventos de interação (n = 3, 16,7%) (Tabela 4). Para alimentação, foi descrito principalmente 'pegar o leite que é solto na água' (n = 8, 53,3 %) e, para vocalização, 'chamar a mãe para perto' (n = 3, 100%).

Todas as etnocategorias referentes à alimentação do filhote se relacionavam à amamentação. O comportamento 'pegar o leite que é solto na água' pode ter sido presenciado pelos pescadores durante a pesca, já que a APA da Baleia Franca é uma das áreas de amamentação da espécie. Durante a amamentação, o leite é ejetado, por músculos da região mamária, direto das glândulas mamárias da mãe para dentro da boca do filhote. Este comportamento é repetido ao longo de todo o dia, supondo que o filhote mergulha a curtos intervalos para mamar (Thomas & Taber, 1984). Os pescadores identificam a baleia-franca-austral como pertencente ao grupo dos mamíferos, podendo compará-la ao comportamento de amamentação em humanos.

Em relação à vocalização entre infantes e adultos, sabe-se que pares de mães e filhotes utilizam sons na faixa entre 100 e 200 Hz para manter contato, mesmo em curtas distâncias (Clark, 1983). Além disso, os filhotes passam a maior parte do tempo das primeiras semanas de vida na companhia das fêmeas, em áreas costeiras e de pouca profundidade (Elwen & Best, 2004). A proximidade da linha de costa permite aos pescadores visualizar grupos formados por fêmeas e filhotes. Por meio da prática diária da atividade de pesca artesanal na APA da Baleia Franca, os entrevistados percebem que o contato do infante com a mãe é intenso. Estas observações permitiram a elaboração de um conhecimento ecológico local sobre o comportamento de vocalização entre mãe e filhote, no qual a emissão de sons pelo último tem a função 'chamar a mãe'.

Neste estudo, foi possível verificar semelhança entre os conhecimentos dos pescadores e a literatura em relação ao comportamento da baleia-franca-austral. Assim, o conhecimento etnoecológico se confirma como uma ferramenta de geração de dados sobre a população de *E. australis* que ocorre na APA da Baleia Franca. Desta forma, a compreensão e a valorização deste saber local de pescadores artesanais sobre cetáceos potencializam o incremento de ações de conservação ao longo das áreas de distribuição das espécies (Zappes *et al*., 2013b). Ainda, devido ao aumento da população de baleia-franca-austral que migra anualmente para o litoral do estado de Santa Catarina, é importante a continuidade de estudos voltados ao conhecimento ecológico local, auxiliando a prevenção de possíveis impactos antrópicos sobre a espécie na região. A aproximação de órgãos de pesquisa com a comunidade pesqueira poderá auxiliar na elaboração de estratégias para o manejo da pesca artesanal na região e no estabelecimento de diretrizes para planos de gestão comunitária nessa APA, visando à manutenção da população da espécie no sítio de reprodução do Atlântico Sul e a continuidade da atividade pesqueira.

## AGRADECIMENTOS

Agradecemos ao presidente do Sindicato dos Pescadores de Garopaba (Z-12), a todos os pescadores entrevistados, a S. C. Moreira, pela elaboração do mapa, aos pesquisadores do Instituto Baleia Franca, em especial a M. Pontalti e C.V. da Silva, pelo apoio logístico durante a etapa de campo, a L. Lodi, A. Zerbini e A. Andriolo (Projeto Monitoramento de Baleias por Satélite), pelas imagens da prancha. Dois revisores anônimos contribuíram com comentários e sugestões para o manuscrito. CAZ agradece à Fundação Carlos Chagas Filho de Amparo à Pesquisa do Estado do Rio de Janeiro (FAPERJ E-26/203.202/2016; E-26/202.789/2019) e ao Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq 400053/2016-0) e APMDB, à FAPERJ (E-26/202.770/2017 e E-26/210.064/2018) e ao CNPq (301.259/2017-8), pelo fomento e pela bolsa de pesquisa.

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Anexo 1. Questionário semiestruturado aplicado aos pescadores. (Continua)

### 1. Perfil dos entrevistados

Local
Data
Nome do entrevistado
Idade do entrevistado
Sexo do entrevistado
Escolaridade
Tempo de pesca
Tempo de pesca na região estudada
Autonomia/mar (dias/embarque)

### 2. Descrição da atividade pesqueira artesanal

Tipo de embarcação e capacidade
Potência do motor
Comprimento/embarcação
Horário da pesca
Local da pesca

Artefatos

*Tipo de rede*
Tamanho da malha
Altura e comprimento
Profundidade em que é armada na água
Época do ano em que utiliza o artefato
Horário em que é armada na água
Horário em que é retirada da água
Espécies-alvo

*Espinhel*
Extensão/comprimento
Profundidade em que é lançado
Época do ano em que utiliza o artefato
Horário em que é lançado na água
Horário em que é retirado da água
Espécies-alvo

*Informações sobre outros artefatos*

### 3. Características de *Eubalaena australis*

Quais animais não alvo da pesca são possíveis de serem observados no mar?
Tem mais de um 'tipo' (espécie) de baleia? (   ) Sim (   ) Não (   ) Não respondeu
Qual baleia aparece mais?
Descreva as características desta baleia (comprimento corporal, coloração e área de ocorrência)
Qual o alimento desta baleia?
Como ela se alimenta? Como é o comportamento de alimentação?

Em qual época do ano esta baleia aparece na região?
As baleias emitem algum som? (   ) Sim (   ) Não (   ) Não respondeu
Qual o comportamento da baleia quando está emitindo som?
São avistados filhotes? (   ) Sim (   ) Não (   ) Não respondeu
Qual a época do ano em que o filhote aparece na região?
Como é o filhote?
Qual é o alimento do filhote?
Como o filhote se alimenta? Como é seu comportamento de alimentação?
Os filhotes emitem algum tipo de som? (   ) Sim (   ) Não (   ) Não respondeu

Anexo 1. (Conclusão)

Qual o comportamento do filhote quando emite som?
Baleias são avistadas: ( ) Sozinhas ( ) Grupos ( ) Não respondeu
Se em grupos, quantas baleias são avistadas?
Onde na região as baleias são mais avistadas? ( ) Mar aberto ( ) Praia ( ) Não respondeu
O que a baleia faz quando o barco se aproxima?
O que a baleia mais faz durante o dia (comportamentos)?
O que a baleia mais faz durante a noite (comportamentos)?
O que a baleia faz quando fica próxima aos artefatos (principalmente rede)?
Porque exibem este comportamento?

**4. Utilização da prancha**

Qual destes animais é a baleia? ( ) A ( ) B ( ) C ( ) D ( ) Não respondeu
Qual destas você avista? ( ) A ( ) B ( ) C ( ) D ( ) Não respondeu
Qual o nome de cada uma dessas baleias da prancha?

Anexo 2. Fotos originais utilizadas na prancha ilustrativa apresentada aos pescadores entrevistados. Espécies: A) orca (*Orcinus orca*), B) baleia-franca-austral (*Eubalaena australis*), C) baleia-de-bryde (*Balaenoptera edeni*) e D) baleia-jubarte (*Megaptera novaeangliae*).

Bol. Mus. Para. Emílio Goeldi. Cienc. Nat., Belém, v. 15, n. 3, p. 617-632, set.-dez. 2020

# Common marmosets *Callithrix jacchus* (Linnaeus, 1758) (Primates: Cebidae: Callitrichinae) in an urban mangrove: behavioral ecology and environmental influences

# Saguis-de-tufos-brancos *Callithrix jacchus* (Linnaeus, 1758) (Primates: Cebidae: Callitrichinae) em um manguezal urbano: ecologia comportamental e influências do ambiente

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**Abstract:** The common marmoset (*Callithrix jacchus*) is a primate found in urban forests and in high density of human population sites, however there is insufficient informations about its behavior in mangroves. One group of marmosets was monitored in the *Espaço Ciência* museum, in the state of Pernambuco, Northeastern Brazil, located in a mangrove area that has been deforested for years, but has a few remaining fragments. We used scan sampling and all occurrences methods for behavioral data collection, between September 2012 and February 2013. Moving was the most frequent behavior, occupying 24.4% of the behavioral repertoire and human-provided food made up 52% of their diet. The group of marmosets interacted with people, wild and domestic animals and objects introduced by humans, such as buckets and nets for collecting organic material belonging to other research projects. While the urban environment offered conditions for group establishment in the study area, the inclusion of human foods in the diet and the relation of the marmosets with various abiotic and biotic components of the landscape endanger the health and survival, and that of other animals and people involved in the interactions.

**Keywords:** Activity pattern. *Callithrix*. Diet. Urban space.

**Resumo:** O sagui-de-tufos-brancos (*Callithrix jacchus*) é um primata encontrado em florestas urbanas e em locais de alta densidade humana, mas não há informações suficientes sobre seu comportamento em áreas de manguezal. Um grupo de saguis foi monitorado no museu Espaço Ciência, no estado de Pernambuco, Nordeste do Brasil, construído em uma área de manguezais que sofreu devastações durante anos e mantém, dentro dos seus limites, um dos poucos fragmentos que restou. Para a coleta de dados comportamentais, foram utilizados os métodos varredura instantânea e todas as ocorrências, entre setembro de 2012 e fevereiro de 2013. Locomoção foi o comportamento mais frequente, ocupando 24,4% do repertório comportamental, e alimentos providos compuseram 52% da sua dieta. O grupo de saguis interagiu com pessoas, animais do manguezal, animais domésticos e com objetos inseridos por humanos, como baldes e redes para coleta de material orgânico pertencentes a outros projetos de pesquisa. Enquanto o ambiente urbano ofereceu condições para o estabelecimento do grupo na área de estudo, a inclusão de alimentos antropogênicos na dieta e a relação dos saguis com variados componentes abióticos e bióticos da paisagem colocaram em risco a saúde e a sobrevivência dos saguis, dos demais animais e das pessoas envolvidos nas interações.

**Palavras-chave:** Padrão de atividades. *Callithrix*. Dieta. Espaço urbano.

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ALBUQUERQUE, J. R. & M. A. B. OLIVEIRA, 2020. Common marmosets *Callithrix jacchus* (Linnaeus, 1758) (Primates: Cebidae: Callitrichinae) in an urban mangrove: behavioral ecology and environmental influences. **Boletim do Museu Paraense Emílio Goeldi. Ciências Naturais** 15(3): 617-632. DOI: http://doi.org/10.46357/bcnaturais.v15i3.219.

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Recebido em 01/12/2019
Aprovado em 10/11/2020
Responsabilidade editorial: Alexandra Maria Ramos Bezerra

## INTRODUCTION

The accelerated growth of urban landscapes and the ecological consequences of this growth are topics of interest and frequent research, regarding the various aspects related to environmental and human health (Bradley & Altizer, 2007; Mucelin & Bellini, 2008). Urbanization modifies the landscape, promotes physical and biological changes over time, compromises ecosystems, and causes environmental impacts such as, the reduction of natural vegetation and the home range of animals (Adams, 2005; McKinney, 2008). Humans see wild species as problems when these species occur near human activities. However, interactions with humans can affect the health of wild animals (Angelici, 2016). The presence of wild animals in urban environments is not uncommon and as such, it is likely that the increasing proximity of these animals to humans is expected. Soulsbury & White (2015) explain that wild animals and humans in urban areas inevitably interact. Yet, the nature of these interactions can vary greatly from admiration, pleasure, fear and loathing (Soulsbury & White, 2015).

Urban areas offer opportunities to study questions on anthropogenic influence on wild animals and natural processes (Parker & Nilon, 2012). From the point of view of behavioral ecology and wildlife conservation, studies on wildlife living in urban environments are relevant and have been increasing over the last few decades (Marion, 1988; Hadidian, 1992; Hadidian & Smith, 2001; Magle *et al.*, 2012; Poessel *et al*., 2017). The process of wild animals adjusting to live in urban conditions is known as synurbization (Luniak, 2004; Adams, 2005). Humans living in high densities and the type of activities they perform play an important role in determining which species are able to adjust to urban ecosystems and how this adjustment affects their behavior (Soulsbury & White, 2015). Animal behavioral responses to urbanization can be classified into three types (Goulart *et al.*, 2010): (1) animals that avoid contact or fail to thrive in urban environments; (2) urban explorers: animals living in higher densities in urban environments compared to their natural environments, and (3) urban adapters: animals living in the same densities in both their urban and natural environments.

Several species can survive in environments that suffer from anthropic disturbance. Important adjustments for the successful establishment of these animals in urban environments include anthropogenic foods in their diet, animals may increase their circadian activity and/or decrease the constancy of their migratory behavior (Lowry *et al.*, 2013). These adjustments can result in behavioral changes, allowing for better interactions with the environment and among conspecifics (Jokimäki *et al.*, 2011). This is the case of the common marmoset *Callithrix jacchus* (Linnaeus, 1758), a Neotropical primate commonly found in Brazilian urban areas within parks, gardens, yards, and villages (Rangel *et al.*, 2011; Silva, G. *et al.*, 2011; Albuquerque *et al.*, 2012; Silva, J. *et al.*, 2014).

*Callithrix jacchus* is native in Northeastern Brazil, occurring in the Caatinga, Atlantic Forest, Cerrado and associated habitats such as mangrove forests (Silva, G. & Monteiro da Cruz, 1993; Paula *et al*., 2005; Rylands *et al*., 2009; Rylands & Mittermeier, 2013). In Southeastern Brazil, the species was introduced as a result of animal trafficking (Ruiz-Miranda *et al.*, 2000; Rangel *et al.*, 2011). All literature available on *C. jacchus* in urban areas, focuses on their occurrence in Atlantic Forest areas (Silva, G. & Monteiro da Cruz, 1993; Mendes Pontes & Soares, 2005; Cunha *et al*., 2006; Lyra-Neves *et al*., 2007; Silva, M. *et al*., 2018), as well as several studies focusing mainly on their behavioral ecology within urban parks or densely populated places by humans (Silva, G. *et al.*, 2011; Traad *et al*., 2012; Silva, J. *et al.*, 2014).

Little is known about the behavior of primates in urban mangroves due to the scarcity of research on this type of habitat (Cutrim, 2013). Mangrove ecosystems are heterogeneous habitats with an unusual variety of animals and plants adapted to the extreme environmental conditions of high salinity, frequent submersion and a soft-bottomed anaerobic mud (Khairnar *et al*., 2009). Depending on climate, land conditions, or human impact, species of mangrove vegetation and animal species may vary and this variation ranges from microfauna to large mammals, including resident and occasional populations and individuals, such as generalist carnivores and primates (Vannucci, 2001).

The aims of this study were: (1) to monitor and describe the behavioral and ecological repertoire of a group of common marmosets (*C. jacchus*) in an urban mangrove fragment; (2) investigate the influence of factors associated with urbanization, including the effect of human presence on the group's behavior; (3) evaluate how these influences develop; and (4) how these factors affect the welfare of marmosets.

## MATERIAL AND METHODS

### STUDY AREA

This study was carried out in the *Espaço Ciência* museum, located in Olinda, a city adjacent to Recife, the capital of Pernambuco state, Northeastern Brazil (Figure 1). The museum has a total area of 12 hectares (Figure 2). It is the largest open science museum in the country (SECTEC, 2016), with areas where visitors circulate and two hectares of an urban mangrove called

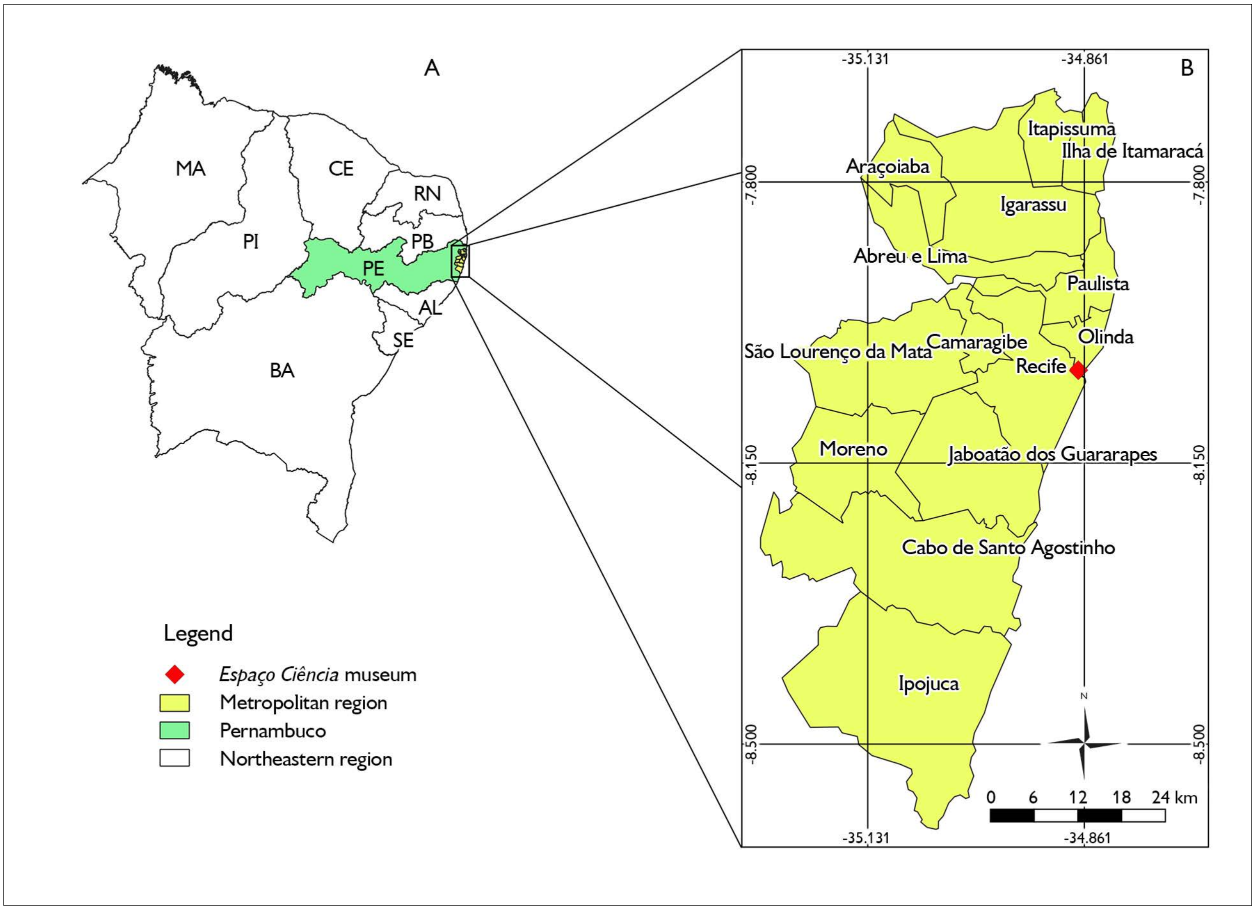

Figure 1. A) Map shown Pernambuco state highlighted (green) within the Northeastern region of Brazil; B) Recife and the Metropolitan Region cities (yellow), where the red dot indicates the location of the *Espaço Ciência* museum, at the city limits of Recife and Olinda municipalities. Sources: adapted from IBGE (2020) and PCR (2020).

Figure 2. Satellite image of the study area, *Espaço Ciência* museum (red outline) and the Chico Science Mangrove (yellow outline). Source: Google Earth®.

Chico Science Mangrove (08° 02' 40" S, 34° 52' 00" W). This mangrove fragment is located approximately 500 m from the Atlantic Ocean, at the mouth of two important rivers in the region, the Beberibe and Capibaribe. Its vegetation is in regeneration, with trees reaching approximately five meters, consisting mainly of red mangrove *Rhizophora mangle* (Linnaeus, 1753) (Rhizophoraceae), white mangrove *Laguncularia racemose* (Linnaeus, 1807) (Combretaceae) and black mangrove *Avicennia schaueriana* (Stapf & Leechman, 1939) (Acanthaceae) species. Several species of resident and migratory birds feed and reproduce in this mangrove forest (Periquito *et al.*, 2008).

The *Espaço Ciência* is surrounded by highways, named the Salgadinho Complex, located in the vicinity of the northern boundary of the fluvial-marine plain of Recife. The landscape of the study area has undergone profound transformations between the years 1970 and 2000, when the original mangrove area was, for years, cut down for the construction of the Salgadinho Complex and later chosen for the development of urban residences and commercial areas (Souza, 2006).

## SUBJECTS AND DATA COLLECT

One group of common marmosets, *C. jacchus,* was monitored. The group was the only one found to inhabit the mangrove and adjacent areas of the museum (Figure 3).

Figure 3. Group of the study marmosets, *Callithrix jacchus* (A), at the edge of the Chico Science Mangrove. (B) Two marmosets of the group (indicated by arrows) between the roots of the mangroves during foraging, and (C) three marmosets in a built-up area of the *Espaço Ciência* museum visitation area. Photos: Juliana Ribeiro de Albuquerque (2012).

During the observations, the animals were individually identified by age, estimated by morphological and behavioral characteristics (body size, length of periauricular tufts). Infants were identified through their being carried and fed by older animals: infant ≤ 5 months, juvenile 6-10 months, subadult 11-15 months and adult > 15 months (Yamamoto, 1993; Albuquerque *et al.*, 2012), sex (male or female) and by marks such as scars or distinguishable physiognomy whenever possible. Group size varied between eight and ten animals due to births and dispersions. The composition of the group at the end of the study was eight animals: two adults (one male and one female), two subadults (one male and one female), two young (one male and one of unidentified sex), and two infants of unidentified sex.

Data were collected from September 2012 to February 2013, throughout the dry season. Observations occurred every month, twice a week, with each period of observation lasting three hours, totaling 150 hours of sampling effort. We used the scan sampling and all occurrences methods (Altmann, 1974) for behavioral data collection. The first behavior displayed and the distances of each animal from the nearest neighbor were described during sessions of five minutes, alternated with five minutes of pause, totaling ten minutes for each scan.

The all occurrences method was applied throughout the observation period, including during the scan period, for the detailed recording of rare or uncommon behaviors and when these behaviors were associated with the presence of biotic or abiotic elements typical of an urban environment. All data were recorded on field recording sheets and, additionally, moments of foraging and feeding behavior were recorded with a digital camera (Sony®, DSC-S 3000).

### STATISTICAL ANALYSES

Descriptive statistical analyses and analyses of variance (ANOVA) complemented with the Tukey test were conducted. These tests made it possible to compare the difference between the most frequent behavioral activities and the occurrence of food seeking behaviors (foraging) and consumption (feeding), in the museum's visiting areas and in the mangrove. The Bioestat software version 5.3 was used to perform the descriptive and variance analyses, considering a significant result at $p < 0.05$ and highly significant at $p < 0.01$.

## RESULTS

### ACTIVITIES PATTERN

For 144 hours of the total 150 hours of sampling effort, 912 sessions of scan were performed and 2,936 behavior records of *C. jacchus* group were collected. Thirty-three behaviors were exhibited by the group of marmosets (Table 1), with a variable pattern between individual and social activities, including both affiliative and agonistic behaviors. Some individual, affiliative and all low agonistic behaviors ($n \leq 88$) were grouped into a single behavioral category, in which case six categories were included: 1 - Social grooming; 2 - Parental care; 3 - Other individual behaviors; 4 - Agonistic behaviors; 5 - Other affiliative behaviors; and 6 - Defecate or urinate.

*Callithrix jacchus* individuals spent a considerable percentage of time moving (24.4%), followed by resting (15.5%), stationary (13.7%), foraging (12.4%), playing (9.5%), feeding (6%) and social grooming (5.7%) behaviors. The categories of agonistic behaviors (1%), other affiliative behaviors (0.4%), interact with people (0.5%), defecate or urinate (0.1%) and interact with animals (0.03%) were expressed for less than 2% of their activity repertoire (Table 2).

The relationships between the monthly means of the highest percentage for each of the seven behavioral categories are shown in Table 3. Mean of moving (119.3 ± 30.1) was highly significant in relation to resting (76.2 ± 16.3) ($p < 0.01$), stationary (67.2 ± 16.3) ($p < 0.01$), foraging (60.5 ± 20.6) ($p < 0.01$), feeding (29.5 ± 18.4) ($p < 0.01$), social grooming (27.8 ± 9.3) ($p < 0.01$) and playing (46.7 ± 15.2) ($p < 0.01$) behaviors. Resting had a highly significant mean in relation to the other categories (feeding, social grooming and moving, $p < 0.01$ in each behavior). Stationary behaviors presented a significantly different mean ($p < 0.05$) in relation to the means of feeding, social grooming and this category was even more significant ($p < 0.01$) when compared to moving. The difference between foraging and playing behaviors was only significant in relation to the moving category ($p < 0.01$). Feeding had a significantly different mean ($p < 0.05$) compared to the stationary behavior category and was significant ($p < 0.01$) compared to resting and moving behaviors.

Table 1. Behavioral categories and their respective descriptions (adapted from Monteiro da Cruz, 1998), referring to the activities pattern of the group of *C. jacchus* observed between September 2012 and February 2013 in the *Espaço Ciência* museum, Olinda, Pernambuco state, Brazil.

| Behaviour | Description |
|---|---|
| Moving | Move slowly or fast |
| Jump | Movement without physical contact with any substrate by jumping |
| Resting | Lie in relaxed posture, closing its eyes or not |
| Stationary | Remain still, but attentive to the environment |
| Foraging | Search for natural or processed foods |
| Feeding | Chew, eat or carry food in the mouth |
| Social grooming | Included the behaviors involving cleaning the hair of another marmoset and being cleaned by another marmoset, either involving two or more marmosets simultaneously |
| Playing | Act of running or fighting, pursuing or grabbing another marmoset without apparent intentions |
| Defecate or urinate | It included the excretion of faeces or urine |
| Parental care | Included behaviors: nurse or infant (carrying nursing behaviors feeding breast milk to the infant or transporting infants on the back or under the breast) and: be breastfed or to be carried (act of an infant feeding from breast milk or being transported on the back or under the breast of another marmoset) |
| Other individual behaviors | Individual behaviors (itching, autogrooming, marking, gnawing tree barks, vocalizing, hiding) emitted with low frequency by marmosets |
| Agonistic behaviors | Included behaviors involving running away, running away from the observer, chasing, being chased, bristling hair, stealing food, attempting to steal food and applying spankings |
| Other affiliative behaviors | Included affiliative behaviors such as contacting or approaching performed with low frequency by marmosets |
| Interaction with people | Interacting directly or indirectly with people |
| Interaction with animals | Interacting directly or indirectly with animals (pets or not) |

Table 2. Behavioral categories, total number of occurrences (N) and equivalent percentage (%) obtained for the *Callithrix jacchus* group observed in the *Espaço Ciência* museum, Olinda, Pernambuco state, Brazil.

(Continue)

| Categories | N | % |
|---|---|---|
| Moving | 716 | 24.4 |
| Jump | 35 | 1.2 |
| Resting | 457 | 15.5 |
| Stationary | 403 | 13.7 |
| Foraging | 363 | 12.4 |
| Feeding | 177 | 6.0 |
| Social grooming | 167 | 5.7 |
| Playing | 280 | 9.5 |
| Defecate or urinate | 3 | 0.1 |
| Parental care | 161 | 5.5 |
| Other individual behaviors | 119 | 4.1 |

Table 2. (Conclusion)

| Categories | N | % |
|---|---|---|
| Agonistic behaviors | 27 | 1.0 |
| Other affiliative behaviors | 13 | 0.4 |
| Interaction with people | 14 | 0.5 |
| Interaction with animals | 1 | 0.03 |
| Total | 2,936 | 100 |

Table 3. Monthly mean values (Mean C1 and C2), difference between the means (Difference), studentized range distribution (Q) and p of the means for the seven most frequent behavioral categories in the *Callithrix jacchus* group, observed in the *Espaço Ciência* museum, Olinda, Pernambuco state, Brazil. Legends: C1 = first category of the line; C2 = second category of the line; ns = not significant.

| Categories | Mean C1 and C2 | Difference | Q | p |
|---|---|---|---|---|
| Moving (C1) and Resting (C2) | 119.3 and 76.2 | 43.1 | 5.6 | < 0.01 |
| Moving (C1) and Stationary (C2) | 119.3 and 67.2 | 52.1 | 6.8 | < 0.01 |
| Moving (C1) and Foraging (C2) | 119.3 and 60.5 | 58.8 | 7.6 | < 0.01 |
| Moving (C1) and Feeding (C2) | 119.3 and 29.5 | 89.8 | 11.7 | < 0.01 |
| Moving (C1) and Social grooming (C2) | 119.3 and 27.8 | 91.5 | 11.9 | < 0.01 |
| Moving (C1) and Playing (C2) | 119.3 and 46.7 | 72.6 | 9.4 | < 0.01 |
| Resting (C1) and Stationary (C2) | 76.2 and 67.2 | 9.0 | 1.1 | ns |
| Resting (C1) and Foraging (C2) | 76.2 and 60.5 | 15.7 | 2.0 | ns |
| Resting (C1) and Feeding (C2) | 76.2 and 29.5 | 46.7 | 6.09 | < 0.01 |
| Resting (C1) and Social grooming (C2) | 76.2 and 27.8 | 48.4 | 6.3 | < 0.01 |
| Resting (C1) and Playing (C2) | 76.2 and 46.7 | 29.5 | 3.8 | ns |
| Stationary (C1) and Foraging (C2) | 67.2 and 60.5 | 6.7 | 0.8 | ns |
| Stationary (C1) and Feeding (C2) | 67.2 and 29.5 | 37.7 | 4.9 | < 0.05 |
| Stationary (C1) and Social grooming (C2) | 67.2 and 27.8 | 39.4 | 5.1 | < 0.05 |
| Stationary (C1) and Playing (C2) | 67.2 and 46.7 | 20.5 | 2.6 | ns |
| Foraging (C1) and Social grooming (C2) | 60.5 and 27.8 | 32.7 | 4.2 | ns |
| Foraging (C1) and Playing (C2) | 60.5 and 46.7 | 13.8 | 1.8 | ns |
| Foraging (C1) and Feeding (C2) | 60.5 and 29.5 | 31.0 | 4.0 | ns |
| Feeding (C1) and Social grooming (C2) | 29.5 and 27.8 | 1.7 | 0.2 | ns |
| Play (C1) and Feeding (C2) | 46.7 and 29.6 | 17.1 | 2.2 | ns |
| Play (C1) and Social grooming (C2) | 46.7 and 27.8 | 18.9 | 2.4 | ns |

## DIET

Foraging areas used by the *C. jacchus* group included sites such as the Chico Science Mangrove, the medium and large trees of the surrounding area for visitors and the areas with buildings. The diet of the marmosets (n = 177) included natural foods such as gum (11%), fruits (0.6%), flowers (0.6%), invertebrates (1.1%), vertebrates (2%) and human-provided food (52%), as well as food that could not be classified (33%) (Figure 4). Foods classified as human-provided were obtained under the following

Figure 4. Marmosets during feeding. Eating bird eggs from a nest in an artificial tree (A), during the gomivory of tree of the species *Terminalia catappa* (B), eating watermelon (C), and marmoset with infants on their back, eating bananas (D). In these last two cases the food was provided by people. Photos: Juliana Ribeiro de Albuquerque (2012).

conditions: a) interaction with visitors and workers, b) removed from the garbage or on the soil, and c) food disposed by humans. In addition to the cited items, the marmosets were observed eating bird eggs, in a nest built on an artificial tree constructed by the museum.

Gum was obtained from trees of *Terminalia catappa* (Linnaeus, 1767) (Combretaceae) and unindentified Leguminosae species. The only fruits identified as food were figs (*Ficus* sp., Moraceae) and a flower from an unidentified plant was also recorded. Among human-provided foods were various fruits (banana, papaya and watermelon), popcorn and cookies. Arthropods consumed were exclusively orthopterans and vertebrates consumed were lizards (Squamata). Gum, fruits, flowers and eggs were acquired in the museum's visiting area, and human-provided food, insects and vertebrates were obtained both in the visitation area and in the mangrove.

## ENVIRONMENTAL INTERFACE: REFLECTIONS OF THE URBAN LANDSCAPE ON THE BEHAVIOR OF THE GROUP OF COMMON MARMOSETS

The *Espaço Ciência* museum occupies 12 hectares, with several outdoor areas for visitors to move around freely, administrative and experimental buildings and the Chico Science Mangrove with 2 hectares. The home range of the marmosets group covered only the mangrove and the visitation area around it. Almost half of the activity occurred (49.3%, n = 1,447) in the mangrove and 50.7% (n = 1,489) occurred in the museum visitation area. There was no significant difference in the use of space between the two sites (ANOVA, F = 0.0211, p = 0.8821).

The descriptive analysis of the seven most common behaviors (Table 4) shows that moving, resting, foraging and social grooming occurred most often in the mangrove and the stationary, playing and feeding activities occurred mainly in the visitation area of museum. The ANOVA test did not indicate significant differences between moving (F = 0.1657, p = 0.6937), resting (F = 0.0483, p = 08245), stationary (F = 0.1763, p = 0.6851) playing (F = 1.6905, p = 0.2212), feeding (F = 1.3835, p= 0.2662), and social grooming (F = 0.8029, p = 0.6052) in the mangrove or visitation area. Regarding the activities associated with diet, *i.e.*, foraging and feeding, it was evident that foraging was, on average, more frequent than feeding, in the mangrove ($p < 0.05$) (Table 5).

Direct (for example, the person fed the marmoset directly, initiating physical contact) or indirect contact (the person placed the food in a certain place where it could be reached by a marmoset) between humans and marmosets (n = 14, 0.5%) related to food provisioning was observed. The people involved in the interactions with marmosets were visitors, museum workers, groundskeepers and snack merchants who passed through the visitor areas and who provided food items to the marmosets in order to observe their behaviors more closely.

Table 4. Behavioral categories, total number of occurrences (N), minimum and maximum values (Min-Max) of monthly occurrence recorded during the research, total amplitude (Ta), monthly mean and standard deviation ($\mu$ ± SD) obtained for the *Callithrix jacchus* group by area use, observed in the *Espaço Ciência* museum, Olinda, Pernambuco state, Brazil.

| Categories | Mangrove | | | | Visitation Area | | | |
|---|---|---|---|---|---|---|---|---|
| | N | Min-Max | Ta | $\mu$ ± SD | N | Min-Max | Ta | $\mu$ ± SD |
| Moving | 372 | 34-103 | 69 | 62.0 ± 25.0 | 344 | 47-82 | 35 | 57.3 ± 12.8 |
| Resting | 238 | 5-66 | 61 | 39.7 ± 23.5 | 219 | 11-79 | 68 | 36.5 ± 26.3 |
| Stationary | 191 | 14-48 | 34 | 31.8 ± 13.1 | 212 | 24-60 | 36 | 35.3 ± 15.7 |
| Foraging | 218 | 7-52 | 45 | 36.3 ± 16.8 | 145 | 11-41 | 30 | 24.2 ± 11.3 |
| Playing | 111 | 11-28 | 17 | 18.5 ± 6.1 | 169 | 9-50 | 41 | 28.2 ± 17.2 |
| Feeding | 64 | 2-21 | 19 | 10.7 ± 7.9 | 113 | 2-38 | 36 | 18.8 ± 15.1 |
| Social grooming | 98 | 4-37 | 33 | 16.3 ± 11.9 | 69 | 2-18 | 16 | 11.5 ± 5.7 |

Table 5. Monthly mean values by area use, difference, studentized range (Q) and p of the comparison between the means of foraging and feeding by area of use, obtained for the *Callithrix jacchus* group observed between September 2012 and February 2013, in the *Espaço Ciência* museum, Olinda, Pernambuco state, Brazil. Legends: C1 = first category of the line; C2 = second category of the line; ns = not significant.

| Categories | Means C1-C2 | Difference | Q | p |
|---|---|---|---|---|
| Foraging in mangrove (C1) and Foraging in visitation area (C2) | 36.3-24.2 | 12.1 | 2.2 | ns |
| Foraging in mangrove (C1) and Feeding in mangrove (C2) | 36.3-10.7 | 25.6 | 4.7 | < 0.05 |
| Foraging in mangrove (C1) and Feeding in visitation area (C2) | 36.3-18.8 | 17.5 | 3.2 | ns |
| Foraging in visitation area (C1) and Feeding in mangrove (C2) | 24.2-10.7 | 13.5 | 2.4 | ns |
| Foraging in visitation area (C1) and Feeding in visitation area (C2) | 24.2-18.8 | 5.4 | 0.9 | ns |
| Feeding in visitation area (C1) and Feeding in mangrove (C2) | 18.8-10.7 | 8.1 | 1.5 | ns |

Adult marmosets interacted with night herons *Nyctanassa violacea* (Linnaeus, 1758) (Aves: Ardeidae), a species associated with wetlands. The birds behaved agonistically, waving their feathers and flapping in the presence of marmosets, especially when the animals attempted to approach their nests. An attempt of physical contact with a crab, *Goniopsis cruentata* (Latreille, 1803) (Crustacea: Brachyura: Grapsidae), probably to capture it, was also observed.

The presence of domestic dogs *Canis familiaris* (Linnaeus, 1758) (Mammalia: Canidae) on two different occasions caused the marmosets to emit alert vocalizations, encouraging the group to seek protection in the mangrove foliage. On one occasion a dog approached the marmosets observing other animals in the Chico Science Mangrove, while the marmosets vocalized in a continuous and agonistic way, until one of the marmosets attacked the dog by defensively jumping on its back.

Objects introduced by humans, set up for other studies conducted simultaneously to ours, were used by the group of marmosets to perform certain behavioral activities. Buckets used to collect *Aedes aegypti* (Linnaeus, 1762) (Diptera: Culicidae) mosquito eggs in the visitation area and nets to collect biological material in the mangrove were used by infants and young (n = 153) as well as by adults (n = 10) for playing. Due to the velocity of the play movements, during which they often formed a type of entangled 'animal ball', with several individuals rolling together, it was not always possible to identify the subjects involved (n = 117).

A dead marmoset, likely a victim of electrocution, was found a few meters outside the boundaries of the *Espaço Ciência* museum. Due to the proximity of the corpse to the area frequented by the monitored group, it is possible that this was one of the animals that had dispersed from the study group. Reports by the museum monitors and local workers often mention marmosets and other animal mortalities due to electrocution and roadkill in the vicinity of the museum. On one occasion, the group of marmosets was on a tree on the edge of a viaduct that passes over the museum, however, the animals did not remain there for a long time due to the sound of the passing vehicles.

## DISCUSSION

### ACTIVITIES PATTERN IN THE URBAN LANDSCAPE

Our results show that the overall time devoted to moving, resting, stationary, foraging and playing behaviors was similar to the behavioral pattern exhibited by *C. jacchus* (Martins, 2007; Amora *et al*., 2013) and *Callitrhix* spp. (Modesto & Bergallo, 2008) in natural environments. However, the distribution of the activities differed between the study group and wild marmosets, as moving or displacement was the least represented behavior by *C. jacchus* in the Caatinga (Martins, 2007; Amora *et al*., 2013), but it was frequently observed in congeners and conspecifics that inhabit the Atlantic Forest whereas, animals inhabiting the anthropic area devoted more time to resting and foraging (Modesto & Bergallo, 2008).

Moving also accounted for highest percentage in two groups of *C. jacchus* studied by Silva, G. *et al.* (2011) in urban areas, totalizing respectively 28% and 48.6% of the activity patterns, respectively, whereas one of the groups resting was the second most frequent behavior with 24.1%. Displacement was also found to be the highest occurring behavior in urban groups of *Callithrix penicillata* (É. Geoffroy, 1812) with 22.4%, followed by resting, with a percentage of 16.58% and inactive alert with 14.95% (Santos, M. *et al.*, 2014) (equivalent to stationary) and therefore, these results are in accordance with the behavior pattern of *C. jacchus* observed in the museum study area. Although fragmentation and human disturbance affect the activity pattern and spatial and temporal use of wild animal habitat (Tigas *et al.*, 2002; Ditchkoff *et al.*, 2006), the high movement of visitors in the museum grounds and the loud noise from the surrounding highway, did not impede moving behaviors of *C. jacchus.* This is especially important since moving is necessary for food acquisition and consequent intake of enough nutrients for the performance of other individual and social activities.

## DIET: NATURAL FOODS X HUMAN-PROVIDED FOODS

The results showed the inclusion of gum, fruits, flowers, invertebrates, vertebrates and bird eggs in the diet of the study group, reaffirming the omnivorous diet of *C. jacchus* (Digby *et al*., 2007; Power & Myers, 2009) and also the inclusion of human-provided foods. Gomivory is an important aspect of the behavioral ecology of *C. jacchus* and their specialized anterior dentition, robust lower incisors lacking lingual enamel, canine height reduction, reduced condylar height, longer jaw-muscle fibers and the enlarged intestinal cecum allows for the inclusion of large amounts of gum in the diet, which is an important food component for marmosets in free-living, natural or urban areas (Rosenberger, 1978; Vinyard *et al.*, 2009; Smith, 2010; Silva, J. *et al.*, 2014; Garbino, 2015).

The amount of gum ingested in natural and urban environments may be different. This difference can be explained by primates' access to food which has been improperly disposed of or through food being offered to these animals on purpose by humans, as a means to attract the animals for closer observation, as was observed in the study site. Additionally, the urban landscapes can make it difficult for animals to access trees that, when present, could serve as a source of food. In an urban environment, outside the native range of the species, gum was found to be the main food source for *C. jacchus* accounting for approximately 40% of their diet, besides fruits and vertebrates which were ingested in smaller quantities (Cunha *et al*., 2006). Silva, J. *et al.* (2014) monitored a group of *C. jacchus* in an urban park surrounded by Atlantic Forest, within the species' native range, and in this case, gum composed 61.9% of the diet, besides the food provided and other foods of vegetal and animal origin.

The diet of another congener, *Callithrix geoffroyi* (Humboldt, 1812), studied in urban areas was found to be comprised of 40.7% gum and 28% fruits, which represents more than half of the total food intake (Nicolaevsky & Mendes, 2011). Unlike other studies (Cunha *et al*., 2006; Nicolaevsky & Mendes, 2011; Veríssimo *et al.*, 2012; Silva, J. *et al.*, 2014), we observed that gum was a secondary food item in the diet of the marmosets observed in our study site. However, gum consumption in our study has assumed the same secondary role in the diet of the animals studied by Amora *et al.* (2013). In the cited study, the proportion of gum in the diet of *C. jacchus* in the Caatinga (28.73% of the diet) was different from the diet of *C. jacchus* in the museum (11%), in relation to the other foods consumed in the diet in each study. The predation of bird eggs and nestlings by *C. jacchus* occurs in their natural environment and although birds demonstrate agonistic behaviors, the marmosets often succeed in this activity (Lyra-Neves *et al*., 2007). As with the group monitored in this study, Begotti & Landesmann (2008) also described the predation of nests by *Callithrix* spp. hybrids in urban areas and emphasized that the local avifauna can be harmed by this type of behavior.

Human-provided foods, i.e. exotic fruits and industrialized items, comprised more than half the study group diet and were obtained through interactions with humans, collected in dumpsters or picked off the ground. The same foraging strategy was used by other species of monkeys in urban areas that fed on human foods (Sabbatini *et al.*, 2006; Nicolaevsky & Mendes, 2011; Albuquerque & Oliveira, M., 2014; Silva, J. *et al.*, 2014). The availability of human food in urban areas can modify the foraging patterns and diets of wild animals, promoting dramatic differences in dietary habits (Ditchkoff *et al.*, 2006) and the behavior of the *C. jacchus* group in the study area corroborates the effects of the presence of this type of food.

## RELATIONSHIP BETWEEN URBAN LANDSCAPE, HOME RANGE AND BEHAVIOR OF COMMON MARMOSETS

The home range of *C. jacchus* can vary between at least one and five hectares in natural and urban environments.

Groups of marmosets in natural environments were found to have home ranges of 4.9 ha (Alonso & Langguth, 1989), 0.7 ha and 2.4 ha (Castro, 2003) in the Atlantic Forest, 1.1 ha and 1.5 ha (Veríssimo *et al.*, 2012) in the Restinga and 2.7 ha (De la Fuente *et al*., 2014) in the Caatinga. In urban environments, groups of marmosets have been found to have home ranges of between 0.2 ha and 4.1 ha (Mendes Pontes & Monteiro da Cruz, 1995), 0.6 ha (Oliveira, I., 2003), 4.7 ha (Albuquerque *et al.*, 2012), 1.9 ha and 3.4 ha (Rocha, 2019). Therefore, there does not appear to be much difference in the home range size of *C. jacchus* in urban and natural areas. In the same way, 2 ha of mangroves and part of the surrounding visitation area used by the study marmosets, is within the described limits for the home range sizes of marmosets observed in the previous studies. Comparatively, the movement and home range size of common raccoons *Procyon lotor* (Linnaeus, 1758), living in urban and suburban areas in Northeastern Illinois, has been found to be lower in relation to the animals living in rural areas due to the abundant presence of artificial foods (Prange *et al.*, 2004).

In accordance with all these studies, the influence of the urban environment on the marmosets group observed at the *Espaço Ciência* museum was evidenced by the frequency of certain activities, which were carried out more often in the mangrove, where marmosets took advantage of the shading provided by vegetation. We noted that the group made fewer trips to open areas, which experienced higher temperatures and greater noise levels from people and vehicle traffic, and sought food mainly in the visitation area, where success was almost always guaranteed. This strategy optimized the acquisition of nutrients to meet the energy needs of the animals. Thus, the study marmosets group also demonstrated a similar adaptation to that of raccoons, observed in a study by Prange *et al.* (2004), reducing their home range, diversifying their diet and avoiding risks. There was no significant difference in the use of the mangrove and visitation areas by the group of marmosets. Although the occurrence of moving, resting, foraging and social grooming activities was higher in the Chico Science Mangrove, and the stationary, playing and feeding activities were more common in the visitation area, there was no significant difference in the performance of these activities between any of the locations. In contrast, the *C. jacchus* group studied by Albuquerque *et al.* (2012) in the Atlantic Forest of Pernambuco state, demonstrated a preference for the visitation area in an urban park for the performance of displacement, social grooming and playing activities, instead of remaining in the forest area.

Regarding the activities associated with diet, foraging was significantly more common compared to feeding in the mangrove ($p < 0.05$). The mangrove is a place with a myriad of microhabitats for small vertebrates and insects, items that usually required a significant amount of time to find and whose capture is not always successful as these prey are large, mobile and may use camouflage to avoid predators (Digby *et al*., 2007). Foods readily available, such as gums, fruits and, especially, human-provided food, were found and consumed, on most occasions, in the visitation area and occasionally human-provided food was placed on the branches of the mangrove by humans for the marmosets. Direct and indirect contact between the public and the *C. jacchus* group involving food was observed. The study area was a place of public visitation, with people passing by and often stopping in close proximity to gaze at the animals or to observe their behavior, they used food to attract the marmosets. Similarly, Paula *et al*. (2005), Leite *et al.* (2011), and Albuquerque & Oliveira, M. (2014) mentioned the use of food by people to attract *Callithrix* spp., *C. penicillata* and *C. jacchus*, respectively.

The study marmosets interacted agonistically with the mangrove night heron *N. violacea*. Lyra-Neves *et al.* (2007) also described behaviors such as flying over and blows with the beak or breast by birds as antipredatory behavior, as an attempt to make marmosets move away from the nests. Furthermore, on two occasions adult marmosets observed the crab, *G. cruentata*, with an unsuccessful contact attempt. Cutrim (2013), in its turn, observed the inclusion of crustaceans, gastropods and bivalves in the diet of *Sapajus libidinosus* (Spix, 1823) in a mangrove fragment and Santos, A. S. (2011) reported the predation of the crab, *Aratus pisonii* (H. Milne Edwards, 1837) by *Callithrix kuhlii* (Wied, 1826) in Bahia state, northeastern Brazil. However, the crab *G. cruentata* was not eaten by the study group.

The presence of domestic dogs during two different occasions elicited the emission of alert vocalizations by the marmosets, after which the group sought protection in the mangrove and on one of the occasions, the marmosets attacked the dog. Free-living domestic dogs can chase and kill primates, as described by Srbek-Araujo & Chiarello (2008), who even reported the predation of a medium-sized primate, the titi monkey *Callicebus personatus* (É. Geoffroy, 1812). To mitigate the effects of predation on capuchin monkeys *Sapajus nigritus* (Goldfuss, 1809), Oliveira, V. *et al.* (2008) proposed an action plan which involved the capture and removal of the dogs.

During playing activities, the common marmosets used objects introduced by humans. This behavior allows for the exploration of the environment and neuromotor and cognitive development in young individuals and infants (Santos, A. C. *et al.*, 2010). As objects were usually hidden in the vegetation, the selection of play sites might be associated with sites safe from predator attacks (Cavalheiro, 2008). One marmoset was found dead, thought to be a victim of electrocution, a consequence of the negative effects of urban land use on local biodiversity (McKinney, 2008). In the urban environment, marmosets can use electric wires as bridges and, when they do not die, they commonly suffer burns or limb amputation (Oliveira, M., 2008).

## CONCLUSION

The behavior of the study marmosets, *C. jacchus,* and the exploration of their home range were adjusted according to the environment in which they were inserted and what it had to offer, allowing for their survival. On the other hand, certain aspects of the urban landscape and anthropic activities in this environment interfered, in different ways, on the relationships between *C. jacchus* and the biotic and abiotic factors of the urban ecosystem.

In our study, the behavior of the marmosets inhabiting the urban mangrove within an outdoor museum was similar to other studies with primates and other wild animals in urban areas, exposed to high circulations of people and different from primate studies in natural areas, particularly in relation to diet. The results of this study will contribute to the continuous monitoring of nonhuman primates living in urban areas and thus outline future actions that may support strategies mitigating the putative and actual conflicts caused by a disturbed environment and by animals and humans living in urban areas.

## ACKNOWLEDGMENT

We thank the management of the *Espaço Ciência* museum, represented by Dr. Antonio Carlos Pavão, for authorizing the study. Pedro Aguilar Cescon and Rebecca Nimrah Umeed for revising the text. We are grateful to Guilherme Garbino e two anonym reviewers for their valuable suggestions and comments in a previous version of the manuscript.

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# Biologia e parasitologia do morcego insetívoro aéreo *Myotis nigricans* (Schinz, 1821) (Chiroptera, Vespertilionidae) no município do Rio de Janeiro, Rio de Janeiro, Brasil

# Biology and parasitology of the aerial insectivorous bat *Myotis nigricans* (Schinz, 1821) (Chiroptera, Vespertilionidae) in the city of Rio de Janeiro, Rio de Janeiro, Brazil

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**Resumo:** *Myotis nigricans* (Schinz, 1821) é um morcego insetívoro aéreo amplamente distribuído na região neotropical, encontrado em todos os biomas brasileiros e adaptado aos centros urbanos. Apresentamos dados bionômicos, reprodutivos, de dieta e parasitológicos de 28 exemplares de *Myotis nigricans* capturados em áreas de Mata Atlântica no município do Rio de Janeiro, Sudeste do Brasil, com o propósito de oferecer mais informações sobre as interações ecológicas, especialmente aquelas oriundas de parques urbanos. Os exemplares apresentaram medidas semelhantes às descritas para a espécie, estando sexualmente ativos na primavera (outubro). Fragmentos de insetos das ordens Diptera, Coleoptera, Hemiptera e Lepidoptera foram encontrados nas amostras fecais examinadas. Cinco indivíduos estavam infestados por *Basilia* sp. (Diptera, Nycteribiidae), e helmintos das classes Trematoda e Cestoda foram encontrados no trato gastrointestinal, estes constituindo o primeiro registro para *M. nigricans*. Apesar da ampla distribuição desta espécie, os dados sobre bionomia e interações ecológicas são fragmentados e pontuais. Desta forma, os resultados aqui apresentados reforçam a importância da realização de acompanhamentos sistemáticos para a compreensão das relações estabelecidas por esses animais em ambientes florestados e antropizados.

**Palavras-chave:** Atividade reprodutiva. Bionomia. Insetivoria. Mata Atlântica. Sinantropia.

**Abstract:** *Myotis nigricans* (Schinz, 1821) is an aerial insectivorous bat widely distributed in the neotropical region, found in all Brazilian biomes and adapted to urban centers. We present bionomic, reproductive, dietetic and parasitological data from 28 specimens of *Myotis nigricans* captured in Atlantic Forest areas in the city of Rio de Janeiro, southeastern Brazil, in order to provide more information on ecological interactions of these animals, especially those from urban parks. The specimens presented measurements similar to those described for the species, being sexually active in spring (October). Insect fragments of the orders Diptera, Coleoptera, Hemiptera and Lepidoptera were found in the stool samples examined. Five individuals were infested with *Basilia* sp. (Diptera, Nycteribiidae), and helminths of the Trematoda and Cestoda classes were found in the gastrointestinal tract, the latter constituting the first record for *M. nigricans*. Despite the widespread distribution of this species, data on bionomy and ecological interactions are fragmented and punctual. Thus, the results presented here reinforce the importance of carrying out systematic follow-ups to understand the relationships established by these animals in forested and anthropized environments.

**Keywords:** Reproductive activity. Bionomy. Insectivory. Atlantic Forest. Synanthropy.

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OLIVEIRA, R. S. D., S. S. P. SILVA, P. G. GUEDES & J. C. ALMEIDA, 2020. Biologia e parasitologia do morcego insetívoro aéreo *Myotis nigricans* (Schinz, 1821) (Chiroptera, Vespertilionidae) no município do Rio de Janeiro, Rio de Janeiro, Brasil. **Boletim do Museu Paraense Emílio Goeldi. Ciências Naturais** 15(3): 633-642. DOI: http://doi.org/10.46357/bcnaturais.v15i3.247.

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Recebido em 20/12/2019

Aprovado em 04/11/2020

Responsabilidade editorial: Alexandra Maria Ramos Bezerra

## INTRODUÇÃO

A Mata Atlântica do estado do Rio de Janeiro, Sudeste do Brasil, abriga grande diversidade biológica, e as modificações propiciadas pela crescente urbanização resultam em redução significativa desta biodiversidade (Esbérard, 2003; Rocha *et al.*, 2003). Segundo Lima (2008), no ambiente urbano, os fragmentos florestais são verdadeiras "ilhas verdes" – como parques municipais, bosques e praças – cercadas por habitações humanas. O levantamento da quiropterofauna nessas áreas remanescentes é fundamental para analisar a diversidade em meio urbano e compreender as interações estabelecidas com outras espécies, incluindo o homem.

Morcegos vespertilionídeos mostram-se mais tolerantes às modificações ambientais causadas pelo homem, ocupando construções humanas como forma de abrigo e utilizando a iluminação pública como fonte de atração de insetos (Rydell, 1992; Bredt & Uieda, 1996). O gênero *Myotis* Knaup, 1829, com distribuição cosmopolita, está representado no Brasil por oito espécies (Nogueira *et al.*, 2018): *Myotis albescens* (E. Geoffroy, 1806), *Myotis izecksohni* Moratelli, Peracchi, Dias & Oliveira, 2011, *Myotis lavali* Moratelli, Peracchi, Dias & Oliveira, 2011, *Myotis levis* (I. Geoffroy, 1824), *Myotis nigricans* (Schinz, 1821), *Myotis riparius* Handley, 1960, *Myotis ruber* (E. Geoffroy, 1806) e *Myotis simus* Thomas, 1901.

*Myotis nigricans* pertence à guilda dos insetívoros aéreos e tem distribuição em todas as regiões brasileiras, não sendo registrado apenas nos estados do Acre, Alagoas, Piauí e Rondônia (Aguirre *et al.*, 2003; Reis *et al.*, 2013). No estado do Rio de Janeiro, essa espécie foi registrada nos principais remanescentes florestais de Mata Atlântica (Dias *et al.*, 2002, 2010; Esbérard, 2003; Dias & Peracchi, 2008; Modesto *et al.*, 2008a, 2008b; Peracchi & Nogueira, 2010), construções humanas e em unidades de conservação (UC) no município do Rio de Janeiro (Pinto, 2008; Silva *et al.*, 2010; Esbérard *et al.*, 2014). Apesar dos morcegos desta espécie terem ampla distribuição e serem conhecidos por sua dieta insetívora, há poucas informações sobre aspectos da biologia desses animais, como a composição da dieta e da reprodução, além da interação com parasitas. O presente estudo tem como objetivo apresentar informações sobre indivíduos de *Myotis nigricans* em ambientes florestais e em área urbana, com vistas a ampliar o conhecimento sobre espécies sinantrópicas que habitam o interior e o entorno de remanescentes florestais no município do Rio de Janeiro, Rio de Janeiro, Brasil.

## MATERIAL E MÉTODOS

### ÁREA DE ESTUDO

As atividades de campo para coleta de morcegos foram realizadas em um período de 25 anos – de março de 1994 a outubro de 2004 no Parque Estadual da Pedra Branca (PEPB) (23° 53' 01" - 23° 04' 29" S, 43° 22' 55" - 43° 35' 21" W), e de janeiro de 2009 a outubro de 2019 nas seguintes unidades de conservação: Parque Natural Municipal Chico Mendes (PNMCM) (23° 01' 15" S , 43° 28' 30" W/23° 01' 40" S, 43° 27' 55" W), Parque Natural Municipal da Freguesia (PNMF) (22° 56' 49" S, 43° 20' 35" W) e Parque Natural Municipal Bosque da Barra (PNMBB) (22° 59' 40" S, 43° 22' 50" W/23° 00' 00" S, 43° 22' 05" W) (Figura 1).

O Parque Natural Municipal Chico Mendes possui 43,64 ha e a vegetação é constituída por formações pioneiras, predominando a mata de restinga (IBGE, 2012). O Parque Natural Municipal Freguesia, conhecido como 'Bosque da Freguesia', possui 30,33 ha e vegetação em estágio inicial e médio de regeneração, pertencente às formações pioneiras e à floresta ombrófila densa de baixada (IBGE, 2012). O Parque Natural Municipal Bosque da Barra, conhecido como 'Bosque da Barra', está localizado em uma região conhecida como 'Baixada de Jacarepaguá', possui 54,398 hectares e é composto por vegetações típicas das matas de restinga (IBGE, 2012). O Parque Estadual da Pedra Branca, com 12.393,84 hectares, está situado no interior do

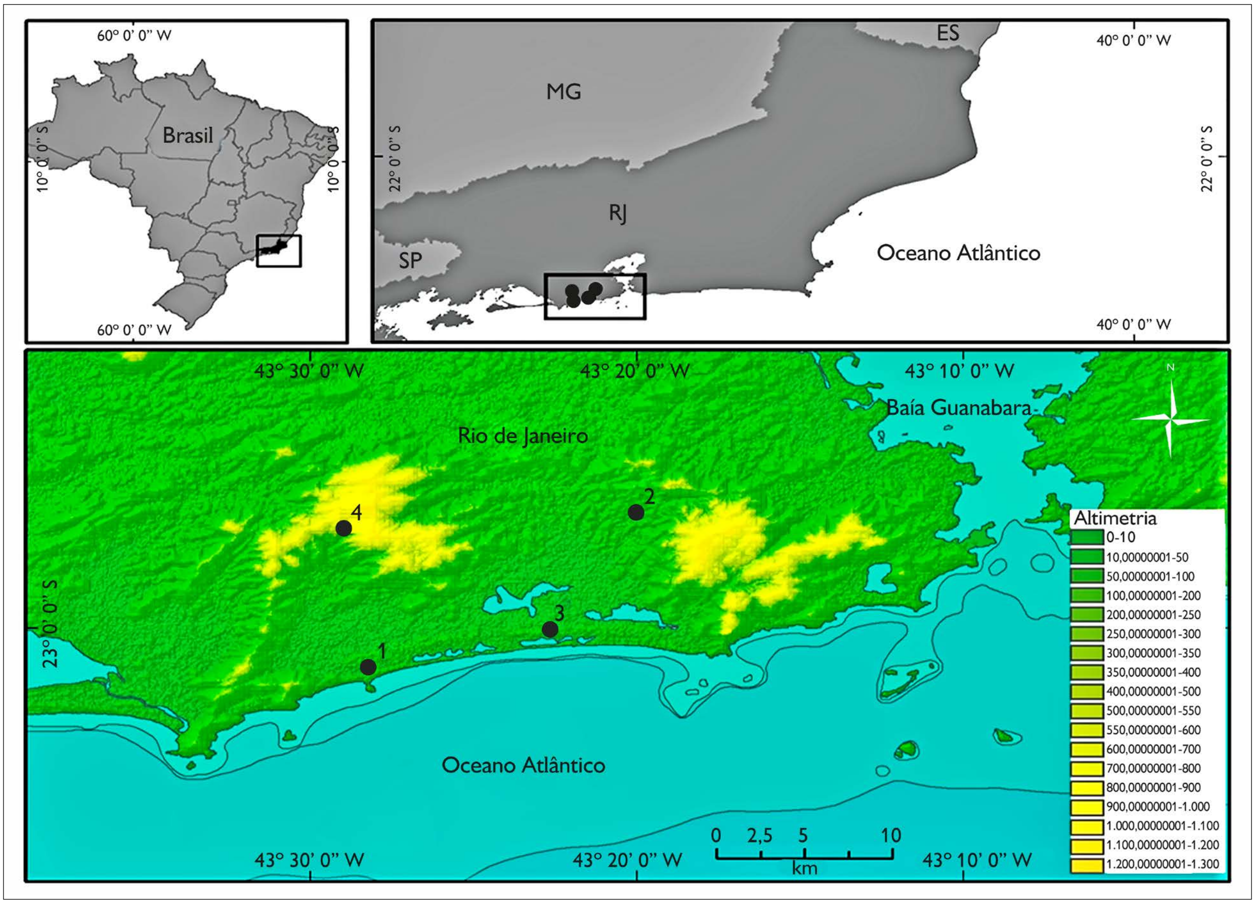

Figura 1. Localização das unidades de conservação no município do Rio de Janeiro, Rio de Janeiro, Brasil: 1 - Parque Natural Municipal Chico Mendes; 2 - Parque Natural Municipal da Freguesia; 3 - Parque Natural Municipal Bosque da Barra; 4 - Parque Estadual da Pedra Branca. Mapa: elaborado por Sergio Moreira (2018) e adaptado por Shirley S. P. Silva (2019).

Maciço da Pedra Branca, acima da cota de 100 metros na região metropolitana do município (INEA, 2015), apresentando vegetação constituída por Floresta Pluvial Baixo Montana, com trechos bem conservados e grande diversidade de formações, como Mata Pluvial Atlântica, Mata Atlântica Seca, Mata Atlântica Úmida, Mata de Encosta, Mata Seca Alta e Capoeiras (Rizzini, 1979).

## AMOSTRAGEM DOS ESPÉCIMES

Os trabalhos de campo ocorreram em períodos distintos e houve diferença no esforço de captura para cada área analisada: 562 m²/h no Parque Natural Municipal Bosque da Barra, 5.400 m²/h no Parque Natural Municipal Chico Mendes, 91.980 m²/h no Parque Natural Municipal da Freguesia e 36.225 m²/h no Parque Estadual da Pedra Branca, perfazendo um esforço de captura total de 134.167m²/h, calculado conforme Straube & Bianconi (2002).

Os morcegos foram capturados com a utilização de cinco a oito redes de neblina de seis a nove metros de comprimento, armadas no sub-bosque, em trilhas existentes na mata ou sobre córregos, abertas antes do pôr do sol e fechadas após seis horas. Os indivíduos foram acondicionados em sacos de pano para obtenção de amostras fecais, guardadas em envelopes de papel individualizados. Dados biométricos padrão para morcegos (comprimentos total, do antebraço, do pé, da orelha, da tíbia, do calcâneo e da cauda; veja Vizotto & Taddei, 1973) foram obtidos com auxílio de paquímetro digital (mm), e a massa corporal (g) foi aferida com uso de dinamômetro. Os ectoparasitos encontrados na pelagem dos animais foram retirados com auxílio de pinças e acondicionados em microtubos plásticos com etanol 70%, etiquetados.

A identificação dos fragmentos de insetos e ectoparasitos foi realizada com base em chaves taxonômicas e descrições disponíveis na literatura, como Carrera (1980), Whitaker (1988), Guerrero (1993) e Shiel *et al*. (1997). Os espécimes de morcegos preparados como material-testemunho tiveram o trato gastrointestinal removido e examinado sob estereomicroscópio (40x) para verificação da presença de endoparasitas, reportados no trabalho de Ferreira & Brasil-Sato (1998).

### ANÁLISE DE HEMOPARASITOS

Para avaliação da ocorrência de hemoparasitos no sangue periférico, amostras de sangue foram obtidas por punção da veia propatagial dos animais, com auxílio de agulhas hipodérmicas estéreis, após antissepsia com etanol 70% (Baptista & Esbérard, 1997). Após a punção venosa, foram preparados três a quatro esfregaços 'a fresco' por indivíduo. As lâminas hematológicas foram identificadas com auxílio de etiquetas adesivas, contendo o número de campo do indivíduo capturado, e foram embaladas individualmente com papel toalha, para posterior análise. Cinco indivíduos de *M. nigricans* do PEPB foram depositados como material-testemunho na Coleção Adriano Lúcio Peracchi (ALP), Universidade Federal Rural do Rio de Janeiro (UFRRJ), Seropédica, Rio de Janeiro: ALP 5727 (♀), ALP 5742 (♂), ALP 5744 (♂) ALP 5821 (♂) e ALP 5861 (♀). Espécimes em período reprodutivo e aqueles das demais localidades (PNMCM, PNMF e PNMBB) foram soltos ao final dos trabalhos de campo.

Em ambiente laboratorial, as lâminas hematológicas foram coradas pelo método ®Panótico Rápido, sendo examinadas com auxílio de microscópio óptico (aumento de 1.000x), para verificar presença de hemoparasitos. As amostras fecais foram analisadas sob estereomicroscópio (40x), após ser realizada a separação, quantificação e identificação dos fragmentos de insetos, que foram montados em lâminas permanentes, posteriormente fotografados.

As amostras dos ectoparasitos estão depositadas na Coleção Acarológica do Instituto Oswaldo Cruz (IOC), da Fundação Oswaldo Cruz (FIOCRUZ), e os endoparasitos na Coleção Helmintológica do Instituto Oswaldo Cruz. Todos os trabalhos de campo foram realizados com autorização para atividades com finalidades científicas: números 11598-1, 11598-2, 11666-1, 18852-1, 22393-1, 22393-2, emitidos pelo Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio), e 01/2009 (Proc. 14/000.047/2009), 12/2009 (Proc. 14/001.059/2009), 0613B, 0713B, 13_14B e 18_16B (Proc. 14/000.627/2013), emitidos pela prefeitura da cidade do Rio de Janeiro. O mapa de localização das áreas de estudo foi elaborado por meio do programa ArcView 3.2.

## RESULTADOS

Ao longo de todo período de estudo, um total de 28 exemplares (10 fêmeas e 18 machos) de *Myotis nigricans* foram capturados (Figura 3A). A massa corporal (média = 4,4 g; desvio padrão (DP) = 2,1) variou de 2,0 a 11,0 g nos machos (média = 4,1 g) e 3,7 a 8,0 g nas fêmeas (média = 5,4 g). A medida do antebraço (média = 34,1 mm; DP = 1,6) foi de 31,5 a 37,0 mm nos machos e 31,6 a 36,9 mm nas fêmeas. Na Figura 2 estão ilustradas as medidas corporais obtidas nos indivíduos. A Tabela 1 apresenta os intervalos dos valores obtidos em cada um dos parques.

Em relação à reprodução, apenas os morcegos capturados no PEPB estavam em período reprodutivo, pois foram observadas quatro fêmeas grávidas no mês de outubro. Os demais indivíduos foram considerados como sexualmente inativos, por não apresentarem evidências externas de estágio reprodutivo ou lactação.

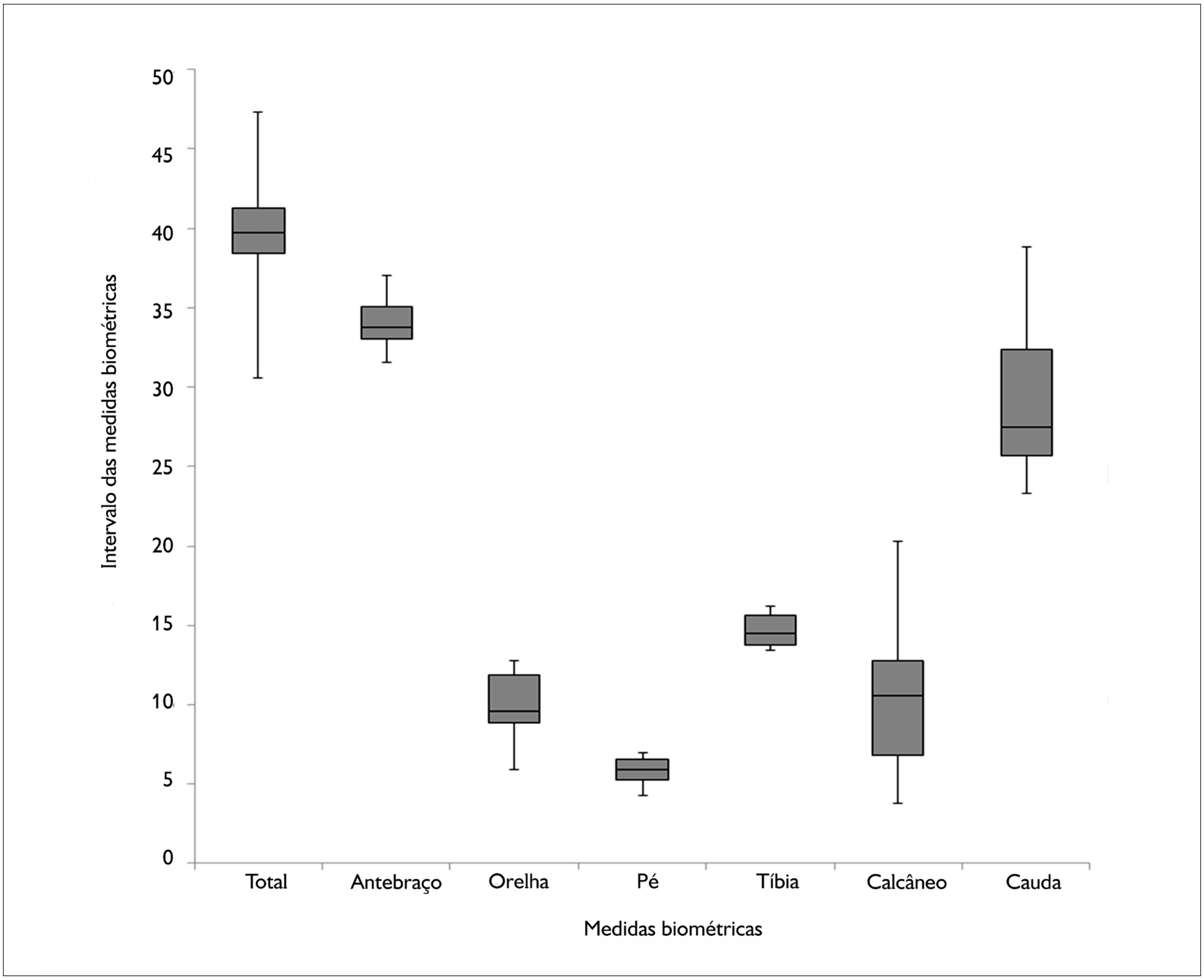

Figura 2. Intervalo das medidas biométricas obtidas em indivíduos de *Myotis nigricans* capturados em quatro unidades de conservação do município do Rio de Janeiro, Rio de Janeiro, Brasil (ver a Figura 1 paras as UC e a seção de Material e Métodos para as medidas biométricas tomadas).

O estudo da dieta foi realizado através da análise de oito amostras fecais obtidas no PNMF (n = 4) e no PEPB (n = 4), que apresentaram somente fragmentos de insetos (Hexapoda), identificados como pertencentes às ordens Hemiptera, Diptera, Coleoptera e Lepidoptera (Figuras 3B-3H). Não foram encontrados resíduos alimentares no trato gastrointestinal dos indivíduos provenientes do PEPB.

Cinco indivíduos de *M. nigricans* capturados no PNMF apresentavam em sua pelagem ectoparasitos identificados como *Basilia* sp. (Diptera: Nycteribiidae) (Figura 3I). No trato gastrointestinal de dois indivíduos, foram encontrados helmintos trematódeos, reconhecidos como pertencentes à espécie *Ochoterenatrema diminutum* (Chandler, 1938) (Ferreira & Brasil-Sato, 1998), e um Cestoda, que não pôde ser identificado devido à fragmentação do exemplar. Do total de exemplares de *M. nigricans* capturados no PNMF (n = 12), foram analisadas lâminas hematológicas de cinco indivíduos, não sendo identificada a presença de hemoparasitos.

Tabela 1. Massa corporal (em g) e comprimento de antebraço (em mm) dos indivíduos de *Myotis nigricans* capturados em unidades de conservação no município do Rio de Janeiro, Rio de Janeiro, Brasil, no período de 1994 a 2019. Legendas: PEPB = Parque Estadual Pedra Branca; PNMBB = Parque Natural Municipal Bosque da Barra; PNMF = Parque Natural Municipal da Freguesia; PNMCM = Parque Natural Municipal Chico Mendes; N = número de indivíduos analisados.

| *Myotis nigricans* | N | Massa corporal (g) | Comprimento do antebraço (mm) |
|---|---|---|---|
| PEPB | | | |
| Macho | 4 | 3,0-4,0 | 32,0-37,0 |
| Fêmea | 7 | 3,0-8,0 | 31,6-36,9 |
| PNMBB | | | |
| Macho | 2 | 5,0-11,0 | 32,3-34,5 |
| PNMF | | | |
| Macho | 11 | 2,0-9,0 | 31,5-36,1 |
| Fêmea | 1 | 5,0 | 33,9 |
| PNMCM | | | |
| Fêmea | 3 | 4,0-6,0 | 32,0-34,9 |
| Total | 28 | - | - |

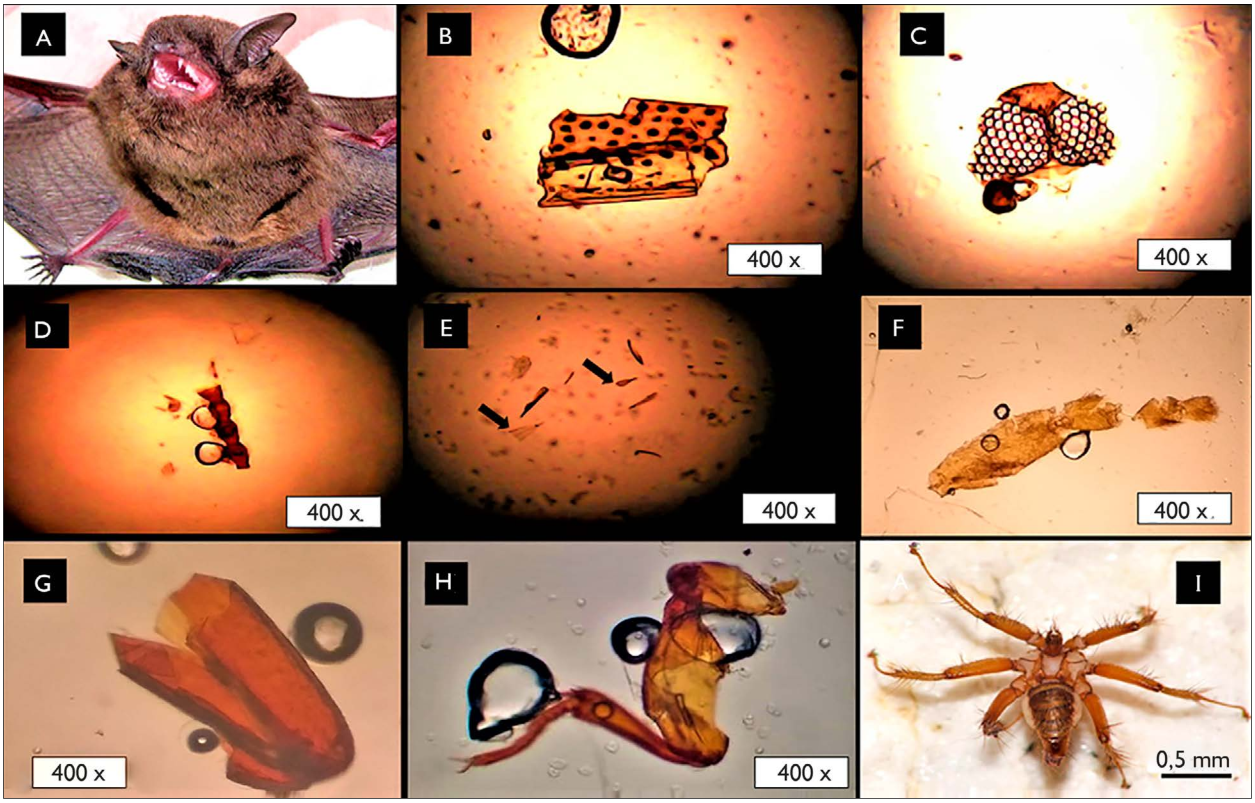

Figura 3. A) indivíduo da espécie *Myotis nigricans*; B) fragmento do hemiélitro de Hemiptera; C) olho composto (Diptera); D) fragmento de antena (Coleoptera); E) escamas de Lepidoptera; F) fragmento de perna (Diptera) (400x); G) fragmento de perna (Coleoptera); H) perna de Coleoptera; I) *Basilia* sp. (Diptera: Nycteribiidae). Foto: A: Shirley S. P. Silva (2010); B-H: Raissa S. D. Oliveira (2018); I: Juliana C. Almeida (2010).

## DISCUSSÃO

### DIETA E HISTÓRIA NATURAL

Os dados biométricos de *M. nigricans* apresentados neste estudo estão de acordo com a literatura, excetuando um macho capturado no PEPB e uma fêmea capturada no PNMCM, que apresentaram peso maior. A partir das medidas de antebraço obtidas nos exemplares coletados, não é possível observar variação nas medidas entre machos e fêmeas que caracterize dimorfismo sexual. No que diz respeito à dieta, a presença de fragmentos de Diptera, Coleoptera, Hemiptera e Lepidoptera nas amostras fecais analisadas corroboram o hábito alimentar insetívoro para a espécie (*e.g.*, Wilson & LaVal, 1974; LaVal & Fitch, 1977; Findley, 1993; Aguiar & Antonini, 2008), embora os dados não sejam suficientes para se propor uma preferência por determinados grupos de insetos. A dieta apresentada permite demonstrar que essa espécie desempenha um serviço ecossistêmico fundamental no controle destas populações de invertebrados (ver Kunz *et al*., 2011). O estudo de Novaes *et al.* (2015) sobre *M. nigricans* na Reserva Ecológica de Guapiaçu (Cachoeiras de Macacu, Rio de Janeiro) registrou indício de frugivoria na dieta de *M. nigricans*, ao relatar a presença de sementes nas fezes dos indivíduos capturados. No presente estudo, não foram observadas sementes ou outras estruturas vegetais nas amostras fecais analisadas.

O baixo número de indivíduos capturados em redes de neblina dificulta o acompanhamento do ciclo reprodutivo das espécies de *Myotis* nas áreas de estudo. No entanto, os dados indicam que indivíduos de *M. nigricans* apresentam uma variação do padrão reprodutivo ao longo de sua distribuição geográfica, que pode estar relacionada a fatores ambientais como temperatura e disponibilidade de alimento (Racey & Entwistle, 2000; Rodrigues, 2004). A presença de fêmeas grávidas de *M. nigricans* no mês de outubro confirma o registro obtido por Mottin *et al.* (2018) no estado de Santa Catarina. Embora nosso estudo contemple 25 anos de amostragens, poucos indivíduos de *M nigricans* foram capturados, informando que a espécie não é abundante e, talvez, não forme grandes colônias. Portanto, não foi possível determinar o padrão reprodutivo da espécie dentro das áreas inventariadas.

### PARASITOLOGIA E CONSERVAÇÃO

*Myotis nigricans* é hospedeiro de ácaros, carrapatos, pulgas e moscas (Wilson & LaVal, 1974). Os espécimes de *M. nigricans* apresentaram em sua pelagem moscas ectoparasitas identificadas como *Basilia* sp. (Nycteribiidae). Essa associação foi registrada em diversos estudos no Brasil (Graciolli & Carvalho, 2001; Graciolli & Aguiar, 2002; Bertola *et al*., 2005; Graciolli & Bianconi, 2007; Camilotti *et al*., 2010), e há pelo menos seis espécies deste gênero infestando *M. nigricans* no país (Graciolli, 2001). Para o estado do Rio de Janeiro, a associação *Basilia* spp. e *Myotis* spp. foi registrada por Patrício *et al.* (2016), ao coletarem exemplares do gênero no município de Seropédica, Rio de Janeiro. No município do Rio de Janeiro, Rio de Janeiro, Almeida *et al*. (2010) relatam a associação entre *Basilia andersoni* (Peterson & Maa, 1970) e *M. nigricans*, em estudo na Fazenda Marambaia, área localizada a 4,3 km do Parque Estadual da Pedra Branca (PEPB).

Morcegos estão associados a zoonoses causadas por vários tipos de agentes etiológicos, como protozoários, vírus, bactérias e fungos (Bredt *et al.*, 1998; Moratelli & Calisher, 2015), além de uma grande variedade de endoparasitos, incluindo protozoários, trematódeos, cestódeos e nematódeos (Ubelaker, 1970; Ubelaker *et al.*, 1979; Cuartas-Calle & Muñoz-Arango, 1999; Santos & Gibson, 2015). Segundo Coggins (1988), a ocorrência de parasitos pode ser afetada pelo hábito alimentar dos morcegos. A presença de *O. diminutum* (trematódeo digenético) no trato gastrointestinal dos exemplares de *M. nigricans* estudados pode estar associada à sua dieta insetívora, pois o ciclo da maioria dos trematódeos inclui insetos como hospedeiros intermediários (Ubelaker, 1970; Coggins, 1988; García-Vargas & Pérez-Ponce De León, 1996). Contudo, não se pode descartar a possibilidade desta infestação estar associada à ingestão de água, pois, de acordo com Pérez-Ponce De León (2001), quanto maior o contato do hospedeiro com a água, maior a probabilidade de infecção por estes helmintos. Segundo Ferreira & Brasil-Sato (1998), esta espécie encontrada em associação com os *M. nigricans* do PEPB é um helminto também encontrado em outros hospedeiros insetívoros, tais como os morcegos da família Molossidae *Molossus molossus* (Pallas, 1766) e *Tadarida brasiliensis* (I. Geoffroy, 1824), e os Vespertilionidae *Eptesicus fuscus* (Beauvois, 1796) e *Lasiurus intermedius* H. Allen, 1862. O registro de *O. diminutum* e de um cestódeo no trato intestinal de *M. nigricans* proveniente do PEPB é importante, pois reforça a necessidade de estudos de morcegos urbanos e suas inter-relações com o ambiente.

O levantamento da quiropterofauna de parques urbanos é fator relevante não somente para conhecer a biodiversidade que habita as cidades, mas também para compreender as interações destes animais em ambientes compartilhados com humanos. A partir dos dados apresentados, conclui-se que *Myotis nigricans* ocupa esse espaço de maneira bem-sucedida nas quatro unidades de conservação: Parque Estadual da Pedra Branca, Parque Natural Municipal da Freguesia, Parque Natural Municipal Chico Mendes e Parque Natural Municipal Bosque da Barra. A despeito dos desafios de viver em ambientes antropizados, não foram encontradas entre os animais capturados evidências de doenças ou prejuízos ao seu desenvolvimento que sejam visíveis e/ou mensuráveis.

## AGRADECIMENTOS

Aos biólogos Alexandre M. S. Carneiro e Joyce S. Damascena, ao médico veterinário Clayton Bernardinelli Gitti e ao Sr. Ricardo P. da Rocha, pelo auxílio nos trabalhos de campo. À Daniela Dias, pela confirmação da identificação dos morcegos, e ao Sérgio Moreira, pela elaboração do mapa. Agradecemos as importantes contribuições de Susi Missel Pacheco e de uma revisora anônima, cujos comentários e sugestões aprimoraram a qualidade do manuscrito.

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Bol. Mus. Para. Emílio Goeldi. Cienc. Nat., Belém, v. 15, n. 3, p. 643-662, set.-dez. 2020

# Non-volant small mammals (Rodentia and Didelphimorphia) diversity in an isolated area of the Serra da Mantiqueira, Minas Gerais state, Brazil

# Diversidade de pequenos mamíferos não voadores (Rodentia e Didelphimorphia) em uma área isolada da Serra da Mantiqueira, Minas Gerais, Brasil

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**Abstract:** The southeastern Atlantic Forest of the *Zona da Mata Mineira* is located in the extreme north of Minas Gerais state, Brazil. The Serra da Mantiqueira, is a mountainous region with a high diversity of small non-volant mammal species, several of which are rare species or endemic lineages. The presence of cryptic species in small mammals makes the karyotype an excellent tool for identification and detection of new lineages. We analyzed the karyotype of 14 species: 11 rodents – *Abrawayaomys ruschii*, *Akodon cursor*, *Blarinomys breviceps*, *Delomys sublineatus*, *Juliomys ossitenuis*, *Oligoryzomys nigripes*, *Oligoryzomys flavescens*, *Oxymycterus dasytrichus*, *Rhipidomys tribei*, *Sooretamys angouya*, and *Thaptomys nigrita*; and three marsupials – *Monodelphis scalops*, *Philander quica*, and *Marmosops incanus*. We described for the first time the fundamental autosomal number and the morphology of sex chromosomes of *Abrawayaomys ruschii*, a rare sigmodontine species, and described a new karyotype for *Blarinomys*. The revision of published karyotypes of the species herein studied enabled the expansion of the geographic distribution of *Oligoryzomys nigripes* and *Delomys sublineatus*.

**Keywords:** Rodents. Marsupials. Chromosome complement. Geographic distribution.

**Resumo:** A Mata Atlântica do sudeste da Zona da Mata Mineira está situada no extremo norte da serra da Mantiqueira, estado de Minas Gerais, Brasil, sendo uma região de montanha, com alta diversidade de espécies de pequenos mamíferos não voadores, várias delas raras e endêmicas. A presença de espécies crípticas torna o cariótipo uma excelente ferramenta para identificação e detecção de novas linhagens. Foi analisado o cariótipo de 14 espécies de pequenos mamíferos não voadores: 11 roedores – *Abrawayaomys ruschii*, *Akodon cursor*, *Blarinomys breviceps*, *Delomys sublineatus*, *Juliomys ossitenuis*, *Oligoryzomys nigripes*, *Oligoryzomys flavescens*, *Oxymycterus dasytrichus*, *Rhipidomys tribei*, *Sooretamys angouya* e *Thaptomys nigrita*; e três marsupiais – *Monodelphis scalops*, *Philander quica* e *Marmosops incanus*. Descrevemos pela primeira vez o número fundamental autossômico e a morfologia dos cromossomos sexuais de *Abrawayaomys ruschii*, uma espécie rara de sigmodontíneos, e descrevemos um novo cariótipo para *Blarinomys*. A revisão de cariótipos publicados das espécies aqui estudadas permitiu ampliar a distribuição geográfica de *Oligoryzomys nigripes* e *Delomys sublineatus*.

**Palavras-chave:** Roedores. Marsupiais. Complemento cromossômico. Distribuição geográfica.

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FARIA, M. B., R. O. LANES & C. R. BONVICINO, 2020. Non-volant small mammals (Rodentia and Didelphimorphia) diversity in an isolated area of the Serra da Mantiqueira, Minas Gerais state, Brazil. **Boletim do Museu Paraense Emílio Goeldi. Ciências Naturais** 15(3): 643-662. DOI: http://doi.org/10.46357/bcnaturais.v15i3.203.

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Recebido em 17/10/2019

Aprovado em 07/10/2020

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## INTRODUCTION

Within the Neotropics the Atlantic Forest, South America, is considering a hotspot region with several endemic mammalian species. The southeastern region of the Atlantic Forest is formed by a topographical complex of mountains such as the Serra do Mar and Serra da Mantiqueira mountains, which directly influence this biome's landscapes (Costa, L. *et al*., 2000). These subparallel mountain systems are composed of the coastal Serra do Mar and the inland Serra da Mantiqueira, distributed along the continental Atlantic border. The Serra da Mantiqueira mountain range, formed by a mountainous area of rainforest vegetation (Ab'Saber, 1977), is about 500 km long, and spans three Brazilian states: São Paulo (30%), Minas Gerais (60%), and Rio de Janeiro (10%). The Serra da Mantiqueira originated in the Paleocene, resulting in a complex of mountains with wide altitudinal variation (Almeida & Carneiro, 1998), and its importance is highlighted in studies of the biogeographical history of different groups of small mammals (Costa, L. *et al*., 2000; Costa, B. *et al*., 2011; Faria *et al*., 2016; Leite, 2003). These studies point to the importance of this mountain range in the diversification of fauna in the region.

Non-volant small mammals, rodents belonging to the families of Cricetidae and Echimyidae and the marsupials of the family Didelphidae, account for 80% of the Atlantic Forest's endemic species, and are usually are the elements responsible for the regionalism of Neotropical mammal communities (Costa, L. *et al*., 2000). The subfamily Sigmodontinae encompasses a wide variety of forms and adaptive diversity (Patton *et al*., 2015), as well as the family Didelphidae (Gardner, 2008 [2007]).

Unfortunately, the levels of taxonomic differentiation of small mammal populations in the Atlantic Forest are still largely unknown to the majority of the genera, especially in the case of sigmodontine rodents. Although the subfamily Sigmodontinae has been studied for a long time (Hershkovitz, 1987), several species and genera have few specimens in scientific collections, *e.g.*, *Pseudoryzomys simplex*, *Phaenomys ferrugineus*, *Phyllomys lundi* (Bonvicino *et al*., 2001b; Faria *et al*., 2016; Wolf *et al*., 2016), thus preventing important taxonomic, phylogenetic and biogeographic inferences. This situation is particularly worrying in view of the speed of destruction of unique environments in the Atlantic Forest, with 95% of its original area having now become the most populous region of South America (Galindo-Leal & Câmara, 2003). This high species diversity in the Neotropics can be attributed to forest refuges formed during the Pleistocene period (Haffer, 1969; Vanzolini & Williams, 1970), with this forest refuge hypothesis explaining the Atlantic Forest's biodiversity and species endemism (Ab'Saber, 1977; Carnaval & Moritz, 2008; Carnaval *et al*., 2009; Porto *et al*., 2012).

Among sigmodontine rodents this high diversity is underestimated due to the presence of morphologically similar species (Yazbeck *et al*., 2011). Although some species have chromosomal polymorphisms or variations (*e.g.*, *Holochilus chacarius* in Nachman & Myers, 1989, and *Oligoryzomys nigripes* in Bonvicino *et al*., 2001a), most of them are characterized by an essential constant chromosomal complement (*e.g.*, species of the genera *Calomys* in Bonvicino *et al*., 2003, *Juliomys* in Paresque *et al*., 2009, *Brucepattersonius* and *Oxymycterus* in Bonvicino, 2011), thus making the karyotype an excellent tool for identifying species, especially small rodents where the presence of cryptic species is constant, in addition to undescribed species (Bonvicino *et al*., 2003; Paresque *et al*., 2009). Studies that integrate morphology, karyotype and DNA sequence data lead to an advance in knowledge about sigmodontinae rodents and Didelphimorphia marsupials, with a substantial increase in the number of recognized species (Gonçalves *et al*., 2005; Jansa & Voss, 2000; Patton *et al*., 2000; Voss *et al*., 2005; Voss & Jansa, 2009). However, few karyotypic studies integrate morphology and geographic distribution data into their analyses (Bonvicino *et al*., 2013; Weksler *et al*., 2017), and this has led to misidentification in the past. For example, the lack of integrated morphology and karyotype studies, led to the association of the same diploid number (2n) of 62 and fundamental autosomal number (FNa) of 64 with different co-generic species, *Oligoryzomys eliurus* and *Oligoryzomys fornesi* (Andrades-Miranda *et al*., 2001; Bonvicino & Weksler, 1998), thus showing the importance of morphologic documentation in karyologic studies. In contrast to morphologic and molecular data, it is impossible to perform a retrospective analysis of karyotype, which also hampers karyological studies.

This study therefore aims to evaluate the chromosomal features and contribute to the debate on the species taxonomy and distribution of rodents and marsupials, including endemic species of the *Zona da Mata Mineira*, a hotspot mountain region in the Atlantic Forest biome. Herein, we karyotyped small mammals, and we discuss the karyotype variation of these species, and comment on the geographic distributions of the species surveyed.

## MATERIAL AND METHODS

The study area is located in the municipality of Alto Jequitibá, Minas Gerais state, in the Atlantic Forest biome (Figure 1), and included two protected areas, classified as *Reserva Particular de Patrimônio Natural* (RPPN) category, in the *Fazenda Harmonia* (farm Harmonia). We carried out six field expeditions during one year in both areas, RPPN *Santuário Ecológico Mata dos Jacus* (-20.483404 S, -42.046899 W) and RPPN *Refúgio dos Sauás* (-20.407001 S, -42.041710 W), both with semi-deciduous mountain vegetation (Veloso *et al*., 1991). In order to conduct inventories for the non-volant small mammals we placed Sherman and tomahawk live traps and one linear transect with 12 buckets (60 l), 10 meters apart, in each locality (Table 1). The study was conducted under permit number 41959-1 from the *Instituto Chico Mendes de Conservação da Biodiversidade* (ICMBio).

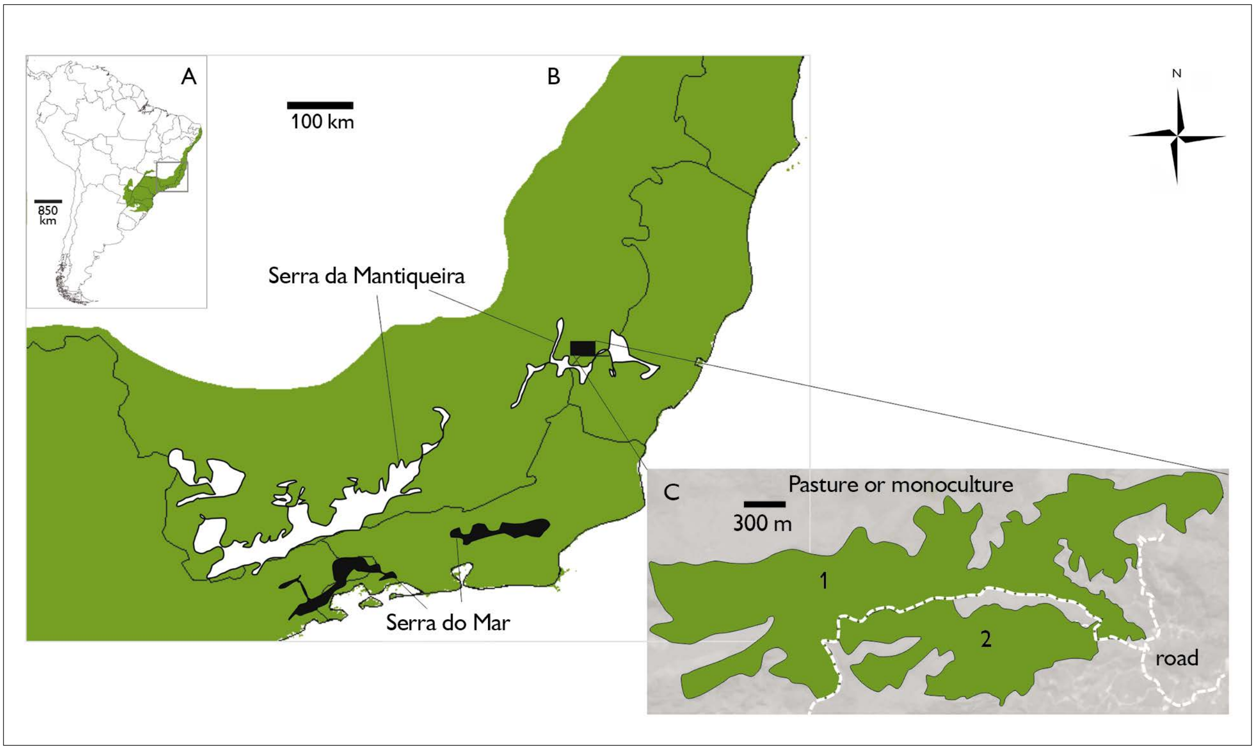

Figure 1. Locality of sampled area: A) South America map with Atlantic forest in green; B) Southeastern Brazil with Atlantic Forest (green), collecting locality (black rectangle), the highlands of the mountain range of Serra da Mantiqueira (white patches) and Serra do Mar (black patches); C) Collecting localities with RPPN *Refúgio dos Jacus* (1) and the RPPN *Refúgio dos Sauás* (2), Minas Gerais state, Brazil.

Table 1. List of studied areas in the municipality of Alto Jequitibá, Minas Gerais state, specifying the collecting data, trap type and total effort per area.

| Study area | Collecting dates | Trap types | Total effort |
|---|---|---|---|
| RPPN *Santuário Ecológico Mata dos Jacus* | November 14-18, 2013<br>January 28 to February 01, March 13-17, May 14-18, August 05-09, October 18-22, 2014 | 40 Sherman<br>40 Tomahawk<br>11 pitfalls | 2,730 trap.nights |
| RPPN *Refúgio dos Sauás* | November 14-18, 2013<br>January 28 to February 01, March 13-17, May 14-18, August 05-09, October 18-22, 2014 | 11 pitfalls<br>40 Sherman<br>40 Tomahawk | 2,730 trap.nights |
| Total | 30 days | 182 traps | 5,460 trap.nights |

To confirm species identifications, specimens were karyotyped in the field using Andrade & Bonvicino's (2003) methodology. In addition, we identified the specimens based on morphologic characters (Gardner, 2008 [2007]; Patton *et al*., 2015), and they were deposited in the mammal collection of the *Museu de Zoologia Newton Baião de Azevedo* (MZNB), Carangola, Minas Gerais State, Brazil. In order of associate species and karyotypes, the skull of one specimen of each species was photographed and composed together the respective species karyotype, except for *Thaptomys nigrita*. All specimens collected alive were karyotyped.

Chromosome preparations were obtained from short bone marrow cultures in RPMI 1640 medium supplemented with 20% fetal calf serum and colchicine ($10^{-6}$ M) for two hours (Andrade *et al*., 2004). Chromosomes were ordered according to morphology and size. Conventional staining was performed with 5% Giemsa solution (phosphate buffer, pH 6.8) and G-banding patterns were carried out according to Seabright (1971). For each cell suspension sample, several metaphases were captured and subjected to microscopic analysis, and five metaphases were mounted. Fundamental number (FNa) refers only to autosome complement. An extensive inventory was carried out in several scientific data bases available online, such as Google Scholar (s. d.) and Web of Science (s. d.) for identifying the localities of karyotyped individuals for each analyzed species. Geographical distributions of each analyzed species were based on Patton *et al.* (2015) for rodent species and on Gardner (2008 [2007]) for Didelphimorphia species.

## RESULTS

We karyotyped 14 species, 11 rodents and three marsupials (Figures 2 to 6), as bellow described.

Order Rodentia: *Abrawayaomys ruschii* Cunha & Cruz, 1979 male MZNB 167 and female MZNB 176, showed 2n = 58 and FNa = 58 (Figure 2). The autosome complement showed 28 chromosome pairs, one small metacentric and 27 acrocentric pairs varying in size from large to small. The sexual X chromosome is the largest acrocentric chromosome of the complement, and the Y a median size acrocentric. The G-band karyotype was also obtained (Figure 2, bottom left). The autosome complement showed 20 chromosome pairs, 15 acrocentric pairs varying in size from medium to small, and five large biarmed pairs; the sexual X chromosome is a median sized acrocentric and Y a small acrocentric.

*Akodon cursor* (Winge, 1887), seven males and four females, showed 2n = 14 (Figure 3A) with different fundamental autosomal numbers, FNa = 18 in MZNB 209, MZNB 192, MZNB 234, MZNB 245, FNa = 19 in MZNB 184, MZNB 232, MZNB 256, FNa = 20 in MZNB 256, MZNB 208, MZNB 248, and FNa = 21 in MZNB 164 (Figure 3A), with a small acrocentric X chromosome and a very small Y chromosome. Polymorphisms in fundamental numbers are due to pericentric inversions in the second, third and fourth pairs. *Blarinomys breviceps* (Winge, 1887)

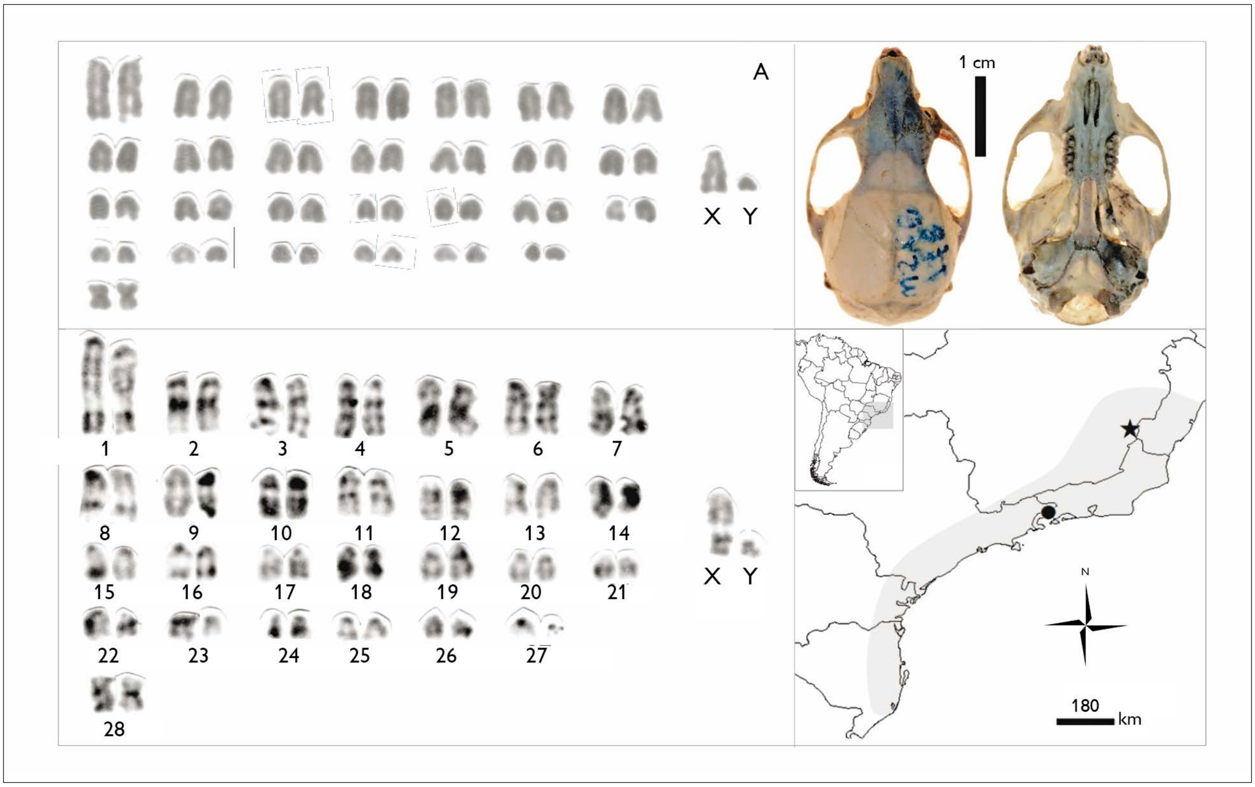

Figure 2. *Abrawayaomys ruschii* male MZNB 167. Giemsa staining (top lef) and G-banding karyotypes with 2n = 58 and FNa = 58 (bottom left), dorsal and ventral views of the skull (top right), and map of species distribution in gray (according to Patton *et al*., 2015), with locality of this study (black star), and localities of karyotyped specimens (black circle, for localities list see Table 2) (bottom right).

male MZNB 268 showed 2n = 42 and FNa = 50 (Figure 3B). The autosome complement showed 20 autosomes pairs, five large sized biarmed pairs and 15 acrocentric pairs varying in size from median to small. The X chromosome is a median sized acrocentric and the Y chromosome a small acrocentric (Figure 3B). *Oxymycterus dasytrichus* (Schinz, 1821), two males (MZNB 171 and MZNB 279), showed 2n = 54 and FN = 64 (Figure 3C), with submetacentric X and Y chromosomes. *Thaptomys nigrita* (Lichtenstein, 1829) female MZNB 275 showed 2n = 52 and FN = 52 (Figure 3C). In this species the acrocentric chromosomes are very similar in size to sexual pair (Colombi, 2013; Ventura *et al*., 2004). So, since we used only Giemsa staining for the karyotype analysis of this sample, we not indicated the sexual pair.

Seven *Oligoryzomys nigripes* (Olfers, 1818) specimens (MZNB 173, MZNB 175, MZNB 179, MZNB 206, MZNB 253, MZNB 255, and MZNB 258) showed 2n = 62 and FNa = 80-82 (Figure 4A), with a large sized submetacentric X chromosome and a small acrocentric Y. In four specimens, the third and fourth metacentric pairs were heteromorphic, with one biarmed and one acrocentric chromosome. *Oligoryzomys flavescens* (Waterhouse, 1837) female MZNB 183 showed 2n = 64 and FNa = 66 (Figure 4B), with a median size submetacentric X chromosome. *Sooretamys angouya* (G. Fischer 1814), males MZNB 197 and MZNB 201, showed 2n = 58 and FNa = 60 (Figure 4C), with a large acrocentric X chromosome and an acrocentric Y chromosome. *Rhipidomys tribei* Costa, Geise, Pereira & Costa, 2011 male MZNB 169 showed 2n = 44 and FNa = 50 (Figure 4D), with a medium sized acrocentric X chromosome and a small acrocentric Y chromosome.

Table 2. List of species found in the study area with karyotypic data, including diploid (2n) and fundamental autosomal number (FNa), locality, and source. Number between parentheses after locality name refers to the number of specimens herein karyotyped. Legends: Brazilian federative unities - BA (Bahia), CE (Ceará), DF (Federal District), ES (Espírito Santo), GO (Goiás), MG (Minas Gerais), MS (Mato Grosso do Sul), PR (Paraná), RJ (Rio de Janeiro), RS (Rio Grande do Sul), SC (Santa Catarina), SP (São Paulo). Source: 1 = Sbalqueiro & Nascimento (1996); 2 = Geise (1995); 3 = Geise *et al.* (1998); 4= Moreira *et al*. (2009); 5 = Yonenaga (1972); 6 = Paresque *et al.* (2004); 7 = Yonenaga *et al.* (1975); 8 = Yonenaga-Yassuda (1979); 9 = Yonenaga-Yassuda *et al*. (1983); 10 = Fagundes *et al.* (1998); 11 = Araújo (2014); 12 = Mochi (2014); 13 = Geise *et al*. (2004); 14 = Delciellos *et al.* (2012); 15 = Ventura *et al.* (2012); 16 = Zanchin *et al.* (1992b); 17 = Gonçalves & Oliveira (2014); 18 = Costa, L. *et al.* (2007); 19 = Grazzini *et al.* (2015); 20 = Aguieiras *et al.* (2013); 21 = Paresque *et al.* (2009); 22= Sbalqueiro *et al*. (1991); 23= Pereira, N. *et al.* (2008); 24 = Di-Nizo *et al.* (2015); 25 = Di-Nizo *et al.* (2014); 26 = Almeida & Yonenaga-Yassuda (1991); 27 = Azevedo (2009); 28 = Almeida Vieira (2012); 29 = Andrades-Miranda *et al*. (2000); 30 = Araújo Soares (2014); 31 = Bonvicino *et al.* (2002); 32 = Bonvicino *et al.* (2014); 33 = Bonvicino *et al.* (2001a); 34 = Brum-Zorrilla *et al.* (1988); 35 = Bueno *et al*. (1987); 36 = Espinosa & Reig (1991); 37 = Gatto de Almeida (2015); 38 = Grazzini (2014); 39 = Myers & Carleton (1981); 40 = Svartman (1989); 41 = Tortato *et al.* (2014); 42 = Weksler & Bonvicino (2005); 43 = Zanchin (1988); 44 = Carvalho, A. (2017); 45 = Ventura *et al.* (2010); 46 = Colombi (2013); 47 = Moreira & Oliveira (2011); 48 = Pereira, N. *et al.* (2008); 49 = Hass *et al.* (2011); 50 = Carvalho, B. *et al.* (2002); 51 = Faria (2008); 52 = Pereira, L. & Geise (2007). (Continue)

| *Taxa* | 2n | FNa | Locality | Source |
|---|---|---|---|---|
| Order Rodentia | | | | |
| *Abrawayaomys ruschii* | 58 | 58 | MG: Alto Jequitibá (n = 2) | This study |
| *Abrawayaomys ruschii* | 58 | - | RJ: Angra dos Reis | 23 |
| *Akodon cursor* | 14 | 18-21 | MG: Alto Jequitibá (n = 13) | This study |
| *Akodon cursor* | 14 | 18 | PR: Guaraqueçaba, RJ: Mendes, Rio Bonito, Angra dos Reis, Sumidouro, Macaé, Casimiro de Abreu<br>SP: Ubatuba, Guaratatuba<br>MG: Simão Pereira, Viçosa, Parque Estadual do Brigadeiro<br>ES: Santa Teresa, Cariacica | 1, 2, 3, 4, 5, 6 |
| *Akodon cursor* | 14 | 19 | RJ: Rio de Janeiro, Pirai, Maricá, Rio Bonito, Rio das Ostras, Resende, Penedo Maromba<br>SP: São Paulo, Picinguaba, Salesópolis, Juquitiba, Sete Barras, Iporanga, Iguapé, Ariri, Ilha do Cardoso, Guatatuba<br>PR: Guaraqueçaba<br>MG: Conceição do Mato Dentro, Rio Pomba<br>ES: Cariacica, Santa Teresa<br>PR: Matinhos, Paranaguá | 1, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13 |
| *Akodon cursor* | 14 | 20 | RJ: Rio de Janeiro, Nova Friburgo, Resende, Penedo, Maromba<br>PR: Guaraqueçaba<br>SP: Iguapé, São Paulo, Sete Barras, Ilha do Cardoso, Picinguaba, Salesópolis Juquitiba, Guatatuba<br>BA: Una<br>ES: Santa Teresa, Cariacica | 1, 2, 3, 5, 6, 7, 9, 10, 11, 13, 14 |
| *Akodon cursor* | 14 | 21 | SP: Iguapé, São Paulo, Picinguaba<br>RJ: Mendes, Rio de Janeiro<br>BA: Una<br>PR: Guaraqueçaba | 1, 2, 3, 7, 10, 11 |
| *Blarinomys breviceps* | 43 | 50 | MG: Alto Jequitibá (n = 1) | This study |
| *Blarinomys breviceps* | 43 | 50 | SP: Parque Estadual da Serra da Cantareira | 15 |
| *Delomys sublineatus* | 72 | 90 | MG: Alto Jequitibá (n = 5) | This study |
| *Delomys sublineatus* | 72 | 90 | PR: Antonina<br>ES: Fazenda Monte Verde<br>MG: Parque Estadual Serra do Brigadeiro<br>SP: Salesópolis, Caucaia do Alto | 16, 17 |

Table 2. (Continue)

| *Taxa* | 2n | FNa | Locality | Source |
|---|---|---|---|---|
| *Juliomys ossitenuis* | 20 | 36 | MG: Alto Jequitibá (n = 1) | This study |
| *Juliomys ossitenuis* | 20 | 36 | MG: Fervedouro, Dores do Rio Preto<br>SP: Bananal, Cotia, Piedade, Tapiraí, Ribeirão Grande<br>PR: Pirai do Sul<br>RJ: Teresópolis | 18, 19, 20, 21 |
| *Oligoryzomys flavescens* | 64 | 66 | MG: Alto Jequitibá (n = 1) | This study |
| *Oligoryzomys flavescens* | 64 | 66 | RS: Mostardas, Osório, Sapiranga Tramandaí, Taim, Alpestre, Rio dos índios, Erechim Horto Florestal, Passo Fundo, Chapecó<br>PR: Ponta Grossa, Curitiba, Piraguara, Esmeralda, Torres, Curitiba<br>SP: Iporó | 12, 22, 24 |
| *Oligoryzomys nigripes* | 62 | 80 - 82 | MG: Alto Jequitibá (n = 9) | This study |
| *Oligoryzomys nigripes* | 62 | 78 - 82 | DF: Brasília<br>BA: Morro do Chapéu, Rio de uma<br>CE: Pacoti<br>ES: Cariacica, Estação Ecológica Santa Lúcia, Monte Verde, Santa Maria de Jetibá, Santa Teresa, Venda Nova dos Imigrantes<br>GO: Caldas Novas, Corumbaíba, Ipameri<br>MG: Alto Caparaó, Caxambu, Juramento, Peirópolis, Serra da Canastra, Parque Estadual da Serra Brigadeiro<br>MS: Bodoquena<br>PR: Iguaçu, FLONA de Piraí do Sul<br>RJ: Itaguaí, Itatiaia, Nova Friburgo, Rio Claro, Sumidouro, Teresópolis<br>RS: Alpestre, Aratiba, Caxias do Sul, Chapecó, Charqueadas, Erechim, Ivaí, PE do Turvo, Derrubadas, Estação Ecológica do Taim, Maquiné, Mostardas, Morro Alto, Muitos Capões, Osório, Picada Verão, Quintão, Reserva Biológica Estadual do Sassafrás, Riozinho, Rio dos Índios, São Francisco de Paula, Sapiranga, Tainhas, Tapes, Torres, Tramandaí, Tupanciretã<br>SC: Concordia, Costa de entro, Ilha de Santa Catarina, São Francisco do Sul<br>SP: Águas de Santa Bárbara, Araçariguama, Araraquara, Casa Grande, Guaratuba, Iguapé, Iporanga, Itapetininga, Intervales, Juquiá, Luiz Antônio, Pedreiras Pedro de Toledo, Parque Estadual Serra do Mar, Pilar do Sul, Santa Maria da Serra, Ribeirão Preto, Rio Claro, Santa Virgínia, Santo Antônio, Taubaté | 4, 6, 13, 12, 21, 24, 25, 26, 28, 29, 30, 31, 32, 33a, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43 |
| *Oxymycterus dasytrichus* | 54 | 64 | MG: Alto Jequitibá (n = 1) | This study |
| *Oxymycterus dasytrichus* | 54 | 64 | MG: Parque Estadual do Brigadeiro<br>RJ: Itatiaia<br>PR: Matinhas | 4, 12, 13 |
| *Rhipidomys tribei* | 44 | 50 | MG: Alto Jequitibá (n = 1) | This study |
| *Rhipidomys tribei* | 44 | 50 | ES: Castelo, Ibitirana, Muqui<br>MG: Fervedouro, Santa Barbara | 44 |
| *Sooretamys angouya* | 58 | 60 | MG: Alto Jequitibá | This study |

Table 2. (Conclusion)

| *Taxa* | 2n | FNa | Locality | Source |
|---|---|---|---|---|
| *Sooretamys angouya* | 58 | 60 | ES: Monte Verde<br>RS: Sapiranga, Tramandaí, Mostardas, Faxinal, Torres, Tramandaí, Caxias do Sul, Quintão, Osorio, Doutor Pedrito<br>SC: Florianópolis<br>PR: Piraí do Sul<br>MG: Parque Nacional do Caparaó<br>SP: Santa Virgínia, Parque Estadual da Serra do Mar | 20, 25, 32, 38, 41 |
| *Thaptomys nigrita* | 52 | 52 | MG: Fervedouro. ES: Santa Teresa, Domingos Martins, Dores do Rio Preto, Luminárias. SP: São Bernardo do Campo, Biritiba Mirim, Pilar Do Sul, Iguapé, São João Batista da Boa Vista, Ibiúna, Piedade, Tapirai, Cotia, Capão Bonito, Piraquara, Santa Virginia<br>PR: Ortigueira, Matinhos, Piraguara, Curitiba<br>RS: Maniqué<br>SC: Blumenau<br>BA: Una | 4, 6, 31, 37, 45, 46, 47, 49 |
| *Thaptomys nigrita* | 52 | 52 | MG: Alto Jequitibá (n = 1) | This study |
| Order Didelphimorphia | | | | |
| *Monodelphis scalops* | 18 | | MG: Alto Jequitibá (n = 2) | This study |
| *Monodelphis scalops* | 18 | 30 | SP: Santa Virginia | 12 |
| *Marmosops incanus* | 14 | 24 | MG: Alto Jequitibá (n = 14) | This study |
| *Marmosops incanus* | 14 | 24 | BA: Pau-Brasil, Lençóis, Remanso<br>MG: Santa Barbara, Pedra Dourada, Fervedouro, Tombos<br>ES: Santa Teresa, Cariacica<br>SP: Caucaia do Alto, Parque Estadual da Serra do Mar, Santa Virginia | 6, 25, 27, 50, 51, 52 |
| *Philander quica* | 22 | | MG: Alto Jequitibá (n = 4) | This study |
| *Philander quica* | 22 | 20 | RJ: Angra dos Reis<br>SP: Santa Virginia, Serra da Cantareira<br>SC: Doutor Pedrito<br>RS: Aratinga, Sapiranga, Osório<br>ES: Santa Teresa | 6, 25, 38, 48, 50 |

Two specimens of *Delomys sublineatus* (Thomas, 1903) were collected, the female MZNB 243 and the male MZNB 216 that showed 2n = 72 and FNa = 90 (Figure 5A), with a large sized submetacentric X chromosome and a small acrocentric Y chromosome. *Juliomys ossitenuis* Costa, Pavan, Leite & Fagundes, 2007, male MZNB 207, showed 2n = 20 and FNa = 36 (Figure 5B), with a large metacentric X chromosome and a medium submetacentric Y chromosome.

Order Didelphimoprhia: two *Monodelphis scalops* (Thomas, 1888) were collected, male MZNB 269, and male MZNB 180 that showed 2n = 18 (Figure 6A), with small acrocentric X and Y sexual chromosomes. Two *Philander quica* (Temminck, 1824) were collected, male MZNB 239, and male MZNB 165 that showed 2n = 22 (Figure 6B), with a medium acrocentric X chromosome and a small acrocentric Y chromosome. *Marmosops incanus* (Lund, 1840) male MZNB 241 showed 2n = 14 (Figure 6C), with a medium submetacentric X chromosome and a small Y chromosome.

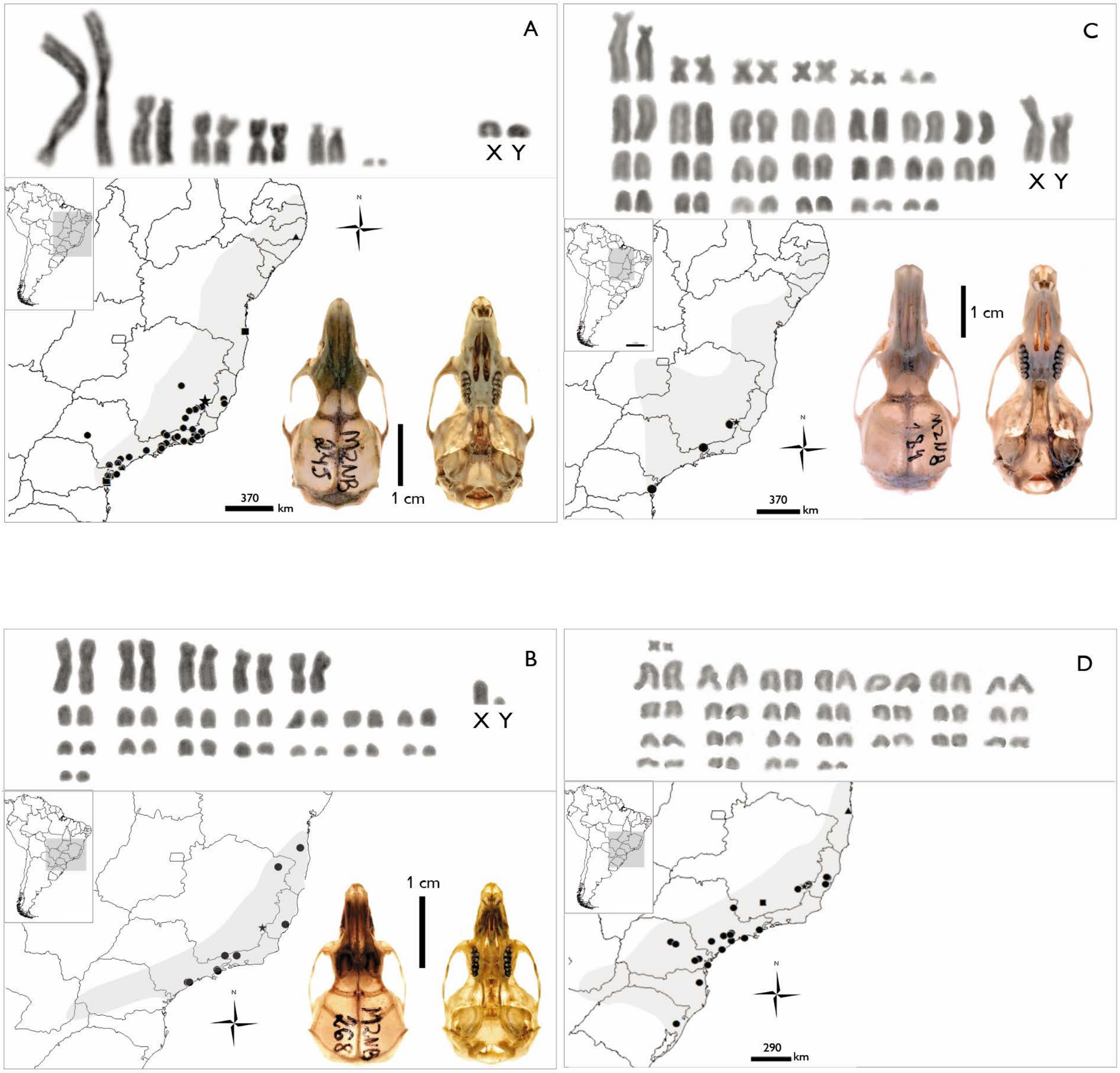

Figure 3. Giemsa staining karyotypes, maps of species distribution in gray (according to Patton *et al*., 2015), with study area (black star) and localities of karyotyped specimens from previous studies (black circle; for localities and sources see Table 2), and ventral and dorsal skull views of: A) *Akodon cursor* male MZNB 164 with 2n = 14 and FNa = 21; B) *Blarinomys breviceps* male MZNB 268 with 2n = 42 and FNa = 50; C) *Oxymycterus dasytrichus* male MZNB 171 with 2n = 54 and FNa = 64; D) *Thaptomys nigrita* female MZNB 275 with 2n = 52 and FNa = 52 (with no indication of sexual pair, and with no figured skull). Black square = locality with different karyotype from the specimens of the study area.

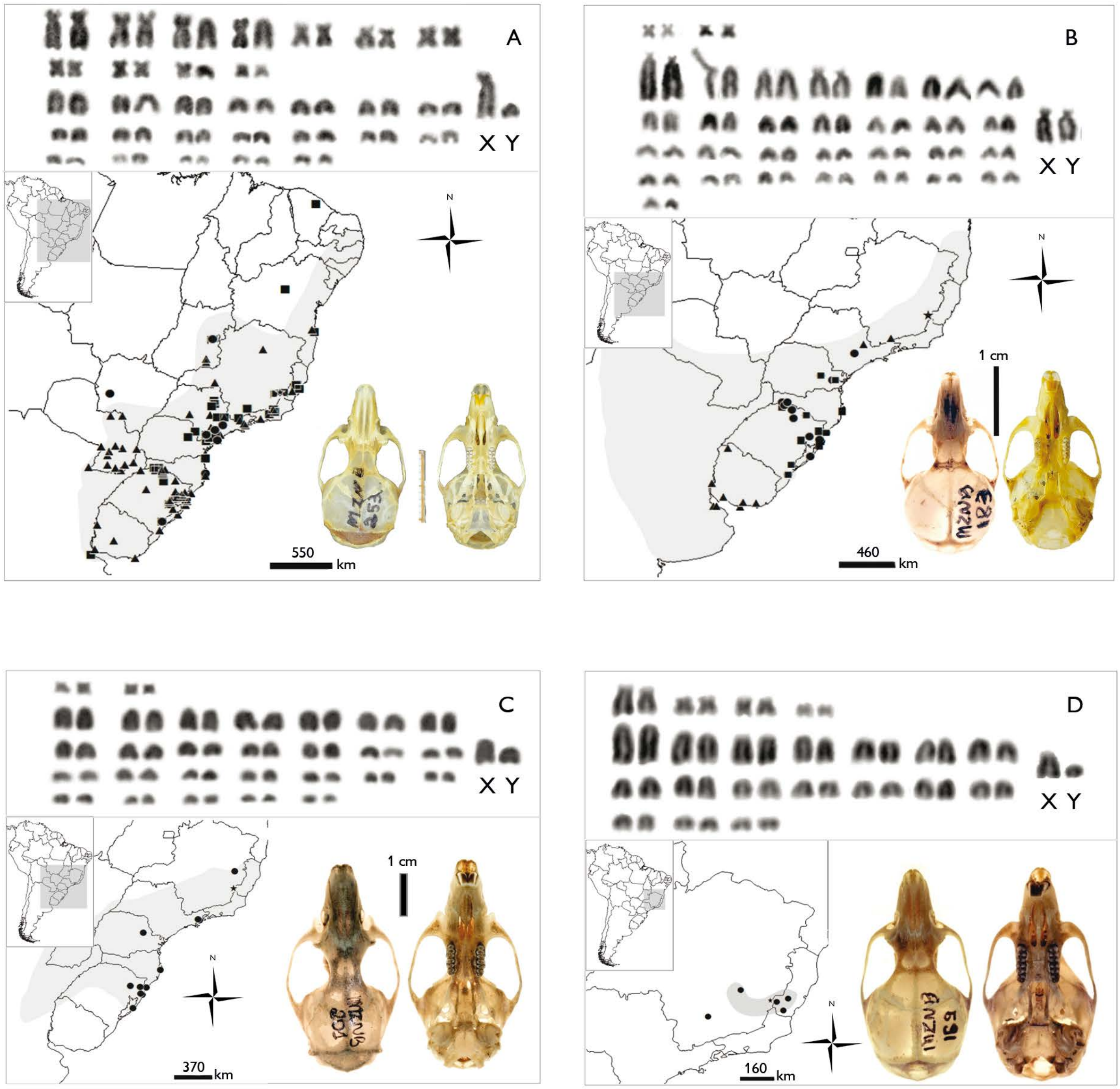

Figure 4. Giemsa staining karyotypes, maps of species distribution in gray (according to Patton *et al*., 2015), with the study area (black star) and localities of karyotyped specimens from previous studies (black circle; for localities and sources see Table 2), and ventral and dorsal skull views of: A) *Oligoryzomys nigripes* male MZNB 179 with 2n = 62 and FNa = 80 (skull MZNB 253); B) *Oligoryzomys flavescens*, MZNB 183, 2n = 64 and FNa = 66; C) *Sooretamys angouya* male MZNB 197 with 2n = 58 and FNa = 60 (skull MZNB 201); D) *Rhipidomys tribei* male MZNB 169 with 2n = 44 and FNa = 50. Black square = locality with different karyotype from the specimens of the study area. Black triangles= localities with the same and different karyotypes.

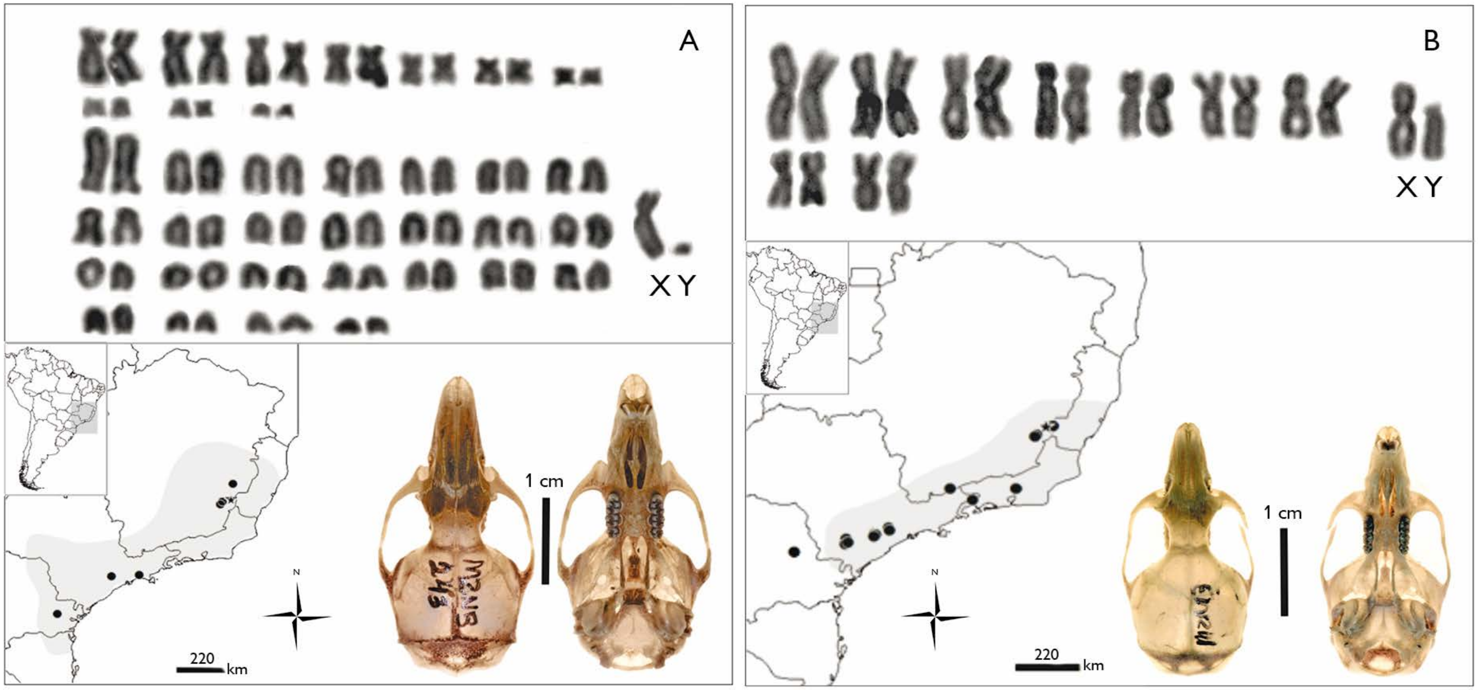

Figure 5. Giemsa staining coloration karyotypes, maps of species distribution in gray (according to Patton *et al*., 2015 and this study), with the study area (black star), and localities of karyotyped specimens from previous studies (black circle; for localities and sources see Table 2), and skull ventral and dorsal views of: A) *Delomys sublineatus* male MZNB 216 with 2n = 72 and FNa = 90, and skull of female MZNB 243, B) *Juliomys ossitenuis* male MZNB 207 with 2n = 20 and FNa = 36.

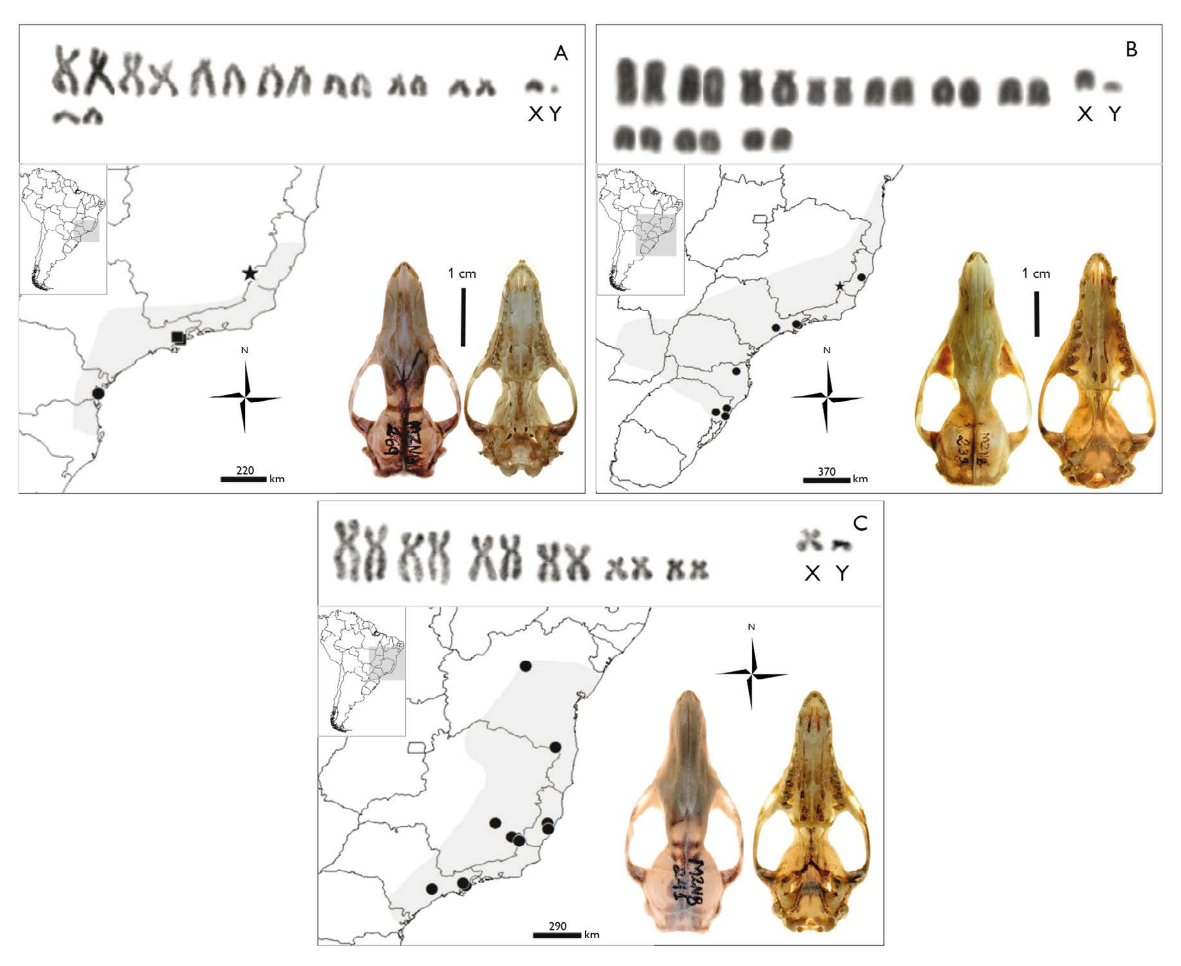

Figure 6. Giemsa staining karyotypes, maps of species distribution (modified from Pine & Handley Jr., 2008 [2007]) in gray, with the study area (black star), and localities of karyotyped specimens from previous studies (black circle; for localities and sources see Table 2), and ventral and skulls dorsal views of: A) *Monodelphis scalops* male MZNB 180 with 2n = 18 and FNa = 20, and skull of male MZNB 269, B) *Philander quica* male MNZB 165 (MBF145) with 2n = 22 and FNa = 20, and skull of male MZNB 239, C) *Marmosops incanus* male MZNB 241 with 2n = 14 and FNa = 24.

## DISCUSSION

The karyotype herein reported for *Abrawayaomys ruschii* with 2n = 58, is similar to the single one previously reported for a specimen from Rio de Janeiro state (Pereira, L. *et al*., 2008). However, the autosomal fundamental number and the sexual chromosomes cannot be identified by Pereira, L. *et al.* (2008) due to the poor quality of the preparation. Herein the acrocentric X and Y sexual chromosomes, and the FNa of 60 is described for the first time. After G-banding, all chromosome pairs of this species could be identified (Figure 2). *Abrawayaomys ruschii* is a poor known species and is considered as *incertae saedis* (Ventura *et al*., 2013), whereas a recent study suggested its close relationship with the tribe Akodontini (Gonçalves *et al*., 2020). Some authors suggested the presence of a third and undescribed species of Minas Gerais *Abrawayaomys* (Pardiñas *et al*., 2009), however our data showed that in the localities sampled in Minas Gerais the species present is *Abrawayaomys ruschii*. The geographical distance (378 km) between the two areas where the karyologic studies have been published, one in the state of Rio de Janeiro and another in Minas Gerais state, suggest a conserved chromosome complement for *A. ruschii*.

*Blarinomys breviceps'* new karyotype herein described, with 2n = 42 and FNa = 50, differs from all others described for this species. Eight distinct karyomorphs have already been described for this monospecific genus with a variation in diploid numbers (2n) due to arrangements involving autosomes and the presence of b chromosomes (B): 2n = 52, 2n = 50 + 2B, 2n = 44 + 1B, 2n = 39 + 4Bs, 2n = 36 + 1, 2n = 34, 2n = 29 + 2Bs, 2n = 28 (Geise *et al*., 2008; Ventura *et al*., 2012). The map in Figure 3 shows localities with cytogenetic studies. All these karyotypes, including the one herein described, share the same fundamental autosomal number of 50 and the XY sexual system, with a variation in diploid numbers due to up 4 supernumerary chromosomes and Robertsonian arrangement (Ventura *et al*., 2012). *Blarinomys* is considered a fossorial rodent due to its adaptations to fossorial living (Teta & Pardiñas, 2015). Fossorial rodents often have a high level of intra and inter-specific polymorphism (Ipucha *et al*., 2008). The presence of two evolutive lineages of *Blarinomys breviceps* in the Atlantic Forest suggested by phylogenetic analysis (Ventura *et al*., 2012), indicate that further studies are necessary for understanding whether the karyologic variation of this taxon is polymorphism.

The tribe Akodontini included several genera that occur in Brazil (Patton *et al*., 2015), and we analyzed karyotypes of specimens belonging to four genera of this tribe, *Akodon*, *Blarinomys*, *Oxymycterus*, and *Thaptomys*. *Akodon cursor* karyotypes herein found were within the variation described for this species (Table 2). Polymorphism due to pericentric inversion and centric fusion/fission in the largest chromosome of the complement is well documented, with karyotypes ranging from 2n = 14 to 16 and FNa = 18 to 26 (Yonenaga, 1975; Yonenaga-Yassuda *et al*., 1983; Maia & Langguth, 1981; Kasahara & Yonenaga-Yassuda, 1984; Fagundes *et al*., 1998; Geise *et al*., 1998; Sbalqueiro & Nascimento, 1996; Ventura *et al*., 2004; Pereira, L. & Geise, 2007; Moreira *et al*., 2009). The 2n = 16 is fixed in the extreme north of the species distribution (Maia & Langguth, 1981) with a single record in the extreme south of distribution in Guaraqueçaba, Paraná state, where all three diploid numbers were found (Sbalqueiro & Nascimento, 1996). Despite this polymorphism, the karyotype of *Akodon cursor* is easily identified, and specimens were karyotyped throughout its distribution (Figure 3A).

*Oxymycterus dasytrichus* karyotype with 2n = 54 and FNa = 62 herein reported is similar to those already described for this species in Minas Gerais and Paraná states (Moreira *et al*., 2009; Mochi, 2014; Figure 3C). Despite variations in external and cranial morphology, all species of this genus share the same 2n and FNa (Mattevi *et al*., 1982; Sbalqueiro *et al*., 1982; Hershkovitz, 1998; Bonvicino, 2011), and this constancy leads to few karyologic studies carried out with *Oxymycterus* species.

*Thaptomys nigrita* karyotype showed 2n = 52 and FNa = 52 (Figure 3D), similar to those reported to specimens from Rio Grande do Sul, Paraná, São Paulo, Rio de Janeiro, Espírito Santo, and Minas Gerais states (Yonenaga *et al*., 1975; Paresque *et al*., 2004; Ventura *et al*., 2004, 2010; Moreira *et al*., 2009; Delciellos *et al*., 2012). Two other karyotypes were attributed to *T. nigrita*, one with 2n = 48-51 and FNa = 52 described for specimens from Luminárias in Minas Gerais state (Colombi, 2013), and another with 2n = 50 and FNa = 48 for specimens from Una, Bahia state (Ventura *et al*., 2004).

The tribe Oryzomyini included several genera that occur in Brazil, and we analyzed karyotypes of specimens belonging to the two genera of this tribe, *Oligoryzomys* and *Sooretamys* (Patton *et al*., 2015). The 2n = 62 is constant in *O. nigripes*, with variations in fundamental autosomal numbers from 78 to 80-82 due to pericentric inversion affecting up to four autosome pairs (pairs 2, 3, 4, 8) throughout its distribution, in Brazil (Yonenaga *et al*., 1976; Bueno *et al*., 1987; Zanchin, 1988; Almeida & Yonenaga-Yassuda, 1991;

Bonvicino & Weksler, 1998; Andrades-Miranda *et al*., 2000; Bonvicino *et al*., 2001a), Paraguay (Myers & Carleton, 1981), and Argentina (Espinosa & Reig, 1991). Despite variations in fundamental autosomal numbers due to pericentric inversions (Almeida & Yonenaga-Yassuda, 1991; Andrades-Miranda *et al*., 2000; Figure 4A), and polymorphism in the morphology of X chromosome (Paresque *et al*., 2007), *O. nigripes* can easily be identified by its chromosome complement. The karyotype data in the literature increased *O. nigripes*' geographic distribution west up to Morro do Chapéu in Bahia state, Pacoti in Ceará state, and Bodoquena in Mato Grosso do Sul state (Paresque *et al*., 2007; Figure 4A), showing the importance of karyologic data in the identification and delimitation of species distribution boundaries.

The *Sooretamys angouya* karyotype with 2n = 58 and FN = 60 is similar to the one found in other localities throughout the Atlantic Forest (Andrades-Miranda *et al*., 2000; Silva & Yonenaga-Yassuda, 2004; Di-Nizo *et al*., 2014). Polymorphism in diploid numbers (57-58) due to a Robertsonian rearrangement involving autosomes has already been reported in specimens identified as *Oryzomys ratticeps* (Kasahara & Yonenaga-Yassuda, 1984), as well as the presence of up to two supernumerary chromosomes, resulting in 2n = 60 (Silva & Yonenaga-Yassuda, 2004). The chromosome complement of *S. angouya* was known only in part of its distribution (Figure 4B), with no karyotype description available for its distribution in the west.

We karyotyped specimens belonging to one genus of the tribe Thomasomyini, *Rhipidomys* (Patton *et al*., 2015). The karyotype of *Rhipidomys tribei*, 2n = 44 and FNa = 50 (Figure 4D) has already been reported for specimens from Espírito Santo and Minas Gerais states (Zanchin *et al*., 1992a; Costa, B. *et al*., 2011; Carvalho, A., 2017). Other *Rhipidomys* species, such as *Rhipidomys cariri* from Pernambuco and Ceará states (Thomazini, 2009; Carvalho, A., 2017), *Rhipidomys Itoan* from São Paulo and Rio de Janeiro states (Geise, 1995; Di-Nizo *et al*., 2014; Carvalho, A., 2017), *R. gardneri* from Acre state (Patton *et al*., 2000) and *R. macconnelli* from Bolivar in Venezuela (Aguilera *et al*., 1994) share the same 2n = 44 and FNa = 50. However, these karyotypes differ from each other in their autosome complement morphology and in the presence of constitutive heterochromatin.

Recently the *Juliomys* genus was considered to belong to the tribe Wiedomyini tribe together with *Wiedomys*, *Phaenomys* and *Wilfredomys* (Gonçalves *et al*., 2020). The *Juliomys ossitenuis* karyotype herein reported is similar to the one found in specimens from Minas Gerais, Rio de Janeiro and Paraná states (Aguieiras *et al*., 2013; Costa, L. *et al*., 2007; Grazzini *et al*., 2015). This species showed a conservative karyotype throughout its distribution and a distribution greater than the one reported in the last compilation for the genus (Patton *et al*., 2015). We karyotype two genera of Sigmodontinae *incertae sedis*, *Abrawayaomys* (above discussed) and *Delomys*. *Delomys sublineatus* karyotype herein reported is similar to the one found throughout its distribution (Zanchin *et al*., 1992b; Gonçalves & Oliveira, 2014).

The Didelphidae species are characterized by a conservative karyotype with only three diploids numbers, 14, 18 and 22 (Reig *et al*., 1977; Carvalho, B. *et al*., 2002). This conserved chromosome complement led to few studies with this group (Figure 6). Data herein presented corroborated previous reports about *Monodelphis scalops* with 2n = 18 and FNa = 30 (Di-Nizo *et al*., 2014), *Marmosops incanus* with 2n = 14 and FNa = 24 (Carvalho, B. *et al*., 2002; Faria, 2008) and *P. quica* with 2n = 22 and FNa = 20 (Pereira, N. *et al*., 2008; Di-Nizo *et al*., 2014).

The different karyotype herein found for *Blarinomys* can be related to the topography of the area. The Serra da Mantiqueira contains the highest inselberg-type landforms in South America, and has a high generic and species-level diversity, probably due to the old age of the Atlantic forest and its flora and fauna (Por, 1992; Porembski & Barthlott, 2000).The southeastern region of Brazil, where the *Zona da Mata* and the Atlantic Forest are located, is formed by a topographical complex of mountains, which directly influence this biome's landscapes (Costa, L. *et al*., 2000) with altitudinal variations of 0 to 2,900 m. The studied area is postulated as a refugium in the Southeast Brazilian

Atlantic Forest (Porto *et al*., 2012), and the data herein reported, with a high number of little known and, or, endemic species, such as *Abrawayaomys ruschii* (Pardiñas *et al*., 2015), *Blarinomys breviceps* (Teta & Pardiñas, 2015), and *Phyllomys lundi* (Leite & Loss, 2015), is consistent with this hypothesis.

This study confirms the *Zona da Mata Mineira* as a hotspot region in the Atlantic Forest and showed the importance of karyotype analysis in identifying known and still unknown small mammals, in addition to likely contributing to biogeographic and taxonomic studies of these rodents.

## ACKNOWLEDGMENTS

We are grateful for Sr. Carlos Monteiro and Rita de Cassia for facilities and permission to collect in *Fazenda Harmonia* (Harmonia farm), where are the RPPNs; to the members of *Museu de Zoologia Newton Baião de Azevedo* for help in field work; to two anonym reviewers and the editor Alexandra Bezerra for valuables suggestions. This work was supported by grants from *Conselho Nacional de Pesquisa e Desenvolvimento* (CNPq) (process number 304498/2014-9) and *Fundação de Amparo à Pesquisa do Estado do Rio de Janeiro* (FAPERJ) (process number E-26/201.200/2014) to CRB. MB receives fellowship from CNPq (process number 150387/2014-8), and RL from CAPES and FAPERJ (process number E26/201.812/2019).

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Bol. Mus. Para. Emílio Goeldi. Cienc. Nat., Belém, v. 15, n. 3, p. 663-681, set.-dez. 2020

# Temporal variation in small nonvolant mammal (Cricetidae and Didelphidae) microhabitat associations in the Upper Paraná Atlantic Forest

# Variación temporal en asociaciones de microhábitats de pequeños mamíferos no voladores (Cricetidae y Didelphidae) en el Bosque Atlántico del Alto Paraná

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**Abstract:** Many questions concerning habitat preferences of Neotropical small mammals remain unanswered. These questions include where the animal lives within and among the available habitats, and the temporal (seasonal and interannual) variation in the habitat associations. The objectives of this research were: (1) to determine the associations of non-volant small mammal species (Rodentia and Didelphimorphia) with specific microhabitat characteristics including vegetation structure in an area near the western boundary of the Upper Paraná Atlantic Forest, and (2) to evaluate seasonal and interannual variation in those associations. Three grids were sampled in three seasons (Dry, Wet, Variable) during two years (2015-2017). The four predominant small mammal species (*Gracilinanus agilis*, *Akodon montensis*, *Hylaeamys megacephalus*, and *Oligoryzomys nigripes*) were evaluated for seasonal and interannual variation in habitat preferences. Each of the four exhibited seasonal and/or interannual variation in microhabitat preferences for three to six of the 17 environmental variables analyzed. This is the first study to explicitly evaluate temporal variation in habitat associations of small mammals in the Atlantic Forest ecoregion. The temporal patterns of habitat association among these four predominant species reveal a complex spatially and temporally dynamic composition and structure in this small mammal community.

**Keywords:** El Niño. Environmental variables. Interannual variation. Paraguay. Seasonal variation. Vegetation structure.

**Resumen:** Muchas preguntas sobre las preferencias de hábitat de los pequeños mamíferos neotropicales siguen sin respuesta. Estas preguntas incluyen dónde vive el animal dentro y entre los hábitats disponibles, y la variación temporal (estacional e interanual) en las asociaciones de hábitats. Los objetivos de esta investigación fueron: (1) determinar las asociaciones de especies de mamíferos pequeños no voladores (Rodentia y Didelphimorphia) con características específicas de microhábitat, incluida la estructura de la vegetación en un área cerca del límite occidental del Bosque Atlántico del Alto Paraná, y (2) evaluar la variación estacional e interanual en estas asociaciones. Se tomaron muestras de tres parcelas en tres épocas (Seca, Húmeda, Variable) durante dos años (2015-2017). Cada uno de los cuatro pequeños mamíferos predominantes (*Gracilinanus agilis, Akodon montensis, Hylaeamys megacephalus* y *Oligoryzomys nigripes*) exhibió variación estacional y/o interanual en las preferencias de microhábitats para tres a seis de las 17 variables ambientales analizadas. Este es el primer estudio que evalúa explícitamente la variación temporal en las asociaciones de hábitat de pequeños mamíferos en la ecorregión del Bosque Atlántico. Los patrones temporales de asociación de hábitat entre estas cuatro especies predominantes revelan una estructura compleja espacial y temporalmente dinámica en esta comunidad de pequeños mamíferos.

**Palabras claves**: El Niño. Variables ambientales. Variación interanual. Paraguay. Variación estacional. Estructura de la vegetación.

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OWEN, R. D., 2020. Temporal variation in small nonvolant mammal (Cricetidae and Didelphidae) microhabitat associations in the Upper Paraná Atlantic Forest. **Boletim do Museu Paraense Emílio Goeldi. Ciências Naturais** 15(3): 663-681. DOI: http://doi.org/10.46357/bcnaturais.v15i3.260.

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Recebido em 18/01/2020
Aprovado em 04/12/2020
Responsabilidade editorial: Alexandra Maria Ramos Bezerra

## INTRODUCTION

In the Neotropics, sigmodontine rodents and didelphid marsupials often comprise rich components of the mammal communities (Emmons & Feer, 1997; Solari *et al*., 2001; D'Elía & Pardiñas, 2015; Owen *et al*., 2018). However, many questions concerning habitat preferences remain unanswered. These questions include where the animal lives within the habitat matrix, and the temporal (seasonal and interannual) variation in the habitat associations (Owen *et al*., 2019). Answers to these questions would enable better understanding of the composition and dynamics of marsupial and rodent communities on a local scale.

Over the past two decades, several studies have investigated habitat associations of small terrestrial mammals within the Southern Cone (primarily Brazil) of South America. Delciellos *et al*. (2016) concluded that habitat structure was an important determinant of mammal assemblages in fragments of Atlantic Forest in Rio de Janeiro state, Brazil. Distinct microhabitat associations were reported for a variety of species in southern Amazonia (Santos-Filho *et al*., 2008), secondary Atlantic Forest remnants (Püttker *et al*., 2008), a western Atlantic Forest region (Owen *et al*., 2010), a southern Atlantic Forest site (Melo *et al*., 2011, 2013), the Pampas region in southern Brazil (Sponchiado *et al*., 2012), and in the southwestern Cerrado (Smith *et al*., 2012; Carmignotto *et al*., 2014).

In this study, particular interest was focused on four small mammal species which are encountered abundantly in the *Reserva Natural del Bosque Mbaracayú* (RNBM), in the Upper Paraná Atlantic Forest (UPAF) of Paraguay, which is near the western limit of the Atlantic Forest (Eastwood *et al*., 2018; Barreto Cáceres & Owen, 2019; Owen *et al*., 2020). *Gracilinanus agilis* (Burmeister, 1854) is a marsupial distributed in forests south of the Amazon Basin, east of the Andes and as far south as central Paraguay. The RNBM is near the southern limit of its distribution. Santos-Filho *et al*. (2008) reported that *G. agilis* was found both in forest and into a pasture matrix, and it is considered a generalist species. It is primarily arboreal (Smith *et al*., 2012) and utilizes dense understory vegetation of branches and vines (Carmignotto *et al*., 2015).

The rodent *Akodon montensis* Thomas, 1913 is distributed throughout the Atlantic Forest regions of Brazil, northeastern Argentina and eastern Paraguay, and into gallery forests of the Brazilian Cerrado (Pardiñas *et al*., 2016). The RNBM is near the western limit of its distribution at this latitude. *Akodon montensis* has been characterized as terrestrial (Cademartori *et al*., 2002; Vieira & Monteiro-Filho, 2003; Naxara *et al*., 2009), although it also exhibits limited climbing behavior (Machado *et al*., 2019). It is not vulnerable to habitat fragmentation (Püttker *et al*., 2008; Jordão *et al*., 2010) and is tolerant of habitat degradation (Barreto Cáceres & Owen, 2019).

*Hylaeamys megacephalus* (G. Fischer, 1814) is a tropical lowland forest oryzomyine, distributed from Trinidad and Tobago, the Caribbean and Atlantic coast of Venezuela and the Guianas, southward across eastern Amazonia and the Cerrado to central eastern Paraguay. The RNBM is near the southern limit of its distribution. *Hylaeamys megacephalus* is a generalist species with high habitat tolerance, inhabiting primary, secondary and degraded forests (Percequillo *et al*., 2016). In the Upper Paran Atlantic Forest it was encountered in all three levels of habitat degradation (Barreto Cáceres & Owen, 2019; Owen *et al*., 2019). In the same forest, Owen *et al*. (2020) found them preferentially associated with bamboo understory.

*Oligoryzomys nigripes* (Olfers, 1818) is a small oryzomyine distributed from northeastern Brazil through the Atlantic Forest and Cerrado ecoregions southward through eastern Paraguay and northeastern Argentina to Uruguay (Bonvicino *et al*., 2016). The RNBM is near the western limit of its distribution at this latitude. *O. nigripes* is a habitat generalist (Martin *et al*., 2012; Garcia, 2018; Owen *et al*., 2020), generally found in forested areas (Cáceres *et al*., 2011), and not vulnerable to forest fragmentation (Püttker *et al*., 2008). Owen *et al*. (2019) found this species to consistently represent around 9% of the sigmodontine rodent community on sampling grids with three different levels of forest degradation, and it did not exhibit microhabitat selection.

This study was conducted in a heterogeneous landscape at the western limit of the Atlantic Forest, an extensive South American ecoregion. Previous studies hypothesized that in such marginal areas with a more heterogeneous forest habitat mosaic, small mammal species might be more strictly associated with the habitat(s) best fulfilling their niche requirements, and thus that microhabitat preference might be more detectable than in localities of more homogeneous habitat (Lozada & Guthmann, 1998; Lozada *et al*., 2000; Bonvicino *et al*., 2002; Owen, 2013). Moreover, the close proximity of multiple microhabitats may facilitate the movement of resident small mammal species from one habitat type to another, so that they may alter their microhabitat associations through time, responding either to seasonal or irregular environmental variation between years. Finally, the four predominant species at the study site are all near their biogeographic limits, and thus may be restricted to certain habitat types within this marginal UPAF habitat. This study evaluates habitat preference explicitly on one scale, termed microhabitat, and evaluates seasonal and interannual variation in habitat associations for each of four common small-mammal species.

## MATERIALS AND METHODS

### STUDY SITE

The study was conducted in the *Reserva Natural del Bosque Mbaracayú* (RNBM), a natural reserve of 64,405.7 hectares that is located in Canindeyú department, northeastern Paraguay between latitudes -24.00 and -24.25 and longitudes -55.33 and -55.53 (Figure 1). This site is located within the climate type Cfa (temperate, without dry season, hot summer – Peel *et al*., 2007). The RNBM is located near the western margin of the Upper Paraná Atlantic Forest (UPAF), depicted as tropical and subtropical moist broadleaf forest in the biome map of Olson *et al*. (2001). The reserve comprises a mosaic of ten different habitat types, eight of which are UPAF and two of which pertain to Cerrado (Naidoo & Hill, 2006; Peña-Chocarro *et al*., 2010). This study was conducted within the mosaic of Atlantic Forest habitat types of the Reserve.

### SAMPLING DESIGN AND ENVIRONMENTAL VARIABLES

Three sampling grids were established, two of 12 x 12 stations and one of 13 x 11: the centroid of Grid A (144 stations) was -24.1239, -55.5048; Grid B (143 stations) -24.1412, -55.3664; and Grid G (144 stations) -24.1306, -55.5369. Trap stations were separated by 10 m. Each grid was sampled six times for five nights during three seasons (Dry, Wet and Variable, *sensu* Owen & Camp, in press) for two years (June 2015 – March 2017). An extreme El Niño event occurred during the first of the two sampling years, with precipitation higher than average (DINAC, 2016), although maintaining the historical seasonal pattern of dry, wet and variable seasons (Figure 2).

During the first sampling session each station had one Sherman Trap™ (7.6 x 8.9 x 22.9 cm) placed on the ground and one placed 1 to 2.5 m above ground in branches or vines. All subsequent sessions included two traps placed on the ground and one above ground. Total sampling effort for the study was 36,365 trap-nights. A mixture of oats and peanut butter was used as bait in the traps, and they were rebaited each morning when checked for captures. For ease of comparing with previous studies based on this field investigation, grid designations (A, B, G) and sampling sessions (2 to 7) correspond with those in the these publications (*e.g*., Barreto Cáceres & Owen, 2019; Owen *et al*., 2019; Sánchez-Martínez & Owen, 2020). All animals captured in the third and sixth sampling session were collected and prepared as standard voucher specimens. A total of 1,143 vouchers were examined after preparation, and all field identifications were confirmed for the four species evaluated in this paper.

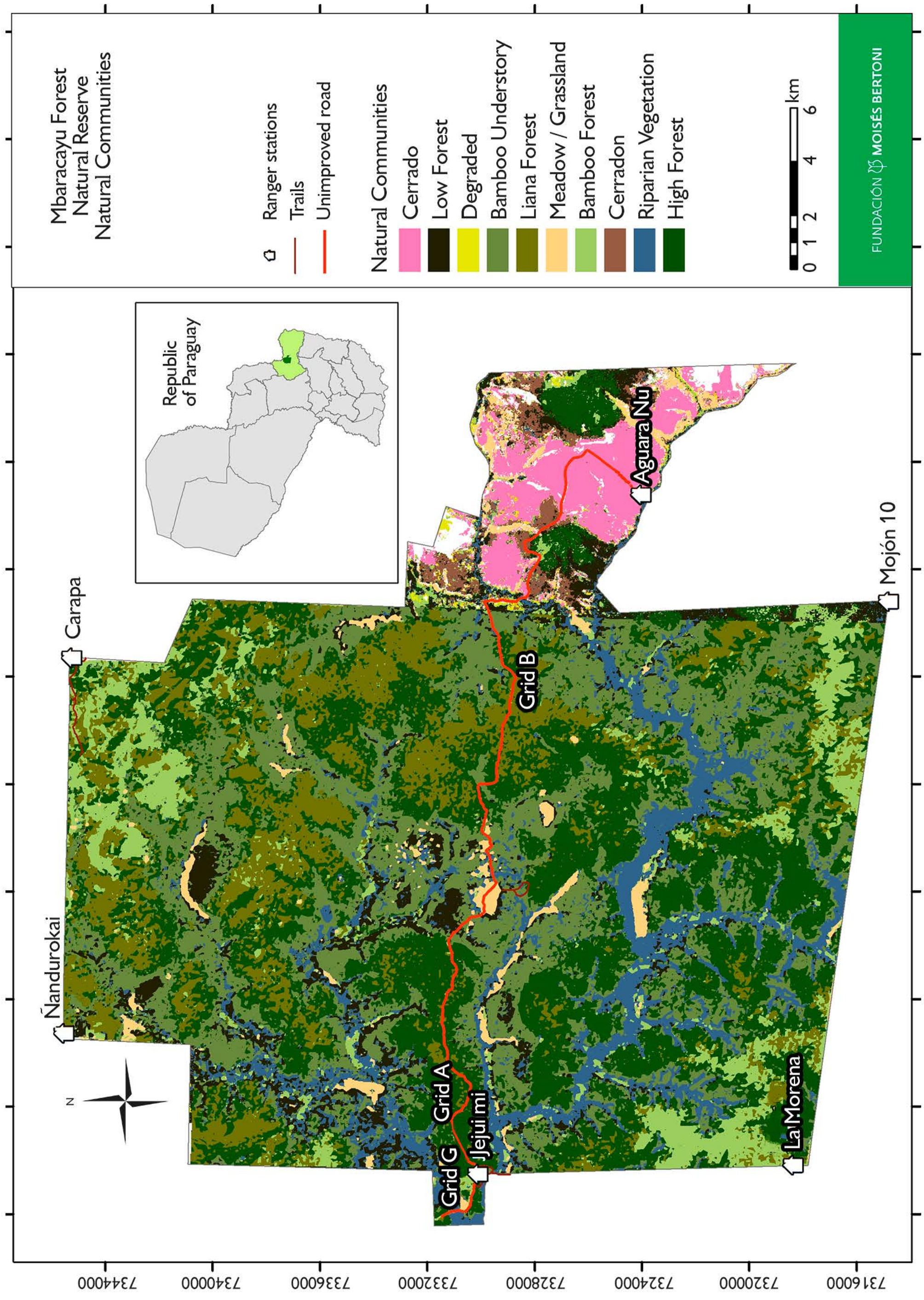

Figure 1. *Reserva Natural del Bosque Mbaracayú* (RNBM) within Canindeyú Department, Paraguay, showing complex mosaic of habitat types. See text for geographical location of the RNBM, and for precise coordinates of the three sampling grids. Map: L. Rodríguez.

In this study microhabitat is defined as the habitat immediately surrounding each trap station within the habitat matrix of the forest. In practical terms it is measured as 17 environmental variables within an area of ca. 2 m in diameter centered on each trap station (Schnell *et al*., 2010; Poindexter *et al*., 2012). Measures were recorded at each of the 431 trap stations included in the three sampling grids, during the first mammal sampling session and repeated during the second session, to ensure that seasonal variation of environmental variables could be detected. No important differences (≥ 10 % in ≥ 10 of the cases) were found between the samples taken in different seasons. Thus, data from the two seasons were averaged for each station, and the mean values were used for the analyses reported here. Three of the 17 variables were nominal, one meristic, seven were percentages and six were direct-measure continuous variables (Table 1). Sampling methods for the environmental variables are described in Schnell *et al*. (2010) and Poindexter *et al*. (2012).

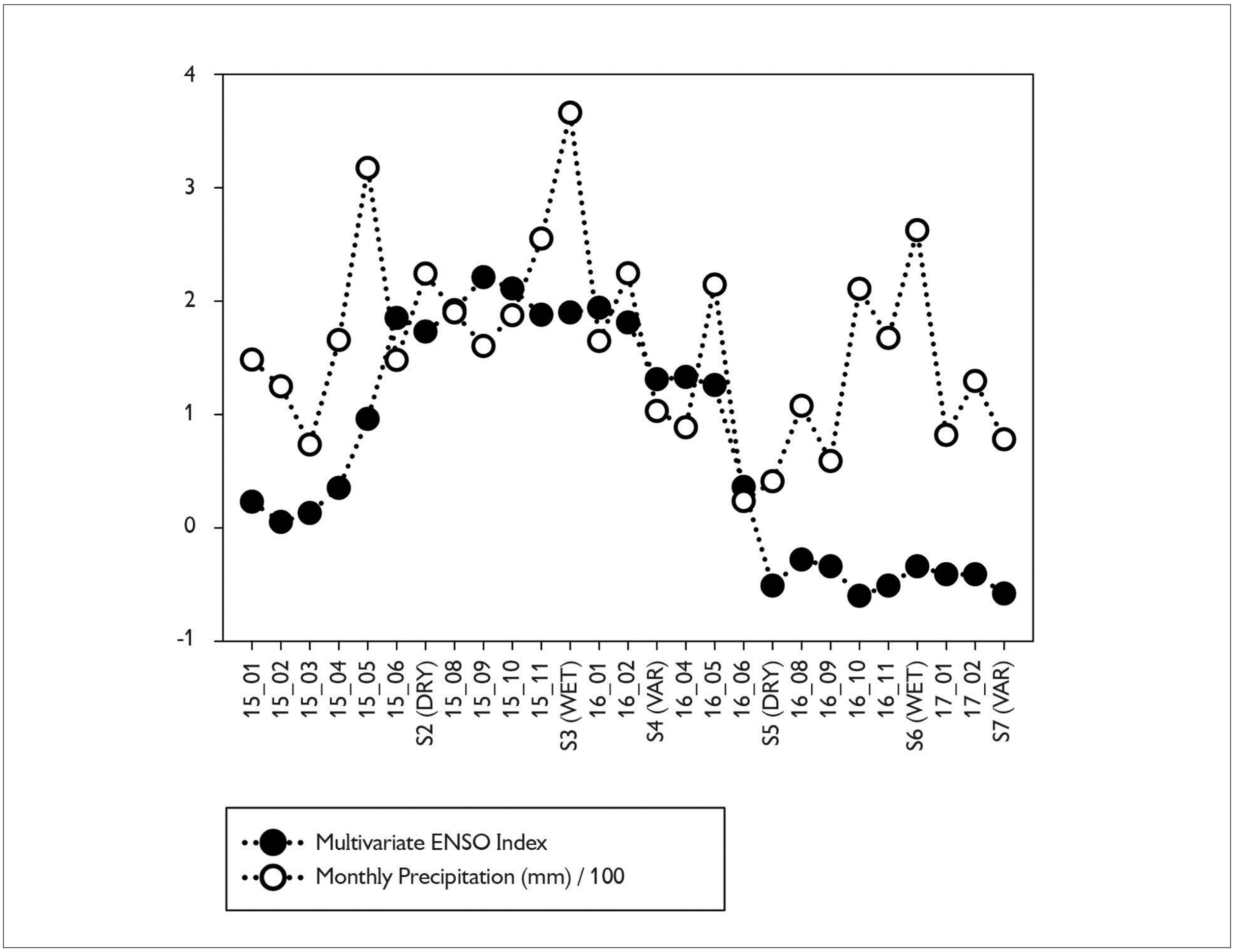

Figure 2. Multivariate ENSO Index (MEI) values and precipitation from January 2015 (approximately 6 months before first sample) through March 2017 (final sample). Abscissa is time (YR-MO), with sampling sessions 2-7 indicated in the month they occurred. MEI value shown for each month is the mean of that month and the previous month, *i.e.*, 15_01 is the mean of December 2014 and January 2015. Ordinate is MEI values (solid circles) and precipitation (open circles, in mm, divided by 100). Precipitation data from Climatic Research Unit (n. d.). MEI data from Multivariate ENSO Index (MEI) (n. d.).

Table 1. List of classification variables used to identify each capture, and the 17 environmental variables measured to characterize the microhabitat. Sampling methods for the environmental variables as described in Schnell *et al*. (2010) and Poindexter *et al*. (2012).

| Variables | Description |
|---|---|
| Classification | |
| ID | Specific identification |
| Year | 1 = 2015-16, 2 = 2016-17 |
| Season | Dry (June-July), Wet (November-December), Variable (February-March) |
| Environmental variables | |
| Nominal | |
| Orange | 1 or 0, presence or absence of *Citrus aurantium* L., 1753 (invasive species) within 10 m |
| Log | 1 or 0, presence or absence of log (fallen tree) within 10 m |
| Height | 1 = captured on ground, 2 = captured above ground |
| Meristic | |
| Bushes | Number of bushes within 1 m |
| Continuous | |
| *Direct* | |
| Slope | Slope of ground measured in degrees |
| Treedist | Distance to nearest tree |
| Canopy1 | Height of 1st canopy |
| Canopy2 | Height of 2nd canopy |
| Canopy3 | Height of 3rd canopy |
| Maxcan | Maximum canopy height |
| *Percentages* | |
| Percan | Percentage closure of canopy |
| Woody | Percentage of 2 x 2 m quadrat covered by woody plants |
| Forbs | Percentage of 2 x 2 m quadrat covered by forbs |
| Grasses | Percentage of 2 x 2 m quadrat covered by grasses |
| Litter | Percentage of 2 x 2 m quadrat covered by vegetative litter |
| Deadwood | Percentage of 2 x 2 m quadrat covered by dead wood |
| Bare | Percentage of 2 x 2 m quadrat with no cover (bare ground) |

## SMALL MAMMAL SAMPLING

Field identification of animals and subsequent identification of prepared specimens followed keys provided in Voss & Jansa (2009) and D'Elía & Pardiñas (2015). Identifications of prepared specimens confirmed field identifications. All standard data of each captured individual were recorded: specific identification, weight, sex, reproductive status and age (adults, sub-adults or juveniles, based on external characteristics of reproductive status, juvenile or adult pelage and weight). Each animal was marked with a Passive Integrated Transponder (PIT) tag (Biomark, Inc.). Every capture was included in the analyses, as each capture was considered to be an independent expression of microhabitat preference by the species, as measured by the 17 environmental variables recorded for each station. Adults and subadults were included in the dataset but juveniles were not, as their capture location was presumed to be at least partially a function of their natal nest-site location (*i.e*., not selected by the juvenile individual).

Animal sampling and collection were carried out under Scientific Collection Permits No. 011/2014, 132/2015 and 269/2016 (Secretary of the Environment, currently the Ministry of Environment and Sustainable Development, Paraguay), and the guidelines of the Animal Care and Use Committee of the American Society of Mammalogists (Sikes *et al*., 2011, 2016). Animal handling protocols were approved by the Institutional Animal Care and Use Committee of Texas Tech University (IACUC Approval No. 14024-03). Specimens[1] are temporarily deposited in the author's research collection, which is an accredited research collection under Approval 004/2015 by the Secretary of the Environment, Paraguay. Following research use of the specimens, they will be deposited in an accredited Paraguayan collection. Tissue which were harvested from the specimens (including blood samples from the released specimens) are deposited in the Genetic Resources Collections of the Museum of Texas Tech University (TTU).

## ANALYTIC METHODS

Using environmental variables from all sites with one or more captures, Spearman correlations were calculated among all pairs of environmental variables, in order to visualize overall correlation patterns of species-environmental associations. This provides a context within which to interpret correlations among variables for which one or more species have significant seasonal or interannual variation in preferences. These correlations analyses were conducted only on the environmental variables, disregarding the species which were captured at those trap stations.

Using all capture records during all sessions for the four species being evaluated, a series of Mann-Whitney Rank Sum pairwise comparisons was used to identify significant seasonal and interannual variation. Pairwise correlations were calculated between each of the species-variable associations showing significant temporal variation. This was done separately for the suites of seasonal and interannual associations. For those species-variable pairs showing seasonal variation, Spearman Rank correlations were used to identify non-significant subsets among seasons. To visualize both the seasonal and interannual patterns of response of the four species to environmental variables, the data for each species were plotted for each variable for which the species showed significant temporal variation. A value of $P \leq 0.05$ was considered significant for all tests. All statistical tests were done using SigmaPlot™ 12.3 (Systat Software, Inc.).

## RESULTS

A total of 1,614 captures (4.4% trap success) were recorded during the study, including 947 individuals and 667 recaptures. The captures included two orders (Didelphimorphia and Rodentia), two families (Didelphidae and Cricetidae) and 17 species (Table 2 and complementary material). Of the 1,614 captures, 1,554 (96.3%) were of subadult or adult animals and thus were included for the correlation analyses among environmental variables. Based on all environmental measures from all capture records, of the 136 pairwise comparisons among the 17 environmental variables, Spearman correlations were significantly positive for 38, negative for 53, and non-significant for 45 (Figure 3). The number of positive correlations ranged from zero (Capture height) to seven (Canopy2); negative correlations from one (Capture height) to seven (Canopy2); and non-significant correlations from two (Slope, Litter) to 15 (Capture height). This indicates that in general (*i.e.*, considering all species together), capture height of small mammals was independent of other environmental variables, whereas Canopy2 (height of second canopy) was either positively or negatively correlated with 14 of the 16 other environmental variables.

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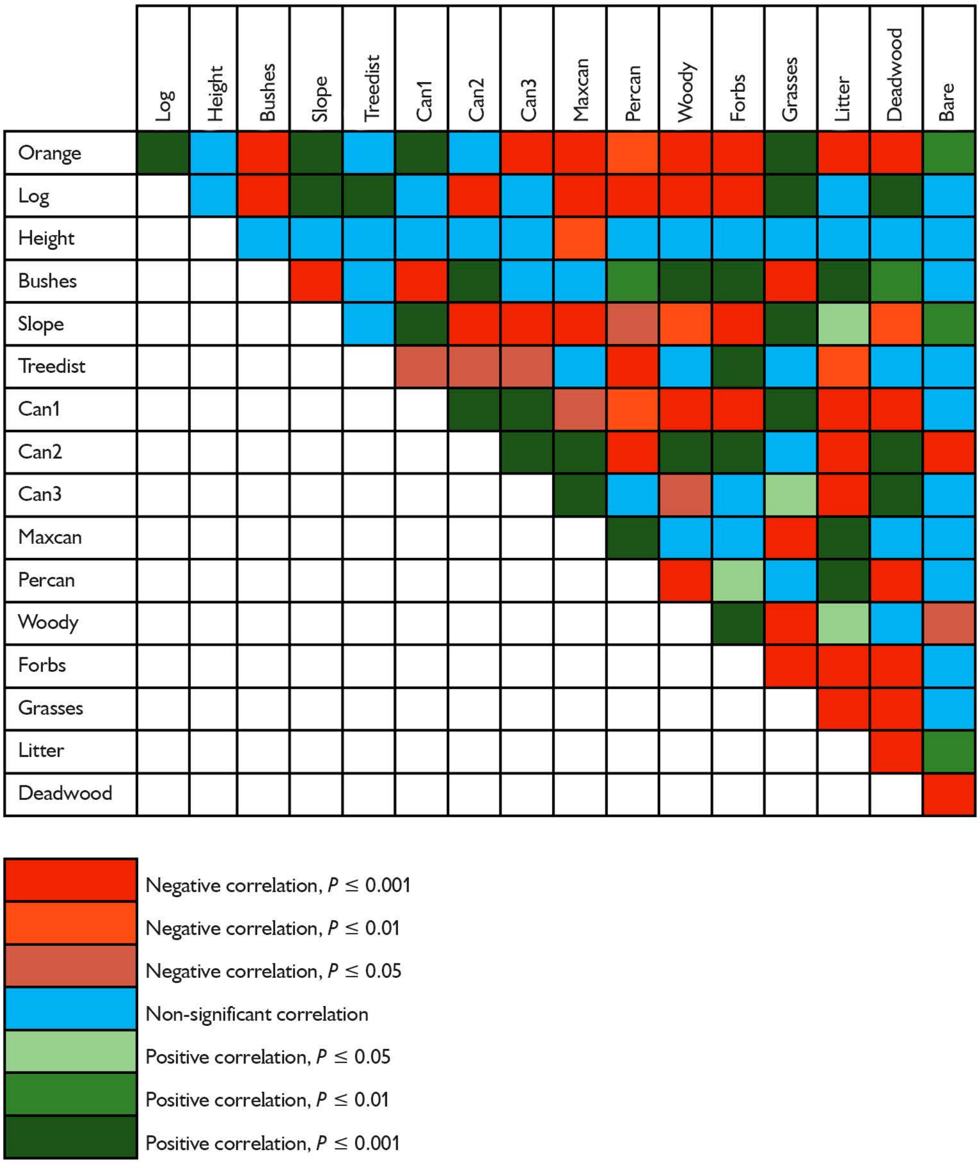
[1] See complementary material to this article, in a table available at link: http://editora.museu-goeldi.br/bn/artigos/cnv15n3_2020/Owen_tableS1.pdf



| | Log | Height | Bushes | Slope | Treedist | Can1 | Can2 | Can3 | Maxcan | Percan | Woody | Forbs | Grasses | Litter | Deadwood | Bare |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Orange | 🟩 | 🟦 | 🟥 | 🟩 | 🟦 | 🟩 | 🟦 | 🟥 | 🟥 | 🟧 | 🟥 | 🟥 | 🟩 | 🟥 | 🟥 | ▩ |
| Log | | 🟦 | 🟥 | 🟩 | 🟩 | 🟦 | 🟥 | 🟦 | 🟥 | 🟥 | 🟥 | 🟥 | 🟩 | 🟦 | 🟩 | 🟦 |
| Height | | | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟧 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 |
| Bushes | | | | 🟥 | 🟦 | 🟥 | 🟩 | 🟦 | 🟦 | ▩ | 🟩 | 🟩 | 🟥 | 🟩 | ▩ | 🟦 |
| Slope | | | | | 🟦 | 🟩 | 🟥 | 🟥 | 🟥 | 🟫 | 🟧 | 🟥 | 🟩 | ▨ | 🟧 | ▩ |
| Treedist | | | | | | 🟫 | 🟫 | 🟫 | 🟦 | 🟥 | 🟦 | 🟩 | 🟦 | 🟧 | 🟦 | 🟦 |
| Can1 | | | | | | | 🟩 | 🟩 | 🟫 | 🟧 | 🟥 | 🟥 | 🟩 | 🟥 | 🟥 | 🟦 |
| Can2 | | | | | | | | 🟩 | 🟩 | 🟥 | 🟩 | 🟩 | 🟦 | 🟥 | 🟩 | 🟥 |
| Can3 | | | | | | | | | 🟩 | 🟦 | 🟫 | 🟦 | ▨ | 🟥 | 🟩 | 🟦 |
| Maxcan | | | | | | | | | | 🟩 | 🟦 | 🟦 | 🟥 | 🟩 | 🟦 | 🟦 |
| Percan | | | | | | | | | | | 🟥 | ▨ | 🟦 | 🟩 | 🟥 | 🟦 |
| Woody | | | | | | | | | | | | 🟩 | 🟥 | ▨ | 🟦 | 🟫 |
| Forbs | | | | | | | | | | | | | 🟥 | 🟥 | 🟥 | 🟦 |
| Grasses | | | | | | | | | | | | | | 🟥 | 🟥 | 🟦 |
| Litter | | | | | | | | | | | | | | | 🟥 | ▩ |
| Deadwood | | | | | | | | | | | | | | | | 🟥 |

🟥 Negative correlation, $P \leq 0.001$
🟧 Negative correlation, $P \leq 0.01$
🟫 Negative correlation, $P \leq 0.05$
🟦 Non-significant correlation
▨ Positive correlation, $P \leq 0.05$
▩ Positive correlation, $P \leq 0.01$
🟩 Positive correlation, $P \leq 0.001$

Figure 3. Heatmap indicating significance levels of Spearman correlations for all pairwise comparisons of environmental variables evaluated in this study, based on all 1,554 captures of 17 small mammal species.

Only the species that were captured in all six sampling sessions (*Gracilinanus agilis*, *Akodon montensis*, *Hylaeamys megacephalus*, and *Oligoryzomys nigripes*) were included in the analyses of temporal variation in habitat preference (Table 2). Seasonal variation was found for six environmental variables, in one or two species, and seven variables were significant for interannual variation in one or two species (Table 3).

*Gracilinanus agilis* was more likely to be captured near Orange trees and Woody understory plants in the variable season, in an area with more Grasses in the wet season, and with more ground Litter in the dry season. *Akodon montensis* shared those seasonal preferences of Woody plants and Grasses, was captured near more ground Litter in the variable season, and with a higher Canopy1 in the dry season. *Hylaeamys megacephalus* did not exhibit seasonal variation in its association with any environmental variable. *Oligoryzomys nigripes* was found associated with more Bare ground during the variable season (Table 4).

Table 2. Number of captures of adult and subadult individuals of small mammal species during the six sampling sessions evaluated in this study. Sampling sessions were: 2 = June – July 2015 (Dry season); 3 = November – December 2015 (Wet); 4 = February – March 2016 (Variable); 5 = June – July 2016 (Dry); 6 = November – December 2016 (Wet); 7 = February – March 2017 (Variable). Sampling session designations (2 to 7) correspond to designations used in other studies based on this field sampling (see Material and Methods).

| | Captures per sampling session | | | | | | |
|---|---|---|---|---|---|---|---|
| Species | 2 | 3 | 4 | 5 | 6 | 7 | Total |
| Didelphimorphia | | | | | | | |
| Didelphidae | | | | | | | |
| *Cryptonanus chacoensis* (Tate, 1931) | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| *Gracilinanus agilis* (Burmeister, 1854) | 16 | 2 | 2 | 12 | 5 | 9 | 46 |
| *Marmosa paraguayana* (Tate, 1931) | 1 | 0 | 2 | 0 | 0 | 2 | 5 |
| *Monodelphis dimidiata* (Wagner, 1847) | 0 | 0 | 0 | 0 | 2 | 0 | 2 |
| *Monodelphis kunsi* Pine, 1975 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| Rodentia | | | | | | | |
| Cricetidae | | | | | | | |
| *Akodon montensis* Thomas, 1913 | 288 | 325 | 106 | 129 | 93 | 119 | 1060 |
| *Calomys callosus* (Rengger, 1830) | 7 | 10 | 2 | 0 | 0 | 0 | 19 |
| *Euryoryzomys russatus* (Wagner, 1848) | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| *Hylaeamys megacephalus* (G. Fischer, 1814) | 60 | 26 | 50 | 34 | 15 | 22 | 207 |
| *Juliomys pictipes* (Osgood, 1933) | 0 | 0 | 0 | 1 | 0 | 1 | 2 |
| *Necromys lasiurus* (Lund, 1840) | 2 | 3 | 0 | 0 | 0 | 0 | 5 |
| *Oecomys mamorae* (Thomas, 1906) | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| *Oligoryzomys mattogrossae* (Allen, 1916) | 11 | 1 | 8 | 17 | 0 | 12 | 49 |
| *Oligoryzomys nigripes* (Olfers, 1818) | 26 | 21 | 16 | 22 | 12 | 20 | 117 |
| *Oligoryzomys* sp. | 1 | 0 | 10 | 9 | 2 | 2 | 24 |
| *Rhipidomys macrurus* (Gervais, 1855) | 0 | 0 | 0 | 2 | 0 | 2 | 4 |
| *Sooretamys angouya* (Fischer, 1814) | 0 | 1 | 1 | 1 | 5 | 2 | 10 |
| Total | 412 | 391 | 197 | 227 | 135 | 192 | 1554 |

Table 3. Environmental variables for the four abundant species that exhibited significant ($\alpha \leq 0.05$, by Mann-Whitney Rank Sum test) seasonal (Season) and/or interannual (Year) variation in their association (X). For description of variables see Table 1. Also included non significant (-) variables in the table for comparison with significant ones.

| | *Gracilinanus agilis* | | *Akodon montensis* | | *Hylaeamys megacephalus* | | *Oligoryzomys nigripes* | |
|---|---|---|---|---|---|---|---|---|
| Variables | Season | Year | Season | Year | Season | Year | Season | Year |
| Orange | X | - | - | X | - | - | - | - |
| Log | - | - | - | - | - | X | - | - |
| Height | - | - | - | X | - | - | - | X |
| Bushes | - | - | - | - | - | - | - | - |
| Slope | - | - | - | - | - | X | - | - |
| Treedist | - | - | - | - | - | - | - | - |
| Canopy1 | - | - | X | - | - | - | - | - |
| Canopy2 | - | - | - | - | - | - | - | X |
| Canopy3 | - | - | - | - | - | - | - | - |
| Maxcan | - | - | - | - | - | - | - | - |
| Percan | - | - | - | - | - | - | - | - |
| Woody | X | - | X | - | - | - | - | - |
| Forbs | - | - | - | - | - | - | - | - |
| Grasses | X | - | X | X | - | X | - | - |
| Litter | X | - | X | X | - | - | - | - |
| Deadwood | - | - | - | - | - | - | - | - |
| Bare | - | - | - | - | - | - | X | - |

Table 4. Subsets of non-significantly different seasonal means (indicated by shared letters A or B, $\alpha \leq 0.05$, by Spearman rank correlations) of the variables for which small nonvolant mammal species showed seasonal variation. For descriptions of environmental variables see Table 1. Seasons: W = wet, D = Dry, V = Variable.

(Continue)

| *Gracilinanus agilis* | | | | *Akodon montensis* | | | | *Oligoryzomys nigripes* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Orange | | | | Canopy1 | | | | Bare | | | |
| Season | Mean | | | Season | Mean | | | Season | Mean | | |
| W | 0.00 | A | B | V | 1.22 | A | | D | 0.10 | A | |
| D | 0.04 | A | | W | 1.28 | | B | W | 0.23 | A | B |
| V | 0.27 | A | B | D | 1.29 | | B | V | 0.76 | | B |
| Woody | | | | Woody | | | | | | | |
| Season | Mean | | | Season | Mean | | | | | | |
| W | 5.71 | A | | W | 7.49 | A | | | | | |
| D | 7.79 | A | | D | 8.30 | A | B | | | | |
| V | 14.32 | | B | V | 8.48 | | B | | | | |

Table 4. (Conclusion)

| *Gracilinanus agilis* | | | | *Akodon montensis* | | | | *Oligoryzomys nigripes* |
|---|---|---|---|---|---|---|---|---|
| Grasses | | | | Grasses | | | | |
| Season | Mean | | | Season | Mean | | | |
| V | 2.27 | A | | V | 11.69 | A | | |
| D | 7.79 | A | | D | 14.72 | A | | |
| W | 25.00 | | B | W | 16.45 | | B | |
| Litter | | | | Litter | | | | |
| Season | Mean | | | Season | Mean | | | |
| W | 37.86 | A | | D | 45.16 | A | | |
| V | 55.68 | | B | W | 46.00 | A | | |
| D | 56.54 | | B | V | 49.18 | | B | |

## CORRELATIONS AMONG SPECIES-VARIABLE ASSOCIATIONS

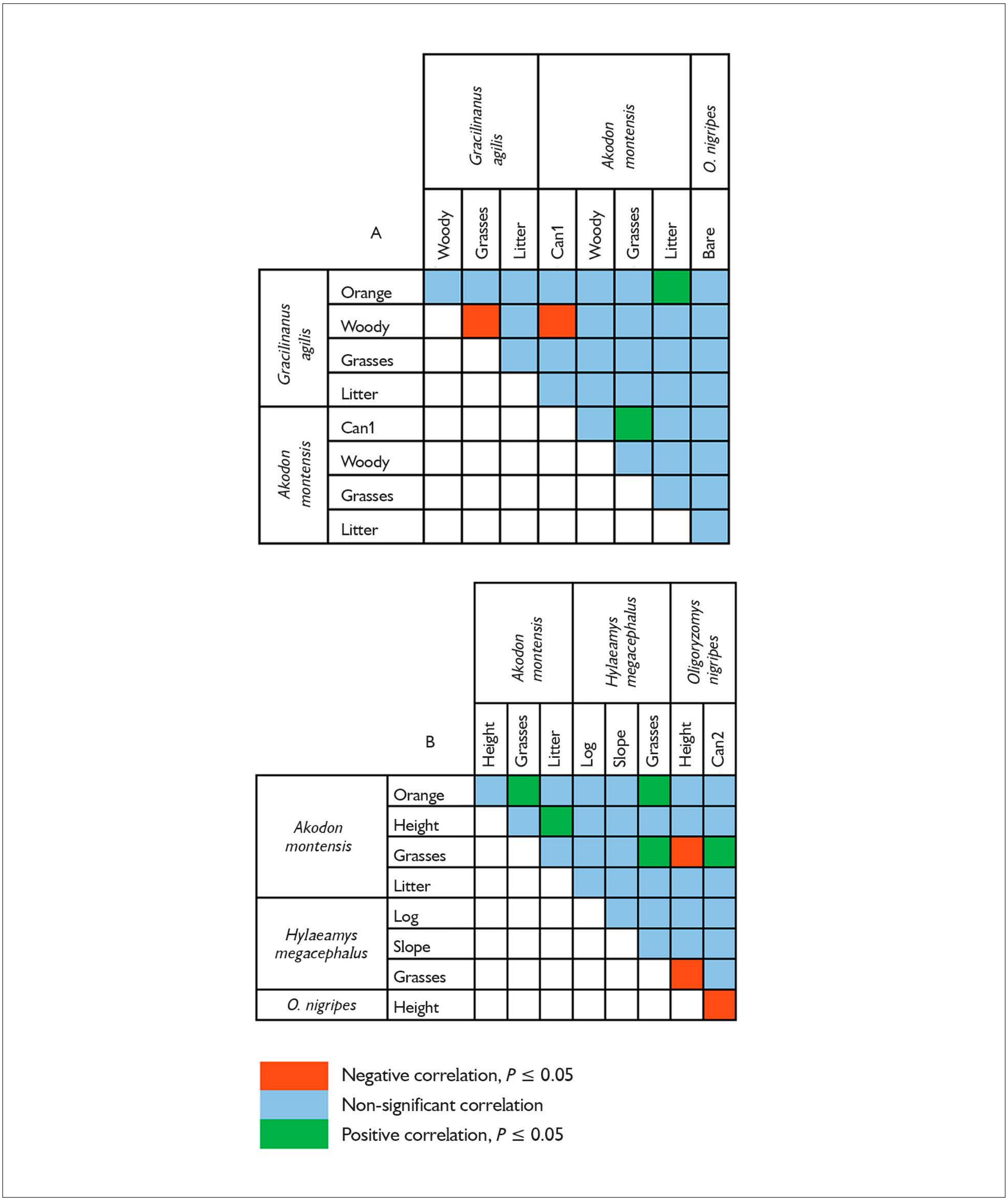
Among significant seasonal species-variable associations, those of *G. agilis* to Orange trees and *A. montensis* to Litter were positively correlated (*i.e*. a concordant temporal pattern was observed in the data), as were those of *A. montensis* to both Canopy1 and Grasses. The temporal pattern of *G. agilis* with regard to Woody plants was negatively correlated with the same species' seasonal association with Grasses, as were those of *G. agilis* to Woody plants and *A. montensis* to Canopy1. Of 36 possible pair-wise correlations among species-variable associations, 32 were non-significant (Figure 4A).

Among the 36 possible correlations of significant interannual species-variable associations, five were found to be positively correlated and three negatively correlated (Figure 4B). The interannual pattern exhibited by *A. montensis* with regard to Orange trees and Height of capture was concordant with the response of the same species to Grasses and Litter, respectively. The response of *A. montensis* to Orange trees and Grasses was concordant in both cases with those of *H. megacephalus* to Grasses, and the response of *O. nigripes* to Canopy2. The response of *O. nigripes* to capture Height was negatively correlated to the response to Grasses by both *A. montensis* and *H. megacephalus*, and the response of *O. nigripes* to Canopy2 was negatively correlated to the same species' response to Height. Twenty-eight of the 36 possible correlations were non-significant.

Significant seasonal and interannual responses of the four species to environmental variables are graphed in Figure 5. These graphs show the temporal association of the species with the variables, and indicate whether the significantly correlated response is seasonal, interannual or both.

## SEASONAL VARIATION

Six of the 17 environmental variables (Orange tree, Canopy1, Woody plants, Grasses, Litter, Bare ground) had seasonally variable responses from one or two of the four species examined. Three of the four abundant species exhibited seasonal variation in their associations with from one to four environmental variables. Both *G. agilis* and *A. montensis* exhibited temporal variation in associations with four variables, three of which (Woody plants, Grasses and Litter) were the same. *Oligoryzomys nigripes* showed seasonal variation in its association with Bare ground, being most strongly associated with this variable in the Variable season. *Hylaeamys megacephalus* was not found to have seasonal variation in association with any environmental variable.



A

| | | *Gracilinanus agilis* | | | *Akodon montensis* | | | | *O. nigripes* |
|---|---|---|---|---|---|---|---|---|---|
| | | Woody | Grasses | Litter | Can1 | Woody | Grasses | Litter | Bare |
| *Gracilinanus agilis* | Orange | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟩 | 🟦 |
| | Woody | | 🟥 | 🟦 | 🟥 | 🟦 | 🟦 | 🟦 | 🟦 |
| | Grasses | | | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 |
| | Litter | | | | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 |
| *Akodon montensis* | Can1 | | | | | 🟦 | 🟩 | 🟦 | 🟦 |
| | Woody | | | | | | 🟦 | 🟦 | 🟦 |
| | Grasses | | | | | | | 🟦 | 🟦 |
| | Litter | | | | | | | | 🟦 |

B

| | | *Akodon montensis* | | | *Hylaeamys megacephalus* | | | *Oligoryzomys nigripes* | |
|---|---|---|---|---|---|---|---|---|---|
| | | Height | Grasses | Litter | Log | Slope | Grasses | Height | Can2 |
| *Akodon montensis* | Orange | 🟦 | 🟩 | 🟦 | 🟦 | 🟦 | 🟩 | 🟦 | 🟦 |
| | Height | | 🟦 | 🟩 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 |
| | Grasses | | | 🟦 | 🟦 | 🟦 | 🟩 | 🟥 | 🟩 |
| | Litter | | | | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 |
| *Hylaeamys megacephalus* | Log | | | | | 🟦 | 🟦 | 🟦 | 🟦 |
| | Slope | | | | | | 🟦 | 🟦 | 🟦 |
| | Grasses | | | | | | | 🟥 | 🟦 |
| *O. nigripes* | Height | | | | | | | | 🟥 |

🟥 Negative correlation, $P \leq 0.05$

🟦 Non-significant correlation

🟩 Positive correlation, $P \leq 0.05$

Figure 4. Heatmaps indicating significance levels of Spearman correlations for all pairwise comparisons of environmental variables for which a small mammals species exhibited significant seasonal (A) or interannual (B) variation in association with the variable.

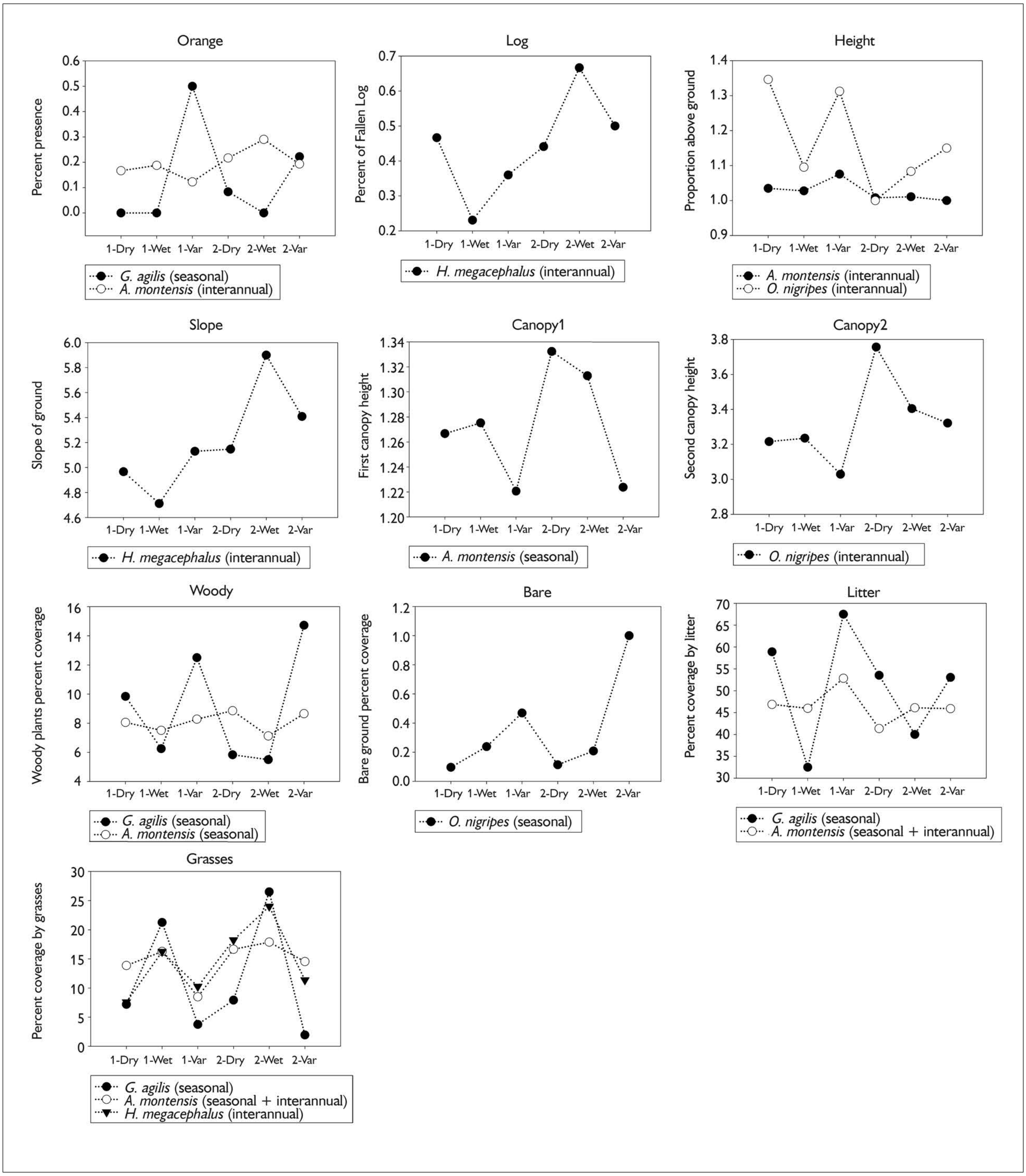


Figure 5. Environmental variables for which one or more species exhibited significant seasonal or interannual variation. Six samples were conducted, with samples in the Dry, Wet and Variable seasons of each of two years. Abscissa indicates sampling year (1 or 2) and season (Dry, Wet, Variable). Legend below each graph indicates the species exhibiting significant variation, and whether the variation was seasonal, interannual or both.

### INTERANNUAL VARIATION

Seven of the 17 environmental variables showed interannual variation in microhabitat preference by one or more of the four abundant species. The marsupial *Gracilinanus agilis* did not exhibit interannual variation in association with any environmental variable, whereas the three rodent species showed significant interannual differences in their associations with from two to four environmental variables. *Akodon montensis* associated more strongly in the first (El Niño) year with Litter and was captured more frequently above the ground, and in the following (normal) year associated more strongly with Orange trees and Grasses. *Hylaeamys megacephalus* associated more strongly in the normal year with fallen Logs, steeper Slope and more Grasses. *Oligoryzomys nigripes* exhibited higher average capture Height in the El Niño year, and was associated with a higher Canopy2 in the normal year.

## DISCUSSION

### MICROHABITAT PREFERENCES OF PREDOMINANT SPECIES

#### *Gracilinanus agilis*

This small opossum is highly arboreal (Smith *et al*., 2012), and 45 of 46 (97.8%) of captures in this study were above the ground. In the forested areas of the Cerrado and the Atlantic Forest, it is found in Cerradão and gallery forest (Alho, 2005), in semi-deciduous transitional forest (Smith *et al*., 2012) and in forests with dense understory vegetation (Carmignotto *et al*., 2015). Barreto Cáceres & Owen (2019) reported higher population levels in areas of greater forest degradation in an Interior Atlantic Forest site, although it was present in all degradation levels sampled. Although Alho (2005) reported seasonal populational variation, no previous study has examined temporal variation in microhabitat preference by this species. In the present study *G. agilis* did not exhibit interannual variation in microhabitat preference, but did show seasonal variation with respect to four environmental variables. Three of these four variables (Woody plants, Litter, Grasses) pertain to ground cover. These results suggest that this didelphid species is more responsive to ground-level habitat variables than previously understood, and conversely may be less influenced by other structural variables (*e.g*., distance to nearest tree and canopy heights) than would be expected for a primarily arboreal species.

#### *Akodon montensis*

This species is primarily terrestrial (1,031 of 1,060 [97.3%] of captures were on the ground). Naxara *et al*. (2009) found *A. montensis* in approximately equal abundance and site occupancy in the cool-dry and the warm-wet seasons in an old-growth forest in São Paulo State. Although they did not explicitly evaluate temporal variation in habitat preference, Owen *et al*. (2010) noted that population densities of *A. montensis* exhibited different temporal patterns in three different habitats, suggesting that the different habitats were differentially favorable to this species through seasonal and/or annual cycles. A 23-month mark-recapture study of small mammals in a Cerrado locality in eastern Paraguay found that *A. montensis* was encountered during sampling sessions from May – September (dry season), and not at other times (Owen, 2013). In the present study, *A. montensis* showed significant seasonal variation for two environmental variables, interannual variation with two variables, and both seasonal and interannual variation with two other variables. Of these, three are ground-cover variables (Woody plants—seasonal, Litter—seasonal and interannual, Grasses—seasonal and interannual), which concurs with reports of the importance to *A. montensis* of dense understory vegetation, bamboo abundance, ferns and shrubs (Dalmagro & Vieira, 2005; Goodin *et al*., 2009; de Lima *et al*., 2010; Melo *et al*., 2011, 2013). This species showed weaker preference for Grasses and stronger preference for Litter during the El Niño year. It also was captured above ground more often in the El Niño year.

### *Hylaeamys megacephalus*

This species exhibits population fluctuations associated with seasonal cycles. In the central Cerrado, it was captured most frequently in the wet season (Carmignotto *et al*., 2014), but in the western Interior Atlantic Forest it was more abundant in the dry season (Barreto Cáceres & Owen, 2019). However no previous study has been made of temporal variation in habitat preference of *H. megacephalus*. This study found no seasonal variation in habitat associations of this species. Nevertheless, interannual differences were exhibited for three environmental variables (fallen Logs, ground Slope and Grasses). In the El Niño year, it had low preference for fallen Logs in the wet season, whereas in the wet season of the following year it showed high preference for Logs. The same pattern was found for ground Slope, perhaps having to do with the rate of rainfall runoff. *Hylaeamys megacephalus* showed a higher preference for Grasses in the wet season in both years, but the preference was weaker during the El Niño year.

### *Oligoryzomys nigripes*

Although considered scansorial (using both the ground and bushes or vines), 97 of 117 (82.9%) of captures of *Oligoryzomys nigripes* in this study were on the ground. This species is considered tolerant of a wide range of habitats, having been reported as occupying both flooded and unflooded grassland and forest in the Brazilian pampas (Sponchiado *et al*., 2012), and not preferentially associated with any of the vegetation variables in a study in Argentina (Gómez-Villafañe *et al*., 2012). Other reports have found an association with fallen logs, ground litter, vegetation density at 1 m and a high density of scrubs (Dalmagro & Vieira, 2005; de Lima *et al*., 2010; Barreto Cáceres & Owen, 2019). Temporal population variation has been reported for this species. Barreto Cáceres & Owen (2019) found higher population levels in an El Niño year than in the following year. Few previous studies are available of temporal variation in habitat preference by *Oligoryzomys nigripes*. Bonvicino *et al*. (2016) state that it prefers more open areas in the dry season, but this statement is unreferenced. In an isolated Cerrado patch in an Atlantic Forest matrix, Owen (2013) reported *O. nigripes* was encountered in small numbers during May, August and September, but not in other months. In the present study the species was found to exhibit both seasonal and interannual responses to some environmental variables. In the El Niño year, it was captured above the ground more often, but in areas with a lower second canopy. It was found in areas of bare ground least often in the dry season, in contrast to the description by Bonvicino *et al*. (2016).

## INTERANNUAL VARIATION IN COMMUNITY STRUCTURE

This study found 16 significant seasonal and/or interannual associations between four species and ten environmental variables, strongly indicating that small-mammal community structure and composition are temporally dynamic, and that the species respond in complex and specifically distinct ways to a variety of environmental variables. Three of the four predominant species exhibited an interannual response to two or more environmental variables. Although the study did not include replicates of the interannual variation, it is likely that the El Niño event, with concordant increased precipitation (Figure 2), was an important driver of interannual variation. As noted, the didelphid *Gracilinanus agilis* did not exhibit an interannual response to any environmental variable, whereas each of the sigmodontine rodents did. This is strong evidence that an El Niño event could affect small mammal community structure in important ways, via the changing microhabitat associations of the more abundant species in this marginal Atlantic Forest region. As noted, this study was conducted near the distributional limits of each of the four predominant small mammal species encountered in the study. Further research should focus on whether the potential 'El Niño' effect is characteristic of these species throughout their distributions, or only near their distributional limits.

## CONCLUSIONS

This is the first study to explicitly evaluate temporal variation in habitat associations of small mammals in the Atlantic Forest ecoregion. Each of four species exhibited seasonal and/or interannual variation in several of the habitat variables analyzed. Some of these species-variable associations were found to be concordant (correlated positively) or opposed (correlated negatively). Interannual variation might be attributable to the extreme El Niño event during the first year of the study, with *Akodon montensis*, *Hylaeamys megacephalus*, and *Oligoryzomys nigripes* showing significant interannual differences in their associations with four, three and two environmental variables respectively, while *Gracilinanus agilis* showed no interannual variation for any variable. Considered together, the differing temporal patterns of habitat association among these four predominant small mammals reveal a complex spatially and temporally dynamic composition and structure in this Atlantic Forest community. Further explicitly experimental studies would be required to discern specific physiologic or behavioral characteristics of the four species that result in the patterns observed in this study.

## ACKNOWLEDGEMENTS

I thank A. M. R. Bezerra for inviting me to contribute to this special issue of the Boletim. At the *Fundación Moises Bertoni*, M. Velásquez, D. Salas, L. Rodriguez, S. Fernández, F. Ramírez and A. Alfonzo are thanked for innumerable acts of assistance—administrative, logistical and otherwise. At the *Secretaría del Ambiente* (now the *Ministerio del Ambiente y Desarrollo Sustentable*), I thank C. Morales, R. Duré, M. Motte, F. Bauer, B. Garcete, R. Barreto and N. Neris for approval of the various permits required for this project. Vegetation data were carefully collected and recorded by A. Rivarola, M. Sánchez, D. Bueno, P. Bogado and E. Galeano. Numerous people helped with establishing the sampling grids and during the six mammal sampling sessions, including V. Martínez, B. Barreto, J. Sánchez, E. Galeano, C. Solà Riera, E. Williams, G. Eastwood, H. Sánchez, E. Ríos, C. Jonsson, L. Valdivieso and A. Pérez-Umphrey. E. Rios, J. Sánchez and B. Barreto prepared the voucher specimens. L. Rodríguez prepared the map for Figure 1. J. Camp, five anonymous reviewers and A. Bezerra provided thoughtful comments on earlier versions of the manuscript. L. Aquino reviewed and corrected the Resumen. Financial support was provided by National Institutes of Health (NIH) Grant I103053 to C.B. Jonsson and the author, through the NIH-NSF Ecology of Infectious Disease Program. The author was partially supported by the *Programa Nacional de Incentivo a los Investigadores* (CONACYT, Paraguay).

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# Checklist of large and medium-bodied mammals from four areas of Tocantins state, Central Brazil

# Lista de espécies de mamíferos de médio e grande porte em quatro áreas no estado do Tocantins, Brasil central

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**Abstract:** The state of Tocantins is located in Central Brazil. The northern extreme of this state corresponds to the southeastern portion of the Amazon biome, while it is covered primarily by Cerrado savanna, as well as the transition area between these two biomes. We provide a checklist of large- and medium-bodied mammals from four localities in Tocantins, update the list of species for the state, and compile the available information on their geographic distribution. We surveyed mammals at four sites during different periods (between 2010 and 2018), using camera traps and opportunistic observations. In spite of the differences in the sampling effort among the sites, we recorded 42 mammal species belonging to eight orders and 20 families. Our list includes rare and threatened species, such as the jaguar (*Panthera onca*), the giant anteater (*Myrmecophaga tridactyla*), and the lowland tapir (*Tapirus terrestris*). One species (*Galictis cuja*) was recorded in the state for the first time and the known range distribution of two others (*Speothos venaticus* and *Alouatta caraya*) was updated.

**Keywords:** Camera trapping. Geographic distribution. *Galictis cuja.* Mammalia.

**Resumo:** O estado do Tocantins está localizado na região central do Brasil, em área de contato entre os biomas Amazônia e Cerrado. O extremo norte do estado corresponde ao bioma amazônico, mas a maior parte do território corresponde ao Cerrado, assim como a áreas de transição entre esses biomas. Fornecemos uma lista de espécies de mamíferos de médio e grande porte de quatro localidades ao longo do estado. Atualizamos a lista de espécies da região e compilamos informações a respeito de suas distribuições geográficas. A amostragem de mamíferos ocorreu em quatro localidades, em diferentes períodos (entre 2010 e 2018). Através do uso de armadilhas fotográficas, obtivemos informações sobre as espécies de mamíferos e também realizamos observações oportunistas nas áreas amostradas. Apesar da diferença de esforço amostral entre as localidades, foi possível registrar considerável diversidade de mamíferos. Foram registrados 42 táxons de mamíferos de médio e grande porte, pertencentes a oito ordens e 20 famílias, incluindo espécies raras e ameaçadas, como a onça-pintada (*Panthera onca*), o tamanduá-bandeira (*Myrmecophaga tridactyla*) e a anta (*Tapirus terrestris*). O furão (*Galictis cuja*) foi registrado pela primeira vez no estado, e a distribuição geográfica de duas espécies (*Speothos venaticus* e *Alouatta caraya*) foi atualizada.

**Palavras-chave**: Armadilha fotográfica. Distribuição geográfica. *Galictis cuja.* Mammalia.

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MERCÊS, M. P., K. R. ALVES-SILVA & W. S. PAULA, 2020. Checklist of large and medium-bodied mammals from four areas of Tocantins state, Central Brazil. **Boletim do Museu Paraense Emílio Goeldi. Ciências Naturais** 15(3): 683-700. DOI: http://doi.org/10.46357/bcnaturais.v15i3.218.

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Recebido em 30/11/2019
Aprovado em 23/10/2020
Responsabilidade editorial: Alexandra Maria Ramos Bezerra

## INTRODUCTION

The Brazilian state of Tocantins has a total area of 277,600 km$^2$ and is located in central Brazil, where it is bordered by six other states (Pará, Maranhão, Mato Grosso, Goiás, Piauí, and Bahia). Tocantins is part of the 'MATOBIPA' region, which also includes portions of Maranhão, Piauí, and Bahia states, where the Cerrado savanna has suffered high rates of deforestation for the cultivation of soybean (Carvalho *et al*., 2019). Tocantins encompasses two principal biomes (IBGE, 2004a), the Amazon (tropical forest), in the far north of the state, and the Cerrado (Neotropical savanna), which covers approximately 87% of the state. The Cerrado and Amazon biomes come together in a transition zone, which is characterized by a mosaic of dense and open vegetation, distributed throughout the southern Amazonia, with a highly dynamics vegetation (IBGE, 2004b). In Tocantins, this zone extends over an area of 250 km$^2$ (Marimon *et al*., 2014; Valadão *et al*., 2016; Marques *et al*., 2019).

The Cerrado biome is considered to be a global hotspot of biodiversity and a priority area for conservation (Myers *et al*., 2000; MMA, 2001), but unfortunately, it is under considerable pressure from farming, wildfires, and the introduction of African grasses, which combine to reduce the diversity of the biome (Klink & Machado, 2005; Marques *et al*., 2019). The Amazon is the richest Brazilian biome for mammalian species, with 399 species and 231 endemic taxa, while the Cerrado is the third richest, with 251 mammal species, of which 32 are endemic (Paglia *et al*., 2012; Percequillo & Gregorin, 2017). Despite its biological relevance, only a limited amount of data is available on the occurrence of the medium- and large-bodied mammal that occur in Tocantins state, and the available species inventories are all restricted to the area of Cerrado (Carmignotto & Aires, 2011; Marinho-Filho *et al*., 2002; Lima *et al*., 2005; Nogueira *et al*., 2011).

Medium- and large-bodied mammals are relatively conspicuous animals, although recent taxonomical reviews (*e.g.*, Bornholdt *et al*., 2013; Mercês *et al*., 2015; Nascimento & Feijó, 2017; Feijó *et al*., 2018) and online database (Percequillo & Gregorin, 2017) indicate that the mammalian diversity of areas of ecological ecotone are underestimated. Here, we present the results of mammal surveys conducted at four sites in Tocantins state between 2010 and 2018, which include one site in the ecotone between the Amazon and Cerrado biomes, and three in the Cerrado. With this, we update the database on the diversity and distribution of mammals in this region and highlight the importance of this area for conservation.

## MATERIAL AND METHODS

### STUDY AREA

We obtained data from four areas in Tocantins state, with three sampling points at each site (see Figure 1 for map of the localities and coordinates), between 2010 and 2018. The localities are distributed throughout the state, with one located in the northern extreme of the state, encompassing four municipalities: Araguatins, Augustinópolis, Esperantina, and Tocantinópolis - denominated AAET here (fieldwork: 2012–2016); one in the central portion of state, in the municipality of Pedro Afonso (fieldwork: 2010–2012); one in the state's central-eastern portion, in Novo Acordo municipality (fieldwork: 2016–2018), and one in the southeastern extreme of the state, in Arraias municipality (fieldwork: 2011–2014). At AAET, the vegetation is dominated by open rainforest interspersed with enclaves of open vegetation, characteristic of the Amazon-Cerrado ecotone zone. The municipalities of Pedro Afonso, Novo Acordo, and Arraias are dominated by Cerrado savanna.

We considered medium- and large-bodied mammals to include all species with a body mass of greater than 1 kg, thus excluding all relatively small, terrestrial mammals (Benchimol, 2016). However, we did include *Sylvilagus brasiliensis* (Linnaeus,1758) in the species list, because it is commonly detected using the methods adopted in the present study.

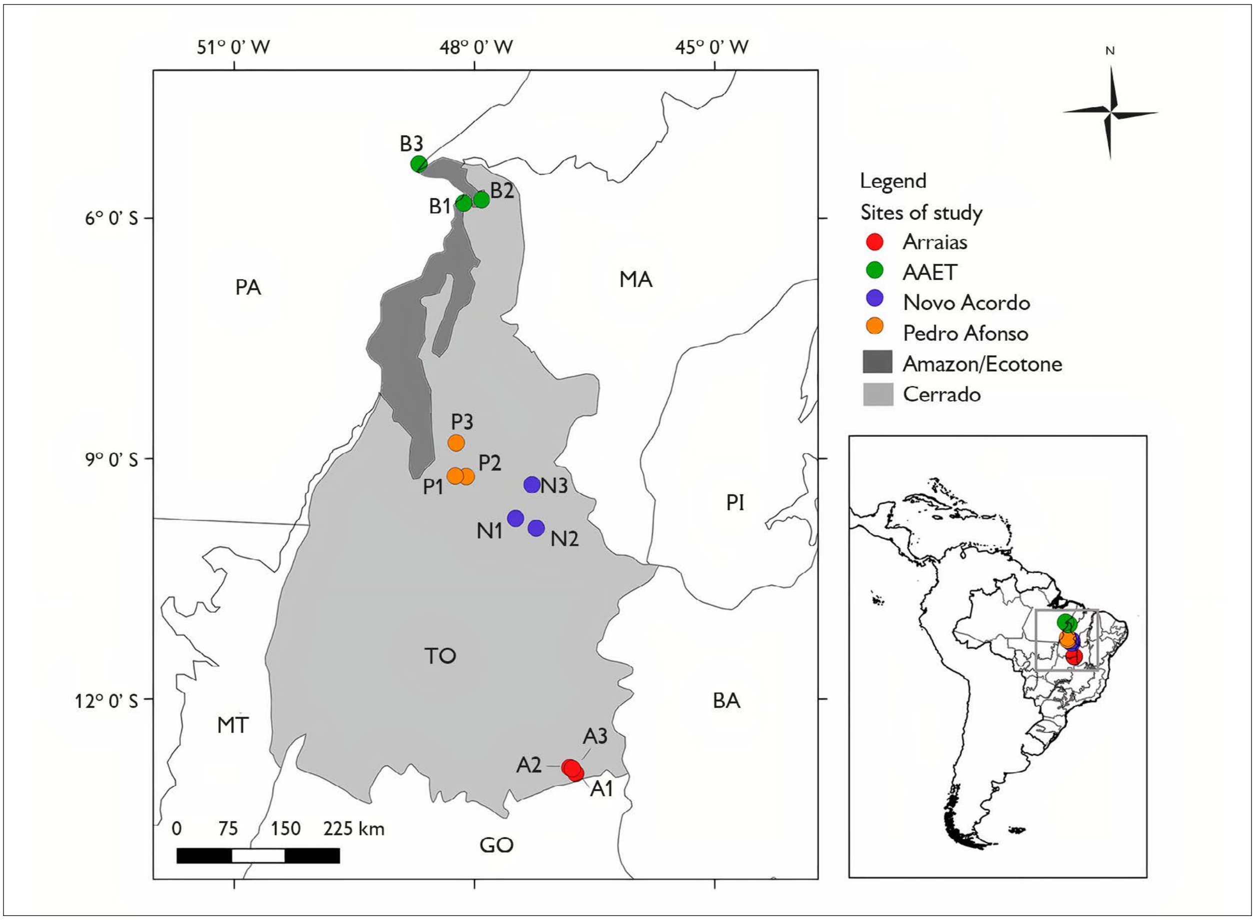

Figure 1. Map of the sites surveyed in the present study. Acronyms: BA = Bahia, GO = Goiás, MA = Maranhão, MT = Mato Grosso, PA = Pará, PI = Piauí, TO = Tocantins. AAET = municipalities of Araguatins, Augustinópolis, Esperantina, and Tocantinópolis (green dots): B1 = Cristalino (5° 48' 35" S, 48° 08' 04" W), B2 = Araguari (5° 46' 08" S, 47° 54' 45" W), B3 = Buriti (5° 12' 37" S, 48° 41' 37" W). Pedro Afonso municipality (orange dots): P1 (9° 13' 35" S, 48° 06' 12" W), P2 = Cana (9° 13' 11" S, 48° 06'12" W), P3 = Tupira (8° 48' 09" S, 48° 13' 42" W). Novo Acordo munipality (purple dots): N1 = Lobo (9° 44' 51" S, 47° 29' 14" W), N2 = Lizarda (9° 52' 12" S, 47° 13'46" W), N3 = Mansinha (9° 19' 30" S, 47° 16' 57" W). Arraias municipality (red dots), A1 = Sítio (12° 55' 53" S, 46° 44' 08" W), A2 = Captação (12° 51' 39" S, 46° 48' 41" W), A3 = GLAPA (12° 52' 23" S, 46° 46' 43" W).

## SAMPLING PROCEDURES

We surveyed mammals using camera traps (15 Bushnell® camera traps), which we deployed randomly within each area. In the first year (2010) at Pedro Afonso, we used Tigrinus® analogical traps, but during the subsequent years, we used Bushnell digital traps. We installed the traps at approximately 45 cm above the ground in different habitats, prioritizing sites such as dirt roads, tracks, and sources of food (*e.g.*, fruiting trees), and water. The cameras were programmed to operate 24 hours per day, with an interval of 5 seconds between each record during each sequence, and no more than three photographs from any given event. Total sampling effort at each site was calculated as: the number of camera traps × the number of sampling days (1 d = 24 h) x number of field surveys. Camera-trapping provides is a non-invasive tool that permits the detection of many mammals, including cryptic species, under most field conditions (Srbek-Araujo & Chiarello, 2005; Tobler *et al.*, 2008). The geographical coordinates of each camera trap site were recorded using a handheld GPS.

We also obtained opportunistic records during each survey, including photographs and indirect evidence of the presence of mammals, such as tracks, feces, and carcasses. While these records were included in the inventory, the sampling effort cannot be quantified.

We identified all the photographs and informal records to the lowest possible taxonomic level, adopting the nomenclature proposed by Paglia *et al*. (2012), with modifications for some groups (as follows). We considered Acosta *et al*. (2020) for the family Tayassuidae, Nascimento (2010) and Nascimento & Feijó (2017) for the genus *Leopardus* Gray, 1842, the review of Bornholdt *et al*. (2013) for the genus *Galictis* Bell, 1826, and Patton & Emmons (2015) for *Dasyprocta* Illiger, 1811. In the case of the primates, we followed Rylands *et al*. (2013) and Schneider & Sampaio (2015) for all genera except *Saimiri* Voigt, 1831, where we adopt the classification of Mercês *et al*. (2015). We also adopted Merino & Rossi (2010) for the genus *Mazama* Rafinesque, 1817, Feijó *et al*. (2018) for *Dasypus* Linnaeus, 1758, and Feijó & Langguth (2013) for *Cabassous* McMurtrie, 1831.

We considered the data available at IUCN web site (IUCN, 2020) for the global conservation status of each species, except in the case of *Saimiri*, for which we had access to the latest assessment (IUCN SSC Primate Specialist Group, 2015). For the Brazilian conservation status, we considered the list of threatened mammal species of Brazil published by ICMBio (2018).

### DATA ANALYSIS

We compiled species rarefaction curves in EstimateS, version 9.1 (Colwell *et al*., 2012), from the number of camera trap records collected in each study area, with a species richness estimator based on 1,000 randomizations. These curves represent the cumulative number of species recorded after a given sampling effort (number of field surveys). We selected the Jackknife 2 estimator to calculate expected richness because it provides the most reliable results for communities with low species equitability, as observed in the present study (Brose *et al*., 2003).

## RESULTS & DISCUSSION

Sampling effort consisted of 300 camera-days (six field trips) at AAET and Novo Acordo, 1800 camera-days (12 field trips) at Pedro Afonso, and 1050 camera-days (seven field trips) at Arraias. The rarefaction curves obtained for all four study areas (Figure 2) were still rising slightly by the end of the sampling period, which indicates that the number of species recorded during the study is lower than that estimated for each area. That is, the camera traps did not record all the species expected to occur in each area. Only one primate, the bearded capuchin, *Sapajus libidinosus* (Spix, 1823), was recorded by a camera trapping, while all the other primate species were recorded by visual observations.

### SPECIES RICHNESS AND TAXONOMIC GROUPS

We recorded a total of 42 taxa of large- and medium-bodied mammals in the four study areas in Tocantins state (Table 1), distributed in the following orders: Artiodactyla (5 species), Carnivora (16 species), Cingulata (5 species), Lagomorpha (1 species), Perissodactyla (1 species), Pilosa (3 species), Primates (5 species), and Rodentia (6 species). Fifteen species were only observed at the Cerrado localities, while three (*Bradypus variegatus* Schinz, 1825, *Alouatta belzebul* (Linnaeus, 1766), and *Saimiri collinsi* Osgood, 1916) were exclusive to the ecotone site.

Our data from the Cerrado localities indicated the presence of 38 taxa (Table 1). This number is much higher than 17 medium- and large-bodied mammalian species recorded by Carmignotto & Aires (2011) in the Cerrado of Tocantins state, but similar to the 36 species recorded by Lima *et al*. (2005), also in Tocantins.

The species richness of the AAET (22 species) correspond to approximately ~56 % of the terrestrial mammalian fauna recorded at four localities in northeastern Pará state by Stone *et al*. (2009). This difference may be related to relatively reduced sampling effort at AAET, as well as the fact that Pará state study was conducted in Amazon forest proper, rather than the ecotonal environment of the AAET.

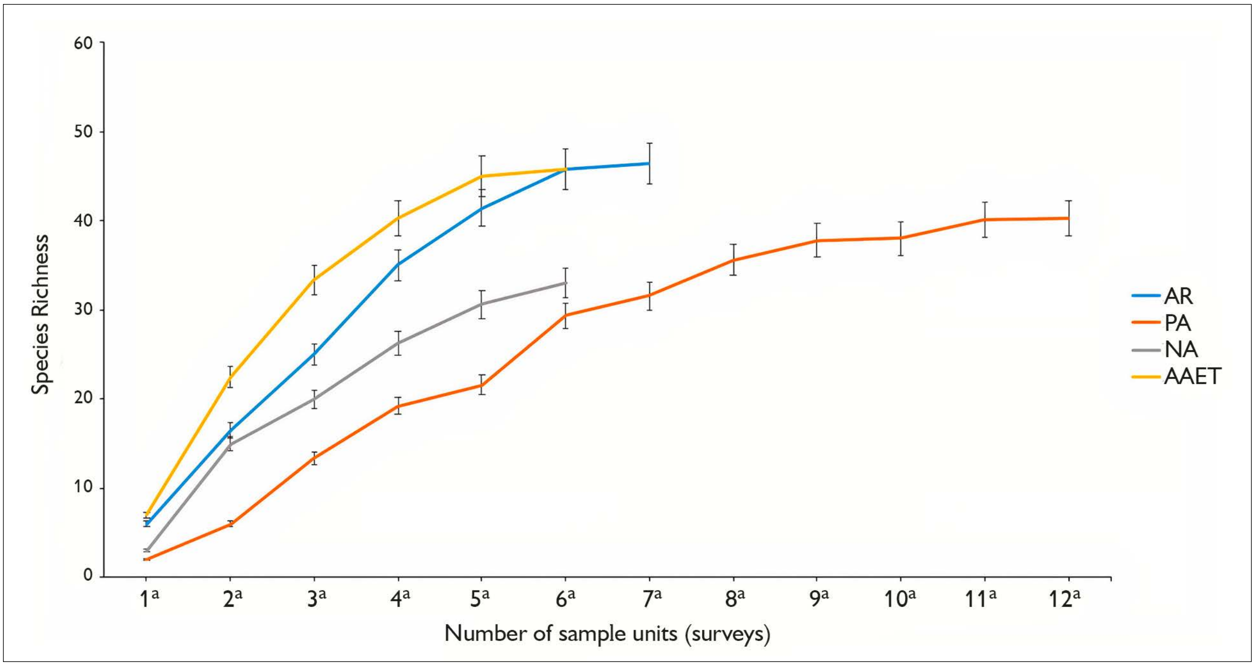

Figure 2. Species accumulation curves based on the rarefaction approach for the four localities in the Tocantins state (Brazil), surveyed in the present study by the camera trapping. AAET (yellow) = Araguatins, Augustinópolis, Esperantina, and Tocantinópolis municipalities, NA (gray) = Novo Acordo municipality, PA (orange) = Pedro Afonso municipality, AR (blue) = Arraias municipality.

Table 1. Mammal species recorded during the present study in Tocantins state, Brazil, showing the respective locality (AAET = Araguatins, Augustinópolis, Esperantina, and Tocantinópolis; AR = Arraias; PA = Pedro Afonso; NA = Novo Acordo), type of record (CT = Camera Trap; CC = Carcass; VI = Visualization; VOC = Vocalization), and conservation status categories [IUCN and ICMBio - Brazil] (LC = Least Concern; NT = Near Threatened; VU = Vulnerable; E = Endangered; DD = Data deficient). Previous studies in region, sources: 1 = Carmignotto & Aires (2011), 2 = Lima *et al*. (2005), and 3 = Stone *et al*. (2009). (Continue)

| Taxa | Localities | | | | Conservation Status | | Previous Studies | | |
|---|---|---|---|---|---|---|---|---|---|
| | AAET | AR | PA | NA | IUCN | ICMBio | Tocantins[1] | Tocantins[2] | Pará[3] |
| ARTIODACTYLA | | | | | | | | | |
| CERVIDAE | | | | | | | | | |
| *Mazama americana* (Erxleben, 1777) | VI | CT | VI | VI, CT | DD | DD | X | X | X |
| *Mazama gouazoubira* (Fischer, 1814) | VI | CT, VI | CT, VI | VI | LC | LC | X | - | X |
| *Blastocerus dichotomus* (Illiger, 1815) | - | VI, CT | - | VI | NT | VU | X | - | - |
| *Ozotocerus bezoarticus* (Linnaeus, 1758) | - | VI, CT | - | VI | NT | VU | X | - | - |
| TAYASSUIDADE | | | | | | | | | |
| *Dicotyles tajacu* (Linnaeus, 1758) | CT | CT | VI, CT | CT | LC | LC | - | X | X |

Table 1. (Continue)

| Taxa | Localities | | | | Conservation Status | | Previous Studies | | |
|---|---|---|---|---|---|---|---|---|---|
| | AAET | AR | PA | NA | IUCN | ICMBio | Tocantins[1] | Tocantins[2] | Pará[3] |
| CARNIVORA | | | | | | | | | |
| CANIDAE | | | | | | | | | |
| *Cerdocyon thous* (Linnaeus, 1766) | VI, CC | VI, CT | VI, CT | VI, CT | LC | LC | X | X | X |
| *Chrysocyon brachyurus* (Illiger, 1815) | VI | VI, CT | VI, CT | VI, CT | NT | VU | X | X | - |
| *Lycalopex vetulus* (Lund, 1842) | VI | VI | CT | VI, CC | NT | VU | X | - | - |
| *Speothos venaticus* (Lund, 1842) | - | CT | VI | - | NT | VU | - | X | X |
| MEPHITIDAE | | | | | | | | | |
| *Conepatus* sp. | - | - | - | FP | - | - | - | - | - |
| MUSTELIDAE | | | | | | | | | |
| *Eira barbara* (Linnaeus, 1758) | - | CT | VI, CT | VI | LC | LC | X | X | X |
| *Galictis cuja* (Molina, 1872) | - | - | VI | - | LC | LC | - | - | - |
| *Lontra longicaudis* (Olfers, 1818) | - | - | VI | - | LC | LC | - | - | - |
| FELIDAE | | | | | | | | | |
| *Herpailurus yagouaroundi* (É. Geoffroy Saint-Hilaire, 1803) | - | CT | CT | FP | LC | LC | - | X | X |
| *Leopardus braccatus* (Cope, 1889) | - | CT | - | VI | NT | VU (=*L. colocolo* | - | - | - |
| *Leopardus emiliae* (Thomas, 1914) | CT | CT | VI, CT | - | - | - | X (= *L. tigrinus*) | X (= *L. tigrinus*) | - |
| *Leopardus pardalis* (Linnaeus, 1758) | - | CT | VI, CT | - | LC | LC | - | X | X |
| *Panthera onca* (Linnaeus, 1758) | - | - | CT | - | NT | VU | - | X | X |
| *Puma concolor* (Linnaeus, 1771) | VI | CT | VI, CT | FP | LC | VU | X | X | X |
| PROCYONIDAE | | | | | | | | | |
| *Nasua nasua* (Linnaeus, 1766) | VI, CC | VI, CT | VI, CT | VI, FP | LC | LC | - | X | X |
| *Procyon cancrivorus* (Cuvier, 1798) | FP | CT | VI, CT | VI, FP | LC | LC | - | X | - |
| CINGULATA | | | | | | | | | |
| DASYPODIDAE | | | | | | | | | |
| *Dasypus novemcinctus* Linnaeus, 1758 | VI | CT | VI, CT | CT | LC | LC | - | X | X |

Table 1. (Continue)

| Taxa | Localities | | | | Conservation Status | | Previous Studies | | |
|---|---|---|---|---|---|---|---|---|---|
| | AAET | AR | PA | NA | IUCN | ICMBio | Tocantins[1] | Tocantins[2] | Pará[3] |
| *Dasypus septemcinctus* Linnaeus, 1758 | - | - | VI | VI | LC | LC | - | X | X |
| CHLAMYPHORIDAE | | | | | | | | | |
| *Cabassous tatouay* (Desmarest, 1804) | - | - | VI | VI | LC | DD | - | - | - |
| *Cabassous unicinctus* (Linnaeus, 1758) | - | - | VI | - | LC | LC | X | X | X |
| *Euphractus sexcinctus* (Linnaeus, 1758) | VI | VI, CT | VI | CC | LC | LC | - | X | X |
| LAGOMORPHA | | | | | | | | | |
| LEPORIDAE | | | | | | | | | |
| *Sylvilagus brasiliensis* (Linnaeus, 1758) | VI | VI | VI | VI | LC | - | - | - | X |
| PERISSODACTYLA | | | | | | | | | |
| TAPIRIIDAE | | | | | | | | | |
| *Tapirus terrestris* (Linnaeus, 1758) | VI, CT | FP | VI, CT | CT, FP | VU | VU | X | X | X |
| PILOSA | | | | | | | | | |
| BRADYPODIDAE | | | | | | | | | |
| *Bradypus variegatus* Schinz, 1825 | VI | - | - | - | LC | LC | - | - | X |
| MYRMECOPHAGIDAE | | | | | | | | | |
| *Myrmecophaga tridactyla* Linnaeus, 1758 | - | - | VI, CT | FP | VU | VU | - | X | X |
| *Tamandua tetradactyla* (Linnaeus, 1758) | VI | VI, CT | VI | VI | LC | LC | - | X | X |
| PRIMATES | | | | | | | | | |
| ATELIDAE | | | | | | | | | |
| *Alouatta belzebul* (Linnaeus, 1766) | VI | - | - | - | VU | VU | - | - | X |
| *Alouatta caraya* (Humboldt, 1812) | - | VI | VI, VOC | VOC | NT | NT | X | X | - |
| CEBIDAE | | | | | | | | | |
| *Saimiri collinsi* Osgood, 1916 | VI | - | - | - | NT | LC | - | - | X (= *S. sciureus*) |
| *Sapajus libidinosus* (Spix, 1823) | VI | VI | VI, CT | VI | NT | NT | X (= *C. apella*) | - | - |

Table 1. (Conclusion)

| Taxa | Localities | | | | Conservation Status | | Previous Studies | | |
|---|---|---|---|---|---|---|---|---|---|
| | AAET | AR | PA | NA | IUCN | ICMBio | Tocantins[1] | Tocantins[2] | Pará[3] |
| CALLITHRICHIDAE | | | | | | | | | |
| *Callithrix penicillata* (É. Geoffroy, 1812) | - | VI | VI, VOC | VI | LC | LC | - | X | - |
| RODENTIA | | | | | | | | | |
| CAVIIDAE | | | | | | | | | |
| *Hydrochoerus hydrochaeris* (Linnaeus, 1766) | FP | - | VI | FP | LC | - | X | X | X |
| CUNICULIDAE | | | | | | | | | |
| *Cuniculus paca* (Linnaeus, 1766) | FP | CT | CT | FP | LC | - | X | X | - |
| DASYPROCTIDAE | | | | | | | | | |
| *Dasyprocta leporina* (Linnaeus, 1758) | VI | VI, CT | - | - | LC | - | - | X | X |
| *Dasyprocta azarae* Lichtenstein, 1823 | - | CT | VI, CT | - | DD | - | - | - | - |
| *Dasyprocta* sp. | - | - | - | CT | - | - | - | - | - |
| ERETHIZONTIDAE | | | | | | | | | |
| *Coendou prehensilis* (Linnaeus, 1758) | - | VI | CC | - | LC | - | - | X | X |
| Species richness | 22 | 29 | 33 | 29 | - | - | 17 | 36 | 42 |

Despite the smaller number of species recorded by Carmignotto & Aires (2011), they did record two species – *Tolypeutes tricinctus* (Linnaeus, 1758) and *Tayassu pecari* (Link, 1795) – which were not observed in the present study. Similarly, Lima *et al*. (2005) registered three species, *Leopardus wiedii* (Schinz, 1821), *Atelocynus microtis* (Sclater, 1883), and *Galictis vittata* (Schreber, 1776), not recorded in the present study. By contrast, we recorded four species – *Galictis cuja* (Molina, 1782), *Cabassous tatouay* (Desmarest, 1804), *Sapajus libidinosus*, and *Saimiri collinsi* – not recorded by either Carmignotto & Aires (2011) or Lima *et al*. (2005).

## ARTIODACTYLA

The number of deers and peccaries observed in the present study (n = 5) corresponds to half of the species known to occur in Brazil (Paglia *et al*., 2012). Two of the three even-toed ungulate families found in South America were recorded, that is, the Tayassuidae (one species) and the Cervidae (with three genera and four species). *Mazama americana* (Erxleben, 1777), *Mazama gouazoubira* (Fischer, 1814), and *Dicotyles tajacu* (Linnaeus, 1758), which are widely distributed in Brazil (Black-Décima *et al*., 2010; Gongora *et al.*, 2011; Black-Décima & Vogliotti, 2016), were observed in all localities. While *M. gouazoubira* appears to be substituted by *Mazama nemorivaga* (Cuvier, 1817) in the Amazon biome (Rossi, 2000), this species was not recorded in the present study, even at AAET.

The marsh deer, *Blastocerus dichotomus* (Illiger, 1815), inhabits seasonally flooded areas (Piovezan *et al*., 2010), and the populations observed in the present study, in central Tocantins, are probably isolated by the advance of agricultural frontiers in the region. The global distribution of the species has declined by 65% in recent years (Weber & González, 2003). The pampas deer, *Ozotocerus bezoarticus* (Linnaeus, 1758), was recorded in the central and southern localities. This species was once widely distributed (González *et al*., 2010, 2016), but habitat loss, especially in open areas of the Cerrado, has led to the isolation of most populations. The two records presented here are thus specially important, considering the fragmentation of the region's populations.

The absence of white-lipped peccary *Tayassu pecari* from all our study sites was unexpected, given that this species has an ample geographic distribution, and has been recorded previously in the east and southeastern of Tocantins (Carmignotto & Aires, 2011; Lima *et al*., 2005). In the Cerrado this peccary has relatively low survival rates due to the fragmentation of its populations, which are better adapted to the conditions available in the Amazon forest (Altrichter *et al*., 2011). The lack of records of *T. pecari* in the present study is unlikely to have been a consequence of inadequate sampling effort, although it is still unclear whether the species is in fact absent from all four study sites.

## CARNIVORA

A total of 16 carnivore species were recorded in the present study, which is more than the number observed in the Serra Geral do Tocantins Ecological Station (n = 6) by Carmignotto & Aires (2011) and the 14 species recorded by Stone *et al*. (2009) in northeastern Pará. However, Lima *et al*. (2005) also recorded 16 carnivores in the Serra do Espírito Santo, in the Jalapão region of eastern Tocantins.

Two canid species, the maned wolf, *Chrysocyon brachyurus* (Illiger, 1815), and the hoary fox, *Lycalopex vetulus* (Lund, 1842), were recorded in all four study areas. Both these canids typically inhabit savannas and other open areas and, while northern Tocantins is an area of ecotone, the presence of Cerrado species would not be totally unexpected. In fact, the range of the maned wolf is expanding into deforested areas of the Atlantic Forest (Queirolo *et al*., 2011) and a similar process may be occurring in the southern Amazon.

The bush dog, *Speothos venaticus* (Lund, 1842), a highly cryptic species, was observed only in the Cerrado (Appendix 1). The two records (one camera trap record and one visualization) represent an extension of the known distribution of the bush dog in the Cerrado, toward the center of Tocantins, given that Oliveira (2009a) recorded the species in the eastern extreme of the state.

Three species of the family Mustelidae were recorded in the present study. The lesser grison, *Galictis cuja*, which is much smaller than the greater grison, *Galictis vittata*, could be identified through both direct observations and photographic records (Appendix 2), based on the review of Bornholdt *et al*. (2013). The observer WSP had already observed *G. vittata* in the field, in Amapá state, and was able to identify *G. cuja* through the direct observation of two individuals (possibly a pair) in Pedro Afonso. This observation increases the known distribution (Bornholdt *et al*., 2013) of the species 800 km to the north, to central Tocantins state, and indicates that it occurs in savanna habitat. Oliveira (2009b) observed both *G. vittata* and *G. cuja* in Maranhão state, and proposed that the range of *G. cuja* was expanding due to the clearance of rainforest, which its conversion into open habitats.

The Neotropical otter, *Lontra longicaudis* (Olfers, 1818), is associated with aquatic environments and was recorded near the Bezerra River in Arraias. This species is amply distributed in Brazil, occurring throughout most of Brazil, and appears to be absent only from the semiarid zone the northeastern region, even though the limits of the distribution of the species in this region have yet to be defined (Rheingantz *et al*., 2017). *Lontra longicaudis* nevertheless appears to be tolerant of some level of habitat degradation (Rheingantz *et al*., 2017).

Kasper *et al*. (2009) recorded the Amazonian hog-nosed skunk, *Conepatus semistriatus* (Boddaert, 1785), in the Brazilian states of Maranhão, Minas Gerais, São Paulo, and Bahia, and in the Federal District, encompassing a large part of the Cerrado. We recorded a single track of *Conepatus* sp. Due to the lack of direct observation and/or photographs we were not able to confirm the identification of the species responsible for this.

We also observed three species of the genus *Leopardus*, the ocelot, *Leopardus pardalis* (Linnaeus, 1758) (Figure 3), which was recorded at two Cerrado sites. This species occurs in a wide variety of habitats, including rainforest, mangrove, savanna, and grassland. The eastern tigrina *Leopardus emiliae* (Thomas, 1914) is a small felid considered to be endemic to Brazil, where it occurs in the Cerrado, Caatinga, Atlantic Forest, and Amazon biomes. We recorded *L. emiliae* in both the ecotone and the Cerrado. The small pampas cat, *Leopardus braccatus* (Cope, 1889), was recorded at two Cerrado localities.

Figure 3. Camera trap still of an ocelot (*Leopardus pardalis*) taken in Pedro Afonso municipality, Tocantins state, Brazil. Photograph: W. S. de Paula.

The other felid species recorded in the present study was the jaguarundi, *Herpailurus yagouaroundi* (É. Geoffroy Saint-Hilaire, 1803), which was observed only in the Cerrado. Despite its ample distribution (from Mexico to southern South America) and preference for open areas, this species typically occurs at low densities (Almeida *et al*., 2018).

## CINGULATA

We recorded five armadillos belonging to two families in the present study. These species include both a forest specialist, *Cabassous unicinctus* (Linnaeus, 1758), and open area-generalists – *Dasypus novemcinctus* Linnaeus, 1758, *D. septemcinctus* Linnaeus, 1758, *Cabassous tatouay*, and *Euphractus sexcinctus* (Linnaeus, 1758). *Dasypus novemcinctus* was observed at all four localities (ecotone and Cerrado) through direct observation and camera trap records, while *D. septemcinctus* was recorded only in Cerrado, through direct observation. *Dasypus septemcinctus* occurs in the eastern Amazon and Cerrado, Atlantic Forest, and Caatinga biomes. The two species were identified through diagnostic characters, i.e., number of movable bands, provided by Feijó *et al*. (2018).

Even though *Cabassous unicintus* is a forest-dwelling species, we recorded it in the Cerrado and at the same locality as *C. tatouay* (Pedro Afonso). These two species can be distinguished reliably by the absence of a clear border in the carapace of *C. tatouay* (Figure 4) and by the large size of *C. tatouay* (Feijó & Langguth, 2013).

Figure 4. Specimen of greater naked-tailed armadillo (*Cabassous tatouay*) from Pedro Afonso municipality, Tocantins state, Brazil. Photograph: W. S. de Paula.

## PERISSODACTYLA

The lowland tapir, *Tapirus terrestris* (Linnaeus, 1758), is the only species of the order Perissodactyla found in Brazil (Paglia *et al*., 2012). *Tapirus terrestris* was observed in both ecotone and Cerrado areas. This species is classified as vulnerable by the IUCN (Varela *et al*., 2019) and the Brazilian Red List (Medici *et al*., 2018). Our records from all four localities are especially relevant for the conservation of the species, given that they indicate that the species persists in areas under intense anthropogenic pressure.

## PILOSA

The Pilosa is represented by three species in the study area, including the giant anteater, *Myrmecophaga tridactyla* Linnaeus, 1758, and the southern tamandua, *Tamandua tetradactyla* (Linnaeus, 1758). These two anteaters were also observed by Lima *et al*. (2005) in the Jalapão region of Tocantins and by Stone *et al*. (2009) in eastern Amazonia, and both species are found in forested and open habitats (Gardner, 2008 [2007]). By contrast, the brown-throated sloth, *Bradypus variegatus*, is an arboreal species found only in forest, and was thus recorded only at AAET (ecotone).

## PRIMATES

Three families of Neotropical monkeys were recorded in the present study (Atelidae, Cebidae, and Callitrichidae), comprising four genera and five species. This diversity is not evenly distributed in the state, however. One species, *Callithrix penicillata* (É. Geoffroy, 1812), is endemic to the Cerrado, and was observed only at the central and southeastern sites, while *Sapajus libidinosus* is endemic to both the Cerrado and the Caatinga (Gutiérrez & Marinho-Filho, 2017), and was observed at the ecotone and Cerrado sites. Rylands & Mittermeier (2013) note that *Callithrix penicillata* occurs to the east of the Araguaia River, which includes Tocantins state.

Two of the other species are either endemic to the Amazon biome (*Saimiri collinsi*) or found predominantly (*Alouatta belzebul*) in this biome and other forested environments in northern Brazil (Mercês *et al*., 2018; Gregorin, 2006), and were recorded only in the ecotone, as expected. The fifth species, the black-and-gold howler monkey *Alouatta caraya* (Humboldt, 1812), is the most widespread species of the genus *Alouatta* Lacépède, 1799 (Gregorin, 2006), and inhabits savannas, floodplains, and forests patches in open areas. As expected, *A. caraya* was recorded only in the Cerrado. *Alouatta caraya* and *A. belzebul* can be easily distinguished by the coloration of their pelage, given that *A. caraya* presents sexual dimorphism, with entirely black males and pale-yellow females, while *A. belzebul* is almost entirely black, with reddish coloration, primarily on the hands, feet, and tail (Gregorin, 2006). Our records increase the known distribution of *Alouatta caraya* (Figure 5) within a region that was previously identified as a distributional gap between these two howler species. Gregorin (2006) and Fernandez-Duque *et al*. (2008) recorded *A. caraya* in Mato Grosso and Maranhão, but not in Tocantins, although Cornejo *et al*. (2013) did propose that *A. caraya* may occur in southern Tocantins. Our record nevertheless confirms its occurrence at the three different sites in central and southeastern Tocantins.

Figure 5. Female specimen of black-and-gold howler monkey (*Alouatta caraya*) observed in Arraias municipality, Tocantins state, Brazil. Photograph: W. S. de Paula.

### RODENTIA

Four rodent families (Caviidae, Cuniculidae, Dasyproctidae, and Erethizontidae) were confirmed in the study area, representing the largest of the rodents, including six species and four genera. The genera *Hydrochoerus* Brisson, 1762 and *Cuniculus* Brisson, 1762 are represented by widespread species, *H. hydrochaeris* (Linnaeus, 1766) and *C. paca* (Linnaeus, 1766) (Paglia *et al*., 2012).

In the case of the genus *Dasyprocta*, we were able to identify the red-rumped agouti, *Dasyprocta leporina* (Linnaeus, 1758), at two study sites of, one in the ecotone and the other in the Cerrado. This species is widespread in eastern South America, between eastern Amazon basin and the coast of eastern Brazil (Emmons & Reid, 2016). We observed Azara's agouti *Dasyprocta azarae* Lichtenstein, 1823 at two Cerrado sites. This species can be distinguished from *D. leporina* by its homogenous yellow-olivaceous coloration with grayish to blackish grizzling (Patton & Emmons, 2015). A third morphotype was observed at Novo Acordo, but we were unable to identify the species.

We recorded the Brazilian porcupine, *Coendou prehensilis* (Linnaeus, 1758), at two Cerrado sites, which was as expected, given the ample distribution of this species in Brazil, where it inhabits dry forests and savannas (Voss *et al*., 2013).

## CONSERVATION

Overall, 12 of the 42 taxa recorded in the present study are classified as vulnerable by either the IUCN (2020) and/or the ICMBio (2018). This represents 26% of the mammalian species richness recorded in the present study, and approximately 9% of the threatened mammals in Brazil (ICMBio, 2018).

The order Carnivora has the highest number of vulnerable species (n = 7), followed by two Artiodactyla (ICMBio, 2018). In our study sites along Tocantins state 23% (IUCN) and 7% (ICMBio) of the species are near threatened. Thus only 9% of the species recorded are vulnerable (IUCN), while for ICMBio evaluation 28% of the species are is this category of threat.

This difference might be related because some of the IUCN data are outdated (*e.g.*, *Speothos venaticus*, De Matteo *et al*., 2011) and many more recent evaluations have not yet been published. The number of vulnerable species (ICMBio) was higher in Cerrado (26%, 11 species) than in ecotone (11%, 6 species). This was also observed in species considered least concern with Cerrado (n = 13) and ecotone (n = 9). One species (*Alouatta belzebul*) classified as vulnerable by the ICMBio (2018) was observed only in the ecotone, while six listed as vulnerable [*Blastocerus dichotomus*, *Ozotocerus bezoarticus*, *Speothos venaticus*, *Leopardus braccatus*, *Panthera onca* (Linnaeus, 1758), and *Myrmecophaga tridactyla*] were observed only in the Cerrado. The occurrence of these species highlights the importance of efforts for the conservation of the Cerrado in Tocantins state, in order to maintain their remaining populations.

Tocantins state is one of the Cerrado states with highest rates of deforestation for soybean cultivation (Carvalho *et al*., 2019). This process entails two major threats for Brazilian mammals, habitat loss and fragmentation (Costa *et al*., 2005). One other threat is hunting. De Paula *et al*. (2017) reported the subsistence hunting of 387 individuals of 23 mammal species by a Xerente indigenous community over a 12-month period, with mammals representing 97% of the total biomass obtained (5,878 kg). This exemplifies the direct impact of hunting, without even considering the negative interactions between the region's farmers and the local carnivores, peccaries, and cervids.

We recorded the two largest Neotropical felids, *Panthera onca* and *Puma concolor* (Linnaeus, 1771), in the present study. The jaguar, *Panthera onca* is classified as near threatened globally (Quigley *et al*., 2017) and as vulnerable in Brazil (Morato *et al*., 2018), while *Puma concolor* is listed as least concern globally (Nielsen *et al*., 2015), and vulnerable in the Brazilian Red List (Azevedo *et al*., 2018).

*Leopardus emiliae* and *Leopardus braccatus* were classified as valid species only recently (Barstow & Leslie Jr., 2012; Nascimento & Feijó, 2017), and in the global assessment, *L. braccatus* (=*L. colocolo*) is listed as near threatened, whereas in Brazil, it is vulnerable (ICMBio, 2018), while *L. emilae* is a more recent revalidation, and has yet to be evaluated at either level (Nascimento & Feijó, 2017). *Lycalopex vetulus* is endemic to the Cerrado and is considered vulnerable in Brazil (Lemos *et al*., 2018), and near threatened globally (Lemos *et al*., 2020).

*Saimiri collinsi* is endemic to the Amazon and was assessed as near threatened by the IUCN SSC Primate Specialist Group (2015), while *Alouatta belzebul* is classified as vulnerable by both the IUCN and the ICMBio (Valença-Montenegro *et al*., 2018, 2019). The record from Tocantins may thus be relevant to the conservation of this species.

The marsh deer, *Blastocerus dichotomus*, was recorded at the two central localities (Pedro Afonso and Novo Acordo). This species is classified as vulnerable by both the IUCN and the ICMBio (Duarte *et al*., 2016, 2018).

## CONCLUSIONS

The results of the present study added one mammal species– *Galictis cuja* – to the inventory for the Brazilian state of Tocantins, and also extend the known geographic distributions of two other species, *Speothos venaticus* and *Alouatta caraya*, in the state. Our analysis of species richness nevertheless indicates that the number of species recorded is underestimated at all four study localities.

Even so, the species richness (42 taxa) was higher than that recorded in other inventories in the Cerrado (36 species; Lima *et al*., 2005) of Tocantins state, but lower when compares with eastern Amazonia (46 species). The presence of vulnerable species (n = 12) is noteworthy. In particular, our data highlight the importance of the ecotonal zone, where both Amazonian (*e. g., Saimiri collinsi*) and Cerrado species (*e. g.*, *Lycalopex vetulus*) were recorded, and the areas of Cerrado which still support a considerable diversity of medium- and large-bodied mammals, such as the 33 found in Pedro Afonso. These findings are encouraging, considering that the region is under increasing pressure from farming and wildfires. The absence of the white-lipped peccary *Tayassu pecari* nevertheless reinforces the need for more attention, in particular, the more systematic monitoring of the region's mammal populations, considering the relentless advance of anthropogenic pressure. Overall, four (*Blastocerus dichotomus*, *Tapirus terrestris*, *Myrmecophaga tridactyla*, and *Alouatta belzebul*) species are listed globally as vulnerable, and 12 are considered vulnerable in Brazil.

## ACKNOWLEDGEMENTS

We are grateful to Gabriel Melo Santos and Victor Fonseca for their comments on the manuscript. We would like to thank the three anonymous reviewers for their excellent input which greatly improved the manuscript. MPM received a doctoral scholarship from the *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* – Brasil (CAPES, Financial Code 001).

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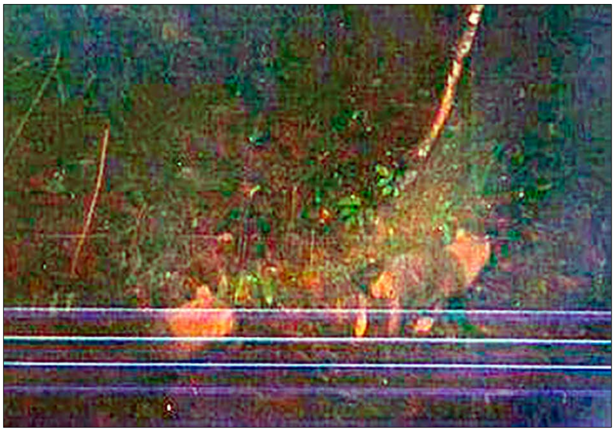
Appendix 1. Two specimens of bush dog (*Speothos venaticus*) from Arraias municipality, Tocantins state, Brazil. Photograph: W. S. de Paula.



Appendix 2. One specimen of lesser grisson (*Galictis cuja*) from Pedro Afonso municipality, Tocantins state, Brazil. Photograph: W. S. de Paula.

Bol. Mus. Para. Emílio Goeldi. Cienc. Nat., Belém, v. 15, n. 3, p. 701-716, set.-dez. 2020

# Understanding the ecology of medium-sized carnivores (Mammalia: Carnivora) from a Tropical Dry Forest in Colombian Caribbean

# Compreendendo a ecologia de carnívoros de médio porte (Mammalia: Carnivora) de uma floresta tropical seca no Caribe colombiano

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**Abstract:** Fauna in Tropical Dry Forest (TDF) is highly dependent on water availability due to a marked seasonality in precipitation. There are few studies addressing carnivore's ecology and the role of seasonality of TDF in Neotropics. We used scent-station and camera trapping to assess seasonal changes in occurrence and habitat use probability with seasonality. We also described activity patterns and collected fresh scats to describe diet for small sized carnivore species in a TDF fragment in the Colombian Caribbean region. We present information regarding: *Cerdocyon thous*, *Leopardus pardalis*, and *Procyon* spp. The analysis showed a significantly higher occurrence probability during the dry season for the three species, and no differences in the detection probability between seasons. The diet of *C. thous* included 24 different food items; for *L. pardalis* it was composed of seven items, and finally, 25 food items were identified in the diet of *Procyon* spp. We found that the three species presented activity patterns corresponding with previous studies. Finally, our results reflect that these species are probably making more/larger habitat use during the dry season than in the wet season, because the area has permanent water ponds by which limited resources (such as water and food) are available almost constantly in this natural reserve.

**Keywords:** *Cerdocyon*. Diet. *Leopardus*. Occupancy. *Procyon*.

**Resumo:** A fauna na floresta seca tropical (TDF) é altamente dependente da disponibilidade de água devido à sazonalidade acentuada na precipitação. Existem poucos estudos que abordam a ecologia dos carnívoros e o papel da sazonalidade do TDF nos neotrópicos. Usamos análises de estação de pegadas, armadilhas fotográficas e fezes para determinar se há mudanças sazonais na ocorrência, ocupação, dieta e padrão de atividade de espécies de carnívoros em um pequeno fragmento de TDF na região do Caribe colombiano. Apresentamos informações sobre: *Cerdocyon thous*, *Leopardus pardalis* e *Procyon* spp. A análise mostrou probabilidade de ocorrência significativamente maior durante a estação seca para as três espécies, e não houve diferenças na probabilidade de detecção entre as estações. A dieta de *C. thous* incluiu 24 itens alimentares diferentes, *L. pardalis* foi composta por sete itens e, finalmente, 25 itens alimentares foram identificados na dieta de *Procyon* spp. Constatamos que as três espécies apresentaram padrões de atividade correspondentes a estudos anteriores. Finalmente, nossos resultados refletem que essas espécies provavelmente estão usando mais um habitat, ou maiores porções desse, durante a estação seca do que na estação chuvosa, uma vez que a área possui lagoas de água permanentes pelas quais recursos limitados (como água e alimentos) estão disponíveis quase constantemente nesta reserva.

**Palavras-chave:** *Cerdocyon*. Dieta. *Leopardus*. Ocupação. *Procyon.*

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GÓMEZ-RUIZ, D. A., C. SÁNCHEZ-GIRALDO, J. L. PARRA & S. SOLARI, 2020. Understanding the ecology of medium-sized carnivores (Mammalia: Carnivora) from a Tropical Dry Forest in Colombian Caribbean. **Boletim do Museu Paraense Emílio Goeldi. Ciências Naturais** 15(3): 701-716. DOI: http://doi.org/10.46357/bcnaturais.v15i3.239.

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Recebido em 19/12/2019
Aprovado em 21/10/2020
Responsabilidade editorial: Alexandra Maria Ramos Bezerra

## INTRODUCTION

Tropical Dry Forests (TDF) are among the most diverse and threatened ecosystems worldwide (Sánchez-Azofeifa & Portillo-Quintero, 2011). In the Americas, TDF are distributed from Mexico to Argentina, and in South American countries include 51 % of the cover (Portillo-Quintero & Sánchez-Azofeifa, 2010). In addition, disturbances derived from the expansion of agriculture and cattle ranching represent the main threat to this ecosystem, leading to a highly fragmented landscape dominated by small patches throughout its distribution (Portillo-Quintero & Sánchez-Azofeifa, 2010). TDF harbors communities with unique flora and fauna components, characterized by high levels of endemism and β diversity, which are highly dependent on water availability due to a marked seasonality in precipitation (Ceballos, 1995; Pennington *et al*., 2000, 2009). Despite its exclusive characteristics and the threats faced, the components and ecological processes of TDF are not well understood (Sánchez-Azofeifa *et al*., 2005). According to this, faunal and flora communities in TDF are limited by the availability of water and food during dry seasons (Dirzo *et al*., 2011). Terrestrial animals can handle these kinds of limitations in several ways: (1) concentrating in areas with permanent water availability, (2) moving seasonally to follow resources (behavioral adaptation), or (3) showing tolerance to water scarcity (physiological adaptation) (Ceballos, 1995; Schmidt-Nielsen, 1997; Stoner & Timm, 2011). Hence, the marked seasonality exhibited by TDF and the ways animals handle it can involve changes in the local distribution of species, generating spatial and temporal patterns mainly related to the water presence and prey availability throughout the landscape (Mortelliti & Boitani, 2008; Davidson *et al*., 2012; Schuette *et al.*, 2013).

Although the seasonality is recognized as a paramount condition for animal ecology in TDF, it has been a poorly addressed factor in ecological studies of selected animal groups in the Neotropics (Del Coro Arizmendi & Ornelas, 1990; Ornelas *et al*., 1993; Andresen, 2005; Mason-Romo *et al*., 2018). Despite the fact that mammalian medium-sized carnivores are relatively common, more abundant than large carnivores, and are a fundamental component in the ecological dynamic as seed dispersers and as controllers of vertebrate prey (Rocha *et al*., 2004; Cazetta & Galetti, 2009; Kimmel *et al*., 2010), few studies addressing their ecology in TDF are available (Hidalgo-Mihart *et al*., 2001; Maffei & Taber, 2003; Cantú-Salazar *et al*., 2005; Arispe *et al*., 2008; Valenzuela-Galván *et al*., 2013), and the most of them did not consider the role of seasonality (but see Valenzuela & Ceballos, 2000). In the particular case of Colombia, studies carried out with medium-sized carnivores in TDF have been mostly focused on describing the composition of the assemblages (Sánchez-Lalinde & Pérez-Torres, 2008; Pineda-Guerrero *et al.*, 2015). Therefore, the effects of seasonality are unknown yet.

Furthermore, assemblages of medium-sized carnivores mammals associated to TDF in Colombia are composed mainly by widely distributed species, including *Cerdocyon thous* (Linnaeus, 1766), *Procyon cancrivorus* (G. Cuvier, 1798), *Eira barbara* (Linnaeus, 1758), *Leopardus pardalis* (Linnaeus, 1758), *Herpailurus yagouaroundi* (É. Geoffroy, 1803), and *Conepatus semistriatus* Boddaert, 1785 (Díaz-Pulido *et al*., 2014). In general, these species use different ecosystems and habitats with a wide range of precipitation and temperature conditions, and are characterized by opportunistic feeding habits (Sánchez-Lalinde & Pérez-Torres, 2008; Galván-Guevara, 2010; Solari *et al*., 2013; Díaz-Pulido *et al*., 2014; García-Herrera *et al*., 2015; Pineda-Guerrero *et al.*, 2015). Like evidenced in other mammalian species in dry ecosystems (Stoner & Timm, 2004), it is expected that most of medium-sized carnivores in TDF exhibit behavioral adaptations for facing seasonal challenges, rather than physiological ones. These adaptations are likely associated with seasonal shifts in the diet, home range, habitat uses, and daily activity (Núñez-Pérez, 2006; Vieira & Port, 2007), which will be reflected through the changes in the spatial and temporal patterns of the species between seasons.

Moreover, the ecological response of mammalian species to seasonal constrains is directly related to habitat conditions. That is to say, water availability is a critical factor for maintenance of carnivore assemblages in dry ecosystems, and as a consequence species might adjust their seasonal changes to this resource (Matos *et al*., 2009; Santos *et al*., 2011). In these ecosystems, habitats with a constant water supply (even during dry season) tend to be used more frequently by mammalian species and concentrate higher density of individuals (Western, 1975; Pérez-Cortez *et al*., 2012). In the Caribbean region of Colombia, where a considerable portion of TDF remains, the dry season is characterized by drastic water decrease, and available water sources become restricted to scattered and scarce natural or artificial ponds (Pizano & García, 2014). Consequently, areas containing this kind of water bodies are fundamental habitats for medium-sized carnivore species that inhabit TDF in Caribbean region.

In this study, we compared the patterns of habitat use between seasons, and describe the feeding habits and activity patterns for common medium-sized carnivore species *Cerdocyon thous*, *Leopardus pardalis*, and *Procyon* spp. in a small TDF reserve in the Colombian Caribbean region. We used data from scent station and camera trapping to determinate the seasonal changes in the occurrence probability and habitat use probability. Besides, using the camera records, we also describe their activity patterns. Likewise, we describe main items in the diet of species according to scat analyses. Unlike many TDF areas in Caribbean region, the study area has a constant water supply due to the presence of two natural, permanent ponds that make this area more stable for these carnivore mammals during the dry season. Considering the expected seasonal use of an area with availability of water in a dry ecosystem, we expect higher occurrence probability and habitat use probability for medium-sized carnivore species during dry season.

## MATERIALS AND METHODS

### STUDY AREA

The study was conducted within the Sanguaré Natural Reserve (9.72017° N, 75.67592° W), north of Morrosquillo Gulf in the Caribbean region, Sucre, Colombia (Figure 1). The area is Tropical Dry Forest, with an annual average rainfall of 1,100 mm, and annual average temperature of 27 °C (Holdridge, 1967; Pizano & García, 2014). It exhibits a markedly seasonal climate, with rainfall concentrated in April-May and October-November, and prolonged dry seasons from December to early April and late June to September (Sánchez-Páez & Álvarez-León, 1997). Within an area of 898 ha, Sanguaré offers a variety of habitats including 80 ha of natural water ponds and flooded habitats, 110 ha of secondary forest, 708 ha composed by shrubland, grassland, and mangrove covers. The forest is dominated by the palm *Attalea butyracea* (Mutis ex L. f.) Wess. Boer, and other trees such as *Sterculia apetala* (Jacq.) H. Karst., *Enterolobium cyclocarpum* (Jacq.) Griseb., *Ceiba pentandra* (L.) Gaertn., *Pseudobombax septenatum* (Jacq.) Dugand, *Bombacopsis quinate* (W. S. Alverson, 1994), *Caesalpinia coriaria* (Jacq.) Willd., *Bursera simaruba* (L.) Sarg., *Lecythis magdalénica* Dugand, *Albizia saman* (Jacq.) Merr., and *Capparis odoratissima* (Jacq.).

### DATA COLLECTION

We obtained records of carnivore mammals in Sanguaré Natural Reserve from surveys carried out between 2010 and 2013, covering periods including both dry and wet seasons. Additionally, we implemented as sampling methods scent stations, camera traps, and scat collection, using sampling designs according to each analyzed ecological aspect.

### OCCURRENCE PATTERNS

We conducted a scent-station survey during four sampling periods of 5-7 consecutive days, between February 2010 and July 2011, covering two wet (May and June) and two dry (February and March) seasons. During each sampling period, we installed nine stations in secondary forest cover and six in shrublands, using two transects of 2.7 and 1.8 km, respectively (Figure 1A). Stations were placed 0.3 km from each other in each transect, and transects

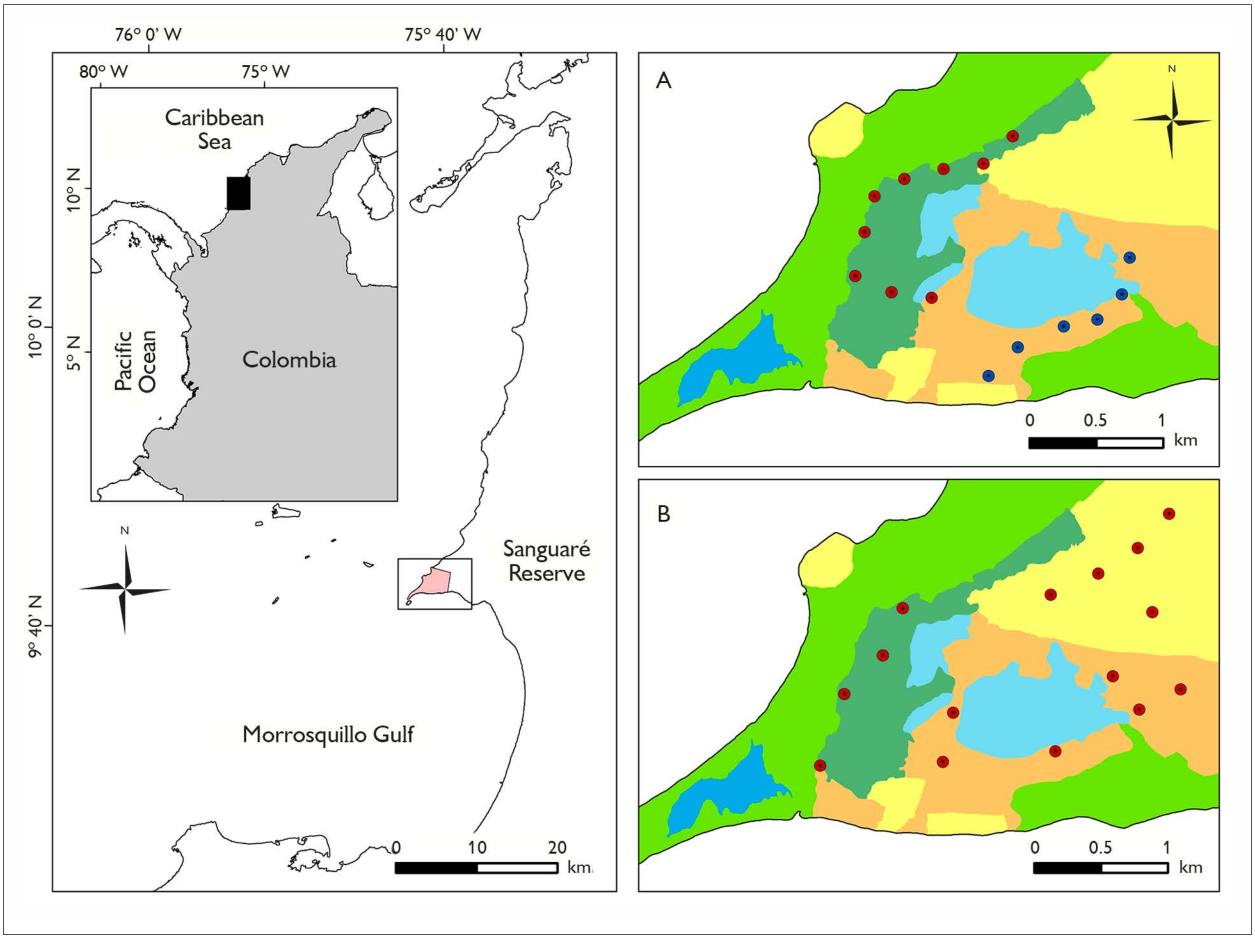

Figure 1. Location of Sanguaré Natural Reserve at Colombian Caribbean coast. Maps showing in detail the cover distribution in Sanguaré Reserve (light blue: freshwater ponds; dark blue: coastal lagoons; dark green: secondary forest; light green: mangrove; orange: shrubland; yellow: grassland), and (A) location of scent-stations within each transect (dark-red dots transect in secondary forest and blue dots transect in shrubland) for occurrence; and (B) location of sampling units (dark-red dots) for occupancy analyses. Map: D. A. Gómez Ruiz (2019).

were separated by 1.8 km, which is far enough to be considered independent from each other (Roughton & Sweeny, 1982; Conner *et al.*, 1983; Acosta-Jamett & Simonetti, 2004). Each station was made of soft sand in a thin layer with a dimension of 1 m x 1 m, and due to the type of substrate we did not add water to the station in any of the seasons. Stations were baited with one of three scent lures Pro's choice, Mink Gland Lure, and Skunk Lure (Carman's® Animal Lures) in an alternating pattern.

Also, we walked along transects daily in the morning to check for the presence of fresh tracks and re-scent at each station. Since multiple tracks of the same species can be generated by a single individual at a specific scent-station, we recorded species presence/absence data in stations (Conner *et al.*, 1983). Tracks were identified following the field guide of Aranda (2000). Likewise, to verify whether stations were working properly, we left a hand-made mark on it during daily checks and recorded if it was there in the following day. Finally, we recorded the number of stations in which each species occurred per day and the total number of active stations.

## HABITAT USE

We implemented a combined camera trap and scent-station survey to record occurrences of carnivore species between February and December 2012. The survey protocol included 15 sampling units or sites randomly selected from a 300 x 300 m grid covering the study area, using the distribution of vegetation cover along the study area (Figure 1B). Each sampling unit was composed of one camera trap (Bushnell Trophy® Cam Trail) and one baited scent-station. Both methods were implemented within the same sampling unit, but camera and scent-stations were located to a minimum distance of 100 m to one another. We implemented the survey in four sampling periods of 12 consecutive days, spanning both the wet (February 22, March 04, and September 14-23, 2012), and dry (June 02-13 and December 04-17, 2012) seasons. During each period the camera traps were active for 24 hours/day, recording 30 s videos with a delay of 15 s between consecutive captures, and scent-stations were checked daily to verify the occurrence of tracks. Therefore, the individual inspection of each video allowed for species identification, following specialized guides (*e.g.*, Eisenberg & Redford, 1989; Emmons & Feer, 1999; Tirira, 2007).

## DIET

We obtained fresh scat samples during the same four sampling periods as the scent-station survey. During each sampling period we collected scats opportunistically along dirt roads and trails within the study area. Scats were identified by size, form, location in latrines, and associated tracks following Aranda (2000) and Chame (2003). The scat samples were stored in ethanol (70%), transported to the lab and washed under running water through a fine mesh screen (1 mm); the remains were then inspected under a stereomicroscope for identification (Arruda Bueno & Mota-Junior, 2004). According to this, food items were identified to the lowest taxonomic level possible and separated into the following food categories: Plants, Insects, Arachnids, Chilopods, Crustaceans, Mollusks, and Vertebrates. Food categories were quantified according to their frequency of occurrence, which was calculated as the proportion of scats containing a particular item (number of scats where each item was present divided by the total number of scats) in each season (Rocha *et al*., 2008). Due to the small sample sized in each season and for each carnivore species we present the diet results as a descriptive assessment.

## ACTIVITY PATTERNS

Moreover, we used 12 to 15 camera traps installed for 10 to 12 days in six surveys carried out between March, 2011 and August, 2013. The camera traps were located at different places in each survey depending of the quantity of records from the previous survey. Thus, the first and last surveys were aimed to study medium-sized mammals in the area, so we installed the cameras along trails; then, the other four surveys focused on collecting presence data of our target species, and the location of the cameras were almost constant during 2012, but not always along trails (Figure 1A).

We described activity patterns as a probability density functions (Ridout & Linkie, 2009) for each carnivore species per season, which was based on the number and temporal distribution of photographs from camera trapping. Also, we defined as independent detection for a species those records that were more than 30 min apart in a given sampling unit (Zimmermann *et al*., 2016). All estimations were made with package *overlap* in R (R Development Core Team, 2015; Meredith & Ridout, 2018).

## DATA ANALYSIS

## OCCURRENCE PROBABILITY

We used data from scent station to analyze changes in the occurrence probability of species between rainfall seasons. Besides, we treated the occurrence of a species in a scent-station as a binary response variable: present or absent in a particular station in each sampling day. We fitted Generalized Linear Models (GLMs) using the occurrence of each species with the rainfall season (dry *vs* wet) and vegetation cover (secondary forest *vs* shrubland) as explanatory variables. We used the *glm* function in R with binomial distribution and logit link function (R Development Core Team, 2015) to fit all models. In this analysis, we did not consider the effects of sampling periods, instead treating observations from the same rainfall season as a group. We adjusted a full model, and models with individual and additive effects from both explanatory variables for each carnivore species, and contrasted the selected model against null model (representing the absence of any effect). The corrected Akaike Information Criterion for small sample sizes (AICc) was used to rank the models, and all models with $\Delta AIC < 2$ were considered equally plausible (Burnham & Anderson, 2004). The contrast with the null model and the selection among plausible models were based on the likelihood-ratio test.

### HABITAT USE PROBABILITY

We used data from combined camera trap and scent station surveys to assess the differences in the habitat use of carnivore mammals in relation to seasonality, using an approach based on a multi-season occupancy model (MacKenzie *et al*., 2003). Occupancy models estimate species detection probability ($p$) based on repeated sampling events over a site, and occupancy probability ($\psi$) accounting for imperfect detection (MacKenzie *et al*., 2002). Occupancy is defined as the proportion of sites where a species is expected to occur, and detection probability as the probability that a species is detected given it is present, with both parameters being estimated using a likelihood-based method (MacKenzie *et al*., 2002). Multi-season occupancy models include the additional estimation of parameters governing changes in occupancy, namely colonization ($\gamma$) and extinction probabilities ($\varepsilon$) (Mackenzie *et al*., 2006). Given that distance between sampling units was less than one kilometer and the vagility capacity of these carnivore species (Maffei & Taber, 2003; Dillon & Kelly, 2008), we considered that the independence assumption was not met. Therefore, assuming that occupancy changed randomly within each season, we interpreted the occupancy parameter as the use probability of the study area (Guillera-Arroita *et al*., 2010; Keane *et al*., 2012).

We built presence-absence matrices of 15 sampling units for each species grouping records from both -camera trap and scent-station- methods into 3-day periods, generating four repetitions for each sampling period. Considering the reduced number of sampling sites, we decided to model the sampling periods from the same season together to improve the inferences about species occupancy. With this approach, modeling included two seasons (dry and wet) each one with eight sampling events, and assumed that occupancy of sites was constant between sampling periods within each season. We modeled detection and occupancy probabilities for carnivore species using a season-dependent detectability model ($\psi(.)\gamma(.)\varepsilon(.)p(season)$) with constant colonization and extinction probabilities. We used the 'unmarked' package in *R* to derived probabilities of occupancy (hereinafter called 'use probability') and detection for each season and their confidence intervals with a bootstrapping approach (Kéry & Chandler, 2012; Fiske & Chandler, 2011, 2019). In addition, we used parametric bootstrapping to evaluate the goodness-of-fit of fitted model for each species (Kéry & Chandler, 2012).

## RESULTS

Five carnivore species were recorded during the four years of study: Crab-eating Fox *Cerdocyon thous*, Ocelot *Leopardus pardalis*, Tayra *Eira barbara*, and two Raccoon species *Procyon cancrivorus* (Cuvier, 1798) and *Procyon lotor* (Linnaeus, 1758). Although the identification of the records, including videos, scats, and tracks were straightforward in most cases, the reliable distinction between records of *P. cancrivorus* and *P. lotor* was not possible. Therefore, we classified all records of both species as *Procyon* spp. We did not include *E. barbara* in the analysis due to the small number of records obtained (one track and six videos).

### OCCURRENCE PROBABILITY

Altogether, we monitored the 15 scent stations for 46 nights during the entire study, with a total effort of 331 active scent-station nights (Table 1). We obtained 116 detections from three carnivore species during both seasons, 38 visits of *C. thous*, 31 of *L. pardalis*, and 47 of *Procyon* spp. The most frequent recorded species were *Procyon* spp.*,* visiting 14.2% of the stations, with 22.5% and 6.43% of the visits in wet and dry seasons, respectively (Table 1).

On the whole, the analysis of occurrence probability showed a similar seasonal pattern for the three carnivore species: occurrence was significantly higher in the dry season (*C. thous* [Season model: $z = -3.975$, $p < 0.001$], *L. pardalis* [Season model: $z = -2.898$, $p < 0.0037$], and *Procyon* spp. [Season model: $z = -4.116$, $p < 0.001$]) (Table 2, Figure 2). In the case of *Procyon* spp., cover type was also a significant covariate ($z = -2.398$, $p = 0.0165$) (Table 2) with higher occurrence in secondary forest (Figure 2).

## HABITAT USE PROBABILITY

We recorded a total of 71 detections of the three carnivore species; 13 of *C. thous* (eight during the dry season and five in wet season), 28 of *L. pardalis* (16 in the dry season and 12 in wet season) and 30 of *Procyon* spp. (22 during the dry season and eight in wet season), with a total effort of 720 camera days, and 720 scent-station nights. Estimated values from fitted models showed no differences in the detection probability between seasons for all the species, and pointed a trend to higher use probabilities during the dry season, with significant differences only for *Procyon* spp. (Figure 3).

## DIET

We collected a total of 72 scats for the three carnivore species during both seasons, 16 of *C. thous*, 14 of *L. pardalis*, and 42 of *Procyon* spp. (Table 3). We found six food categories with 24 different food items for *C. thous*, including fruits from seven plant species, insects from the orders Orthoptera, Coleoptera, Hymenoptera, Hemiptera, and Blattodea; centipedes (Chilopoda), mollusks, reptiles [*Iguana iguana* (Linnaeus, 1758)], and rodents (*Zygodontomys* sp.). The diet of *L. pardalis* was composed of five food categories with seven items, mainly *Iguana iguana*, birds, and rodents of the genera *Diplomys*, *Zygodontomys* and *Rattus*. Finally, five food categories with 25 food items were identified in the diet of *Procyon* spp., including 11 plant species, insects from the orders Coleoptera, Orthoptera, Blattodea, Hymenoptera, crustaceans, mollusks, and vertebrates. Vertebrates were represented mainly by fishes, but also consisted of some (unidentified) birds and amphibians.

## ACTIVITY PATTERNS

Likewise, we recorded 114 independent detections for the three carnivore species from all survey periods, investing

Table 1. Number of nights and scent-stations installed during the study. Percentage of visited stations for three carnivore species recorded in Sanguaré Natural Reserve, Sucre, Colombia. Number in parentheses corresponds to the number of visits.

| | Dry | | | Wet | | | General |
|---|---|---|---|---|---|---|---|
| | Secondary Forest | Shrubland | Total | Secondary Forest | Shrubland | Total | |
| Effort | | | | | | | |
| Nights | 11 | 11 | 22 | 13 | 11 | 24 | 46 |
| Active Scent-stations | 95 | 65 | 160 | 113 | 59 | 171 | 331 |
| % Visited stations | | | | | | | |
| *Cerdocyon thous* | 17.89 (17) | 21.54 (14) | 19.38 (31) | 5.31 (6) | 1.69 (1) | 4.09 (7) | 11.48 (38) |
| *Leopardus pardalis* | 18.95 (18) | 7.69 (5) | 14.38 (23) | 5.31 (6) | 3.39 (2) | 4.68 (8) | 9.37 (31) |
| *Procyon* spp. | 28.42 (27) | 13.85 (9) | 22.5 (36) | 7.96 (9) | 3.39 (2) | 6.43 (11) | 14.2 (47) |

a 1560 camera-days effort. *Cerdocyon thous* was the least frequently detected species with only a total of 15 detections (dry season: eight detections, wet season: seven detections), while *L. pardalis* (dry season: 14 detections, wet season: 27 detections) and *Procyon* spp. (dry season: 21 detections, wet season: 37 detections) were detected 41 and 58 times, respectively. From the combined detections of both seasons, we found that *C. thous* had crepuscular habits, being principally active during the first hours in the night and in the morning (Figure 4). *Leopardus pardalis* was active during the night, with the main activity after midnight, and some scarce records during day time (Figure 4). Finally, *Procyon* spp. presented records mainly during the night (Figure 4).

Table 2. Occurrence probability models compared for three carnivore species in Sanguaré Natural Reserve, Sucre, Colombia. *K*: number of parameters in a model. Delta: between the model AICc and the lowest AICc in the model set. *w*AICc: Akaike model weight.

| Species | Model | *K* | AICc | Delta | *w*AICc | Cumulative *w*AICc |
|---|---|---|---|---|---|---|
| *Cerdocyon thous* | Season | 2 | 94.48 | 0.00 | 0.65 | 0.65 |
| | Season+Cover | 3 | 96.78 | 2.30 | 0.20 | 0.85 |
| | Season*Cover | 4 | 97.43 | 2.95 | 0.15 | 1.00 |
| | Null model | 1 | 112.49 | 18.01 | 0.00 | 1.00 |
| *Leopardus pardalis* | Season+Cover | 3 | 101.15 | 0.00 | 0.58 | 0.58 |
| | Season | 2 | 103.14 | 1.99 | 0.21 | 0.79 |
| | Season*Cover | 4 | 103.24 | 2.09 | 0.20 | 0.99 |
| | Null model | 1 | 110.51 | 9.37 | 0.01 | 1.00 |
| *Procyon* spp. | Season+Cover | 3 | 123.82 | 0.00 | 0.70 | 0.70 |
| | Season*Cover | 4 | 126.24 | 2.41 | 0.21 | 0.91 |
| | Season | 2 | 127.88 | 4.06 | 0.09 | 1.00 |
| | Null model | 1 | 143.90 | 20.08 | 0.00 | 1.00 |

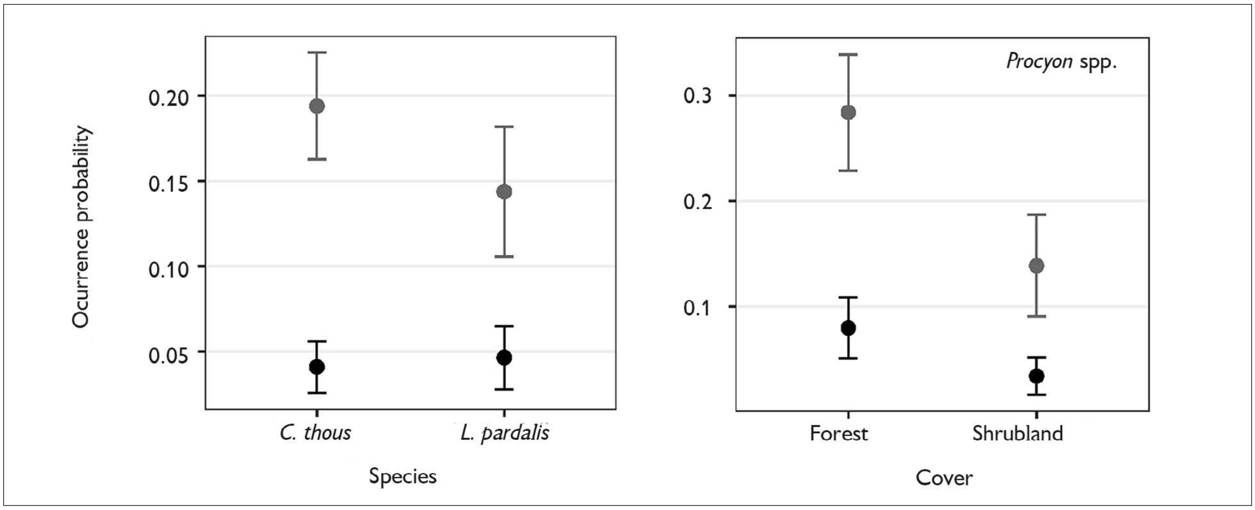

Figure 2. Occurrence probability of *Cerdocyon thous* and *Leopardus pardalis* during the dry (gray bar) and wet (black bar) seasons (left); and occurrence probability of *Procyon* spp. during dry (gray bar) and wet (black bar) seasons in secondary forest and shrubland covers (right), in Sanguaré Natural Reserve, Sucre, Colombia. Bars correspond to standard error.

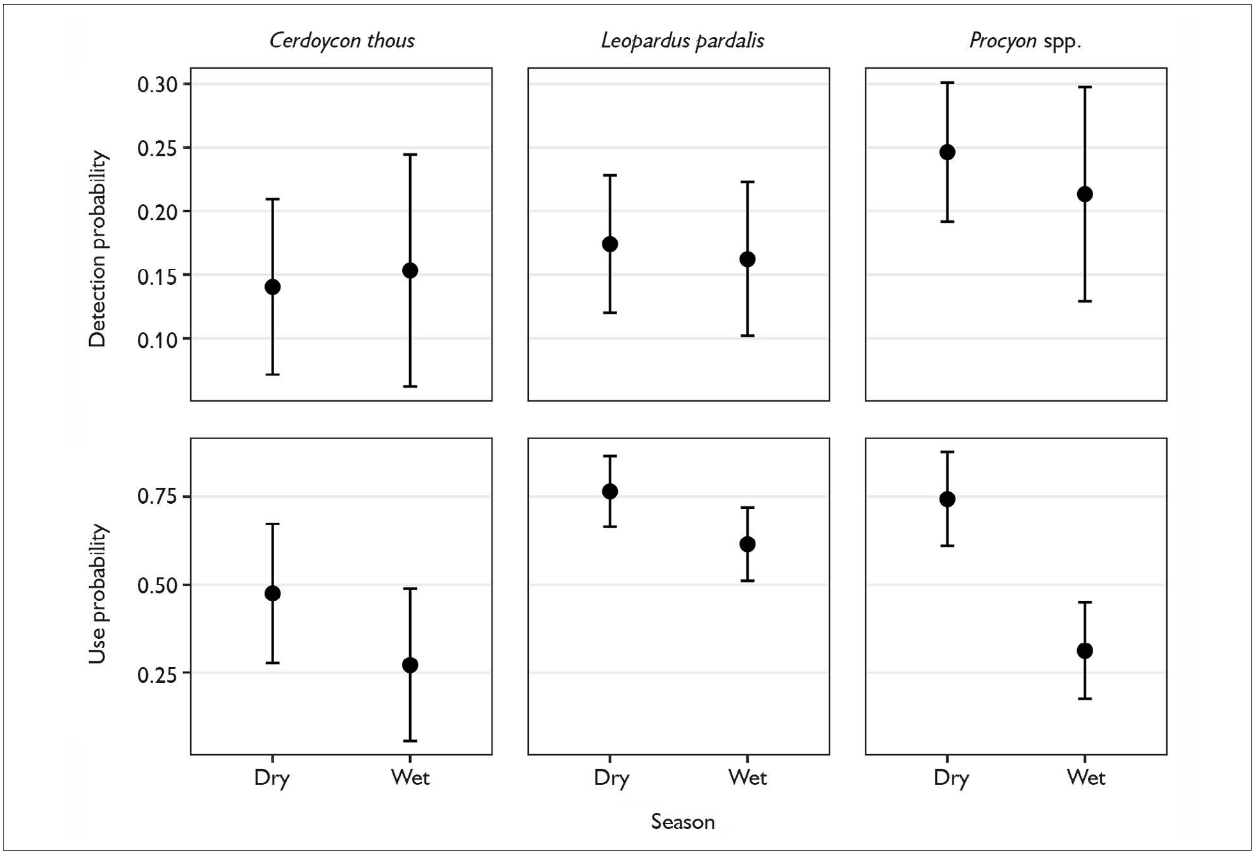

Figure 3. Estimated detection (above) and use probabilities (below) for the carnivore species *Cerdocyon thous*, *Leopardus pardalis*, and *Procyon* spp., in Sanguaré Nutural Reserve, Sucre, Colombia. Bars correspond to standard error.

Table 3. Frequency of each food category and food items in each category in scats collected (number in parenthesis) during dry and wet seasons for carnivore species recorded in Sanguaré Natural Reserve, Sucre, Colombia.

(Continue)

| Food Category | *Cerdocyon thous* | | *Leopardus pardalis* | | *Procyon* spp. | |
|---|---|---|---|---|---|---|
| | Dry (11) | Wet (5) | Dry (12) | Wet (5) | Dry (29) | Wet (13) |
| Plants | 0.45 | 0.40 | 0.75 | 0.60 | 0.86 | 0.85 |
| Seeds | 0.45 | 0.40 | - | - | 0.86 | 0.85 |
| Other | - | - | 0.75 | 0.60 | - | -- |
| Insects | 0.27 | 0.40 | 0.42 | 0.40 | 0.86 | 0.62 |
| Odonata | 0.09 | - | - | - | 0.04 | - |
| Orthoptera | 0.18 | - | - | - | 0.25 | - |
| Coleoptera | - | 0.20 | - | - | 0.32 | 0.23 |
| Hymenoptera | - | 0.20 | - | - | - | - |
| Blattodea | - | - | - | - | 0.25 | 0.08 |
| Others | - | - | - | - | - | 0.31 |
| Crustaceans | - | - | 0.33 | 0.20 | 0.41 | 0.62 |
| Arachnids | 0.09 | - | - | - | - | - |

Table 3. (Conclusion)

| Food Category | *Cerdocyon thous* | | *Leopardus pardalis* | | *Procyon* spp. | |
|---|---|---|---|---|---|---|
| | Dry (11) | Wet (5) | Dry (12) | Wet (5) | Dry (29) | Wet (13) |
| Chilopods | 0.18 | 0.20 | 0.08 | 0.40 | - | - |
| Molusks | 0.09 | - | - | - | 0.07 | - |
| Vertebrates | 0.64 | 0.80 | 1.00 | 1.00 | 0.66 | 0.23 |
| Reptiles | 0.63 | 0.80 | 0.66 | 0.6 | 0.10 | - |
| Birds | - | - | 0.78 | 0.4 | 0.14 | 0.07 |
| Fish | | | | | 0.34 | 0.15 |
| Amphibians | | | | | 0.07 | 0.07 |
| Mammals | 0.09 | | 0.44 | 0.2 | | |

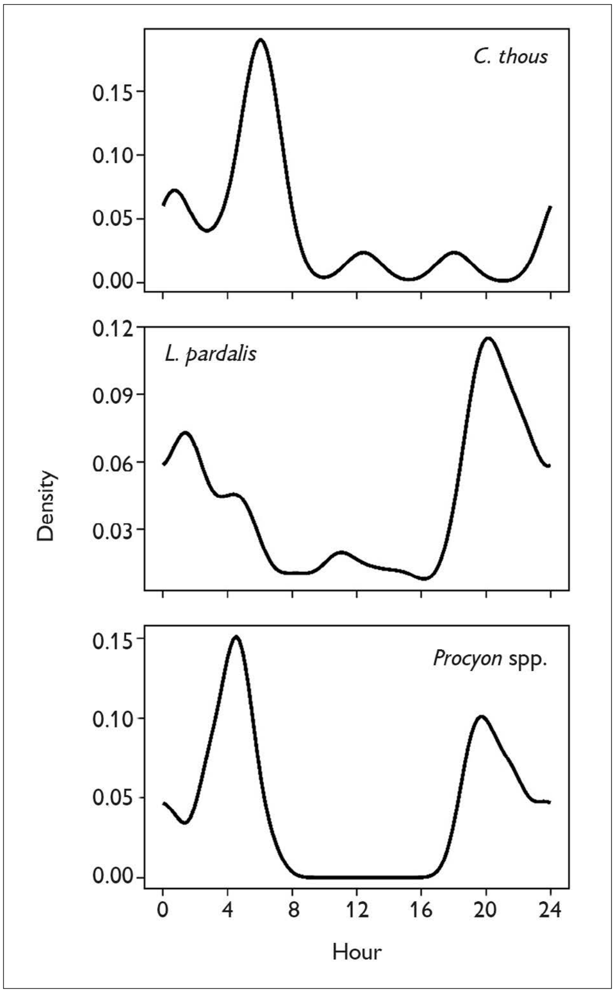

Figure 4. Diel activity patterns from camera trap data using Kernel density function in Sanguaré Natural Reserve, Sucre, Colombia, for the carnivore species: *Cerdocyon thous*, *Leopardus pardalis* and *Procyon* spp.

## DISCUSSION

This study is the first attempt to assess the changes in the habitat use patterns of common medium-sized carnivore species (*C. thous*, *L. pardalis*, and *Procyon* spp.) in relation to seasonality in TDF area of Colombian Caribbean. Likewise, it provides information about their diet and activity patterns in this ecosystem. Our results in Sanguaré Natural Reserve were partially congruent with the expected seasonal behavior of medium-size mammals in dry ecosystems, with the occurrence probability of the three carnivore species and the habitat use probability for *Procyon* spp. being higher during the dry season. Study species exhibited behavioral changes to cope with seasonality in TDF, probably associated to variations in local movements during the dry season and the constant water availability. Water availability in Sanguaré Natural Reserve throughout the year contrasts with the predominant one (drought) in the surrounding areas.

### OCCURRENCE AND HABITAT USE PROBABILITIES

Our study showed seasonal increase in occurrence probability for the three carnivore species during the dry season. For this reason, it is probably that climatic conditions of the region promote wildlife concentration around the reserve, as animals can have permanent availability of water during the dry season (*e.g.*, Valenzuela & Ceballos, 2000;

Santos *et al*., 2011). The low frequency of tracks records during the wet season would lead to think that such differences in occurrence probability are linked to detection bias (Silveira *et al.*, 2003). However, raw data shows (Table 1) that the number of active scent-stations was not different between seasons. Therefore, we think occurrence pattern responds to seasonality instead detection differences. Furthermore, the non-variation of detection probabilities from habitat use analysis could suggest that occurrence probability is a reasonable inference.

Additionally, seasonal difference in habitat use probability only was found in *Procyon* spp. Lack of significant differences in the habitat use probabilities of *C. thous* and *L. pardalis* can be consequence of our small sample sizes, but it also could be indicating the presence of a stable number of resident individuals in the study area. As has been documented in other dry ecosystems, the occupancy patterns of resident species tend to exhibit negligible seasonal changes because species use regularly the habitat (Martin *et al*., 2017). In this way, Sanguaré Natural Reserve might support a high proportion of resident individuals of both species using the area along year, and although the arriving of individuals during the dry season may happen, it would not generate changes in the habitat use probabilities.

Furthermore, seasonal pattern in *Procyon* spp. could be associated directly to the arriving of individuals to the study area during the dry season as animals move to wet habitats where they can secure food and water resources (*e.g*., Valenzuela & Ceballos, 2000; Maffei & Taber, 2003; Mendes-Pontes, 2004). In addition, the pattern also could be a response to the movements of the resident individuals within the study area during the wet season. Lower habitat use probabilities of *Procyon* spp. in Sanguaré Natural Reserve could be derived from movements of individuals to non-surveyed habitats (*i.e*. mangrove) or to follow seasonal pounds or temporal streams in surrounding areas – which appears in wet season. In coastal and Pantanal systems, *Procyon* species prefer foraging in mangrove stands and freshwater ponds respectively, where food resources as fishes, crabs and mollusks are mostly available (Villa-Meza *et al.*, 2011; Carvalho, 2012).

Finally, habitat preferences are also important behavioral changes to cope with dry season in tropical dry forests, as shown by previous studies (Ceballos, 1995; Stoner & Timm, 2011). For example, *Procyon* spp. habitat preferences have been described as riparian forest and palm forests (Arispe *et al*., 2008), which coincides with our results in showing higher occurrence probability in secondary forest vegetation cover than in shrubland and grassland. The pattern of preference does not change with seasonality, probably since *Procyon* spp. can be found within the most profitable habitat all year around in Sanguaré, near water ponds with secondary forest vegetation, which is also connected to mangrove habitat (Figure 1).

## DIET

Few studies on the diet of these mesocarnivore species have been undertaken in Colombia, mostly in Andean ecosystems, for example, the diets of *C. thous* (Delgado-V., 2002; Delgado-V. & Zurc, 2007) and *L. pardalis* (Sánchez *et al*., 2008). We found that *C. thous* is a generalist omnivorous species that consume mainly vertebrates, fruits and insects, as has been previously reported (Macdafem & Marinho-Filho, 2002; Bianchi *et al*., 2014). Previous studies indicate *L. pardalis* is a specialized feline, whose prey includes between eight and 11 different species of vertebrates, mostly mammals in humid forests (Chinchilla, 1997; Sánchez *et al*., 2008) and reptiles in deciduous forests (Villa-Meza *et al*., 2002). However, our study reports just four vertebrate prey species; furthermore, we report a new prey item, a centipede (Chilopoda). Our finding of invertebrates as the main food item for *Procyon* spp. is in agreement with studies on *Procyon cancrivorus* in Brazil (Gatti *et al*., 2006) and Venezuela (Bisbal, 1986).

Moreover, diet descriptive analyses in this study did not show changes in composition between wet and dry seasons for these carnivore species, being these the best examples of trophic generalists in tropical dry forest, and several studies have documented seasonal variation in the diet of generalist carnivores (Vaughan-Dickhaut & Rodríguez-Sáenz, 1986; Stoner & Timm, 2011 and references therein). For our studied species, there are only studies reporting seasonal changes in diet of *C. thous*, which has been reported feeding on insects during the wet season and small vertebrates during the dry season (Bisbal & Ojasti, 1980; Sunquist *et al*., 1989; Bianchi *et al*., 2014).

Despite of our data does not show changes between seasons, due to the reduced number of scats collected, we believe that, much like *C. thous,* other species present in the TDF may present seasonal changes in their diets. Hence, further studies are needed. These must include a more representative sample sized for each season (scats collected in several months through the years) and to analyze categories informative enough to detect subtler changes than the categories we have evaluated (*e.g*., Bianchi *et al*., 2014).

## ACTIVITY PATTERNS

In regard to activity patterns, species in the study area are mainly nocturnal and crepuscular as other studies reported. *Cerdocyon thous* has been reported as a nocturnal species in Bolivia (Maffei & Taber, 2003; Maffei *et al*., 2007) and Brazil (Faria-Correa *et al*., 2009); *L. pardalis* has been described as a nocturnal species without evidence of crepuscular activity (Kolowski & Alonso, 2010; Porfirio *et al*., 2016), and the pattern described to *Procyon* spp. agrees with studies for *P. cancrivorus* reported in a dry forest habitat in Bolivia (Arispe *et al*., 2008). Only for *L. pardalis* seasonal changes in activity patterns have been addressed in Brazil (Porfirio *et al*., 2016), but with no differences detected and assessed with a big set of independent record, which suggest that activity patterns would be a conservative behavior during the marked seasonality of TDF.

Of course, these results highlight the importance of private initiatives for conservation and management of tropical dry forests. Likewise, they represent potential refuge to local fauna due to the matrix of landscape with cattle ranching pastures and few forest remnants. This and other research efforts are contributing towards an effective protection and management of the local biodiversity, as well as its services for local communities in the Caribbean region of Colombia.

## CONCLUSIONS

To sum up, three medium-sized carnivore species were recorded at Sanguaré Natural Reserve: *C. thous*, *L. pardalis* and *Procyon* spp. Also, these species showed seasonally changes in occurrence probability with no differences in detection probability between seasons. The observed pattern reflects that these species, in Sanguaré, are probably making more/larger habitat use during the dry season than in the wet season, this because the area has permanent water ponds. This has been already shown in other small carnivore and ungulate species in TDF, where they used areas with available water resources during the dry season (Valenzuela & Ceballos, 2000; Pérez-Cortez *et al*., 2012). Certainly, our result highlights the importance of permanent water to explain the occurrence of medium-sized carnivore species in tropical dry forest. Generalist carnivore species such as the target ones in this study depend on behavioral strategies such as movement during dry season to cope with environmental constraints of this kind of ecosystems.

## ACKNOWLEDGEMENTS

This study was financed through a grant of Rufford Small Grants and *Universidad de Antioquia* internal financial program to investigation. Some of the equipments were provided by Idea Wild. Also the Department of Biology of *Universidad de Antioquia* provided a scholarship grant to the first author. We thank to the staff of Sanguaré Natural Reserve for their support during the field work, to C. Calderón, S. Botero, L. Vargas, C. Diaz and L. López for their help with data recording in field and laboratory, and to two anonymous reviewers for their comments to improve the manuscript.

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# Genetic diversity and chromosome complement of *Galictis cuja* (Molina, 1782) (Carnivora: Mustelidae) with comments about its role as parasite hosts

## Diversidade genética e complemento cromossômico de *Galictis cuja* (Mustelidae), com comentários sobre seu papel como hospedeiro de parasitas

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**Abstract:** The distribution of *Galictis cuja* encompasses several countries of South America, including Brazil, where it inhabits the Atlantic Forest, part of Caatinga and part of Cerrado biomes. Herein we analyzed *G. cuja* specimens from localities in the Brazilian states of Rio de Janeiro, Minas Gerais, and Bahia, and the Distrito Federal, mainly roadkilled animals. The genetic diversity was estimated based on DNA sequence data of the mitochondrial gene cytochrome b (*mt-cyb*). Analysis of *mt-cyb* identified high haplotypic diversity, albeit with low nucleotide diversity, suggesting that this population is in expansion and confirming the presence of gene flow. The karyotypes of two *Galictis cuja* specimens were described as 2n = 38 and FNa = 66. Our data showed that *G. cuja* is frequent in the investigated areas of Atlantic Forest biome, being a common roadkill mammal. Our data suggest that *G. cuja* may play a role as a spreader of zoonotic parasites.

**Keywords:** Lesser grison. Cytochrome b. Karyotype. Geographic distribution. Helminths.

**Resumo:** A distribuição de *Galictis cuja* abrange vários países da América do Sul, incluindo o Brasil, onde habita a Mata Atlântica, parte da Caatinga e parte do Cerrado. Aqui, analisamos espécimes de *G. cuja* de localidades nos estados brasileiros do Rio de Janeiro, Minas Gerais, Bahia e no Distrito Federal, a maioria deles encontrada atropelada em rodovias. A diversidade genética foi estimada com base em sequências de DNA do gene mitocondrial citocromo b (*mt-cyb*). A análise do *mt-cyb* identificou alta diversidade haplotípica, embora com baixa diversidade de nucleotídeos, sugerindo que a população está em expansão e confirmando a presença de fluxo gênico. O cariótipo de dois espécimes de *Galictis cuja* mostrou que 2n = 38 e FNa = 66. Nossos dados mostraram que *G. cuja* é frequente nas áreas de Mata Atlântica investigadas, sendo um mamífero comumente atropelado nas rodovias. Eles sugerem que *G. cuja* tem um papel como disseminador de parasitas zoonóticos.

**Palavras-chave:** Furão. Citocromo b. Cariótipo. Distribuição geográfica. Helmintos.

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BONTEMPO, J., C. BUENO, P. S. D'ANDREA & C. R. BONVICINO, 2020. Genetic diversity and chromosome complement of *Galictis cuja* (Molina, 1782) (Carnivora: Mustelidae) with comments about its role as parasite hosts. **Boletim do Museu Paraense Emílio Goeldi. Ciências Naturais** 15(3): 717-726. DOI: http://doi.org/10.46357/bcnaturais.v15i3.199.

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Recebido em 16/10/2019
Aprovado em 21/09/2020
Responsabilidade editorial: Alexandra Maria Ramos Bezerra

## INTRODUCTION

*Galictis* Bell, 1826 is a genus of the order Carnivora belonging to the family Mustelidae including two extant recognized species, the greater grison, *Galictis vittata* (Schreber, 1776) and the lesser grison, *Galictis cuja* (Molina, 1782). The distribution of *G. cuja* encompasses several countries of South America, including Brazil, where it inhabits the Atlantic Forest, part of Caatinga and part of Cerrado biomes (Bornholdt *et al*., 2013).

Phylogenetic reconstructions within the Carnivora were extensively carried out (*e.g*., Flynn & Nedbal, 1998; Flynn *et al*., 2005; Eizirik *et al*., 2010; Koepfli *et al*., 2007) as well as within the mustelids (*e.g*., Koepfli & Wayne, 2003; Koepfli *et al*., 2008; Sato *et al*., 2012), showing the monophyly of *Galictis* (Bornholdt *et al*., 2013). In contrast, phylogeographic studies in *Galictis* are less common (Bornholdt *et al*., 2013). Despite extensive studies of the chromosomal complement of species of the order Carnivora (Franco-de-Sá *et al*., 2007; Freitas *et al*., 1982; Kurose *et al*., 2000), there is a single karyotype description of *Galictis cuja* only published in a PhD thesis (Barbosa, 2013). Furthermore, this widespread genus has been observed to be infected by several etiological agents of zoonoses as: trypanosomiasis (Ferriolli & Barretto, 1969; Tremori, 2018), leishmaniasis (Melo, 2008), *Toxoplasma gondii* (Nicolle & Manceaux, 1908) (Torres-Castro *et al*., 2019), zoonotic giant kidney worm *Dioctophyme renale* (Goeze, 1782) (Barros *et al*., 1990; Zabott *et al*., 2012), nematodeosis (Vieira, F. *et al*., 2012), and a domestic dog strain of Canine Distemper virus (CDV, genus *Morbilivirus*), that can be transmitted by free-ranging dogs (Megid *et al*., 2013). The aims of this study are describing the karyotype of *Galictis cuja* from Southeastern Brazil, investigating the genetic diversity using the mitochondrial gene cytochrome b (*mt-cyb*) as a marker, and discuss its role as a spreader of zoonotic parasites.

## MATERIAL AND METHODS

We collected 55 specimens of *G. cuja*; mainly roadkilled animals. Thirty-nine specimens were roadkilled in the BR-040 between 2007 and 2017, three in the RJ-122 in 2018, and 11 were live trapped in rural peridomicile and small fragment borders in Atlantic Forest of Rio de Janeiro and Minas Gerais state (Figure 1). In the Cerrado biome one roadkilled specimen was collected in Distrito Federal. For understanding the extant and ancient distribution of *G. cuja*, we added the locality of a Pleistocene fossil from Aurora do Tocantins, in Tocantins state (Rodrigues *et al*., 2015) in the map of Figure 1. *Voucher* specimens were deposited in the mammal collections of Museu Nacional, UFRJ (MN) and *Laboratório de Biologia e Parasitologia de Mamíferos Reservatórios Silvestres* (LBCE), *Instituto Oswaldo Cruz/ Fundação Oswaldo Cruz* (IOC/FIOCRUZ), Rio de Janeiro state, and in *Universidade Federal da Paraíba* (UFPB), João Pessoa, Paraíba state, Brazil (Appendix 1). The sample were stored at scientific tissue collection of the *Laboratório de Biologia e Parasitologia de Mamíferos Reservatórios Silvestres*, IOC/FIOCRUZ, and in the Ecology Laboratory, *Universidade Veiga de Almeida*, Rio de Janeiro state, Brazil (Appendix 1). Samples of CB and CRB 3283 in Appendix 1 refer to field numbers of Cecília Bueno (CB) and Cibele R. Bonvicino (CRB) and are only tissue samples, without a *voucher*.

One specimen of *Galictis cuja* from Sumidouro (LBCE6437), and one from Teresópolis (LBCE7963), Rio de Janeiro state, were karyotyped. Chromosome preparations were obtained following short cultures of bone marrow tissue (Andrade & Bonvicino, 2003). Only Giemsa staining coloration was carried out. Chromosomes were ordered according to morphology and decreasing size, with fundamental numbers (FNa) referring to the autosome complement (Levan *et al*., 1964).

DNA was isolated from liver and muscle samples preserved in ethanol following a phenol-chloroform protocol (Sambrook *et al.*, 1989). The *mt-cytb* sequence was amplified in 28 samples (Appendix 1) with primers "Carnivora *Forward*" and "Carnivora *Reverse*" (Ledje & Arnason, 1996), following a pre-denaturation step at 94 °C for 2 min following by 35 subsequent cycles with denaturation at 94 °C for 30 sec and annealing at

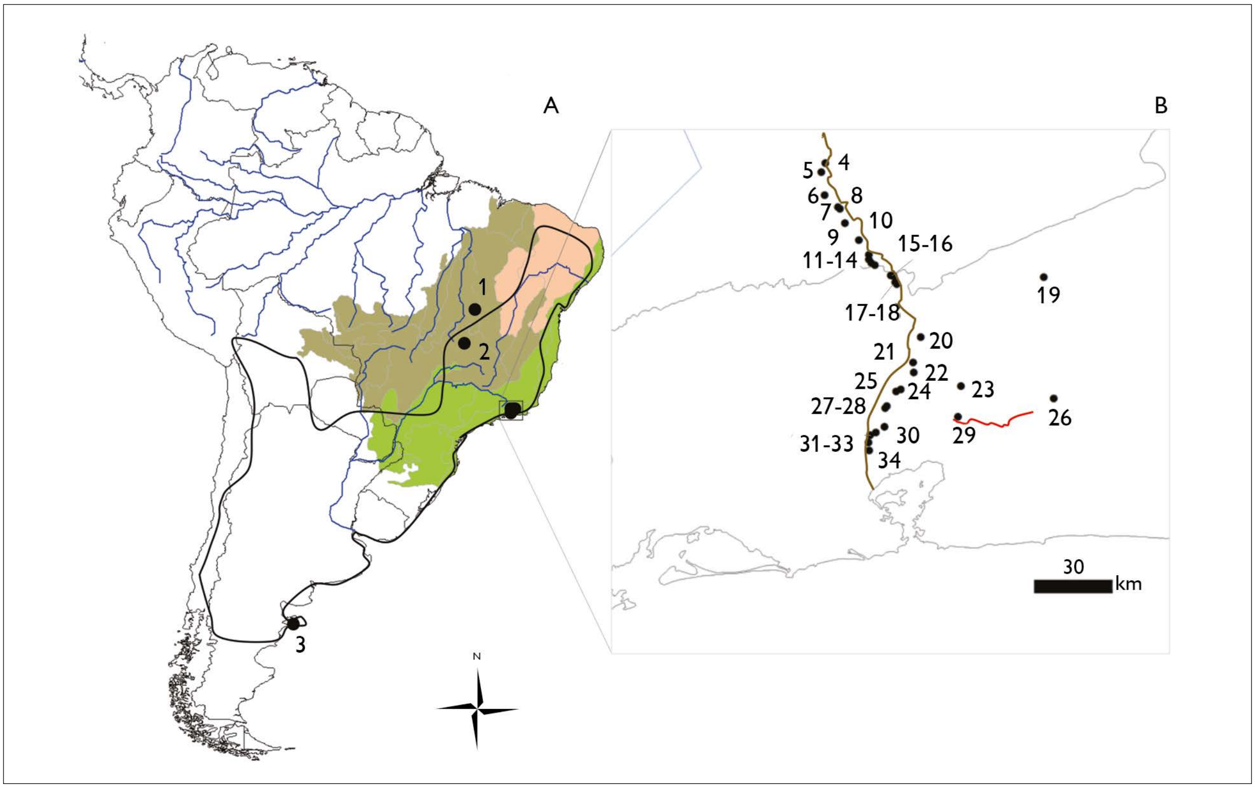

Figure 1. A) South America map showing Atlantic forest (green), Caatinga (salmon), and Cerrado (olive), the current geographic distribution of *Galictis cuja* (black line), the localities of analyzed specimens (as referred in Table 1 and Appendix 1) and locality 1 of the fossil (Rodrigues *et al*., 2015); B) the region of BR-040 (in brown) and RJ-122 (line red) highways was amplified for better visualization of collection points.

54 °C for 30 sec, and extension at 72 °C for 45 sec, and final extension of 72 °C for 5 min. Amplified products were purified with Gel Band Purification Kit (GE Healthcare), and labelling was carried out using the same primers in addition to the internal primers SOT - In1 (5'-TTRTTRGATCCTGTTTCTTG-3' - Cassens *et al*., 2000) and SOT - In2 (5'-TGAGGACAAATATCATTTTGAG-3' - Cassens *et al*., 2000). Reactions were run in an ABI3130xl (Applied Biosystems™) platform. Electropherograms were manually checked using CHROMAS PRO 1.41 (Technelysium Pty Ltd). The complete *mt-cyb* was amplified for all samples, but the different sequenced size was obtained (Table 1). Each sequence was aligned manually with MEGA 7 (Tamura *et al.*, 2013) and a concatenated matrix was manually constructed. The most appropriate nucleotide substitution model for phylogenetic reconstructions was selected using MEGA 7.0. Maximum likelihood (ML) reconstructions were carried with MEGA 7.0, and branch support was calculated using bootstrap. We also used sequences available in GenBank for *G. cuja* (KT626650, AB564025, EF987754) and *G. vittata* (AF498155). We used as outgroup two species of genera considered as closely related to *Galictis* (Koepfli *et al*., 2008; Wolsan & Sato, 2010), *Ictonyx striatus* (Perry, 1810) (AF498156.1) and *Poecilogale albinucha* (Gray, 1864) (EF472349.1). Kimura two-parameters genetic distance estimates were calculated with Mega 7.0.

Network v.4.5.1.6 (Fluxus, s. d.) was used for reconstructing a Median-Joining (MJ) network (Bandelt *et al*., 1999) based on variable sites and excluding sites containing missing *mt-cytb* data to evaluate population structure and geographic distribution patterns.

Table 1. Samples of *Galictis cuja* sequenced in this study, with GenBank accession numbers (GenBank), field or scientific collection numbers (*voucher*), localities (Loc), haplotype (H), number of sequenced base pairs (pb), and source. See Appendix 1 for localities (Loc) of collecting specimens. The number after the GenBank accession number refers to the year the sample was collected.

| GenBank/year | *Voucher* | Loc | H | pb | Source |
|---|---|---|---|---|---|
| MT537199/unknown | CB118 | 10 | H1 | 1.122 | Present study |
| MT537200/2011 | MN79404 | 10 | H1 | 1.140 | Present study |
| MT537201/2010 | MN79247 | 16 | H2 | 1.133 | Present study |
| MT537202/2003 | LBCE5276 | 19 | H2 | 1.140 | Present study |
| MT537203/2004 | LBCE6587 | 19 | H2 | 1.140 | Present study |
| MT537204/2004 | LBCE6619 | 19 | H2 | 1.140 | Present study |
| MT537205/2010 | MN79294 | 16 | H3 | 1.118 | Present study |
| MT537206/2004 | LBCE6437 | 19 | H3 | 1.140 | Present study |
| MT537207/unknown | LBCE7241 | 19 | H3 | 1.084 | Present study |
| MT537208/2011 | MN79358 | 6 | H4 | 1.140 | Present study |
| MT537209/2011 | MN79407 | 11 | H4 | 1.140 | Present study |
| MT537210/2015 | CB991 | 9 | H4 | 1.140 | Present study |
| MT537211/2012 | MN79445 | 8 | H5 | 1.085 | Present study |
| MT537213/2012 | MN79501 | 30 | H6 | 1.140 | Present study |
| MT537214/2013 | MN79550 | 30 | H6 | 1.126 | Present study |
| MT537212/2016 | CB1089 | 12 | H6 | 1.140 | Present study |
| MT537215/2014 | MN83564 | 13 | H7 | 1.126 | Present study |
| MT537218/2011 | MN79363 | 9 | H8 | 1.067 | Present study |
| MT537227/2015 | MN83597 | 5 | H8 | 601 | Present study |
| MT537216/2016 | CB1012 | 7 | H8 | 1.140 | Present study |
| MT537217/2016 | CB1185 | 21 | H9 | 1.118 | Present study |
| MT537220/2005 | LBCE7780 | 19 | H9 | 1.126 | Present study |
| MT537221/2006 | LBCE7949 | 23 | H9 | 1.140 | Present study |
| MT537222/2006 | LBCE7956 | 23 | H9 | 1.140 | Present study |
| MT537223/2006 | LBCE7963 | 23 | H9 | 1.140 | Present study |
| MT537224/2006 | LBCE7969 | 23 | H9 | 1.140 | Present study |
| KT626650/unknown | Unknown | - | H9 | 1.140 | GenBank, unpublished |
| MT537225/unknown | CRB3283 | 2 | H10 | 1.140 | Present study |
| MT537226/2004 | MN74461 | 19 | H11 | 1.140 | Present study |
| EF987754/unknown | Unknown | - | H12 | 1.140 | Koepfli *et al*. (2008) |
| AB564025/unknown | MC795 | 3 | H12 | 1.140 | Sato *et al*. (2012) |

## RESULTS

Karyotypic analysis of two females (LBCE6437 and LBCE7963) captured in Sumidouro and Teresópolis municipalities at Rio de Janeiro Atlantic Forest, showed 2n = 38 and FN = 66, with a metacentric medium-sized X chromosome, and a secondary constriction in the largest acrocentric pair (Figure 2). The autosome complement was composed by 15 pairs of biarmed chromosome varying in size from large to small, and three pair of acrocentric chromosomes (Figure 2).

The *mt-cytb* gene sequences of 32 *G. cuja* samples, 28 herein sequenced showed 13 variable sites and 13 haplotypes. Maximum likelihood analysis showed two well defined lineage, one with *G. vittata* and another with *G. cuja* (Figure 3), with genetic distance estimates between than more than 12 %. In contrast, intraspecific genetic distance estimates within *G. cuja* vary from 0 to 0.44 %. MJ network showed a central haplotype (H9) directly connected with all other haplotypes, except H4 (Figure 3).

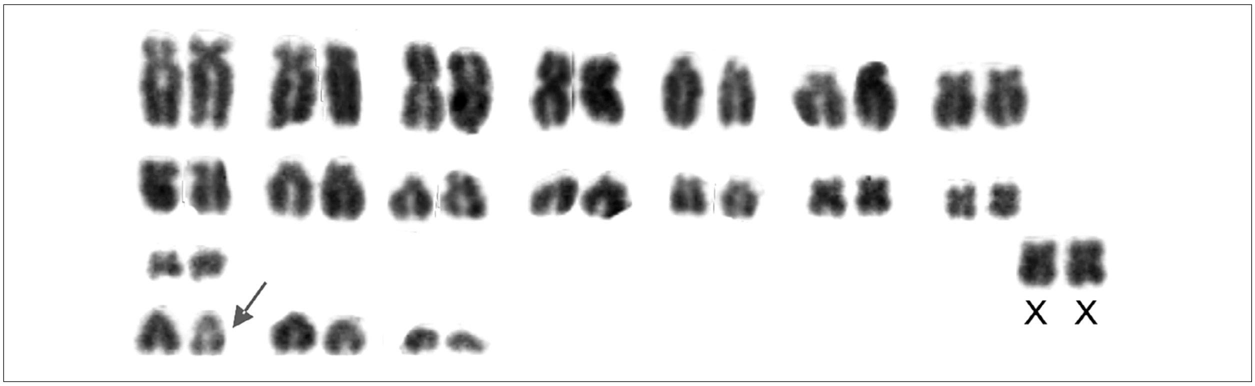

Figure 2. Karyotype with Giemsa staining of a female of *Galictis cuja* (LBCE7963) from Teresópolis, Rio de Janeiro state, Brazil, with 2n = 38 and FNa = 66. X = sexual X chromosome. The arrow indicates the secondary constriction.

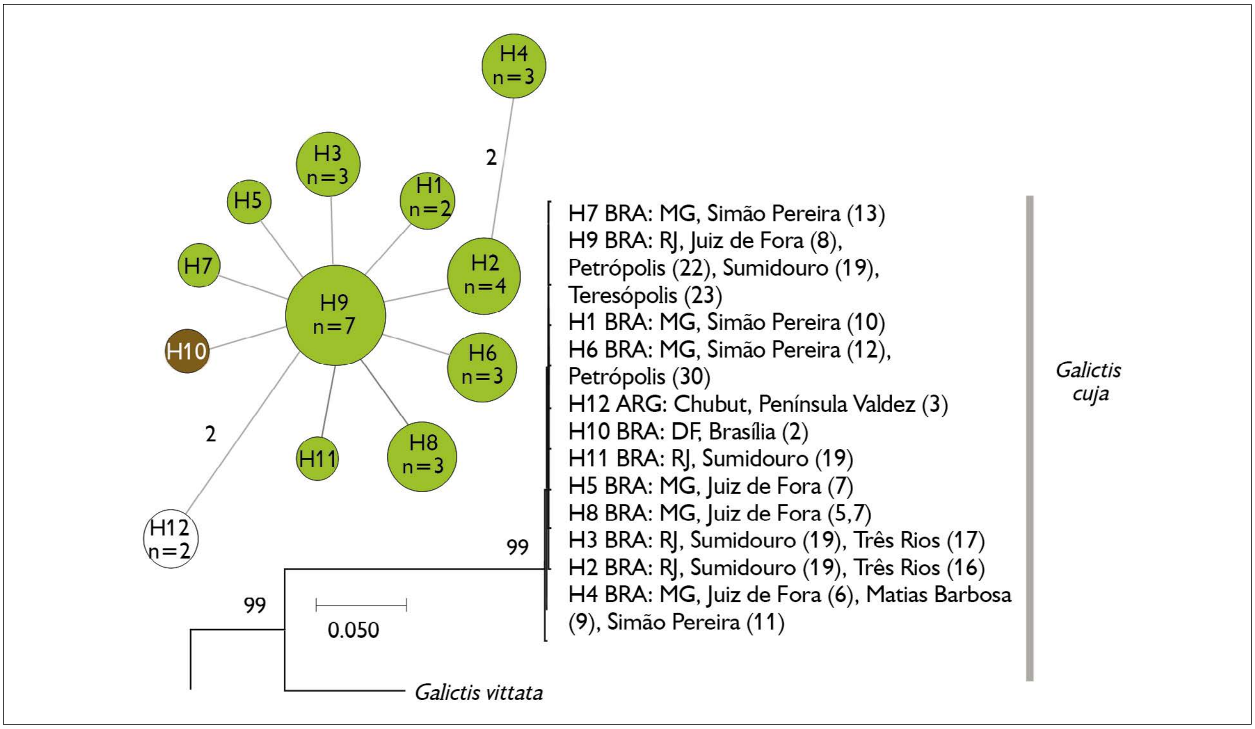

Figure 3. Maximum likelihood (ML, right) topology and median-joining (MJ, left) of *Galictis* based on *mt-Cytb*. In ML number near nodes are bootstrap values. In MJ circle size corresponds to number of individuals with a given haplotype, light gray are haplotypes from Atlantic Forest, dark gray from Cerrado, and white from Argentina. Numbers connecting branches denote more than one nucleotide substitutions; connecting branches without a number indicate one nucleotide substitution. Numbers between parentheses refer to localities in the Figure 1.

## DISCUSSION

### GENETIC CONSIDERATION

The karyotype of specimens from Rio de Janeiro state, with 2n = 38 and FNa = 66, recorded in this study, is similar to the single chromosome complement already reported for one male *Galictis cuja* (2n = 38 and FN = 68) from Massaranduba in Santa Catarina state (Barbosa, 2013), both karyotypes showing a median sized biarmed X chromosome. The difference in fundamental autosome number is due to a small-sized chromosome. It can be due to different interpretation in relation to the centromere position, or a pericentric inversion affecting this pair. The karyotype herein describes for *G. cuja* confirm the diploid number of 38 as widespread in both genera and species of the order Carnivora, as in *Lontra longicaudis* (Olfers, 1818) (Freitas *et al*., 1982), *Martes itatsi* Temminck, 1844 (Kurose *et al*., 2000), and *Ptenoruna brasiliensis* (Gmelin, 1788) (Franco-de-Sá *et al*., 2007), but differing in the morphology of autosome and sexual chromosomes.

The phylogenetic analysis confirms previous publication in showing *Galictis* with two lineages. *Galictis cuja* showed high haplotypic diversity (0.9021) and a low nucleotidic diversity (only 13 variable sites) suggesting that this population expanded after a period of small population size (Su *et al*., 2015). Even sample from the same locality showed high haplotypic diversity (*i.e*., Juiz de Fora with 3 haplotypes in 6 sequences; Sumidouro, with 4 haplotypes in 6 sequences). However, specimens collected in the same fragments and different years shared the same haplotype (*e.g*., LBCE7949, LBCE7956, LBCE7963, LBCE7969 from Teresópolis, haplotype H9; LBCE6587 and LBCE6619 from Sumidouro, haplotype H19; Table 1, Figure 3). The network did not show population structure, suggesting connectivity between populations as previously shown for this species using another marker (Bornholdt *et al*., 2013).

Our data confirm *G. cuja* as a common roadkilled mammal in Atlantic Forest, similar to the Cerrado, where *G. cuja* was considered the fifth more roadkill mammalian species, corresponding to 6.1% of roadkilled mammals (Vieira, E., 1996). This high frequency of roadkill *G. cuja* was well documented (Rosa & Mauhs, 2004; Casella *et al*., 2006; Cherem *et al*., 2007; Coelho *et al*., 2008; Sousa & Miranda, 2010; Bueno *et al.*, 2015). Impressive, the roadkill specimens in BR-040 were captured near urban areas with forest patches or in forested areas, but not in crop fields (Figure 1).

Traditionally *Galictis vittata* is considered as an inhabitant of humid forests from northern South America to Central America, whereas *Galictis cuja* is considered as an inhabitant of open areas in southern South America (Rodrigues *et al*., 2015). However, our data showed that *G. cuja* could be common in the areas of Atlantic Forest. The fossil records showed that these two species already occurred in Lagoa Santa in the Brazilian Cerrado biome (Rodrigues *et al*., 2015). The most recent map with the geographic distribution of *Galictis cuja* places its northmost localities in northeastern Brazil, in the Caatinga biome, and in the Federal District, in the Cerrado of central Brazil (Bornholdt *et al*., 2013). However, in the Pleistocene deposits, this species also was recorded for the north Cerrado, at Aurora do Tocantins municipality, Tocantins state (Rodrigues *et al*., 2015; Figure 1). These data showed that the extant southern South America distribution of *G. cuja*, and the northern South America distribution of *G. vittata* could have been moulded modulated by climate change (Rodrigues *et al*., 2015), together with the current anthropogenic induced range contraction.

### ZOONOTIC IMPLICATIONS

Part of the *G. cuja* roadkill specimens herein analyzed (Appendix 1) was previously investigated for helminth parasitism by Corrêa *et al*. (2016), and was detected nematodes [*Molineus elegans* (Travassos, 1921), *Dioctophyme renale* (Goeze, 1782)], acanthocephalan [*Pachysentis gethi* (Machado-Filho, 1950)], and digenetic [*Platynosomum illiciens* (Braum, 1901)], showing the possible role of these animals as a spreader of parasites with zoonotic potential, particularly to domestic carnivores, as dogs and cats. Other populations of *G. cuja* from South and Southeastern Brazil were also reported with parasites (Pesenti *et al*., 2012; Vieira, F. *et al*., 2017). Furthermore, a Canine Distemper virus has also been reported in a free-ranging *G. cuja* (Megid *et al*., 2013). These authors argue that the CDV found in *G. cuja* and other wild carnivores have resulted from a spillover transmission from domestic dogs, potential reservoirs of this pathogen. The area where the majority of *Galictis* species were collected is intensively populated, and the contact between *G. cuja* specimens and dogs in the rural area should be intense. This scenario, plus the connectivity between *G. cuja* populations suggested this mustelid can play a role in the maintenance or even the amplification of the transmission cycle of this pathogen, and that dogs non vaccinated with distemper vaccine can be a threat for *G. cuja* conservation.

## CONCLUSION

Our data confirm that *G. cuja* is a common inhabitant of Atlantic Forest of southeastern Brazil, being a frequent roadkill mammal, similar to the Cerrado region. The karyotype of specimens from Rio de Janeiro state, with $2n = 38$ and $FNa = 66$, is similar to the single chromosome complement already reported for one male *Galictis cuja* ($2 n =38$ and $FNa = 68$) from Massaranduba in Santa Catarina state (Barbosa, 2013), being the difference in FN due to a small-sized chromosome pair. The phylogenetic analysis showed *Galictis cuja* with high haplotypic diversity and a low nucleotidic diversity, confirming that this population expanded after a period of small population size. The network did not show population structure, suggesting connectivity between populations as previously showed for this species.

## ACKNOWLEDGMENT

We thank the *Laboratório de Biologia e Parasitologia de Mamíferos Reservatórios Silvestres* field team for supporting fieldwork, to Vânia de Araujo Soares for collecting roadkill specimen from Distrito Federal, to Concer for support to *Caminhos da Fauna* Project, to Rayque Lanes for helping with maps. Work supported by grants to CR Bonvicino (CNPq 304498/2014-9, and FAPERJ E26/201.200/2017, in *Instituto Oswaldo Cruz*). We are grateful to Riccardo Castiglia and one unknown reviewer for their valuable suggestions and comments in a previous version of this manuscript.

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Appendix 1. List of samples of *Galictis cuja*. *Voucher* numbers are between parentheses. Numbers in square brackets refers to localities in Figure 1. Asterisk (*) = specimens investigated for parasites in previous publication (Corrêa *et al*., 2016), ($^{P}$) = specimens used in molecular analysis.

## ARGENTINA

No locality (EF987754, no *voucher*); **Chubut**, **[3]** Peninsula Valdez -24.5000, -64.0000 (AB564025, *voucher* MC795).

## BRAZIL

**Distrito Federal: [2]** Brasília, -15.7833, -47.9167 (CRB3283$^{P}$).

**Minas Gerais state**: Juiz de Fora, **[4]** BR-040 km 775, -21.6608, -43.4342 (MN79510), **[5]** BR-040 km 779-783, -21.6917, -43.4483 (MN79153, CB1013, MN83597$^{P}$), **[6]** BR-040 km 789, -21.7697, -43.4372 (MN79358$^{*,P}$), **[7]** BR-040 km 796-797, -21.8111, -43.3906 (CB1012$^{P}$), **[8]** BR-040 km 798, -21.8172, -43.3842 (MN79471$^{*,P}$), Matias Barbosa, -21.8658, -43.3669 (MN79445$^{*,P}$), **[9]** BR-040 km 796 (MN79363$^{P}$), BR-040 km 805 (CB991$^{P}$), km 807 (MN79162*); Simão Pereira, **[10]** BR-040 km 816 -21.9239, -43.3194 (MN79404$^{*,P}$), **[11]** BR-040 km 823, -21.9747, -43.2853 (MN79407$^{*,P}$), **[12]** BR-040 km 825, -21.9908, -43.2847 (CB1089$^{P}$), **[13]** BR-040 km 827, -22.0022, -43.2767 (MN83564$^{*,P}$, MN79190*).

**Rio de Janeiro state**: Areal, **[20]** BR-040 km 42 (MN79314*); Cachoeiras de Macacu, **[26]** RJ-122 km 25, -22.4667, -42.6500 **[26]** km 25 (CB1321); Comendador Levy Gasparian, -22.0097, -43.2642 **[14]** BR-040 km 1-4 (MN79213, CB1237), **[15]** BR-040 km 10 (MN79154); Duque de Caxias, **[31]** BR-040 km 97, -22.5833, -43.2606 (MN79452), **[32]** BR-040 km 100-102, -22.5925, -43.2800 (MN79326*, MN69904), **[33]** BR-040 km 103, -22.6175, -43.2864 (MN79379*), **[34]** BR-040 km 106, -22.6442, -43.2836 (MN79421*); Guapimirim, -22.5298, -42.9788, **[29]** RJ-122 km 10-17 (CB1320, CB1310); Petrópolis, **[21]** BR-040 km 53, -22.3428, -43.1328 (CB1185$^{P}$, MN79216*), **[22]** BR-040 km 54, -22.3772, -43.1303 (MN79261*), [**24**] BR-040 km 67, -22.4361, -43.1747 (MN79308), **[25]** BR-040 km 69, -22.4428, -43.1914 (MN79443*), **[27]** BR-040 km 77, -22.4931, -43.2231 (MN79334), **[28]** km 78, -22.4997, -43.2292 (MN83573), **[30]** BR-040 km 71, -22.5631, -43.2314 (MN79501$^{*,P}$, MN83244, MN79550$^{P}$); Sumidouro, **[19]** -22.0504, -42.6842 (MN74461$^{P}$), Bairro da Volta (LBCE7780$^{P}$), Piedade (LBCE6587$^{P}$), Soledade (LBCE6619$^{P}$), Vale do Encanto (LBCE5276$^{P}$, LBCE6437$^{P}$), Vale do Pamparrão (LBCE7241$^{P}$); Teresópolis, **[23]** -22.4241, -42.9680 (LBCE7949$^{P}$, LBCE7956$^{P}$, LBCE7963$^{P}$, LBCE7969$^{P}$); Três Rios, **[16]** BR-040 km 11, -22.0469, -43.2006 (MN79247$^{*,P}$), **[17]** BR-040 km 14, -22.0681, -43.1942 (MN79294$^{*,P}$), **[18]** BR-040 km 15, -22.0744, -43.1892 (MN79436, CB1294).

**Tocantins state**: **[1]** Aurora do Tocantins, -12.7121, -46.4072 (fossil specimen, Rodrigues *et al*., 2015).

# Lista comentada de los pequeños roedores de Iquitos y sus alrededores (Loreto, Perú)

# Commented checklist of small rodents from Iquitos and its surroundings (Loreto, Peru)

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**Resumen:** Se presentan los resultados de relevamientos de pequeños roedores en 39 sitios a lo largo de la carretera Iquitos-Nauta (Perú) entre 2002 y 2005. El esfuerzo total de captura fue de 18.081 trampas-noches con trampas Sherman, 19.271 con Tomahawk, 591 con trampas de caída y 287 con Sherman y Tomahawk colocadas en altura. Los muestreos se realizaron en tres tipos de ambientes: bosque primario y secundario y área rural. Los resultados se presentan por especies; indicando su distribución, localidades de registro e historia natural. El mayor éxito de captura se obtuvo en las trampas colocadas en altura (3,83%), seguido por las trampas de caída (2,71%) y en el suelo (1,74%), lo que refleja el grado de actividad de las especies en el dosel en la Amazonía. Se colectaron 685 ejemplares pertenecientes a 25 especies, 13 géneros y tres familias; además se incluye el tratamiento de 14 especies como registros adicionales. Los resultados indican que el área se puede considerar como una zona de alta diversidad de especies, haciéndose fundamental la preservación del ambiente por ser una zona altamente presionada por la agricultura y extracción de madera, afectando en consecuencia la riqueza de especies y la dinámica de sus poblaciones.

**Palabras claves:** Amazonia Peruana. Diversidad. Historia natural. Rodentia.

**Abstract:** The results from surveys of small rodent carried out in 39 collecting sites along the Iquitos-Nauta Highway (Perú), between 2002 and 2005, are presented. Total capture effort was of 18,081 night traps using Sherman traps, 19,271 with Tomahawk, 591 with pitfall traps, and 287 with arboreal traps (Sherman and Tomahawk). The surveys were carried out in three types of environments: primary and secondary forest, and rural area. The results are presented by species indicating distribution, collecting localities, and information about natural history. The greatest capture success was obtained in the arboreal traps (3.83%), followed by the pitfall traps (2.71%), and the traps placed on the ground (1.74%), reflecting the degree of activity of the species in the Amazon canopy. Six hundred and eighty-five rodents, belonging to 25 species, 13 genera, and three families were collected; additionally, information from other 14 species are added in additional records. These results indicate that the studied area can be considered as an area with great diversity of species, being important its conservation, because it is very affected by the increase of the population, agriculture, and the use of wood, which has a negative effect on the species richness and the population dynamics.

**Keywords:** Peruvian Amazon. Diversity. Natural history. Rodentia.

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DÍAZ, M. M., 2020. Lista comentada de los pequeños roedores de Iquitos y sus alrededores (Loreto, Perú). **Boletim do Museu Paraense Emílio Goeldi. Ciências Naturais** 15(3): 727-766. DOI: http://doi.org/10.46357/bcnaturais.v15i3.250.

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Recebido em 21/12/2019
Aprovado em 13/11/2020
Responsabilidade editorial: Alexandra Maria Ramos Bezerra

## INTRODUCCIÓN

Perú, uno de los países más diversos en su fauna de mamíferos, el quinto en el mundo y el tercero en el Neotrópico; registra 559 especies de mamíferos, de los cuales aproximadamente 160 son roedores (Patton *et al*., 2015; Pacheco *et al.*, 2018). Por otro lado, el noreste del país está incluido en una de las zonas con mayor diversidad de especies y especies amenazadas, los denominados 'hotspots' (ver Ceballos & Ehrlich, 2006). La Amazonía no es sólo una de las selvas más diversas del mundo, sino que también es la región en el trópico de América con mayor contribución a su diversidad total (Antonelli *et al*., 2018). Y dentro de esta área, la riqueza de especies de mamíferos en el oeste de la Amazonía es probablemente el más grande en América e incluso en el mundo (Voss & Emmons, 1996; Defler, 2019). La elevada diversidad de la fauna de mamíferos no voladores en esta área se atribuye a la alta diversidad genérica y congenérica, siendo tres grupos (marsupiales, primates y roedores) los más diversos entre la fauna de no voladores de la Amazonia (Defler, 2019).

En el noreste de Perú muchas especies de mamíferos fueron recientemente incluidas en el área e incluso especies nuevas fueron descriptas procedentes de la región (Hice, 2001, 2003; Angulo & Díaz, 2004; Díaz & Willig, 2004; Hice *et al.*, 2004; Voss *et al.*, 2009; Lim *et al.*, 2010; Díaz, 2011, 2014; Velazco *et al.*, 2014, 2017; Velazco & Patterson, 2019). La alta diversidad de pequeños mamíferos puede explicarse por diferentes factores, como ser el gradiente latitudinal, las extensas regiones tropicales que proporcionan grandes áreas de distribución geográfica más que cualquier otro bioma (Rosenzweig, 1992), y la ausencia de precipitaciones estacionales en esta región cálida y húmeda (Gentry, 1988; Gentry & Ortiz-S., 1993). Por otro lado, el levantamiento de los Andes y su efecto sobre el clima cambiaron el paisaje y los ecosistemas amazónicos volviéndose extremadamente ricos en especies, particularmente en el oeste de la Amazonia, con los patrones actuales de biodiversidad arraigado profundamente en el pre-Cuaternario (Hoorn *et al*., 2010). Otras explicaciones del porqué de la alta diversidad de la Amazonia son el gran intercambio de linajes evolutivos entre las diferentes regiones neotropicales, el tiempo que los linajes amazónicos han ocupado el área y las altas tasas de eventos de dispersión en todo el continente (Antonelli *et al*., 2018). A nivel mundial la Amazonía es uno de los ecosistemas que sufre uno de los más altos impactos antrópicos, lo que altera el ecosistema original y causa la extinción de las especies, y entre ellos, la deforestación es una de las expresiones más obvias de la intervención del hombre en bosques tropicales; en Perú, al menos un 15% de la Amazonia peruana ha sido deforestada, siendo una de las áreas protegidas más deforestadas la Reserva Nacional Allpahuayo-Mishana (Dourojeanni, 2014). La zona de amortiguamiento de la Reserva Nacional Allpahuayo-Mishana, muy cerca de Iquitos, está comprometida, con 25% de su superficie ya deforestada, aunque dentro de ella la deforestación abarca solo el 5,5% (Dourojeanni, 2014). Hice & Velazco (2012) mencionan para la Reserva Nacional Allpahuayo-Mishana 37 especies de pequeños mamíferos no voladores, 21 de los cuales son roedores de las tres familias incluidas en este trabajo, considerando al sitio como una de las comunidades más diversas en el Neotrópico.

En este trabajo se reportan 25 especies (no se incluye *Neacomys* sp., ver explicación más abajo, ni los dos ejemplares de oryzominos no identificados), 13 géneros y tres familias, específicamente para Iquitos y registradas en este trabajo, nueve especies en zonas cercanas y cinco en área algo más alejadas del área de estudio, procedentes de registros adicionales. El objetivo de este trabajo es contribuir al conocimiento de la diversidad de pequeños roedores en un área de alta diversidad, aportando datos importantes e inéditos sobre su historia natural, desconocidos para algunas especies.

## MATERIALES Y MÉTODOS

### ÁREA DE STUDIO

Los especímenes fueron colectados, entre diciembre de 2002 y diciembre de 2005, completando un total de 157 días de muestreos, en 39 puntos de colecta a lo largo de la carretera Iquitos-Nauta y 55 registros adicionales, incluyendo diferentes distritos de las provincias de Alto Amazonas, Loreto, Maynas, Mariscal Ramón Padilla y Requena, departamento de Loreto (el Apéndice 1 incluye las localidades de colecta y las adicionales textual como la citaron los autores, Figura 1).

Iquitos se ubica sobre la orilla izquierda del Río Amazonas, entre los ríos Itaya y Nanay, a una altura de 116 m (Villarejo, 1979). El clima de la región presenta una temperatura media anual de 26 °C y una precipitación media anual de 2.700 mm, con una temporada húmeda muy lluviosa desde enero hasta junio, y una seca moderada desde julio a septiembre (Tafur Rengifo, 2001; Madigosky & Vatnick, 2000). El área de estudio se encuentra ubicada dentro del bosque húmedo tropical de selva baja (Brack, 1986), conformado en su mayoría por tierras aluviales expuestas a inundaciones anuales de los ríos constituyendo la planicie inundable de la Amazonía peruana. La selva baja se extiende dentro de la llanura amazónica por debajo de los 800 m de altitud e incluyen los bosques inundables, bosques húmedos de terrazas, bosques húmedos de colinas, aguajales y pacales (Brack, 2008). Los bosques húmedos de terraza y de colinas, forman los denominados bosques

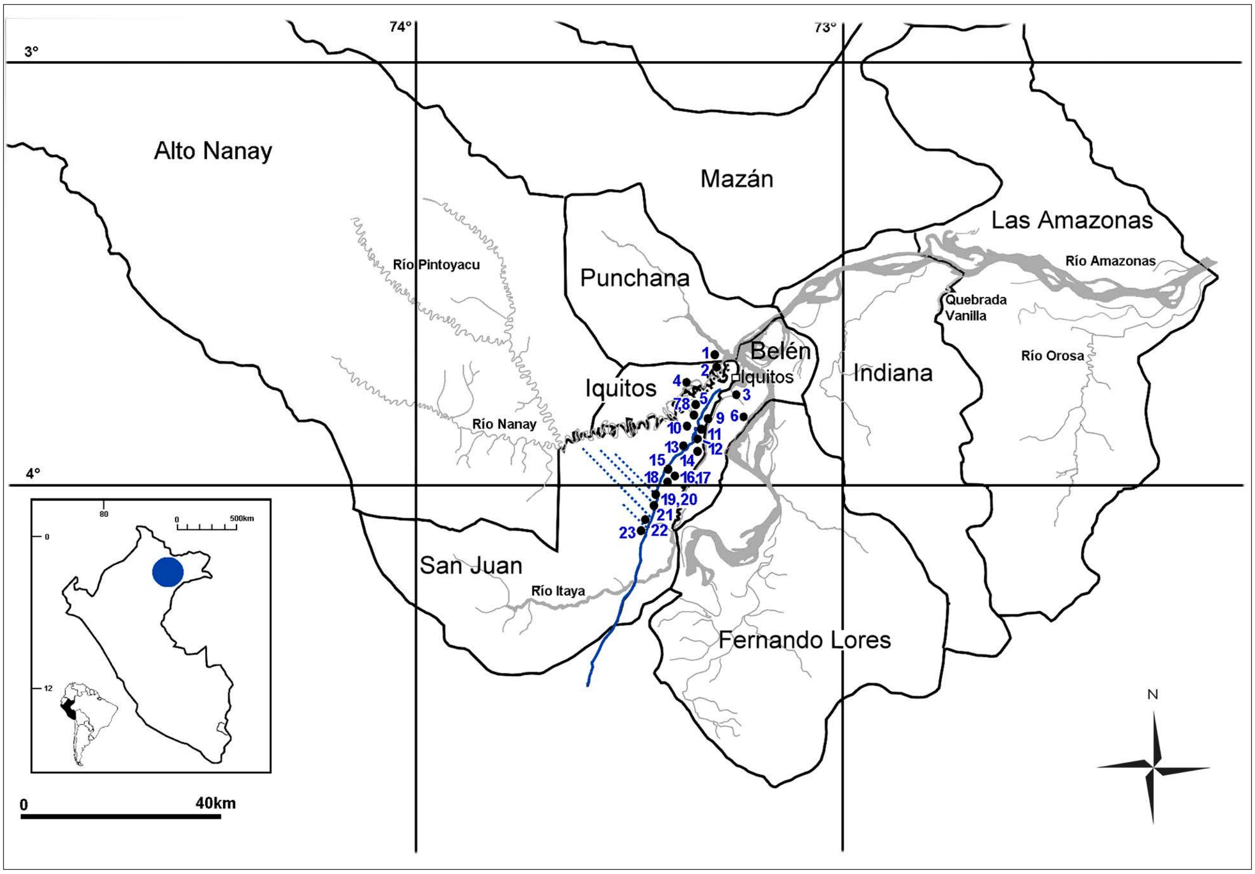

Figura 1. Mapa del área de estudio en la provincia de Maynas y sus distritos, donde se destaca la carretera Iquitos-Nauta en azul, caminos secundarios en azul con líneas punteadas y localidades de colecta (debido a la cercanías de las localidades sólo se colocaron localidades de referencia): 1 = Padrecocha; 2 = Manacamiri; 3 = Moenacaño; 4 = Caserío Santa Sofía; 5 = Santo Tomás; 6 = Mazanillo; 7 = Zungarocha; 8 = Correntillo; 9 = Puerto Alegría; 10 = Ninarumi; 11 = Los Delfines; 12 = Peña Negra; 13 = Varillal; 14 = Moralillo; 15 = 22,7 km de la carretera Iquitos-Nauta; 16 = El Dorado; 17 = 25,3 km de la carretera Iquitos-Nauta; 18 = 28,8 km de la carretera Iquitos-Nauta; 19 = 13 de Febrero; 20 = Camino a Paujil; 21 = Paujil; 22 = Ex-Petroleros; 23 = San Lucas. Mapa: modificado de Díaz (2014).

no inundables o de tierra firme, los primeros se ubican en áreas planas o de pendiente ligera, pudiendo encontrarse más o menos lejos del río; presentan un vigor alto, medio y pobre según la altura del dosel superior y diámetro de las copas (Tuomisto, 1993). Los bosques húmedos de colinas ocupan los terrenos colinosos en diferentes altitudes y con diferentes pendientes. La mayoría de los bosques amazónicos ocupan suelos arcillosos; sin embargo, también se encuentran bosques en suelos de arena blanca distribuidos en forma dispersa; en la Amazonía peruana estos bosques reciben el nombre de varillales. El área más grande de varillales, conocida en Perú, se encuentra hacia el suroeste de la ciudad de Iquitos y a lo largo de la margen derecha del río Nanay, donde se encuentran diferentes tipos de este bosque: varillal alto seco, varillal alto húmedo, varillal bajo seco, varillal bajo húmedo y Chamizal (herbazal) (García Villacorta *et al*., 2003).

## MUESTREO

El estudio se desarrolló en bosque primario, bosque secundario y áreas rurales (incluye áreas suburbanas; zonas de cultivo de yuca, plátano, piña, entre otros; criaderos de cuises; áreas con algún grado de perturbación) (Figura 2). Cabe destacar que la selva primaria como tal en el área de Iquitos prácticamente no existe, son áreas en recuperación de la actividad humana, y se considera dentro de esta

Figura 2. Diferentes hábitats relevados durante el estudio: A) bosque primario; B) bosque secundario; C) área de cultivo; D) gramalotal. Fotos: M. M. Díaz (2003 - A, D; 2004 - B, C).

categoría zonas en recuperación por más de 50 años (ver Hice & Velazco, 2012). En cada punto de colecta se hicieron transectas de 500 m, en cada estación se colocaron dos trampas (una Sherman y una Tomahawk), con las estaciones colocadas a intervalos de 10 m, cada punto fue muestreado durante siete días. Las trampas fueron colocadas en el suelo (Figura 3A), cerca de árboles, troncos caídos, entre hojas secas, en el interior de troncos huecos y sobre lianas o troncos (Figura 3B); cebadas con diferentes tipos de frutas (*e.g.*, plátano, piña, papaya, manzana) o una mezcla de avena y manteca de maní, eran chequeadas diariamente por la mañana y recebadas por la tarde.

Las trampas arbóreas (entre 4-10 trampas por sitio) consistían en una trampa Sherman atada sobre una Tomahawk, y a veces unida a una plataforma de madera o directamente atada a una rama de un árbol (Figura 3C). Se colocaban sobre troncos a diferentes alturas entre 6 y 19 m siguiendo la transecta del suelo, y el cebo (avena con manteca de maní) se colocaba en un trozo de tela para prevenir que las hormigas lo removieran. Todas estas trampas eran chequeadas diariamente, en la mañana, con binoculares. Las trampas de caída ('*pitfall traps*'), colocadas principalmente en bosque primario, consistían en nueve baldes (seis de 20 litros y tres de 40 litros, con

Figura 3. Tipos de trampas usadas en el estudio: A) trampa Sherman en el suelo; B) trampa Tomahawk sobre tronco; C) trampas colocadas en altura, Sherman atada sobre una Tomahawk, montadas en una base de madera. D) transecta de trampas de caída ('*pitfall trap*'). Fotos: M. M. Díaz (2004).

la base perforada) separados uno de otro por 5 m. Para las divisorias se usaron plásticos sostenidos con estacas cada 2 m (Figura 3D). Todas las trampas permanecían abiertas siete noches consecutivas por mes, colocadas de manera simultánea a las trampas Sherman y Tomahawk. En total se colocaron 18.081 trampas-noches con Sherman, 19.271 trampas-noches con Tomahawk y 591 trampas-noches con trampas de caída. Solo 287 trampas-noches correspondieron a trampas arbóreas. El éxito de colecta fue calculado dividiendo el número total de especímenes colectados por el número total de trampas-noches x 100.

## TOMA DE DATOS E IDENTIFICACIÓN

Para cada uno de los especímenes se registraron datos morfométricos, peso, sexo y condición reproductiva siguiendo a Díaz *et al.* (1998); en las hembras preñadas se registraron la cantidad de los fetos y su posición, izquierda (L) o derecha (R) y el tamaño del mismo medido (en mm) de la nuca a la cadera (CR = crown-rump), *e.g*. R1, L1, CR = 28 mm. Además se preservaron muestras de sangre y tejidos, y se colectaron ejemplares de referencia preparados en piel y esqueleto o conservados en alcohol. En las especies del género *Proechimys* se removieron los penes en el momento de la taxidermia o antes de ser colocado en alcohol, con el objetivo de observar el tamaño y la forma de los báculos característicos de cada especie. Los mismos fueron colocados en alcohol 70%, posteriormente diafanizados siguiendo una modificación del método de Lidicker Jr. (1968) y preservados en glicerina 100%. Las medidas externas registradas de los especímenes colectados fueron las siguientes: longitud total (LT), longitud de la cola (LC), longitud de la pata trasera (LP), longitud de la oreja (LO) en milímetros y peso (P) en gramos. Las medidas craneales, tomadas con calibre digital con una precisión de 0,01 mm, fueron las descriptas en Patton *et al.* (2000): longitud cóndilo-incisivo (LCI), longitud del rostro (LR), ancho del rostro (AR), longitud nasal (LN), ancho menor interorbital (AMI), constricción postorbital (CP), ancho zigomático (AZ), ancho del mastoideo (AM), longitud del diastema (LD), longitud del paladar (LP), longitud de la hilera maxilar de dientes (LHMx). Otras medidas que se incluyeron fueron: longitud occipito-nasal (LON), distancia medida desde el hueso occipital hasta el borde de los nasales; ancho caja craneana (ACC), ancho máximo de la caja craneana medida desde el lado dorsal y posteriormente a los arcos cigomáticos; molar-molar (M-M), distancia medida entre los bordes externos de los últimos molares superiores; longitud de la mandíbula (LMd), distancia entre el extremo anterior sin incluir los incisivos y el extremo posterior de la mandíbula, ya sea el proceso angular o el cóndilo; longitud de la hilera de dientes mandibulares (LHMd), distancia entre el extremo anterior del alvéolo del primer diente hasta el borde posterior del último molar.

Los ejemplares fueron identificados usando literatura específica (Pacheco, 1991; Patton *et al*., 2000, 2015; Hurtado & Pacheco, 2017; Sánchez-Vendizú *et al*., 2018; Abreu-Jr *et al*., 2020) y por comparación con ejemplares de museos y colecciones sistemáticas. La taxonomía sigue las últimas revisiones realizadas en cada uno de los géneros (ver Patton *et al*., 2015) y las actualizaciones posteriores mencionadas en cada género o especie. Los especímenes se encuentran depositados en el Museo de Historia Natural de la Universidad de San Marcos (MUSM), Lima, Perú, y en la Colección Mamíferos Lillo (CML), Tucumán, Argentina. Aquellos ejemplares que se encuentran en proceso de catalogado en la CML se designan con el acrónimo: MMD (catálogo personal de M. Mónica Díaz, curador en CML). Las colectas siguieron las recomendaciones de Animal Care and Use Committee de la Texas Tech University, Lubbock, EE.UU. y la University of California, San Diego, EE.UU., y fueron aprobadas por el Ministerio del Interior de Perú.

El tratamiento de las especies incluye a aquellas colectadas en este trabajo y las registradas en otros estudios en un radio de aproximadamente 300 km de Iquitos. Se decidió este radio ya que quedan incluidas localidades amazónicas muy bien muestreadas (*e.g*., Jenaro Herrera), con características similares al área de estudio y especies compartidas [*e.g*., *Holochilus sciureus* Wagner, 1842, *Oligoryzomys microtis* (J. A. Allen, 1916), *Scolomys ucayalensis* Pacheco, 1991, *Proechimys simonsi* Thomas, 1900] lo que eleva significativamente el número de taxones probables para el área.

## RESULTADOS

En total se colectaron 789 ejemplares, 685 silvestres y 104 exóticas (*Rattus norvegicus* Berkenhout, 1769 y *Rattus rattus* Linnaeus, 1758). Los roedores silvestres pertenecen a 25 especies (no se incluye *Neacomys* sp., ver explicación más abajo, ni los dos ejemplares de oryzominos no identificados), 13 géneros y tres familias: Sciuridae (2 ejemplares, 1 especie), Cricetidae (229 ejemplares, 16 especies), y Echimyidae (454 ejemplares, 8 especies) (Tabla 1). Las medidas de los ejemplares examinados por especie se incluyen en la Tabla 2.

Tabla 1. Cantidad de ejemplares, por especie, colectados por cada método de colecta (se incluyen los ejemplares no identificados). En 'Otros' se incluyen aquellos ejemplares colectados por mano (*Mesomys hispidus*) o encontrado muerto (*Neacomys* sp.) (* = no incluidos en el total de las especies del área, ver explicación en el texto).

(Continúa)

| Taxón | Método de colecta | | | | |
|---|---|---|---|---|---|
| | En el suelo | Arbóreo | Pitfall | Otros | Total |
| Sciuridae | | | | | |
| *"Microsciurus" flaviventer* | 2 | 0 | 0 | 0 | 2 |
| Cricetidae | | | | | |
| *Holochilus sciureus* | 11 | 1 | 0 | 0 | 12 |
| *Hylaeamys perenensis* | 33 | 0 | 0 | 0 | 33 |
| *Hylaeamys yunganus* | 35 | 0 | 0 | 0 | 35 |
| *Neacomys amoenus* | 40 | 0 | 2 | 0 | 42 |
| *Neacomys minutus* | 19 | 0 | 5 | 0 | 24 |
| *Neacomys musseri* | 1 | 0 | 0 | 0 | 1 |
| *Neacomys* sp.* | 3 | 0 | 1 | 1 | 5 |
| *Nectomys apicalis* | 6 | 0 | 0 | 0 | 6 |
| *Oecomys bicolor* | 3 | 2 | 1 | 0 | 6 |
| *Oecomys paricola* | 0 | 1 | 2 | 0 | 3 |
| *Oecomys phaeotis* | 0 | 1 | 0 | 0 | 1 |
| *Oecomys roberti* | 2 | 0 | 0 | 0 | 2 |
| *Oecomys trinitatis* | 0 | 0 | 1 | 0 | 1 |
| *Oligoryzomys microtis* | 46 | 0 | 0 | 0 | 46 |
| "Oryzominos"* | 2 | 0 | 0 | 0 | 2 |
| *Rhipidomys leucodactylus* | 1 | 0 | 0 | 0 | 1 |
| *Scolomys melanops* | 5 | 0 | 2 | 0 | 7 |
| *Scolomys ucayalensis* | 0 | 0 | 2 | 0 | 2 |
| Echimyidae | | | | | |
| *Isothrix bistriata* | 0 | 1 | 0 | 0 | 1 |
| *Mesomys hispidus* | 7 | 2 | 0 | 1 | 10 |
| *Proechimys brevicauda* | 118 | 0 | 0 | 0 | 118 |

Tabla 1. (Conclusión)

| Taxón | Método de colecta | | | | |
|---|---|---|---|---|---|
| | En el suelo | Arbóreo | Pitfall | Otros | Total |
| *Proechimys cuvieri* | 207 | 0 | 0 | 0 | 207 |
| *Proechimys quadruplicatus* | 96 | 1 | 0 | 0 | 97 |
| *Proechimys simonsi* | 13 | 0 | 0 | 0 | 13 |
| *Proechimys* sp. | 6 | 0 | 0 | 0 | 6 |
| *Toromys rhipidurus* | 0 | 2 | 0 | 0 | 2 |
| | 656 | 11 | 16 | 2 | 685 |

Tabla 2. Medidas externas y craneales (en mm): se indican media, rango de cada medida y número de ejemplares examinados. Solo se incluyen ejemplares adultos. *Scolomys ucayalensis* no se incluye en la tabla, las medidas se encuentran en el texto, tampoco se incluyen los ejemplares de *Neacomys* sp., ver explicación en el texto. Ver acrónimos en Materiales y Métodos.

(Continúa)

| Medidas | *"Microsciurus" flaviventer* | *Holochilus sciureus* | *Hylaeamys perenensis* | *Hylaeamys yunganus* | *Neacomys amoenus* | *Neacomys minutus* | *Neacomys musseri* | *Nectomys apicalis* |
|---|---|---|---|---|---|---|---|---|
| LT | 313 | 340,89 | 262,39 | 239,44 | 188,13 | 148,89 | 144 | 443,40 |
| | 300-325 | 300-385 | 226-298 | 193-281 | 170-211 | 132-163 | - | 418-486 |
| | 2 | 9 | 31 | 27 | 32 | 19 | 1 | 5 |
| LC | 160 | 161,89 | 123,77 | 105,67 | 92,78 | 76,89 | 72 | 221,60 |
| | - | 145-178 | 104-147 | 87-140 | 72-109 | 68-84 | - | 210-243 |
| | 1 | 9 | 31 | 26 | 32 | 19 | 1 | 5 |
| LP | 43 | 41,78 | 31,35 | 29,96 | 23,28 | 19,70 | 20 | 52,80 |
| | - | 40-44 | 26-34 | 26-32 | 21-25 | 17-22 | - | 52-54 |
| | 1 | 9 | 31 | 27 | 39 | 23 | 1 | 5 |
| LO | 18 | 17,22 | 20,26 | 18,44 | 14,61 | 13,22 | 13 | 21,60 |
| | - | 15-20 | 18-23 | 12-22 | 11-17 | 11-15 | - | 21-23 |
| | 1 | 9 | 31 | 27 | 38 | 23 | 1 | 5 |
| P | 114 | 164,89 | 72,77 | 58,89 | 27,44 | 17,39 | 14 | 296 |
| | 88-139 | 90-231 | 46-112 | 34-86 | 21-40 | 9,75-115 | - | 220-390 |
| | 2 | 9 | 31 | 27 | 39 | 23 | 1 | 5 |
| LCI | 34,93 | 35,05 | 30,53 | 28,57 | 21,43 | 17,88 | 18,31 | 45,60 |
| | 33,81-36,05 | 32,55-39,24 | 27,95-34,41 | 24,45-30,87 | 20,11-23,06 | 16,69-18,71 | - | 41,34-47,51 |
| | 2 | 6 | 21 | 17 | 10 | 11 | 1 | 4 |
| LON | 39,46 | 38,13 | 34,25 | 31,57 | 24,33 | 20,45 | 20,47 | 48,37 |
| | 37,92-40,99 | 35,96-41,85 | 30,68-37,93 | 27,39-34,08 | 23,2-26,02 | 19,04-21,46 | - | 45,72-49,46 |
| | 2 | 6 | 21 | 17 | 10 | 11 | 1 | 4 |
| ACC | 19,09 | 14,65 | 13,67 | 13,36 | 11,32 | 10,14 | 10,20 | 17,39 |
| | 18,94-19,23 | 14,11-15,46 | 11,94-15,02 | 12,76-14,07 | 10,86-11,72 | 9,66-10,64 | - | 16,44-19,32 |
| | 2 | 6 | 21 | 17 | 10 | 11 | 1 | 4 |

Tabla 2. (Continúa)

| Medidas | *"Microsciurus" flaviventer* | *Holochilus sciureus* | *Hylaeamys perenensis* | *Hylaeamys yunganus* | *Neacomys amoenus* | *Neacomys minutus* | *Neacomys musseri* | *Nectomys apicalis* |
|---|---|---|---|---|---|---|---|---|
| LR | 15,50 | 14,28 | 13 | 11,45 | 8,42 | 6,50 | 6,64 | 18,22 |
| | 14,40-16,59 | 13,16-16,25 | 10,59-15,42 | 9,77-13,68 | 7,44-9,78 | 4,19-7,79 | - | 16,95-19,11 |
| | 2 | 6 | 21 | 17 | 10 | 11 | 1 | 4 |
| AR | 6,43 | 6,57 | 5,52 | 5,17 | 3,93 | 3,59 | 3,77 | 9,08 |
| | 6,16-6,69 | 6,01-7,23 | 4,85-6,41 | 4,21-6,09 | 3,55-4,41 | 3,03-4,06 | - | 7,26-10,61 |
| | 2 | 6 | 21 | 17 | 10 | 11 | 1 | 4 |
| LN | 10,66 | 15,18 | 12,80 | 11,18 | 9,25 | 7,60 | 7,29 | 19,65 |
| | 9,77-11,55 | 14,21-16,69 | 10,6-14,99 | 9,31-12,27 | 8,51-10,84 | 6,52-8,34 | - | 19,25-20,45 |
| | 2 | 6 | 21 | 17 | 10 | 11 | 1 | 4 |
| AMI | 13,68 | 5,13 | 5,57 | 5,18 | 4,74 | 4,24 | - | 7,82 |
| | 12,92-14,44 | 4,53-5,75 | 5,23-6,18 | 4,85-5,64 | 4,54-5,02 | 3,88-4,64 | - | 7,2-8,1 |
| | 2 | 6 | 19 | 10 | 9 | 7 | - | 4 |
| CP | 15,01 | - | 5,33 | 5,29 | 4,75 | 5,03 | 4,21 | 11,51 |
| | 14,56-15,46 | - | 5,24-5,42 | 5,10-5,51 | - | 4,26-6,78 | - | 11,51-11,51 |
| | 2 | - | 2 | 7 | 1 | 6 | 1 | 2 |
| AZ | 23,43 | 20,71 | 16,99 | 16,10 | 12,51 | 10,57 | - | 26,01 |
| | 22,46-24,39 | 19,4-22,43 | 15,89-18,96 | 14,66-17,31 | 12,01-13,03 | 9,92-11,05 | - | 23,56-27,1 |
| | 2 | 6 | 21 | 16 | 9 | 8 | - | 4 |
| AM | 17,27 | 13,09 | 11,28 | 11,19 | 9,54 | 8,68 | 8,91 | 15,93 |
| | 17,14-17,40 | 12,45-13,97 | 10,59-12,14 | 10,35-12,11 | 9,22-10,04 | 8,28-9,04 | - | 15,26-16,31 |
| | 2 | 6 | 21 | 17 | 10 | 11 | 1 | 4 |
| LD | 9,14 | 10,82 | 8,94 | 8,23 | 6,22 | 5,01 | 5,29 | 13,51 |
| | 8,17-10,10 | 9,52-13,35 | 7,88-10,12 | 6,77-9,24 | 5,75-6,86 | 4,56-5,45 | - | 11,95-14,41 |
| | 2 | 6 | 21 | 17 | 10 | 11 | 1 | 4 |
| LP | 17,10 | 18,21 | 15,12 | 14,10 | 9,87 | 8,01 | 8,44 | 24,12 |
| | 16,84-17,35 | 15,56-21,05 | 13,39-16,79 | 12,52-15,13 | 9,36-10,72 | 6,38-9,44 | - | 20,54-26,33 |
| | 2 | 6 | 21 | 17 | 10 | 11 | 1 | 4 |
| LHMx | 6,45 | 7,40 | 5,27 | 5,10 | 3,30 | 2,78 | 2,64 | 7,56 |
| | 6,39-6,51 | 7,11-7,75 | 4,89-5,93 | 4,86-5,40 | 3,14-3,61 | 2,66-3,04 | - | 7,36-7,84 |
| | 2 | 6 | 21 | 17 | 10 | 11 | 1 | 4 |
| M-M | 8,49 | 6,72 | 5,48 | 5,62 | 3,97 | 3,46 | 3,38 | 8,43 |
| | 8,45-8,52 | 6,16-7,41 | 5,05-6,02 | 5,26-6,08 | 3,68-4,40 | 3,12-3,72 | - | 8,10-8,65 |
| | 2 | 6 | 20 | 17 | 10 | 11 | 1 | 4 |
| LMd | 21,205 | 20,98 | 17,82 | 17,14 | 11,91 | 10,66 | 12,56 | 27,61 |
| | 21,06-21,35 | 19,77-22,82 | 15,99-20,3 | 14,72-19,70 | 11,16-13,37 | 9,24-11,64 | - | 24,38-30,14 |
| | 2 | 6 | 21 | 17 | 10 | 11 | 1 | 4 |
| LHMd | 6,45 | 7,33 | 5,33 | 5,25 | 3,42 | 2,91 | 2,82 | 7,66 |
| | 6,43-6,46 | 6,93-7,57 | 4,96-5,92 | 4,98-5,49 | 3,24-4,01 | 2,71-3,37 | - | 7,51-7,79 |
| | 2 | 6 | 21 | 17 | 10 | 11 | 1 | 4 |

Tabla 2. (Continúa)

| Medidas | *Oecomys bicolor* | *Oecomys paricola* | *Oecomys phaeotis* | *Oecomys roberti* | *Oecomys trinitatis* | *Oligoryzomys microtis* | *Rhipidomys leucodactylus* | *Scolomys melanops* |
|---|---|---|---|---|---|---|---|---|
| LT | 208 | 183,33 | 212 | 243 | 309 | 189 | 407 | 144 |
| | 189-227 | 174-191 | - | 236-250 | - | 165-204 | - | 130-156 |
| | 6 | 3 | 1 | 2 | 1 | 38 | 1 | 3 |
| LC | 106 | 99,33 | 111 | 135,50 | 178 | 97,82 | 222 | 55,67 |
| | 87-118 | 92-105 | - | 132-139 | - | 83-111 | - | 48-62 |
| | 6 | 3 | 1 | 2 | 1 | 38 | 1 | 3 |
| LP | 21,50 | 21,33 | 23 | 25,50 | 27 | 22,24 | 34 | 20 |
| | 21-23 | 21-22 | - | 25-26 | - | 20-24 | - | 17-22 |
| | 6 | 3 | 1 | 2 | 1 | 38 | 1 | 7 |
| LO | 13,83 | 13,33 | 15 | 15,50 | 18 | 12,61 | 19 | 14,57 |
| | 13-16 | 13-14 | - | 15-16 | - | 10-15 | - | 13-15 |
| | 6 | 3 | 1 | 2 | 1 | 38 | 1 | 7 |
| P | 32,96 | 19,42 | 27 | 35 | 55 | 22,47 | 160 | 27,43 |
| | 23,75-48,00 | 19,25-19,50 | - | 32-38 | - | 13,50-34,00 | - | 15-35 |
| | 6 | 3 | 1 | 2 | 1 | 38 | 1 | 7 |
| LCI | 25,55 | 22,38 | 24,06 | 26,85 | 32,65 | 21,15 | 39,07 | 19,95 |
| | 25,34-25,76 | 21,88-22,87 | - | - | - | 18,99-22,70 | - | 17,85-21,44 |
| | 3 | 2 | 1 | 1 | 1 | 25 | 1 | 5 |
| LON | 28,38 | 25,10 | 26,61 | 30,05 | 35,44 | 23,59 | 42,08 | 21,38 |
| | 27,67-28,77 | 24,88-25,32 | - | - | - | 21,77-24,88 | - | 19,53-22,65 |
| | 3 | 2 | 1 | 1 | 1 | 25 | 1 | 5 |
| ACC | 13,06 | 11,79 | 12,23 | 13,48 | 14,32 | 10,85 | 19,23 | 11,36 |
| | 12,79-13,53 | 11,75-11,83 | - | - | - | 10,28-11,37 | - | 10,83-11,67 |
| | 3 | 2 | 1 | 1 | 1 | 25 | 1 | 5 |
| LR | 9,25 | 7,52 | 9,11 | 10,27 | 12,56 | 8,03 | 14,27 | 7,11 |
| | 8,82-9,5 | 7,4-7,63 | - | - | - | 7,24-9,01 | - | 6,37-7,90 |
| | 3 | 2 | 1 | 1 | 1 | 25 | 1 | 5 |
| AR | 4,56 | 4,30 | 3,61 | 4,81 | 5,97 | 3,81 | 6,71 | 3,78 |
| | 4,31-5,01 | 4,14-4,45 | - | - | - | 3,34-4,20 | - | 3,12-4,23 |
| | 3 | 2 | 1 | 1 | 1 | 25 | 1 | 5 |
| LN | 9,70 | 7,95 | 8,94 | 10,38 | 12,03 | 8,88 | 11,78 | 7,02 |
| | 8,72-10,86 | 7,35-8,55 | - | - | - | 6,83-10,2 | - | 6,13-7,99 |
| | 3 | 2 | 1 | 1 | 1 | 25 | 1 | 5 |
| AMI | 4,68 | 4,64 | 5,13 | 5,1 | 6,35 | 3,77 | - | 5,28 |
| | 4,33-5,16 | 4,46-4,81 | - | - | - | 3,50-4,14 | - | 4,95-5,56 |
| | 3 | 2 | 1 | 1 | 1 | 23 | - | 5 |

Tabla 2. (Continúa)

| Medidas | *Oecomys bicolor* | *Oecomys paricola* | *Oecomys phaeotis* | *Oecomys roberti* | *Oecomys trinitatis* | *Oligoryzomys microtis* | *Rhipidomys leucodactylus* | *Scolomys melanops* |
|---|---|---|---|---|---|---|---|---|
| CP | 15,2 | - | - | - | - | 3,99 | 6,71 | - |
|  | 15,05-15,43 | - | - | - | - | 3,96-4,01 | - | - |
|  | 3 |  | - | - | - | 2 | 1 | - |
| AZ | 11,16 | 12,91 | 14,42 | 16,02 | 17,75 | 12,41 | 22,58 | 12,63 |
|  | 10,53-11,62 | - | - | - | - | 11,09-13,57 | - | 12,18-13,55 |
|  | 3 | 1 | 1 | 1 | 1 | 18 | 1 | 5 |
| AM | 7,37 | 10,40 | 9,92 | 10,98 | 12,38 | 9,19 | 15,44 | 10,02 |
|  | 7,16-7,50 | 10,24-10,56 | - | - | - | 8,62-9,8 | - | 9,30-10,95 |
|  | 3 | 2 | 1 | 1 | 1 | 25 | 1 | 5 |
| LD | 11,62 | 6,65 | 6,46 | 7,65 | 9,90 | 5,88 | 11,68 | 5,74 |
|  | 11,42-11,74 | - | - | - | - | 4,99-6,61 | - | 5,14-6,21 |
|  | 3 | 1 | 1 | 1 | 1 | 25 | 1 | 5 |
| LP | 3,98 | 10,14 | 11,76 | 12,74 | 15,72 | 9,53 | 18,29 | 9,16 |
|  | 3,77-4,23 | 9,88-10,39 | - | - | - | 8,87-10,16 | - | 8,16-9,91 |
|  | 3 | 2 | 1 | 1 | 1 | 23 | 1 | 5 |
| LHMx | 4,70 | 3,87 | 4,27 | 4,80 | 5,20 | 3,19 | 6,41 | 2,67 |
|  | 4,64-4,75 | 3,77-3,97 | - | - | - | 3,01-3,42 | - | 2,46-2,90 |
|  | 3 | 2 | 1 | 1 | 1 | 25 | 1 | 5 |
| M-M | - | 4,34 | 4,37 | 5,37 | 5,92 | 3,74 | 7,55 | 3,65 |
|  | - | 4,12-4,55 | - | - | - | 3,47-3,97 | - | 3,37-3,92 |
|  | - | 2 | 1 | 1 | 1 | 35 | 1 | 5 |
| LMd | 15,93 | 13,87 | 12,77 | 15,54 | 19,59 | 11,46 | 24,17 | 11,36 |
|  | 14,27-16,88 | 13,48-14,26 | - | - | - | 10,13-12,92 | - | 9,76-12,47 |
|  | 3 | 2 | 1 | 1 | 1 | 25 | 1 | 5 |
| LHMd | 4,2 | 4,12 | 4,30 | 4,98 | 5,36 | 3,21 | 6,53 | 2,7 |
|  | 3,96-4,54 | 4,00-4,23 | - | - | - | 2,95-3,47 | - | 2,58-2,77 |
|  | 3 | 2 | 1 | 1 | 1 | 25 | 1 | 5 |

| Medidas | *Isothrix bistriata* | *Mesomys hispidus* | *Proechimys brevicauda* | *Proechimys cuvieri* | *Proechimys quadruplicatus* | *Proechimys simonsi* | *Proechimys* sp. | *Toromys rhipidurus* |
|---|---|---|---|---|---|---|---|---|
| LT | 498 | 392,67 | 356,19 | 363,01 | 407,38 | 381,86 | 414 | 481 |
|  | - | 380-403 | 271-431 | 290-416 | 325-462 | 336-418 | 409-419 | 470-492 |
|  | 1 | 3 | 53 | 101 | 47 | 7 | 2 | 2 |
| LC | 260 | 189 | 137,68 | 141,30 | 158,85 | 153,71 | 157 | 223 |
|  | - | 186-194 | 105-170 | 113-165 | 127-185 | 143-165 | 150-164 | 215-231 |
|  | 1 | 3 | 53 | 101 | 47 | 7 | 2 | 2 |

Tabla 2. (Continúa)

| Medidas | *Isothrix bistriata* | *Mesomys hispidus* | *Proechimys brevicauda* | *Proechimys cuvieri* | *Proechimys quadruplicatus* | *Proechimys simonsi* | *Proechimys* sp. | *Toromys rhipidurus* |
|---|---|---|---|---|---|---|---|---|
| LP | 49 | 32,86 | 46,49 | 46,13 | 53,33 | 53,10 | 54,50 | 43,50 |
| | - | 31-35 | 38-57 | 39-53 | 47-60 | 50-55 | 53-55 | 42-45 |
| | 1 | 7 | 78 | 142 | 64 | 10 | 4 | 2 |
| LO | 12 | 12,57 | 20,82 | 22,13 | 22,34 | 21,30 | 22 | 16,50 |
| | - | 10-15 | 18-23 | 19-25 | 20-27 | 20-23 | 21-23 | 16-17 |
| | 1 | 7 | 78 | 141 | 65 | 10 | 4 | 2 |
| P | 320 | 192,29 | 282,13 | 283,90 | 392,48 | 351,80 | 507,50 | 365 |
| | - | 164-230 | 104-460 | 124-440 | 220-580 | 210-560 | 440-560 | 330-400 |
| | 1 | 7 | 78 | 141 | 65 | 10 | 4 | 2 |
| LCI | 48,3 | 40,86 | 43,06 | 43,19 | 48,17 | 45,9 | 49,20 | 52,54 |
| | - | 39,17-42,81 | 37,37-49,06 | 39,27-47,49 | 42,87-53,64 | 42,13-50,41 | 48,35-50,05 | - |
| | 1 | 5 | 20 | 53 | 30 | 4 | 2 | 1 |
| LON | 54,06 | 45,42 | 52,40 | 53,25 | 58,63 | 56,30 | 60,19 | 58,56 |
| | - | 43,27-46,90 | 43,93-63,15 | 49,08-59,07 | 50,60-64,26 | 51,46-60,11 | 59,47-60,91 | - |
| | 1 | 5 | 19 | 52 | 29 | 4 | 2 | 1 |
| ACC | 21,38 | 18,98 | 20,29 | 20,15 | 21,19 | 20,67 | 21,56 | 22,76 |
| | - | 18,09-19,75 | 18,72-22,58 | 17,79-22,68 | 19,3-22,85 | 19,48-21,75 | 21,00-22,12 | - |
| | 1 | 5 | 20 | 54 | 30 | 4 | 2 | 1 |
| LR | 20,89 | 15,56 | 20,89 | 21,07 | 23,67 | 21,89 | 23,91 | 21,86 |
| | - | 14,63-16,39 | 17,01-26,38 | 19,07-23,36 | 21,21-26,44 | 19,18-24,21 | 23,55-24,26 | - |
| | 1 | 5 | 19 | 52 | 29 | 4 | 2 | 1 |
| AR | 8,66 | 6,30 | 7,85 | 6,93 | 7,70 | 7,23 | 7,52 | 7,99 |
| | - | 6,13-6,85 | 6,65-8,98 | 5,94-8,35 | 6,77-9,52 | 7,14-7,47 | 7,18-7,86 | - |
| | 1 | 5 | 20 | 54 | 29 | 4 | 2 | 1 |
| LN | 14,07 | 13,61 | 19,22 | 19,85 | 22,23 | 20,93 | 23,61 | 17,15 |
| | - | 12,46-14,25 | 8,45-23,69 | 16,61-22,54 | 19,46-25,48 | 19,19-22,27 | 23,12-24,10 | - |
| | 1 | 5 | 19 | 52 | 29 | 4 | 2 | 1 |
| AMI | - | 11,27 | 12,02 | 11,91 | 12,87 | 12,32 | 12,36 | - |
| | - | 10,75-11,6 | 10,85-13,78 | 10,95-12,88 | 11,7-14,31 | 11,64-13,74 | - | - |
| | - | 5 | 20 | 51 | 27 | 4 | 1 | |
| CP | 8,64 | - | 12,81 | 12,33 | 13,48 | - | - | 16,1 |
| | - | - | 11,38-14,32 | 11,3-14,37 | 10,9-15,72 | - | - | - |
| | 1 | - | 12 | 8 | 6 | - | - | 1 |
| AZ | 27,21 | 24,03 | 25,58 | 25,22 | 27,41 | 25,85 | 27,53 | 28,13 |
| | - | 23,37-24,66 | 23,34-27,77 | 22,60-27,3 | 22,70-31,09 | 24,52-27,34 | 26,74-28,31 | - |
| | 1 | 5 | 20 | 53 | 30 | 4 | 2 | 1 |

Tabla 2. (Conclusión)

| Medidas | *Isothrix bistriata* | *Mesomys hispidus* | *Proechimys brevicauda* | *Proechimys cuvieri* | *Proechimys quadruplicatus* | *Proechimys simonsi* | *Proechimys* sp. | *Toromys rhipidurus* |
|---|---|---|---|---|---|---|---|---|
| AM | 21,88 | 17,48 | 17,82 | 17,13 | 19,11 | 17,71 | 21,83 | 21,33 |
| | - | 16,35-18,6 | 16,02-20,34 | 14,88-20,52 | 13,42-26,94 | 16,72-19,77 | 21,60-22,06 | - |
| | 1 | 5 | 20 | 53 | 30 | 4 | 2 | 1 |
| LD | 11,95 | 9,74 | 11,19 | 10,72 | 12,67 | 11,65 | 13,49 | 12,38 |
| | - | 9,22-10,53 | 9,27-12,86 | 9,41-12,12 | 10,39-20,12 | 10,49-13,42 | 13,17-13,81 | - |
| | 1 | 5 | 20 | 53 | 30 | 4 | 2 | 1 |
| LP | 19,57 | 15,73 | 19,51 | 18,91 | 20,17 | 19,46 | 20,56 | 25,40 |
| | - | 15,07-16,67 | 16,46-22,15 | 15,26-21,37 | 17,18-22,27 | 17,8-21,75 | 20,40-20,72 | - |
| | 1 | 5 | 20 | 53 | 30 | 4 | 2 | 1 |
| LHMx | 10,79 | 7,59 | 8,68 | 8,32 | 9,11 | 9,22 | 8,78 | 12,48 |
| | - | 7,28-7,95 | 8,19-9,50 | 7,35-9,76 | 8,03-9,97 | 8,66-9,66 | 8,08-9,47 | - |
| | 1 | 5 | 17 | 53 | 30 | 4 | 2 | 1 |
| M-M | 8,82 | 6,94 | 8,65 | 8,14 | 9,08 | 8,77 | 9,01 | 7,17 |
| | - | 6,66-7,20 | 7,71-9,81 | 6,71-9,05 | 8,1-9,94 | 8,60-9,10 | 8,82-9,20 | - |
| | 1 | 5 | 17 | 54 | 30 | 4 | 2 | 1 |
| LMd | 30,41 | 23,71 | 28,45 | 27,29 | 30,86 | 29,53 | 30,64 | 36,33 |
| | - | 22,90-24,73 | 24,25-33,89 | 24,61-30,72 | 27,07-34,34 | 27,03-32,62 | 29,77-31,51 | - |
| | 1 | 5 | 20 | 54 | 30 | 4 | 2 | 1 |
| LHMd | 11,17 | 7,71 | 9,36 | 8,55 | 9,48 | 9,49 | 9,38 | 11,48 |
| | - | 7,48-8,02 | 8,54-10,16 | 7,88-10,14 | 8,51-10,69 | 9,07-9,64 | 8,93-9,83 | - |
| | 1 | 5 | 17 | 54 | 29 | 4 | 2 | 1 |

De los 685 ejemplares colectados, 654 fueron capturados en el suelo (219 en trampas Sherman y 437 en Tomahawk) y 11 en trampas arbóreas (4 en trampas Sherman y 7 en Tomahawk), 16 en trampas de caída (‘*pitfall traps*’), uno con la mano y uno espécimen fue encontrado muerto (Tabla 1). Las trampas de caída fueron las más exitosas (2,71% éxito de captura), seguidas por las trampas Tomahawk 2,27% y Sherman 1,21%. Las trampas arbóreas fueron más exitosas que las del suelo, ya que en 287 trampas-noches se colectaron 11 ejemplares, mientras que en el suelo con 37.656 trampas-noches se capturaron 654 ejemplares, representando un 3,83 y un 1,74% de éxito de captura respectivamente. Con respecto a los ambientes donde fueron colectados el mayor número de colectas se realizó en bosque primario (305), seguido por bosque secundario (261) y finalmente el hábitat rural (107); con pocos registros en áreas de ecotono (12) (Tabla 3).

Del total de taxones incluidos en el tratamiento de especies, colectadas y de la literatura (39 especies), cuatro [*Hadrosciurus ignitus* (Gray, 1867), *Amphinectomys savamis* Malygin, 1994, *Nectomys rattus* Pelzeln, 1883 y *Proechimys steerei* Goldman, 1911] fueron registrados fuera del área de Iquitos, en provincias diferentes a la de Maynas. Cabe destacar que algunos ejemplares del género *Neacomys* no pudieron ser identificados a nivel de especie y se incluyeron como *Neacomys* sp., pero como podrían pertenecer a algunas de las especies ya registradas no se considera en el total de las especies. Sólo se presenta el tratamiento de las especies silvestres. En cada una de las especies se indica ubicación taxonómica, especie, autor y año, distribución general, especímenes examinados, registros adicionales de citas de la literatura y comentarios preferentemente relacionados con las colectas de campo, sistemática, observaciones de distribución, historia natural y hábitat. Cabe aclarar que dentro de los cricétidos, dos oryzominos no pudieron ser identificados y no se consideran dentro del tratamiento de las especies.

Tabla 3. Cantidad de especímenes por formación vegetal de colecta. Acrónimos: BP = bosque primario, BS = bosque secundario, R = rural. (* = no incluidos en el total de las especies del área, ver explicación en el texto).

| Taxón | Bosque primario | Bosque secundario | Rural | Ecotono BP-BS | Ecotono BP-R | Ecotono BS-R | Total |
|---|---|---|---|---|---|---|---|
| Sciuridae | | | | | | | |
| *"Microsciurus" flaviventer* | 2 | 0 | 0 | 0 | 0 | 0 | 2 |
| Cricetidae | | | | | | | |
| *Holochilus sciureus* | 0 | 2 | 10 | 0 | 0 | 0 | 12 |
| *Hylaeamys perenensis* | 30 | 3 | 0 | 0 | 0 | 0 | 33 |
| *Hylaeamys yunganus* | 19 | 12 | 2 | 2 | 0 | 0 | 35 |
| *Neacomys amoenus* | 4 | 30 | 8 | 0 | 0 | 0 | 42 |
| *Neacomys minutus* | 16 | 8 | 0 | 0 | 0 | 0 | 24 |
| *Neacomys musseri* | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Neacomys* sp.* | 1 | 4 | 0 | 0 | 0 | 0 | 5 |
| *Nectomys apicalis* | 0 | 1 | 5 | 0 | 0 | 0 | 6 |
| *Oecomys bicolor* | 3 | 3 | 0 | 0 | 0 | 0 | 6 |
| *Oecomys paricola* | 2 | 1 | 0 | 0 | 0 | 0 | 3 |
| *Oecomys phaeotis* | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Oecomys roberti* | 1 | 1 | 0 | 0 | 0 | 0 | 2 |
| *Oecomys trinitatis* | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Oligoryzomys microtis* | 0 | 9 | 35 | 0 | 0 | 2 | 46 |
| "Oryzominos"* | 1 | 1 | 0 | 0 | 0 | 0 | 2 |
| *Rhipidomys leucodactylus* | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Scolomys melanops* | 5 | 2 | 0 | 0 | 0 | 0 | 7 |
| *Scolomys ucayalensis* | 2 | 0 | 0 | 0 | 0 | 0 | 2 |
| Echimyidae | | | | | | | |
| *Isothrix bistriata* | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| *Mesomys hispidus* | 5 | 2 | 3 | 0 | 0 | 0 | 10 |
| *Proechimys brevicauda* | 64 | 40 | 12 | 0 | 1 | 1 | 118 |
| *Proechimys cuvieri* | 117 | 82 | 8 | 0 | 0 | 0 | 207 |
| *Proechimys quadruplicatus* | 27 | 43 | 22 | 0 | 0 | 5 | 97 |
| *Proechimys simonsi* | 0 | 12 | 1 | 0 | 0 | 0 | 13 |
| *Proechimys* sp. | 2 | 3 | 0 | 0 | 0 | 1 | 6 |
| *Toromys rhipidurus* | 0 | 2 | 0 | 0 | 0 | 0 | 2 |
| | 305 | 261 | 107 | 2 | 1 | 9 | 685 |

### Suborden Sciuromorpha Brandt, 1855

### Familia Sciuridae G. Fischer, 1817

### Subfamilia Sciurillinae Moore, 1959

### *Sciurillus pusillus* (É. Geoffroy St.-Hilaire, 1803)

Distribución: esta especie es conocida de pocas localidades mostrando una distribución disyunta entre el este y el oeste de la selva baja en Sudamérica, registrándose en Perú, Colombia, centro-norte de Brasil, y noreste de Brasil, Guyana Francesa, Suriname y Guyana (Calderón-Capote *et al.*, 2015; Koprowski & Roach, 2019).

Especímenes examinados: ninguno.

Registros adicionales: Provincia de Mariscal Ramón Castilla, Distrito de Pebas: Pebas (Thomas, 1928; de Vivo & Carmignotto, 2015). Provincia de Maynas, Distrito de Indiana: Santa Cecilia, Río Maniti (de Vivo & Carmignotto, 2015). Distrito de San Juan Bautista: Cuenca del río Alto Itaya (Aquino *et al.*, 2012). Distrito de Fernando Lores: Amazon Research Center in Área de Conservación Regional Tamshiyacu-Tahuayo (Jessen *et al*., 2013; Palmer & Koprowski, 2015); Estación Biológica Quebrada Blanco (Heymann & Knogge, 1997). Distrito de Las Amazonas: Quebrada Orán, ca. 5 km N Rio Amazonas, 85 km NE Iquitos, 110 m (Hafner *et al.*, 1994). Provincia de Requena, Distrito de Requena: Jenaro Herrera (Tovar Narváez, 2011).

Comentarios: se reconocen tres subespecies: *S. p. pusillus*, *S. p. glaucinus* Thomas, 1914 y *S. p. kuhlii* (Gray, 1867), la última distribuida en el noroeste de Perú; dichas subespecies podrían representar diferentes especies (ver Koprowski *et al.*, 2016).

### Subfamilia Sciurinae G. Fischer, 1817

### *Hadrosciurus ignitus* (Gray, 1867)

Distribución: esta especie se distribuye en las tierras bajas al este de los Andes desde las tierras bajas de Perú al oeste de la Amazonia de Brasil y Bolivia, alcanzando el noroeste de Argentina (de Vivo & Carmignotto, 2015; Abreu-Jr. *et al*., 2020).

Especímenes examinados: ninguno.

Registros adicionales: Provincia de Alto Amazonas, Distrito de Morona: Quebrada Pushaga, Río Morona, upper Río Amazonas (de Vivo & Carmignotto, 2015). Provincia de Loreto, Distrito de Nauta: Nauta, Rio Samiria, right bank, elev. 150 m; Nauta, Rio Tigre, 1 km above Rio Tigrillo, left bank, elev. 150 m (Timm *et al*., 2015 como *Sciurus ignitus*).

Comentarios: esta especie incluye las tres subespecies de *Notosciurus pucheranii* (Fitzinger, 1867) consideradas por de Vivo & Carmignotto (2015), *N. p. ignitus* (Gray, 1867), *N. p. boliviensis* (Osgood, 1921) y *N. p. argentinius* (Thomas, 1921) (Abreu-Jr. *et al*., 2020). De acuerdo a de Vivo & Carmignotto (2015), en ejemplares del departamento de Loreto (Perú) hacia el sur, predomina el fenotipo *N. p. ignitus*, cuyos animales son marrón oscuro dorsalmente, sin una línea media dorsal, el cuello es blanco grisáceo y el pecho y abdomen naranja, con la base de los pelos grises.

### *Hadrosciurus igniventris* (Wagner, 1842)

Distribución: *Hadrosciurus igniventris* se distribuye en el noroeste de la Amazona en Venezuela, Brasil, Colombia, Ecuador y norte de Perú al este de los Andes (de Vivo & Carmignotto, 2015; Abreu-Jr. *et al*., 2020).

Especímenes examinados: ninguno.

Registros adicionales: Provincia de Loreto, Distrito de Parinari: Santa Elena, Río Samiria (de Vivo & Carmignotto, 2015). Provincia de Mariscal Ramón Castilla, Distrito de Pebas: Pebas (Thomas, 1928; de Vivo & Carmignotto, 2015). Provincia de Maynas, Distrito de San Juan Bautista: Cuenca del río Alto Itaya (Aquino *et al.*, 2012 como *Sciurus igniventris* Wagner, 1842). Distrito de Iquitos, Iquitos (Thomas, 1928); Santa Rita, Iquitos (de Vivo & Carmignotto, 2015).

Comentarios: todos los ejemplares incluidos en esta especie deberían ser revisados cuidadosamente ya que podrían pertenecer a *H. pyrrhinus* Thomas, 1898, como sucedió con aquellos ejemplares registrados en la Reserva Nacional Allpahuayo Mishana (Loreto) (ver Abreu-Jr. *et al*., 2020).

### *Hadrosciurus pyrrhinus* (Thomas, 1898)

Distribución: esta especie ocurre en las tierras bajas del Amazonas en Brasil, Bolivia, Perú, Ecuador y Colombia (Abreu-Jr. *et al*., 2020).

Especímenes examinados: ninguno.

Registros adicionales: Provincia de Maynas, Distrito San Juan Bautista: Reserva Nacional Allpahuayo-Mishana (Hice & Velazco, 2012 como *Sciurus igniventris*; Abreu-Jr. *et al*., 2020). Provincia de Requena, Distrito de Yaquerana: Nuevo San Juan, Río Gálvez (Abreu-Jr. *et al*., 2020).

Comentarios: Hice & Velazco (2012) reportan dos ejemplares machos colectados en la Reserva Nacional Allpahuayo-Mishana.

### *Hadrosciurus spadiceus* (Olfers, 1818)

Distribución: esta especie ocurre en las tierras bajas del Amazonas en Brasil, Bolivia, Perú, Ecuador y Colombia (Abreu-Jr. *et al*., 2020).

Especímenes examinados: ninguno.

Registros adicionales: Provincia de Maynas, Distrito de Las Amazonas: Río Apayacu. Distrito de Napo: boca del Río Curaray (de Vivo & Carmignotto, 2015). Distrito de Iquitos: Cuenca del río Itaya (Aquino *et al.*, 2012). Provincia de Requena, Distrito de Yaquerana: Nuevo San Juan, Río Gálvez (Abreu-Jr. *et al*., 2020).

Comentarios: de acuerdo a Abreu-Jr. *et al.* (2020), esta especie se encuentra en simpatría en el Río Galvez con una especie no identificada, nombrada por ellos como *Hadrosciurus* 'species 3'.

### *"Microsciurus" flaviventer* (Gray, 1867)

Distribución: esta especie se distribuye en las tierras bajas de la Amazonas en Brasil, Bolivia, Ecuador y Perú (Abreu-Jr. *et al*., 2020).

Especímenes examinados (2): Provincia de Maynas, Distrito de San Juan Bautista: Moralillo, 1,5 km E 500 m S del km 15,2 de la carretera Iquitos-Nauta, 1 (CML 13545); Zungarococha, 6,5 km al W del km 6 de la carretera Iquitos-Nauta, 1 (MUSM 30844).

Registros adicionales: Provincia de Loreto, Distrito de Parinari: Hacienda Santa Elena, ca. 35 km NE of Tingo Maria (Thomas, 1928). Provincia de Maynas, Distrito de Las Amazonas: Quebrada Orán, 5 km N of Río Amazonas, 85 km NE of Iquitos (Abreu-Jr. *et al*., 2020). Distrito de San Juan Bautista: Cuenca del río Alto Itaya (Aquino *et al.*, 2012). Distrito de Iquitos: Santa Rita, Iquitos (de Vivo & Carmignotto, 2015). Distrito de Mazan: Mazan, between Iquitos and Pebas (Thomas, 1928). Distrito de Napo: boca Río Curaray (de Vivo & Carmignotto, 2015). Distrito de San Juan Bautista: Reserva Nacional Allpahuayo-Mishana (Hice & Velazco, 2012). Distrito Yaquerana: left bank at mouth of Río Yaquerana, alto Río Yavarí (Thomas, 1928); Provincia de Mariscal Ramón Castilla, Distrito de Pebas: Pebas (Thomas, 1928); Pebas, Río Amazonas (de Vivo & Carmignotto, 2015). Distrito de Yavarí: San Fernando, left bank Río Yavari (de Vivo & Carmignotto, 2015).

Comentarios: Abreu-Jr. *et al*. (2020) deciden hasta tener datos morfológicos más consistentes dejar el clado integrado por *flaviventer*, *sabanillae* y una 'especie 2', bajo el nombre "*Microsciurus*". En el área de estudio se colectaron dos hembras adultas, una en enero, preñada (R0 L2, CR = 5 mm) con las mamas desarrolladas, y otra en diciembre; ambas en bosque primario en trampas colocadas en el suelo.

## Suborden Myomorpha Brandts, 1855
## Familia Cricetidae G. Fischer, 1817
## Subfamilia Sigmodontinae Wagner, 1843

### *Amphinectomys savamis* Malygin, 1994

Distribución: esta especie es solo conocida de tres localidades en la selva baja amazónica del este de Perú y una localidad en Ecuador (Medina *et al.*, 2015; Weksler & Valqui, 2015; Chiquito & Percequillo, 2017).

Especímenes examinados: ninguno.

Registros adicionales: Provincia de Requena, Distrito de Requena: Jenaro Herrera: 7 km E of Jenaro Herrera, right bank Río Ucayali (localidad tipo de *Amphinectomys savamis*);

San Pedro, 80 km NE of Jenaro Herrera (Weksler & Valqui, 2015).

Comentarios: es una especie muy rara cuya localidad tipo se ubica muy cerca del área donde se realizó este estudio. Recientemente Medina *et al.* (2015) registró dos ejemplares más para Perú en la Zona Reservada Sierra del Divisadero (depto. Loreto), extendiendo su rango de distribución 177 km al sur.

### *Euryoryzomys macconnelli* (Thomas, 1910)

Distribución: *Euryoryzomys macconelli* se distribuye ampliamente en la Amazonia, en Guyana, Guyana Francesa, Suriname, Colombia, Venezuela, Brasil, Perú y Ecuador (Percequillo, 2015a).

Especímenes examinados: ninguno.

Registros adicionales: Provincia de Maynas, Distrito de San Juan Bautista: Yanayacu, Seis Unidos, Agua Blanquillo en el río Itaya (Calderón Saravia & Rengifo Vásquez, 2010).

Comentarios: esta especie fue descripta bajo el género *Oryzomys*, pero Weksler *et al*. (2006) la colocan en el nuevo género *Euryoryzomys*. Actualmente es considerada monotípica, pero presenta mucha variación en el cariotipo y en el ADN mitocondrial, lo que podría ser un señal de diversidad específica o subespecífica (Percequillo, 2015a).

### *Holochilus sciureus* Wagner, 1842

Distribución: esta especie se distribuye en las tierras bajas de las Guyanas, Bolivia, Perú y Brasil, probablemente se extienda hasta el noroeste de Argentina (Gonçalves *et al.*, 2015).

Especímenes examinados (12). Provincia de Maynas, Distrito de Punchana: Padrecocha, 1 (CML 13549). Distrito de San Juan Bautista: El Dorado, km 25 de la carretera Iquitos-Nauta, app. 1,5 km al E, 1 (MUSM 30285); El Dorado, km 25 de la carretera Iquitos-Nauta, app. 500 m al E, 2 (1 CML 13546, 1 MUSM 30286,); Moralillo, 2 km E del km 15,2 de la carretera Iquitos-Nauta, 1 (CML 13547); Ninarumi, 7,4 km al W y 500 m al SE del km 6 de la carretera Iquitos-Nauta, 3 (1 CML 13448, 1 MMD 2835, 1 MUSM 30289;); Ninarumi, 7,4 km al W del km 6 de la carretera Iquitos-Nauta, 1 (MUSM 30287); Paujil, W km 37,45 de la carretera Iquitos-Nauta, 1 (MUSM 30290); Varillal, 400 m W 200 m N del km 14 de la carretera Iquitos-Nauta, 1 (CML 13550); Zungarococha, 5,2 km al W del km 6 de la carretera Iquitos-Nauta, 1 (MUSM 30291).

Registros adicionales: Provincia de Maynas, Distrito de San Juan Bautista: Reserva Nacional Allpahuayo-Mishana (Hice & Velazco, 2012). Provincia de Requena, Distrito de Requena: Jenaro Herrera: Genaro Herrera (Aniskin, 1994).

Comentarios: Massoia (1981) eleva de categoría a *sciureus* separándola de los miembros del grupo *brasiliensis*. En el área de estudio se colectaron tres hembras y nueve machos; las hembras fueron colectadas en enero, dos de ellas presentaban las mamas desarrolladas, una estaba preñada; respecto a los machos, se registró una cría en febrero, dos juveniles, uno en diciembre y otro en junio, un subadulto en enero, y cinco adultos con testículos escrotales en marzo, junio y noviembre. Los ejemplares fueron colectados en crecimiento secundario (2) y en áreas de cultivo (9).

### *Hylaeamys perenensis* (J. A. Allen, 1901)

Distribución: Esta especie se extiende desde las tierras bajas y las selvas montanas al oeste de la Amazonia, desde Colombia, pasando por Ecuador y Perú hasta el noreste de Bolivia y el oeste de Brasil (Percequillo, 2015b).

Especímenes examinados (33). Provincia de Maynas, Distrito de Punchana: Comunidad de Manacamiri, Río Nanay, Fundo Morropón, 1 (MUSM 30295). Distrito de San Juan Bautista: 1 km E km 25,3 de la carretera Iquitos-Nauta (Fundo San Martín), 1 (MMD 4666); 2,9 km E del km 28,8 de la carretera Iquitos-Nauta (caserío Palo Seco), 3 (1 CML 7528; 2 MUSM 30292, 30293); Camino a El Paujil, 1,8 km al W del km 35 de la carretera Iquitos-Nauta, 2 (MMD 3518; MUSM 30294); El Dorado, km 25 de la carretera Iquitos-Nauta, app. 1,5 km al E, 4 (1 CML 7531; 3 MUSM 30296, 30297, 30298); Ex Petroleros, 300 m W km 39,8 de la carretera Iquitos-Nauta, 1 (CML 7532); Moralillo, 1,5 km E 400 m S del km 15,2 de la carretera Iquitos-Nauta, 1 (MUSM 30299); Moralillo, 1,5 km E 500 m

S del km 15,2 de la carretera Iquitos-Nauta, 8 (1 CML 7534; 7 MMD 729, 833, 2192; MUSM 30300, 30301, 30302, 30303); Paujil, W km 37,45 de la carretera Iquitos-Nauta, 2 (30304, 30305); San Lucas, W km 43 de la carretera Iquitos-Nauta, 2 (MUSM 30306, 30307); Varillal, 2 km W del km 13,6 de la carretera Iquitos-Nauta, 2 (MMD 1001; MUSM 30308); Zungarococha, 6,5 km al W del km 6 de la carretera Iquitos-Nauta, 6 (MMD 573, 586, 595, 609; MUSM 30309, 30311).

Registros adicionales: Provincia de Maynas, Distrito de San Juan Bautista: Agua Blanquillo en el río Itaya (Calderón Saravia & Rengifo Vásquez, 2010). Reserva Nacional Allpahuayo-Mishana (Hice & Velazco, 2012).

Comentarios: tanto esta especie como *yunganus* antes pertenecían al género *Oryzomys*, pero Weskler *et al.* (2006) las colocan en el nuevo género *Hylaeamys* Weksler, Percequillo & Voss, 2006, actualmente siete especies son reconocidas (Percequillo, 2015b). Se registraron hembras preñadas en enero (R1, L1, CR = 28 mm), mayo (L1, R2, CR = 25 mm), junio (R0, L4, CR = 33 mm), septiembre (R2, L1, CR = 21 mm) y diciembre (R2, L2, CR = 25 mm; R2, L2, CR = 14 mm); un juvenil en noviembre; subadultos en septiembre; y machos con testículos escrotales en los meses de enero, febrero, abril, junio, julio, octubre y diciembre. La mayoría de los ejemplares fueron colectados en bosque primario (30), sólo tres en bosque secundario, todos en trampas colocada en el suelo. Se registraron ninfas de *Ixodes luciae* Sénevet, 1940 (Acari: Ixodidae) en seis ejemplares (Díaz *et al*., 2007, 2009). Una muestra de riñón de un ejemplar resultó positiva para Leptospirosis (J. M. Vinetz, datos no publicados).

### *Hylaeamys yunganus* (Thomas, 1902)

Distribución: esta especie tiene una amplia distribución en la selva baja de la Amazonas de Brasil, Bolivia, Perú, Ecuador, Colombia, Venezuela, Guyana, Suriname y Guyana Francesa (Percequillo, 2015b).

Especímenes examinados (35). Provincia de Maynas, Distrito de San Juan Bautista: 1 km E km 25,3 de la carretera Iquitos-Nauta (Fundo San Martín), 6 (2 CML 7526, 7527; 2 MMD 4615, 4661; 2 MUSM 30312, 30313); 2,9 km E del km 28,8 de la carretera Iquitos-Nauta (caserío Palo Seco), 5 (1 CML 7529; 1 MMD, 4765; 3 MUSM 30315, 30316, 30317); app. 500 m E km 28,8 de la carretera Iquitos-Nauta, 3 (MUSM 30332, 30333, 30334); El Dorado, km 25 de la carretera Iquitos-Nauta, app. 1,5 km al E, 4 (1 CML 7530; 3 MUSM 30318, 30319, 30320); Moralillo, 1,5 km E 400 m S del km 15,2 de la carretera Iquitos-Nauta, 7 (2 CML 7533, 7536; 3 MMD 773, 819, 839; 2 MUSM 30321, 30322); Moralillo, 1,5 km E 500 m S del km 15,2 de la carretera Iquitos-Nauta, 2 (MUSM 30326, 30327); Ninarumi, 7,4 km al W y 1 km al SE del km 6 de la carretera Iquitos-Nauta, 1 (MMD 2831); Paujil, W km 37,45 de la carretera Iquitos-Nauta, 1 (CML 7537); Peña Negra, 800 m al E del km 11 de la carretera Iquitos-Nauta, 1 (MUSM 30328); San Lucas, W km 43 de la carretera Iquitos-Nauta, 1 (MUSM 30329); Varillal, 1,8 km W del km 13,6 de la carretera Iquitos-Nauta, 1 (MUSM 30330); Zungarococha, 5,2 km al W del km 6 de la carretera Iquitos-Nauta, 2 (1 MMD 1975; 1 MUSM 30331); Zungarococha, 6,5 km al W del km 6 de la carretera Iquitos-Nauta, 1 (MMD 1947).

Registros adicionales: Provincia de Maynas, Distrito de San Juan Bautista: Reserva Nacional Allpahuayo-Mishana (Hice & Velazco, 2012).

Comentarios: se registraron hembras preñadas en enero (sin medidas), junio (R2, L2, CR = 26 mm), septiembre (R1, L1, CR = 5 mm; R1, L1, CR = 31 mm), marzo (R1, L3, CR = 12 mm), abril (L2, R2, CR = 10 mm) y junio (R2, L1, CR = 28 mm); una cría en mayo; juveniles en enero, marzo, junio y agosto; subadultos en enero, abril, junio y agosto; y machos con testículos escrotales en enero, marzo, abril, junio y noviembre. La mayoría de los ejemplares fueron colectados en bosque primario (19) y secundario (12), dos en ecotono entre ambos bosques y dos en área cultivada, en trampas colocadas en el suelo.

Al igual que en la especie anterior se registraron ninfas de *I. luciae* (Acari: Ixodidae) en nueve especímenes, la prevalencia mostró que *H. perenensis* y *H. yunganus* fueron especies significativamente más propensas a estar infectadas por ninfas de *I. luciae* que *Oligoryzomys microtis* (Díaz *et al.*, 2007, 2009). Nemátodos fueron registrados en el estómago de un ejemplar colectado en crecimiento secundario (Portocarrero *et al.*, 2005). Un ejemplar, tanto en tejidos de riñón y en orina, resultó positivo para Leptospirosis (J. M. Vinetz, datos no publicados).

### *Neacomys amoenus* Thomas, 1903

*Neacomys “amoenus carceleni”* Hershkovitz, 1940

Distribución: esta especie se distribuye en la Amazonía, en Ecuador (departamentos de Pastaza y Francisco de Orellana), Perú (departamentos de Loreto, Madre de Dios y Ucayali) y en Brasil (estados de Acre y Amazonas), entre los 200 y 750 m (Hurtado & Pacheco, 2017).

Especímenes examinados (42): Provincia de Maynas, Distrito de Punchana: Comunidad de Manacamiri, Río Nanay, Fundo Morropon, 11 (1 MMD 3189; 10 MUSM 30354, 30355, 30356, 30357, 30358, 30359, 30360, 30361, 30362, 30363). Distrito de San Juan Bautista: 2,9 km E del km 28,8 de la carretera Iquitos-Nauta (caserío Palo Seco), 3 (1 MMD 4797; 3 MUSM 30339, 30352, 30353); app. 500 m E km 28,8 de la carretera Iquitos-Nauta, 1 (CML 13576); El Dorado, km 25 de la carretera Iquitos-Nauta, app. 1,5 km al E, 6 (1 CML 13578; 2 MMD 1672, 1683; 3 MUSM 30364, 30365, 30366); Moralillo, 1,5 km E 400 m S del km 15,2 de la carretera Iquitos-Nauta, 7 (1 CML 13579; 7 MUSM 30367, 30368, 30369, 30370, 30371, 30372, 30373); Moralillo, 2 km E del km 15,2 de la carretera Iquitos-Nauta, 3 (1 CML 13580; 2 MUSM 30374, 30375); San Lucas, W km 43 de la carretera Iquitos-Nauta, 7 (1 MMD 3803; 6 MUSM 30376, 30377, 30378, 30379, 30380, 30381); Zungarococha, 5,2 km al W del km 6 de la carretera Iquitos-Nauta, 2 (CML 13581, 13582).

Registros adicionales: Provincia de Maynas, Distrito de Iquitos: Colonia, Criadero en Laboratorio Casa Pevas 354. Distrito San Juan Bautista: Cahuide km 61 carretera Iquitos-Nauta; Caserío Cahuide km 60 carretera Iquitos-Nauta, O del camino; Caserío Cahuide km 59 carretera Iquitos-Nauta; La Habana km 54,5 carretera Iquitos-Nauta, 0,78 km O del camino; El Triunfo km 49 carretera Iquitos-Nauta; El Triunfo km 48 carretera Iquitos-Nauta; El Paujil km 37 carretera Iquitos-Nauta; 1 km E km 25,3 de la carretera Iquitos-Nauta, Fundo San Martín; Iquitos Avícola San Miguel, km 3 carretera Iquitos-Nauta; Manzanillo Río Amazonas (Hurtado & Pacheco, 2017); Reserva Nacional Allpahuayo-Mishana [Hice & Velazco, 2012 como *Neacomys spinosus* (Thomas, 1882)].

Comentarios: Hurtado & Pacheco (2017) concluyen de acuerdo a la evidencia procedentes de los análisis morfológicos y moleculares que *N. spinosus* s.l. es monofilético pero representa un complejo de especies, reconociendo *N. spinosus* s.s. como especie válida y a *N. amoenus* como un taxón complejo donde *N. a. amoenus* y *N. a. carceleni* se consideran subespecies. Por otro lado, dichos autores consideran a *N. spinosus* endémico de las selvas de montañas de Perú. Si bien en este trabajo se decidió colocar todos los ejemplares identificados originalmente como *N. spinosus* como *N. a. carceleri* por la distribución dada por Hurtado & Pacheco (2017) cabe mencionar que algunos de los ejemplares de la zona de Iquitos presentan el vientre con base de pelos grises y otros blanco puros, incluso ejemplares colectados en la misma localidad el mismo día; por lo que no coincidiría con el carácter propuesto por Hurtado & Pacheco (2017) para *N. a. carceleni*, al igual que algunos caracteres propuestos para *N. spinosus* como el extremo de los pelos dorsales de color negro, siendo por lo tanto necesario revisar los ejemplar para establecer si se trata de una o dos especies como así también la lista de caracteres aportada por estos autores.

En total se colectaron 14 hembras, dos juveniles en los meses de junio y diciembre, y de las adultas nueve estuvieron preñadas (algunas medidas de los fetos son: en enero R3, L1, CR = 24 mm; R1, L2, en abril R1, L2, CR = 20 mm; R1, L3, CR =15 mm; R2, L2, CR = 15 mm; en junio CR = 8 mm; R2, L1, en octubre CR = 4 mm; en noviembre R3, L1, CR = 17 mm). Respecto a los machos se registraron todos ejemplares adultos (27) excepto un subadulto en junio, 18 con testículos escrotales a lo largo del año exceptuando febrero, mayo, julio y agosto. Sólo dos ejemplares fueron colectados en trampas de caída, el resto se colectaron en trampas colocadas en el suelo. Cuatro especímenes se colectaron en bosque primario, 30 en bosque secundario y ocho en área de cultivo.

### *Neacomys minutus* Patton, da Silva & Malcolm, 2000

Distribución: *Neacomys minutus* se encuentra en las tierras bajas del oeste del Amazonas, desde las secciones central y más bajas del Río Juruá en Brasil y el río Gálvez en el noroeste de Perú (Weksler & Bonvicino, 2015a).

Especímenes examinados (24): Provincia de Maynas, Distrito de Punchana: Padrecocha, 1 (MUSM 30345). Distrito de San Juan Bautista: 1 km E km 25,3 de la carretera Iquitos-Nauta (Fundo San Martín), 6 (1 CML 13573; 1 MMD 4662; 4 MUSM 30335, 30336, 30337, 30338); 2,9 km E del km 28,8 de la carretera Iquitos-Nauta (caserío Palo Seco), 2 (MMD 4771, 4783); app. 500 m E km 28,8 de la carretera Iquitos-Nauta, 1 (MUSM 30351); Camino a El Paujil, 1,8 km al W del km 35 de la carretera Iquitos-Nauta, 4 (2 CML 13574, 13575; 2 MUSM 30340, 30341); El Dorado, km 25 de la carretera Iquitos-Nauta, app. 1,5 km al E, 1 (CML 13570); Ex Petroleros, 300 m W km 39,8 de la carretera Iquitos-Nauta, 2 (1 CML 13571; 1 MUSM 30343, 30344); Moralillo, 1,5 km E 500 m S del km 15,2 de la carretera Iquitos-Nauta, 2 (1 MMD 782, 1 CML 13572); Peña Negra, 800 m al E del km 11 de la carretera Iquitos-Nauta, 1 (MUSM 30347); San Lucas, W km 43 de la carretera Iquitos-Nauta, 2 (1 MMD 3798; 1 MUSM 30348); Zungarococha, 6,5 km al W del km 6 de la carretera Iquitos-Nauta, 1 (MUSM 30350).

Registros adicionales: Provincia de Requena, Distrito de Yaquerana: Nuevo San Juan, Río Gálvez (Weksler & Bonvicino, 2015a).

Comentarios: hasta el momento *Neacomys minutus* no había sido citada para la provincia de Maynas, la localidad más cercana correspondía a Río Gálvez; estos registros extienden la distribución aproximadamente 160 km al noroeste; esta extensión es importante ya que son escasos los registros que se conocen de esta especie.

Dos de los ejemplares aquí citados fueron identificados por Hurtado & Pacheco (2017) como *N. a. carceleni* (MUSM, 30335, 30336), pero son de pequeño tamaño para pertenecer a esta especie. El ejemplar MUSM 30350 es considerado como una especie nueva descripta recientemente por Sánchez-Vendizú *et al*. (2018); sin embargo en este trabajo se mantiene bajo esta especie hasta poder revisarlo nuevamente. Se capturaron nueve hembras, cuatro preñadas (en mayo L1, R1, CR = 22 mm; L2, R0, CR = 10 mm; en junio R1, L0, CR = 15 mm; en diciembre R2, L0, CR = 4 mm), tres con vagina abierta y mamas desarrolladas en junio (2) y julio, y dos con vagina cerrada y mamas desarrolladas en marzo y mayo, y 15 machos, siete con testículos escrotales en enero (2), febrero, mayo, julio (2) y diciembre, un subadulto en febrero. Ocho ejemplares procedían de crecimiento secundario y 16 de bosque primario; cinco fueron colectados en trampa de caída y el resto en trampas colocadas en el suelo.

### *Neacomys musseri* Patton, da Silva & Malcolm, 2000

Distribución: esta especie se distribuye al oeste del Amazonas de Brasil y Perú (Weksler & Bonvicino, 2015a).

Especímenes examinados (1): Provincia de Maynas, Distrito de San Juan Bautista: app. 500 m E km 28,8 de la carretera Iquitos-Nauta, 1 (CML 13569).

Registros adicionales: Provincia de Requena, Distrito de Yaquerana: Nuevo San Juan, Río Gálvez (Weksler & Bonvicino, 2015a).

Comentarios: al igual que la especie anterior, *N. musseri* no había sido citada para la provincia de Maynas, y el registro más cercano también corresponde al Río Gálvez; por lo tanto, estos registros extienden la distribución aproximadamente 160 km al noroeste, el registro más boreal de la especie. El único ejemplar examinado, una hembra adulta con mamas desarrolladas, fue colectado en el mes de marzo en bosque primario en una trampa colocada en el suelo.

### *Neacomys rosalindae* Sánchez-Vendizú, Pacheco & Vivas-Ruiz, 2018

Distribución: esta especie se distribuye al norte del río Amazonas en el noroeste de Perú, en los departamentos de Loreto y Amazonas y al este de Ecuador (Sánchez-Vendizú *et al*., 2018).

Especímenes examinados: ninguno.

Registros adicionales: <u>Provincia de Maynas</u>, Distrito de Punchana: Punto Alegre. Distrito de San Juan Bautista, Llanchama; Llanchama near to the Varillal station of the Allpahuayo-Mishana National Reserve; km 25 road Iquitos-Nauta; south bank of the Nanay River; Nina Rumi; Nuevo Horizonte km 39 road Iquitos-Nauta; Peña Negra km 10 road Iquitos-Nauta; San Gerardo km 18,5 road Iquitos-Nauta; San Lucas km 44 road Iquitos-Nauta (Sánchez-Vendizú *et al*., 2018).

Comentarios: esta especie fue descripta recientemente y procede de la zona de estudio, por lo que todos los *Neacomys* de esta zona deberán ser revisado con el objetivo de establecer si algún ejemplar pertenece a esta especie.

### *Neacomys* sp.

Especímenes examinados (5): <u>Provincia de Maynas</u>, Distrito de Punchana: Comunidad de Manacamiri, Río Nanay, Fundo Morropón, 1 (MUSM 30342); Padrecocha, carretera Shihua, 1 (MUSM 30346). Distrito de San Juan Bautista: Moralillo, 1,5 km E 400 m S del km 15,2 de la carretera Iquitos-Nauta, 2 (MMD 2166, 2202); Varillal, 2 km W del km 13,6 de la carretera Iquitos-Nauta, 1 (MUSM 30349).

Comentarios: los ejemplares aquí listados pertenecen a una forma pequeña del género, no pudieron identificarse debido a su preservación en alcohol (sin cráneos removidos) no pudieron evaluarse aquellos caracteres que permiten definir la especie. Los ejemplares podrían pertenecer a algunas de las especies tratadas en este estudio.

### *Melanomys robustulus* Thomas, 1914

Distribución: se encuentra en el sureste de Ecuador y noroeste de Perú (Weksler & Lóss, 2015).

Especímenes examinados: ninguno.

Registros adicionales: <u>Provincia de Maynas</u>, Distrito de Napo: Boca del Río Curaray (Pacheco *et al.*, 2009).

Comentarios: este género fue tratado como subgénero de *Oryzomys* Baird, 1857 por Tate (1932); si bien la monofilia del género fue recuperado con caracteres morfológicos, los análisis con datos moleculares recuperan *Sigmodontomys* J. A. Allen, 1897 dentro de este género, es necesario realizar más estudios para aceptar o rechazar este ordenamiento (ver Weksler & Lóss, 2015). Esta especie se registra en selva baja, es nocturna, terrestre y solitaria, los demás aspectos de su historia natural son desconocidos (Weksler & Lóss, 2015; Vallejo & Boada, 2018a). Es la especie más grande dentro del género y su coloración es cobriza a diferencia de *M. caliginous* (Tomes, 1860) y *M. columbianus* (J. A. Allen, 1899) que son oliváceos (Weksler & Lóss, 2015).

### *Nectomys apicalis* Peters, 1861

Distribución: se encuentra en Brasil, Perú, Ecuador y Bolivia (Gómez-Laverde *et al*., 2016).

Especímenes examinados (6). <u>Provincia de Maynas</u>, Distrito de San Juan Bautista: 13 de Febrero, Fundo Nemith, E km 33 de la carretera Iquitos-Nauta, 2 (MUSM 30382, 30383); El Dorado, km 25 de la carretera Iquitos-Nauta, app. 500 m al E, 1 (CML 13583); Paujil, W km 37,45 de la carretera Iquitos-Nauta, 2 (1 MMD 3850, 1 CML 13584); Varillal, 400 m W 200 m N del km 14 de la carretera Iquitos-Nauta, 1 (MUSM 30384).

Registros adicionales: <u>Provincia de Maynas</u>, Distrito de Napo: Boca del Río Curaray (Bonvicino & Weksler, 2015). Distrito de San Juan Bautista: Reserva Nacional Allpahuayo-Mishana (Hice & Velazco, 2012).

Comentarios: se registró una hembra subadulta en noviembre y una hembra vagina abierta en octubre, y machos testículos escrotales en junio, octubre y noviembre. Esta especie está asociada a cuerpos de agua (Patton *et al*., 2000); en el área de estudio los ejemplares fueron colectados en bosque de crecimiento secundario (1) y área de cultivo (5), uno de ellos fue capturado cerca de una quebrada con agua y otro en un tronco en el suelo. Se registraron endoparásitos en dos ejemplares, nemátodos y pentastómidos (Portocarrero *et al.*, 2005).

### *Nectomys rattus* Pelzeln, 1883

Distribución: se encuentra en Colombia, Venezuela, Perú, Guyana, Guyana Francesa, Paraguay y Brasil (Bonvicino & Weksler, 2015).

Especímenes examinados: ninguno.

Registros adicionales: Provincia de Alto Amazonas, Distrito de Lagunas: Lagunas (Bonvicino & Weksler, 2015).

Comentarios: no se colectó ningún ejemplar de esta especie en el área de estudio, el registro en Lagunas se ubica aproximadamente 300 km al sudoeste de Iquitos.

### *Oecomys bicolor* (Tomes, 1860)

Distribución: se encuentra en las tierras bajas de las selvas trasandinas desde Panamá a Ecuador, la Amazonia en Colombia, Venezuela, las Guyanas, Perú, Ecuador, Bolivia y Brasil (Carleton & Musser, 2015).

Especímenes examinados (6). Provincia de Maynas, Distrito de San Juan Bautista: 1 km E km 25,3 de la carretera Iquitos-Nauta (Fundo San Martín), 3 (1 CML 13585; 2 MUSM 30385, 30386); Ex Petroleros, 300m W km 39,8 de la carretera Iquitos-Nauta, 2 (MUSM 30387, 30388); Moralillo, 1,5 km E 400 m S del km 15,2 de la carretera Iquitos-Nauta, 1 (CML 13586).

Registros adicionales: Provincia de Loreto, Distrito de Nauta: San Jacinto (Carleton & Musser, 2015); Provincia de Maynas, Distrito de San Juan Bautista: Reserva Nacional Allpahuayo-Mishana (Hice & Velazco, 2012).

Comentarios: se capturaron dos hembras preñadas en enero y febrero, en esta última los datos de los fetos son: R1, L1, CR = 13 mm. Todos los machos registrados fueron adultos, tres con testículos escrotales en febrero y marzo. Tres ejemplares fueron colectados en bosque de crecimiento primario y tres en crecimiento secundario; dos de ellos en trampas colocadas en lianas a 80 cm del suelo, dos en trampas en el suelo, una sobre un tronco y un ejemplar en trampa de caída. Y precisamente las especies de este género son consideradas arborícolas y suelen registrarse en áreas con abundantes lianas a pocos metros del suelo (Hershkovitz, 1960; Emmons & Feer, 1999; Patton *et al*., 2000). En uno de los ejemplares se registraron larvas de *Ixodes* Latreille, 1795, dichas larvas fueron tentativamente identificadas como *I. luciae* con la salvedad que son indistinguibles de *I. loricatus* Neumann, 1899 (Díaz *et al.*, 2009).

### *Oecomys paricola* (Thomas, 1904)

Distribución: *Oecomys paricola* se encuentra en el centro de Brasil y noreste de Perú (Carleton & Musser, 2015).

Especímenes examinados (3): Provincia de Maynas, Distrito de San Juan Bautista: 1 km E km 25,3 de la carretera Iquitos-Nauta (Fundo San Martín), 1 (MUSM 30389); 2,9 km E del km 28,8 de la carretera Iquitos-Nauta (caserío Palo Seco), 1 (MUSM 34390); app. 500 m E km 28,8 de la carretera Iquitos-Nauta, 1 (CML 13589).

Registros adicionales: Provincia de Loreto, Distrito de Nauta: San Jacinto (Carleton & Musser, 2015). Provincia de Maynas, Distrito de San Juan Bautista: Estación Biológica Allpahuayo, 25 km SW of Iquitos, on Iquitos-Nauta Highway (Hice & Velazco, 2012; Carleton & Musser, 2015).

Comentarios: se colectaron tres ejemplares, un macho con testículos escrotales en marzo y dos hembras con vagina cerrada en mayo y junio. Dos ejemplares fueron colectados en trampas de caída en bosque primario y el tercer ejemplar en una trampa colocada sobre una rama a medio metro del suelo en un área de crecimiento secundario.

### *Oecomys phaeotis* (Thomas, 1901)

Distribución: esta especie se encuentra en la ladera este de los Andes desde Perú al norte de Bolivia (Carleton & Musser, 2015).

Especímenes examinados (1): Provincia de Maynas, Distrito de San Juan Bautista: Camino a El Paujil, 1,8 km al W del km 35 de la carretera Iquitos-Nauta, 1 (CML 13587).

Registros adicionales: Provincia de Maynas, Distrito de Las Amazonas: Quebrada Orán, 5 km N of Río Amazonas, 85 km NE of Iquitos (Carleton & Musser, 2015).

Comentarios: en este estudio sólo se colectó un ejemplar adulto macho con testículos abdominales, en el mes de julio, en una trampa colocada sobre un árbol en bosque primario.

### *Oecomys roberti* (Thomas, 1904)

Distribución: esta especie se encuentra al sur de Venezuela, Guyana, Suriname, norte y centro oeste de Brasil, este de Colombia y Perú y extremo este de Bolivia (Carleton & Musser, 2015).

Especímenes examinados (2): Provincia de Maynas, Distrito de Belén: Moenacaño, 1 (MUSM 30398). Distrito de San Juan Bautista: Zungarococha, 6,5 km al W del km 6 de la carretera Iquitos-Nauta, 1 (CML 13588).

Registros adicionales: Provincia de Mariscal Ramon Castilla, Distrito San Pablo: Boca Río Peruate (Carleton & Musser, 2015). Provincia de Maynas, Distrito de San Juan Bautista: Reserva Nacional Allpahuayo-Mishana (Hice & Velazco, 2012); Seis Unidos; Yanayacu (Calderón Saravia & Rengifo Vásquez, 2010).

Comentarios: se capturaron dos machos adultos con testículos semiescrotales en agosto y noviembre, uno en bosque primario y otro en bosque secundario, en trampas colocadas en el suelo.

### *Oecomys superans* Thomas, 1911

Distribución: Colombia, Ecuador, Perú y Brasil (Carleton & Musser, 2015).

Especímenes examinados: ninguno.

Registros adicionales: Provincia de Maynas, Distrito de Napo: Boca del Río Curaray (Carleton & Musser, 2015).

Comentarios: el registro más cercano a la zona de estudio corresponde al río Curaray aproximadamente a 170 km al noroeste de Iquitos.

### *Oecomys trinitatis* (J. A. Allen and Chapman, 1893)

Distribución: esta especie se distribuye en Trinidad y Tobago, Venezuela, Guyana, Suriname, Ecuador, Perú, Brasil y Bolivia (Carleton & Musser, 2015).

Especímenes examinados (1): Provincia de Maynas, Distrito de San Juan Bautista: Ex Petroleros, 300 m W km 39,8 de la carretera Iquitos-Nauta, 1 (CML 13590).

Registros adicionales: Provincia de Loreto, Distrito de Nauta: San Jacinto (Carleton & Musser, 2015). Provincia de Requena, Distrito de Yaquerana: Río Gálvez (Pardiñas *et al.*, 2016).

Comentarios: sólo se colectó un ejemplar, adulto macho con testículos escrotales en febrero, en una trampa de caída colocado en bosque primario. Este registro sería el primero para la provincia de Maynas, ya que solo había sido registrado para Loreto y Requena, al sur de Maynas.

### *Oligoryzomys microtis* (J. A. Allen, 1916)

Distribución: esta especie tiene una amplia distribución en el Amazonas del este de Perú, noreste de Bolivia, y oeste de Brasil extendiéndose al este a lo largo del Río Amazonas (Weksler & Bonvicino, 2015b).

Especímenes examinados (46): Provincia de Maynas, Distrito de San Juan Bautista: El Dorado, km 25 de la carretera Iquitos-Nauta, app. 1,5 km al E, 1 (MUSM 30391); El Dorado, km 25 de la carretera Iquitos-Nauta, app. 500 m al E, 2 (1 CML 13591; 1 MUSM 30392); Ex Petroleros, 300 m W km 39,8 de la carretera Iquitos-Nauta, 6 (1 MMD 4312; 5 MUSM 30393, 30394, 30395, 30396, 30397); km 22,7 de la carretera Iquitos-Nauta, 1 (CML 13592); Moralillo, 1,5 km E 400 m S del km 15,2 de la carretera Iquitos-Nauta, 2 (MUSM 30399, 30400); Moralillo, 2 km E del km 15,2 de la carretera Iquitos-Nauta, 12 (2 CML 13593, 13594; 1 MMD 2219; 9 MUSM 30401; 30402, 30403, 30404, 30405, 30406, 30407, 30408, 30409); Peña Negra, 200 m al E del km 10,7 de la carretera Iquitos-Nauta, 3 (2 CML 13595, 13596; 1 MUSM 30410); Varillal, 400 m W 200 m N del km 14 de la carretera Iquitos-Nauta, 4 (1 CML 13597; 1 MMD 1031, 2 MUSM 30411, 30412); Zungarococha, 5,2 km al W del km 6 de la carretera Iquitos-Nauta, 15 (4 CML 13598, 13599, 13600, 13601;

1 MMD 1948; 10 MUSM 30413, 30414, 30415, 30416, 30424, 30419, 30420, 30421, 30422, 30423).

Registros adicionales: Provincia de Maynas, Distrito de Iquitos: Zona Marina district of the City of Iquitos (Powers *et al.*, 1999). Distrito de San Juan Bautista: Mishana Allpahuayo (Aniskin, 1994); Reserva Nacional Allpahuayo-Mishana (Hice & Velazco, 2012). Provincia de Requena, Distrito de Requena: Jenaro Herrera (Aniskin, 1994).

Comentarios: se colectaron 14 hembras, cuatro juveniles, dos en enero, uno en marzo y uno en septiembre; de las adultas siete estaban preñadas, cinco en diciembre, una en marzo y una en septiembre (medidas registradas en los fetos: en marzo R3, L0, CR = 12 mm; en diciembre R2, L2, CR = 7 mm; R0, L4, CR = 10 mm; R2, L2, CR = 3 mm; R0, L3, CR = 11 mm); además se registraron dos hembras lactando en diciembre y con mamas desarrolladas en mayo. Respecto a los machos se colectaron 32 ejemplares, cuatro juveniles, dos en enero y los otros uno en junio y el otro en diciembre; adultos con testículos escrotales (22) se registraron en los meses de enero (3), febrero (2), marzo (1), mayo (1), junio (2), septiembre (3) y diciembre (6); testículos semiescrotales se registraron solo tres, en agosto y diciembre; y el resto con testículos abdominales (7), en febrero (4), marzo (1) y septiembre (2). Todos los ejemplares fueron colectados en trampas Sherman colocadas en el piso, nueve en crecimiento secundario, 35 en ambientes rurales, uno en una casa y el resto en área de cultivo, y dos en un ecotono entre crecimiento secundario y área de cultivo. En un ejemplar de esta especie (CML 13593) se registró una ninfa de *Ixodes luciae* (Díaz *et al*., 2007, 2009).

### *Rhipidomys leucodactylus* (Tschudi, 1845)

Distribución: *Rhipidomys leucodactylus* se encuentra en las Guyanas, sur de Venezuela, norte y centro de Brasil, Ecuador, Perú, y oeste y centro de Bolivia (Patton *et al.*, 2016).

Especímenes examinados (1): Provincia de Maynas, Distrito de San Juan Bautista: 1 km E km 25,3 de la carretera Iquitos-Nauta (Fundo San Martín), 1 (MUSM 30425).

Registros adicionales: Provincia de Maynas, Distrito de Napo: Mouth of Río Curaray (Tribe, 2015). Distrito de San Juan Bautista: Reserva Nacional Allpahuayo-Mishana (Hice & Velazco, 2012).

Comentarios: durante este estudio solo se colectó una hembra adulta en el mes de mayo lactando, sobre un árbol en una trampa colocada a 19 m en bosque primario. La colecta de ejemplares en un árbol era de esperarse ya que es una especie especialista en la vida arborícola lo que se refleja en la estructura de sus patas traseras; puede usar todos los estratos del bosque, incluso se registraron refugios en huecos de árboles (Emmons & Feer, 1999; Tribe, 2015; Vallejo & Boada, 2018b).

### *Scolomys melanops* Anthony, 1924

Distribución: se encuentra al este de Ecuador y noroeste de Perú al norte del río Amazonas (Patton, 2015).

Especímenes examinados (7): Provincia de Maynas, Distrito de Punchana: Comunidad de Manacamiri, Río Nanay, Fundo Morropón, 1 (MUSM 30428). Distrito de San Juan Bautista: 1 km E km 25,3 de la carretera Iquitos-Nauta (Fundo San Martín), 1 (CML 13602); 2,9 km E del km 28,8 de la carretera Iquitos-Nauta (caserío Palo Seco), 2 (MUSM 30426, 30427); Moralillo, 1,5 km E 500 m S del km 15,2 de la carretera Iquitos-Nauta, 2 (1 CML 136031; 1 MUSM 30429); Paujil, W km 37,45 de la carretera Iquitos-Nauta, 1 (MUSM 30430).

Registros adicionales: Provincia de Loreto: Distrito de Nauta: Nauta (Calderón Saravia & Rengifo Vásquez, 2010). Provincia de Maynas, Distrito de San Juan Bautista: Estación Biológica Allpahuayo (Hice, 2001; Hice & Velazco, 2012); Seis Unidos; Yanayacu (Calderón Saravia & Rengifo Vásquez, 2010); Yanayacu, cuenca alta del Río Itaya, 70 km al suroeste de Iquitos (Rengifo & Aquino, 2012). Distrito de Las Amazonas: Quebrada Orán, ca. 5 km N of Río Amazonas, 85 km NE of Iquitos (Patton, 2015). Provincia de Loreto, Distrito de Nauta: San Jacinto (Patton, 2015).

Comentarios: se colectaron solo dos hembras, ambas con mamas desarrolladas en abril y en septiembre, y esta última preñada (R1, L1, CR = 7 mm); y sólo un macho con testículos escrotales en mayo. Dos ejemplares fueron colectados en purma, el resto en bosque primario, dos de ellos colectados en trampas de caída y el resto en trampas colocadas en el suelo.

### *Scolomys ucayalensis* Pacheco, 1991

Distribución: esta especie se distribuye en la selva baja desde el extremo sur de Colombia al noreste de Perú, oeste de Brasil y sur de Ecuador (Patton, 2015).

Especímenes examinados (2): Provincia de Maynas, Distrito de San Juan Bautista: Ex Petroleros, 300 m W km 39,8 de la carretera Iquitos-Nauta, 2 (1 CML 13604; 1 MMD, 4278).

Registros adicionales: Provincia de Requena, Distrito de Requena: 2,8 km E of Jenaro Herrera (type locality of *Scolomys ucayalensis* Pacheco). Distrito de Yaquerana: Nuevo San Juan, Río Gálvez (Patton, 2015).

Comentarios: sólo se colectaron una hembra adulta preñada (CR = 5 mm) y un macho juvenil en el mes de febrero. Ambos fueron colectados en trampas de caída en bosque primario. Las únicas medidas con las que se cuenta de la hembra adulta son: longitud cabeza y cuerpo, 98 mm; longitud de la pata, 21 mm; longitud de la oreja; 17 mm y el peso, 22,5. Algunos autores mencionan la probabilidad que las especies de *Scolomys* Anthony, 1924 se encuentren en simpatría al norte del eje Río Marañón-Río Amazonas (Hice & Velazco, 2012; Patton, 2015). Aquí se confirmaría la presencia de ambas especies en la misma área.

## Suborden Hystricomorpha Brandt, 1855

## Familia Echimyidae Gray, 1825

### *Isothrix bistriata* Wagner, 1845

Distribución: esta especie se encuentra en la Amazonia del Perú, Bolivia y Brasil, y probablemente se extienda al Ecuador y sur de Colombia (Emmons & Patton, 2015a).

Especímenes examinados (1): Provincia de Maynas, Distrito de Belén: Mazanillo, 1 (MUSM 30431).

Registros adicionales: Provincia de Maynas, Distrito de Napo: Boca Río Curaray (Patton & Emmons, 1985). Distrito de Mazán: at the mouth of the Rio Mazán [Thomas, 1928, as *Isothrix villosa* (Deville, 1852)]. Distrito San Juan Bautista: Reserva Nacional Allpahuayo-Mishana (Hice & Velazco, 2012). Provincia Mariscal Ramón Castilla, Distrito de Pebas: Pebas (Thomas, 1928 as *Isothrix villosa*). Provincia de Requena, Distrito de Yaquerana: Nuevo San Juan Bautista (Emmons & Patton, 2015a).

Comentarios: sólo se colectó un ejemplar, una hembra adulta con las mamas inguinales marcadas en octubre de 2005, en una Tomahawk a 8 m de altura en un árbol de mango, en un área cultivada cercana a una zona de crecimiento secundario.

### *Makalata macrura* (Wagner, 1842)

Distribución: se distribuye en el oeste de la Amazonia, incluyendo el sur de Colombia y Venezuela, este de Ecuador, norte y centro de Perú y este de Brasil (Emmons & Patton, 2015b).

Especímenes examinados: ninguno.

Registros adicionales: Provincia Mariscal Ramón Castilla, Distrito de Yavarí: Nazareth (= Amelia) (Emmons & Patton, 2015b); Provincia de Maynas, Distrito San Juan Bautista: Reserva Nacional Allpahuayo-Mishana (Hice & Velazco, 2012).

Comentarios: Hice & Velazco (2012) citan tres ejemplares de esta especie para la Reserva Nacional Allpahuayo-Mishana todos colectados en selva inundada.

### *Mesomys hispidus* (Desmarest, 1817)

Distribución: se distribuye en la Amazonia desde el norte y este de Bolivia, este de Perú y Ecuador, sureste de Colombia, sur de Venezuela, las Guyanas y Brasil (Patton & Emmons, 2015).

Especímenes examinados (10): Provincia de Maynas, Distrito de San Juan Bautista: app. 500 m E km 28,8 de la carretera Iquitos-Nauta, 2 (1 CML 13605, 1 MMD 4474);

Camino a El Paujil, 1,8 km al W del km 35 de la carretera Iquitos-Nauta, 1 (MUSM 30433); Moralillo, 1,5 km E 400 m S del km 15,2 de la carretera Iquitos-Nauta, 2 (MUSM 30434); Moralillo, 1,5 km E 500 m S del km 15,2 de la carretera Iquitos-Nauta, 1 (MUSM 30435); Ninarumi, 7,4 km al W y 500 m al SE del km 6 de la carretera Iquitos-Nauta, 1 (MUSM 30436); Peña Negra, 200 m al E del km 10,7 de la carretera Iquitos-Nauta, 2 (CML 13606, 13607); Zungarococha, 5,2 km al W del km 6 de la carretera Iquitos-Nauta, 1 (MUSM 30437); Zungarococha, 6,5 km al W del km 6 de la carretera Iquitos-Nauta, 1 (CML 13608).

Registros adicionales: <u>Provincia de Maynas</u>, Distrito San Juan Bautista: Agua Blanquillo (Calderón Saravia & Rengifo Vásquez, 2010). Reserva Nacional Allpahuayo-Mishana (Hice & Velazco, 2012).

Comentarios: sólo se colectaron 10 ejemplares, dos en trampas colocada a 14 m, seis en trampas colocadas en el suelo, uno en una Sherman colocada sobre un tronco y un juvenil fue capturado por mano por un poblador en un árbol, en el mismo se registró el nido donde estaba el ejemplar. Tres ejemplares fueron juveniles, dos hembras y un macho, capturados en febrero, marzo y julio (ver Figura 4, ejemplar MUSM 30433). Entre los adultos, se registraron tres hembras, dos preñadas (R0, L2, CR = 46 mm) en diciembre y enero, y una lactando en mayo; de los cuatro machos colectados, sólo uno presentó testículos escrotales en el mes de diciembre. En bosque primario se registraron cinco ejemplares, dos en bosque secundario y tres en áreas cultivadas. Si bien se han incluido todos los ejemplares colectados bajo la misma especie se han encontrado algunas variaciones en el pelaje y en los cráneos que deberían revisarse, como ser la variación en el desarrollo del pincel, en el color del vientre (varía de ocre fuerte a blanco sucio) y algunas variaciones en el largo del paladar.

### *Proechimys brevicauda* (Günther, 1876)

Distribución: esta especie ocurre a través del oeste de la Amazonia, desde el sur de Colombia y este de Ecuador, Perú, noroeste de Bolivia y Brasil (Patton & Leite, 2015).

Figura 4. Espécimen hembra (MUSM 30433), juvenil de *Mesomys hispidus* (Echimyidae) colectado en Camino a El Paujil, 1,8 km al W del km 35 de la carretera Iquitos-Nauta. Foto: M. M. Díaz (2004)

Especímenes examinados (118): <u>Provincia de Maynas</u>, Distrito de San Juan Bautista: 13 de Febrero, Fundo Nemith, E km 33 de la carretera Iquitos-Nauta, 8 (1 CML 13609; 7 MUSM 30439, 30440, 30441, 30442, 30443, 30444, 30445); 2,9 km E del km 28,8 de la carretera Iquitos-Nauta (caserío Palo Seco), 8 (MUSM 30446, 30447, 30448, 30450, 30451, 30452, 30453, 30454); app. 500 m E km 28,8 de la carretera Iquitos-Nauta, 4 (MUSM 30547, 30548, 30549, 30550); Camino a El Paujil, 1,8 km al W del km 35 de la carretera Iquitos-Nauta, 13 (1 CML 13610; 12 MUSM 30456, 30457, 30458, 30459, 30460, 30461, 30462, 30463, 30464, 30465, 30466, 30467); Ex Petroleros, 300 m W km 39,8 de la carretera Iquitos-Nauta, 4 (MUSM 30468, 30469, 30470, 30471); Moralillo, 1,5 km E 400 m S del km 15,2 de la carretera Iquitos-Nauta, 14 (1 CML 13611; 13 MUSM 30472, 30473, 30474, 30475, 30476, 30477, 30478, 30479, 30480, 30481, 30482, 30483, 30484); Moralillo, 2 km E del km 15,2 de la carretera Iquitos-Nauta, 3 (2 MMD 760, 2220; 1 MUSM 30485); Paujil, W km 37,45 de la carretera Iquitos-Nauta, 24 (1 CML 13612; 23 MUSM 30486, 30487, 30488, 30489, 30490, 30491, 30492, 30493, 30494, 30495, 30496, 30497, 30498, 30499, 30500, 30501, 30502, 30503, 30504, 30505, 30506, 30507, 30508); Peña Negra, 800 m al E del km 11 de la carretera Iquitos-Nauta, 23 (1 CML 13613; 22 MUSM 30509, 30510, 30511, 30512, 30513, 30514, 30515, 30516, 30517, 30518, 30519, 30520, 30521, 30522, 30523, 30524, 30525, 30526, 30527, 30528, 30529, 30530); San Lucas, W km 43 de la carretera Iquitos-Nauta, 15 (1 CML 13614; 14 MUSM 30531, 30532, 30533, 30534, 30535, 30536, 30537, 30538, 30539, 30540, 30541, 30542, 30543, 30544); Zungarococha, 5,4 km al W del km 6 de la carretera Iquitos-Nauta, 2 (MUSM 30545, 30546).

Registros adicionales: <u>Provincia Mariscal Ramón Castilla</u>, Distrito de Pebas: Pebas (Thomas, 1928). Distrito de Yavarí: San Fernando, Río Yavari (Patton, 1987). <u>Provincia de Maynas</u>, Distrito de Iquitos: Iquitos (Thomas, 1928). Distrito San Juan Bautista: Agua Blanquillo (Calderón Saravia & Rengifo Vásquez, 2010); Reserva Nacional Allpahuayo-Mishana (Hice & Velazco, 2012); Seis Unidos; Yanayacu (Calderón Saravia & Rengifo Vásquez, 2010).

Comentarios: se colectaron 13 ejemplares crías o muy jóvenes, seis hembras y siete machos, en los meses de marzo (1), mayo (2), junio (1), julio (3), septiembre (1), octubre (2) y noviembre (3); 24 juveniles, 12 hembras y 12 machos, en enero (2), marzo (1), mayo (2), junio (1), julio (2), agosto (1), septiembre (4), octubre (3) y noviembre (8). Entre los adultos se colectaron 34 hembras, 19 preñadas, en los meses de enero (1), mayo (4), junio (1), julio (2), septiembre (3), octubre (3) y noviembre (5) (enero: R0, L2, CR = 14 mm; mayo: R2 gemelos, CR = 9 mm; R1, L1, CR = 52 mm; R2, L2, CR = 43 mm; R1, L2, CR = 47 mm; junio: R0, L3, CR = 42 mm; julio: R3, L1, CR = 25 mm; R3, L0, CR = 12 mm; R1, septiembre: L1, CR = 55 mm; R1, L1, CR = 6 mm; R1, L1, CR = 23 mm; octubre: R0, L2, CR = 11 mm; R0, L2, CR = 14 mm; R2, L0, CR = 28 mm; noviembre: R1, L3, CR = 50 mm; R1, L1, CR = 22 mm; R2, L0, CR = 15 mm; R1, L1, CR = 25 mm; R0, L2, CR = 24 mm). Entre los machos (46), 18 tenían testículos escrotales en los meses de febrero (1), mayo (4), junio (1), julio (2), octubre (3) y noviembre (7). Todos los ejemplares fueron colectados en trampas colectadas en el suelo, 64 en bosque primario, uno en un ecotono entre bosque primario y área cultivada y uno en el ecotono entre bosque secundario y área cultivada, 40 en bosque secundario, y 12 en área rural (cerca de casa cultivos, gramalotales y zonas abiertas). Cinco ejemplares, tanto en tejido de riñón como en orina, y cuatro solo en orina, resultaron positivos para Leptospirosis (J. M. Vinetz, datos no publicados).

### *Proechimys cuvieri* Petter, 1978

Distribución: esta especie está ampliamente distribuida a través de la Amazonia, desde el este de Ecuador y Perú al este de Brasil, Venezuela y las Guyanas (Patton & Leite, 2015).

Especímenes examinados (207): <u>Provincia de Maynas</u>, Distrito de Punchana: Comunidad de Manacamiri, Río Nanay, Fundo Morropon, 9 (MUSM 30577, 30578, 30579, 30580, 30581, 30582, 30583, 30584, 30585); Padrecocha, 1 (MUSM 30656). Distrito de San Juan Bautista: 1 km E km 25,3 de la carretera Iquitos-Nauta (Fundo San Martín), 19 (MUSM 30551, 30552, 30553, 30554, 30555, 30556, 30557, 30558, 30559, 30560, 30561, 30562, 30563, 30564, 30565, 30566, 30567, 30568, 30569); Camino a El Paujil, 1,8 km al W del km 35 de la carretera Iquitos-Nauta, 7 (MUSM 30570, 30571, 30572, 30573, 30574, 30575, 30576); El Dorado, km 25 de la carretera Iquitos-Nauta, app. 1,5 km al E, 22 (2 CML 13615, 13616; 1 MMD 1653; 19 MUSM 30586, 30587, 30588, 30589, 30590, 30591, 30592, 30593, 30594, 30595, 30596, 30597, 30598, 30599, 30600, 30601, 30602, 30603, 30604); El Dorado, km 25 de la carretera Iquitos-Nauta, app. 400 m al E, 2 (MUSM 30605, 30606); El Dorado, km 25 de la carretera Iquitos-Nauta, app. 500 m al E, 1 (MUSM 30607); Moralillo, 1,5 km E 400 m S del km 15,2 de la carretera Iquitos-Nauta, 3 (1 MMD 2179; 2 MUSM 30608, 30609); Moralillo, 1,5 km E 500 m S del km 15,2 de la carretera Iquitos-Nauta, 30 (MUSM 30415, 30610, 30611, 30612, 30613, 30614, 30616, 30617, 30618, 30619, 30620, 30621, 30622, 30623, 30624, 30625, 30626, 30627, 30628, 30629, 30630, 30631, 30632, 30633, 30634, 30635, 30636, 30637, 30638, 30639); Moralillo, 2 km E del km 15,2 de la carretera Iquitos-Nauta, 1 (MUSM 30640); Ninarumi, 7,4 km al W y 1 km al SE del km 6 de la carretera Iquitos-Nauta, 11 (1 CML 13617;

10 MUSM 30641, 30642, 30643, 30644, 30645, 30646, 30647, 30648, 30649, 30650); Ninarumi, 7,4 km al W y 500 m al SE del km 6 de la carretera Iquitos-Nauta, 5 (MUSM 30651, 30652, 30653, 30654, 30655); Paujil, W km 37,45 de la carretera Iquitos-Nauta, 7 (1 CML 13618; 6 MUSM 30657, 30658, 30659, 30660, 30661, 30662); Peña Negra, 600 m al W del km 10 de la carretera Iquitos-Nauta, 32 (MUSM 30663, 30664, 30665, 30666, 30667, 30668, 30669, 30670, 30671, 30672, 30673, 30674, 30675, 30676, 30677, 30678, 30679, 30680, 30681, 30682, 30683, 30684, 30685, 30686, 30687, 30688, 30689, 30690, 30691, 30692, 30693, 30694); Peña Negra, 800 m al E del km 11 de la carretera Iquitos-Nauta, 1 (MUSM 30695); San Lucas, W km 43 de la carretera Iquitos-Nauta, 2 (MUSM 30696, 30697); Varillal, 1,8 km W del km 13,6 de la carretera Iquitos-Nauta, 15 (MUSM 30698, 30699, 30700, 30701, 30702, 30703, 30704, 30705, 30706, 30707, 30708, 30709, 30710, 30711, 30712); Varillal, 2 km W del km 13,6 de la carretera Iquitos-Nauta, 2 (1 CML 13619; MUSM 30713); Zungarococha, 5,2 km al W del km 6 de la carretera Iquitos-Nauta, 3 (MUSM 30714, 30715, 30716); Zungarococha, 5,4 km al W del km 6 de la carretera Iquitos-Nauta, 1 (MUSM 30717); Zungarococha, 6,5 km al W del km 6 de la carretera Iquitos-Nauta, 33 (3 CML 13620, 13621, 13622; 1 MMD, 1960; 29 MUSM 30718, 30719, 30721, 30722, 30723, 30724, 30725, 30726, 30727, 30728, 30729, 30730, 30731, 30733, 30734, 30735, 30736, 30737, 30738, 30739, 30740, 30741, 30742, 30743, 30744, 30745, 30746, 30747, 30748).

Registros adicionales: Provincia de Maynas, Distrito de Alto Nanay: Santa Luisa, Río Nanay (Patton, 1967). Distrito San Juan Bautista: Agua Blanquillo (Calderón Saravia & Rengifo Vásquez, 2010); Reserva Nacional Allpahuayo-Mishana (Hice & Velazco, 2012); Seis Unidos; Yanayacu (Calderón Saravia & Rengifo Vásquez, 2010).

Comentarios: en esta especie se colectaron seis ejemplares crías o muy jóvenes, 3 hembras y 3 machos, en los meses de abril (3), mayo (1), agosto (1) y septiembre (1); 26 juveniles, 12 hembras y 14 machos, en enero (15), febrero (6), marzo (1), abril (4), mayo (1), junio (7), agosto (2), septiembre (4) y noviembre (4). Entre los adultos se registraron 109 hembras, 65 preñadas a lo largo de todo año: enero (15), febrero (7), marzo (3), abril (7), mayo (6), junio (8), julio (2), agosto (6), septiembre (3) noviembre (1) y diciembre (9) (medidas de algunos fetos, enero: R0, L1, CR = 34 mm; R1, L1, CR = 57 mm; R1, L0, CR = 54 mm; R0, L1, CR = 85 mm; R0, L2, CR = 12 mm; R2, L1, CR = 25 mm; R1, L1, CR = 58 mm; R1, L1, CR = 20 mm; R1, L2, CR = 27 mm; R1, L1, CR = 55 mm; R0, L3, CR = 27 mm; R3, L0, CR = 21 mm; febrero: R1, L2, CR = 40 mm, R2, L0, CR = 35 mm, R0, L2, CR = 20 mm, R0, L1, CR = 23 mm, R0, L3, CR = 20 mm, CR = 50 mm; marzo: R3, L0, CR = 36 mm, R0, L2, CR = 40 mm, R0, L2, CR = 30 mm; abril: R1, L1, CR = 23 mm, R1, L0, CR = 16 mm, L0, R2, CR = 20 mm, L0, R2, CR = 17 mm, L0, R2, CR = 50 mm, L1, R0, CR = 20 mm, L0, R2, CR = 60 mm; mayo: R0, L1, CR = 42 mm, R0, L1, CR = 38 mm, R1, L1, CR = 29 mm, L0, R3, CR = 25 mm; junio: R1, L0, CR = 26 mm, R2, L1, CR = 30 mm, R1, L2, CR = 56 mm, R0, L1, CR = 57 mm, R1, L1, CR = 37 mm, R1, L1, CR = 20 mm, R0, L1, CR = 40 mm; julio: R2, L1, CR = 45 mm, R1, L1, CR = 58 mm; agosto: R0, L2, CR = 55 mm, R0, L1, CR = 10 mm, R0, L2, CR = 65 mm, R0, L1, CR = 17 mm, R0, L3, CR = 32 mm; septiembre: R0, L1, CR = 35 mm, R1, L0, CR = 32 mm, R1, L1, CR = 17 mm; noviembre: R1, L2, CR = 35 mm; diciembre: R0, L2, CR = 10 mm, R1, L1, CR = 16 mm, R1, L1, CR = 45 mm, R0, L1, CR = 19 mm, R1, L1, CR = 13 mm, R1, L2, CR = 44 mm, R1, L0, CR = 7 mm). De los 66 machos, en 31 se registraron testículos escrotales, enero (5), febrero (3), marzo (2), mayo (4), abril (1), junio (4), julio (2), agosto (3), septiembre (3) y noviembre (4). Todos los ejemplares fueron colectados en trampas colectadas en el suelo, 117 en bosque primario, 82 en bosque secundario y ocho en área rural (dos en cercanías de una casa y el resto en área de cultivo). Tres ejemplares en tejido de riñón resultaron positivos para Leptospirosis (J. M. Vinetz, datos no publicados).

*Proechimys kulinae* M. M. F. da Silva, 1998

Distribución: esta especie es conocida solo del noreste de Perú, sur del río Amazonas y el oeste de Brasil a lo largo de ambos lados del río Juruá (Patton & Leite, 2015).

Especímenes examinados: ninguno.

Registros adicionales: Provincia de Maynas, Distrito de Fernando Lores: San Pedro Provincia de Requena, Distrito de Requena: Jenaro Herrera. Distrito de Yaquerana: Nuevo San Juan (Patton & Leite, 2015).

Comentarios: no se registraron ejemplares de esta especie en el área de estudio, pero existe una alta probabilidad de su presencia, ya que se ha citado en dos localidades cercanas, una de ellas como San Pedro a menos de 40 km de algunos sitios de colecta de este estudio.

*Proechimys quadruplicatus* Hershkovitz, 1948

Distribución: esta especie se distribuye en el norte de la Amazonia, norte de Perú, este de Ecuador, sur de Colombia y Venezuela y norte de Brasil (Patton & Leite, 2015).

Especímenes examinados (97): Provincia de Maynas, Distrito de Punchan: Comunidad de Manacamiri, Río Nanay, Fundo Morropón, 4 (MUSM 30758, 30759, 30760, 30761); Padrecocha, 2 (MUSM 30773, 30774). Distrito de San Juan Bautista: 2,9 km E del km 28,8 de la carretera Iquitos-Nauta (caserío Palo Seco), 11 (1 MMD 4804; 10 MUSM 30449, 30749, 30750, 30751, 30752, 30753, 30754, 30755, 30756, 30757); app. 500 m E km 28,8 de la carretera Iquitos-Nauta, 17 (1 MMD 4459; 16 MUSM 30821, 30822, 30823, 30824, 30825, 30826, 30827, 30828, 30829, 30830, 30831, 30832, 30833, 30834, 30835, 30836); Corrientillo, km 6 de la carretera Iquitos-Nauta, 4,5 km W camino a Zungarococha, 1 (MUSM 30762); Ex Petroleros, 300m W km 39,8 de la carretera Iquitos-Nauta, 6 (MUSM 30763, 30764, 30765, 30766, 30767, 30768); Los Delfines, km 9 de la carretera Iquitos-Nauta, 1 (MUSM 30769); Ninarumi, 7,4 km al W del km 6 de la carretera Iquitos-Nauta, 1 (MUSM 30770); Ninarumi, 7,4 km al W y 1 km al SE del km 6 de la carretera Iquitos-Nauta, 1 (MUSM 30771); Ninarumi, 7,4 km al W y 500 m al SE del km 6 de la carretera Iquitos-Nauta, 2 (1 MMD 2834; 1 MUSM 30772); Paujil, W km 37,45 de la carretera Iquitos-Nauta, 2 (1 MMD 3842; 1 MUSM 30775); Peña Negra, 200 m al E del km 10,7 de la carretera Iquitos-Nauta, 6 (1 MMD 1253; 5 MUSM 30776, 30777, 30778, 30779, 30780); Peña Negra, 600 m al W del km 10 de la carretera Iquitos-Nauta, 7 (MUSM 30781, 30782, 30783, 30784, 30785, 30786, 30787); San Lucas, W km 43 de la carretera Iquitos-Nauta, 3 (MUSM 30788, 30789, 30790); Santo Tomás, 6 km al W del km 1 de la carretera Iquitos-Nauta, 4 (MUSM 30791, 30792, 30793, 30794); Varillal, 1,6 km W del km 13,6 de la carretera Iquitos-Nauta, 2 (MUSM 30795, 30796); Varillal, 2 km W del km 13,6 de la carretera Iquitos-Nauta, 5 (MUSM 30797, 30998, 30799, 30800, 30801); Varillal, 400 m W 200 m N del km 14 de la carretera Iquitos-Nauta, 2 (MUSM 30802, 30803); Zungarococha, 5,2 km al W del km 6 de la carretera Iquitos-Nauta, 12 (1 MMD 599; 11 MUSM 30805, 30806, 30807, 30808, 30809, 30810, 30811, 30812, 30813, 30814); Zungarococha, 5,4 km al W del km 6 de la carretera Iquitos-Nauta, 7 (2 MMD 543, 1954; 5 MUSM 30815, 30816, 30817, 30818, 30819); Zungarococha, 6,5 km al W del km 6 de la carretera Iquitos-Nauta, 1 (MUSM 30820).

Registros adicionales: Provincia de Loreto, Distrito de Nauta: Nauta (Calderón Saravia & Rengifo Vásquez, 2010); Río Tigre (Patton & Leite, 2015). Provincia de Mariscal Ramón Castilla, Distrito de Pebas: Pebas (Patton, 1987). Provincia de Maynas, Distrito de Fernando Lores, El Chino (Patton & Leite, 2015). Distrito San Juan Bautista: Agua Blanquillo (Calderón Saravia & Rengifo Vásquez, 2010); Reserva Nacional Allpahuayo-Mishana (Hice & Velazco, 2012); Seis Unidos; Yanayacu (Calderón Saravia & Rengifo Vásquez, 2010).

Comentarios: algunos ejemplares incluidos bajo esta especie deben ser revisados ya que sus báculos son algo diferentes a lo típico de lo observado en *P. quadruplicatus*. Se registraron cinco ejemplares crías o muy jóvenes, marzo (2), mayo (2) y junio (1); siete juveniles en febrero (1), marzo (1), mayo (1), junio (3) y agosto (1). Entre los adultos se registraron 36 hembras, 19 preñadas en los meses de febrero (2), marzo (8), abril (1), agosto (5), noviembre (1) y diciembre (2) (febrero: R3, L1, CR = 22, R5, L1, CR = 54 mm, R0, L5, CR = 34 mm; marzo: R1, L4, CR = 18 mm, R3, L1, CR = 35, 2, CR = 58 mm, CR = 20 mm, R0, L2, CR = 30 mm, R2, L2, CR = 47 mm, R0, L1, CR = 25 mm, R1, L1, CR = 24 mm, R2, L1, CR = 75 mm; abril: R1, L1, CR = 12 mm; junio: R1, L5, CR = 12 mm, R2, L3, CR = 25 mm; agosto: R2, L0, CR = 30 mm, R2, L1, CR = 35 mm, R2, L2, CR = 30 mm, R2, L0, CR = 17 mm; octubre, R1, L1, CR = 28 mm; noviembre, R1, L1, CR = 40 mm; diciembre: R2, L0, CR = 48 mm, R1, L2, CR = 23 mm). Entre los machos (40), 12 presentaron testículos escrotales, enero (1), marzo (2), abril (1), mayo (2), agosto (1), octubre (1), noviembre (2) y diciembre (2). Tres ejemplares, en tejido de riñón, y cinco, en orina, resultaron positivos para Leptospirosis (J. M. Vinetz, datos no publicados).

### *Proechimys simonsi* Thomas, 1900

Distribución: se encuentra al oeste de la Amazonia, incluyendo la ladera este de los Andes, desde el sur de Colombia a través del este de Ecuador, este de Perú, norte de Boliviay oeste de Brasil (Patton & Leite, 2015).

Especímenes examinados (13): app. 500 m E km 28,8 de la carretera Iquitos-Nauta, 1 (MUSM 30843); Ex Petroleros, 300 m W km 39,8 de la carretera Iquitos-Nauta, 2 (MUSM 30837, 30838); Moenacaño, 2 (1 MMD 2631; 1 MUSM 30839); Moralillo, 1,5 km E 400 m S del km 15,2 de la carretera Iquitos-Nauta, 6 (3 CML 13634, 13635, 13636; 1 MMD 2200; 2 MUSM 30840, 30841); Moralillo, 2 km E del km 15,2 de la carretera Iquitos-Nauta, 1 (MMD 2205); Varillal, 2 km W del km 13,6 de la carretera Iquitos-Nauta, 1 (MUSM 30842).

Registros adicionales: Provincia de Loreto, Distrito de Nauta: Nauta (Calderón Saravia & Rengifo Vásquez, 2010). Provincia de Mariscal Ramón Castilla, Distrito de Pebas: Orosa (Patton, 1987). Provincia de Maynas, Distrito de Napo: Boca Río Curaray (Patton, 1987). Distrito de San Juan Bautista: Reserva Nacional Allpahuayo-Mishana (Hice & Velazco, 2012). Provincia de Requena, Distrito de Requena: Jenaro Herrera (Gorchov *et al.*, 2004).

Comentarios: se colectaron tres ejemplares jóvenes, dos en febrero y uno en marzo; entre los adultos se registraron dos hembras preñadas en enero y marzo (R1, L2, CR = 54 mm; R0, L3, CR = 14 mm), y de los 11 machos solo uno presentaba testículos escrotales en el mes de enero. Todos los ejemplares fueron colectados en trampas colectadas en el suelo, 12 en crecimientos secundario y uno en un área de cultivo. Dos ejemplares, resultaron positivos para Leptospirosis, uno de una muestra de tejido de riñón y uno de orina (J. M. Vinetz, datos no publicados).

### *Proechimys steerei* Goldman, 1911

Distribución: se encuentra desde el este y sur de Perú, noroeste de Bolivia y oeste de Brasil (Patton & Leite, 2015).

Especímenes examinados: ninguno

Registros adicionales: Provincia de Mariscal Ramón Castilla, Distrito de Pebas: Orosa (Patton, 1987). Provincia de Loreto, Distrito de Parinari: Santa Elena (Patton, 1987).

Comentarios: no se registraron ejemplares de esta especie en el área de estudio, los registros más cercanos se ubican en provincias vecinas de Maynas.

### *Proechimys* sp.

Especímenes examinados (6): Provincia de Maynas, Distrito de Belén: Comunidad Puerto Alegría, Río Itaya, 1 (MMD 5124); Moenacaño, 1 (MMD 2675). Distrito de San Juan Bautista: 2,9 km E del km 28,8 de la carretera Iquitos-Nauta (caserío Palo Seco), 1 (MMD 4787); app. 500 m E km 28,8 de la carretera Iquitos-Nauta, 1 (MMD 4498); Moralillo, 1,5 km E 400 m S del km 15,2 de la carretera Iquitos-Nauta, 1 (MMD 842); Zungarococha, 5,4 km al W del km 6 de la carretera Iquitos-Nauta, 1 (MMD 544).

Comentarios: estos ejemplares no pudieron ser identificados bajo ninguna de las especies conocidas, especialmente la estructura de los báculos analizados. Dichos ejemplares se encuentran bajo estudio con el objetivo de establecer su identificación.

*Toromys rhipidurus* (Thomas, 1928)

Distribución: esta especie se conoce solo del norte de Perú en el oeste de la Amazonía (Emmons *et al.*, 2015).

Especímenes examinados (2): Provincia de Maynas, Distrito de San Juan Bautista: Caserío Santa Sofía, 300 m N, 2 (1 CML 13641; 1 MUSM 30432).

Registros adicionales: Provincia Mariscal Ramón Castilla, Distrito de Pebas: Pebas (type locality of *Echimys rhipidurus* Thomas, 1928). Distrito de Yavarí: Nazareth. Provincia de Maynas, Distrito de Indiana, Puerto Indiana (Emmons *et al.*, 2015).

Comentarios: esta especie fue descripta bajo el género *Echimys*, pero posteriormente se incluyó en el género *Makalata* Husson, 1978 (Emmons & Feer, 1997; Emmons, 2005). Iack-Ximenes *et al.* (2005) reconocen un nuevo género *Toromys* Iack-Ximenez, de Vivo & Percequillo, 2005 para la especie *grandis*, y recientemente Iack-Ximenes *et al.* (2015) incluyen a *rhipidurus* en este nuevo género. *Toromys rhipidurus* se registra exclusivamente en la Amazonía Peruana con la mayoría de los ejemplares registrados procedente de los bosques rivereños, siendo otros aspectos de su biología poco conocidos (Emmons *et al*., 2015). En este estudio, se colectaron dos ejemplares adultos en agosto de 2005, un macho con testículos escrotales y una hembra preñada, en trampas Tomahawk colocada a un metro y medio sobre un árbol, en crecimiento secundario a orillas de una cocha.

## DISCUSIÓN Y CONCLUSIONES

De acuerdo a los resultados obtenidos el área de estudio posee una alta riqueza de especies de pequeños roedores, ya que en total se registraron 25 especies (incluida *Proechimys* sp.), además de algunos ejemplares de los géneros *Neacomys* y dos ejemplares de oryzominos que no pudieron ser identificados. Este número de especies se eleva a 39 si se consideran las citas de la literatura (14), nueve en el área de Iquitos y cinco en zonas más alejadas del área de estudios.

Aquí se reportan cinco especies no registradas por Hice & Velazco (2012): *Neacomys minutus*, *N. musseri*, *Oecomys phaeotis*, *O. trinitatis* y *Toromys rhipidurus*. *Oecomys trinitatis* y las dos especies de *Neacomys* se citan por primera vez para la provincia de Maynas, y en el caso de las dos últimas se extiende su distribución en el noroeste de Perú. Respecto a *T. rhipidurus* se suma información para esta rara especie cuya biología es poco conocida (Emmons *et al.*, 2015). Entre las especies más abundantes se pueden mencionar a *H. perenensis*, *H. yunganus* (Cricetidae) y las especies de *Proechimys* (Echimyidae). Cabe destacar que estas últimas son altamente consumidas por los pobladores de la zona (Linares García, 2012).

Respecto a las formaciones vegetales donde las especies fueron colectadas, 19 estuvieron presentes en bosque primario, 18 en bosque secundario y 10 en ambientes rurales; los bosques primario y secundario compartieron 13 especies; el rural con el bosque primario compartieron seis especies y con el secundario 10. *Mesomys hispidus* y las especies del género *Proechimys* se registraron en todos los ambientes, excepto *P. simonsi* que no fue registrada en bosque primario. Algunas especies estuvieron exclusivamente en bosque primario, pero fueron registradas por uno o dos ejemplares (*"Microsciurus" flaviventris*, *N. musseri*, *O. trinitatis*, *R. leucodactylus* y *S. ucayalensis*), y *Toromys rhipidurus* fue la única especie exclusiva de bosque secundario, pero en este caso también se colectaron solo dos ejemplares.

En lo que respecta al tipo de trampas utilizadas y sitos donde fueron colocadas, las trampas de altura fueron las más exitosas, lo que era de esperar por la actividad en el dosel, que poseen muchas de las especies en la Amazonia. El valor obtenido en estas trampas puede considerarse entre normal y alto si se compara con otros estudios realizados en la Amazonía (Santos-Filho *et al*., 2012; Graipel, 2003), mientras que el éxito de captura en el suelo fue bajo. De las 24 especies registradas, ocho se colectaron en trampas altas, cuatro de manera exclusiva (*O*. *paricola*, *O*. *phaeotis*, *I*. *bistriata* y *T*. *rhipidurus*). En la trampas de caída, que a pesar de su efectividad ya que capturan especies raras (ver Hice & Schmidly, 2002) no suelen ser muy utilizadas en los muestreos de micromamíferos, también capturaron ocho especies, sólo dos de manera exclusiva (*O*. *trinitatis* y *S*. *ucayalensis*), y su éxito de captura fue también superior al de las trampas colocadas en el suelo.

Finalmente es importante destacar la importancia de preservar la zona ya que presenta una alta diversidad no sólo de roedores, sino también de marsupiales (Hice & Velazco, 2012; Díaz & Willig, 2004; Díaz, 2014) y murciélagos (Angulo & Díaz, 2004; Willig *et al.*, 2007; Díaz, 2011), pero que lamentablemente está sufriendo amplias modificaciones por el avance de la agricultura (Hice, 2003; Willig *et al*., 2007) lo que produce efectos negativos, disminuyendo la riqueza de especies y modificando su dinámica poblacional (Luque *et al.*, 1994; Iida & Nakashizuka, 1995; Luque, 2000).

## AGRADECIMIENTOS

Un inmenso agradecimiento a V. Linares, S. Mananita, H. Portocarrero, C. Ahuanari, R. Angulo, y los estudiantes de la Universidad Nacional de San Marcos, por su colaboración tanto en el campo como en el laboratorio. El trabajo de campo fue subsidiado por *United States Public Health Service National Institute of Allergy and Infectious Diseases*, Estados Unidos de América (becas R01TW005860, D43TW007120 y K24AI068903). Un especial agradecimiento a J. M. Vinetz el investigador principal de las becas que subsidiaron el trabajo de campo por su apoyo constante durante los cuatro años que se desarrolló este proyecto. Al Instituto Nacional de Recursos Naturales (INRENA), Ministerio de Agricultura de Perú por los permisos de captura y colecta de los ejemplares aquí citados. Finalmente, agradezco a dos revisores anónimos que contribuyeron a mejorar el manuscrito.

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Apéndice 1. Lista de localidades en el departamento de Loreto, Perú, en orden alfabético por provincias y distritos, las coordenadas geográficas se indican entre paréntesis. Con un asterisco (*) se indican las localidades de colecta en este estudio. Las localidades con las mismas coordenadas se colocan bajo el mismo número.

(Continúa)

PROVINCIA DE ALTO AMAZONAS

Distrito de Lagunas

1. Lagunas (-5.233333 -75.633333)

Distrito de Morona

2. Quebrada Pushaga, left bank Río Morona, Alto Río Amazonas, 2,200 m (-4.000000 -77.333330)

PROVINCIA DE LORETO

Distrito de Nauta

3. San Jacinto (-4.673932 -73.959394)
4. Nauta (-4.509044444 -73.581325)
5. Nauta, Rio Samiria, right bank, elev. 150 m (-4.533333 -73.550000)
6. Nauta, Río Tigre, 1 km below Río Tigrillo (-4.283333 -74.316670)

Nauta, Rio Tigre, 1 km above Rio Tigrillo, left bank, elev. 150 m (-4.283333 -74.316670)

7. Río Tigre (-4.283333 -74.316670)

Distrito de Parinari

8. Hacienda Santa Elena, ca. 35 km NE of Tingo Maria, 1,000 m (-4.833330 -74.216670)

Santa Elena, Río Samiria, 130 m (-4.833333 -74.216670)

Santa Elena (-4.833333 -74.216670)

PROVINCIA DE MARISCAL RAMÓN CASTILLA

Distrito de Pebas

9. Orosa, Río Amazonas (-3.433333 -72.133333)
10. Pebas (-3.3197833 -71.860108)

Pebas, Río Amazonas, 300 ft (-3.3197833 -71.860108)

Distrito San Pablo

11. Río Peruate boca [= mouth], Río Amazonas, 90–100 m (-3.70000000 -71.48300000)

Distrito de Yavarí

12. Nazareth [= Amelia] (-4.33333000 -70.08333000)
13. San Fernando, left bank Río Yavarí, 100 m (-4.200000 -70.233333)

PROVINCIA DE MAYNAS

Distrito de Alto Nanay

14. Santa Luisa, Río Nanay (-3.333333 -74.583333)

Distrito de Belén

15. Comunidad Puerto Alegría, Río Itaya (-3.835533 -73.306050)*
16. Manzanillo, Río Amazonas (-3.828083 -73.219517)/ Mazanillo (-3.828083 -73.219517)*

Apendice 1. (Continúa)

17. Moena Caño (-3.778800 -73.224917)*
Distrito de Fernando Lores
18. Amazon Research Center in Área de Conservación Regional Tamshiyacu-Tahuayo (-4.293611 -73.236111)
19. El Chino, right bank Río Tahuayo (-4.306953 -73.218175)
20. Estación Biológica Quebrada Blanco, right bank Quebrada Blanco (-4.350000 -73.150000)
21. San Pedro (-4.336900 -73.197800)/ San Pedro, 80 km NE of Jenaro Herrera (-4.336900 -73.197800)/ San Pedro, right bank Río Blanco (-4.336900 -73.197800)
Distrito de Indiana
22. Puerto Indiana (-3.501100 -73.048108)
23. Santa Cecilia, Río Maniti, 110 m (-3.545464 -72.999283)
Distrito de Iquitos
24. Iquitos, Iquitos (-3.749722 -73.250000)
25. Iquitos Zona Marina district of the City of Iquitos (-3.730006 -73.23839722)
26. Iquitos, Colonia, Criadero en Laboratorio Casa Pevas 354 (-3.746986 -73.243717)
27. Santa Rita, Iquitos, 120 m (-3.731503 -73.323717)
Distrito de Las Amazonas
28. Quebrada Orán, ca. 5 km N of Río Amazonas, 85 km NE of Iquitos, 110 m (-3.475000 -72.517000)
29. Río Apayacu (-3.488894 -72.190697)
Distrito de Mazán
30. Mazán, between Iquitos and Pebas (-3.496433 -73.089983)
Mazan, at the mouth of the Rio Mazan (-3.496433 -73.089983)
Distrito de Napo
31. Río Curaray, boca [= mouth] (-2.383181 -74.083242)
Río Curaray, vicinity (-2.383181 -74.083242)
Distrito de Punchana
32. Comunidad de Manacamiri, Río Nanay, Fundo Morropón (-3.709900 -73.302833)*
33. Padrecocha (-3.691500 -73.285333)*
34. Padrecocha, carretera Shihua (-3.709000 -73.294450)*
35. Punto Alegre (-3.482158 -73.424389)
Distrito San Juan Bautista
36. 1 km E km 25,3 de la carretera Iquitos-Nauta (Fundo San Martín) (-3.965900 -73.404317)*
37. 13 de Febrero, Fundo Nemith, E km 33 de la carretera Iquitos-Nauta (-4.025400 -73.429600)*
38. 2,9 km E del km 28,8 de la carretera Iquitos-Nauta (caserío Palo Seco) (-3.995817 -73.405983)*
39. Agua Blanquillo (-4.20003 -73.869028)
40. app. 500 m E km 28,8 de la carretera Iquitos-Nauta (-3.987117 -73.415333)*
41. Cahuide km 61 carretera Iquitos-Nauta (-4.262680 -73.501450)
42. Camino a El Paujil, 1,8 km al W del km 35 de la carretera Iquitos-Nauta (-4.020283 -73.446450)*

Apendice 1. (Continúa)

43. Caserio Cahuide km 59 carretera Iquitos-Nauta (-4.243370 -73.486760)
44. Caserio Cahuide km 60 carretera Iquitos-Nauta, O del camino (-4.248280 -73.49934)
45. Caserío Santa Sofía, 300 m N (-3.779267 -73.354817)*
46. Corrientillo, km 6 de la carretera Iquitos-Nauta, 4,5 km W camino a Zungarococha (-3.832583 -73.362500)*
47. Cuenca del río Itaya (-3.764444 -73.233200)
48. El Dorado, km 25 de la carretera Iquitos-Nauta, app. 1,5 km al E (-3.966833 -73.393667)*
49. El Dorado, km 25 de la carretera Iquitos-Nauta, app. 400 m al E (-3.960233 -73,416450)*
50. El Dorado, km 25 de la carretera Iquitos-Nauta, app. 500 m al E (-3.961650 -73.399067)*
51. El Paujil km 37 carretera Iquitos-Nauta (-4.053981 -73.441231)
52. El Triunfo km 48 carretera Iquitos-Nauta (-4.150570 -73.468290)
53. El Triunfo km 49 carretera Iquitos-Nauta (-4.155810 -73.479870)
54. Estación Biológica Allpahuayo, 25 km SW of Iquitos, 171 m (-3.943942 -73.604575)/ Mishana Allpahuayo (-3.943942 -73.604575)/ Reserva Nacional Allpahuayo-Mishana, 28 km SW of Iquitos (-3.943942 -73.604575)
55. Ex Petroleros, 300 m W km 39.8 de la carretera Iquitos-Nauta (-4.079000 -73.453000)*
56. Iquitos Avicola San Miguel, km 3 carretera Iquitos-Nauta (-3.807300 -73.311469)
57. km 22.7 de la carretera Iquitos-Nauta (-3.939517 -73.395167)*
58. km 25 road Iquitos–Nauta, 120 m (-3.959461 -73.421939)
59. La Habana km 54,5 carretera Iquitos-Nauta, 0,78 km O del camino (-4.207880 -73.487670)
60. Llanchama, 114 m (-3.871247 -73.396461)
61. Llanchama near to the Varillal station of the Allpahuayo-Mishana National Reserve, 105 m (-3.866022 -73.410700)
62. Los Delfines, km 9 de la carretera Iquitos-Nauta (-3.847483 -73.339733)*
63. Moralillo, 1,5 km E 400 m S del km 15,2 de la carretera Iquitos-Nauta (-3.909050 -73.343067)*
64. Moralillo, 1,5 km E 500 m S del km 15,2 de la carretera Iquitos-Nauta (-3.906317 -73.343617)*
65. Moralillo, 2 km E del km 15,2 de la carretera Iquitos-Nauta (-3.909467 -73.337970)*
66. Moralillo, 2 km E y 1 km S del km 15,2 de la carretera Iquitos-Nauta (-3.909950 -73.345083)*
67. Ninarumi, 7,4 km al W del km 6 de la carretera Iquitos-Nauta (-3.841717 -73.38078)*
68. Ninarumi, 7,4 km al W y 1 km al SE del km 6 de la carretera Iquitos-Nauta (-3.849833 -73.373933)*
69. Ninarumi, 7,4 km al W y 500 m al SE del km 6 de la carretera Iquitos-Nauta (-3.843917 -73.381650)*
70. Nina Rumi, 120 m (-3.86589 -73.388289)
71. Nuevo Horizonte km 39 road Iquitos–Nauta, 120 m (-4.073911 -73.457050)
72. Paujil, W km 37,45 de la carretera Iquitos-Nauta (-4.058783 -73.442250)*
73. Peña Negra, 200 m al E del km 10,7 de la carretera Iquitos-Nauta (-3.866150 -73.332950)*
74. Peña Negra, 600 m al W del km 10 de la carretera Iquitos-Nauta (-3.855367 -73.345150)*
75. Peña Negra, 800 m al E del km 11 de la carretera Iquitos-Nauta (-3.873267 -73.335550)*
76. Peña Negra km 10 road Iquitos–Nauta, 120 m (-3.853850 -73.346719)
77. San Gerardo km 18,5 road Iquitos– Nauta, 120 m (-3.906819 -73.367250)
78. San Lucas km 44 road Iquitos–Nauta, 120 m (-4.118331 -73.451281)

Apêndice 1. (Conclusión)

79. San Lucas, W km 43 de la carretera Iquitos-Nauta (-4.104117 -73.463183)*
80. Santo Tomás, 6 km al W del km 1 de la carretera Iquitos-Nauta (-3.809683 -73.338133)*
81. Seis Unidos (-4.201667 -73.822500)
82. Varillal, 1,6 km W del km 13,6 de la carretera Iquitos-Nauta (-3.874300 -73.358950)*
83. Varillal, 1,8 km W del km 13,6 de la carretera Iquitos-Nauta (-3.877167 -73.362900)*
84. Varillal, 2 km W del km 13,6 de la carretera Iquitos-Nauta (-3.880033 -73.366850)*
85. Varillal, 400 m W 200 m N del km 14 de la carretera Iquitos-Nauta (-3.882483 -73.354800)*
86. Yanayacu (-4.230000 -73.702778)/Yanayacu, cuenca alta del Río Itaya, 70 km al suroeste de Iquitos) (-4.230000 -73.702778)
87. Zungarococha, 5,2 km al W del km 6 de la carretera Iquitos-Nauta (-3.834567 -73.368283)*
88. Zungarococha, 5,4 km al W del km 6 de la carretera Iquitos-Nauta (-3.830417 -73.371467)*
89. Zungarococha, 6,5 km al W del km 6 de la carretera Iquitos-Nauta (-3.833983 -73.377217)*

PROVINCIA DE REQUENA
Distrito de Requena
90. Genero [= Jenero] Herrera (-4.907503 -73.666719)/ Jenaro Herrera (-4.907503 -73.666719)
91. Jenaro Herrera, 2,8 km E, 135 m (-4.866670 -73.650000)
92. Jenaro Herrera, 7 km E, right bank Río Ucayali (-4.916670 -73.766670)
Distrito de Yaquerana
93. Nuevo San Juan, Río Gálvez, 150 m (-5.258300 -73.163900)/ Río Gálvez (-5.258300 -73.163900)
94. Río Yaquerana, left bank at mouth, alto Río Yavarí (-5.757811 -73.046389)

# Rethinking the living diversity of the *Abrocoma cinerea* Thomas, 1919 species complex (Rodentia, Abrocomidae)

## Repensando a diversidade atual do complexo de espécies de *Abrocoma cinerea* Thomas, 1919 (Rodentia, Abrocomidae)

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**Abstract:** The genus *Abrocoma* Waterhouse includes eight living species of medium-sized rats with long, soft, and dense fur, large ears, and moderate to short tails. Six of these species are included within the informally called *A. cinerea* species complex (*A. cinerea* Thomas, *A. budini* Thomas, *A. famatina* Thomas, *A. schistacea* Thomas, *A. vaccarum* Thomas, and *A. uspallata* Braun and Mares). Based both on the study of specimens housed in biological collections and the reinterpretation of previous morphological evidence, I suggest that the current recognized species richness of the genus could be overestimated. Both qualitative and quantitative morphological approaches are consistent with the recognition of no more than two morphotypes within the *A. cinerea* species complex. However, additional lines of evidence and approaches are needed to disentangle the complex taxonomy of this genus (e.g., phylogenetic analysis of DNA sequences). Until then, I prefer to not make changes in the current classification of *Abrocoma*, especially taking into account that any taxonomic change could have undesirable consequences in the conservation of these rodents.

**Keywords:** Hystricognathi. Caviomorpha. Octodontoidea. Chinchilla rat.

**Resumo:** O gênero *Abrocoma* Waterhouse inclui oito espécies viventes de ratos de tamanho médio, com pêlos longos, macios e densos, orelhas grandes e caudas moderadas a curtas. Seis dessas espécies estão incluídas informalmente no complexo de espécies de *A. cinerea* (*A. cinerea* Thomas, *A. budini* Thomas, *A. famatina* Thomas, *A. schistacea* Thomas, *A. vaccarum* Thomas, and *A. uspallata* Braun and Mares). Os estudos de espécimes alojados em coleções biológicas e na reinterpretação de evidências morfológicas anteriores sugerem que a atual riqueza de espécies reconhecida do gênero possa ser superestimada. As abordagens morfológicas qualitativas e quantitativas são consistentes com o reconhecimento de não mais que dois morfotipos no complexo de espécies de *A. cinerea*. Contudo, linhas adicionais de evidência e abordagens são necessárias para desembaraçar a complexa taxonomia deste gênero (por exemplo, análise filogenética de sequências de DNA). Até então, prefiro não fazer alterações na classificação atual da *Abrocoma*, especialmente levando em consideração que qualquer alteração taxonômica pode ter consequências indesejáveis na conservação desses roedores.

**Palavras-chave:** Hystricognathi. Caviomorpha. Octodontoidea. Rato chinchila.

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TETA, P., 2020. Rethinking the living diversity of the *Abrocoma cinerea* Thomas, 1919 species complex (Rodentia, Abrocomidae). **Boletim do Museu Paraense Emílio Goeldi. Ciências Naturais** 15(3): 767-775. DOI: http://doi.org/10.46357/bcnaturais.v15i3.198.

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Recebido em 16/10/2019
Aprovado em 14/09/2020
Responsabilidade editorial: Alexandra Maria Ramos Bezerra

## INTRODUCTION

The genus *Abrocoma* Waterhouse, 1837 includes eight living species of medium-sized rats (164-196 g) of rotund bodies with long, soft, and dense fur; large ears; and moderate to short tails (Emmons, 1999). Based on their external and cranial features, three main species groups can be recognized within this genus (Glanz & Anderson, 1990; Braun & Mares, 2002; Patton & Emmons, 2015). Two of these contain a single species each, *A. bennettii* Waterhouse 1837, and *A. boliviensis* Glanz and Anderson 1990, while the third one, the informally called *A. cinerea* species complex, includes the other six species (*A. cinerea* Thomas, 1919; *A. budini* Thomas, 1920; *A. famatina* Thomas, 1920; *A. schistacea* Thomas, 1921; *A. vaccarum* Thomas, 1921; and *A. uspallata* Braun and Mares, 2002). Species of the *A. cinerea* complex are specialized for a saxicolous life, inhabiting mostly in stonewalls and rock crevices above 1800 m (Patton & Emmons, 2015; Emmons, 2016).

Five of the six species currently included within the *A. cinerea* complex were described by Thomas (1919, 1920a, 1920b, 1921a, 1921b) under the paradigm of the typological species concept. Subsequently, all these taxa were considered by Ellerman (1940) as subspecies of *A. cinerea*, a view followed during most of the XX century (*e.g.*, Cabrera, 1961). More recently, Braun & Mares (2002) reviewed this group based on morphological evidences, reinstalling the specific status of *A. budini*, *A. famatina*, *A. schistacea*, and *A. vaccarum* and describing an additional nominal form of species level, *A. uspallata*. Species delimitation within the *A. cinerea* species complex was mostly based on geography and subtle differences in both qualitative and quantitative morphological traits (Braun & Mares, 2002; Patton & Emmons, 2015). In fact, even when recognized as distinct species, the multivariate statistical analysis presented by Braun & Mares (2002) do not allow for a complete separation between *A. budini*, *A. famatina*, *A. schistacea*, *A. vaccarum*, and *A. uspallata*.

In this contribution, based on a moderately large sample from Salta (*A. cinerea*) and few additional individuals from Mendoza (here referred to *A*. cf. *A. uspallata*) and San Juan (*A. schistacea*), I put the emphasis in the intraspecific variability of some external and cranial characters. In addition, I present a reinterpretation of previous qualitative and quantitative morphological evidences, suggesting that the current diversity in *Abrocoma* could be overestimated.

## MATERIALS AND METHODS

Studied specimens, consisting of skins and skulls, are housed in the following biological collections (see Appendix 1 for a detail): American Museum of Natural History (AMNH) (New York, USA); *Instituto Argentino de Investigaciones de Zonas Áridas* (CMI) (Mendoza, Argentina); *Facultad de Ciencias Naturales e Instituto Miguel Lillo* (CML) (Tucumán, Argentina); Field Museum of Natural History (FMNH) (Chicago, USA); *Museo Argentino de Ciencias Naturales "Bernardino Rivadavia"* (MACN) (Buenos Aires, Argentina); *Universidad Austral de Chile* (UACh) (Valdivia, Chile).

Anatomical terminology follows Braun & Mares (2002) and Verzi *et al*. (2016). Fifteen skull measurements were recorded with digital calipers (accurate to 0.01 mm), including: total length of the skull (TLS); condyle-incisive length (CIL); least interorbital breadth (LIB); zygomatic breadth (ZB); braincase breadth (BB); nasal length (NL); nasal width (NW); frontal length (FL); upper diastema length (DL); incisive foramina length (IFL); incisive foramina width (IFW); maxillary toothrow (MTR); palatal length (PL); breadth of palatal bridge across upper fourth premolars (BP4); and tympanic bullae length (TBL).

Skull measurements, all of which were first transformed to logarithms (base 10), were analyzed to summarize patterns of variation within and between the sampled populations, using between group principal component analyses. Multivariate statistical procedures were restricted to adult specimens and made with software PAST v. 2.17 (Hammer *et al*., 2001).

Age classes were based on size, craniodental morphology and fusion of cranial sutures (see Braun & Mares, 2002). Both females and males were pooled together in order to obtain more robust samples for its inclusion in the statistical analyses (for a similar procedure, see Braun & Mares 2002).

## RESULTS

Studied specimens of the species of the *A. cinerea* species complex were relatively uniform in its skull morphology, depicting some minor variation in some cranial measurements and in the shape of the interorbital constriction (see the Results below). Craniums are moderately delicate, with a narrowed and elongated rostrum and a bowed dorsal profile; nasals are narrow for most of their length, tapering to a point posteriorly; frontals are not constricted posterior to the postorbital process; braincase is rounded, without well developed parietal ridges or supraoccipital crests; mastoid islands are medium to large in size and are enclosed between the occipitals and parietals; paroccipital processes are short, broad, and adhered to the posterior surface of the tympanic bullae; incisors are narrow; maxillary toothrows are slightly convergent anteriorly; molar teeth are hypselodont, flat-crowned, and have a 8-shaped occlusal pattern. Shape and size of nasals, shape of the anterior border of the mesopterygoid fossa, size of mastoid islands, orientation of zygomata, and procumbency of the upper incisors vary moderately between individuals. For example, some specimens (n = 2) from Chorrillos and San Antonio de Los Cobres (northwestern Salta, Argentina) have their nasals wider at their proximal third (Figure 1A), while in other specimens of this same locality (n = 3) are wider towards their middle portion (Figure 1B). In that same population, mastoid islands varied between large (n = 3; Figure 1C) to medium (n = 3; Figure 1D) and the anterior border of the mesopterygoid fossa from pointed (n = 4; Figure 1E) to nearly rounded (n = 2; Figure 1F, 1G). Additional specimens from Mendoza (*A.* cf. *A. uspallata*) and San Juan (*A. schistacea*) also presented some degree of morphological variation, departing from the diagnosis provided by Braun & Mares (2002) for *A. uspallata* and *A. schistacea* or other closely distributed species such as *A. vaccarum*. For example, I recorded either a rounded (FMNH 46157) or V-shaped mesopterygoid fossa (MACN-Ma 18828) within samples referred to *A. schistacea*, while Braun & Mares (2002) mentions a rounded mesopterygoid fossa as diagnostic for this species.

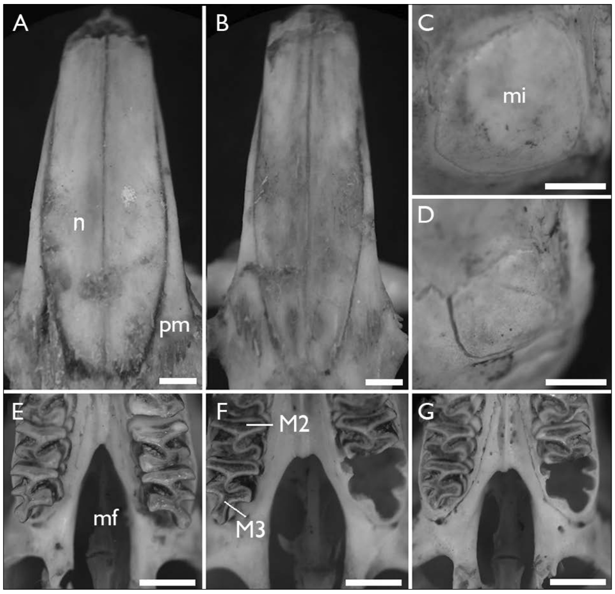

Figure 1. Selected anatomical traits for *Abrocoma cinerea* (= morphotype 1) from northwestern Salta, Argentina. A, B: nasals (n) (A, MACN-Ma 26117; B, MACN-Ma 30.61); C, D: mastoid islands (mi) (C, MACN-Ma 30.61; D, MACN-Ma 30.62); E-G: mesopterygoid fossa (mf) (E, MACN-Ma 30.118; F, MACN-Ma 30.61; G, MACN-Ma G30.62). Other abbreviations: pm = premaxillary; M2 = upper second molar; M3 = upper third molar. Scales = 2 mm.

Despite the morphological variation and the overall similarity among populations, two main morphotypes were recognized on the base of differences in tail length, shape of the interorbital region, and skull size (see the Discussion below). Morphotype 1 is characterized by a short tail (~63 mm), having a proportionally broader interorbital region with divergent and slightly beaded supraorbital borders and moderately developed postorbital processes (Figure 2A). Within this group are included those samples from northwestern Argentina in the provinces of Salta and Tucumán, Bolivia and Chile. Morphotype 2 is represented by samples from the Argentinean provinces of Catamarca, Mendoza, and San Juan and has moderately long to large tails (94-144 mm), proportionally narrow and elongated interorbital regions, with almost parallel outer borders and conspicuous postorbital processes (Figure 2B).

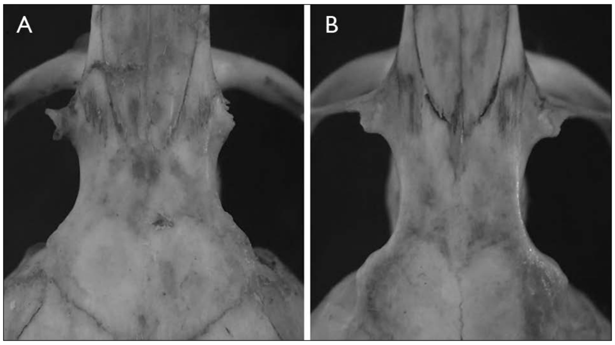

Figure 2. Interorbital region in *Abrocoma*, showing the shape differences between the (A) morphotype 1 (MACN-Ma 30.61; least interorbital breath = 7.92 mm), and (B) morphotype 2 (MACN-Ma 18828; least interorbital breath = 6.82 mm) populations.

Results from the principal component analysis showed that plots of individual scores are segregate in two main clusters along the second PC, which are coincident with the morphotypes described above. On PC1, the highest loadings corresponded to BP4 and FL towards positive values and IFL towards the negative ones; on PC2 the largest positive loading corresponds to the LIB (Figure 3; Table 1). Regarding the additional individuals from Mendoza and San Juan, the multivariate space of *A. schistacea* was completely overlapped with those of *A*. cf. *A. uspallata*.

Among the newly studied specimens, the dorsal coloration of three individuals of *A.* cf. *A. uspallata* varies between grayish brown (*e.g.*, CMI 7012, CMI 3769) to grayish drab (*e.g.*, CMI 7011). The ventral hairs are dark gray for about three-fourths of their length and with creamy tips. The specimen CMI 7012 was the only in to have a drab throat patch. Hairs of sternal gland are white to base, forming (*e.g.*, CMI 7012) or not (*e.g.*, CMI 7011, CMI 3769) a distinctive patch on mid-venter. The area surrounding the perianal region is covered with hairs white to creamy to base and not contrasting with the overall ventral coloration. The forefeet and hindfeet are covered with white (*e.g.*, CMI 7012) to creamy hairs (*e.g.*, CMI 7011, CMI 3769). The tail was bicolored, grayish brown above and creamy below. Unfortunately, no skins are available for new specimens here referred to *A. schistacea*.

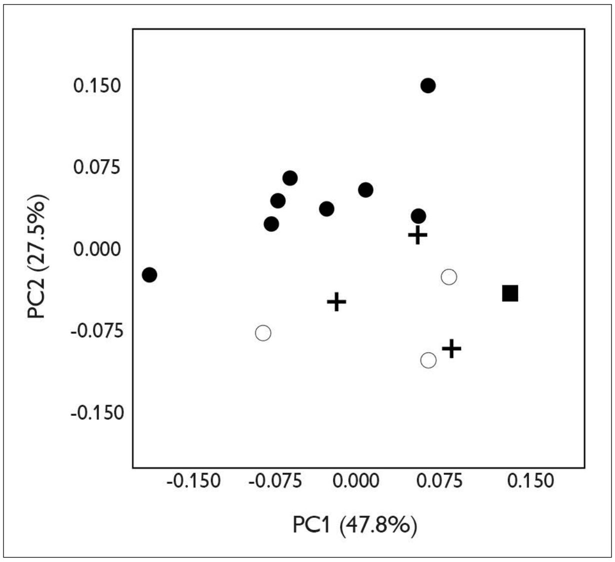

Figure 3. Specimen scores of adult individuals of *Abrocoma* (n = 15) for principal components 1 and 2. Symbols are as follow: black circles = *A. cinerea*; black square = *A. budini;* crosses = *A. schistacea*; hollow circles = *A.* cf. *A. uspallata*.

Table 1. Results of principal components analyses performed on young adult and adult individuals of *Abrocoma* (N = 15). See Materials and Methods for explanation of the abbreviations.

| | PC1 | PC2 |
|---|---|---|
| TLS | 0.2406 | 0.1449 |
| CIL | 0.2369 | 0.1878 |
| LIB | -0.2027 | 0.6537 |
| ZB | 0.2549 | -0.0034 |
| BB | 0.1919 | 0.1800 |
| NL | 0.2704 | 0.2222 |
| NW | 0.0963 | 0.3184 |
| FL | 0.3583 | -0.1549 |
| DL | 0.1897 | 0.2527 |
| IFL | -0.3328 | 0.0985 |
| IFW | 0.2588 | -0.1368 |
| MTR | 0.2434 | 0.0816 |
| PL | 0.2071 | 0.1878 |
| BP4 | 0.4095 | -0.2878 |
| TBL | 0.1646 | 0.2777 |
| Eigenvalue | 0.0089 | 0.00514 |
| % variance | 47.79 | 27.49 |

## DISCUSSION

Qualitative and quantitative external and cranial features have allowed me to recognize two main morphotypes within the *Abrocoma cinerea* species complex. One of these (morphotype 1) coincides with the concept of *A. cinerea* s.s, as had been defined by Braun & Mares (2002). This species is distributed from southern Peru, western Bolivia and northern Chile to northwestern Argentina (with documented records for the provinces of Catamarca, Jujuy, Salta, and Tucumán; Figure 4A). Externally, this species is characterized by a weakly bicolored, short tail (35-42% of head and body length; Patton & Emmons, 2015) and an overall grayish coloration. *A. cinerea* s.s. has an interorbital constriction that is significantly greater than that of the other nominal forms within this species group (> 7.5 mm; Braun & Mares, 2002; Figure 2A); in addition, the supraorbital borders are posteriorly divergent and beaded, with moderately developed postorbital process (Figure 2A). The second morphotype distributes in central-western Argentina, from southern Catamarca province to northwestern Mendoza (Figure 4B). At least five nominal forms can be linked with this morphotype, including *A. budini*, *A. famatina*, *A. schistacea*, *A. uspallata*, and *A. vaccarum*; all these taxa are characterized by grayish to brownish dorsal colorations and moderately long to large and sometimes strongly bicolored tails (53-68% head and body length; Patton & Emmons, 2015; Figure 4B). The interorbital regions of these samples are narrow and elongated, with almost parallel outer borders and conspicuous postorbital processes (Figure 2B).

Most of qualitative morphological traits mentioned as diagnostic for those taxa within the *A. cinerea* species complex (*e.g.*, shape and size of nasals, shape of the anterior border of the mesopterygoid fossa, size of mastoid islands, orientation of zygomata, and procumbency of the upper incisors) probe to be even within populations. This situation diminishes their value as diagnostic traits, at least within this species group, suggesting the need to carry out detailed studies of intraspecific variability to construct robust morphology-based taxonomic hypotheses (Bezerra & De Oliveira, 2010; Teta *et al.*, 2017).

Despite the fact that the number of specimens included in my multivariate analysis is much smaller than those used by Braun & Mares (2002), results of both studies are fully congruent. The principal component analysis conducted by Braun & Mares (2002) also recovers two main groups within the *Abrocoma cinerea* species complex (Braun & Mares, 2002, fig. 2; see also Figure 5), which correspond with the morphotypes recognized here. In accordance with my data, the specimens studied by Braun & Mares (2002) segregates mostly along the second component, corresponding also to the interorbital constriction the highest absolute loading on this axis.

The overall similarity among the different putative species of *Abrocoma* was firstly noted by Thomas (1921b, p. 217), which stated that "All these Argentine species of *Abrocoma* are nearly allied and very similar to each other, but the characters used, slight as they are, seem to be locally constant, while the respective mountain habitats are well separated and often completely isolated". Partly based on this assertion, Braun & Mares (2002) recommend to regard as distinct species the forms described by Thomas (1919, 1920a, 1920b, 1921a, 1921b), indicating that isolated distribution in patches of rocky habitat along the Precordillera and Sierra Pampeanas chains of the various members of the *cinerea* species complex (excluding *A. cinerea*) would be indicative of a pattern of allopatric speciation. Despite that some records correspond to nearly isolated localities, additional trapping effort suggests that at least in some areas, populations of *Abrocoma* are much widely distributed than previously envisioned (*e.g.*, *A. schistacea* in San Juan; Taraborelli *et al.*, 2015). In addition, rocky environments are almost nearly continuous along western Argentina, suggesting that some level of connectivity among populations is highly likely. Another caviomorph rodent with saxicolous adaptations, the mountain vizcachas of the genus *Lagidium* Meyen, 1833, present a similar distributional pattern, with more or less phenotypically differentiated populations along this same general area (Teta & Lucero, 2017). As in the case of *Abrocoma*, these rodents have a moderate variability in their dorsal coloration, which has resulted in the description of several subspecies (Teta & Lucero, 2017).

My results are consistent with the recognition of no more than two morphotypes among the *Abrocoma cinerea* species complex, for which the names *cinerea* and *budini* are available for nomenclatorial purposes. Saying that, I cannot rule out that some minor variation in qualitative (*e.g.*, external coloration) and quantitative traits (*e.g.*, tail

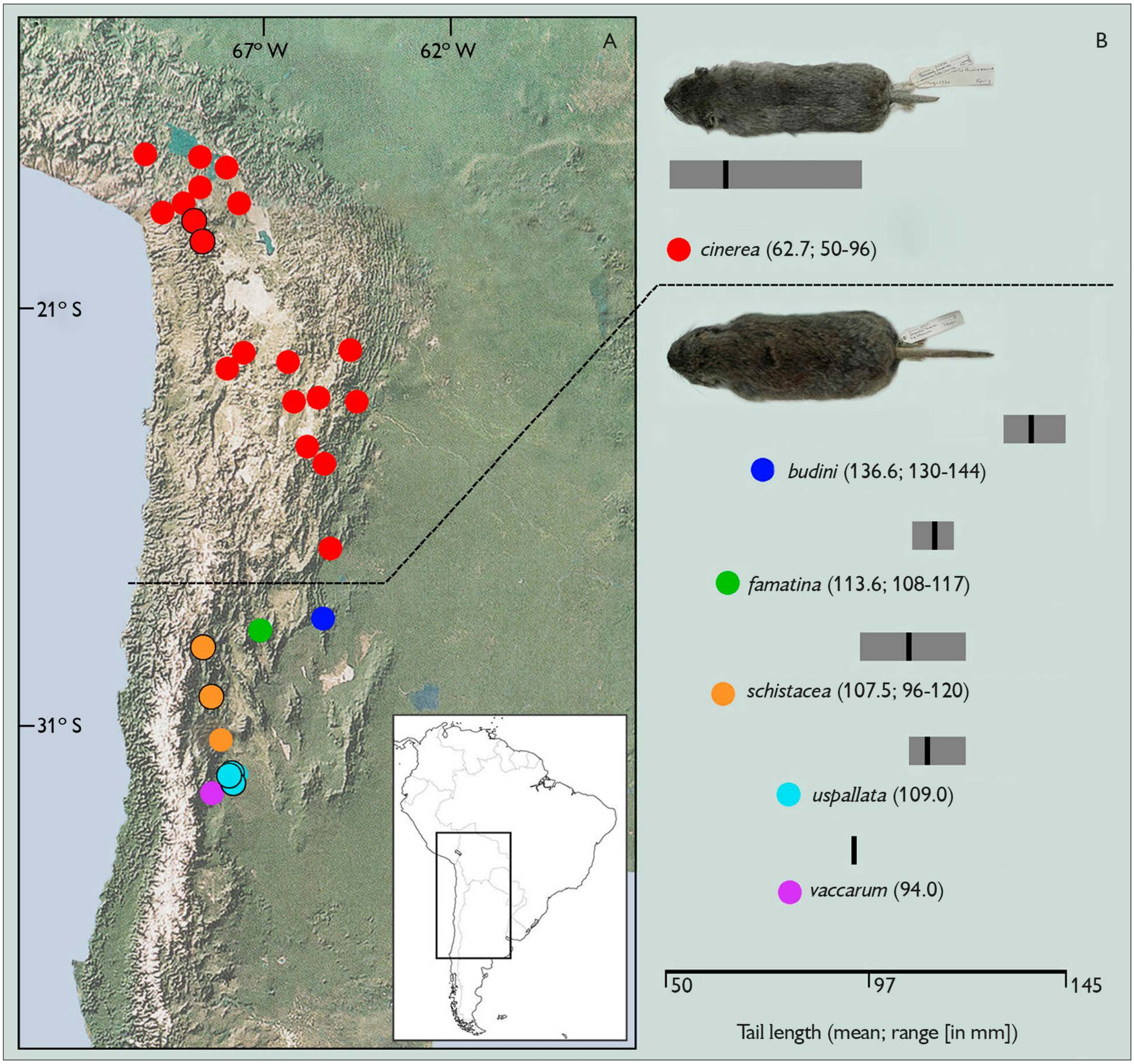

Figure 4. (A) Localities for *Abrocoma* specimens (taken from Braun & Mares, 2002; localities not reviewed by these authors are encircled with black) and (B) differences in tail length between different species; mean values are indicated by black vertical lines, while the gray areas depict the ranges (*cf*. Braun & Mares, 2002; this work).

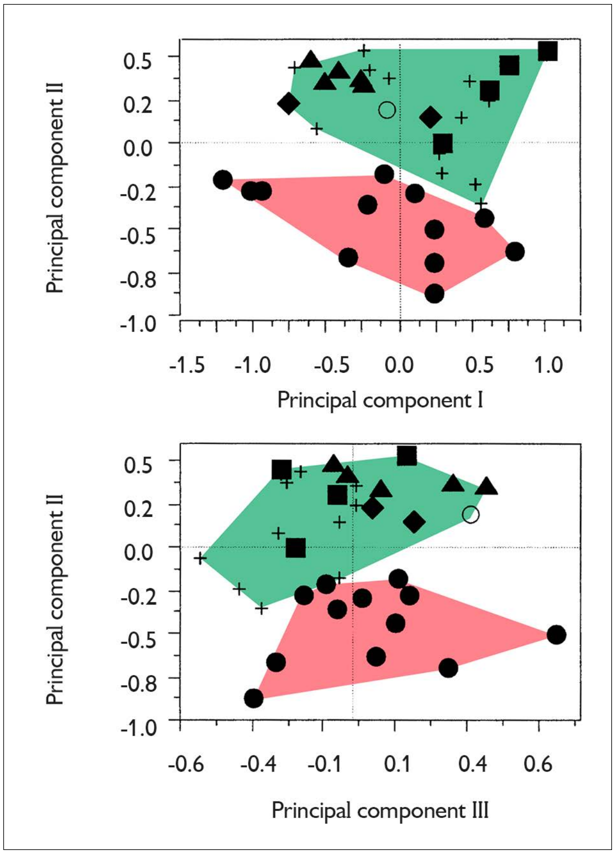

Figure 5. Specimen scores of adult individuals of *Abrocoma* for principal components 1 and 2 (above) and 2 and 3 (below) after Braun & Mares (2002). Symbols are as follow: black squares = *A. budini*; black circles = *A. cinerea*; black triangles = *A. famatina*; crosses = *A. schistacea*; hollow circles = *Abrocoma uspallata*; black diamonds = *A. vaccarum*. Red and green polygons were added by my and correspond to morphotypes 1 (= *A. cinereal*) and 2 recognized in this contribution.

length, *cf.* Braun & Mares, 2002) is indicative of different cryptic species or subspecies within each morphotype. For example, as was noted by Braun & Mares (2002) there are some metric differences between the northern and southern populations of *Abrocoma cinerea* s.s, being those animals from Bolivia and Peru larger than those from northwestern Argentina in some external measurements (*e.g.*, length of head and body, length of hindfoot). In any case, the resolution of these and other questions need the concourse of additional lines of evidence and approaches, among which phylogenetic analysis of DNA sequences will be much useful to disentangle the complex taxonomy of these rodents. Until then, I prefer to not make changes in the current classification of this genus, especially taking into account that any taxonomic change could have undesirable consequences in the conservation of these rare rodents.

## ACKNOWLEDGEMENTS

I acknowledge the invitation of Alexandra Bezerra to contribute with this volume. I am indebted to the curators and staff of all museums and collections studied: Ricardo Ojeda and Benjamín Bender, CMI; Rubén Barquez and M. Mónica Díaz, CML; Nancy Simmons, Robert Voss, and Brian O'Toole, AMNH; Bruce Patterson, FMNH; Guillermo D'Elía, UACh; Darrin Lunde, USNM. The American Society of Mammalogists contributed with the funds, trough its "O. P. Pearson Award," to travel across the United States. Noé de La Sancha and family provided support during my stay in Chicago.

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**Appendix 1**. List of studied specimens and their collecting localities. Specimens consist primarily in skins with their associate skulls and are housed in the following institutions: AMNH, American Museum of Natural History (New York, USA); CMI, *Instituto Argentino de Investigaciones de Zonas Áridas* (Mendoza, Argentina); CML, *Facultad de Ciencias Naturales e Instituto Miguel Lillo* (Tucumán, Argentina); FMNH, Field Museum of Natural History (Chicago, USA); MACN, *Museo Argentino de Ciencias Naturales "Bernardino Rivadavia"* (Buenos Aires, Argentina); UACh, *Universidad Austral de Chile* (Valdivia, Chile). Specimens not reviewed by Braun & Mares (2002) are indicated with an asterisk.

*Abrocoma budini*: ARGENTINA: **Catamarca**: Otro Cerro (FMNH 23641; incorrectly referred to the USNM by Braun & Mares, 2002).

*Abrocoma cinerea*: ARGENTINA: **Salta**: Chorrillos (CML 89, FMNH 35239, MACN-Ma 30.115, MACN-Ma 30.117; MACN-Ma 30.118, MACN-Ma 30.119), San Antonio de los Cobres (MACN-Ma 30.61, MACN-Ma 30.62, MACN 30.63); **Tucumán**: Concepción (CML 91). BOLIVIA: **La Paz**: 8.5 km W of San Andres de Machaca (AMNH 268930). CHILE: **Parinacota**, Chapiquiña, Putre (UACh 3586*); **Camarones**: Salar Surire (UACh 4178*).

*Abrocoma famatina*: ARGENTINA: **La Rioja**: Sierra de Famatina (MACN-Ma 27.55), without precise locality (MACN 49.247, MACN-Ma 49.248).

*Abrocoma schistacea*: ARGENTINA: **San Juan**: Reserva Don Carmelo (MACN s/n*), Los Sombreros (FMNH 46157; incorrectly referred to the USNM by Braun & Mares, 2002), Reserva San Guillermo (MACN-Ma 18828), without precise locality (MACN-Ma 39.758).

*Abrocoma cf. A. uspallata:* ARGENTINA: **Mendoza**: 7 km de Uspallata, on road to Cerro de Siete Colores (CMI 7011*), Arroyo Uspallata, 2000 m (CMI 3769*), Cerro Cacheuta, Agua de Las Avispas (CMI 7080), Villavicencio (CMI 7012*).

# Roedores muroideos (Mammalia, Cricetidae e Muridae) da Toca dos Ossos, Ourolândia, Caatinga do estado da Bahia, Brasil

# Muroid rodents (Mammalia, Cricetidae and Muridae) from Toca dos Ossos, Ourolândia, Caatinga of the State of Bahia, Brazil

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**Resumo:** Roedores muroideos incluem as duas famílias mais diversas de mamíferos do mundo, Cricetidae e Muridae. Apesar disso, são ainda pouco estudados em muitas regiões, como a Caatinga. O presente estudo dá a conhecer os roedores muroideos da Toca dos Ossos, situada em Ourolândia, centro-norte da Bahia. A Toca dos Ossos é uma cavidade natural escavada em maciço calcário da Formação Caatinga, destacando-se por ser um importante sítio paleontológico. O material estudado é constituído por fragmentos cranianos e mandibulares coletados em duas áreas da caverna. Em uma delas, egagropilos de *Tyto furcata* foram coletados em uma dolina e, na outra, o material foi coletado no sedimento de superfície em salões e condutos internos da caverna. Sete espécies foram registradas: *Necromys lasiurus*, a mais frequente na amostra, *Cerradomys* sp., *Holochilus sciureus*, *Oligoryzomys* sp., *Calomys* sp., *Wiedomys pyrrhorhinos* e *Rattus rattus*, este exclusivo nas amostras de egagropilos. Apesar das diferenças nas frequências dos táxons, as amostras em ambas as áreas da caverna apresentam grande similaridade taxonômica e são compostas por espécies de ocorrência atual na Caatinga, incluindo a espécie exótica *R. rattus*, o que sugere uma idade recente para o material, posterior à expansão desse bioma, que ocorreu há cerca de 4.000 anos.

**Palavras-chave:** Caverna. Egagropilo de coruja. Floresta tropical sazonal seca. Sigmodontinae.

**Abstract:** Muroid rodents include the two most diversified mammalian families of the world, Cricetidae and Muridae. Despite this, muroids are still poorly addressed in many regions, such as the Caatinga biome. This study reports the muroid rodents from the 'Toca dos Ossos', municipality of Ourolândia, central-northern Bahia state. The 'Toca dos Ossos' is a natural cavity excavated in the limestone massif of the Caatinga Formation, standing out as an important paleontological site. The studied material consists of cranial and mandibular fragments retrieved in two cave areas. One of them represent *Tyto furcata* pellets collected at a sinkhole, and the other is from material collected in the surface sediment of cave halls and internal conduits. The following species were recorded: *Necromys lasiurus*, the most frequent in the samples, *Cerradomys* sp., *Holochilus sciureus*, *Oligoryzomys* sp., *Calomys* sp., *Wiedomys pyrrhorhinos*, and *Rattus rattus*, the latter exclusively found in the owl pellets samples. Even though there are differences in the frequencies of the taxa, the communities from both of the cave areas possess great taxonomic similarity and include species currently found in the Caatinga, including the exotic species *R. rattus*, suggesting a recent age for the material, subsequent to the expansion of this biome, which happened 4,000 years ago.

**Keywords:** Cave. Owl pellet. Seasonally dry tropical forest. Sigmodontinae.

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GOMES, A. C., C. S. SCHERER, P. HADLER, J. J. CHEREM, T. V. OLIVEIRA & N. S. STUTZ, 2020. Roedores muroideos (Mammalia, Cricetidae e Muridae) da Toca dos Ossos, Ourolândia, Caatinga do estado da Bahia, Brasil. **Boletim do Museu Paraense Emílio Goeldi. Ciências Naturais** 15(3): 777-794. DOI: http://doi.org/10.46357/bcnaturais.v15i3.215.

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Recebido em 29/11/2019
Aprovado em 08/10/2020
Responsabilidade editorial: Alexandra Maria Ramos Bezerra

## INTRODUÇÃO

Os muroideos compreendem um grupo de roedores miomorfos caracterizados por sua fórmula dentária simplificada (ausência de pré-molares nas mandíbulas e maxilas) e pela presença de anterocone/ídeo bem desenvolvido no primeiro molar (Flynn *et al.*, 1985). Eles compõem uma parte significativa das assembleias de mamíferos na maioria dos continentes, ocorrem nos mais variados ambientes, perfazendo, aproximadamente, 28% do total de espécies de mamíferos, e incluem as duas famílias mais diversas de mamíferos, Cricetidae (792 espécies) e Muridae (834 espécies) (Jansa & Weksler, 2004; Honeycutt *et al.*, 2007; Fabre *et al.*, 2012; Burgin *et al.*, 2018).

Na América do Sul, a família Cricetidae é representada pela subfamília Sigmodontinae, que inclui mais de 430 espécies viventes e ilustra um dos mais extraordinários eventos de radiação explosiva, considerando que sua história evolutiva no continente pode se estender por um período inferior a 4 milhões de anos (Pardiñas *et al.*, 2017; Barbière *et al.*, 2019). Por outro lado, as três espécies de Muridae distribuídas amplamente na América do Sul são invasoras recentes, tendo sido introduzidas acidentalmente pelos exploradores do Novo Mundo (Catzeflis, 2018).

A Caatinga é um bioma típico do semiárido do Nordeste brasileiro, formada por um mosaico de ambientes arbustivos e florestais (Leal *et al.*, 2005). Atualmente considerada uma das maiores áreas de floresta tropical sazonalmente seca do Novo Mundo, a Caatinga abriga uma biodiversidade considerável para uma região semiárida, composta por, pelo menos, 3.150 espécies de plantas, 98 de anfíbios, 79 de répteis e 548 de aves (Silva *et al.*, 2017). Em relação aos mamíferos, Carmignotto & Astúa (2017) registraram 183 espécies autóctones, 11 das quais são endêmicas do bioma. Rodentia é a segunda ordem em riqueza, com 41 espécies, sendo que 23 delas pertencem à família Cricetidae (Carmignotto & Astúa, 2017). Além disso, as três espécies de murídeos invasores também estão presentes na Caatinga (Moojen, 1952).

Nesse bioma, destaca-se a Reserva Particular do Patrimônio Natural (RPPN) Toca dos Ossos, criada em 27 de dezembro de 2016 (INEMA, 2016), a qual tem, entre outros aspectos, elevada relevância paleontológica (*e.g.*, Cartelle & Lessa, 1988, 1989; Cartelle & Abuhid, 1994; Czaplewski & Cartelle, 1998; Lessa *et al.*, 1998; Lobo *et al.*, 2017; Gomes *et al.*, 2019). Por outro lado, poucos estudos foram realizados sobre a fauna atual de mamíferos da Toca dos Ossos e região do entorno (*e.g.*, Sbragia & Cardoso, 2008; Jesus & Oliveira, 2017). Entre os roedores da Toca dos Ossos, foram conduzidos apenas estudos sobre variação em caracteres cranianos do caviomorfo *Kerodon rupestris* (Wied-Neuwied, 1820) (Lessa & Pessôa, 2005; Lessa *et al.*, 2005).

Apesar da elevada riqueza dos roedores no estado da Bahia como um todo, levantamentos abordando esse grupo têm sido conduzidos principalmente na Mata Atlântica (*e.g.*, Vaz, 2005; Geise & Pereira, 2008; Carvalho & Oliveira, 2015), havendo, entretanto, poucos na Caatinga (Oliveira *et al.*, 2003; Freitas *et al.*, 2005; Oliveira & Pessôa, 2005; Pereira & Geise, 2009). Devido à escassez de registros de roedores neste bioma, é de fundamental importância o estudo da fauna da Toca dos Ossos. Neste sentido, este trabalho tem como objetivos fornecer uma lista comentada de roedores muroideos dessa localidade, bem como apontar o provável intervalo temporal de depósito do material.

## MATERIAL E MÉTODOS

### ÁREA DE ESTUDO

A Toca dos Ossos está localizada na bacia do rio Salitre, município de Ourolândia, estado da Bahia, região Nordeste do Brasil. Sua entrada principal situa-se 560 m acima do nível do mar (10° 55' 51,25" S, 41° 3' 27,10" O) (Figuras 1A e 1B). A Toca dos Ossos representa uma cavidade natural escavada em um maciço calcário da Formação Caatinga, situada na porção norte da Chapada Diamantina, com grande concentração de fósseis (*e.g.*, Lessa *et al.*, 1998; Gomes *et al.*, 2019).

A Toca dos Ossos possui 14.200 m de projeção horizontal mapeados (Rubbioli *et al.*, 2019). Apresenta padrões morfológicos peculiares que a diferem de outras cavernas brasileiras, com galerias meandrantes interconectadas em vários pontos. Entre as galerias maiores, pode ser observada uma complexa rede labiríntica, responsável pela ligação de áreas distintas da caverna (Figura 1C) (Auler *et al.*, 2006; Rubbioli *et al.*, 2019). Esse aspecto espongiforme, sem padrões definidos, fica evidente no período chuvoso, quando o alagamento da galeria principal escoa água para as áreas mais baixas da caverna, enquanto as áreas posicionadas em um nível superior permanecem com seu sedimento seco (Auler *et al.*, 2006).

A bacia do rio Salitre, na qual se situa a Toca dos Ossos, está inserida no bioma Caatinga e é caracterizada predominantemente por duas fitofisionomias, Caatinga Arbustiva (esparsa ou densa, formada por arbustos de 2 a 3 metros de altura e arvoretas de 5 a 6 metros) e Caatinga Arbórea (composta predominantemente por árvores de 8 a 10 metros) (Rizzini, 1997; CBHS, 2017). No entanto, grande parte da vegetação nessa região encontra-se atualmente alterada por ação antrópica, com a conversão de quase 50% da cobertura vegetal natural em áreas de cultivo agrícola e pastagem. As estações seca e chuvosa são bem definidas, e a estação chuvosa está concentrada nos meses de novembro a março. A precipitação total anual varia de 300 a 600 mm (CBHS, 2017). O clima, segundo a classificação de Köppen, é do tipo BSh, semiárido, de baixas latitude e altitude, caracterizado pela baixa pluviosidade e temperatura média anual de cerca de 25 °C (Alvares *et al.*, 2013).

## AMOSTRAGEM

O material estudado consiste de 210 fragmentos cranianos e mandibulares, coletados em 03 de julho de 2011, 10-11 de agosto de 2012 e 09 de junho de 2013, em duas áreas da Toca dos Ossos (doravante denominadas TO), distantes 500 metros uma da outra, aproximadamente. A primeira compreende uma dolina, denominada TO-I (Figuras 1C e 1D), onde o material foi obtido a partir da triagem de egagropilos inteiros ou desagregados de corujas-das-igrejas – *Tyto furcata* (Temminck, 1827) – (Figura 1E). A segunda área, denominada TO-II, localiza-se na parte mais interna da caverna e está composta por vários salões e condutos (Figuras 1C e 1F), onde o material foi coletado diretamente do sedimento de superfície (Figura 1G). A coleta dos espécimes na caverna foi autorizada pelo Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio), por meio das licenças números 27530 e 35904.

## TRIAGEM E IDENTIFICAÇÃO

Em laboratório, o material foi limpo sob estereomicroscópio binocular, com o auxílio de pincel e agulha. Posteriormente, os espécimes da TO-I foram depositados na Coleção de Mamíferos do Museu de Zoologia da Universidade Estadual de Feira de Santana (MZFS-DM) e da TO-II nas coleções Paleontologia de Vertebrados do Museu de Zoologia e Paleontologia da Universidade Federal do Recôncavo da Bahia (UFRB-PV).

A identificação das espécies foi realizada a partir de fontes bibliográficas (Pardiñas & Teta, 2011; Bonvicino, 2015; Brandão & Nascimento, 2015; Salazar-Bravo, 2015; Weksler & Bonvicino, 2015; Catzeflis, 2018; Cherem *et al.*, 2018; Stutz *et al.*, 2018) e da comparação com espécimes depositados nas coleções de mamíferos do Museu de Zoologia da Universidade Estadual de Feira de Santana (MZFS-DM) e do Departamento de Ecologia e Zoologia da Universidade Federal de Santa Catarina (UFSC) (Apêndice 1). Quando necessário, foram tomadas medidas utilizando-se paquímetro digital com precisão de 0,02 mm: largura do forâmen incisivo (LFI); comprimento da série molar superior (CM1-M3); comprimento da série molar inferior (Cm1-m3); comprimento do primeiro molar inferior (Cm1).

A nomenclatura dentária seguiu Reig (1977) e Percequillo (2006). A nomenclatura e o ordenamento taxonômicos seguiram Patton *et al.* (2015) para Sigmodontinae e Wilson & Reeder (2005) para Muridae. O número mínimo de indivíduos (NMI) por espécie foi determinado segundo Beisaw (2013).

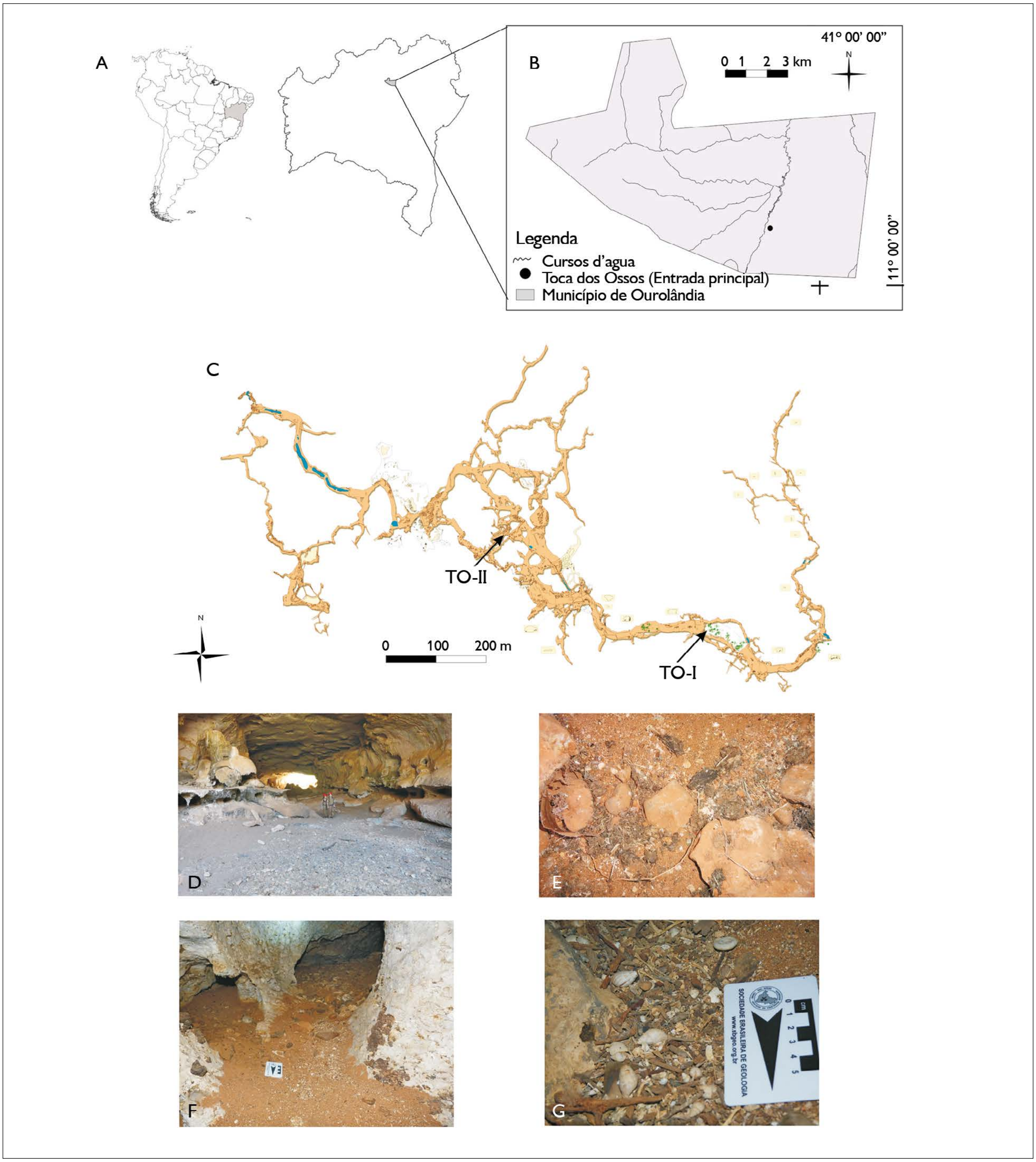

Figura 1. Localização e imagens da Toca dos Ossos: A) mapa da América do Sul, com destaque para o estado da Bahia, no Brasil; B) município de Ourolândia; C) mapa da caverna Toca dos Ossos, indicando os pontos de coleta do material (modificado de Rubbioli *et al*., 2019); D) dolina da Toca dos Ossos-I; E) egagropilos de *Tyto furcata* coletados na Toca dos Ossos-I; F) porção interna da caverna, denominada Toca dos Ossos-II; G) detalhe do material coletado no sedimento de superfície da Toca dos Ossos-II. Mapas: modificados de Rubbioli *et al*. (2019). Fotos: C. S. Scherer (2013).

## RESULTADOS

### COMPOSIÇÃO DAS AMOSTRAS

A amostra total de roedores muroideos da Toca dos Ossos foi composta por duas famílias e sete espécies, com NMI = 99 (Tabela 1; Apêndice 2). Entre os cricetídeos, foram registrados táxons pertencentes a quatro tribos: Akodontini (33,3% dos indivíduos), que apresentou a maior abundância relativa, e Phyllotini (22,2%), Wiedomyini (21,2%) e Oryzomyini (21,3%), com abundâncias similares. Apesar de menos frequente na amostra, a tribo Oryzomyini apresentou maior riqueza, com três táxons (*Cerradomys* sp., *Holochilus sciureus* Wagner, 1842 e *Oligoryzomys* sp.). *Rattus rattus* (2%) foi o único representante da família Muridae identificado na área de estudo.

A amostra TO-I apresentou NMI = 39 e foi representada por seis espécies de Cricetidae e uma de Muridae. A amostra TO-II, com NMI = 60, incluiu as mesmas seis espécies de Cricetidae. Apesar da composição taxonômica semelhante, as duas amostras apresentaram diferenças nas frequências dos táxons. *Necromys lasiurus* (Lund, 1840) foi o táxon dominante (56,4%) em TO-I, seguido por *Wiedomys pyrrhorhinos* (Wied-Neuwied, 1821) (18%) e *Calomys* sp. (10,4%). Por outro lado, *Calomys* sp. predominou na TO-II, com 30%, seguido por *W. pyrrhorhinos*, com 23,3%, *N. lasiurus* e *H. sciureus*, ambos com 18,3% (Tabela 1).

### IDENTIFICAÇÃO DOS TÁXONS

Família Cricetidae Fischer, 1817
Subfamília Sigmodontinae Wagner, 1843
Tribo Akodontini Vorontsov, 1959
*Necromys lasiurus* (Lund, 1840)
Figuras 2A, 2B, 3A, 4A e 5A

Material: 18 crânios, 21 maxilares e 39 dentários (Apêndice 2).

Descrição: material de médio porte. Crânio alto com rostro curto e forâmen incisivo longo, estendendo-se posteriormente até o nível do protocone do M1; crista supraorbital presente, mas pouco marcada. Dentário baixo e robusto, com projeção capsular desenvolvida.

Tabela 1. Número mínimo de indivíduos (NMI) e percentual de indivíduos por táxon registrado nas duas áreas de amostragem (TO-I e TO-II) na Toca dos Ossos, Ourolândia, estado da Bahia, Brasil.

| Táxon | TO-I | | TO-II | | Total | |
|---|---|---|---|---|---|---|
| | NMI | % | NMI | % | NMI | % |
| Família Cricetidae | | | | | | |
| Tribo Akodontini | | | | | | |
| *Necromys lasiurus* (Lund, 1840) | 22 | 56,4 | 11 | 18,3 | 33 | 33,3 |
| Tribo Oryzomyini | | | | | | |
| *Cerradomys* sp. | 1 | 2,5 | 5 | 8,4 | 6 | 6,1 |
| *Holochilus sciureus* Wagner, 1842 | 2 | 5,1 | 11 | 18,3 | 13 | 13,2 |
| *Oligoryzomys* sp. | 1 | 2,5 | 1 | 1,7 | 2 | 2,0 |
| Tribo Phyllotini | | | | | | |
| *Calomys* sp. | 4 | 10,4 | 18 | 30 | 22 | 22,2 |
| Tribo Wiedomyini | | | | | | |
| *Wiedomys pyrrhorhinos* (Wied-Neuwied, 1821) | 7 | 18 | 14 | 23,3 | 21 | 21,2 |
| Família Muridae | | | | | | |
| *Rattus rattus* (Linnaeus, 1758) | 2 | 5,1 | 0 | 0 | 2 | 2,0 |
| Total | 39 | 100 | 60 | 100 | 99 | 100 |

Molares com cúspides alternadas; flexo anteromediano ausente; mesolofo ausente, exceto em UFRB-PV 2857, 2975 e MZFS-DM 0820, 0864; flexídeo anteromediano presente apenas em espécimes jovens (UFRB-PV 2998, 3002, 3031, 3119; MZFS-DM 0841, 0843, 0847, 0848, 0855, 0861, 0862, 0863, 0874 e 0875); mesolofídeo ausente.

Comentários: as características apresentadas, em particular sobre seu porte, desenvolvimento do rostro, extensão do forâmen incisivo, presença de crista supraorbital e morfologia dos molares, permitiram atribuir esses espécimes a *N. lasiurus*, de acordo com Anderson & Olds (1989), Pardiñas *et al*. (2015b) e Stutz *et al*. (2018). *Necromys lasiurus* foi o roedor mais frequente na Toca dos Ossos e único representante da tribo Akodontini registrado nas amostras. Carmignotto & Astúa (2017) relacionaram uma segunda espécie da tribo para a Caatinga, *Akodon cursor* (Winge, 1887), que se diferencia de *N. lasiurus* principalmente por seu crânio mais baixo e crista supraorbital ausente (Geise, 2012). Além disso, *Akodon* Meyen, 1833 apresenta flexo/ídeo anteromediano e mesolofo/ídeo (exceto em espécimes mais velhos, com molares muito gastos) (Stutz *et al*., 2018).

Tribo Oryzomyini Vorontsov, 1959

*Cerradomys* sp.

Figuras 3B, 4B e 5B

Material: um crânio fragmentado, seis maxilares e seis dentários (Apêndice 2).

Descrição: material de médio porte. Forâmen incisivo, geralmente se estende posteriormente até a margem anterior do M1; palato longo, estendendo-se posteriormente à margem posterior do M3, exceto em espécimes jovens (UFRB-PV 959, 2820 e 2990). Dentário alto e robusto, com projeção capsular bem desenvolvida; processo coronoide pequeno; crista massetérica inferior pouco marcada. Molares pentalofodontes; M2 com paracone e protocone opostos; flexo/ídeo anteromediano ausente; cíngulo anterolabial presente nos molares inferiores; procíngulo no m1 curto; mesolofídeo bem desenvolvido.

Comentários: o tamanho e a morfologia dos molares, conforme descrito, são caracteres diagnósticos do gênero *Cerradomys* Weksler, Percequillo & Voss, 2006, de acordo com Weksler *et al*. (2006) e Percequillo *et al*. (2008). Em relação ao material utilizado para comparação (Apêndice 1), *Cerradomys* apresenta forâmen incisivo mais longo, projeção capsular mais desenvolvida e hipoflexídeo menos profundo do que *Hylaeamys* Weksler, Percequillo & Voss, 2006; palato mais longo do que *Rhipidomys* Coues, 1884, o qual apresenta flexo/ídeo anteromediano; crista massetérica inferior menos marcada e molares pouco maiores do que em *Euryoryzomys* Weksler, Percequillo & Voss, 2006; forâmen incisivo mais longo, dentário mais alto e diastema mais longo do que em *Oecomys* Thomas, 1906. O dentário mais robusto, mas com processo coronoide mais baixo, a posição relativa do protocone e paracone no M2 e a presença de mesolofídeo nos molares inferiores permitem diferenciar *Cerradomys* de *Wiedomys* Hershkovitz, 1959.

*Cerradomys* inclui oito espécies, duas das quais estão presentes atualmente na Caatinga, *Cerradomys langguthi* Percequillo, Hingst-Zaher & Bonvicino, 2008 e *Cerradomys vivoi* Percequillo, Hingst-Zaher & Bonvicino, 2008 (Bonvicino *et al*., 2014; Carmignotto & Astúa, 2017). Dentre essas duas, apenas *C. vivoi* possui registro recente para o estado da Bahia (Percequillo *et al*., 2008). Os espécimes registrados na Toca dos Ossos foram referidos como *Cerradomys* sp. por não haver caracteres morfológicos que permitam distinguir confiavelmente essas duas espécies (Percequillo *et al*., 2008; Caccavo & Oliveira, 2016).

*Holochilus sciureus* Wagner, 1842

Figuras 2C, 2D, 3C, 4C e 5C

Material: quatro crânios, 11 maxilares e nove dentários (Apêndice 2).

Descrição: material de grande porte, o maior entre os cricetídeos nas amostras da Toca dos Ossos. Palato longo, estendendo-se além da margem posterior do M3; forâmen incisivo muito curto, não alcançando a margem anterior do M1. Dentário robusto e crista massetérica inferior bem marcada. Molares com cúspides alternadas e lofídeos com margem prismática; fossetídeo anteromediano pequeno; borda posterior do proto e hipoconídeo orientado transversalmente.

Comentários: as características listadas e a ausência de mesolofídeo permitiram identificar o material como *H. sciureus*, conforme Pardiñas & Teta (2011) e Brandão & Nascimento (2015). Esta é a única espécie do gênero com ocorrência atual na Caatinga (Carmignotto & Astúa, 2017).

*Oligoryzomys* sp.

Figuras 2E, 2F, 3D, 4D e 5D

Material: um crânio, um maxilar e dois dentários (Apêndice 2).

Descrição: material de tamanho diminuto. Forâmen incisivo estendendo-se posteriormente até o nível da borda anterior do M1. Dentário alto, com dois alvéolos para as raízes do m2 e m3. Molares baquiodontes; mesolofo presente no M1 e M2; flexo/ídeo anteromediano presente, mas pouco marcado (MZFS-DM 0825) ou perdido pelo desgaste (UFRB-PV 2735, MZFS-DM 0856); mesoestilídeo presente no m2, mas mesolofídeo ausente.

Comentários: entre os espécimes da Toca dos Ossos, *Oligoryzomys* sp. Bangs, 1900 apresenta porte similar a *Calomys* sp., diferenciando-se pela menor extensão posterior do forâmen incisivo, menor número de alvéolos no M2/m2 e M3/m3 (três nesses molares de *Calomys*), e presença de mesolofo.

Quatro espécies de *Oligoryzomys* Bangs, 1900 ocorrem atualmente na Caatinga (Carmignotto & Astúa, 2017). Entre elas, *O. rupestris* Weksler & Bonvicino, 2005 apresenta o anterocone não dividido por um flexo anteromediano (Weksler & Bonvicino, 2015), diferindo do material da Toca dos Ossos. *Oligoryzomys nigripes* (Olfers, 1818) e *O. stramineus* Bonvicino & Weksler, 1998 apresentam porte relativamente grande para o gênero, enquanto *O. mattogrossae* (Allen, 1916) é comparativamente menor (Weksler *et al*., 2017), mas há sobreposição nas medidas dentárias entre essas espécies (Tabela 2). Desta forma, considerando o pequeno tamanho da amostra da Toca dos Ossos, sua natureza fragmentária e a ausência de caracteres claramente diagnósticos, esses espécimes foram identificados apenas em nível de gênero.

Tribo Phyllotini Vorontsov, 1959

*Calomys* sp.

Figuras 2G, 2H, 3E, 4E e 5E

Material: seis crânios, nove maxilares e 36 dentários (Apêndice 2).

Tabela 2. Comparação entre as medidas dentárias (em milímetros) dos espécimes de *Oligoryzomys* sp. registrados na Toca dos Ossos (MZFS-DM 0825 e UFRB-PV 2735) e das espécies do gênero presentes na Caatinga: 1 = espécimes de *O. mattogrossae* do Nordeste do Brasil (Weksler *et al*., 2017); 2 = espécimes de *O. mattogrossae* ao longo de toda a distribuição (Weksler *et al*., 2017); 3 = espécimes de *O. rupestris*, *O. stramineus* e *O. nigripes* ao longo de suas distribuições (Weksler & Bonvicino, 2005); 4 = espécimes de *O. nigripes* do estado do Espírito Santo ao estado do Rio Grande do Sul (Machado *et al*., 2011); n = número de espécimes.

| Espécimes/Espécies | Comprimento M1-M3 | Largura M1 |
|---|---|---|
| MZFS-DM 0825 | 3,37 | 1,05 |
| UFRB-PV 2735 | - | 1,00 |
| *O. mattogrossae*$^1$ | 2,94-3,15 (n = 4) | 0,86-0,96 (n = 4) |
| *O. mattogrossae*$^2$ | 2,84-3,64 (n = 39) | 0,81-1,20 (n = 39) |
| *O. rupestris*$^3$ | 3,2-3,5 (n = 8) | 1,0-1,1 (n = 8) |
| *O. stramineus*$^3$ | 3,3-4,2 (n = 36) | 1,0-1,3 (n = 36) |
| *O. nigripes*$^3$ | 3,5-4,0 (n = 35) | 1,0-1,2 (n = 35) |
| *O. nigripes*$^4$ | 3,06-4,28 (n = 153) | 0,84-1,12 (n = 155) |

Descrição: espécimes de tamanho diminuto. Crânio com crista supraorbital desenvolvida e forâmen incisivo longo, alcançando o protocone do M1. Dentário delicado, mas alto; projeção capsular medianamente desenvolvida; três alvéolos para as raízes do M2/m2 e M3/m3. Molares tetralofodontes e braquiodontes; M1 com flexo anteromediano muito profundo, dividindo o anterocone em dois cônulos, sendo um menor, anterolingual, e outro maior, anterolabial. No espécime UFRB-PV 2991, o flexo anteromediano não está visível, em razão do desgaste.

Comentários: o material foi atribuído ao gênero *Calomys* pelo conjunto de características descritas, conforme Salazar-Bravo (2015). *Calomys* foi o único representante da tribo Phyllotini registrado nas amostras. Revisões recentes têm apontado *C. expulsus* (Lund, 1840) como a única espécie do gênero presente na Caatinga (Salazar-Bravo, 2015; Carmignotto & Astúa, 2017). No entanto, considerando a natureza fragmentária dos espécimes da Toca dos Ossos e a ausência de caracteres diagnósticos que permitam a identificação da espécie, optou-se por tratar o material como *Calomys* sp.

Tribo Wiedomyini Reig, 1980

*Wiedomys pyrrhorhinos* (Wied-Neuwied, 1821)

Figuras 2I, 2J, 3F, 4F e 5F

Material: 14 crânios, 12 maxilares e 12 dentários (Apêndice 2).

Descrição: material de tamanho mediano nas amostras da Toca dos Ossos. Palato curto, não se estendendo além da margem posterior do M3, exceto em três espécimes (MZFS-DM 0956, 0965 e 2907), nos quais o palato é longo; forâmen incisivo longo, com sua borda posterior ultrapassando a margem anterior do M1. Dentário comparativamente delicado e processo coronoide baixo. M2 com paracone e protocone alternados; flexo/ídeo anteromediano conspícuo, exceto em indivíduos com maior desgaste (MZFS-DM 0905, 0955, 0956, 0965; UFRB-PV 906, 2819, 2897, 2956, 2957, 2983, 3121 e 3176); mesolofo presente; mesolofídeo ausente; m1 com procíngulo longo.

Comentários: o comprimento do forâmen incisivo, a alternância das cúspides, a presença de mesolofo e a ausência de mesolofídeo estão entre os caracteres diagnósticos de *Wiedomys*, assim como o palato curto (Bonvicino, 2015). No entanto, alguns espécimes podem apresentar palato longo, como observado em três casos da Toca dos Ossos e no espécime ilustrado por Bezerra *et al*. (2013, fig. 2).

*Wiedomys* foi o único representante da tribo Wiedomyini registrado para a Toca dos Ossos. O gênero inclui duas espécies, *W. pyrrhorhinos* e *W. cerradensis* Gonçalves, Almeida & Bonvicino, 2005, ambas com ocorrência atual na Caatinga (Carmignotto & Astúa, 2017). De acordo com Bonvicino (2015), *W. pyrrhorhinos* apresenta forâmen incisivo mais largo (> 2,22 mm) e série molar superior mais longa (> 4,6 mm) do que *W. cerradensis*. Desta maneira, as medidas do material da Toca dos Ossos – LFI = 2,30-2,57 mm (n = 12); CM1-M3 = 4,56-4,81 mm (n = 17) – indicam se tratar de *W. pyrrhorhinos*.

Família Muridae Illiger, 1811

*Rattus rattus* (Linnaeus, 1758)

Figura 3G

Material: dois dentários (Apêndice 2).

Descrição: espécimes de grande porte. Dentários grandes e robustos, com projeção capsular pouco marcada e processo coronoide desenvolvido.

Comentários: a família Muridae está representada no continente americano por dois gêneros: *Mus* inclui apenas uma espécie, *M. musculus* (Linnaeus, 1758), de pequeno porte, enquanto *Rattus* Fischer de Waldheim, 1830 inclui duas espécies de maior tamanho (Catzeflis, 2018). Dentre eles, *Rattus* foi o único gênero registrado na Toca dos Ossos. O material inclui os dois maiores dentários presentes nas amostras. O comprimento da

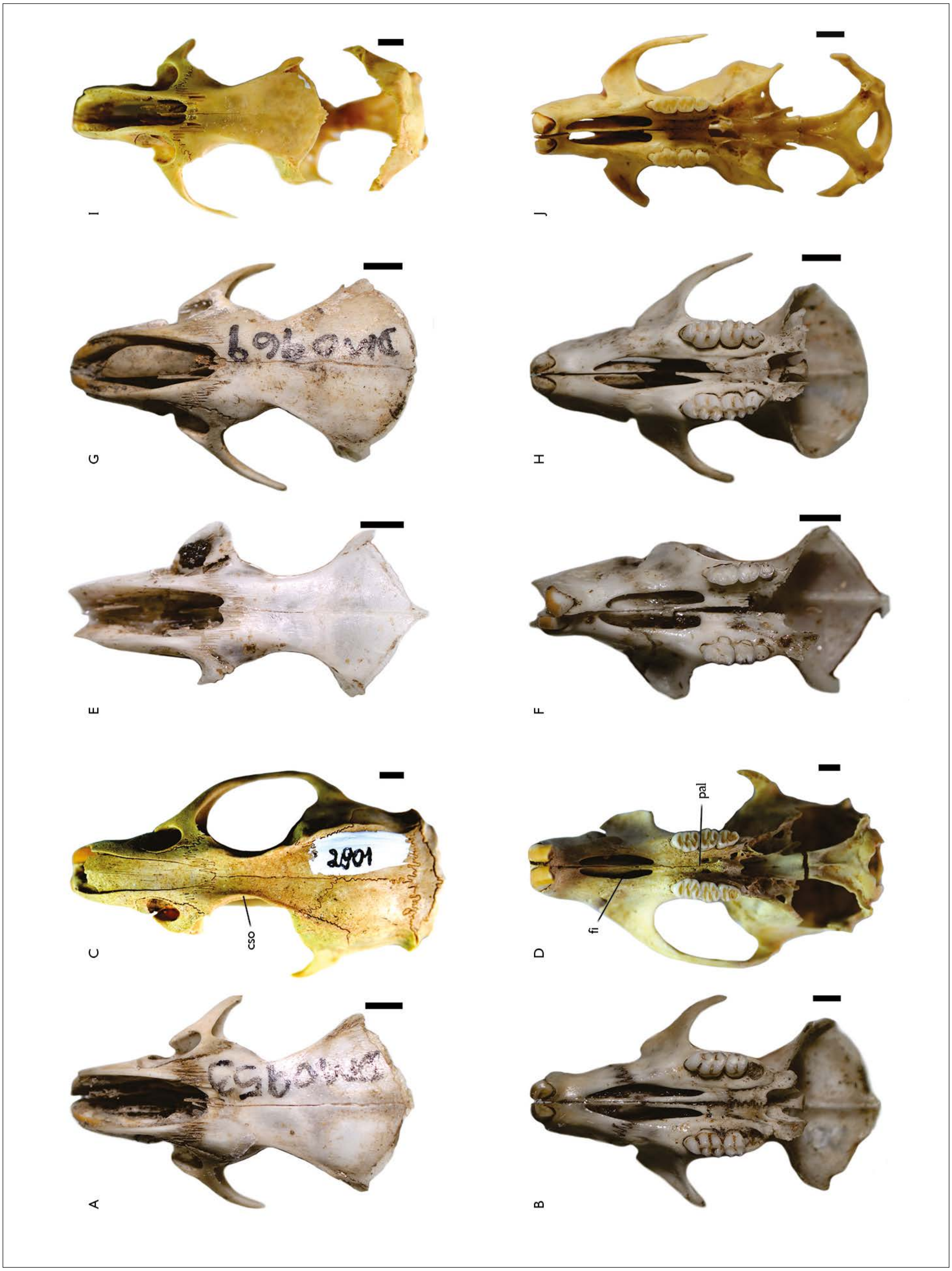

Figura 2. Vista dorsal e ventral dos crânios de: A, B) *Necromys lasiurus*, MZFS-DM 0953; C, D) *Holochilus sciureus*, UFRB-PV 2901; E, F) *Oligoryzomys* sp., MZFS-DM 0825; G, H) *Calomys* sp., MZFS-DM 0969; I, J) *Wiedomys pyrrhorhinos*, UFRB-PV 2898. Escala = 2 mm. Abreviaturas: cso = crista supraorbital; fi = forâmen incisivo; pal = palato.

série molar inferior (Cm1-m3 = 5,94 mm, MZFS-DM 0924) e o comprimento do m1 (Cm1 = 2,43 mm, MZFS-DM 0839; Cm1 = 2,63 mm, MZFS-DM 0924) desses espécimes estão dentro da variação registrada para *R. rattus* (Cm1-m3 = 5,8-6,7 mm; Cm1 = 2,5-2,9 mm) e abaixo dos valores para *R. norvegicus* (Berkenhout, 1769) (Cm1-m3 = 6,7-7,5 mm; Cm1 = 3,0-3,2 mm) (Catzeflis, 2018).

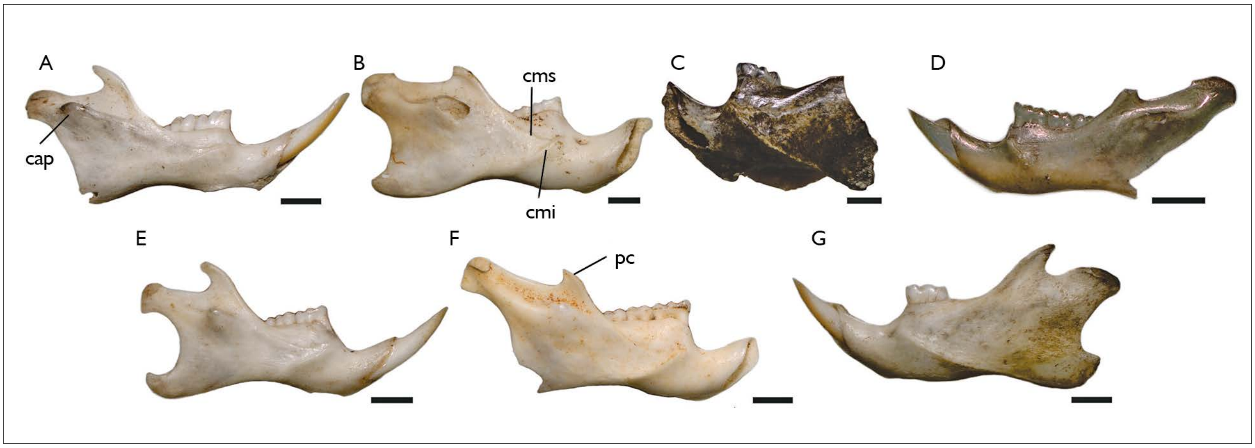

Figura 3. Vista lateral do dentário de: A) *Necromys lasiurus*, MZFS-DM 0831, direito; B) *Cerradomys* sp., MZFS-DM 0826, direito; C) *Holochilus sciureus*, UFRB-PV 908, esquerdo; D) *Oligoryzomys* sp., MZFS-DM 0867, esquerdo; E) *Calomys* sp., MZFS-DM 0835, direito; F) *Wiedomys pyrrhorhinos*, MZFS-DM 0838, direito; G) *Rattus rattus*, MZFS-DM 0839, esquerdo. Escala = 2 mm. Abreviaturas: cap = projeção capsular; cmi = crista massetérica inferior; cms = crista massetérica superior; pc = processo coronoide.

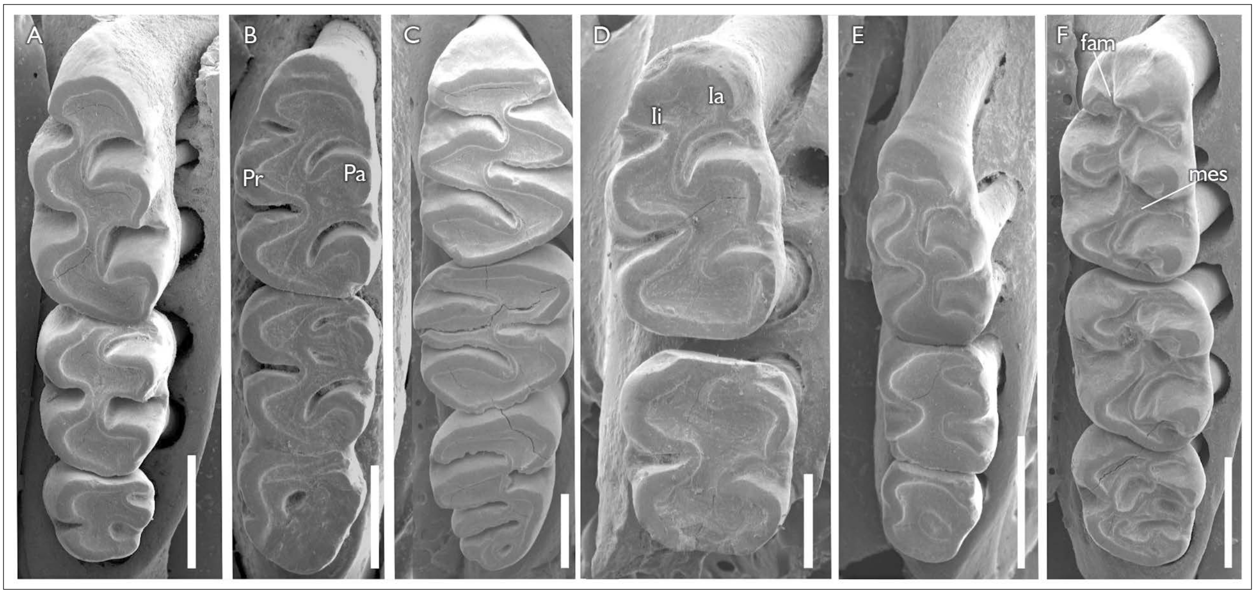

Figura 4. Vista oclusal dos molares superiores de: A) *Necromys lasiurus*, UFRB-PV 2748, M1-M3 esquerdos; B) *Cerradomys* sp., UFRB-PV 2861, M1-M3 esquerdos; C) *Holochilus sciureus*, UFRB-PV 2992, M1-M3 direitos; D) *Oligoryzomys* sp., UFRB-PV 2735, M1-M2 esquerdos; E) *Calomys* sp., UFRB-PV 2745, M1-M3 esquerdos; F) *Wiedomys pyrrhorhinos*, UFRB-PV 2823, M1-M3 esquerdos. Escala = 1 mm. Notar que o flexo anteromediano é indistinto devido ao desgaste dos molares em *Oligoryzomys* sp. e *Calomys* sp. Escala A, B, C, E, F = 1 mm; D = 0,5 mm. Abreviaturas: fam = flexo anteromediano; la = cônulo anterolabial; li = cônulo anterolingual; mes = mesolofo; Pa = paracone; Pr = protocone.

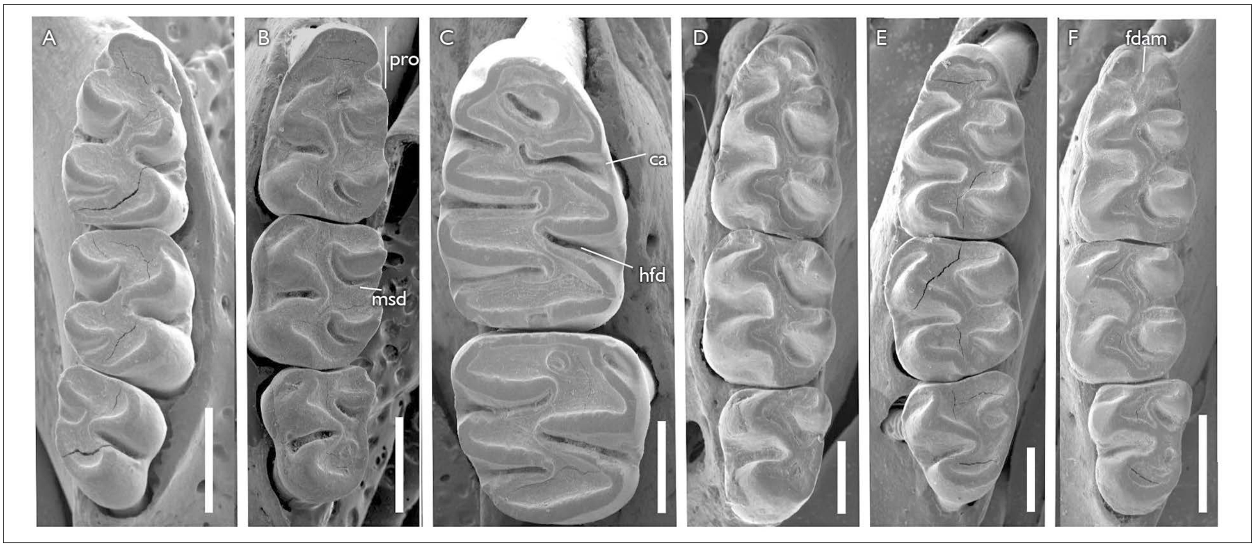

Figura 5. Vista oclusal dos molares inferiores de: A) *Necromys lasiurus*, MZFS-DM 0840, m1-m3 direitos; B) *Cerradomys* sp., MZFS-DM 0828, m1-m3 esquerdos; C) *Holochilus sciureus*, UFRB-PV 907, m1-m2 direitos; D) *Oligoryzomys* sp., MZFS-DM 0867, m1-m3 esquerdos; E) *Calomys* sp., MZFS-DM 0833, m1-m3 esquerdos; F) *Wiedomys pyrrhorhinos*, MZFS-DM 0836, m1-m3 esquerdos. Escala = 1 mm. Notar que o flexídeo anteromediano está pouco marcado devido ao desgaste dos molares em *Oligoryzomys* sp. e *Calomys* sp. Escala A, B, C, F = 1 mm; D, E = 0,5 mm. Abreviaturas: ca = cíngulo anterolabial; fdam = flexídeo anteromediano; hfd = hipoflexídeo; msd = mesolofídeo; pro = procíngulo.

## DISCUSSÃO

Todos os táxons registrados neste trabalho possuem ocorrência atual na Caatinga e nas florestas estacionais associadas a este bioma, sendo *Wiedomys pyrrhorhinos* o único endêmico da Caatinga (Carmignotto & Astúa, 2017). A riqueza registrada na Toca dos Ossos (sete espécies) representou 26,9% dos roedores muroideos conhecidos para a Caatinga, que abriga 23 espécies de cricetídeos e três espécies de murídeos (Moojen, 1952; Carmignotto & Astúa, 2017). Em comparação com outros levantamentos conduzidos nesse bioma, a maior parte dos estudos cuja amostragem se baseou na captura com armadilhas registrou riquezas menores, como no Parque Nacional de Ubajara, no Ceará (Guedes *et al*., 2000; três espécies); no Morro do Chapéu, Chapada Diamantina (Oliveira & Pessôa, 2005; quatro espécies); em cinco localidades dos estados da Bahia e de Sergipe (Bezerra *et al*., 2014; quatro espécies); em Ouricuri, Pernambuco (Delciellos, 2016; quatro espécies); e no Parque Nacional do Catimbau, município de Buíque, Pernambuco (Geise *et al*., 2010; cinco espécies). Por outro lado, Souza, M. *et al*. (2004) registraram 12 espécies de muroideos nos brejos de altitude nos estados da Paraíba e de Pernambuco. Assim, a análise dos egagropilos de corujas, dos quais provêm pelo menos parte do material da Toca dos Ossos (TO-I), demonstra ser uma importante ferramenta de amostragem de pequenos mamíferos, como já apontado em estudos prévios (*e.g*., Massoia, 1984; Bonvicino & Bezerra, 2003; Formoso *et al*., 2016; Heisler *et al*., 2016).

A riqueza de roedores muroideos na Toca dos Ossos (sete espécies) foi intermediária àquelas obtidas em estudos com pelotas de *Tyto furcata* conduzidos em outros biomas. Por exemplo, três espécies foram registradas em uma área urbana e quatro em uma área rural na Mata Atlântica do estado de Pernambuco (Souza, D. *et al*., 2010); sete espécies em duas localidades no ecótono entre Amazônia e Cerrado do médio Araguaia (Rocha *et al*., 2011); oito espécies em uma restinga do estado do Rio de Janeiro (Lemos *et al*., 2015); dez espécies no Cerrado do estado da Bahia (Bonvicino & Bezerra, 2003); e 13 espécies em duas localidades em Floresta Ombrófila Mista na Mata Atlântica do estado de Santa Catarina (Cherem *et al*., 2018).

A diversidade encontrada nos egagropilos de coruja da TO-I foi semelhante à de outras cavernas estudadas na região Nordeste. Mancini *et al*. (2018) conduziram um levantamento de mamíferos recentes de pequeno porte através da análise de egagropilos de corujas em sete cavernas nos estados da Bahia e Sergipe. Esses autores obtiveram sete espécies de cricetídeos e duas de murídeos, e uma riqueza total variando de duas a nove espécies entre as cavernas, o que corresponde a uma espécie a mais para cada família, em comparação com os dados obtidos na Toca dos Ossos. Além disso, Mancini *et al*. (2018) registraram *Calomys* cf. *expulsus* como o táxon mais frequente entre os roedores muroideos, seguido por *Necromys lasiurus*, enquanto, na Toca dos Ossos, *N. lasiurus* foi a espécie mais abundante na TO-I e *Calomys* sp., a mais abundante na TO-II. *Holochilus sciureus* foi o único táxon aqui registrado que não foi encontrado na amostra analisada por Mancini *et al*. (2018).

Dados sobre roedores muroideos do Quaternário do Nordeste do Brasil são muito escassos. Castro *et al*. (2014) estudaram a assembleia de vertebrados da Gruta do Ioiô, no município de Palmeiras, Bahia, e reportaram apenas uma espécie de Sigmodontinae, *Holochilus sciureus*. Neves *et al*. (2017) analisaram a assembleia de sigmodontíneos da Serra da Capivara, estado do Piauí, e registraram sete táxons. Entre estes, *Pseudoryzomys simplex* (Winge, 1887) e *Bibimys* sp., gênero atualmente ausente na região Nordeste (Pardiñas *et al*., 2015a), não estiveram presentes na TO-II. O único táxon registrado em TO-II e que não estava entre os espécimes analisados por Neves *et al*. (2017) foi *Oligoryzomys* sp. Na amostra da Serra da Capivara, *Calomys* sp. foi o táxon mais frequente.

A amostra de TO-I representa material recente, visto que a espécie exótica *Rattus rattus* foi encontrada nos egagropilos de *Tyto furcata*. Por outro lado, o material proveniente da TO-II foi encontrado no sedimento de superfície da caverna e pode representar um intervalo de tempo maior. Auler *et al*. (2003) demonstraram que há considerável variação no tipo e na intensidade dos processos de acúmulo de material nas cavernas brasileiras, tanto na escala de regiões cársticas quanto de condutos dentro de uma mesma caverna, resultando em sítios fossilíferos complexos. Auler *et al*. (2006) analisaram a tafonomia relacionada a 19 espécies de megafauna da Toca dos Ossos e concluíram que esses fósseis foram transportados para o interior da caverna pelo escoamento de corpos d'água durante um ou vários momentos de maior precipitação. Os autores também demonstraram, através de datação de espeleotemas, que o período de deposição de fósseis nas cavernas brasileiras é bastante amplo, variando do Pleistoceno Médio ao Holoceno. Entretanto, não foi possível obter datas para a Toca dos Ossos no referido trabalho. Considerando a ausência de datações e de análise tafonômica detalhada do material de pequeno porte, não é possível indicar a idade do material da TO-II. No entanto, a ocorrência dos mesmos táxons na TO-I e na TO-II e sua similaridade com o registro atual na Caatinga (Carmignotto & Astúa, 2017) podem sugerir que o material analisado proveniente da TO-II seja recente, tendo sido depositado após o estabelecimento local da Caatinga.

Os dados paleopalinológicos para a região noroeste da Bahia, onde se insere a Toca dos Ossos, indicam clima mais frio e úmido no início do Holoceno e a ocorrência de florestas úmidas de galeria, sendo que o estabelecimento das condições áridas teria ocorrido nos últimos 4.000 anos, levando a uma expansão da Caatinga (De Oliveira *et al*., 1997). A partir do registro de *Myocastor coypus* (Molina, 1782), Cartelle & Lessa (1989) sugeriram clima mais úmido e frio durante o fim do Pleistoceno e início do Holoceno, com vegetação provavelmente composta por matas ciliares e cerrado. Lessa *et al*. (1998) também registraram espécies de hábitos florestais – *e.g.*, *Eira barbara* (Linnaeus, 1758) – e semiaquáticos – *e.g.*, *Lontra longicaudis* (Olfers, 1818) – entre os carnívoros fósseis coletados na Toca dos Ossos.

A análise e a identificação de fragmentos pertencentes a outros grupos de pequenos mamíferos coletados na Toca dos Ossos, como marsupiais e roedores caviomorfos, constituem importante etapa subsequente do estudo dessa caverna do Nordeste brasileiro. Além disso, a análise tafonômica do material de pequenos mamíferos da Toca dos Ossos também deverá ser objeto dos próximos estudos e poderá auxiliar no entendimento da assembleia dessa caverna. Esses dados serão importantes para a compreensão dos pequenos mamíferos em uma região ainda pouco amostrada, como a Caatinga.

## CONCLUSÃO

A análise de 210 fragmentos cranianos e mandibulares de roedores muroideos provenientes da Toca dos Ossos, no bioma Caatinga, resultou no registro de 99 indivíduos, pertencentes a duas famílias, Cricetidae e Muridae, e sete espécies (*Necromys lasiurus*, *Cerradomys* sp., *Holochilus sciureus*, *Oligoryzomys* sp., *Calomys* sp., *Wiedomys pyrrhorhinos* e *Rattus rattus*). Essa riqueza é considerável e relevante, comparada a outros trabalhos sobre a mastofauna deste bioma. Apesar de muito semelhantes taxonomicamente, as amostras dos dois pontos de coleta (TO-I e TO-II) apresentaram diferenças nas frequências dos táxons. No entanto, ambas as áreas da Toca dos Ossos incluíram somente táxons de ocorrência atual na Caatinga, o que sugere que o material de TO-II também é bastante recente, tendo sido depositado após o estabelecimento deste bioma na região, o qual ocorreu há cerca de 4.000 anos.

## AGRADECIMENTOS

Agradecemos à Universidade Federal do Recôncavo da Bahia (UFRB), pela infraestrutura concedida; ao Laboratório Central de Microscopia Eletrônica da UFSC, pelas fotografias em MEV. Ao Sr. Admir Brunelli, pelo apoio aos trabalhos de campo. À editora Alexandra Bezerra e a três revisores anônimos, por suas correções e sugestões nas versões preliminares do texto. Ao Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), através dos editais MCT/CNPq 14/2010 - Universal (475291/2010-7) e MCT/CNPq 14/2011 - Universal (475287/2011-8).

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Apêndice 1. Lista dos espécimes depositados na Coleção de Mamíferos do Museu de Zoologia da Universidade Estadual de Feira de Santana (MZFS-DM) e do Departamento de Ecologia e Zoologia da Universidade Federal de Santa Catarina (UFSC) utilizados para a comparação com os fragmentos amostrados na Toca dos Ossos.

*Akodon cursor* – UFSC 4712, 4785.
*Calomys tener* – UFSC 5166, 5490.
*Cerradomys subflavus* – MZFS-DM 0202; UFSC 2248, 2251, 2254, 2257, 2258, 2260, 2280.
*Cerradomys vivoi* – MZFS-DM 0109, 0111; UFSC 5222, 5223.
*Euryoryzomys russatus* – UFSC 3940, 3944, 4891, 5689.
*Holochilus* grupo *brasiliensis* – UFSC 5074, 5890.
*Holochilus sciureus* – UFSC 2754, 2755.
*Hylaeamys laticeps* – MZFS-DM 0003, 0004, 0010, 0020.
*Necromys lasiurus* – MZFS-DM 0033; UFSC 3599, 3600, 3876, 4714, 4815, 5212.
*Oecomys catherinae* – UFSC 2277, 2278, 2279.
*Oligoryzomys* sp. – UFSC 2525, 2527, 2530, 3707, 3950, 3951, 4399, 4717, 4791, 4792, 6025.
*Rhipidomys* sp. – MZFS-DM 0651.
*Rhipidomys mastacalis* – MZFS-DM 0025.
*Wiedomys cerradensis* – UFSC 6191.
*Wiedomys pyrrhorhinos* – UFSC 2822, 2823, 2827, 2828, 2829, 5224.

Apêndice 2. Lista do material estudado da TO-I depositado na Coleção de Mamíferos do Museu de Zoologia da Universidade Estadual de Feira de Santana (MZFS-DM) e da TO-II na Coleção de Paleovertebrados da Universidade Federal do Recôncavo da Bahia (UFRB-PV). Os dentes, se presentes, são indicados entre parênteses. Abreviaturas: Cr: crânio; dir = direito; Dn = dentário; esq = esquerdo; M = molar superior; m = molar inferior; Mx = maxilar.

## TO-I

***Calomys* sp.**: Cr: MZFS-DM 0876, 0968 (M1-M3 dir e M1-M3 esq); 0964 (M2-M3 dir e M1-M3 esq); 0966 (M1-M3 dir e M1 esq); Dn dir: MZFS-DM 0835, 0846, 0877 (m1-m3); Dn esq: MZFS-DM 0829, 0833 (m1-m3). ***Cerradomys* sp.**: Mx dir: MZFS-DM 0815 (M1-M2); Dn dir: MZFS-DM 0826 (m1-m3); Dn esq: MZFS-DM 0828 (m1-m3). ***Holochilus sciureus***: Cr: MZFS-DM 0950 (M1-M3 dir e M1-M3 esq); Mx dir: MZFS-DM 0913 (M1). ***Necromys lasiurus***: Cr: MZFS-DM 0857, 0948, 0949, 0951, 0952, 0953, 0959, 0967, 0969 (M1-M3 dir e M1-M3 esq); 0957 (M1-M2 dir e M1-M3 esq); 0954, 0958, 0963 (M1-M2 dir e M1-M2 esq); 0983 (M1-M2 dir); 0960 (M1 e M3 dir e M1 esq); 0961 (M1 dir e M1 esq); Mx dir: MZFS-DM 0821, 0823, 0866 (M1-M2); 0824, 0864 (M1); Mx esq: MZFS-DM 0818, 0820, 0821, 0823, 0824 (M1-M3); 0816, 0865 (M1-M2); 0817 (M1); Dn dir: MZFS-DM 0840, 0843 (m1-m3); 0841, 0844 (m1-m2); 0842, 0863 (m1); Dn esq: MZFS-DM 0847, 0848, 0852, 0858, 0859 (m1-m3); 0849, 0853, 0860 (m1-m2); 0831, 0834, 0837, 0845, 0854, 0855, 0861, 0862, 0874, 0875 (m1). ***Oligoryzomys* sp.**: Cr: MZFS-DM 0825 (M1-M3 dir e M1-M3 esq); Dn dir: MZFS-DM 0856 (m1); Dn esq: MZFS-DM 0867 (m1-m3). ***Wiedomys pyrrhorhinos***: Cr: MZFS-DM 0691, 0905, 0946, 0956, 0965, 2907 (M1-M3 dir e M1-M3 esq); 0955 (M2-M3 dir e M1-M3 esq); Mx esq: MZFS-DM 0822 (M1-M2); 0819 (M1); Dn dir: MZFS-DM 0832 (m1-m3), 0850 (m1-m2); Dn esq: MZFS-DM 0836, 0838 (m1-m3). ***Rattus rattus***: Dn esq: MZFS-DM 0924 (m1-m3); 0839 (m1).

## TO-II

***Calomys* sp.**: Cr: UFRB-PV 2862 (M1-M3 dir e M1-M3 esq); UFRB-PV 2960 (M1-M3 dir e M3 esq); Mx dir: UFRB-PV 3132 (M1-M3); 2746 (M1-M2); 951 (M1); Mx esq: UFRB-PV 2738, 2745, 2863, 2955 (M1-M3); 2991, 3157 (M1-M2); Dn dir: UFRB-PV 2714; 2873, 2874, 2935, 2937, 2939, 2994, 3007; 3017, 3113 (m1-m3); 2707, 2713, 2715, 2825, 3114 (m1-m2); 2712, 2993, 3022 (m1); Dn esq: UFRB-PV 2872, 2997 (m1-m3); 2709, 2716, 2824, 2954, 3018 (m1-m2); 949, 2705, 2711, 2718, 2869, 2876 (m1). ***Cerradomys* sp.**: Cr: UFRB-PV 2861 (M1-M3 dir e M1-M3 esq); Mx dir: UFRB-PV 2820 (M1-M3); Mx esq: UFRB-PV 959, 2818, 2990 (M1-M3); 2987 (M1-M2); Dn dir: UFRB-PV 3019, 3020, 3028 (m1); Dn esq: UFRB-PV 2934 (m1-m2). ***Holochilus sciureus***: Cr: UFRB-PV 2901, 2919, 2969 (M1 dir e M1-M3 esq); Mx esq: UFRB-PV 2911, 2918, 2965 (M1-M3); 2992, 3123 (M1-M2); 962, 2988 (M2-M3); 2864, 2989 (M1); 972 (M2); Dn dir: UFRB-PV 907, 2978 (m1-m3); 2852, 2972, 2977 (m1-m2); 936 (m1); Dn esq: UFRB-PV 2956 (m1-m3); 908 (m1-m2), 948 (m2). ***Necromys lasiurus***: Cr: UFRB-PV 2975 (M1-M3 dir e M1-M2 esq); 2857 (M1 dir e M1-M2 esq), Mx dir: UFRB-PV 2733, 2952, 2986, 3012 (M1-M2); Mx esq: UFRB-PV 2748, 2822 (M1-M3); 2737, 2740, 2743, 3131 (M1-M2); 2747, 2953, 2985 (M1); Dn dir: UFRB-PV 947, 2829, 2999, 3109, 3112 (m1-m2); 2998 (m1); Dn esq: UFRB-PV 3001, 3002, 3026 (m1-m3); 2731, 2833, 3031 (m1-m2); 2936, 3030, 3119 (m1). ***Oligoryzomys* sp.**: Mx esq: UFRB-PV 2735 (M1-M2). ***Wiedomys pyrrhorhinos***: Cr: UFRB-PV 2855, 2858, 2898 (M1-M3 dir e M1-M3 esq); 2859 (M1-M3 dir e M2-M3 esq); 2897 (M1-M3 dir e M1 e M3 esq); 2957 (M1-M2 dir e M1-M2 esq); 906 (M3 dir e M1-M3 esq); Mx dir: UFRB-PV 2819, 3108, 3134, 3176 (M1-M3); Mx esq: UFRB-PV 2823, 3121, 3130 (M1-M3); 956 (M2-M3), 973, 2983 (M1); Dn dir: UFRB-PV 2826, 3023 (m1-m3); 3006 (m1-m2); Dn esq: UFRB-PV 2690 (m1-m3); 3021, 3024 (m1-m2); 2710, 2877 (m1).

# Leporidae Fischer, 1817 (Mammalia: Lagomorpha) de um depósito Quaternário do Brasil: comentários taxonômicos e tafonômicos

# Leporidae Fischer, 1817 (Mammalia: Lagomorpha) from a Quaternary deposit in Brazil: taxonomic and taphonomic comments

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**Resumo:** Leporidae (Lagomorpha) é um clado de pequenos mamíferos que inclui os coelhos e as lebres, animais raros em sítios paleontológicos e arqueológicos e, por isso, leporídeos são pouco estudados na América do Sul. Durante o Quaternário, muitas cavernas calcárias serviram como armadilhas naturais para inúmeros grupos de animais, incluindo leporídeos. A Gruta Cuvieri, parte do complexo cárstico de Lagoa Santa (Minas Gerais, Brasil), preservou grande quantidade de restos desses animais. O presente estudo descreve o material osteológico (dentários, maxilas e alguns ossos apendiculares) atribuído a *Sylvilagus* cf. *brasiliensis*, encontrado na Gruta Cuvieri, além de revisar sua ocorrência durante o Quaternário e comparar as datações obtidas com a frequência de ocorrências desse táxon em sítios paleontológicos e arqueológicos. Os espécimes estavam presentes no Pleistoceno final, reaparecendo no Holoceno médio e persistindo até recentemente.

**Palavras-chave:** Gruta Cuvieri. Holoceno. Lagoa Santa. Paleoambiente. Pleistoceno. *Sylvilagus*.

**Abstract:** Leporidae (Lagomorpha) is a clade of small mammals that include rabbits and hares, rarely found in paleontological and archaeological sites and, therefore, leporids are poorly studied in South America. During the Quaternary, many limestone caves worked as natural traps for several groups of animals, including Leporidae. The Cuvieri Cave, part of the Lagoa Santa (Minas Gerais state, Brazil) karst complex, preserved a large amount of the remains of these animals. The present study describes the osteological material (mandibles, jaws and some appendicular bones) assigned to *Sylvilagus* cf. *brasiliensis*, which were found in the Cuvieri Cave. In addition, we reviewed the occurrences of these animals in Quaternary sites and compared the radiometric ages obtained with the frequency of occurrences of this taxon. The specimens were present in the late Pleistocene, reappearing in the middle Holocene and persisting until recently.

**Keywords:** Cuvieri Cave. Holocene. Lagoa Santa. Paleoenviroment. Pleistocene. *Sylvilagus*.

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CHAHUD, A., G. S. MINGATOS & M. OKUMURA, 2020. Leporidae Fischer, 1817 (Mammalia: Lagomorpha) de um depósito Quaternário do Brasil: comentários taxonômicos e tafonômicos. **Boletim do Museu Paraense Emílio Goeldi. Ciências Naturais** 15(3): 795-806. DOI: http://doi.org/10.46357/bcnaturais.v15i3.299.

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Recebido em 11/04/2020
Aprovado em 27/11/2020
Responsabilidade editorial: Adriano Oliveira Maciel e Alexandra Maria Ramos Bezerra

## INTRODUÇÃO

Os registros mais antigos de Lagomorpha são do Eoceno da Índia (Rose *et al*., 2008), porém foi durante o Oligoceno que espécies semelhantes aos atuais Leporidae surgiram na América do Norte (Emry & Gawne, 1986). Apesar de ocorrerem durante boa parte do Cenozoico, os registros mais antigos na América do Sul são do final do Pleistoceno, da região pré-andina do Equador, Formação Cangahua (Ficcarelli *et al*., 1992), durante o quarto Grande Intercâmbio Biótico Americano (GABI 4), ocorrido em torno de 125 mil anos atrás (Woodburne, 2010).

No Brasil, a ocorrência de fósseis é bastante escassa. As primeiras citações são da região do Rio das Velhas, estado de Minas Gerais, coletadas por Peter Lund e estudadas por Winge (1887), que considerou a espécie encontrada como pertencente ao gênero *Sylvilagus* Gray, 1867, como uma variedade pleistocênica de *Sylvilagus brasiliensis* Linnaeus, 1758, de tamanho um pouco maior. Outro registro foi feito por Ameghino (1907), para o município de Iporanga, estado de São Paulo, porém a revisão desse material, realizada por Paula Couto (1979), resultou na proposta de que tais espécimes pertenceriam à espécie atual, *S. brasiliensis*.

A Gruta Cuvieri, localizada no Carste de Lagoa Santa, estado de Minas Gerais, Brasil, é conhecida por possuir grande quantidade de material osteológico quaternário (Hubbe *et al*., 2011; Chahud, 2020a, 2020b, 2020c; Chahud & Okumura, 2020a, 2020b), incluindo material de Leporidae. Contudo, as ocorrências em sítios arqueológicos da mesma região são raras ou pouco registradas (Kipnis, 2002; Mingatos & Okumura, 2016; Mingatos, 2017; Chim, 2018).

O objetivo desta contribuição é reportar a ocorrência de Leporidae na Gruta Cuvieri e revisar ocorrências em sítios paleontológicos e arqueológicos, acrescentando informações sobre esse grupo, pouco conhecido do Quaternário do Brasil.

## MATERIAL E MÉTODOS

A Gruta Cuvieri, localizada no município de Lagoa Santa, centro-sul do estado de Minas Gerais, Brasil, coordenadas UTM 23k 7846105N e 0603756E, é constituída de três pequenas cavidades verticais, armadilhas naturais que foram denominadas *Loci* 1, 2 e 3 (Figura 1), com 16 metros, 4 metros e 8 metros de profundidade, respectivamente. O material osteológico foi coletado com rigoroso detalhamento estratigráfico dos *Loci* 2 e 3 (Hubbe *et al*., 2011;

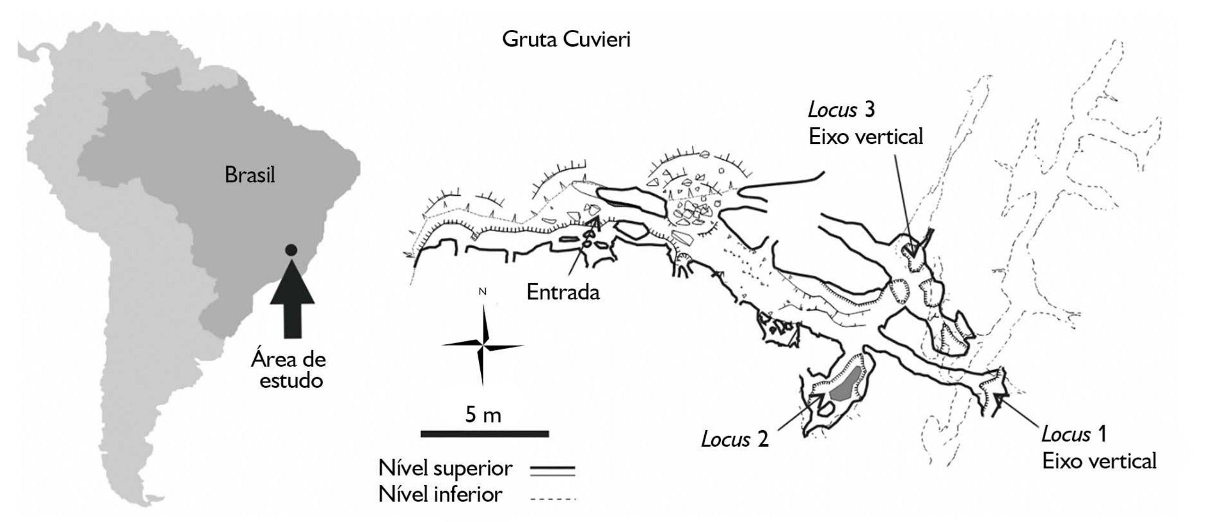

Figura 1. Localização geográfica da área de estudo no Brasil (esquerda) e da Gruta Cuvieri mostrando a posição do *Loci* 1, 2 e 3 (direita). Mapa produzido por Alex Hubbe e Grupo Bambuí de Pesquisas Espeleológicas para o Laboratório de Estudos Evolutivos Humanos.

Haddad-Martim *et al*., 2017). Segundo Hubbe (2008), Hubbe *et al.* (2011), Mayer (2011) e Haddad-Martim *et al.* (2017), o sedimento encontrado na Gruta Cuvieri estava pouco consolidado, remobilizado ou modificado por fatores intempéricos externos, o que favoreceu a escavação e a exploração mais cuidadosa, com obtenção de dados estratigráficos detalhados.

Os aspectos tafonômicos, como definição de número de indivíduos, abrasão ou desgaste, nível de exposição, quebras, ataque de carniceiros ou predadores, presença de epífises e articulação, foram os principais itens avaliados, seguindo os conceitos de Voorhies (1969), Badgley (1986), Behrensmeyer (1991) e Lyman (1994). Para a identificação dos espécimes, foi feita a comparação com aqueles da Coleção de Referência "Renato Kipnis" do Laboratório de Estudos Evolutivos Humanos do IB-USP, além de consulta às obras de Paula Couto (1979), Ruedas (2017), Ruedas *et al.* (2017) e Diersing & Wilson (2017).

O material osteológico coletado referente à Gruta Cuvieri é constituído de 82 elementos ósseos (excluindo dentes isolados), sendo 46 do *Locus* 2 e 36 do *Locus* 3. O material é constituído de fragmentos cranianos, ossos apendiculares e poucas vértebras. Os espécimes e o inventário de suas partes ósseas estão depositados no Laboratório de Estudos Evolutivos Humanos (LEEH) do Instituto de Biociências da Universidade de São Paulo (IB-USP), São Paulo, Brasil.

## CONSIDERAÇÕES SOBRE IDADE E PALEOAMBIENTE

Não foi possível a datação dos espécimes encontrados, no entanto Hubbe (2008) e Hubbe *et al.* (2011) obtiveram inúmeras datações de diversos grupos animais no *Locus* 2 e de espeleotema e fauna do *Locus* 3. No total, de acordo com os dados reportados por esses autores, 17 datações foram realizadas no *Locus 2* (Tabela 1),

Tabela 1. Datações 14C-AMS (AMS = *Accelerator Mass Spectrometry*) obtidas no *Locus* 2 da Gruta Cuvieri, Lagoa Santa, estado de Minas Gerais (Hubbe *et al*., 2011). Abreviações: m = metros, AP = anos antes do presente.

| Espécime | Táxons | Profundidade (m) | Idade convencional (AP) | Calibração 2σ (AP) |
|---|---|---|---|---|
| CVL2-P260 | Cervidae | 0,62 | 1.960 ± 40 | 1.990-1.830 |
| CVL2-P163/196 | *Tapirus* cf. *terrestris* | 0,62 | 2.050 ± 40 | 2.120-1.900 |
| CVL2-P258/234 | *Cuniculus paca* | 0,62 | 220 ± 40 | 310-0 |
| CVL2-2290 | Cervidae | 0,69 | 2.830 ± 40 | 3.060-2.850 |
| CV-L2-4041 | Amphibia | 0,73 | 3.550 ± 40 | 3.960-3.710 |
| CVL2-4630 | Tayassuidae | 0,76 | 5.250 ± 50 | 6.180-5.920 |
| CVL2-5998 | *Cuniculus paca* | 0,80 | 5.050 ± 40 | 5.910-5.670 |
| CVL2-7108 | Cervidae | 0,86 | 5.200 ± 50 | 6.010-5.900 |
| CVL2-7402 | Cervidae | 0,86 | 9.500 ± 50 | 11.070-10.660 |
| CVL2-7456 | Tayassuidae | 0,86 | 5.150 ± 50 | 5.990-5.750 |
| CV-L2-8040 | Cervidae | 0,87 | 7.050 ± 50 | 7.970-7.790 |
| CVL2-9648 | Cervidae | 0,94 | 9.740 ± 40 | 11.210-11.130 |
| CVL2-10365 | Cervidae | 0,96 | 6.930 ± 40 | 7.850-7.680 |
| CV-L2-13122 | *Smilodon populator* | 1,11 | 10.790 ± 60 | 12.880-12.720 |
| CV-L2 14310 | *Valgipes bucklandi* | 1,14 | 11.020 ± 40 | 13.060-12.870 |
| CV-L2 14827 | Cervidae | 1,16 | 7.690 ± 50 | 8.580-8.400 |
| CV-L2 15266 | Tayassuidae | 1,20 | 10.470 ± 40 | 12.670-12.140 |

todas utilizando a técnica de 14C-AMS (*Accelerator Mass Spectrometry*) (Hubbe *et al*., 2011). Observando as datações, é perceptível que a maior parte delas (total de 12) seguia uma estratigrafia organizada, sendo o material mais antigo encontrado nas camadas mais profundas. Os espécimes coletados no *Locus* 2 estão bem distribuídos e posicionados, se fazendo presentes desde a superfície até 0,80 m de profundidade (Tabela 1). Nesses níveis, foram estimadas idades que não superaram 6.180 anos AP (antes do presente) (datações calibradas).

O *Locus* 3 possui poucas datações e, mesmo que existissem outras, a associação entre restos faunísticos e datações seria mais difícil, pois os ossos ocorrem desde a superfície até a parte mais profunda escavada, estando assim espalhados por todo o pacote sedimentar. No *Locus* 3, foram obtidas duas datações utilizando a técnica de 14C-AMS: uma de 12.390 ± 50 AP para um espécime de Tapiridae e outra de 12.510 ± 70 AP para uma preguiça terrestre, sendo que o primeiro estava próximo da superfície. Além das datações citadas, existem três datações realizadas com a técnica de U/Th (Urânio/Tório) que obtiveram valores entre 27 e 31 mil anos a partir de análise de material obtido em capa estalagmítica (Hubbe, 2008).

A sedimentação nos dois *loci* é diferente. Segundo Hubbe (2008), o aporte de sedimento no *Locus* 3 é diferenciado do *Locus* 2, na medida em que no primeiro ocorre grande variedade de fácies, verticalmente e horizontalmente, enquanto no segundo a sedimentação é homogênea. Esta característica pode ter favorecido maior remobilização de material no *Locus* 3, se compararmos com o *Locus* 2, causando a mistura do material osteológico de diferentes idades. Considerando a menor remobilização de sedimento e seus conteúdos no *Locus* 2, em comparação com o *Locus* 3, o levantamento estratigráfico mostrou-se suficientemente confiável para associação dos materiais com as idades propostas. No entanto, por ser um depósito em caverna, essa associação deve ser feita com cautela, pois ocorre remobilização de ossos menores que, em geral, é maior do que a de ossos maiores ou mais pesados (Voorhies, 1969; Behrensmeyer, 1991), colocando no mesmo nível material ósseo de diferentes idades.

Partindo dessas observações e de que os Leporidae surgiram na América do Sul ainda no Pleistoceno (Woodburne, 2010), é possível inferir que foram mais comuns na região da Gruta Cuvieri em torno de 5.000-6.000 AP, baseando-se nas ocorrências do *Locus* 2. Porém, não se deve descartar um período de abundância e presença no Pleistoceno devido às ocorrências no *Locus* 3, observando que as datações obtidas neste *locus* são pleistocênicas. Estudos paleoambientais realizados na região de Lagoa Santa apontaram para um clima úmido ao longo do Holoceno inicial (11.700-8.200 AP), seguido por um período seco que se teria iniciado por volta de 8.000 AP (Araujo *et al*., 2005). No entanto, Hermenegildo (2009) considera que, na região de Lagoa Santa, a pluviosidade teria aumentado a 6.200 AP. Esse último dado estaria de acordo com o esperado para um clima que favorecesse o reaparecimento dos Leporidae na Gruta Cuvieri em torno de cinco e seis mil anos.

## PALEONTOLOGIA SISTEMÁTICA

Mammalia Linnaeus, 1758
Lagomorpha Brandt, 1855
Leporidae Fischer von Waldheim, 1817
*Sylvilagus* Gray, 1867
*Sylvilagus* cf. *brasiliensis* Linnaeus, 1758
(Figuras 2-3)

Material estudado do *Locus* 2: o material utilizado para a identificação inclui quatro dentários (CVL2-4922, CVL2-3694, CVL2-P2879, CVL2-P712), cinco maxilas (CVL2-4162, CVL2-4252, CVL2-4253, CVL2-P184, CVL2-P316), dois fêmures (CVL2-4956, CVL2-591), três tíbias (CVL2-2552, CVL2-4752, CVL2-1156), uma ulna (CVL2-5570), cinco calcâneos (CVL2-P3731, CVL2-P3396, CVL2-4757, CVL2-P200, CVL2-P2880), uma escápula (CVL2-P3408) e três úmeros (CVL2-3097, CVL2-P3692, CVL2-P3693).

Material estudado do *Locus* 3: o material utilizado para a identificação inclui dez dentários (CVL3-2024, CVL3-3362, CVL3-13, CVL3-2754, CVL3-P1505, CVL3-P126, CVL3-P9530, CVL3-3801, CVL3-P938, CVL3-10367), uma maxila (CVL3-P10318), quatro fêmures (CVL3-4225, CVL3-7A, CVL3-1489, CVL3-4226), quatro tíbias (CVL3-369, CVL3-1976, CVL3-2025, CVL3-4236), três rádios (CL3-4A, CVL3-6A, CVL3-4171), uma ulna (CVL3-6B) e três úmeros (CVL3-3425, CVL3-2213, CVL3-1977).

Distribuição geográfica e ambiental: espécie típica de florestas tropicais úmidas do sul do México ao norte da Argentina e Sul do Brasil (Hoffman & Smith, 2005).

Comentários: a taxonomia dos representantes de *Sylvilagus* na América do Sul é controversa, não havendo consenso entre os trabalhos publicados. Para Hoffman & Smith (2005), apenas uma espécie, *Sylvilagus brasiliensis* Linnaeus, 1758, era válida e os autores reconheciam ainda mais 21 subespécies, porém Ruedas (2017) reconhece sete espécies atribuídas ao gênero *Sylvilagus* na América do Sul: *Sylvilagus brasiliensis* Linnaeus, 1758, *S. tapetillus* Thomas, 1913, *S. floridanus* J. A. Allen, 1890, *S. andinus* Thomas, 1897, *S. sanctaemartae* Hershkovitz, 1950, *S. varynaensis* Durant & Guevara, 2001 e *S. parentum* Ruedas, 2017. As espécies *S. andinus*, *S. floridanus*, *S. sanctaemartae*, *S. varynaensis* e *S. parentum* ocorrem localmente, sendo as quatro primeiras observadas em regiões dos Andes, e *S. parentum* está restrita à Guiana (Ruedas, 2017). A classificação de Ruedas (2017) não foi aceita por Diersing & Wilson (2017), que consideraram *Sylvilagus sanctaemartae* como sinônimo de *S. gabbi* J. A. Allen, 1877, da América Central, e *Sylvilagus andinus* como subespécie de *S. brasiliensis*, considerada *S. b. andinus*.

Entre todas as subespécies e espécies citadas anteriormente, apenas duas, *Sylvilagus brasiliensis* e *S. tapetillus*, ocorrem no Brasil. A espécie *S. tapetillus* foi reconhecida a partir de três indivíduos coletados na região do Vale do Paraíba, no município de Resende, estado do Rio de Janeiro. Segundo Bonvicino *et al.* (2015) e Ruedas *et al.* (2017), a espécie é diagnóstica tanto com base na morfologia externa, quanto pelos dados genéticos. Os espécimes da Gruta Cuvieri puderam ser classificados com base nos poucos dentários recuperados (Figura 2). A dentição e o formato são características da família Leporidae e podem ser atribuídas ao gênero *Sylvilagus* (Paula Couto, 1979; Ruedas *et al*., 2017).

Comparando com *Sylvilagus tapetillus*, os dentários são mais alongados, finos e gráceis dorsoventralmente e o forame mentoniano é característico de *Sylvilagus brasiliensis* em forma, tamanho e posição (Figuras 2A, 2D e 2F). Segundo Ruedas *et al.* (2017), há variação no tamanho do forame mentoniano em *S. brasiliensis*, porém é maior e mais desenvolvido em *S. tapetillus*. Embora os espécimes da Gruta Cuvieri apresentem ossos pós-cranianos, esses não são informativos para a identificação de espécie. Não foram preservadas outras partes cranianas, portanto, a identificação taxonômica foi baseada apenas nos dentários. Por esse motivo, optou-se por atribuir os espécimes a *Sylvilagus* cf. *brasiliensis.* Assim, espécimes mais completos são necessários para uma identificação taxonômica mais segura.

## TAFONOMIA

As observações dos ossos pós-cranianos revelaram diferenças de tamanho de alguns indivíduos, porém não havia filhotes recém-nascidos ou indivíduos muito jovens que poderiam caracterizar que a Gruta Cuvieri foi utilizada como habitação e proteção segura para a reprodução. Evidências da presença de indivíduos jovens aparecem na forma de um fêmur, uma tíbia (Figuras 3A e 3B) e uma epífise de fêmur não fusionada no *Locus* 2, porém eram formas adolescentes e, pelas proporções, poderiam pertencer ao mesmo indivíduo.

Todos os espécimes estavam desarticulados e com várias quebras e desgastes (Figuras 3A, 3C e 3D), considerando que houve remobilização de diversas partes ósseas e os ossos menores e mais frágeis foram perdidos. Esse dado é importante devido ao fato de não ter sido observada essa perda e desarticulação de

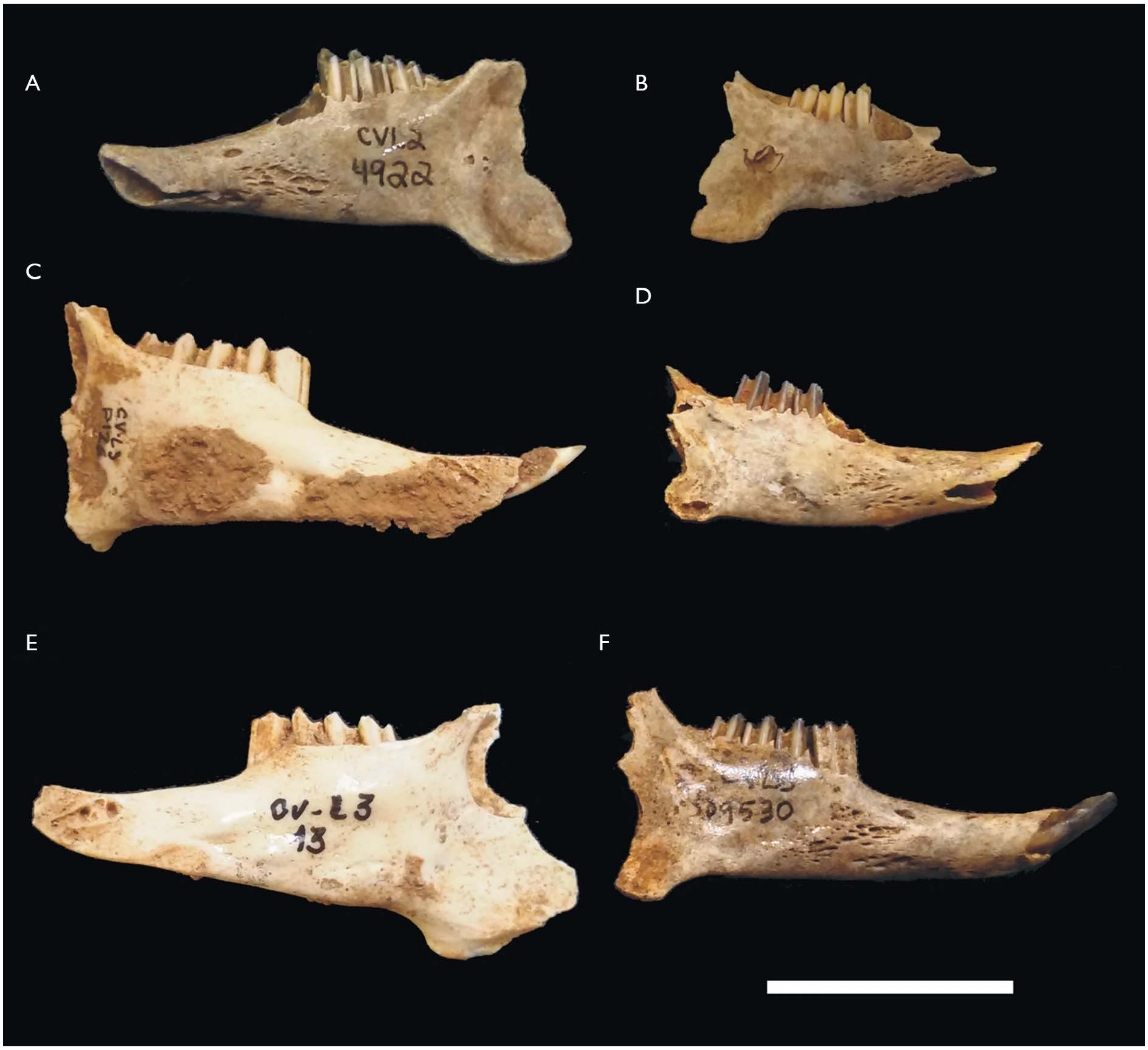

Figura 2. Dentários de *Sylvilagus* cf. *brasiliensis*: A-B) dentários provenientes do *Locus* 2 (CVL2-4922, CVL2-2879); C-F) dentários encontrados no *Locus* 3 (CVL3-P126, CVL3-P3801, CVL3-13, CVL3-P9530). Vistas laterais. Escala: 20 mm. Fotos: Artur Chahud (2020).

forma frequente nos esqueletos de animais maiores (cervos, porcos, antas) da Gruta Cuvieri, na qual foram observadas diversas carcaças ainda articuladas ou em posição de morte (Hubbe *et al*., 2011). Dessa forma, é possível inferir que o tamanho dos espécimes teria sido um fator significativo na fragmentação e dispersão do material osteológico.

Aparentemente os espécimes de *Sylvilagus* cf. *brasiliensis* teriam caído nas armadilhas naturais formadas pelos abismos da Gruta Cuvieri, do mesmo modo que teria ocorrido com animais de maior tamanho (Hubbe, 2008; Mayer, 2011). Essa hipótese é suportada pelo fato de um espécime do *Locus* 3 (dentário ilustrado na Figura 2E) ter sido encontrado com os ossos

Figura 3. Ossos apendiculares de *Sylvilagus* cf. *brasiliensis* coletados do *Locus* 2: A) fêmur de um indivíduo adulto (CVL2-4956) ao lado de um jovem (CVL2-591), ambos com quebras e desgaste na superfície; B) tíbia de indivíduo jovem (CVL2-2552) ao lado de uma tíbia de adulto (CVL2-4752) com quebras e desgaste na extremidade; C) úmeros com quebras nas partes proximais (CVL2-P3692, CVL2-3097, CVL2-P3693); D) ulna fragmentada (CVL2-5570). Escala: 20 mm. Fotos: Artur Chahud (2020).

pós-cranianos associados na camada superior do *locus*. Além disso, devido ao tamanho diminuto das partes ósseas encontradas, dificilmente essas teriam suportado grandes períodos de transporte e retrabalhamento.

A partir do número de elementos ósseos coletados e reconhecidos nos dois *loci*, foi possível determinar o número de indivíduos, utilizando a técnica de mínimo número de indivíduos (MNI), baseada nos calcâneos e dentários do *Locus* 2 e nos dentários do *Locus* 3, que são os elementos mais abundantes. Assim, estimou-se que o número mínimo de indivíduos no *Locus* 2 seria de três indivíduos e no *Locus* 3, seis indivíduos. Observando as características homogêneas de deposição do *Locus* 2, seria possível a definição do número de indivíduos baseada nas idades obtidas de outros espécimes datados. Porém, o material osteológico está restrito a 30 cm de espessura, camada muito pouco espessa e que poderia conter alguma mistura temporal de ossos menores, e também ao registro de algumas idades variadas (Hubbe *et al*., 2011), demonstrando idades maiores em níveis similares (Tabela 1). A determinação do número de indivíduos por níveis ou estratos não se mostrou segura ou confiável, observando que a sedimentação em caverna não era totalmente estável, contínua, sem perturbação biológica ou física, como esperado em ambiente de decantação sedimentar em fundo de lagos ou mares (Holz & Simões, 2002).

A Tabela 2 apresenta os elementos de *Sylvilagus* cf. *brasiliensis* encontrados nos *Loci* 2 e 3 da Gruta Cuvieri. É possível observar que o *Locus* 2 tem maior número de elementos, embora apresente maior quantidade de partes ósseas muito frágeis, como vértebras (11 no *Locus* 2 e apenas uma no *Locus* 3). Já o *Locus* 3 possui partes esqueletais mais difíceis de serem perdidas, como dentários (dez no *Locus* 3 e apenas quatro no *Locus* 2).

No *Locus* 3, as partes frágeis existentes incluem três metacarpos, uma vértebra e uma ulna, que pertencem a um único indivíduo que estava próximo da superfície. Dadas a coloração esbranquiçada (Figura 2E) e a pouca abrasão observada, possivelmente deve ser um espécime mais recente e que não sofreu os processos físicos e biológicos locais por muito tempo. Ao todo, esse espécime é constituído por dez ossos que estavam associados e muito próximos entre si, representando quase 27,8% de todo o material do *Locus* 3.

Ocorrem dentes isolados em ambos os *Loci*, porém, no *Locus* 2, a quantidade é muito maior, com 27 elementos (muitos associados a dentários ou maxilas já citadas na Tabela 2 e, por isso, não foram contabilizados) contra três do *Locus* 3. Esse dado reforça que o ambiente deposicional do *Locus* 2 foi menos perturbado do que no *Locus* 3, possibilitando, assim, a preservação de pequenos ossos e de dentes.

Tabela 2. Elementos esqueléticos coletados de espécimes de *Sylvilagus* encontrados nos *Loci* 2 e 3 da Gruta Cuvieri, Lagoa Santa, Minas Gerais, Brasil. Abreviações: E = esquerdo, D = direito, I = indeterminado, N= número de elementos.

| *Locus* 2 | | *Locus* 3 | |
|---|---|---|---|
| Parte óssea | N | Parte óssea | N |
| Calcâneo | 5 (2E e 3D) | Escápula | 2 (2E) |
| Costela | 1 | Fêmur | 4 (3D e 1E) |
| Epífise distal de fêmur | 1 | Dentário | 10 (4E e 6D) |
| Escápula | 1 (1E) | Maxila | 1 (1E) |
| Falange | 1 | Metacarpo | 3 |
| Fêmur | 2 (2D) | Pélvis | 4 (2E e 2D) |
| Dentário | 4 (3D e 1E) | Rádio | 3 (2E e 1D) |
| Maxila | 5 (1D, 2E, 2I) | Tíbia | 4 (2D e 2E) |
| Metapódio | 3 | Ulna | 1 (1E) |
| Metatarso | 1 | Úmero | 3 (2E e 1D) |
| Pélvis | 3 (3D) | Vértebra | 1 |
| Rádio | 1 (1D) | - | - |
| Tíbia | 3 (1D e 2E) | - | - |
| Ulna | 1 (1E) | - | - |
| Úmero | 3 (3E) | - | - |
| Vértebra | 11 | - | - |
| Total | 46 | Total | 36 |

## OCORRÊNCIAS EM SÍTIOS ARQUEOLÓGICOS

O registro de ocorrências de Leporidae em sítios arqueológicos é muito abundante no hemisfério norte, com evidência da caça desses animais em sítios Clovis (Waguespack & Surovell, 2003) e pré-Clovis (Hockett & Jenkins, 2013). A presença desses animais no registro arqueológico se explica possivelmente devido a esse grupo ser grande e diversificado na América do Norte. Na América do Sul, especialmente no Brasil, os registros são escassos e a ocorrência, muitas vezes, está restrita a um único osso ou fragmento (Kipnis, 2002). Além de Kipnis (2002), outros estudos mencionam a presença de *Sylvilagus brasiliensis* em sítios arqueológicos: sítio Garivaldino, município de Brochier, estado do Rio Grande do Sul (Queiroz, 2001; Rosa, 2009; Jacobus & Rosa, 2013); sítio Água Limpa, em Monte Alto (Alves *et al.*, 2005), e sambaqui fluvial Laranjal, em Miracatu (Borges, 2009), ambos no estado de São Paulo; e sambaqui costeiro do Moa, em Saquarema, estado do Rio de Janeiro (Imazio da Silveira, 2001). A Tabela 3 apresenta o MNI e o número de espécimes identificados (NISP) desse táxon nos sítios arqueológicos supracitados.

Aparentemente, devido à sua raridade (Tabela 3), os *Sylvilagus* não eram escolhas preferenciais dos grupos caçadores-coletores do Holoceno e, de acordo com o modelo proposto por Kipnis (2002), ocupariam o trigésimo lugar na preferência de caça desses grupos. No estado de Minas Gerais estão registrados, no Cadastro Nacional de Sítios Arqueológicos (CNSA), cerca de 1.300 sítios arqueológicos pré-coloniais. Desses, poucos possuem informações sobre composição faunística e apenas Lapa do Boquete (Kipnis, 2002), Lapa dos Bichos (Kipnis, 2002), Santana do Riacho (Kipnis, 2002), Lapa das Boleiras (Kipnis *et al.*, 2010) apresentam informação sobre a presença de *Sylvilagus brasiliensis* (Tabela 3). Contudo, no que se refere

Tabela 3. Espécimes de *Sylvilagus* observados em sítios arqueológicos no Brasil. * = Datas inferidas a partir de Kipnis (2002). Abreviações: MNI = mínimo número de indivíduos, NISP = número de espécimes identificados, UF = unidade da federação, MG = Minas Gerais, RJ = Rio de Janeiro, RS = Rio Grande do Sul, SP = São Paulo, AP = anos antes do presente.

| Sítio | Município | UF | MNI | NISP | Idade convencional (AP) | Fonte |
|---|---|---|---|---|---|---|
| Santana do Riacho | Vale do Peruaçu | MG | 3 | 8 | < 6.000* | Kipnis (2002) |
| Lapa dos Bichos | Vale do Peruaçu | MG | 3 | 3 | < 6.000* e > 8.500* | Kipnis (2002) |
| Lapa do Boquete | Vale do Peruaçu | MG | 2 | 3 | > 9.000* | Kipnis (2002) |
| Sambaqui do Moa | Saquarema | RJ | 1 | 2 | 3.960 ± 200 | Imazio da Silveira (2001) |
| Garivaldino | Brochier | RS | 1 | 2 | 7.520 ± 350 | Queiroz (2001) |
| Garivaldino | Brochier | RS | 1 | 4 | 8.020 ± 150 | Queiroz (2001) |
| Garivaldino | Brochier | RS | 1 | 3 | 8.290 ± 130 | Queiroz (2001) |
| Garivaldino | Brochier | RS | 1 | 1 | 9.439 ± 360 | Queiroz (2001) |
| Sambaqui Laranjal | Miracatu | SP | 2 | 2 | 6.890 ± 90 | Borges (2009) |
| Sítio Água Limpa | Monte Alto | SP | - | - | 1.524 ± 152 | Alves *et al.* (2005) |

ao sítio Lapa das Boleiras, o único fragmento ósseo obtido ao longo das escavações e identificado como *Sylvilagus brasiliensis* foi encontrado em uma das quadras localizada na porção norte do sítio. É sabido que nas quadras da parte norte desse sítio foram encontrados fragmentos de cerâmica, vidro e louça do século XIX, misturados a fragmentos de fauna e material lascado ao longo de um metro de profundidade. De acordo com Araujo *et al.* (2010), tais quadras (K25 e L25) foram datadas em 180 ± 40 AP e, por isso, não deve ser descartada a possibilidade de este espécime ser recente e doméstico.

São poucas as ocorrências de *Sylvilagus brasiliensis* em sítios arqueológicos brasileiros, porém é possível observar que as ocorrências ao sul do estado de Minas Gerais concentram-se no limite do Holoceno médio e Holoceno inicial (datas de Garivaldino e Laranjal), enquanto os sítios mineiros pesquisados por Kipnis (2002) possuem idades equivalentes às observadas no *Locus* 2 da Gruta Cuvieri, contudo também apresentam datações anteriores, do Holoceno inicial.

## CONCLUSÃO

Os espécimes estudados foram encontrados em duas localidades (*Locus* 2 e *Locus* 3), que apresentam diferentes características deposicionais, sendo o *Locus* 2 de sedimentação mais homogênea, favorecendo a preservação de material osteológico menor e/ou mais frágil (vértebras, costelas, falanges e dentes). Devido à sedimentação homogênea e à pouca remobilização, o *Locus* 2 também pôde ser usado para fazer uma correlação entre idade e camada, através da qual foi possível sugerir que os espécimes encontrados não seriam mais antigos do que seis mil anos. Ao material osteológico do *Locus* 3, baseado nas idades obtidas e na correlação estratigráfica, foi atribuída uma idade pleistocênica.

Os espécimes encontrados na Gruta Cuvieri foram identificados como *Sylvilagus* cf. *brasiliensis*, a partir de características morfológicas dos dentários e, por isso, essa identificação deve ser considerada com cautela. Todavia, dados os estudos recentes de revisão do gênero *Sylvilagus*, que propõem a presença de outras espécies atuais (Ruedas, 2017; Ruedas *et al*., 2017; Diersing & Wilson, 2017), não é impossível pensar que uma diversidade desconhecida de espécies possa ter existido no Pleistoceno.

O registro de *Sylvilagus* observado na Gruta Cuvieri aponta para sua existência no final do Pleistoceno, com desaparecimento no Holoceno inicial e reaparecimento em torno de 6 mil anos, no Holoceno médio.

Apesar dessa ausência no registro da jazida, os *Sylvilagus* existiram em outras localidades ao Sul do Brasil até o limite do Holoceno inicial e médio e também persistiram do final do Pleistoceno até 8.500 AP no norte de Minas Gerais (Tabela 3). A variação da frequência no registro pode ser sugestiva de mudanças ambientais diferenciadas geograficamente durante o Holoceno. A presença de um período seco proposto por Araujo *et al.* (2005) na região de Lagoa Santa pode ter sido um limitador ambiental para o registro deste gênero nesta região entre 12.000 e 6.000 AP.

## AGRADECIMENTOS

Agradecemos aos pesquisadores que coletaram o material da Gruta Cuvieri e que forneceram informações importantes para a realização deste trabalho. Ao revisor, Dr. Leonardo Kerber, pelas válidas contribuições. Agradecemos ao apoio financeiro dado aos autores: MO recebeu bolsa de produtividade do Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) (302163/2017-4) e auxílio à pesquisa Jovem Pesquisador da Fundação de Amparo à Pesquisa do Estado de São Paulo (JP FAPESP) (2018/23282-5), GSM, bolsa de doutorado pleno da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) (88882.425678/2019-01).

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# Notas de pesquisa

Bol. Mus. Para. Emílio Goeldi. Cienc. Nat., Belém, v. 15, n. 3, p. 809-816, set.-dez. 2020

# A brief report on the bioaccumulation of small terrestrial mammals: a suggestion for a new line of research in Brazil

## Breve relato sobre bioacumulação em pequenos mamíferos terrestres: uma sugestão para nova linha de pesquisa no Brasil

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**Abstract:** Small mammals are potential elements to evaluate mining impacts because they occupy key positions in food webs and can be sampled using relatively inexpensive, easy and quick methods. They have been used as environmental indicators for various purposes, such as ecological succession gradients and pollution, among others. However, little is mentioned about bioaccumulation in South America. Our objective is to present data from a heavy metal accumulation test using the Brazilian gracile opossum *Gracilinanus microtarsus* (J. A. Wagner, 1842) as an experimental model. We concluded that the contents of heavy metals found in the animals' tissues showed differences when compared to other individuals of the same species from an area without the influence of heavy metals. As a result, we encourage the scientific community to carry out more studies in this little mentioned line in the literature in South America and incipient in Brazil.

**Keywords:** Bioaccumulation of heavy metals. Didelphimorphia. Ecology. *Gracilinanus microtarsus*.

**Resumo:** Pequenos mamíferos são elementos potenciais para avaliar os impactos da mineração, porque ocupam posições-chave nas redes alimentares e podem ser amostrados usando métodos relativamente baratos, fáceis e rápidos. Eles têm sido utilizados como indicadores ambientais para diversos fins, como gradientes de sucessão ecológica, poluição, entre outros. No entanto, pouco é mencionado sobre a bioacumulação na América do Sul. Nosso objetivo é apresentar os resultados de um teste realizado com um pequeno marsupial da espécie *Gracilinanus microtarsus* (J. A. Wagner, 1842), no qual foi concluído que o conteúdo de metais pesados encontrados nos tecidos do animal apresentou diferenças quando comparado a outro indivíduo da mesma espécie proveniente de uma área sem influência de metais pesados. Com esses resultados, procuramos incentivar a comunidade científica a realizar mais pesquisas nessa linha, pouco mencionada na literatura da América do Sul e incipiente para o Brasil.

**Palavras-chave:** Bioacumulação de metais pesados. Didelphimorphia. Ecologia. *Gracilinanus microtarsus*.

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MACHADO, F. S., A. S. MOURA, R. F. MARIANO, R. A. T. BORÉM & M. A. L. FONTES, 2020. A brief report on the bioaccumulation of small terrestrial mammals: a suggestion for a new line of research in Brazil. **Boletim do Museu Paraense Emílio Goeldi. Ciências Naturais** 15(3): 809-816. DOI: http://doi.org/10.46357/bcnaturais.v15i3.217.

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Recebido em 30/11/2019
Aprovado em 01/10/2020
Responsabilidade editorial: Alexandra Maria Ramos Bezerra

## INTRODUCTION

Brazil has suffered from an increasing impact of mining activities in recent years, such as the collapse of dams in Minas Gerais state, thereby affecting important watersheds of the Southeastern and Northeastern regions of Brazil, such as the Doce River and São Francisco River basins (Cionek *et al.*, 2019; Thompson *et al*., 2020). In addition to rupturing dams, mining activities can release contaminants through the acidic drainage of wastes, erosion, and surface runoffs (Fan *et al*., 2014; Vosoogh *et al*., 2016).

Small mammals are potential elements to evaluate the mining impacts because they occupy key positions in food webs (Kaufman *et al.*, 1998) and can be sampled using relatively inexpensive, easy and quick methods (Graipel *et al.*, 2003; Astúa *et al.*, 2006; Hice & Velazco, 2013). These animals have been used as environmental indicators (Machado *et al.*, 2013) for a wide range of purposes, such as changes in agriculture (Fischer *et al.*, 2011), ecological succession (Briani *et al.*, 2004), and altitude gradients (Moreira, J. *et al.*, 2009), and seed dispersal (Horn *et al.*, 2008; Andreazzi *et al.*, 2009). Rodents and marsupials are the most diverse terrestrial group of mammals in numbers of species and sub-species (Costa *et al.*, 2005; Paglia *et al.*, 2012). Small mammals act in a fundamental way in the trophic chain, contributing to the control and dispersion of plant species, serving as prey for larger predators, and controlling smaller species (invertebrates, other mammals, reptiles and birds) (Redford & Eisenberg, 1992).

We can also take measurements aiming to understand bioaccumulation processes from these mammals, since most species of these groups are omnivores and habitat generalists, therefore they are able to acquire different doses of chemical elements (metals or not) from various food sources (Hunter *et al.*, 1989). Heavy metals can enter food chains by plants and soil fauna, and in heavy metal accumulation areas, small mammals can present a high concentration of heavy metals in their kidney and bone tissues, and is usually correlated with its diet (Ma, 1989), mainly composed small invertebrates (Santori *et al.*, 1997, 2012; Finotti *et al.*, 2012). Many herbivores are less affected than carnivores/omnivores as the heavy metals are absorbed in derisory amounts by them (Ma *et al.*, 1983). However, earthworms and other soil invertebrates present high accumulation potential when they reside in heavy metal accumulation sites (Ma *et al.*, 1983).

The mining impacts in Brazil are disastrous and the contamination means in environments must be evaluated, including bioaccumulation in animals. Thus, herein we present data from a heavy metal accumulation test using the Brazilian gracile opossum *Gracilinanus microtarsus* (J. A. Wagner, 1842) as an experimental model. As a result, we encourage the scientific community to perform more studies on little mentioned line of research in the literature and incipient in Brazil.

## MATERIAL AND METHODS

We performed an experimental test with two individuals of the *Gracilinanus microtarsus* species to analyze the bioaccumulation of heavy metals, one collected in a mining pit and the other in a natural environment. The first one (CMUFLA 2474) was captured in a mining area with high cadmium (Cd) and lead (Pb) contents, located in Vazante municipality (17° 55' 23" S, 46° 48' 56" W – 650 m), Minas Gerais state, Brazil (Figure 1).

In order to verify if the marsupial collected in the mining area had higher concentrations of cadmium and lead than other marsupials of the same species which were not exposed to these heavy metals, quantitative analyzes of cadmium and lead were carried out from tissues of both the animal test and from other individuals (frozen) from the Federal University of Lavras (UFLA) Mammalian Collection (CMUFLA), herein referred to as control samples. The animal control was collected in Itutinga (21° 17' 53" S and 44° 39' 28" W – 969 m), Minas Gerais state. We used sherman traps (250 x 80 x 90 mm) arranged in linear transects with baits composed of a mixture of peanut butter, cod liver oil, sardines, cornmeal, banana

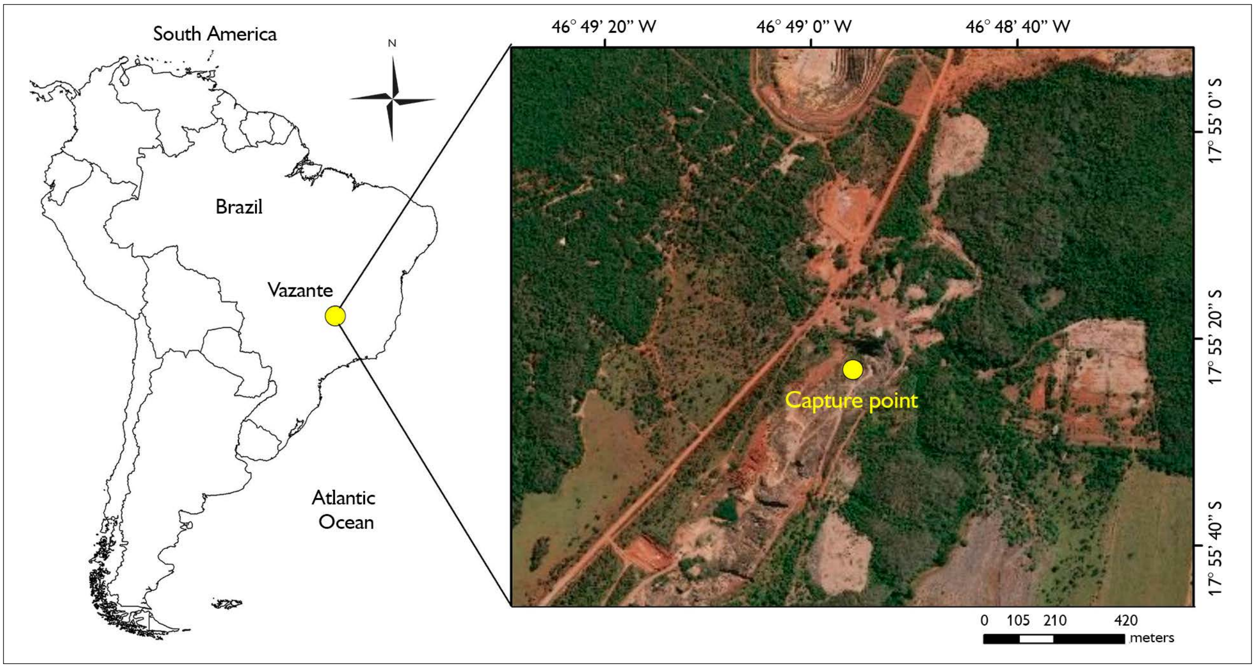

Figure 1. Study area map in Vazante municipality, Minas Gerais state, Southeastern Brazil. Map produced by the authors, 2020.

essence and mashed pineapple on small pieces of banana to capture both individuals (test and control). The species were identified following Gardner (2008).

The test animal came from a wildlife monitoring study and was captured in a forest area adjacent to a mining plant. We found the individual dead inside one of the Sherman traps after nine months of performing a capture-recapture program. The individual was taxidermized and its soft tissues and bones were divided into sub-samples (Table 1).

After obtaining the wet weight, the control and experimental samples were oven dried at 60 °C for 12 h, and then weighed again to perform the heavy metal analysis, in which each sub-sample had a minimum weight of 0.05 g. This material was placed in Teflon® PTFE tubes with five milliliters of $HNO_3$ (nitric acid) and microwaved at a pressure of 0.76 MPa and a temperature of 175 °C for 10 min. Cd and Pb contents were determined by atomic absorption spectrophotometry using a PerkimElmerAAnalyst 800® flame atomizer (similar to Carvalho *et al.*, 2013).

Table 1. Sub-samples obtained from the animal test and respective references for the quantitative analysis of cadmium and lead.

| Sub-samples | References |
|---|---|
| 1 | Liver, heart, spleen and kidneys |
| 2 | Intestine and stomach |
| 3 | Thoracic and pelvic limbs |
| 4 | Ribs |
| 5 | Vertebra |

## RESULTS & DISCUSSION

The results showed that the specimen captured near the mining area had high levels of cadmium and lead when compared to the control samples. These values showed differences between some of the sub-samples (1 to 5 – Figures 2 and 3). The cadmium and lead contents present in the test animal are highly discrepant in relation to those found in the control samples.

The results demonstrated the potential of small terrestrial mammals as a bioindicator, in this case using the Brazilian gracile opossum of the *Gracilinanus microtarsus* species. Lead accumulation in trialkylated form (Leite, 2006) can affect organs in the different body systems such as endocrinology and cardiovascular, among others. Furthermore, this heavy metal can also accumulate in bone tissues (Moreira, F. & Moreira, J., 2004). In the case of Cadmium, interaction with the liver results in oxidative stress, competing with zinc for protein binding sites and causing DNA strand breaks, or inhibiting the pathway associated with repair of base-pairing DNA (Lauer, 2007). Moreover, Cadmium negatively affects reproduction, and causes cardiotoxicity, hepatotoxicity, and neurotoxicity (Tomza-Marciniak *et al.*, 2019). Critical levels reported in the literature are 15 µg/g of lead in mammals in general (Ma, 2011) and 30-60 mg/kg of wet weight and 105-210 mg/kg of dry weight of small mammals for cadmium (Cooke, 2011). It is reiterated that these values were analyzed in large animals, such as cattle, monkeys, dogs and rats in Ma (2011) and the values to Cooke (2011) were found with captive wild European species studied in the laboratory with chronic oral doses equivalent to those encountered by wild small mammals in contaminated habitats. Therefore, the levels found in our research are considered high in relation to these critical levels.

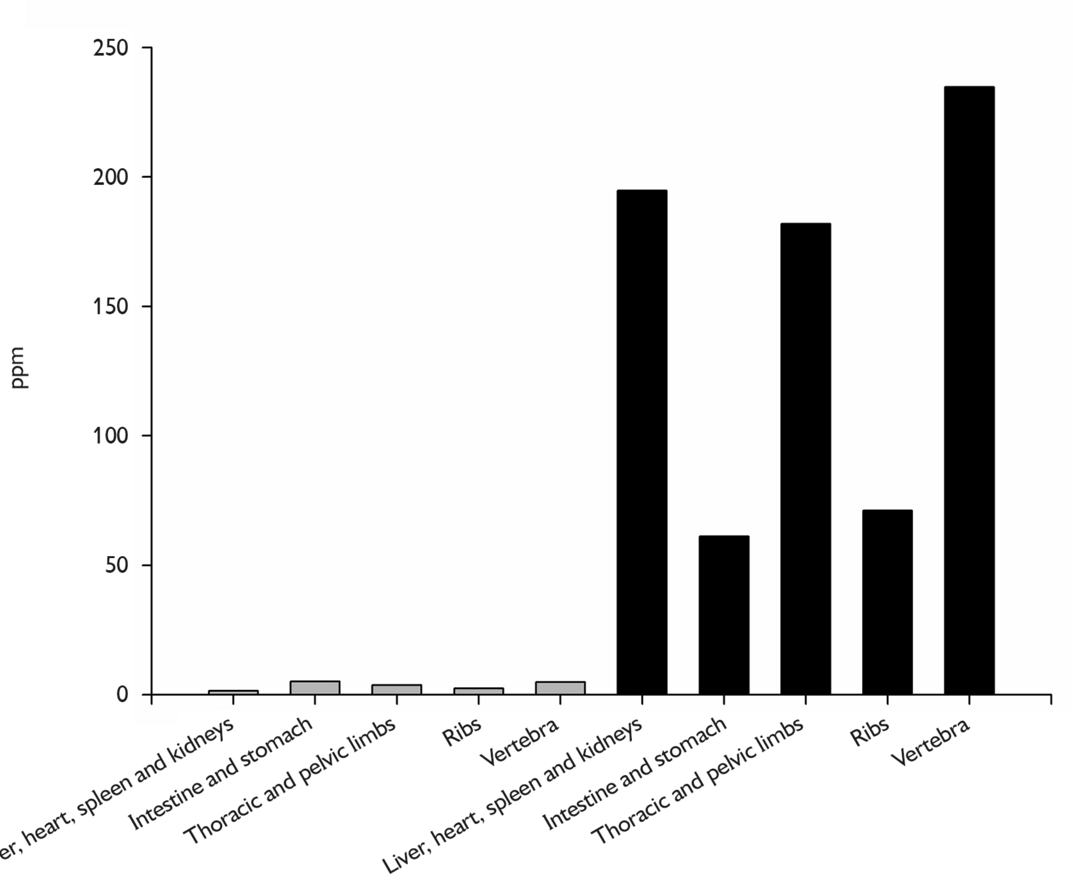

Figure 2. Cadmium contents accumulated in tissues of small terrestrial mammals in ppm. The gray bars represent the sub-samples from the control animal, and black bars represent the sub-samples from the animal test.

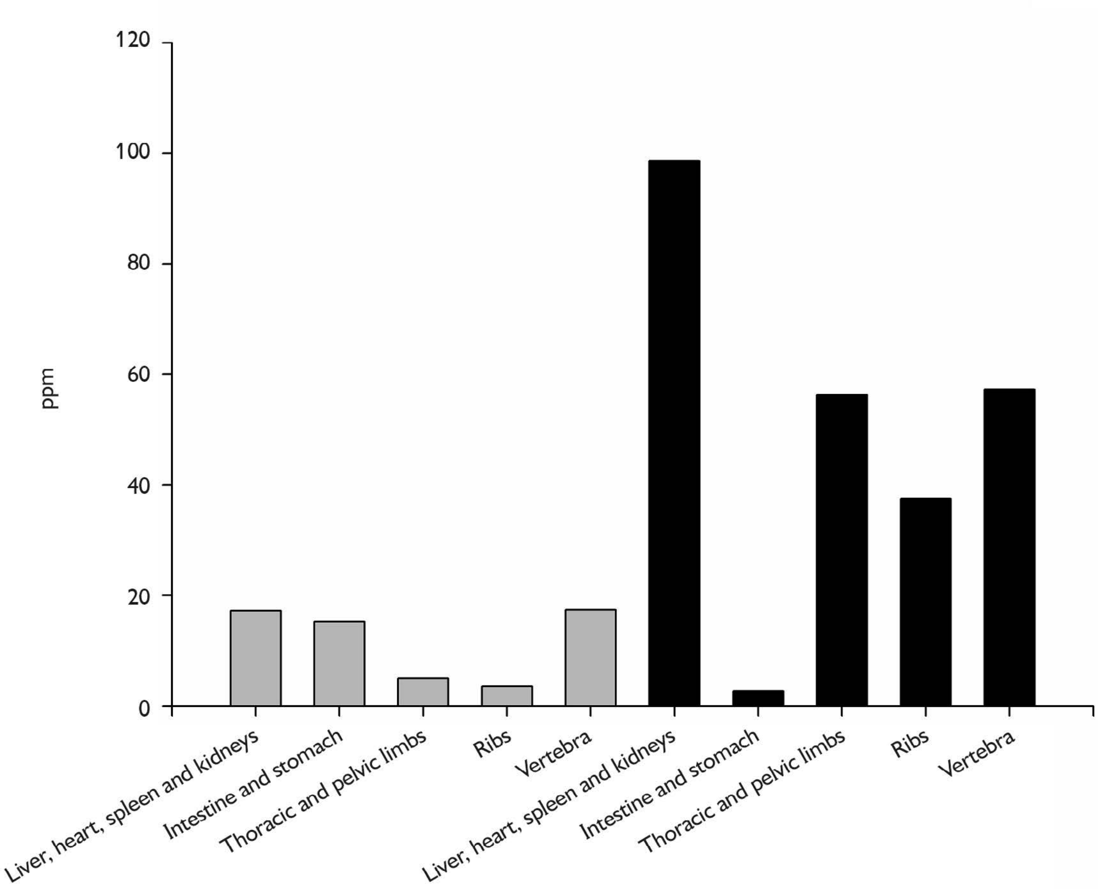

Figure 3. Lead contents accumulated in tissues of small terrestrial mammals in ppm. The numbers gray bars represent the sub-samples from the control animal, and black bars represent the sub-samples from the animal test.

These marsupials can bioaccumulate these two metals and disperse them in nature in different environments and in food chains. This can occur by the animal decomposing after death and/or when the animal is preyed upon by predators. Cadmium and lead are macronutrients. Only a few super-accumulating species can easily remove this metal from the soil [*e.g.*, the plant species *Gomphrena claussenii* Moq. – Carvalho *et al.* (2013)]. Nevertheless, some animals can retain these elements, but carnivorous and omnivorous animals accumulate more than herbivores when feeding on smaller animals such as earthworms or other soil associated invertebrates (Ma, 1989; Veltman *et al.*, 2007).

Some studies on bioaccumulation in Europe and Asia (*e.g.*, Hamers *et al.*, 2006; Veltman *et al.*, 2007; Wijnhoven *et al.*, 2007) found high cadmium values in the liver and kidney of herbivorous and carnivorous voles and shrews, correlating them with available soil elements. When studying sympatric species of small mammals in the north of France, Fritsch *et al.* (2010) verified different bioavailability response patterns, with age being a key factor in response to exposure to metals.

In addition, this is the first report of bioaccumulation of these two chemical elements in neotropical marsupials and has the secondary objective of presenting technical-scientific arguments to encourage more studies in this line in South America, mainly in Brazil (Zocche *et al*., 2010). Ferreira *et al*. (2014) mentioned that Brazil has many mining (or degraded) zones, presenting ecological implications of the expansion of these areas. However, studies in Brazil focusing on mining impacts related on fauna contamination are still incipient.

Bioaccumulation in mammals of medium and large size has already been shown, mainly for capybara and marine mammals (*e.g.*, Monteiro-Neto *et al.*, 2003; Ramm, 2015), both related to the bioaccumulation of metals such as silver, lead, copper, zinc and cadmium due to agricultural activities (agrochemicals) which are leached into lakes and rivers. There are promising initiatives for small mammals in Brazil (*e.g.*, Castro *et al*., 2018) with accumulation of Triphenyltin, and by Zocche *et al.* (2010) on the influence of heavy metals on blood cells in bats), however this study scope needs more attention by researchers, considering the increased contact with heavy metals and other toxic chemical elements from agrochemicals and mining activities in Brazil (for example, environmental disasters causing spillage of metal tailings in Mariana, in 2015, and Brumadinho, in 2019, in Minas Gerais state).

Our results raise questions about the bioaccumulation process from mining actvities: How much of the heavy metal bioaccumulation found in animals living in mining area surroundings is the result of the mining activities, and how much is result of an ecosystem established in an area which naturally has high concentrations of heavy metals? What is the concentration of heavy metals in surrounding soils and plants? What is the concentration of heavy metals in organisms consumed by the analyzed marsupial? Thus, these questions must be answered by future studies to clarify the environmental impacts of contaminating activities.

## ACKNOWLEDGMENTS

We are grateful to the editor Alexandra Bezerra, Diogo Loretto and an anonymous reviewer for the considerations for improving previous version of this article. FSM received research fellowship from *Fundação de Amparo à Pesquisa do Estado de Minas Gerais* (FAPEMIG) (ID-11511); ASM received research fellowship from FAPEMIG (ID-11512); RFM research fellowship from *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* (CAPES) (Code 001).

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Bol. Mus. Para. Emílio Goeldi. Cienc. Nat., Belém, v. 15, n. 3, p. 817-827, set.-dez. 2020

# New records of disk-winged bats *Thyroptera tricolor* Spix, 1823 and *T. devivoi* Gregorin, Gonçalves, Lim & Engstrom, 2006 (Chiroptera: Thyropteridae) for the Brazilian Amazonia and Cerrado

# Novo registro de morcegos-de-ventosa *Thyroptera tricolor* Spix, 1823 e *T. devivoi* Gregorin, Gonçalves, Lim & Engstrom, 2006 (Chiroptera: Thyropteridae) para a Amazônia brasileira e Cerrado

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**Abstract:** We present new records for the disk-winged bats *Thyroptera tricolor* and *T. devivoi* in central and northern Brazil. Records of *T. tricolor* are from Aripuanã, *Usina Hidrelétrica* (UHE) Colíder (both in the northern Mato Grosso state) and Santana do Araguaia (southern Pará state). New records of *T. devivoi* are from a Cerrado area in the Rio Manso, Rio Quilombo (both in Mato Grosso state) and from an Amazon rainforest area at Juruti (Pará state). The records of *Thyroptera devivoi* for Pará and Mato Grosso are the first ones for these states and the records from the latter are based on two specimens previously identified as *T. discifera.* Based on the new identifications, we argue that *T. discifera* does not occur in the Cerrado.

**Keywords:** Geographic distribution. Mato Grosso. Pará. Range extension.

**Resumo:** Apresentamos novos registros para as espécies de morcegos *Thyroptera tricolor* e *Thyroptera devivoi* no Brasil central e norte. Os registros de *T. tricolor* são de Aripuanã, Usina Hidrelétrica (UHE) Colíder (ambos no norte do estado do Mato Grosso) e Santana do Araguaia (sul do estado do Pará). Os novos registros de *T. devivoi* são de área de Cerrado nos rios Manso e Quilombo (ambos no estado do Mato Grosso) e em uma área de floresta amazônica em Juruti (estado do Pará). Estes são os primeiros registros de *Thyroptera devivoi* para os estados do Pará e Mato Grosso, sendo os registros do Mato Grosso baseados em dois exemplares previamente identificados como *T. discifera*. Com base na nova identificação, sugerimos que *T. discifera* não ocorre no Cerrado.

**Palavras-chave:** Distribuição geográfica. Mato Grosso. Pará. Extensão de distribuição.

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SEMEDO, T. B. F., G. S. T. GARBINO, N. ARDENTE, P. F. COLAS-ROSAS, M. A. TORRES & R. V. ROSSI, 2020. New records of disk-winged bats *Thyroptera tricolor* Spix, 1823 and *T. devivoi* Gregorin, Gonçalves, Lim & Engstrom, 2006 (Chiroptera: Thyropteridae) for the Brazilian Amazonia and Cerrado. **Boletim do Museu Paraense Emílio Goeldi. Ciências Naturais** 15(3): 817-827. DOI: http://doi.org/10.46357/bcnaturais.v15i3.213.

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Recebido em 21/11/2019
Aprovado em 21/10/2020
Responsabilidade editorial: Alexandra Maria Ramos Bezerra

## INTRODUCTION

The genus *Thyroptera* Spix, 1823 includes five extant species of disk-winged bats: *Thyroptera devivoi* Gregorin, Gonçalves, Lim & Engstrom, 2006; *Thyroptera discifera* (Lichtenstein & Peters, 1854); *Thyroptera lavali* Pine, 1993; *Thyroptera tricolor* Spix, 1823; and *Thyroptera wynneae* Velazco, Gregorin, Voss & Simmons, 2014 (Velazco *et al*., 2014; Lee Jr., 2019). Disk-winged bats are insectivores that usually capture prey directly from the substrate and use foliage as day roost (Dechmann *et al*., 2006; Wilson, 2008). They inhabit humid lowland forests, including gallery forests in some Neotropical savannas (Gregorin *et al*., 2006; Tavares & Mantilla-Meluk, 2015). Four species, *T. devivoi*, *T. discifera*, *T. lavali*, and *T. wynneae*, are restricted to South America, occurring in savannas and in the Amazonia and Atlantic rainforests (Wilson, 2008; Lee Jr., 2019). The species with the widest range, *T. tricolor*, occurs in lowland rainforests from southern Mexico to southeastern Brazil (Lee Jr., 2019).

*Thyroptera tricolor* is distributed in southern Mexico, Central America and South America, where it has been recorded on the island of Trinidad, in Venezuela, Guyana, French Guiana, Surinam, Colombia, Ecuador, Peru, Bolivia, and Brazil (Wilson, 2008; Lee Jr., 2019). In Brazil, it has an apparent disjunct distribution, with records in the Amazonia (Amazonas, Acre, Maranhão, Rondônia, Roraima, and Pará states) and in the Atlantic Forest (Bahia, São Paulo, Paraná, Rio de Janeiro, and Espírito Santo states) (Esbérard *et al*., 2007; Wilson, 2008; Passos *et al*., 2010; Castro & Michalski, 2015; Tavares *et al*., 2017). It has been reported in sympatry with *T. discifera* and *T. lavali* in several areas within its range of distribution, especially in the Amazonia (Wilson, 2008; Velazco *et al*., 2014). *Thyroptera tricolor* commonly roosts in the young rolled leaves of *Heliconia* (Heliconiaceae) and may occasionally use leaves of other plants as roosts, such as *Calathea* (Marantaceae), *Phenakospermum* (Strelitziaceae), and *Musa* (Musaceae) (Goodwin & Greenhall, 1961; Wilson & Findley, 1977; Lee Jr., 2019).

*Thyroptera devivoi* is known from six localities: one in the Colombian llanos, one in the Guyanan Rupununi savanna, and four in the Brazilian Cerrado (Maranhão, Tocantins, and Piauí states) (Gregorin *et al*., 2006; Santos, C. *et al*., 2013; Rodríguez-Posada *et al*., 2017; Rosa *et al.*, 2020). There is scarce information on the ecology of this recently-described species: one individual from Guyana was captured 'under and eaté palm leaf' (Gregorin *et al*., 2006); in Colombia, a specimen was caught in a *Mauritia flexuosa* L. f. grove (Rodríguez-Posada *et al*., 2017); and in Maranhão state, Brazil, a roosting group was found in a dead palm leaf sheath (Rosa *et al.*, 2020).

In this paper, we present six new records of *Thyroptera tricolor* and *T. devivoi* for the southern Brazilian Amazonia, extending the known distribution of both species, and we also comment on the presence of *T. discifera* in the Cerrado.

## MATERIALS AND METHODS

We examined six specimens of *Thyroptera* preserved as fluid and taxidermied. The specimens are housed in the following institutions: *Coleção da Universidade do Estado de Mato Grosso* (CZAFMA), *campus* Alta Floresta, Alta Floresta; *Museu Paraense Emílio Goeldi* (MPEG), Belém; *Museu de Zoologia da Universidade de São Paulo* (MZUSP), São Paulo; *Universidade Federal de Mato Grosso* (UFMT), Cuiabá; *Universidade de Brasília* (UNB), Brasília. To identify the specimens, we analyzed qualitative characters of pelage, integument, and dentition based on Gregorin *et al*. (2006) and Velazco *et al*. (2014). The external and cranial measurements were taken and are described in the following lines and summarized in Table 1. External measurements were obtained directly from the labels, or were measured by us (GSTG, NA, and PFCR) while preparing the specimens using digital calipers (0.01 mm precision), and include: total length (TL) – distance from the tip of the snout to the tip of the last caudal vertebra; length of the tail (T) – measured from the point of dorsal flexure of the tail with the sacrum to the tip of the last caudal vertebra;

Table 1. External and cranial measurements (in mm) and body mass (grams) of *Thyroptera devivoi* and *Thyroptera tricolor.* See Material and Methods for abbreviations.

| | *Thyroptera devivoi* | | | *Thyroptera tricolor* | |
|---|---|---|---|---|---|
| Measurements | UnB 982 | UnB 989 | MPEG 45677 | UFMT 4881 | MZUSP 36011 |
| Sex | Male | Male | Male | Male | Male |
| Age | Adult | Adult | Adult | Sub-adult | Adult |
| W | - | - | 6 | 5 | 3.6 |
| Ear | - | - | 9.97 | 9.62 | 14 |
| FA | 34.99 | 34.27 | 37.6 | 36.91 | - |
| HF | 6.12 | - | 6.28 | 5.79 | 3 |
| T | 24.68 | 21.59 | 25.13 | 26.16 | 33 |
| TL | - | - | 42.58 | 41.14 | 46 |
| GLS | 14.80 | 14.05 | 14.95 | 14.44 | - |
| CIL | 12.82 | - | 13.92 | 12.51 | - |
| BB | 6.50 | 6.19 | 6.90 | 6.76 | - |
| ROL | 4.71 | 5.05 | 5.48 | 4.32 | - |
| ZB | 6.90 | - | 7.82 | 7.57 | - |
| PB | 2.85 | 3.03 | 2.38 | 2.91 | - |
| MTRL | 5.76 | 5.33 | 5.78 | 6.03 | - |
| M3-M3 | 2.66 | 2.12 | 2.98 | 2.62 | - |
| LMA | 10.75 | 9.85 | 10.86 | 10.90 | - |
| MANDL | 5.69 | 5.07 | 5.88 | 4.94 | - |

hind foot length (HF) – measured from the anterior edge of the base of the calcar to the tip of the claw of the longest toe; ear length (Ear) – measured from the ear notch to the fleshy tip of the pinna; forearm length (FA) – distance from the elbow (tip of the olecranon process) to the wrist (including the carpals, this measurement made with the wing at least partially folded); and mass (W) in grams.

Ten cranial measurements were taken from the specimens using digital calipers (0.01 mm precision), followed Velazco *et al*. (2014) are described as follows: greatest length of the skull (GLS) – distance from the posteriormost point on the occiput to the anteriormost point on the premaxilla (excluding the incisors); condyloincisive length (CIL) – distance between the anteriormost point on the upper incisor and a line connecting the posteriormost margins of the occipital condyles; braincase breadth (BB) – greatest breadth of the globular part of the braincase, excluding mastoid and paraoccipital processes; rostral length (ROL) – distance from the alveolar process of the premaxilla above the first upper incisor to the ipsilateral postorbital constriction; zygomatic breadth (ZB) – greatest breadth across the zygomatic arches; postorbital breadth (PB) – least breadth at the postorbital constriction; maxillary toothrow length (MTRL) – distance from the anteriormost surface of the upper canine to the posteriormost surface of the crown of M3; width at M3 (M3–M3) – greatest width of palate across labial margins of the M3s; length of the mandible (LMA) – distance from the anteriormost point on the first lower incisor to the posteriormost point on the ipsilateral coronoid process; mandibular toothrow length (MANDL) – distance from the anteriormost surface of the lower canine to the posteriormost surface of M3.

Thyropterids are easily distinguished from all other Neotropical bats by the presence of a circular adhesive disk on the sole of the foot and an oval or circular disk attached by a short pedicle to the base of the thumb (Figure 1). The species of this genus are characterized by their small size (forearm length between 31 and 41 mm); an elongate, slender muzzle; circular and well-separated nares; and funnel-shaped ears. The skull has a rounded braincase elevated above the slender rostrum, with complete premaxillae and no postorbital processes (Wilson, 2008).

To determine the identity of the *T. devivoi* specimens, we observed a bicolored ventral pelage (Figures 1A-1B and 2) (unicolored in *T. discifera* and *T. tricolor*, tricolored in *T. wynneae*), with frosted tips (Figure 1A) (non-frosted in *T. lavali*), oblong adhesive disks on the thumb (Figure 1C) (circular in *T. tricolor* and *T. discifera*), absence of lappets on the calcar (present in the other species or faintly developed in *T. devivoi*) (Figure 1B); I2 with transversely oriented buccal and labial cusps (obliquely oriented in *T. discifera* and *T. tricolor*) (Figures 3A and 4); and the i3 with twice the buccolingual width of i1 and i2 (Figures 3B and 4) (1.5 times the buccolingual width of i1 and i2 in *T. discifera*, *T. tricolor*, and *T. wynneae*) (Gregorin *et al*., 2006; Velazco *et al*., 2014; Rodríguez-Posada *et al*., 2017).

The characters used to identify the *T. tricolor* specimens were: unicolored 'pure white' ventral pelage (Figure 5) (ventral pelage not conspicuously contrasting with dorsum in the other species), circular adhesive disks on the thumb (oblong in *T. devivoi, T. lavali*, and *T. wynneae*), calcar with two lappets projecting posterolaterally from the shaft (single lappet in *T. discifera* and *T. lavali*, or poorly developed in *T. devivoi*), and smaller dimension when compared with *T. devivoi* and *T. lavali* (Table 1).

## RESULTS

### *Thyroptera tricolor* SPIX, 1823

The records of *Thyroptera tricolor* are based on three specimens. The first is from Aripuanã (10° 04' 22" S,

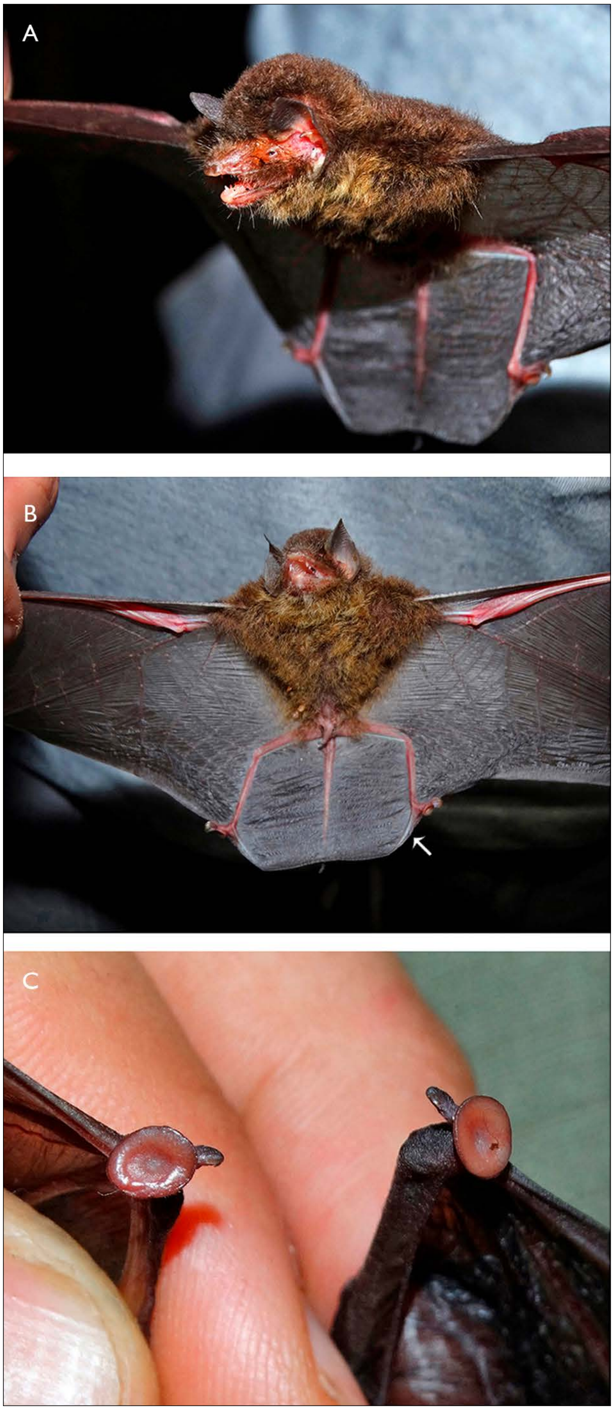

Figure 1. Specimen of *Thyroptera devivoi* MPEG 45677 collected in Juruti, Pará state, Brazil. Note the frosted ventral pelage (A, B), absence of lappets on the calcaneum (B), and oblong adhesive disks of wing (C). The calcaneum is indicated by a white arrow. Photos: Paul François Colas-Rosas (2015).

59° 30' 41" W, 175 m), Mato Grosso state, and is a sub-adult male weighing 5 g, captured at 18.30 h on 29 May, 2019, in a ground-level mist net set across a trail of forested *habitat*, during the dry season. It is fluid-preserved and had its skull removed, and it is deposited at the *Coleção Zoológica da Universidade Federal de Mato Grosso* under the collection number UFMT 4881 (Figures 5 and 6). The second specimen of *T. tricolor* is from *Fazenda Fartura* in Santana do Araguaia (9° 37' 41" S, 50° 29' 42" W, 180 m), Mato Grosso state. It is an adult male, hand-caught by GSTG while roosting during the day inside a rolled leaf of *Heliconia*, on 13 April, 2017. The capture area was in a swampy area in a mature lowland Amazon rainforest, approximately 5-8 meters from a dirt road. It is preserved as a taxidermied skin with separated skull and partial skeleton, and it is deposited at the *Museu de Zoologia da Universidade de São Paulo* (MZUSP 36011). The third specimen of *T. tricolor* was captured at UHE Colíder (10° 49' 08" S, 55° 27' 03" W, 265 m), Pará state. It is a fluid-preserved specimen deposited at the *Universidade do Estado de Mato Grosso*, *campus* Alta Floresta, under the collection number CZAF MA 08. The specimen CZAF MA 08 was previously mentioned in a checklist of mammals from Mato Grosso (Brandão *et al*., 2019), but no locality information was given. These records expand the distribution of *T. tricolor* in the southern Amazonia, filling a wide gap in the southern part of the distribution of this species in this ecoregion (Figure 7A).

Figure 2. Specimen of *Thyroptera devivoi* (UnB 982) collected in Rio Manso, Chapada dos Guimarães, Mato Grosso state, Brazil.

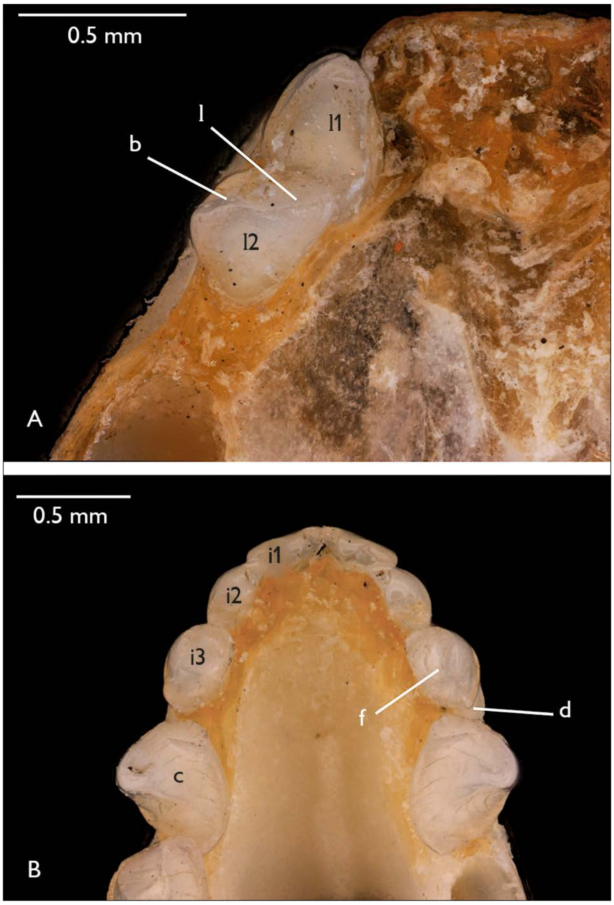

Figure 3. A) Upper incisors, in occlusal view, of *Thyroptera devivoi* (UnB 982) from Rio Manso, Mato Grosso state, Brazil; B) lower incisors and canine, in occlusal view of the same specimen. Legends: I1 = first upper incisor; I2 = second upper incisor; i1 = first lower incisor; i2 = second lower incisor; i3 = third lower incisor; c = lower canine; b = buccal cusp; d = distostyle; f = fossalike concavity; l = lingual cusp.

## *Thyroptera devivoi* GREGORIN, GONÇALVES, LIM & ENGSTROM, 2006

The records of *Thyroptera devivoi* are based on three specimens. The first specimen is from Rio Manso, Chapada dos Guimarães (14° 50' 43.03" S, 55° 34' 47.30" W, 274 m), Mato Grosso state. It is fluid-preserved with the skull removed, and is deposited at the *Coleção Zoológica da Universidade de Brasília* under the collection number UnB 982 (Figures 2, 3, 4). The second specimen is from Rio Quilombo, Chapada dos Guimarães

(15° 4' 17.96" S, 55° 42' 51.86" W, 287 m), Mato Grosso state. It is fluid-preserved with the skull removed, and deposited at the *Coleção Zoológica da Universidade de Brasília* under the collection number UnB 989. Both UnB specimens were previously identified as *T. discifera* by Bezerra *et al.* (2005) and considered to be the only known records of the species for the Cerrado. The third record of *T. devivoi* is from Juruti (2° 15' 46.28" S, 56° 04' 55.51" W, 132 m), Pará state. It is fluid-preserved and had its skull removed, and it is deposited at the *Museu Paraense Emílio Goeldi* (MPEG 45677, field number PF 4809). The specimen from Juruti is an adult male, captured with understory mist net in a fragment of mature lowland Amazon rainforest with developed vertical stratification in the dry season. Close to the fragment there are pastures and a railway (Figure 7B).

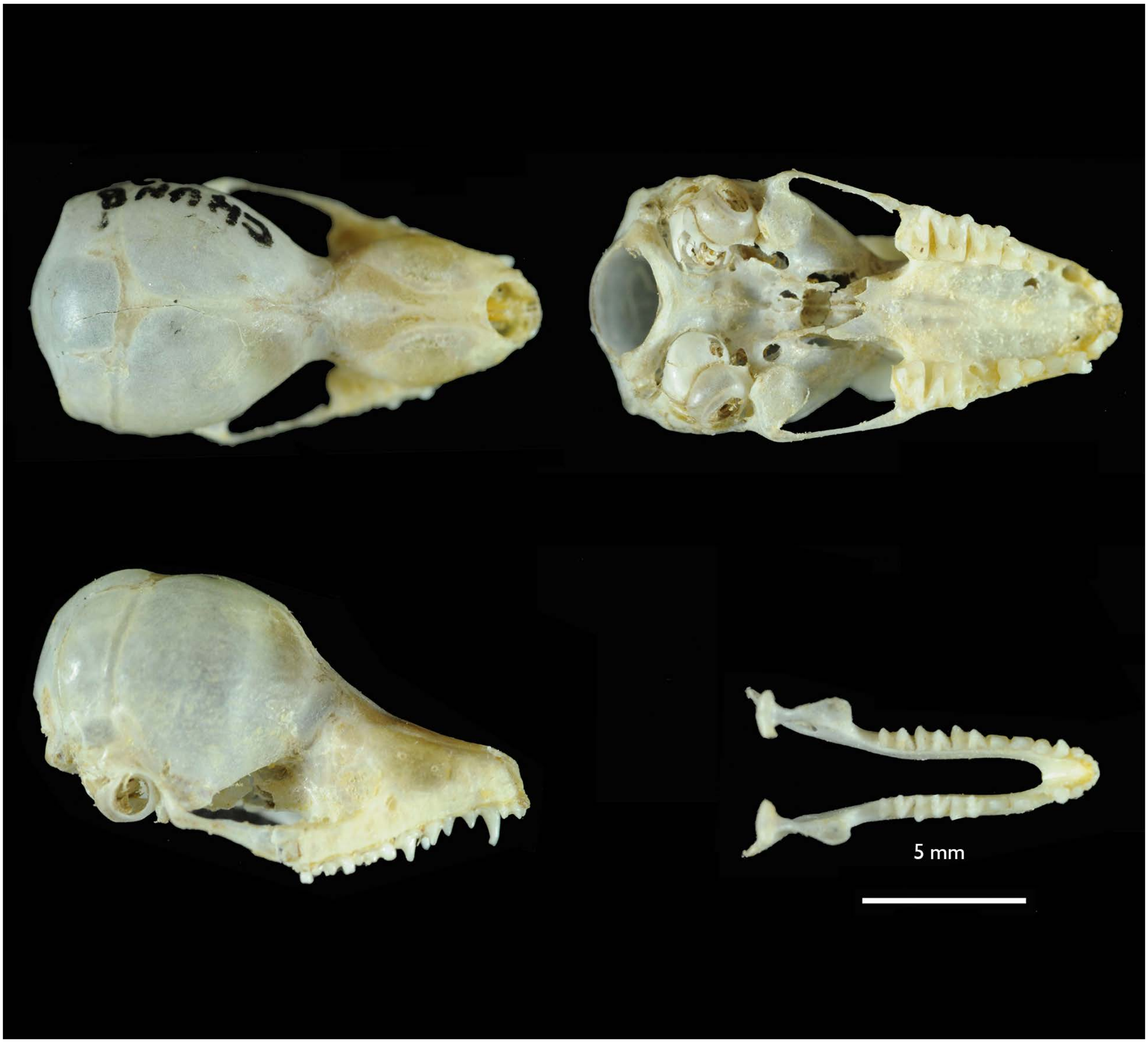

Figure 4. Dorsal, ventral, and lateral views of skull and superior view of mandible of *Thyroptera devivoi* (UnB 982) collected in Rio Manso, Chapada dos Guimarães, Mato Grosso state, Brazil.

Figure 5. Specimen of *Thyroptera tricolor* (UFMT 4881) collected in southern Amazonia, Aripuanã, Mato Grosso state, Brazil. Note the pure white ventral fur. Photos: Thiago Semedo (2019).

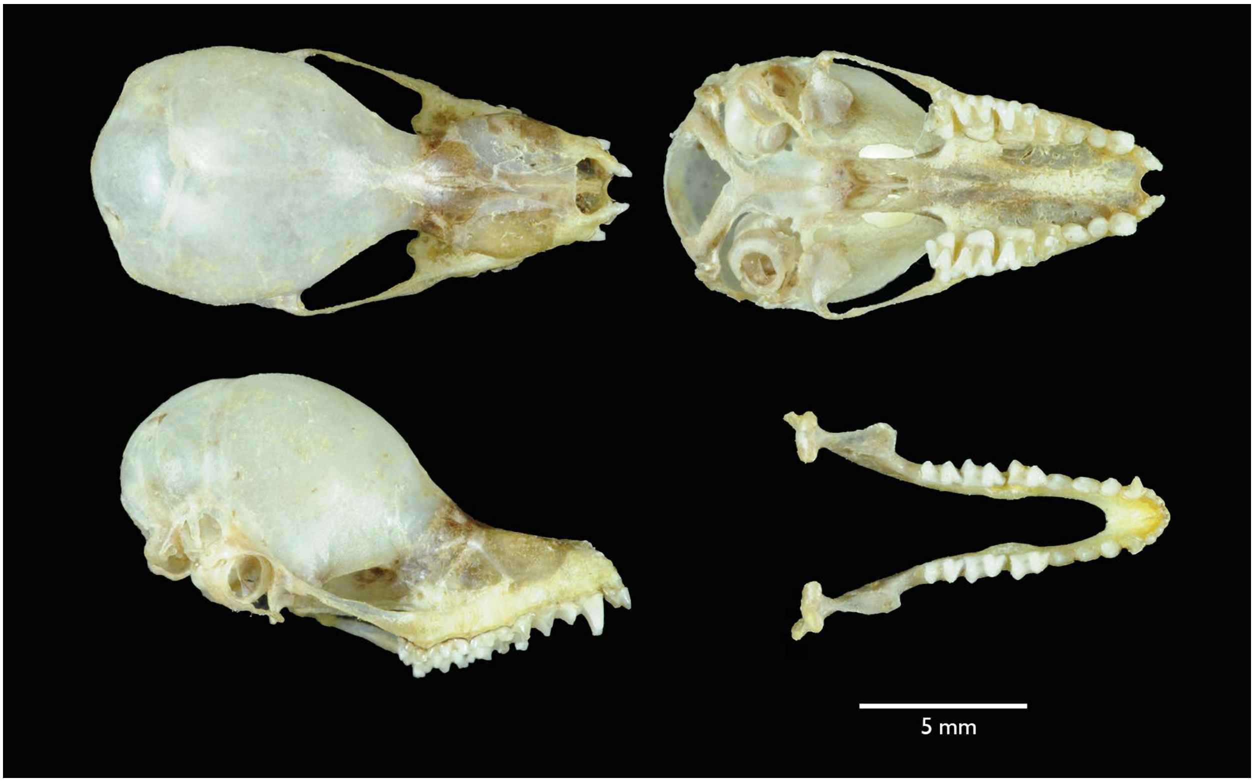

Figure 6. Dorsal, ventral and lateral views of skull of *Thyroptera tricolor* (UFMT 4881), collected in southern Amazonia, Aripuanã, Mato Grosso state, Brazil.

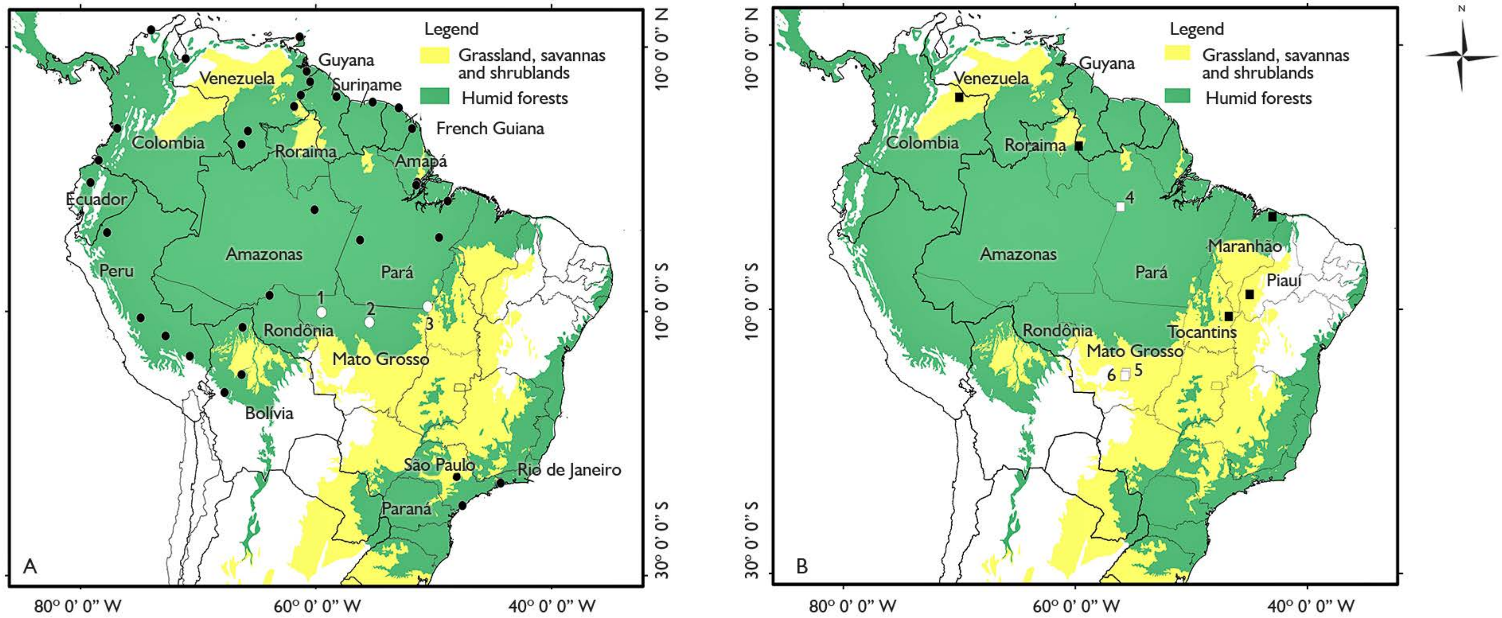

Figure 7. A) Localities of *Thyroptera tricolor*. Solid circles correspond to marginal South American localities reported by Wilson (2008) with the addition of Esbérard *et al*. (2007), Passos *et al*. (2010), Castro & Michalski (2015), Garbino (2016), and Tavares *et al*. (2017). Empty circles correspond to new records reported here: 1 = Aripuanã, Mato Grosso state; 2 = UHE Colíder, Mato Grosso state; 3 = *Fazenda Fartura*, Santana do Araguaia, Pará state; B) localities of *Thyroptera devivoi*. Solid squares correspond to localities previously reported by Gregorin *et al*. (2006), Santos, C. *et al.* (2013), Rodríguez-Posada *et al*. (2017), and Rosa *et al*. (2020). Empty squares correspond to the new records reported here: 4 = Juruti, Pará state; 5 = Rio Quilombo, Mato Grosso state; 6 = Rio Manso, Mato Grosso state. The green and yellow areas correspond to the ecoregions of Olson *et al.* (2001). Map: Thiago Semedo.

## DISCUSSION

With the verification that the specimens from the Cerrado of Mato Grosso, previously identified as *T. discifera* by Bezerra *et al*. (2005), are in fact *T devivoi*, we suggest that the distribution of *T. discifera* is restricted to the Amazonia and Atlantic Forest (Gregorin *et al*., 2006; Bocchiglieri *et al*., 2016). It is important to note, however, that the '*T. discifera*' records of Bezerra *et al*. (2005) were published before the taxonomic reassessment of *Thyroptera* that resulted in the description of the *T*. *devivoi* by Gregorin *et al*. (2006).

The records of *T. devivoi* are the first for Pará and Mato Grosso states and for southern Amazonia, filling a distribution gap in this biome, as this species was previously reported in the Rupununi savannas, Guyana (Wilson, 2008), approximately 650 km to the NW from our record in locality 4, Pará state, and our records in localities 5 and 6, Mato Grosso state, are ca. 1,100 to 2,000 km NE from previous records in Maranhão, Piauí, and Tocantins states (Wilson, 2008) (see Figure 7B). The new records extend the distribution of the species southwestward and establish a new southern limit for the taxon (Figure 7B). The records from Mato Grosso are from a 'cerrado' *sensu stricto* area (i.e. savanna woodland with 10-60% tree cover), with the occurrence of typical Amazonian taxa, as attested by the presence of the slender mouse opossum *Marmosops noctivagus* (Tschudi, 1845) (Lacher Jr. & Alho, 2001) and the Southern Amazon red squirrel *Hadrosciurus spadiceus* (Olfers, 1818) (Vivo & Carmignotto, 2015). Our records fit a recent pattern of published range expansions of Amazonian bats for central and southern Amazonia due to increased sampling efforts in these regions and also from review of zoological specimens. Some of these range expansions include records of the molossid *Cynomops planirostris* (Peters, 1866) (Santos, T. *et al*., 2015); the emballonurids *Centronycteris maximiliani* (Fischer, 1829) (Rocha *et al*., 2015), *Peropteryx kappleri* Peters, 1867, and *Peropteryx leucoptera* Peters, 1867 (Dalponte *et al*., 2016), the vespertilionid *Histiotus diaphanopterus* Feijó, Rocha & Althoff, 2015 (Semedo & Feijó, 2016); and the phyllostomids *Glyphonycteris sylvestris* (Thomas, 1896), *Lonchorhina inusitata* Handley & Ochoa, 1997, *Phyllostomus latifolius* (Thomas, 1901), *Tonatia saurophila* Koopman & Williams, 1951, and *Artibeus concolor* Peters, 1865 (Miranda *et al*., 2015; Dalponte *et al*., 2016).

## CONCLUSION

Our paper clarifies the geographical distributions of *T. tricolor* and *T*. *discifera*, the latter which, according to us is restricted to the Amazonia and Atlantic rainforest. We also report a major range extension of *T. devivoi*, highlighting that the distribution of this taxon is still poorly known. The records presented here reinforce the notion, expressed in recent papers, that the large Brazilian states of Mato Grosso and Pará are still under sampled in relation their mammalian diversity, especially regarding small species (Bernard *et al*., 2011; Brandão *et al*., 2019). Thyropterids are rare in scientific collections, but we suggest that new records of disk-winged bats will be obtained, and distributional gaps will be filled, as more attention is given to active search in diurnal roosts.

## ACKNOWLEDGMENTS

We are grateful to the following curators and collection managers for allowing access to specimens under their care: Luis Fábio Silveira and Juliana Gualda (MZUSP), José de Souza e Silva Junior and Alexandra Bezerra (MPEG), Jader Marinho-Filho and Pedro De Podestà (UnB), and Mendelson Guerreiro (CZAFMA). We thank *SETE Soluções e Tecnologia Ambiental* and Nexa companies for the financial support for the fieldwork and for permission for sampling. GSTG is grateful to Luis Fábio Silveira for the opportunity to work in the *Fazenda Fartura*. We are grateful to Renato Gregorin, Miguel Rodriguez Posada, and Ciro Libio for helping with the identification of *Thyroptera* species. We are grateful to two anonym reviewers for their valuable suggestions and comments in a previous version of this manuscript. This work was accomplished under the license (Processes 1785/89-IBAMA and 4156/95-46 AC-SUPES/DF/IBAMA to NC Ardente). TSBF is supported by the *Conselho Nacional de Desenvolvimento Científico e Tecnológico* (CNPq, process number 300659/2019-2) through the *Programa de Capacitação Institucional* (PCI) of *Museu Paraense Emílio Goeldi* (MPEG) and *Instituto Nacional de Pesquisa do Pantanal* (INPP). We thank the *Laboratório de Scarabaeoidologia* at *Universidade Federal de Mato Grosso* (Cuiabá, Mato Grosso, Brazil) which provided access to the equipment that we used for the Figure 3, obtained through subproject EECBio of UFMT/FINEP (agreement FINEP # 01.12.0359.00) and Arturo González who helped us to obtain the photos.

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# Nota sobre morcegos (Mammalia, Chiroptera) e moscas ectoparasitas (Insecta, Diptera) do Parque Nacional da Serra do Pardo, estado do Pará, Brasil

# Note on bats (Mammalia, Chiroptera) and ectoparasite flies (Insecta, Diptera) from Serra do Pardo National Park, Pará state, Brazil

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**Resumo:** Os morcegos apresentam grande diversidade de hábitos alimentares, o que faz com que possam ser utilizados como indicadores de qualidade ambiental, além de prestarem serviços ecossistêmicos, como dispersão de sementes, estruturação de comunidade de plantas e controle de insetos. Além disso, o estudo da interação de morcegos com ectoparasitas pode possibilitar melhor compreensão dos processos ecológicos e evolutivos associados. Dessa forma, o objetivo desse estudo é contribuir para o conhecimento de algumas espécies de morcegos e suas moscas ectoparasitas no Parque Nacional da Serra do Pardo, interflúvio Xingu-Tapajós, estado do Pará, Brasil. A captura dos morcegos foi realizada em quatro pontos amostrais, através de redes de neblina e busca ativa. Em cada indivíduo capturado foi realizada inspeção da pelagem e das asas para retirada das moscas ectoparasitas. Foram amostrados 13 indivíduos de morcegos, representados por duas famílias (Phyllostomidae e Molossidae), seis gêneros e seis táxons, sendo *C. perspicillata* a mais amostrada. Quanto à guilda trófica, observamos espécies insetívoras e frugívoras, sendo a última a mais abundante. Para moscas ectoparasitas, observamos apenas a família Streblidae. Todos os ectoparasitas estavam relacionados aos indivíduos de *C. perspicillata.*

**Palavras-chave:** Área de proteção. Conservação. Espécies indicadoras de qualidade. Lista de espécies. Terra do Meio.

**Abstract:** Bats have a great diversity of eating habits, means that they can be used as indicators of environmental quality, in addition to providing ecosystem services such as: seed dispersal, structuring of plant communities and insect control. In addition, the interaction of bats with ectoparasites may allow a better understanding of the associated ecological and evolutionary processes. The main of this work is contribute for the knowledge of bats and their ectoparasite fly species from Serra do Pardo National Park, Xingu-Tapajos interfluve, Pará state, Brazil. The capture of the bats was performed in four sampling points, through fog networks and active search. Each bat individual captured, the coat and wings were inspected to remove ectoparasitic flies. We sampled 13 bat individuals, represented by two families (Phyllostomidae and Molossidae), six genera and six species, being *C. perspicillata* the most abundant. As for the trophic guild, we observed insectivorous and frugivorous species, being the latter the most abundant species. For ectoparasite flies, we observed only the family Streblidae. All ectoparasites were related to *C. perspicillata* individuals.

**Keywords:** Protected areas. Conservation. Quality indicator species. Species list. Terra do Meio.

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SILVA, J. B., L. C. N. DA SILVA, K. DIAS-SILVA, A. P. OLIVEIRA JÚNIOR, B. T. S. SILVA, G. K. O. VELOSO, K. M. MOY, P. C. P. SANTANA, R. F. REZENDE, T. S. MARTINS & T. B. VIEIRA, 2020. Nota sobre morcegos (Mammalia, Chiroptera) e moscas ectoparasitas (Insecta, Diptera) do Parque Nacional da Serra do Pardo, estado do Pará, Brasil. **Boletim do Museu Paraense Emílio Goeldi. Ciências Naturais** 15(3): 829-841. DOI: http://doi.org/10.46357/bcnaturais.v15i3.263.

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Recebido em 22/01/2020
Aprovado em 22/11/2020
Responsabilidade editorial: Alexandra Maria Ramos Bezerra

## INTRODUÇÃO

A região da Terra do Meio é uma das áreas contínuas conservadas de alta importância nacional e mundial (ICMBio, 2012; ARPA, 2015). O termo 'Terra do Meio' foi criado na década de 1970, durante a abertura das rodovias Transamazônica (BR-230) e Cuiabá-Santarém (BR-163), que, associadas com a abertura da estrada da Canopus (Transiriri), ligando o rio Iriri a São Félix do Xingu, na década seguinte, propagaram uma série de atividades conflitantes (Escada *et al.*, 2005; ARPA, 2015). A região está situada às margens do rio Xingu, localizada entre os municípios de Altamira e São Félix do Xingu, abrangendo cerca de 8,5 milhões de hectares, ocupando cerca de 50% do território paraense (ARPA, 2015). A Terra do Meio é composta por 11 áreas de proteção (AP), formando um mosaico de unidades de conservação (UC) de proteção integral e uso sustentável e territórios indígenas (TI). Entre essas UC, encontra-se o Parque Nacional da Serra do Pardo (PNSP), estrategicamente delimitado para garantir a conservação dos recursos naturais e minerais (Velásquez *et al.*, 2006; ARPA, 2015). Criado sob o Decreto s/n de 17 de fevereiro de 2005 (Brasil, 2005), o PNSP é uma UC federal de proteção integral amazônica, com 446.552 ha (Barros, 2010; ARPA, 2015). Apesar do histórico de uso por colonos, comunidades tradicionais e fazendeiros, o parque ainda mantém cerca de 95% da sua vegetação nativa (Barros, 2010; Fávaro, 2011). Essa área de extrema importância para conservação vem sendo ameaçada por atividades de mineração, obras de infraestrutura planejadas e, principalmente, pela pecuária (Velásquez *et al.*, 2006; Aleixo, 2009; Develey, 2009). Em relação à fauna e à flora do PNSP, alguns estudos foram realizados para o desenvolvimento do Plano de Manejo (ARPA, 2015), porém informações sobre a quiropterofauna não foram contempladas no Plano de Manejo ou em estudos pretéritos.

A ordem Chiroptera é a segunda mais especiosa entre os mamíferos (Paglia *et al.*, 2012; Nogueira *et al.*, 2014). Atualmente, são reconhecidas aproximadamente 1.400 espécies de morcegos no mundo (Simmons & Cirranello, 2020), das quais 181 ocorrem no Brasil (Garbino *et al.*, 2020). Os morcegos apresentam grande diversidade de hábitos alimentares, com animais insetívoros, nectarívoros, piscívoros, frugívoros, onívoros, carnívoros ou hematófagos (Kunz *et al.*, 2011). Os efeitos na estruturação de comunidades de plantas (Fleming & Heithaus, 1981; Kunz *et al.*, 2011) e a atuação no controle de populações de insetos (Williams-Guillén *et al.*, 2008; Kalka *et al.*, 2008), inclusive de pragas agrícolas (Cleveland *et al.*, 2006; Ghanem & Voigt, 2012), reforçam o reconhecimento desse grupo como espécies-chave em florestas tropicais. Os morcegos também têm importante relação com os ectoparasitas, em especial os dípteros das famílias Streblidae e Nycteribiidae (Rui & Graciolli, 2005; Graciolli & Bianconi, 2007; Santos, F. *et al.*, 2012). Essas duas famílias estão distribuídas por toda a região Neotropical (Frank *et al.*, 2014), compondo cerca de 96 espécies de Streblidae (Graciolli, 2020) e 26 espécies de Nycteribiidae (Graciolli *et al.*, 2007) para o continente americano. Geralmente, o parasitismo é em espécie específica e a infestação pode ser relacionada às características intrínsecas do hospedeiro, como idade, sexo, estado reprodutivo e de saúde (Rui & Graciolli, 2005; Santos, F. *et al.*, 2012). Porém, os estudos envolvendo parasitismo são principalmente voltados à taxonomia, às taxas de infestação, à prevalência e às variações morfológicas, enquanto que a relação parasito-hospedeiro de dípteros em morcegos vem sendo explorada apenas em estudos mais recentes (Prevedello *et al.*, 2005; Rui & Graciolli, 2005; Silva & Ortêncio Filho, 2011; Santos, F. *et al.*, 2012).

Lacunas de conhecimento dificultam estratégias eficientes de conservação em unidades de conservação (Hopkins, 2007; Collen *et al.*, 2008; Sousa-Baena *et al.*, 2014; Oliveira *et al.*, 2016) e esse déficit ainda é mais comum nas regiões tropicais (Kier *et al.*, 2005; Collen *et al.*, 2008; Xu *et al.*, 2017), inclusive a Amazônia, que abriga unidades em 49% de sua extensão (Oliveira *et al.*, 2017). O planejamento de estratégias para conservação é baseado em dados de ocorrência de espécies e as coletas de dados de campo são essenciais (Sousa-Baena *et al.*, 2014; Oliveira *et al.*, 2016), assim como englobar o maior número possível de táxons em estudos de biodiversidade (Oliveira *et al.*, 2017). Porém, mesmo grupos de relevantes serviços ecossistêmicos são sistematicamente negligenciados (Potts *et al.*, 2016; Oliveira *et al.*, 2017). Nesse contexto, o objetivo do presente estudo foi contribuir para o conhecimento de algumas espécies de morcegos e suas moscas ectoparasitas no Parque Nacional da Serra do Pardo, interflúvio Xingu-Tapajós, estado do Pará.

## MATERIAL & MÉTODOS

### ÁREA DE ESTUDO

O Parque Nacional da Serra do Pardo (PNSP) é uma das UC localizadas na região denominada Terra do Meio, situada nos municípios de Altamira e São Félix do Xingu, à margem do médio rio Xingu, na porção centro-oeste do estado do Pará (Figura 1, Tabela 1). Criado em 2005, com 446.552 ha, o PNSP está inserido em uma posição estratégica, a região marginal da Amazônia ainda preservada, de frente à região denominada 'Arco do desmatamento' (ARPA, 2015). Perturbações antrópicas no entorno e, principalmente, nos limites da Área de Proteção Ambiental (APA) Triunfo do Xingu (Doblas, 2015) vêm preocupando a sua manutenção (ARPA, 2015).

A fitofisionomia é representada pela Floresta Tropical Ombrófila Aberta, sub-montanhosa e densa e por Cerrado (Fávaro, 2011). O clima é predominantemente de monção Am (classificação Köppen), com temperatura média em seu regime térmico superior a 22 ºC ao longo de todo o ano, podendo chegar a 40 ºC nos meses de setembro e outubro (ISA, 2003; ARPA, 2015). A elevada pluviosidade (77% anual em relação à precipitação total) é marcada entre os meses de dezembro a maio, com redução no curto período de junho a novembro no Pará (Moraes *et al.*, 2006).

### AMOSTRAGEM DE MORCEGOS E ECTOPARASITAS

As coletas foram conduzidas no mês de agosto de 2018, durante três noites, uma em cada ponto (P1, P2 e P3; Tabela 1), com utilização de oito redes de neblina (12 m x 2,5 m). As redes foram abertas ao pôr do sol e mantiveram-se assim durante seis horas, sendo verificadas em intervalos de uma hora (Fleming, 1988). Adicionalmente, foi realizado um dia de busca ativa, com captura manual utilizando puçás (P4; Tabela 1, Figura 2). A busca ativa foi realizada em uma ilha, denominada de Buraco da Arara, localizada no limítrofe da UC, na margem esquerda do rio Xingu. Chegamos ao P4 por meio de informação de moradores locais, que relataram a ocorrência de muitos morcegos nas fendas das rochas. O esforço amostral foi calculado segundo Straube & Bianconi (2002).

Tabela 1. Pontos amostrados no Parque Nacional da Serra do Pardo, estado do Pará, com a data de coleta, coordenadas geográficas e metodologia empregada.

| Ponto | Data da amostragem | Coordenadas (Grau decimal) | | Método de amostragem | Esforço total |
|---|---|---|---|---|---|
| | | Latitude | Longitude | | |
| P1 | 09/08/2018 | -5.77553 | -52.61872 | Rede de neblina | 1.440 m$^2$.h |
| P2 | 10/08/2018 | -5.77166 | -52.62146 | Rede de neblina | 1.440 m$^2$.h |
| P3 | 13/08/2018 | -5.77095 | -52.62637 | Rede de neblina | 1.440 m$^2$.h |
| P4 | 12/08/2018 | -5.70389 | -52.65472 | Coleta manual | 2 h |

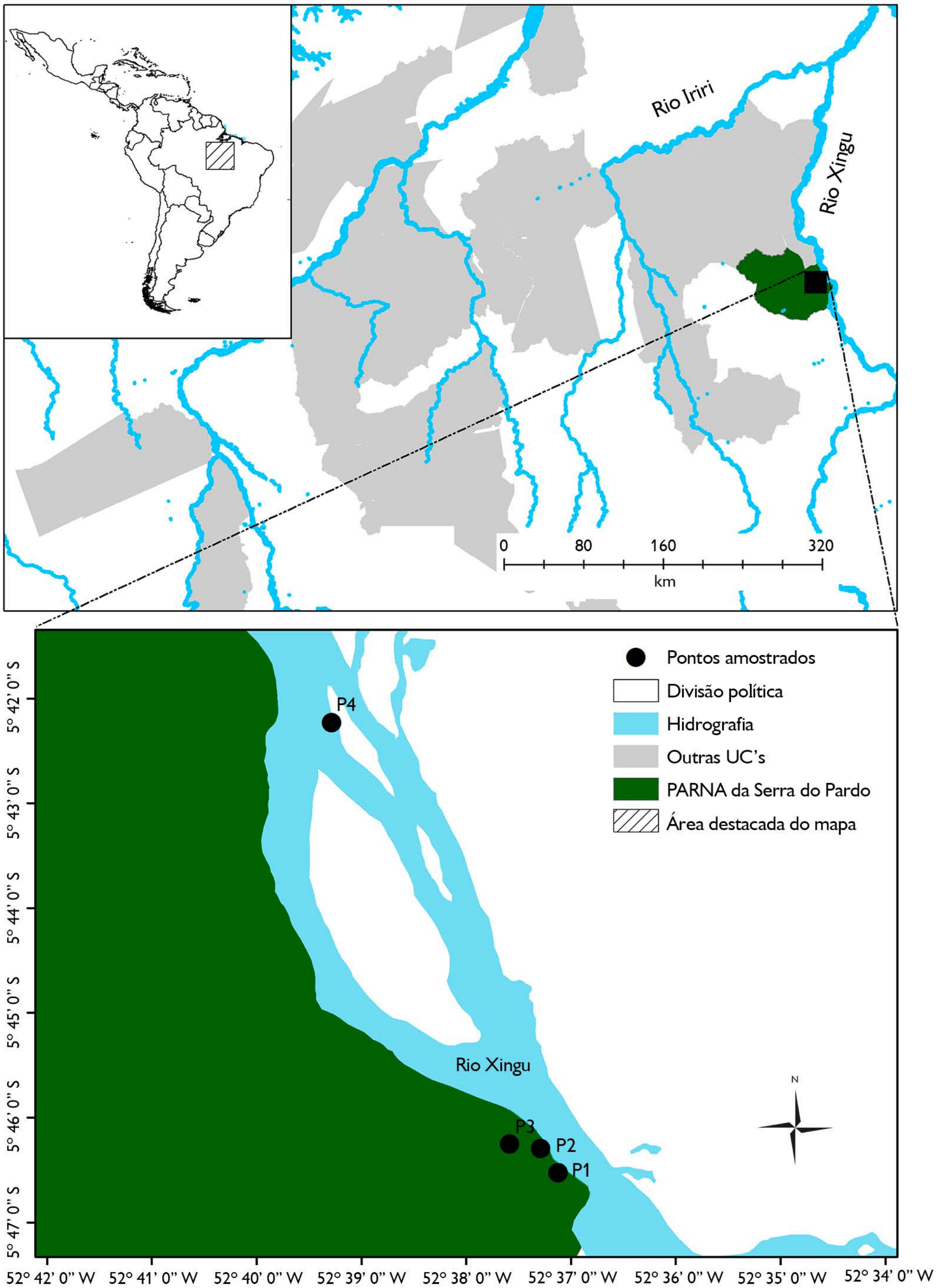

Figura 1. Localização do Parque Nacional Serra do Pardo (PNSP), estado do Pará, Brasil. Pontos amostrados: P1, P2, P3 e P4. Mapa: Thiago Vieira (2019).

Figura 2. Locais (pontos) amostrados no Parque Nacional Serra do Pardo (PNSP): A) ponto P1; B) ponto P2; C) ponto P3; e ilha do Buraco da Arara (D-G) durante a campanha de agosto de 2018 - ponto P4, com destaque para os aglomerados rochosos em que foram realizadas buscas ativas e captura de morcegos. A ilha do Buraco está localizada no rio Xingu, no limite oriental do Parque Nacional Serra do Pardo, estado do Pará, Brasil. Fotos: acervo ChiroXingu.

Os morcegos capturados foram acondicionados em sacos de algodão. Após a triagem dos morcegos, os sacos eram revisados, para que as moscas e sementes presentes fossem retiradas, evitando a contaminação das amostras seguintes. Ao menos um casal de cada espécie foi coletado e depositado na Coleção de Morcegos do ChiroXingu (Tabela 2), localizada no Laboratório de Zoologia da Universidade Federal do Pará, *campus* Altamira, servindo como espécimes-testemunhos, identificadas com a utilização das chaves dicotômicas (*e.g.*, Vizotto & Taddei, 1973; Gardner, 2008). Cada morcego capturado e não coletado recebeu uma coleira de identificação, numerada com anéis coloridos, conforme Esbérard & Daemon (1999) e Esbérard *et al.* (2011). Foi dada preferência para a coleta de um casal de cada espécie, evitando fêmeas grávidas, lactantes e indivíduos jovens. A classificação das guildas alimentares seguiu Kalko *et al.* (1996), que considera o habitat utilizado pela espécie, o modo de forrageamento e a dieta.

Após a retirada dos morcegos da rede e imediatamente antes da morfometria, foi realizada a busca ativa por ectoparasitos em todo o corpo do indivíduo (pelagem, asas e orelhas). Aqueles encontrados foram extraídos com pinças de ponta fina e pincéis umedecidos em álcool etílico 70%. Os ectoparasitos foram fixados em álcool etílico 70% e acondicionados em recipientes individuais, etiquetados de acordo com cada hospedeiro. Em laboratório, os espécimes de moscas foram identificados até o menor nível taxonômico, utilizando bibliografia específica (Guerrero, 1993, 1994, 1995, 1996; Wenzel, 1976) e depositados na Coleção de Dípteras do ChiroXingu (Tabela 3), localizada no Laboratório de Zoologia da Universidade Federal do Pará, *campus* Altamira. Este estudo foi autorizado pelo Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio) através da licença SEI/ICMBIO – 3661775.

## RESULTADOS & DISCUSSÃO

Foram amostrados 13 indivíduos de morcegos, 11 com rede de neblina e dois por captura manual (Tabela 2, Figura 3). Com exceção do ponto P4 (onde capturamos os indivíduos durante 2 horas com auxílio de luvas de raspa de couro), os

Tabela 2. Espécies de morcegos capturados no Parque Nacional da Serra do Pardo (PNSP), estado do Pará, Brasil, em 2018. Os morcegos (táxon) estão organizados em família, subfamília e espécie. Além disso, são apresentadas as guildas tróficas e as abundâncias totais e por pontos de coletas (P1, P2, P3 e P4), bem como os números de tombo dos espécimes-testemunhos (TV = Coleção de Morcegos do ChiroXingu, UFPA, *campus* Altamira).

| Táxon | Guilda trófica | P1 | P2 | P3 | P4 | Total | Espécimes-testemunhos |
|---|---|---|---|---|---|---|---|
| MOLOSSIDAE | Insetívoro aéreo | | | | | | |
| *Nyctinomops laticaudatus* (É. Geoffroy, 1805) | | - | - | - | 2 | 2 | TV45, TV46 |
| PHYLLOSTOMIDAE | | | | | | | |
| Carollinae | | | | | | | |
| *Carollia perspicillata* (Linnaeus, 1758) | Frugívoro | 2 | 4 | 1 | - | 7 | TV144 |
| *Rhinophylla fischerae* Carter, 1966 | Frugívoro | - | 1 | - | - | 1 | TV143 |
| Phyllostominae | | | | | | | |
| *Micronycteris* sp. | Insetívoro catador | - | 1 | - | - | 1 | - |
| Stenodermatinae | | | | | | | |
| *Artibeus fimbriatus* Gray, 1838 | Frugívoro | 1 | - | - | - | 1 | TV141 |
| *Platyrrhinus lineatus* (É. Geoffroy, 1810) | Frugívoro | - | 1 | - | - | 1 | TV142 |
| Abundância | | 3 | 7 | 1 | 2 | 13 | |
| Riqueza | | 2 | 4 | 1 | 1 | 6 | |

Tabela 3. Espécies de moscas ectoparasitas amostradas nos morcegos capturados no Parque Nacional da Serra do Pardo, estado do Pará, Brasil, em 2018. São apresentadas a riqueza e as abundâncias totais nos quatro pontos de coletas (P1, P2, P3 e P4) e os números de tombo dos espécimes-testemunhos (CX---D = Coleção Dípteras do ChiroXingu, UFPA, *campus* Altamira).

| Táxon | P1 | P2 | P3 | P4 | Total | Espécimes-testemunhos |
|---|---|---|---|---|---|---|
| STREBLIDAE | | | | | | |
| *Speiseria ambigua* Kessel, 1925 | - | 1 | - | - | 1 | CX049D |
| *Strebla mirabilis* (Waterhouse, 1879) | 1 | - | 1 | - | 2 | CX058D |
| *Trichobius dugesioides dugesioides* Wenzel, 1966 | 2 | 4 | - | - | 6 | CX036D, CX044D, CX057D, CX090D |
| Abundância | 3 | 5 | 1 | 0 | 9 | - |
| Riqueza | 2 | 2 | 1 | 0 | 3 | - |

pontos onde foram utilizadas redes de neblina (P1, P2 e P3) tiveram o mesmo esforço amostral: 1.440 m$^2$.h por ponto e 4.320 m$^2$.h total (Tabela 1). Os resultados não apresentaram espécies inesperadas, e todas as associações entre morcegos e moscas são comuns, conforme discutido nos parágrafos a seguir. Os morcegos capturados representam duas famílias (Phyllostomidae e Molossidae), seis gêneros e seis táxons, com 12 indivíduos identificados em nível de espécie e um em nível de gênero (Tabela 2, Figura 3). O local com maior diversidade foi o ponto 2, com sete indivíduos, distribuídos em quatro táxons (Tabela 2, Figura 3). Somente a espécie *Nyctinomops laticaudatus* (É. Geoffroy, 1805) teve fêmea capturada e apenas um indivíduo (TV146).

A espécie mais conspícua foi *Carollia perspicillata* (Linnaeus, 1758), com sete indivíduos amostrados, presente em três dos quatro pontos amostrados (Tabela 2). Não foi possível identificar o espécime de *Micronycteris* Gray, 1866 em nível de espécie porque o indivíduo fugiu. Durante os trabalhos de campo, um indivíduo adulto e reprodutivamente inativo de *C. perspicillata* foi coletado com injúrias, possivelmente provenientes de um evento de predação ou briga entre animais da colônia (Figura 3). Quanto à guilda trófica, observamos espécies insetívoras aéreas forrageadoras de espaço aberto e frugívoras, sendo as últimas as mais abundantes (Tabela 2). Para moscas ectoparasitas, registramos a ocorrência apenas da família Streblidae, apresentando três gêneros e três espécies entre os oito indivíduos de moscas coletados (Tabela 3). Todos os ectoparasitas estavam relacionados aos indivíduos de *C. perspicillata*.

O baixo esforço amostral e o reduzido número de capturas impossibilitam testes elaborados para o presente estudo. Contudo, podemos observar uma sugestão do padrão de diversidade observado entre áreas abertas e áreas fechadas. Essa sugestão de padrão é baseada nas observações dos dados brutos. As áreas abertas (P1 e P2) apresentaram maior riqueza de espécies de morcegos, com composição diferente da área fechada (P3). A maior riqueza nas áreas abertas pode ser explicada pelo fato de estas serem ecótonos entre as áreas abertas e as mais densamente florestadas. Ecótonos tendem a apresentar maior riqueza e diversidade de espécies (Whittaker *et al.*, 2001; McCain & Grytnes, 2010). Além disso, Phyllostomidae é a família de morcegos com maior riqueza na Amazônia (Bernard, 2001; Sampaio *et al.*, 2003; Bernard *et al.*, 2011; Miranda *et al.*, 2015), e suas espécies frugívoras geralmente estão relacionadas à estrutura de vegetação de florestas primárias, sub-bosque e áreas alteradas (Bernard & Fenton, 2003) e ao comportamento de forrageio (Bernard & Fenton, 2003; Loayza & Loiselle, 2008; Bobrowiec & Gribel, 2009), o que pode facilitar sua captura em redes de neblina (Calouro *et al.*, 2010). Além disso, o método de amostragem utilizado neste estudo é considerado mais eficiente para captura de Phyllostomidae, o que pode ter contribuído para a menor diversidade de guildas (Kunz, 1988; Kalko *et al.*, 1996; Costa *et al.*, 2012).

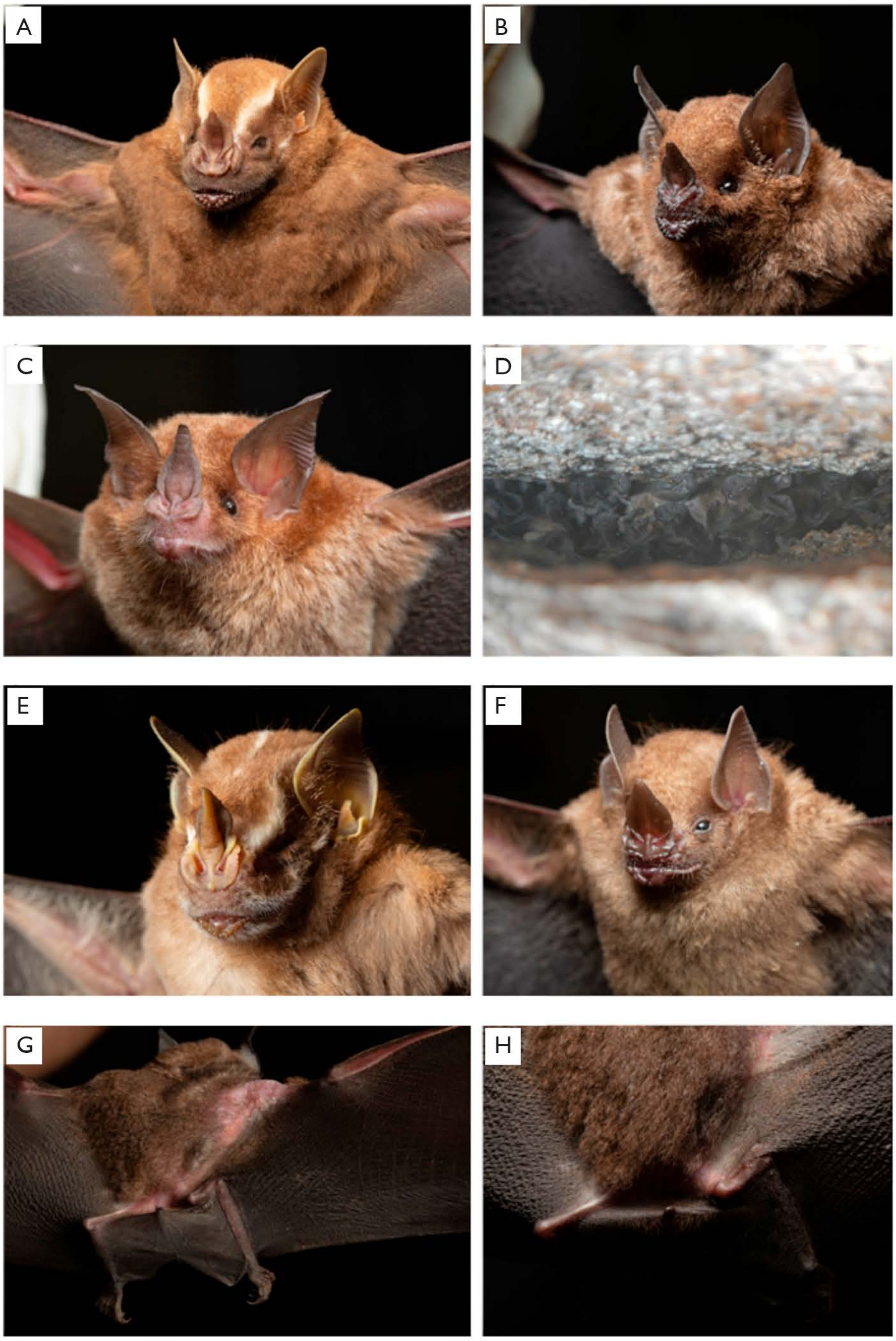

Figura 3. Morcegos capturados no Parque Nacional Serra do Pardo (PNSP): A) *Artibeus fimbriatus* Gray, 1838; B) *Carollia perspicillata* (Linnaeus, 1758); C) *Micronycteris* sp.; D) colônia de *Nyctinomops laticaudatus* (É. Geoffroy, 1805) observada nas fendas de rochas da ilha Buraco das Araras (P4); E) *Platyrrhinus lineatus* (É. Geoffroy, 1810); F) *Rhinophylla fischerae* Carter, 1966; G) detalhe do dorso de um *C. perspicillata* com marcas de predação; H) detalhe da perna direita de um exemplar de *C. perspicillata* com marcas de predação. Fotos: acervo ChiroXingu.

Os dados coletados para esse estudo não são suficientes para indicar a real riqueza de espécies de morcegos que ocorrem no PNSP. No entanto, entre as espécies amostradas, *C. perspicillata* foi a mais abundante. Entre os frugívoros, essa espécie *é* considerada generalista, com ampla distribuição, sendo abundante na Amazônia (Bernard, 2001; Bernard & Fenton, 2007; Calouro *et al.*, 2010; Miranda *et al.*, 2015; Verde *et al.*, 2018). As associações observadas aqui entre *C. perspicillata* com *Speiseria ambigua* Kessel, 1925, *Strebla mirabilis* (Waterhouse, 1879) e *Trichobius dugesioides* Wenzel, 1966 já foram previamente descritas, tanto para outros biomas como para a Amazônia (*e.g.*, Graciolli & Aguiar, 2002; Dias *et al.*, 2009; Santos, C. *et al.*, 2009; Urbieta *et al.*, 2018; Torres *et al.*, 2019). Ambientes de baixa qualidade e a disponibilidade de recursos podem reduzir a fidelidade de *C. perspicillata* ao abrigo, provocando maior contato com outras espécies de morcegos, o que poderia influenciar no compartilhamento de moscas ectoparasitas (Bush & Lotz, 2000; Santos, F. *et al.*, 2012; Barbier & Graciolli, 2016; Urbieta *et al.*, 2018). Considerando a escassez de estudos sobre ectoparasitas em morcegos da Amazônia (*e.g.*, Santos, F. *et al.*, 2012; Lourenço *et al.*, 2016; Urbieta *et al.*, 2018), pesquisas de longo prazo, com mais de um método de amostragem e ampliação do esforço e de pontos amostrais, são fundamentais para aumentar o conhecimento da diversidade de morcegos e a inter-relação com seus ectoparasitos. Além disso, estudos de longo prazo permitiriam o acompanhamento da qualidade ambiental na área protegida.

## AGRADECIMENTOS

O presente trabalho foi realizado com apoio da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - código de financiamento 001. Dois revisores anônimos contribuíram com importantes sugestões e comentários que melhoraram significativamente a qualidade do presente estudo. Agradecemos também ao Programa de Pós-Graduação em Biodiversidade e Conservação (PPGBC), que contribuiu financeiramente na coleta dos dados, ao Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio) e ao Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA), pelo o apoio na pesquisa.

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Bol. Mus. Para. Emílio Goeldi. Cienc. Nat., Belém, v. 15, n. 3, p. 843-848, set.-dez. 2020

# Interspecific association between brown-nosed coatis and capybaras in an urban area of Brazil

## Associação interespecífica entre quatis e capivaras em uma área urbana do Brasil

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**Abstract:** This study aimed to report an interspecific association between brown-nosed coatis (*Nasua nasua*) and capybaras (*Hydrochoerus hydrochaeris*) in an urban area of Brazil. We recorded *N. nasua* feeding on ectoparasites (ticks) attached to *H. hydrochaeris*, which in turns, did not show any reaction of discomfort with the situation. Thus, we report an unprecedented case of protocooperation between apparently unrelated species. Moreover, the interspecies interaction reveals other interesting scenarios as the inclusion of ticks in the diet of *N. Nasua* and the possibility of parasite transmission and adaptation to a new host species, a phenomenon known as 'host switching'. We associate these new records as adaptations of wildlife to urbanization, and their effects should be further investigated from both wildlife conservation and 'One Health' approach.

**Keywords:** Carnivora. Protocooperation. Rodentia. Urban ecology.

**Resumo:** O objetivo deste estudo foi relatar uma associação interespecífica entre quatis (*Nasua nasua*) e capivaras (*Hydrochoerus hydrochaeris*) em uma área urbana do Brasil. Registramos *N. nasua* se alimentando de ectoparasitas (carrapatos) aderidos em *H. hydrochaeris*, que, por sua vez, não mostrou nenhuma reação de desconforto com a situação. Logo, relatamos um caso de protocooperação entre espécies aparentemente não relacionadas. Além disso, a interação interespecífica revela outros cenários interessantes, como a inclusão de carrapatos na dieta de *N. nasua* e a possibilidade de transmissão e adaptação de parasitas a uma nova espécie hospedeira, fenômeno conhecido como 'troca de hospedeiro'. Associamos esses novos registros como adaptações da vida selvagem à urbanização, e seus efeitos devem ser investigados a partir da perspectiva da conservação da vida selvagem e da abordagem de Saúde Única.

**Palavras-chave:** Carnívora. Protocooperação. Rodentia. Ecologia urbana.

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RUCCO, A. C., H. M. HERRERA, F. M. SANTOS & G. E. O. PORFIRIO, 2020. Interspecific association between brown-nosed coatis and capybaras in an urban area of Brazil. **Boletim do Museu Paraense Emílio Goeldi. Ciências Naturais** 15(3): 843-848. DOI: http://doi.org/10.46357/bcnaturais.v15i3.284.

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Recebido em 20/02/2020
Aprovado em 10/11/2020
Responsabilidade editorial: Alexandra Maria Ramos Bezerra

It is well documented that some wild animals inhabit, and therefore benefit from, remnant forest fragments found in urban and peri-urban areas worldwide. In South America, a widely distributed mesocarnivore, the brown-nosed coati *Nasua nasua* (Linnaeus, 1766), and the largest extant rodent species, the capybara *Hydrochoerus hydrochaeris* (Linnaeus, 1766), are both known to inhabit several urban areas of Brazil (Costa *et al*., 2009; Ferreira, G. *et al*., 2013; Tonin *et al*., 2016). Notably, the city of Campo Grande, Mato Grosso do Sul state, in the western Brazilian Cerrado, has a diverse array of wild fauna utilizing the urban environment (Ferreira, C. *et al*., 2010). From the human perspective, interacting with wildlife is positive for the wellbeing of people, and has the added benefit of attracting tourism to the area, particularly if wildlife has become used to human presence (Mamede & Benites, 2018; Calderan *et al*., 2019). However, wild animals in urban areas can provide other scenarios as they can pose risk of traffic accidents, invade residences, and even maintain zoonotic parasites (Soulsbury & White, 2016). *Hydrochoerus hydrochaeris*, for example, play a primary role in the transmission cycle of *Rickettsia rickettsii* (Ricketts, 1909), which is the etiological agent of Brazilian spotted fever, considered the most deadly rickettsiosis worldwide (Labruna, 2013). Furthermore, from an ecological viewpoint, urbanization can change population parameters and the behavioral dynamics of animal species in these areas, revealing previously undescribed, or seemingly unlikely, relationships among species (Soulsbury & White, 2016).

Here we report on an interspecific association between *N. nasua* and *H. hydrochaeris* at *Parque das Nações Indígenas* (PNI), regarded as one of the most important urban parks of Campo Grande city, Mato Grosso do Sul state, Brazil (Figure 1). The PNI is an urban secondary forest fragment with an area of 119 hectares; the forest formations and wildlife species assemblages of the park are typical of the Cerrado biome. The connectivity of PNI with other forest fragments allows several species of wild animals to use the park, for example *Didelphis albiventris* Lund, 1840, *Dasyprocta azarae* Lichtenstein, 1823, *Ara ararauna* (Linnaeus, 1758), *Dasypus novemcinctus* Linnaeus, 1758, and *Ramphastos toco* Müller, 1776, besides *N. nasua* and *H. hydrochaeris* (G. Porfirio, personal observation, 2017).

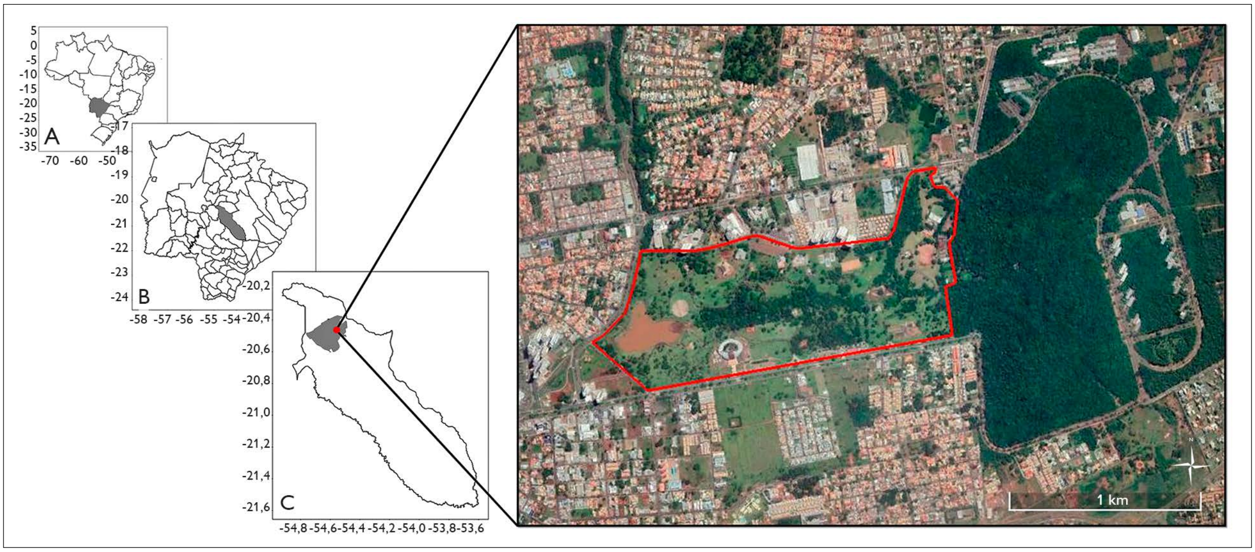

Figure 1. A) Mato Grosso do Sul state in Brazil (pale gray); B) location of the municipality of Campo Grande in Mato Grosso do Sul state (pale gray); and C) location of *Parque das Nações Indígenas* in the city of Campo Grande (pale gray), and its land use in the enlarged image. Map: Filipe Martins Santos (2020).

Interspecific associations between *N. nasua* and *H. hydrochaeris* in the PNI were recorded on two occasions, in January (rainy season) and August (dry season) 2019, respectively. Individuals of *N. nasua* were observed feeding on ectoparasites (ticks) attached to *H. hydrochaeris* (Figures 2A and 2B). *Nasua nasua* group composition consisted of adult females and their cubs, and juveniles. Animals were classified according to their age and sex, based on Barros & Frenedozo (2010): (i) adult males: animals with large body and head size, in addition to the presence of the scrotal sac; (ii) adult females: smaller than adult males, rarely seen alone; (iii) youngs: smaller than adult females or of similar proportions; (iv) cubs: smaller than the youngs, with similar head/body proportions.

Cubs were the first individuals of the group to be observed foraging on ticks attached to *H. hydrochaeris*, just prior to sunset (approximately 17:00 pm in both occasions). Initially, adult females foraged on fruit in the surrounding area; adult females and the rest of the group were later observed alternating between foraging on ticks attached to *H. hydrochaeris*. Interactions were interrupted when casual human observers approached the site resulting in the dispersal of both wildlife species involved in the interaction. During both observation periods, *H. hydrochaeris* did not show any avoidance behavior toward *N. nasua*, instead individuals remained immobile, in the ventral position, while *N. nasua* foraged for ticks.

Although there are other reported cases of mammalian interspecies associations (McClearn, 1992; Haugaasen & Peres, 2008; Desbiez *et al*., 2010), this is the first time an interspecies association between *N. nasua* and *H. hydrochaeris* has been described. Moreover, we consider this species interaction particularly interesting because, although *N. nasua* and *H. hydrochaeris* coexist in several tropical ecosystems (see Paglia *et al*., 2012), they are thought to rarely interact in natural areas due to their contrasting habits (H. Herrara and G. Porfirio, personal observations, 2020). While, *H. hydrochaeris* is a herbivorous and semi-aquatic species (Mones & Ojasti, 1986; Desbiez *et al*., 2011), *N. nasua* (although classified as a carnivore taxonomically) is ecologically classified as an omnivore (Gompper & Decker, 1998; Desbiez *et al*., 2010), consuming mainly fruits and invertebrates (insects and other arthropods) (Bianchi *et al*., 2013).

Accordingly, we report here on three interesting ecological scenarios associated with the described interspecies interaction. The first is protocooperation between *N. nasua* and *H. hydrochaeris* in an urban forest fragment.

Figure 2. Groups of brown-nosed coatis (*Nasua nasua*) foraging on capybara (*Hydrochoerus hydrochaeris*) (A and B) in the *Parque das Nações Indígenas*, urban area of Campo Grande, Mato Grosso do Sul state, Brazil. Photos: Andreza Castro Rucco (2019) (A) and Gabriel Tirintan de Lima (2019) (B).

Protocooperation is defined as a harmonic interspecific relationship whereby both species benefit from the interaction but neither species require the interaction to survive (Odum & Barrett, 2011). *Nasua nasua* gained a novel food source, while the *H. hydrochaeris* had its ectoparasite load reduced. Interestingly, this type of association has been described on multiple occasions for herbivorous African mammals and birds (Mikula *et al*., 2018). For *H. hydrochaeris*, association with birds is commonly reported in Brazil, especially involving two bird species, the cattle tyrant *Machetornis rixosa* (Vieillot, 1819) and the yellow-headed caracara *Milvago chimachima* (Vieillot, 1816) (Sazima *et al*., 2012; D'Angelo *et al*., 2016). However, this is the first record of *H*. *hydrochaeri*s in a harmonic interspecific relationship with *N. nasua*. For *N. nasua*, in turns, interspecific association with other mammals is not a novelty. *Nasua nasua* is known to associate with squirrel monkeys *Saimiri ustus* I. Geoffroy, 1843 in Amazonian dry forest, but the association was limited to foraging in the same place, in different *strata* (Haugaasen & Peres, 2008). According to the Haugaasen & Peres (2008), no interspecific interference or aggression was observed in any occasion of such observations. In the same study site, these authors reported two events of associations between *N. nasua* and brown-capuchins *Cebus* (*Sapajus*) *apella* (Linnaeus, 1758), but unlike the previous association described, *N. nasua* and *C.* (*S.*) *apella* foraged side by side. Again, no interspecific interference or aggression was recorded (Haugaasen & Peres, 2008). In the Brazilian Pantanal, *N. nasua* was observed associating with *Dicotyles tajacu* (Linnaeus, 1758), also to forage together on fruits (Desbiez *et al*., 2010).

The second point of interest is the inclusion of ticks as a food item in the diet of *N. nasua*. Although invertebrates are a known part of the species' diet (Gompper & Decker, 1998; Bianchi *et al*., 2013; Ferreira, G. *et al*., 2013), the consumption of ticks has not been observed before. On the other hand, *Nasua narica* (Linnaeus, 1766), another procyonid species occurring from south United States, Central America up to northern South America (Cuarón *et al*., 2016), was recorded grooming and ingesting ticks attached to *Tapirus bairdii* (Gill, 1865) in Barro Colorado Island, Panamá (McClearn, 1992). On these occasions, both individuals were habituated to humans, and McClearn (1992) suggested that the association was probably a learned phenomenon occurring in a small subset of both populations. According to McClearn (1992) humans and their behavior favor this kind of association.

Finally, we highlight the possibility of parasite transmission and adaptation to a new host species, in this case *Nasua nasua*, in a phenomenon known as 'host switching' (Araujo *et al*., 2015). This scenario can happen because some parasites have arthropods as intermediate hosts (Avancini & Ueta, 1990; Bennett *et al*., 1992; Labruna *et al*., 2004), and it may be that certain parasite species that co-evolved with ticks attached to *H*. *hydrochaeris* (the host species), such as *Rickettsia* spp. (Queirogas *et al.*, 2012) and *Mycoplasma* spp. (Cubilla *et al*., 2017) could be transmitted to a new mammalian host, in this case, *N. nasua*. Additionally, as some of the same microorganisms infect animals and humans, possible transmission of parasites to urban inhabiting *N. nasua* could potentially impact human populations occupying the same environment. Therefore, tick consumption by *N. nasua* in urban areas should be investigated further from both wildlife conservation and human health perspectives (i.e., 'One Health' approach) (Dantas-Torres *et al*., 2012).

In conclusion, urban parks in Campo Grande city, appear to provide an environment that can support interspecific interactions between apparently disparate wildlife species. *Nasua nasua* and *H. hydrochaeris* were found to have a previously undescribed, interspecific association. Based on our observations, we propose that ticks (from *H. hydrochaeris*) appear to be a new food item in the diet of urban inhabiting *N. nasua*. Additionally, we consider the possibility of a new parasitic adaptation associated with tick consumption by *N. nasua*, and possible concerns for the conservation of *N. nasua* in urban forest fragments associated with this. Accordingly, research into this interspecies association warrants further investigation.

## ACKNOWLEDGMENTS

Authors thanks *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* (CAPES, Brazil) for the grants received (88882.315124/2019-01; 88887.369261/2019-00), and *Conselho Nacional de Desenvolvimento Científico e Tecnológico* (CNPq) (308768/2017-5). We are grateful to two anonym reviewers for their valuable suggestions and comments in a previous version of this manuscript. This study was financed in part by the *Fundação Universidade Federal de Mato Grosso do Sul* (UFMS/MEC) and CAPES (Finance Code 001).

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# Memória


Leopardus
Urban Ecology
Carnivora
Owl pellet
South America
Didelphimorphia
Occupancy
Lagoa Santa
Vegetation
Synanthropy
Sylvilagus
Behavior
Chromosome
Aquatic mammals
Activity pattern
Santa Catarina
Pleistocene
Red List
Agribusiness
Habitat conversion
Urban space
West Indian manatee
Structure
Cerdocyon
Deforestation
Atlantic Ocean
Hystricognathi
Environmental variables
Natural history
Ecological niche model
Camera trapping
Peruvian Amazon
Diet
Extinction risk
Pantanal
Diversity
Callithrix
Geographic distribution
Quality indicator species
Scientific collection
Cerrado
Insectivory
Naturalistic museum
manatee
Amazon
Mammalogy
Rodentia
Travels in Peru
Interannual variation
Atlantic Forest
Conservation
Maxent
Species list
Chinchilla
Ecology
Seasonally dry tropical forest
Dasypus pilosus
Sigmodontinae
Caviomorpha

# Neotropical mammals in natural history collections and research in Rome, Italy

# Mamíferos neotropicais em coleções de história natural e pesquisa em Roma, Itália

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**Abstract:** The occurrence and the history of Neotropical mammal specimens in the collections of naturalistic museums in Rome, Italy, and their scientific utilization is here reviewed. These specimens belong to several scientific expeditions made after the discovery of the new Continent. The oldest specimens date back to the famous Museum of Athanasius Kircher at the *Collegio Romano* (1651) and to the *Museo Zoologico della Università di Roma* that was established inside the University of the Pontificial State (*Archigymnasium*) (1823). Many of these early specimens are now lost due to the complex history of Roman scientific museology, but some specimens are now available mainly in two institutions, the Museo Civico di Zoologia (established in 1932) and the *Museo di Anatomia Comparata "Battista Grassi"* of "Sapienza" University of Rome (1935). Among the numerous specimens, is noteworthy the presence of a hairy long-nosed armadillo, *Dasypus pilosus*, the first record in an Italian zoological collection and the 26th known specimen of this species in world museums. More recently, some Roman researchers have maintained a scientific interest for Neotropical mammals, including primates, with collaboration with South American mammalogists. A greater historical knowledge of scientific activities concerning the work of Italians researchers on Neotropical biodiversity should be pursued.

**Keywords:** *Dasypus pilosus*. Mammalogy. Naturalistic museum.

**Resumén:** En este trabajo se revisa la ocurrencia y la historia de especímenes de mamíferos neotropicales en las colecciones de museos naturalistas en Roma y su utilización científica. Estos especímenes pertenecen a varias expediciones científicas realizadas después del descubrimiento del nuevo continente. Los ejemplares más antiguos se remontan al famoso *Museo de Atanasio Kircher en el Collegio Romano* (1651) y al *Museo Zoológico* que se estableció dentro de la Universidad del Estado Pontificio (*Archigymnasium*) (1823). Muchos de estos primeros especímenes ahora se pierden debido a la compleja historia de la museología científica romana, pero algunos especímenes ahora están disponibles principalmente en dos instituciones, el *Museo Civico de Zoologia* (establecido en 1932) y en el *Museo di Anatomia Comparata "Battista Grassi"* de la Universidad Sapienza de Roma (1935). Entre los numerosos especímenes, cabe destacar la presencia de un quirquincho peludo, *Dasypus pilosus*, el primer registro en una colección zoológica italiana y uno de los 26 especímenes conocidos de esta especie en museos mundiales. Más recientemente, algunos investigadores romanos mantuvieron un interés científico por los mamíferos neotropicales, incluidos los primates, con la colaboración de los especialistas en mamíferos sudamericanos. Se debe buscar un mayor conocimiento histórico de las actividades científicas que vieron a los italianos trabajando en la biodiversidad neotropical.

**Palabras-clave:** *Dasypus pilosus.* Mammalogía. Museo naturalista.

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GIPPOLITI, S. & R. CASTIGLIA, 2020. Neotropical mammals in natural history collections and research in Rome, Italy. **Boletim do Museu Paraense Emílio Goeldi. Ciências Naturais** 15(3): 851-862. DOI: http://doi.org/10.46357/bcnaturais.v15i3.254.

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Recebido em 04/01/2020
Aprovado em 12/11/2020
Responsabilidade editorial: Alexandra Maria Ramos Bezerra

## INTRODUCTION

After the discovery of the 'New World', live and dead American mammals reached the most important cities of Europe, and Rome was no exception. As the capital of the temporal power of Christianity, Rome was at the time an important political and research center. Capanna (2009) illustrated the history of the publication in Rome of Francisco Hernandez's *Novae Hispaniae Theosaurus* in 1648. He recalled how armadillos were particularly famous in Baroque Rome, with one specimen in the Museum of Athanasius Kircher (1602-1680) at the *Collegio Romano* that probably was the model utilized by Gian Lorenzo Bernini for his reproduction in the *Fontana dei Fiumi* in Piazza Navona (Capanna, 2007, 2009).

This contribution aims to provide a review on the occurrence and the history of Neotropical mammal specimens in the collections of naturalistic museums in Rome and their scientific utilization. Except in a few cases, we did not attempt a systematic taxonomic revision of the material and the main goal of the present paper is to resume a forgotten chapter about the history of scientific relationship between Italy and South America.

## MATERIAL AND METHODS

We reviewed historical evidences and current specimens of South American origin housed or known to have been held in the two oldest public natural history collections sited at Rome, Italy (Giuseppini & Capanna, 2010): the *Museo Civico di Zoologia*, and the *Museo di Anatomia Comparata* "*Battista Grassi*" of the "Sapienza" University of Rome. The *Museo Civico di Zoologia* derived from the former *Museo Zoologico della Università di Roma*, but some specimens of the latter are now found elsewhere, including the *Museo di Antropologia* "*Giuseppe Sergi*" in "Sapienza" University of Rome.

For the *Museo Civico di Zoologia*, old catalogues available were checked and the specimens were surveyed along with the historic tracking of gathering of these collections in literature. Owing to the current health situation due to COVID-19, it was not possible to examine, with very few exceptions, any specimen in this Museum for the specific purpose of this paper. Therefore, the original nomenclature is always retained unless explicitly stated. For the *Museo di Anatomia Comparata* "*Battista Grassi*" all the specimens have been checked. For both the museums, when it was possible to study the specimens, we adopted the nomenclature as following: Gardner (2008) for the orders Didelphimorphia, Cingulata, and Pilosa; Patton *et al*. (2015) for Rodentia, Emmons & Feer (1997) for Primates, Acosta *et al*. (2020) for family Tayassuidae, Nascimento & Feijó (2017) for the genus *Leopardus* Gray, 1842, Merino & Rossi (2010) for the genus *Mazama* Rafinesque, 1817.

## THE *MUSEO ZOOLOGICO DELLA UNIVERSITÀ DI ROMA*

A formal zoological museum was established inside the University of Rome (*Archigymnasium*) in 1823, leaded by Luigi Metaxà (1778-1842) (Giuseppini & Capanna, 2010). According to the first catalogue of the museum, realized by Temistocle Metaxà in 1853, South American mammals were prevalent inside the small zoological collection of the University (Metaxà, 1853), thus indicating the strong bond existing between the New World and the Capital of Christianity. Most of them are referred as originated from 'Brazil' (Table 1). A notable exception being three marmosets identified as *Simia jacchus* Linnaeus, 1758 and originating from Montevideo, Uruguay (although the species was unknown in this country), a gift of Pope Pio IX. Also notable are two squirrel specimens indicated to belong to *Sciurus castaneus*, a species that was reported as "descritto dal direttore del Museo di Rio de Janeiro. Esemplari del Brasile" (described by the director of the Rio de Janeiro Museum) (Metaxà, 1853), but that was never officially introduced to zoological nomenclature (a *nomen nudum*).

Already in 1853, the Museum acquired new Brazilian mammals, including two marsupial specimens: a water opossum *Chironectes minimus* (Zimmermann, 1780) (voucher n° 2609) and a brown four-eyed opossum

*Metachirus nudicaudatus* (É. Geoffroy, 1803) (voucher n° 2607). In 1870, Rome became the capital of the Reign of Italy. A program of development of the University of Rome was established, but it had little effects on the Zoological Museum, which remained a secondary institution in the Italian scientific panorama (Marzagora & Capanna, 2001). This suddenly changed in 1883, when Antonio Carruccio (1839-1923) moved from Modena to Rome as chair of the *Instituto e Museo di Zoologia* of Rome University (Marangoni & Gippoliti, 2011). In his 30 years of directorship, Carruccio completely refunded the museum creating an *ex novo* Rome Provincial collection and illustrating most of the new materials, including mammals, in several papers (*cf.*, Carruccio, 1898, 1899). Although no Italian explorers-naturalists of the time were closely linked to the Zoological Museum of Rome, Carruccio exploited his position in the capital of Italy to a maximum.

The Royal Family (particularly the kings Umberto I and Vittorio Emanuele III, and the Queen Elena) were among the major donors of the Zoological Museum. In 1903, thanks to Vittorio Emanuele III, the Museum received the third specimen of okapi *Okapia johnstoni* (Sclater, 1901) that reached a western museum (Carruccio, 1903). Other donors were the *Società Geografica Italiana*, the Italian *Ministero della Difesa* (Leopoldo Traversi collection from Ethiopia), the Czech explorer Emil Holub, and the *Museo Nazionale Etnografico* directed by Luigi Pigorini (nowadays *Museo Nazionale Preistorico Etnografico* '*Luigi Pigorini*', in his honor).

Table 1. List of Neotropical mammals cited by Metaxà (1843), including order, family and original identification, taxonomic comments with the presumed updated identification (see Material and Methods), number of cited specimens (N) and locality of origin (Origin). (Continue)

| Original identification | Taxonomic comments | N | Origin |
|---|---|---|---|
| DIDELPHIMORPHIA | | | |
| Didelphidae | | | |
| *Didelphis azarae* Temminck, 1824 | *Didelphys aurita* Wied-Neuwied, 1826 | 1 | Brazil |
| *Didelphis opossum* Linnaeus, 1758 | *Philander* cf. *opossum* | 1 | Brazil |
| PRIMATES | | | |
| Cebidae | | | |
| *Simia sciurea* Linnaeus, 1758 | *Saimiri* sp. | 1 | Brazil |
| *Cebus griseus* Cuvier, 1819 | *Cebus* sp. | 1 | |
| Pitheciidae | | | |
| *Pithecia hirsuta* (Spix, 1823) | *Pithecia monachus* (É. Geoffroy, 1812) | 1 | Brazil |
| *Pithecia rufiventer* (É. Geoffroy, 1812) | *Pithecia pithecia* (Linnaeus, 1758) | 1 | - |
| Aotidae | | | |
| *Pithecia miriquouina* É. Geoffroy, 1898 | *Aotus azarae* (Humboldt, 1811) | 1 | Brazil |
| Callitrichidae | | | |
| *Simia jacchus* Linnaeus, 1758 | *Callithrix jacchus* (Linnaeus, 1758) | 3 | Montevideo (Uruguay) |
| *Simia penicillata* É. Geoffroy, 1812 | *Callithrix penicillatus* (É. Geoffroy, 1812) | 1 | Brazil |
| *Simia bicolor* Spix, 1823 | *Saguinus bicolor* (Spix, 1823) | 1 | Brazil |
| *Simia ursulus* (incorrect spell of *Simia ursula* Humboldt, 1812) | *Saguinus ursula* Hoffmannsegg, 1807 | 1 | Brazil |
| *Simia mystax* Spix, 1823 | *Saguinus mystax* (Spix, 1823) | 1 | Brazil |
| *Simia rosalia* Linnaeus, 1766 | *Leontopithecus rosalia* (Linnaeus, 1766) | 3 | Brazil |

Table 1. (Conclusion)

| Original identification | Taxonomic comments | N | Origin |
|---|---|---|---|
| CARNIVORA | | | |
| Procyonidae | | | |
| *Nasua nasua* (Linnaeus, 1766) | *Nasua nasua* (Linnaeus, 1766) | 1 | Brazil |
| *Nasua narica* (Linnaeus, 1766) | *Nasua nasua* (Linnaeus, 1766)? | 4 | Brazil |
| Mustelidae | | | |
| *Mustela barbara* Linnaeus, 1758 | *Eira barbara* (Linnaeus, 1758) | 2 | Brazil |
| Felidae | | | |
| *Felis tigrina* Schreber, 1775 | *Leopardus* sp. | 1 | Brazil |
| *Felis onca* Linnaeus, 1758 | *Panthera onca* (Linnaeus, 1758) | 1 | - |
| PILOSA | | | |
| Myrmecophagidae | | | |
| *Tamandua* Gray, 1825 | *Tamandua tetradactyla* (Linnaeus, 1758) | 2 | Brazil |
| Bradypodidae | | | |
| *Bradypus tridactylus* Linnaeus, 1758 | *Bradypus* sp. | 2 | Brazil |
| *Bradypus* var. *stellata* | *Bradypus* sp. | 1 | Brazil |
| CINGULATA | | | |
| Dasypodidae | | | |
| *Dasypus novemcinctus* Linnaeus, 1758 | *Dasypus* cf. *novemcinctus* | 2 | Brazil |
| *Dasypus octocinctus* Schreber, 1774 | *Dasypus* cf. *novemcinctus* | 1 | Brazil |
| RODENTIA | | | |
| Sciuridae | | | |
| *Sciurus castaneus nomen nudum* | *Guerlinguetus* sp. | 2 | Brazil |
| Cricetidae | | | |
| *Mus pyrrhorhinos* Wied-Neuwied, 1821 | *Wiedomys pyrrhorhinos* (Wied-Neuwied, 1821) | 1 | Brazil |
| Echimyidae | | | |
| *Echimys* | Echimyidae | 1 | Brazil |
| Erethizontidae | | | |
| *Sphiggurus spinosa* F. Cuvier, 1823 | *Coendou* sp. | 1 | Brazil |
| *Sphiggurus villosa* F. Cuvier, 1823 | *Coendou spinosus* (F. Cuvier, 1823) | 1 | Brazil |
| Dasyproctidae | | | |
| *Dasyprocta aguti* (Linnaeus, 1766) | *Dasyprocta* sp. | 1 | Brazil |
| Cuniculidae | | | |
| *Cuniculus paca* (Linnaeus, 1766) | *Cuniculus paca* (Linnaeus, 1766) | 1 | - |
| CETARTIODACTYLA | | | |
| Cervidae | | | |
| *Odocoileus virginianus* (Zimmmermann, 1780) | *Odocoileus virginianus* | 1 | Brazil |

Particularly interesting and little-known are the results of several circumnavigations done by the Italian Royal Navy in South America. It should be considered that from 1866 to 1890 the Italian Royal Navy effected 11 circumnavigations of the globe and 21 oceanic campaigns (Dimpflmeier, 2014), and most of these were involved with scientific data collecting. Zoological collections were received by the corvette Caracciolo circumnavigation during the years 1881 to 1884 (Carruccio, 1885). Most mammal specimens come from South America, including two capuchins *Cebus variegatus* É. Geoffroy, 1812 from Guayaquil (Ecuador), one titi monkey *Callicebus melanochir* (Wied-Neuwied, 1820), one deer of the genus *Odocoileus* Rafinesque, 1832 from Ecuador, and one three-throated sloth *Bradypus tridactylus* Linnaeus, 1758 from Guayaquil (Carruccio, 1885). Although the period of Carruccio's directorship was the best documented for zoological collections of Rome history, the expansion of the collections was so great that the collection could not be completely studied and/or published in the journal created by himself in 1893, the *Bollettino della Società Romana di Studi Zoologici* (renamed in 1900 to *Bollettino della Società Zoologica Italiana*). After Carruccio retirement in 1914, it was given a new direction to experimental research in the Institute of Zoology. Moreover, due to lack of a definitive location for the Institute of Zoology, in 1932 most of the zoological collections were rented to the Municipality of Rome to create the *Museo Civico di Zoologia* inside the *Giardino Zoologico di Roma*.

The application of new labels and the removal of the old ones contribute to obscure the history of the University collections (*cf.*, Gippoliti & Bruner, 2007). In recent years, the discovery of an old University Museum catalogue, now preserved in the *Museo Civico di Zoologia* of Rome, has allowed to shed light about the origin of some of the specimens still in existence, including one *Dasypus villosus* (Fitzinger, 1856) from "Perù" (mounted skin) that has been re-identified by one of us (SG) as a hairy long-nosed armadillo *Dasypus pilosus* (Fitzinger, 1856) (voucher n° 2629). Presently, 25 specimens of this species are known in world museums (Feng *et al*., 2017), none of which from Italy. This is the first record in an Italian zoological collection. The species required a special attention since itis listed as "data deficient" in the IUCN red list of threatened Species (Superina & Abba, 2014).

That very important *Dasypus pilosus* specimen is the result of the collections gathered from the surgeons of the Italian Royal navy Teofilo Moscatelli and Giovanni Petella during the voyage around South America of Flavio Gioia (carried out during 1883-1886) (Petella, 1889). This was evidently possible thanks to the advice in Peru of one of the fathers of Peruvian Natural History, Antonio Raimondi (Milan 1824 – Lima 1890) (Mazzotti, 2011). Petella (1889, p. 74) regarding their exploration of the interior of Peru says "viaggio di esplorazione tracciatoci dal Raimondi per Cajamarca e Moyobamba fino a Yurimaguas sulle rive dell'Huallaga e per numerosi andirivieni fluviali a cercare la comunicazione del Purus e del Jorua coll'Ucayali al gran padre delle Amazzoni" (translation: "An exploration journey traced from Raimondi to Cajamarca and Moyobamba up to Yurimaguas on the banks of the Huallaga and for numerous river trips to seek communication between Purus and Jorua with the Ucayali to the great father of the Amazons"). Among the mammal specimens from Peru donated by Moscatelli and Petella to the Zoological Museum, we found evidence of a *Thiosmus quitensis* Less, 1838 from the interior of Peru catalogued as voucher n° 2845, probably a striped hog-nosed skunk *Conepatus amazonicus* Lichtenstein, 1838. Same origin has a squirrel *Sciurus stramineus* P. Gervais, 1841 (voucher n° 2787) and an agouti *Dasyprocta prymnolopha* Wagler, 1831 (voucher n° 2720). Further research is necessary to understand the exact origin of the mounted skin of hairy long-nosed armadillo *D. pilosus*.

Among Carruccio's paper there is often reference to specific Neotropical specimens, such as a night monkey *Aotus azarae* (Humboldt, 1811), from the Paraguayan Chaco that died in Rome and belonged to Mr. Francesco Tonini

Del Furia, formerly of the *Museo di La Plata* (Carruccio, 1896a), or to a pink hairy armadillo *Chlamyphorus truncatus* Harlan, 1825 from Mendoza, Argentina, collected by the Italian explorer Giacomo Bove around 1883-1884. Anatomical studies were performed on exotic mammals dying in Rome, such as a pale-throated sloth *Bradypus tridactylus* Linnaeus, 1758, from Brazil, or the above mentioned night monkey (Carruccio, 1896b; Condorelli Francaviglia, 1893, 1894, 1896).

An interesting small collection was acquired in 1909 from Mr. Silvio Bondimai, who spent one year in the Cerro S. Ana, Misiones province, Argentina (Carruccio, 1910). Lepri (1912) identified two felid species – the ocelot *Leopardus pardalis* (Linnaeus, 1758) and the margay *Leopardus wiedii* (Schinz, 1821), but the most interesting result was the herpetological one, with the description of two species of amphisbenids by Luigi Masi (Masi, 1911).

## THE *MUSEO CIVICO DI ZOOLOGIA*

Carruccio's retirement in 1914 marks the end of this golden age for the zoological museums in Rome. After almost two decades of neglect, only in 1932 an agreement between the Rome Municipality agency and the University of Rome allowed the opening of the *Museo Civico di Zoologia*. This new zoological museum e was established inside a building in the zoological garden (in the Villa Borghese garden), under the scientific directorship of Giuseppe Lepri. Donations of trophy collections and the recovering of specimens that died at the zoological garden marked the first years (Gippoliti, 2010). Apparently, the University osteological collections were only partially sent to the new *Museo Civico di Zoologia*. Gippoliti & Bruner (2007) found that primate skulls and skeletons are now in the *Museo di Antropologia "Giuseppe Sergi"* of the "Sapienza" University in Rome. Several skulls of howler monkeys of the genus *Alouatta* Lacépède, 1799, possibly *Alouatta guariba* (Humboldt, 1812) (see next), which have been used in a study of functional morphology (Bruner *et al.*, 2004), are originated from the '*Società Geografica Italiana*' donation in 1889 to the *Museo Zoologico della Università di Roma*. The physician Giuseppe Franco Grillo (1842-1903) sent these skulls to Rome from the Paraná state, Brazil (see Figure 1), and also several other specimens are listed in the old University catalogue, such as: a marsupial – indicated as *Philander cancrivorus* (J. A. Wagner, 1843) (voucher n° 2608), a raccoon *Procyon cancrivorus* (G. Cuvier, 1798) (voucher n° 2830), a giant otter *Pteronura brasiliensis* (Zimmermann, 1780) (voucher n° 2844), and a skull of a deer *Ozotocerus bezoarticus* (Linnaeus, 1758) (as *Cervus campestris* Cuvier, 1817) (voucher n° 2672). Giuseppe Franco Grillo was also a regular collector for the *Museo di Storia Naturale di Genova* (Thomas, 1900), as well as another Italian emigrant in Brazil, Camillo Vanzolini (Poggi, 2017). The latter is perhaps a more famous name among South American zoologists. Camillo Vanzolini married the daughter of Giuseppe Franco Grillo, Teresa Franco Grillo, and his first son, Carlos Alberto Vanzolini, was the father of Paulo Emílio Vanzolini (1924-2013) one of the most famous Brazilian herpetologists, biogeographer and musician (Burgos Dias, 2013).

After the Wold War II, particular attention was devoted by Giuseppe Tamino, curator of the *Museo Civico*, to recover cetacean specimens stranded along the

Figure 1. Skulls of primate specimens of the genus *Alouatta* presently at the *Museo di Antropologia* of "Sapienza" University, Rome, Italy. The specimen on the left (n° 2579) is one of the *Alouatta* skulls sent by Giuseppe Franco Grillo from Palmeiras, Paraná state, Brazil. Photo: Gippoliti (2006).

Italian coasts, but otherwise little documentation exists on the development of the mammal collection. During 1962-1963, Francesco Baschieri Salvadori and Guglielmo Mangili (Figure 2), of the *Giardino Zoologico* and the *Museo Civico di Zoologia* in Rome, participated in a scientific mission to Brazilian Amazon, on the Rio Negro Basin. This expedition was financed by CNR (*Consiglio Nazionale delle Ricerche*) and leaded by parasitologist Ettore Biocca of the "Sapienza" University of Rome. Although a list of vertebrate specimens, collected during the expediton, was published (Baschieri-Salvadori & Mangili, 1966; Gippoliti, 2014), including some live mammals sent to the zoological garden, they were not adequately studied and most of them were subsequently lost. The primatological results were discussed shortly by Gippoliti (2004). Parasites collected during the expedition, although never published, are presently at the *Museo Civico di Zoologia* (Annamaria Epiceno, personal communication). After his retirement, Biocca donated his zoological and ethnographical collections to the Camerino University, Macerata, Italy (Blasetti & Magnoni, 2010). There are a few mammal skins in this material, including an interesting primate of the genus *Chiropotes* Lesson, 1840 from Rio Uapés (Amazonas), obtained perhaps during the World War II, when Biocca had his first permanence in Brazil (De Marino & Schiena, 2015).

An important research program on a Neotropical primate, the robust capuchin of the genus *Sapajus* Kerr, 1792, began in the 1980's at the newly established Laboratory of Comparative Psychology of CNR (now Institute of Cognitive Sciences and Technologies), inside the Zoological Garden of Rome (Gippoliti, 2010). These researches focussed on tool use and cognitive comparison between tufted capuchin monkeys and apes. In recent years, research activities have been moved also in the field, and precisely on the robust capuchin monkey *Sapajus libidinosus* (Spix, 1823) at the *Fazenda Boa Vista* and adjacent lands, Piauí state, Brazil (Visalberghi & Fragaszy, 2013).

Figure 2. Guglielmo Mangili while preparing some primate specimens of the genus *Cacajao* taken on the Rio Cauaburi (Amazonas). Photo: Baschieri Salvadori (1963).

## THE *MUSEO DI ANATOMIA COMPARATA* "*BATTISTA GRASSI*", IN "SAPIENZA" UNIVERSITY OF ROME

The vertebrate collections presently hold at the Museum Comparative Anatomy (hereafter *Museo di Anatomia Comparata* "*Battista Grassi*") of "Sapienza" University, is largely originated from the collection of the early Institute of Comparative Anatomy. The Institute, founded in 1873 with the annexed Museum of Anatomy and Comparative Physiology of the University, was entrusted to the German neurophysiologist and histologist Franz Böll (Giuseppini & Capanna, 2010). In 1878 this collection was placed in the former convent of S. Antonio alle Quattro Fontane, Rome, Italy, where it remained until 1929. Into following years, the collections grew especially in relation to the teaching of Comparative Anatomy by Giovanni Battista Grassi (1854-1959), who gave an evolutionary imprint to the discipline.

The *Museo*, now located in the "Sapienza" University of Rome, was inaugurated in 1935 inside the Human Anatomy building. Due to its complex history, almost all the vertebrate specimens from this institution are with no information on their origin, and often, only the type of label bearing the name of the species can reveal the period to which it belongs. Among the specimens in the *Museo di Anatomia Comparata*, some 20 of them are certainly attributable to Neotropical mammals (Table 2), often purchased by specialized companies, such as those from the natural history dealer Gustav Adolph Frank (1809-1880, Amsterdam, Netherlands) (Steinheimer, 2003). From a quick glance at the distribution of the species in the various taxonomic orders of mammals, it is clear that the acquisition criterion was mainly didactic. In fact, the most typical components of the fauna of Neotropical mammals are well represented, in particular the xenarthrans, absent in the Old World. Out of 24 total specimens, about half belongs to this group with good representation of the two orders Pilosa and Cingulata (Table 1, Figures 3 and 4). The other specimens included Neotropical rodents showing peculiar specializations as the hairy dwarf porcupine *Coendou insidiosus* (Olfers, 1818) and the capybara *Hydrochoerus hydrochaeris* (Linnaeus, 1766), tayassuids and some small primates (*e.g.*, the marmosets of the genera *Callithrix* Erxleben, 1777 and *Saimiri* Voigt, 1831) (Table 2).

Table 2. Neotropical mammal specimens housed at the *Museo di Anatomia Comparata* "*Battista Grassi*", "Sapienza" University, Rome, Italy.

(Continue)

| Taxon | Preparation type |
|---|---|
| PILOSA | |
| Myrmecophagidae | |
| *Myrmecophaga tridactyla* Linnaeus, 1758 | Mounted skeleton |
| *Tamandua mexicana* (Saussure, 1860) | Naturalized skin |
| *Tamandua mexicana* (Saussure, 1860) | Skull |
| Bradypodidae | |
| *Bradypus variegatus* Schinz, 1825 | Naturalized skin |
| *Choloepus didactylus* (Linnaeus, 1758) | Mounted skeleton |
| CINGULATA | |
| Chlamyphoridae | |
| *Chaetophractus vellerosus* (Gray, 1865) | Naturalized skin |
| *Euphractus sexcinctus* (Linnaeus, 1758) | Naturalized skin |
| Dasypodidae | |
| *Dasypus* sp. | Mounted skeleton |
| *Dasypus* sp. | Mounted skeleton |
| *Dasypus* sp. | Skull |
| *Dasypus* sp. | Skull |
| RODENTIA | |
| Chinchillidae | |
| *Lagostomus maximus* (Desmarest, 1817) | Naturalized skin |
| Dasyproctidae | |
| *Dasyprocta* sp. | Naturalized skin |
| Erethizontidae | |
| *Coendou insidiosus* (Olfers, 1818) | Naturalized skin |

Table 2. (Conclusion)

| Taxon | Preparation type |
|---|---|
| Caviidae | |
| *Hydrochoerus hydrochaeris* (Linnaeus, 1766) | Skull |
| CETARTIODACTYLA | |
| Tayassuidae | |
| *Dicotyles tajacu* (Link, 1795) | Naturalized skin |
| *Dicotyles tajacu* (Link, 1795) | Skull |
| Camelidae | |
| *Lama guanicoe* (Müller, 1776) | Mounted skeleton |
| PRIMATES | |
| Atelidae | |
| *Alouatta palliata* (Gray, 1849) | Skeleton and naturalized skin |
| *Alouatta palliata* | Skull |
| *Alouatta* cf. *belzebul* | Skull |
| Callitrichidae | |
| *Callithrix jacchus* (Linnaeus, 1758) | Skull and mounted skin |
| Cebidae | |
| *Saimiri* sp. | Mounted skeleton |
| SIRENIA | |
| Trichechidae | |
| *Trichechus manatus* Linnaeus, 1758 | Skull |

Figure 3. Entire mounted skeleton of a Southern two-toed sloth *Choloepus didactylus*, from the *Museo di Anatomia Comparata* of "Sapienza" University, Rome, Italy. Photo: Paolo Ragazzini (2000).

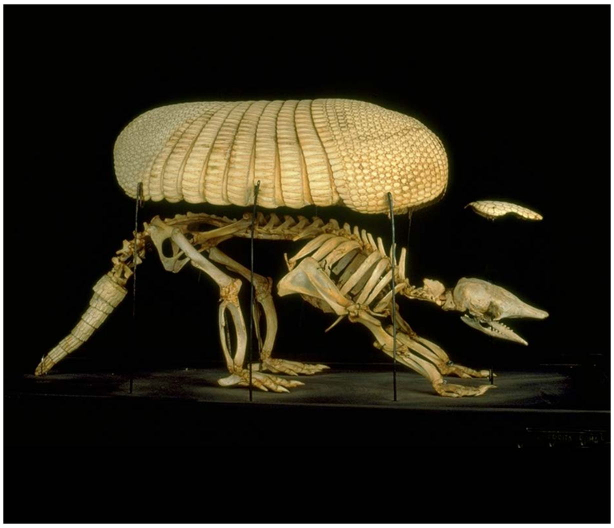

Figure 4. A peculiar entire skeleton of long nosed armadillo (*Dasypus* sp.) showing the dermal armour at *Museo di Anatomia Comparata* of "Sapienza" University, Rome, Italy. Photo: Paolo Ragazzini (2000).

In recent years, the Institute of Comparative Anatomy now merged into the Department of Biology and Biotechnology, has been involved in taxonomic studies on Neotropical rodents collaborating with South American researchers. We refer to the works of Ernesto Capanna and Marco Corti, both former directors of the Museum of Comparative Anatomy, carried out in collaboration with the Venezuelan researchers Angela M. G. Martino (*Universidad Nacional Experimental Francisco de Miranda*) and Marisol Aguilera (*Universidad Simón Bolívar*) (*e.g.*, Corti *et al.*, 2001; Martino & Capanna, 2002). More recently, studies on mammalian fauna of Brazil have been carried out in collaboration among the current director Riccardo Castiglia (from 2016) and the Brazilian researchers Alexandra M. R. Bezerra (*Museu Paraense Emílio Goeldi*, Belém, PA, Brazil), Cibele R. Bonvicino, and Fabiana Caramaschi (Oswaldo Cruz Foundation, Instituto Nacional de Câncer, Rio de Janeiro, RJ, Brazil) (*e.g.*, Bezerra *et al.*, 2018, 2019, 2020).

## CONCLUSIONS

Although scarcely investigated, in recent years there has been traditionally a considerable scientific interest for South America biodiversity from several Italian institutions and researchers. Even if Rome cannot claim natural history institutions such as those in Turin, Milan and Genoa that had long-term programs and contacts with South America (*cf.* Gippoliti, 2005), yet the present overview shows as even minor Italian centre of research had the opportunity to maintain and study interesting Neotropical zoological specimens (Gippoliti *et al.*, 2014). Hopefully, the present paper may serve as an invite to other students to make available to a wider audience the results of ancient and often forgotten biological surveys in the Neotropics leaded by Italian explorers and naturalists.

## ACKNOWLEDGEMENT

We wish to thank Prof. Ernesto Capanna for his long-term interest in Roman scientific museology and Rossella Carlini and Annamaria Epiceno for useful advices regarding the history of *Museo Civico di Zoologia* in Rome. Thanks are extended to the editor Alexandra M. R. Bezerra for comments and advice on this manuscript, to Giovanni Amori and one anonymous reviewer for comments on the early version of text, and to Flavia Annesi for the English revision.

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# Catalog of medium and large-sized mammals from the state of Pará, Brazil, housed in the *Museu de Zoologia da Universidade de São Paulo* (MZUSP)

## Catálogo de médios e grandes mamíferos do estado do Pará, Brasil, depositados no Museu de Zoologia da Universidade de São Paulo (MZUSP)

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**Abstract:** The Mammal Collection of the *Museu de Zoologia da Universidade de São Paulo* (MZUSP) is one of the largest collections of Neotropical mammals in Latin America, housing about 50,000 specimens. One of the most representative series in this collection comes from the Brazilian Amazon Biome. Among the Brazilian Amazon states, Pará was target of several scientific expeditions led by MZUSP researchers, becoming one of the most representative in terms of number of specimens and species richness in the collection. Here we present a list of the medium and large-sized mammal specimens from Pará state housed in the MZUSP, with comments about taxonomy, the conservation status of the species and other associated information. We found 1,910 specimens representing 79 species and nine orders of medium and large-sized mammals from Pará. Among these, 24 species are currently classified as threatened in Brazil. Furthermore, we found some areas with higher concentration of collection localities, such as at the banks of the lower Rio Tapajós and in the northeastern region of the state. The present catalog plays an important role in presenting the currently known biodiversity of medium and large-sized mammals of Pará, also acting as a primary source for systematics, ecological, conservation and biogeographic studies.

**Keywords:** Amazon. List of specimens. Mammalogy. Scientific collection.

**Resumo:** A Coleção de Mamíferos do Museu de Zoologia da Universidade de São Paulo (MZUSP) é uma das maiores coleções de mamíferos neotropicais da América Latina, abrigando cerca de 50.000 espécimes. Uma de suas séries mais representativas é proveniente da Amazônia brasileira. Entre os estados amazônicos brasileiros, o Pará foi alvo de inúmeras expedições científicas conduzidas por pesquisadores do MZUSP, tornando-se um dos mais representativos em termos de quantidade de espécimes e riqueza de espécies na coleção. Aqui, apresentamos uma lista de mamíferos de médio e grande porte do Pará depositados no MZUSP, com comentários sobre taxonomia, estado de conservação da espécie e outras informações associadas. Listamos 1.910 espécimes, representando 79 espécies e nove ordens de mamíferos de médio e grande porte do Pará. Entre estes, 24 espécies estão atualmente ameaçadas no Brasil. Além disso, observamos algumas áreas com maior concentração de coletas, tais como as próximas às margens do baixo rio Tapajós e na região nordeste do estado. O presente catálogo desempenha papel importante em apresentar a biodiversidade atualmente conhecida de mamíferos de médio e grande porte do Pará, também atuando como uma fonte primária para estudos sistemáticos, ecológicos, conservacionistas e biogeográficos.

**Palavras-chave:** Amazônia. Lista de espécimes. Mastozoologia. Coleção científica.

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NASCIMENTO, F. O. & R. L. VENDRAMEL, 2020. Catalog of medium and large-sized mammals from the state of Pará, Brazil, housed in the *Museu de Zoologia da Universidade de São Paulo* (MZUSP). **Boletim do Museu Paraense Emílio Goeldi. Ciências Naturais** 15(3): 863-903. DOI: http://doi.org/10.46357/bcnaturais.v15i3.240.

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Recebido em 19/12/2019
Aprovado em 23/10/2020
Responsabilidade editorial: Alexandra Maria Ramos Bezerra

## INTRODUCTION

The Mammal Collection of the *Museu de Zoologia da Universidade de São Paulo* (MZUSP) currently houses about 50,000 specimens preserved as dry skins, skulls and postcranial skeletons, and in liquid, including whole specimens in alcohol. This collection is one of the largest collections of Neotropical mammals in Brazil and Latin America (de Vivo *et al.*, 2011; Bezerra, 2012). The MZUSP does not have concentrated sampling in certain Brazilian regions or biomes but has a broad geographic coverage that includes every biome and most Brazilian states (Percequillo, 2005). One of the most representative series in MZUSP comes from the Brazilian Amazon biome. Since its beginning in the late nineteenth and early twentieth centuries, the MZUSP has sent professional specimen collectors to the Amazon (Pinto, O., 1945).

Among the Brazilian states that encompass the Amazon, Pará is one of the most representative in number of specimens housed in MZUSP. Located in northern Brazil, the Pará state is the second-largest federal unity of the country, with an area of 1,245,759 km$^2$, representing 14% of the Brazilian territory (IBGE, 2018). This state encompasses five areas of endemism: Belém, Guiana, Rondônia, Tapajós, and Xingu (Silva, S. *et al.*, 2019, fig. 1). The predominant vegetation is composed of ombrophilous forest, with areas of dense and open forests, and transitional areas with the Cerrado in the southern region of the state (IBGE, 2004). According to Köppen's classification, the climate of Pará state is mainly monsoonal and some areas do not have a dry season (Alvarez *et al.*, 2013).

Localities within Pará were explored by several MZUSP scientific expeditions. The region was explored by Ernst Garbe (in the early 1920s), Alonso Olalla (in the 1930s and 1940s), and the "Expedição Permanente à Amazônia" project (EPA; 1967-1987), coordinated by Paulo Emílio Vanzolini (Pinto, O., 1945; Rodrigues *et al.*, 2000). Contrastingly, in the first two decades of the 21st century, much of the mammal material from Pará state was not derived from collection expeditions aimed to increase the collection, but rather from environmental impact studies for large enterprises such as railways, highways, mining, and hydroelectric power plants (J. Gualda-Barros, personal communication). In such cases, there is a bias towards the collection of small mammals, especially rodents, bats, and marsupials. In environmental impact studies, the collection of medium and large-sized mammals is mostly occasional, derived from dead individuals found in the wild or roadkilled (F. O. Nascimento, personal observation).

Due to the large collection expeditions carried out in the last century, and few other occasional contributions, the MZUSP is one of the most representative collections in terms of the number of specimens and species from Pará. Here, we present a complete list of the medium and large-sized mammal specimens from Pará state housed in the MZUSP, commenting about the taxonomy, conservation status of the species and other noteworthy associated information.

## MATERIAL AND METHODS

We surveyed and listed all specimens from Pará state, Brazil, housed in the MZUSP, including both wild and domestic species. For each specimen, we catalog the preserved parts such as skin, skull and/or skeleton. We transcribed the information on the species name, collection locality and sex present on the specimens labels as well as the handwritten, typed and digitized specimens catalogs held in the MZUSP. Furthermore, we reidentified all specimens.

We consider species belonging to the orders Cingulata, Pilosa, Sirenia, Carnivora, Artiodactyla, Perissodactyla, and Primates as medium and large-sized mammals, as well as some conspicuous and larger species of the orders Didelphimorphia (genera *Chironectes* Illiger, 1811, *Didelphis* Linnaeus, 1758, *Metachirus* Burmeister, 1854, and *Philander* Brisson, 1762), Lagomorpha (genus *Sylvilagus* Gray, 1867) and Rodentia (genera *Hydrochoerus* Brisson, 1762, *Cuniculus* Brisson, 1762, *Dasyprocta* Illiger, 1811, *Myoprocta* Thomas, 1903, and *Coendou* Lacépède, 1799). For cetaceans, we included only coastal and freshwater species (genera *Inia* d'Orbigny, 1834 and *Sotalia* Gray, 1866). The taxonomy of the species follows the latest comprehensive revisions published for each taxon:

(a) Stein & Patton (2008), Cerqueira & Tribe (2008), Patton & Silva (2008), Gardner & Dagosto (2008), Brandão *et al.* (2015), and Voss *et al.* (2018, 2019) for the large species of didelphids (*Chironectes*, *Didelphis*, *Metachirus*, and *Philander*);

(b) Wetzel *et al.* (2008) and Gardner (2008) for the orders Cingulata and Pilosa, respectively, except in the following cases: the armadillos are classified in the families Dasypodidae and Chlamyphoridae (Delsuc *et al*., 2016; Gibb *et al*., 2016); the taxonomic arrangements for long-nosed armadillos (*Dasypus* Linnaeus, 1758), proposed by Feijó & Cordeiro-Estrela (2016) and Feijó *et al.* (2018), and for silky anteaters (*Cyclopes* Gray, 1821), proposed by Miranda *et al.* (2017); the use of the name Choloepodidae instead of Megalonychidae for living two-toed sloths (*Choloepus* Illiger, 1811), as proposed by Delsuc *et al.* (2019);

(c) Shoshani (2005) and Grubb (2005a) for Sirenia and Perissodactyla, respectively;

(d) Wozencraft (2005) for Carnivora, except for Felidae, which we follow Segura *et al.* (2013) and Kitchener *et al.* (2017) in using *Herpailurus* Severtzov, 1858 as the generic name for the jaguarundi, and Nascimento & Feijó (2017) for the taxonomy of the *Leopardus tigrinus* (Schreber, 1775) species group;

(e) Grubb (2005b) for Artiodactyla, except for Cervidae, which we adopted the arrangement proposed by Duarte & González (2010), and for Tayassuidae (Acosta *et al*., 2020). Moreover, we keep the name Artiodactyla for the clade containing terrestrial artiodactyls and cetaceans, following Asher & Helgen (2010). For the taxonomy of cetacean species, we follow Silva, V. & Martin (2014) for *Inia*, and Caballero *et al.* (2007, 2008, 2010) for *Sotalia*;

(f) Mittermeier *et al.* (2013) for Primates, with the following updates: Garbino & Martins-Junior (2018) for the genus-group taxa of callitrichines; Silva Jr. (2001), Feijó & Langguth (2013), Garbino (2015), Gutiérrez & Marinho-Filho (2017), and Brandão *et al*. (2019) for the usage of *Cebus* Erxleben, 1777 and *Sapajus* Kerr, 1792 as subgenera of *Cebus*; Serrano-Villavicencio *et al*. (2017), Gutiérrez & Marinho-Filho (2017), Garbino & Aquino (2018), and Brandão *et al*. (2019) keeping *Callicebus* Thomas, 1903 for all titis and *Plecturocebus* Byrne, Rylands, Carneiro, Lynch-Alfaro, Bertuol, da Silva, Messias, Groves, Mittermeier, Farias, Hrbek, Schneider, Sampaio & Boubli, 2016 as its subgenus (contra Byrne *et al*., 2016); Mercês *et al.* (2015) for the eastern Amazonian populations of *Saimiri* Voigt, 1831; and Serrano-Villavicencio *et al*. (2019) and Hershkovitz (1987) for the saki taxa (*Pithecia* spp.) from Pará state (contra Marsh, 2014). See the contents of each primate species for more details on taxonomic issues;

(g) Ruedas (2017) and Ruedas *et al.* (2017) for *Sylvilagus* Gray, 1867;

(h) For rodents, we have adopted the taxonomic arrangements proposed by Dunnum (2015) for *Hydrochoerus*, Patton (2015) for *Cuniculus*, Patton & Emmons (2015) for *Dasyprocta* and *Myoprocta*, and Voss (2015) for *Coendou*.

We have included the conservation status of species based on the most recent assessments by the *Instituto Chico Mendes de Conservação da Biodiversidade – Ministério do Meio Ambiente do Brasil* (ICMBio, 2018) and the International Union for Nature Conservation (IUCN, 2019). The conservation status categories and their respective acronyms used here are: Least Concern (LC), Near Threatened (NT), Vulnerable (VU), Endangered (EN), Critically Endangered (CR), and Data Deficient (DD). We use Not Applicable (N/A) for taxa not identified at the species level or for domestic forms in a feral state, in the same manner as Brandão *et al*. (2019).

The geographical coordinates of the collection localities were obtained from gazetteers (Paynter Jr. & Traylor Jr., 1991; Vanzolini, 1992) and the MZUSP localities index, elaborated by Paulo Emílio Vanzolini (unpublished data). All localities and their geographical coordinates are presented in the gazetteer available in the Appendix 1. Additionally, a map was elaborated with inclusion of the collection localities of the specimens listed here, showing the range of geographical distribution across Pará state. Specimens with 'unknown locality' were certainly collected in Pará state, however, we could not define the exact locality.

## RESULTS AND DISCUSSION

### TAXONOMIC ACCOUNT AND LIST OF SPECIMENS

Order Didelphimorphia Gill, 1872
Family Didelphidae Gray, 1821

Genus *Chironectes* Illiger, 1811
*Chironectes minimus* (Zimmermann, 1780)

Common names: *cuíca-d'água* (Port.); water opossum (Eng.).

Records (1 locality and 22 specimens): Cametá, Rio Tocantins: MZUSP 4644 (skin and skull; female), 4654 (skin and skull; male), 4655–4656 (skin; male), 4657 (skin and skull; female), 4658 (skin and skull; male), 4659 (skin and skull; female), 4669–4670 (skin and skull; female), 4671 (skin; female), 4672–4673 (skin and skull; female), 4674 (skin; unknown sex), 4755 (skin and skull; female), 4757 (skin; female), 4759 (skin; male), 4762 (skin and skull; female), 4837 (skin and skull; male), 5334 (skin; unknown sex), 16544 (skull; male), 16545 (skull; female), 16585 (skull; female).

Conservation status: ICMBio (2018): DD; IUCN (2019): LC.

Genus *Didelphis* Linnaeus, 1758
*Didelphis marsupialis* Linnaeus, 1758

Common names: *gambá-comum*, *gambá-de-orelha-preta*, *mucura*, *saruê*, *sarigueia* (Port.); common opossum, black-eared opossum (Eng.).

Records (19 localities and 256 specimens): Ananindeua: MZUSP 8558–8560 (skull; female), 8561 (skull; unknown sex), 8562 (skull; male), 8563 (skull; male), 8565 (skull; unknown sex), 16549 (skull; unknown sex), 17099–17112 (skull; unknown sex), 17114–17118 (skull; unknown sex); Belém: 16546 (skull; unknown sex), 16555 (skin and skull; unknown sex), 16558 (skin and skull; male), 16560–16561 (skin; female), 16562 (skin; male), 16563 (skin; female), 17098 (skull; unknown sex), 17390 (skull; unknown sex), 17392 (skull; unknown sex), 19090 (skull; unknown sex), 19099–19103 (skull; unknown sex), 19111–19112 (skull; unknown sex), 19206 (skull; unknown sex), 19277 (skull; unknown sex), 19293 (skull; unknown sex), 19343 (skull; unknown sex), 19233 (skull; unknown sex), 19358 (skull; unknown sex); Boa Fé, Parque Nacional do Tapajós: 11867 (skin, skull and partial skeleton; female); BR-010, km 87-94: 17132 (skull; unknown sex), 17134–17135 (skull; unknown sex), 17138 (skull; unknown sex), 17140–17142 (skull; unknown sex), 17145–17150 (skull; unknown sex), 17153–17154 (skull; unknown sex), 17157–17165 (skull; unknown sex), 17167–17169 (skull; unknown sex), 17171–17173 (skull; unknown sex), 17176 (skull; unknown sex), 17178–17180 (skull; unknown sex), 17182–17190 (skull; unknown sex), 17192–17193 (skull; unknown sex), 17200–17203 (skull; unknown sex), 17205 (skull; unknown sex), 17207 (skull; unknown sex), 17238–17277 (skull; unknown sex); BR-010, km 92: 19092–19098 (skull; unknown sex), 19190–19208 (skull; unknown sex), 19234–19242 (skull; unknown sex), 19250 (skull; unknown sex), 19254–19265 (skull; unknown sex), 19267–19279 (skull; unknown sex), 19285 (skull; unknown sex), 19341 (skull; unknown sex), 19344–19348 (skull; unknown sex), 19350–19351 (skull; unknown sex), 19353–19355 (skull; unknown sex); BR-010, km 93: 8971 (skin and skull; male); Cachoeira do Espelho, Rio Xingu: 21311 (skin and skull; female), 21312 (skin and skull; male), 21313 (skull and skeleton; female), 21315 (skin, skull and skeleton; female); Cametá, Rio Tocantins: 4741 (skin and skull; male), 4742 (skin and skull; female), 4746 skin and skull; female), 4747 (skin and skull; male), 4748 (skin and skull; female), 4765–4766 (skin and skull; male), 4782 (skin and skull;

female), 4784 (skin and skull; male), 10581 (skull; male), 10585 (skull; female), 10586 (skull; male), 10593 (skull; female), 10594 (skull; male), 10596 (skull; male), 20078 (skull; unknown sex); Capim: 19091 (skull; unknown sex); Caxiricatuba, Rio Tapajós: 4768 (skin and skull; female), 4786 (skin and skull; male), 4787 (skin; female), 4788 (skin and skull; male), 10589 (skull; male), 10595 (skull; female), 16547 (skull; female); Fordlândia: 12871 (skin and skull; female), 12872 (skin and skull; female); Igarapé Bravo, Rio Amazonas: 4781 (skin; male); Igarapé São José, near Itaituba: 11866 (skin, skull and partial skeleton; female); Pau de Letra, Rio Tapajós: 4743 (skin and skull; male), 4783 (skin and skull; male); Piquiatuba, Rio Tapajós: 10587 (skull; male); Santarém, Fazenda Marucu: 3653 (skull; unknown sex); São Miguel do Guamá: 8972 (skin and skull; female); Transamazônica km 15, near Itaituba: 11868 (skin; female), 11869 (skin and skull; male); Vila Bravo, Rio Tocantins: 13474–13475 (skull; unknown sex).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC.

### Genus *Metachirus* Burmeister, 1854

#### *Metachirus myosuros* (Temmink, 1824)

Common names: *cuíca-de-quatro-olhos*, *cuíca-marrom*, *jupati* (Port.); brown four-eyed opossum (Eng.).

Records (10 localities and 51 specimens): BR-010, km 87: MZUSP 17018 (skin and skull; female); BR-010, km 87-94: 17156 (skull; unknown sex), 17170 (skull; unknown sex), 17174 (skull; unknown sex), 17177 (skull; unknown sex), 17181 (skull; unknown sex); BR-010, km 92: 19116 (skull; unknown sex), 19246 (skull; unknown sex), 19251–19252 (skull; unknown sex), 19281–19282 (skull; unknown sex), 19298–19303 (skull; unknown sex), 19305–19308 (skull; unknown sex), 19312 (skull; unknown sex), 19342 (skull; unknown sex), 19352 (skull; unknown sex), 19357 (skull; unknown sex), 20039 (skull; unknown sex); Capim, BR-010, km 94: 17019 (skin; female), 17020–17021 (skin and skull; female); Belém: 9782 (skin and skull; male), 9937 (skin and skull; female), 17022 (skin, skull and skeleton; female), 17023 (skull and skeleton; female), 17195 (skull; unknown sex), 17395 (skull; female), 19117 (skull; unknown sex), 19280 (skull; unknown sex), 19290–19291 (skull; unknown sex), 19309 (skull; unknown sex), 19311 (skull; unknown sex); Cachoeira do Espelho, Rio Xingu: 21305 (skin, skull and skeleton; male), 21334 (skin, skull and skeleton; female); Fordlândia: 17024 (skin and skull; male); Juruá, Rio Xingu: 25731 (in alcohol; female), 25732 (in alcohol; three fetuses of female 25731), 25733 (in alcohol; unknown sex); Piquiatuba, Rio Tapajós: 4527 (skin and skull; male); São Miguel do Guamá: 8964 (skin and skull; male), 8965 (skin and skull; female).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC.

Comments: a single species, *M. nudicaudatus* (É. Geoffroy, 1803), with five subspecies in South America has been traditionally recognized in the genus (Gardner & Dagosto, 2008). However, a recent study based on morphologic and molecular data has suggested the existence of more than a single species (Voss *et al.*, 2019). Furthermore, *M. nudicaudatus* was restricted to the populations of Guyana, French Guiana, Suriname and the state of Amapá, in Brazil, while every other South American populations were provisionally placed in *M. myosuros* (Voss *et al.*, 2019). The specimens of *Metachirus* present in the MZUSP collection are from localities south of the Rio Amazonas and they show the diagnostic characters of *M. myosuros* indicated by Voss *et al.* (2019), such as a small maxillopalatine fenestrae, large entoconids, strongly convergent temporalis and sagittal crest usually present.

### Genus *Philander* Brisson, 1762

#### *Philander opossum* (Linnaeus, 1758)

Common names: *cuíca-de-quatro-olhos*, *cuíca-verdadeira* (Port.); gray four-eyed opossum (Eng.).

Records (12 localities and 89 specimens): Ananindeua: MZUSP 17113 (skull; unknown sex); Belém: 9943 (skin and skull; male), 17066 (skin; male), 17197–17198 (skull; unknown sex), 17199 (skull; unknown sex), 17391 (skull;

unknown sex), 19114–19115 (skull; unknown sex), 19243 (skull; unknown sex), 19247–19249 (skull; unknown sex), 19288 (skull; unknown sex), 19292 (skull; unknown sex), 19294 (skull; unknown sex), 19295–19296 (skull; unknown sex), 19356 (skull; unknown sex); Boiuçu: 4540 (skin and skull; female); BR-010, km 87: 17027 (skin; male), 19310 (skull; unknown sex); BR-010, km 87-94: 17152 (skull; unknown sex), 17155 (skull; unknown sex), 17175 (skull; unknown sex), 17204 (skull; unknown sex), 17206 (skull; unknown sex), 17278–17282 (skull; unknown sex); BR-010, km 92: 19113 (skull; unknown sex), 19244–19245 (skull; unknown sex), 19266 (skull; unknown sex), 19283–19284 (skull; unknown sex), 19286–19287 (skull; unknown sex), 19289 (skull; unknown sex), 19297 (skull; unknown sex), 19349 (skull; unknown sex); BR-010, km 94: 17026 (skin and skull; female), 17028–17029 (skin and skull; male); Cachoeira do Espelho, Rio Xingu: 21306 (skin, skull and skeleton; female), 21307 (skin and skull; male), 21308 (skin, skull and skeleton; female), 21309–21310 (skin, skull and skeleton; male), 21314 (skull and skeleton; male); Cametá, Rio Tocantins: 4535–4538 (skin; female), 4539 (skin; male), 4542 (skin and skull; male), 4543 (skin and skull; female), 4544–4646 (skin; male), 4648–4650 (skin; female), 4651 (skin and skull; male), 4652 (skin and skull; female), 4653 (skin and skull; male), 9941 (skin; male), 17031 (skull; male), 17063 (skull; male), 17064–17065 (skull; female), 17069 (skull; male), 17070 (skull; female), 17071–17072 (skull; male), 17073 (skull; female), 20079 (skull; unknown sex); Fordlândia: 17030 (skin and skull; female); Igarapé Taperebá, Ilha de Marajó: 8679 (skin, skull and skeleton; male); Rio Bacajá (mouth): 25454 (skin, skull and skeleton; male); São Miguel do Guamá: 8966 (skin and skull; male), 8967 (skin and skull; female), 8968–8969 (skin and skull; male), 8970 (skin and skull; female); Vila Bravo, Rio Tocantins: 13478 (skin and skull; unknown sex), 13479 (unknown sex).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC. The recent taxonomic changes (see Comments) were not included in the latest conservation assessments by ICMBio (2018) and IUCN (2019).

Comments: Voss *et al.* (2018) revised the genus *Philander*, recognizing eight species: *P. andersoni* (Osgood, 1913), *P. canus* (Osgood, 1913), *P. mcilhennyi* Gardner & Patton, 1972, *P. melanurus* (Thomas, 1899), *P. opossum*, *P. pallidus* (Allen, 1901), *P. pebas* Voss, Diaz-Nieto & Jansa, 2018 and *P. quica* (Temminck, 1824). According to them, *P. opossum* occurs in Guyana, French Guiana, Suriname and the Eastern Brazilian Amazon (Amapá, Pará, Roraima, and part of Amazonas states), east of the Rio Negro and Rio Madeira, on both banks of the Rio Amazonas.

## Order Cingulata Illiger, 1811

## Family Chlamyphoridae Bonaparte, 1850

### Genus *Euphractus* Wagler, 1830

*Euphractus sexcinctus* (Linnaeus, 1758)

Common names: *tatu-peba*, *tatu-peludo* (Port.); six-banded armadillo, yellow armadillo (Eng.).

Records (1 locality and 1 specimen): Cachimbo, Formiga: MZUSP 8035 (skin; male).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC.

### Genus *Priodontes* F. Cuvier, 1825

*Priodontes maximus* (Kerr, 1792)

Common names: *tatu-canastra*, *tatuaçu* (Port.); giant armadillo (Eng.).

Records (2 localities and 2 specimens): Reserva Biológica do Rio Trombetas: MZUSP 19995 (partial skull); Vila Bravo, Rio Tocantins: 13492 (skin, skull and skeleton).

Conservation status: ICMBio (2018): VU A2cd; IUCN (2019): VU A2cd.

## Family Dasypodidae Gray, 1821

### Genus *Dasypus* Linnaeus, 1758

*Dasypus beniensis* Lönnberg, 1942

Common names: *tatu-de-quinze-quilos* (Port.); greater long-nosed armadillo (Eng.).

Records (1 locality and 3 specimens): Capim, Rodovia BR-14, km 93: MZUSP 8950 (skin and skull; unknown sex); Tavio, Rio Tapajós: 19973–19974 (skull; female).

Conservation status: ICMBio (2018): LC (as *Dasypus kappleri*); IUCN (2019): LC (as *Dasypus kappleri*). The recent taxonomic changes (see Comments) were not included in the latest conservation assessments by ICMBio (2018) and IUCN (2019). Therefore, this species was classified by these agencies as *Dasypus kappleri*.

Comments: Feijó & Cordeiro-Estrela (2016) and Feijó *et al.* (2018) recently revalidated *D. beniensis* as full species, which traditionally was considered a junior synonym of *D. k. pastasae* (Thomas, 1901) (Cabrera, 1958; Gardner, 2005; Wetzel *et al.*, 2008). Placed in the subgenus *Hyperoambon* Peters, 1864 by Wetzel & Mondolfi (1979) and Feijó *et al.* (2019).

*Dasypus kappleri* Krauss, 1862

Common names: *tatu-de-quinze-quilos* (Port.); greater long-nosed armadillo (Eng.).

Records (1 locality and 1 specimen): As Pedras, Rio Cuminá-Miri: MZUSP 19967 (skin and skull; male).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC. The recent taxonomic changes (see Comments) were not included in the latest conservation assessments by ICMBio (2018) and IUCN (2019).

Comments: traditionally *D. kappleri* has been considered a species with two subspecies, *D. k. kappleri* Krauss, 1862 and *D. k. pastasae* (Thomas, 1901) (Cabrera, 1958; Gardner, 2005; Wetzel *et al.*, 2008), but Feijó & Cordeiro-Estrela (2016) and Feijó *et al.* (2018) raised them as full species and revalidated *D. beniensis* (above), formerly junior synonym of *D. k. pastasae*. Placed in the subgenus *Hyperoambon* Peters, 1864 by Wetzel & Mondolfi (1979) and Feijó *et al.* (2019).

*Dasypus novemcinctus* Linnaeus, 1758

Common names: *tatu-galinha*, *tatuetê* (Port.); nine-banded armadillo, long-nosed armadillo (Eng.).

Records (13 localities and 15 specimens): Alegre, 15 km NE Marapanim: MZUSP 19982 (skull; unknown sex); Bagagem, Rio Tocantins: 13485 (skin and skull; unknown sex); Cachimbo: 8073 (skin and skull; male), 19970 (skin and skull; unknown sex); Cachoeira do Espelho, Rio Xingu: 20923 (skin and skull; male), 20924 (skin and skull; female), 21301 (skin and skull; female); Caxiricatuba, Rio Tapajós: 5113 (skin and skull; female); Fordlândia: 19969 (skin and skull; female); Igarapé Jaramacaru: 19980 (skin; unknown sex); Piquiatuba, Rio Tapajós: 5112 (skin and skull; male); Rio Curuá (mouth): 5110 (skin; female); Transamazônica km 50, near Itaituba: 19965 (skin and skull; male); Transamazônica km 62, near Itaituba: 19981 (skull; unknown sex); Transamazônica km 75, near Itaituba: 19966 (partial skin; unknown sex).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC.

Comments: *D. novemcinctus* has been traditionally treated as a polytypic species, with the number of recognized subspecies varying among different authors (Cabrera, 1958; Hall, 1981; McBee & Baker, 1982; Gardner, 2005). However, Wetzel & Mondolfi (1979) and Feijó *et al.* (2018) did not recognize any intraspecific subdivisions, and these later authors suggested that a comprehensive study to test geographic races is still needed. *Dasypus novemcinctus* was placed in the subgenus *Dasypus* by Feijó *et al.* (2019), together with *D. pilosus* (Fitzinger, 1856), *D. mazzai* Yepes, 1933, *D. sabanicola* Mondolfi, 1968 and an undescribed species from the Guianas.

*Dasypus septemcinctus* Linnaeus, 1758

Common names: *tatu-galinha-pequeno*, *tatu-china*, *tatuí* (Port.); Brazilian lesser long-nosed armadillo, seven-banded armadillo (Eng.).

Records (3 localities and 3 specimens): Cachimbo: MZUSP 8111 (skin and skull; male); Soure, Fazenda Teso, Ilha de Marajó: 9970 (skin; unknown sex); Cametá, Rio Tocantins: 5111 (skin and skull; male).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC.

Comments: Feijó *et al.* (2018) recognized three subspecies: *D. s. septemcinctus* Linnaeus, 1758, *D. s. hybridus* (Desmarest, 1804) and *D. s. cordobensis* Feijó, Patterson & Cordeiro-Estrela, 2018; the former occurring from the Amazon Basin to northern Argentina. Placed in subgenus *Muletia* Gray, 1874 by Feijó *et al.* (2019).

### Order Pilosa Flower, 1883

### Suborder Folivora Delsuc, Catzeflis, Stanhope & Douzery, 2001

### Family Bradypodidae Gray, 1821

### Genus *Bradypus* Linnaeus, 1758

*Bradypus tridactylus* Linnaeus, 1758

Common names: *preguiça-de-bentinho*, *preguiça-de-três-dedos* (Port.); pale-throated sloth (Eng.).

Records (1 locality and 1 specimen): Igarapé Bravo, Rio Amazonas: 5302 (skin and skull; female).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC.

*Bradypus variegatus* Schinz, 1825

Common names: *preguiça-comum*, *preguiça-de-garganta-marrom*, *preguiça-de-três-dedos* (Port.); brown-throated sloth (Eng.).

Records (16 localities and 159 specimens): Aveiro: MZUSP 13504 (skin; female), 20003 (skull; female); Barreira, Rio Tapajós: 13507 (skin; female), 13509 (skin; female), 20005 (skull; female), 20006 (skull; female); Belém: 10660–10661 (skin and skull; female), 10663–10665 (skin and skull; male), 10666–10669 (skin and skull; female), 13510 (skin and skull; female), 23486–23598 (skull; unknown sex); Cachoeira do Espelho, Rio Xingu: 21327 (skin, skull and skeleton; female); Cametá, Rio Tocantins: 5429 (skin and skull; male), 5431 (skin and skull; female), 5432 (skin and skull; male), 5433 (skin; male), 5434 (skin and skull; female), 7118–7119 (skull; female), 13517 (skin and skull; male), 19918 (skull; female), 25209 (skin and skull; female); Caxiricatuba, Rio Tapajós: 5427 (skin and skull), 5430 (skin; unknown sex), 19914 (skin and skull; female), 19917 (skull; female); Fordlândia: 13515 (skeleton; female), 13495–13496 (skin and skull; female), 13497 (skin and skull; unknown sex), 13498 (skin and skull; male), 13499 (skin and skull; female), 13501–13502 (skin and skull; male); Igarapé São José, near Itaituba: 19902 (skull; unknown sex); Piquiatuba, Rio Tapajós: 5426 (skin and skull; female); Ilha de Santa Helena, Rio Pará: 13512 (skin and skull; female); Santarém, Alter do Chão: 19911 (formalina; unknown sex); Santarém, Fazenda Marucu: 3649–3650 (skin and skull; male); São Luís, Rio Tapajós: 13508 (skin; female), 20004 (skull; unknown sex); Transamazônica km 58, near Itaituba: 19929 (skin; unknown sex).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC.

### Family Choloepodidae Gray, 1871

### Genus *Choloepus* Illiger, 1811

*Choloepus didactylus* (Linnaeus, 1758)

Common names: *preguiça-real*, *preguiça-de-dois-dedos*, *unau* (Port.); Linnaeus's two-toed sloth (Eng.).

Records (6 localities and 8 specimens): Cachoeira do Espelho, Rio Xingu: MZUSP 21328 (skin, skull and skeleton; unknown sex); Cametá, Rio Tocantins: 5457 (skin; female), 5458 (skin; unknown sex), 19925 (skull; female); Morro da Terra Preta, Transamazônica km 60, near Itaituba: 19930 (skeleton; unknown sex); Óbidos: 3651 (skin and skull; male); Oriximiná: 19931 (skin; unknown sex); unknown locality: 8640 (skin; male) (ex-Zoo).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC.

Comments: two-toed sloths were classified together with *Bradypus* in Bradypodidae (Simpson, 1945; Cabrera, 1958) or in a distinct family Choloepodidae (Wetzel & Ávila-Pires, 1980). They have also been considered the living forms of the extinct family Megalonychidae (Wetzel, 1985; Gardner & Naples, 2008). This latter view has been widely accepted for decades, but recent molecular studies have pointed out that *Choloepus* is phylogenetically close to the extinct Mylodontidae (Delsuc *et al*., 2019; Presslee *et al*., 2019). Thus, *Choloepus* was classified into a separate family, Choloepodidae, as some previous authors have proposed.

### Suborder Vermilingua Illiger, 1811
### Family Cyclopedidae Pocock, 1924

### Genus *Cyclopes* Gray, 1821

*Cyclopes didactylus* (Linnaeus, 1758)

Common names: *tamanduaí* (Port.); common silky anteater, common pygmy anteater (Eng.).

Records (6 localities and 30 specimens): Arimateua, Rio Tocantins: MZUSP 19946 (skull; unknown sex); Belém: 8680 (skin, skull and skeleton; female), 8681 (skin, skull and skeleton; male), 24137 (skull; unknown sex); Igarapé Bravo, Rio Amazonas: 4696 (skin and skull; female); Cametá, Rio Tocantins: 4675–4678 (skin and skull; male), 4680 (skin and skull; male), 4681–4683 (skin and skull; female), 4684 (skin; male), 4685–4687 (skin and skull; female), 4689 (skin and skull; female), 4690 (skin; female), 4691–4692 (skin and skull; female), 4693–4695 (skin and skull, male), 4697 (skin and skull; female), 4698 (skin and skull; male), 4701 (skin and skull; female), 4702–4703 (skin; unknown sex), 19932 (skin, skull and skeleton; male).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC.

Comments: a recent taxonomic revision recognizes seven species rather than a single polytypic species of silky anteater (Miranda *et al.*, 2017). In this new arrangement, *C. didactylus* is the only species of the genus *Cyclopes* to have dorsal and ventral stripes clearly marked, and is found from eastern Venezuela, Trinidad, the Guianas, northeastern Brazilian Amazon (state of Pará, north of Rio Amazonas) towards states of Maranhão and Piauí, with a disjunct population in the northeastern Atlantic Forest (from the states of Rio Grande do Norte to Alagoas).

*Cyclopes xinguensis* Miranda, Casali, Perini, Machado & Santos, 2018

Common names: *tamanduaí* (Port.); Xingu silky anteater, Xingu pygmy anteater (Eng.).

Records (3 localities and 8 specimens): Caxiricatuba, Rio Tapajós: MZUSP 4700 (skin and skull; female); Fordlândia: 19934 (skin and skull; female), 19935 (skin and skull; male), 19936 (skin; female), 19937–19938 (skin and skull; female), 19939 (skin and skull; male); Santarém: 3691 (skin and skull; female).

Conservation status: ICMBio (2018): LC (as *Cyclopes didactylus*); IUCN (2019): LC (as *Cyclopes didactylus*). The recent taxonomic changes (see Comments) were not included in the latest conservation assessments by ICMBio (2018) and IUCN (2019). Therefore, this species was classified by these agencies as *Cyclopes didactylus*.

Comments: *Cyclopes xinguensis* has been described by Miranda *et al.* (2017), who characterized the species as having a grayish body color with a dorsal stripe clearly marked, yellow rump and pale yellowish venter (Miranda *et al*, 2017). It is found in the region south of the Rio Amazonas, east of the Rio Madeira and west of the Rio Xingu (Miranda *et al.*, 2017).

### Family Myrmecophagidae

### Genus *Myrmecophaga* Linnaeus, 1758

*Myrmecophaga tridactyla* Linnaeus, 1758

Common names: *tamanduá-bandeira*, *tamanduá-açu*, *tamanduá-cavalo*, *jurumim* (Port.); giant anteater (Eng.).

Records (1 locality and 1 specimen): Fordlândia: MZUSP 19958 (skin and skull; female).

Conservation status: ICMBio (2018): VU A2c; IUCN (2019): VU A2c.

### Genus *Tamandua* Gray, 1825

*Tamandua tetradactyla* (Linnaeus, 1758)

Common names: *tamanduá-mirim*, *tamanduá-de-colete*, *melete* (Port.); Southern tamanduá, collared anteater, lesser anteater (Eng.).

Records (13 localities and 38 specimens): Ananindeua: MZUSP 8566 (skin; unknown sex); Barreira, Rio Tapajós: 19959 (skin and skull; male); Belém: 23593–23594 (skull; unknown sex); Cachoeira do Espelho, Rio Xingu: 21329 (skin, skull and skeleton; male); Cametá, Rio Tocantins: 4979 (skin and skull; female), 5234 (skin and skull; male), 5236 (skin and skull; male), 5237–5239 (skin and skull; female), 5440 (skin and skull; female), 5442 (skin and skull; female), 5448–5449 (skin and skull; male), 5450 (skin; unknown sex), 5451 (skin and skull; male), 5452 (skin; male), 5453 (skin and skull; female), 10484 (skull; male), 19986 (skull; unknown sex); Capim, BR-010, km 93: 8999 (skin and skull; male); Caxiricatuba, Rio Tapajós: 4977 (skin; female), 5240 (skin and skull; female); Fordlândia: 19951 (skin and skull; male), 19952–19954 (skin and skull; female), 19960–19962 (skin and skull; female), 19972 (skin and skull; female), 20002 (skull and skeleton); Lago Jacaré, Rio Trombetas: 10708 (skin and skull; female); Óbidos: 3652 (skin and skull; female); Piquiatuba, Rio Tapajós: 5456 (skin and skull; male); Rio Curuá (mouth): 5454 (skin and skull; female); Santo Antônio, Rio Tocantins: 13484 (skin and skull; unknown sex).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC.

Comments: *T. tetradactyla* presents body-color with great geographical variation, especially the vest (Wetzel, 1975). Most specimens from Pará in the MZUSP have a yellow body with a black or dark brown vest. However, one individual (MZUSP 3652) has the yellow body color with partial fading black vest, with a grayish appearance due to black hair with yellowish tips, while two others (MZUSP 5138 and 10708) are entirely yellow and without the vest. There are no records of melanistic specimens in the MZUSP collection.

Order Sirenia Illiger, 1811

Family Trichechidae Gill, 1872

Genus *Trichechus* Linnaeus, 1758

*Trichechus inunguis* (Natterer, 1883)

Common names: *peixe-boi-da-amazônia*, *manati* (Port.); Amazonian manatee (Eng.).

Records (3 localities and 3 specimens): Lago Sapucuá, Rio Trombetas: MZUSP 19535 (skull and skeleton; unknown sex); Óbidos: 19545 (skull and skeleton; male); Oriximiná: 19544 (skull and skeleton; unknown sex).

Conservation status: ICMBio (2018): VU A4cd; IUCN (2019): VU A3cd.

Order Carnivora Bowdich, 1821

Suborder Caniformia Kretzoi, 1943

Family Canidae Fischer, 1817

Genus *Atelocynus* Cabrera, 1940

*Atelocynus microtis* (Sclater, 1883)

Common names: *cachorro-do-mato-de-orelhas-curtas*, *raposa-de-orelhas-pequenas* (Port.); short-eared dog, short-eared zorro, small-eared dog (Eng.).

Records (2 localities and 5 specimens): Fordlândia: MZUSP 19751 (skin, skull and skeleton; male), 19752 (skin, skull and skeleton; female), 19753 (skin and skull; male), 19754 (skin and skull; male); Morro da Terra Preta, Transamazônica km 60, near Itaituba: 19750 (skull and partial skeleton).

Conservation status: ICMBio (2018): VU A2c; IUCN (2019): NT.

Genus *Cerdocyon* C.E.H. Smith, 1839

*Cerdocyon thous* (Linnaeus, 1766)

Common names: *cachorro-do-mato*, *lobinho*, *lobete* (Port.); crab-eating fox (Eng.).

Records (2 localities and 2 specimens): Canaã dos Carajás: MZUSP 34778 (skull; unknown sex); unknown locality: 2762 (skull; unknown sex).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC.

Comments: the oldest MZUSP specimen from Pará is MZUSP 2762, already identified as *Cerdocyon thous* and collected in 1909. Originally, this specimen was a stuffed animal with a separated skull; however, only the skull was found.

### Family Procyonidae Gray, 1825

#### Genus *Nasua* Storr, 1780

*Nasua nasua* (Linnaeus, 1766)

Common names: *quati*, *quati-de-cauda-anelada*, *quati-de-nariz-marrom* (Port.); South American coati, ring-tailed coati (Eng.).

Records (15 localities and 28 specimens): Baixo Amazonas: MZUSP 19785 (skin; unknown sex); Igarapé Bravo, Rio Amazonas: 5540 (skin and skull; female); Cachimbo: 8034 (skin; female); Cachoeira do Espelho, Rio Xingu: 20926 (skin and skull; male), 21333 (skin, skull and skeleton; female); Cametá, Rio Tocantins: 5233 (skin; female), 5242 (skin and skull; male), 7157 (skull; female); Caxiricatuba, Rio Tapajós: 5228 (skin and skull; female), 5230 (skin and skull; female), 5247 (skin and skull; female), 5251 (skin and skull; female); Fordlândia: 19777 (skin and skull; female), 19781 (skin and skull; female), 19783 (skin and skull; male), 19784 (skin and skull; female); Ilha do Limão, Rio Xingu: 25456 (skin, skull and skeleton; male); Itaituba: 24834 (skull; unknown sex), 24835 (skull; male); Monte Cristo, Rio Tapajós: 19773 (skin and skull; female); Piquiatuba, Rio Tapajós: 5241 (skin; female); Rio Curuá (mouth): 5246 (skin and skull; female); Santarém, Fazenda Marucu: 3648 (skin; male); Sumaúma, Rio Tapajós: 19765 (skin and skull; male), 19768 (skin and skull; female); Urucurituba, Rio Tapajós: 19778–19779 (skin and skull; female), 19780 (skin and skull; male).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC.

#### Genus *Potos* É Geoffroy & F.G. Cuvier, 1795

*Potos flavus* (Schreber, 1774)

Common names: *jupará*, *jurupará*, *macaco-da-noite* (Port.); kinkajou (Eng.).

Records (5 localities and 7 specimens): Belém: MZUSP 8645 (skin; male); Cachoeira do Espelho, Rio Xingu: 21330 (skin, skull and skeleton; female); Cametá, Rio Tocantins: 5534 (skin and skull; male), 5563 (skin and skull; female), 5564(skin; male); Capim: 8951 (skin and skull, female); Fordlândia: 12000 (skin and skull; male).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC.

#### Genus *Procyon* Storr, 1780

*Procyon cancrivorus* (G. Cuvier, 1798)

Common names: *mão-pelada*, *guaxinim*, *jaguacinim* (Port.); crab-eating raccoon, South American raccoon (Eng.).

Records (2 localities and 2 specimens): Cametá, Rio Tocantins: MZUSP 5559 (skin and skull; female); Fordlândia: 19794 (skin and skull; male).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC.

### Family Mustelidae Fischer, 1817

#### Genus *Eira* C.E.H. Smith, 1842

*Eira barbara* (Linnaeus, 1758)

Common names: *irara*, *papa-mel*, *jaguapé* (Port.); tayra (Eng.).

Records (9 localities and 30 specimens): Boiuçu: MZUSP 5183 (skin and skull; female), 5186 (skin and skull; female), 5195 (skin and skull; female); Caxiricatuba, Rio Tapajós: 5184 (skin and skull; male), 5187 (skin and skull; male), 5190 (skin, female), 5275 (skin and skull; male), 19845 (skull; female); Fordlândia: 10143 (skin and skull; female), 10144 (skin and skull; male), 10145 (skin and skull; female), 19798 (skull and skeleton; male), 19800–19801 (skin and skull; female), 19803 (skin and skull; female), 19804 (skin and skull; male), 19805–19806 (skin and skull; female), 19808–19809 (skin and skull; female), 19810 (skin and skull; male), 19811–19812 (skull; unknown sex), 19813 (skull and skeleton; female); Óbidos: 3672 (skin and skull; female);

Rio Tapajós: 19825 (skin; unknown sex); Tauari, Rio Tapajós: 19799 (skin and skull; female); Urucurituba, Rio Tapajós: 19802 (skin and skull; female), 19807 (skin and skull; male); unknown locality: 8642 (skin, skull and skeleton; female).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC.

Comments: all specimens in the MZUSP have the typical coat color pattern, *i.e.*, trunk, limbs, and tail black or dark brown contrasting with light-colored head and neck (grayish bronze, grayish brown or light yellow), except one individual, MZUSP 5186 (from Boiuçu), which has the body entirely whitish-yellow. Entirely dark specimens are not represented in the MZUSP collection.

### Genus *Galictis* Bell, 1826

*Galictis vittata* (Schreber, 1776)

Common names: *furão*, *furão-grande* (Port.); greater grison (Eng.).

Records (3 localities and 3 specimens): Belém: MZUSP 19826 (skin and skull; female); Brasília Legal, Rio Tapajós: 19824 (skin; female); Sumaúma, Rio Tapajós: 19823 (skin; male).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC.

Comments: genus *Galictis* revised by Bornholdt *et al.* (2013). *Galictis vittata* distinguishes from its sister species, *G. cuja* (Molina, 1782), by its shorter fur, larger body size and presence of metaconid in the m1 (Yensen & Tarifa, 2003a, 2003b; Bornholdt *et al.*, 2013).

### Genus *Mustela* Linnaeus, 1758

*Mustela africana* Desmarest, 1818

Common names: *doninha-amazônica* (Port.); Amazon weasel, tropical weasel (Eng.).

Records (3 localities and 3 specimens): Icoaraci: MZUSP 6632 (skin; female); Tauari, Rio Tapajós: 19828 (skin; male); unknown locality: 24837 (skin; male).

Conservation status: ICMBio (2018): DD; IUCN (2019): LC.

Comments: there is scarce information regarding this species in the literature, with only a few specimens known to exist worldwide, collected mainly in the early 20th century (Oliveira, T., 2009; Ramírez-Chaves *et al.*, 2014). According to the Global Biodiversity Information Facility (GBIF, 2019), only 31 specimens are housed in mammals' collections from Europe, USA, and Brazil. Thus, the specimens preserved at the MZUSP have a high scientific value for this poorly sampled species.

### Genus *Pteronura* Gray, 1837

*Pteronura brasiliensis* (Zimmerman, 1780)

Common names: *ariranha*, *lontra-gigante*, *onça-d'água* (Port.); giant otter, giant river otter (Eng.).

Records (1 locality and 1 specimen): Cachimbo: MZUSP 8061 (skin and skull; male).

Conservation status: ICMBio (2018): VU A3cd; IUCN (2019): EN A3ce.

## Suborder Feliformia Kretzoi, 1945

## Family Felidae Fischer, 1817

### Genus *Herpailurus* Severtzov, 1858

*Herpailurus yagouaroundi* (É. Geoffroy, 1803)

Common names: *jaguarundi*, *gato-mourisco* (Port.); jaguarundi (Eng.).

Records (4 localities and 7 specimens): Cametá, Rio Tocantins: MZUSP 5175–5176 (skin and skull; female); Fordlândia: 13598 (skin and skull; female), 13606 (skin and skull; female), 13607 (skin and skull; male); Óbidos: 3692 (skull; unknown sex); Puraquecuara, Rio Tocantins: 13481 (skin, skull and skeleton; unknown sex).

Conservation status: ICMBio (2018): VU C1; IUCN (2019): LC.

Comments: all specimens of jaguarundi from Pará state in the MZUSP are brownish or blackish gray, except for MZUSP 13598 (from Fordlândia), which has a reddish pelage.

### Genus *Leopardus* Gray, 1842

*Leopardus emiliae* (Thomas, 1914)

Common names: *gato-do-mato-pequeno*, *gato-do-mato-pequeno-do-norte*, *gato-macambira* (Port.); Eastern tigrina, Snethlage's tigrina (Eng.).

Records (1 locality and 1 specimen): Terra Santa, Rio Jamari: MZUSP 13605 (skin, skull and skeleton; female).

Conservation status: ICMBio (2018): EN C2 (as *Leopardus tigrinus*); IUCN (2019): VU A2c (as *Leopardus tigrinus*).

Comments: previously considered a junior synonym of *L. tigrinus* (Schreber, 1775), Eastern or Snethlage's tigrina has been raised to species rank by Nascimento & Feijó (2017).

*Leopardus pardalis* (Linnaeus, 1758)

Common names: *jaguatirica*, *maracajá-açu* (Port.); ocelot (Eng.).

Records (5 localities and 6 specimens): As Pedras, Rio Cuminá-Miri: MZUSP 13595 (skull and skeleton; unknown sex); Curuá, Lago Cuiteuá, Rio Amazonas: 5553 (skin and skull; male); Ponta de Pedras, Ilha de Marajó: 29025 (skin; male); Vila Bravo, Rio Tocantins: 13470 (skin and skull; unknown sex); unknown Locality: 8633–8634 (skin, skull and skeleton; male).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC.

*Leopardus wiedii* (Schinz, 1821)

Common names: *maracajá*, *maracajá-mirim*, *gato-peludo* (Port.); margay (Eng.).

Records (2 localities and 4 specimens): Anajás: MZUSP 13604 (skin; male); Cametá, Rio Tocantins: 5560 (skin and skull; male), 5561 (skull; male), 5562 (skin and skull; male).

Conservation status: ICMBio (2018): VU C1; IUCN (2019): NT.

### Genus *Puma* Jardine, 1834

*Puma concolor* (Linnaeus, 1771)

Common names: *suçuarana*, *onça-parda*, *onça-vermelha*, *puma* (Port.); cougar, mountain lion, puma (Eng.).

Records (2 localities and 2 specimens): Serra do Cachimbo: MZUSP 8121 (skin and skull; female); Transamazônica km 46: 24904 (skull; unknown sex).

Conservation status: ICMBio (2018): VU C1; IUCN (2019): LC.

### Genus *Panthera* Oken, 1816

*Panthera onca* (Linnaeus, 1758)

Common names: *onça-pintada*, *jaguar*, *jaguaretê* (Port.); jaguar (Eng.).

Records (3 localities and 4 specimens): Taperinha: MZUSP 3685 (skin and skull; male), 3686 (skull; male); Transamazônica km 100: 13596 (mandible and skeleton); Vila Bravo, Rio Tocantins: 13493 (skin, skull and skeleton; unknown sex).

Conservation status: ICMBio (2018): VU A2bcd+3cd; C1; IUCN (2019): NT.

## Order Artiodactyla Owen, 1848

## Suborder Ruminantia Scopoli, 1777

## Infraordem Pecora Flower, 1883

## Family Bovidae Gray, 1821

### Genus *Bubalus* C.E.H. Smith, 1827

*Bubalus bubalis* (Linnaeus, 1758)

Common names: *búfalo-d'água*, *búfalo-asiático* (Port.); water buffalo, domestic water buffalo (Eng.).

Records (1 locality and 1 specimen): Ilha de Marajó: no record number (horns; unknown sex).

Conservation status: N/A.

Comments: species introduced in the region in the last decade of the 19th century, with populations currently living in a semi-feral state (Tiepolo & Tomas, 2011).

## Family Cervidae Goldfuss, 1820

### Genus *Mazama* Rafinesque, 1817

*Mazama americana* (Erxleben, 1777)

Common names: *veado-mateiro*, *veado-vermelho*, *veado-pardo*, *suaçupita* (Port.); red brocket deer (Eng.).

Records (7 localities and 13 specimens): Cachimbo: MZUSP 8039 (skin; female); Caxiricatuba, Rio Tapajós: 5483 (skin; female); Capim, BR-010, km 94: 9627 (skin and skull; female), 9628 (skull; female), 9629 (skin and skull; female), 9630 (skin and skull; male), 9631 (skin and skull; female); Fordlândia: 13562 (skin and skull; female); Itaituba, Parque Nacional da Amazônia: 13570 (skull; male); Lago Jacaré, Rio Trombetas: 10713 (skin and skull; female); Vila Bravo, Rio Tocantins: 13494 (skull; unknown sex), 13516 (skin; unknown sex), 19996 (skull; unknown sex).

Conservation status: ICMBio (2018): DD; IUCN (2019): DD.

### *Mazama nemorivaga* (F. Cuvier, 1817)

Common names: *veado-roxo*, *fuboca* (Port.); Amazonian brown brocket deer, small brown brocket deer (Eng.).

Records (5 localities and 26 specimens): Caxiricatuba, Rio Tapajós: MZUSP 4994 (skin; male), 4995 (skin; unknown sex), 4997 (skin and skull; male), 4998–4999 (skin; female), 5177 (skin; female), 5260 (skin and skull; female), 5261 (skin and skull; male), 7163 (skull; female), 7165 (skull; male), 7263 (skin; unknown sex), 13559 (skull; male); Fordlândia: 10150 (skin and skull; female), 13563 (skin and skull; male), 13573 (skin and skull; female), 13575 (skin and skull; male), 13576 (skin and skull; female), 13577–13579 (skin and skull; male); Pimental: 19994 (skull; unknown sex); Rio Curuá-Una (mouth): 5262 (skin and skull; female); Tauari, Rio Tapajós: 13564 (skin and skull; male), 13565 (skin and skull; female), 13566 (skin and skull; male), 13567 (skin and skull; female).

Conservation status: ICMBio (2018): DD; IUCN (2019): LC.

## Suborder Suina Gray, 1868

## Family Tayassuidae Palmer, 1897

### Genus *Dicotyles* Cuvier, 1816

### *Dicotyles tajacu* (Linnaeus, 1758)

Common names: *caititu*, *cateto*, *porco-do-mato* (Port.); collared peccary (Eng.).

Records (7 localities and 9 specimens): Aruã, Rio Arapiuns: MZUSP 5339 (skin and skull; female); Cametá, Rio Tocantins: 5338 (skin and skull; female); Capim, BR-010, km 93: 8942 (skull; male); Ilha de Nova Olinda, Rio Tapajós: 20022 (skull; unknown sex); Rio Curuá (mouth): 5335 (skin; male), 5340 (skin and skull; female); Transamazônica km 80, near Itaituba: 20019 (skull; unknown sex); Vila Bravo, Rio Tocantins: 13488 (skin and skull; unknown sex), 13490 (skin and skull; unknown sex).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC.

Comments: Acosta *et al*. (2020) solved the nomenclatural issues involving peccaries and according to these authors the valid genus for the collared peccary is *Dicotyles* Cuvier, 1816, with *Pecari* Reichenbach, 1835 as its junior synonym.

### Genus *Tayassu* Fischer, 1814

### *Tayassu pecari* (Link, 1795)

Common names: *queixada*, *porco-do-mato* (Port.); white-lipped peccary (Eng.).

Records (6 localities and 15 specimens): Cachimbo: MZUSP 8087 (skull; female); Caxiricatuba, Rio Tapajós: 5437 (skin and skull; male), 5594 (skin and skull; male), 5597 (skin and skull; male), 5598 (skin; male), 5599 (skin and skull; male); Fordlândia: 20014 (skin and skull; male); Parque Nacional da Amazônia, Rio Tapajós: 20016 (skull; unknown sex), 20017 (skull; unknown sex); Uruá, Rio Tapajós: 20018 (skull; unknown sex), 20020 (mandible; unknown sex), 20021 (partial skull; unknown sex); Vila Bravo, Rio Tocantins: 13487 (skull; unknown sex), 13489 (skin and skull; unknown sex), 13491 (skin, skull and partial skeleton; female).

Conservation status: ICMBio (2018): VU A2abcde+3abcde; IUCN (2019): VU A2bcde+3bcde.

### Suborder Whippomorpha Wadell, Okada & Hasegawa, 1999

### Infraorder Cetacea Brisson, 1762

### Family Delphinidae Gray, 1821

### Genus *Sotalia* Gray, 1866

*Sotalia fluviatilis* (Gervais & Deville, 1853)

Common names: *tucuxi*, *pirajaguara*, *boto-preto* (Port.); tucuxi (Eng.).

Records (2 localities and 3 specimens): Lago Jacaré, Rio Trombetas: MZUSP 18946 (skull; female), 19913 (skull; unknown sex); Oriximiná: 18924 (skeleton; female).

Conservation status: ICMBio (2018): NT; IUCN (2019): DD.

*Sotalia guianensis* (Van Beneden, 1864)

Common names: *boto-cinza* (Port.); Guiana dolphin (Eng.).

Records (2 localities and 2 specimens): Maracanã, Ilha de Maiandeua, Algodoal: MZUSP 27383 (skull; unknown sex); Marapanim, Marudá: 28413 (partial skull; unknown sex).

Conservation status: ICMBio (2018): VU A3bcde; IUCN (2019): NT A2d+3d+4d.

### Family Iniidae Gray, 1846

### Genus *Inia* d'Orbigny, 1834

*Inia geoffrensis* (Blainville, 1817)

Common names: *boto*, *boto-cor-de-rosa*, *boto-rosa*, *boto-vermelho* (Port.); boto, Amazon river dolphin, pink river dolphin (Eng.).

Records (2 localities and 2 specimens): Lago Jacaré, Rio Trombetas: MZUSP 18871 (skull; male); Taperinha: 18883 (skull; female).

Conservation status: ICMBio (2018): EN A3cde; IUCN (2019): EN A2acd+3cd+4acd.

Comments: traditionally, a single polytypic species has been recognized for Amazonian river dolphins, but the number of subspecies is a matter of debate, with authors recognizing two subspecies *I. g. geoffrensis* and *I. g. boliviensis* (d'Orbigny, 1834) (Committee on Taxonomy, 2017), while others recognize a third *I. g. humboldtiana* Pilleri & Gihr, 1977 (Mead & Brownell Jr., 2005). Moreover, for some authors (Martínez-Agüero *et al.*, 2006) at least one of these subspecies (*I. g. boliviensis*) would be a full species. Recently some studies (Hrbek *et al.*, 2014; Siciliano *et al.*, 2016) have pointed out that the populations present in the Rio Araguaia Basin are a valid species, named *I. araguaiaensis* Hrbek, da Silva, Dutra & Farias, 2014, which is not represented in the MZUSP.

### Order Perissodactyla Owen, 1848

### Family Tapiridae Gray, 1821

### Genus *Tapirus* Brisson, 1762

*Tapirus terrestris* (Linnaeus, 1758)

Common names: *anta*, *tapir* (Port.); lowland tapir, South American tapir, Brazilian tapir (Eng.).

Records (3 localities and 5 specimens): Ilha da Nova Olinda, Rio Tapajós: MZUSP 20037 (skull; unknown sex); Lago Jacaré, Rio Trombetas: 10715 (skull; unknown sex), 20035 (skin and skull; female), 20036 (skin and skull; male); Transamazônica km 66, Parque Nacional da Amazônia: 20033 (skull; unknown sex).

Conservation status: ICMBio (2018): VU A2bcd+3bcd; IUCN (2019): VU A2cde+3cde.

Comments: Cozzuol *et al.* (2013) described a new species of tapir from Brazilian and Colombian Amazon, named as *Tapirus kabomani* Cozzuol, Clozato, Holanda, Rodrigues, Ienow, Thoisy, Redondo & Santos, 2013. However, the validity of this species has been questioned by some authors (Voss *et al*., 2014; Ruiz-García *et al*., 2016) due to morphologic and genetic similarities with *T. terrestris*. Thus, here we provisionally treat *T. kabomani* as a junior synonym for *T. terrestris*.

### Order Primates Linnaeus, 1758

### Suborder Haplorhini Pocock, 1918

## Family Cebidae Bonaparte, 1821
## Subfamily Callitrichinae Gray, 1821

### Genus *Mico* Lesson, 1840

*Mico argentatus* (Linnaeus, 1771)

Common names: *sagui-branco*, *sagui-argênteo* (Port.); silvery marmoset (Eng.).

Records (8 localities and 55 specimens): Cametá, Rio Tocantins: MZUSP 4833 (skin and skull; female), 4916 (skin and skull; female), 4967 (skin and skull; male), 4968 (skin and skull; female); Caxiricatuba, Rio Tapajós: 4829 (skin; female), 4865 (skin and skull; female), 4900 (skin and skull; male), 4901 (skin and skull; female), 4902 (skin; female), 4903 (skin; male), 4904 (skin and skull; female), 4906–4907 (skin and skull; female), 4908–4909 (skin and skull; male), 4911 (skin and skull; male), 4913 (skin and skull; female), 4940 (skin and skull; male), 4959 (skin and skull; female), 4964–4966 (skin and skull; male), 4969–4970 (skin and skull; male), 4972–4974 (skin and skull; male), 4975 (skin and skull; female), 5007 (skin and skull; male), 5026 (skin and skull; female), 11407 (skin and skull; male), 18865 (skull; female); Piquiatuba, Rio Tapajós: 4840 (skin and skull; male), 4899 (skin and skull; male), 4905 (skin and skull; female), 4910 (skin and skull; female), 4914 (skin and skull; female), 4915 (skin and skull; male), 4918 (skin and skull; male); Os Patos: 11367 (skin, skull and skeleton; female); Santarém: 6633 (skin; female); Santarém, Fazenda Marucu: 3588–3589 (skin and skull; female), 3590 (skull; female), 3591 (skin and skull; female), 3592 (skull; male), 3593 (skin and skull; male), 3594–3596 (skin and skull; female); Santarém: 4971 (skin and skull; male); Tauari, Rio Tapajós: 4313 (skin and skull; male), 11272 (skin and skull; male), 11307–11308 (skin and skull; male); unknown locality: 3587 (skull; unknown sex).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC.

*Mico humeralifer* (É. Geoffroy Saint-Hilaire, 1812)

Common names: *sagui-de-tufos* (Port.); black and white tassel-ear marmoset (Eng.).

Records (7 localities and 67 specimens): Arara, Rio Tapajós: MZUSP 11396 (skin; male); Barreira, Rio Tapajós: 11360 (skin and skull; male); Boim: 4927 (skin; female), 7108 (skull; female); Brasília Legal, Rio Tapajós: 11294 (skin and skull; male), 11298 (skin and skull; female), 11299 (skin and skull; male), 11300 (skin and skull; female), 11301 (skin and skull; female), 11306 (skin and skull; female), 11309–11310 (skin and skull; male), 11312 (skin and skull; female); Itaituba: 3577 (skin and skull; female), 3578–3580 (skin and skull; male), 3581 (skull; female), 3582 (skin and skull; male), 3583 (skull; male), 3584 (skin and skull; female), 3585–3586 (skin and skull; male); Monte Cristo, Rio Tapajós: 3597 (skull; male); Santa Rosa, Ilha de Urucurituba: 11397 (skin and skull; male), 11398 (skin and skull; female), 11399 (skin and skull; male), 11400 (skin and skull; female), 11401 (skin and skull; male); Sumaúma, Rio Tapajós: 11254 (skin and skull; male), 11264 (skin and skull; female), 11265–11266 (skin and skull; male), 11267 (skin and skull; unknown sex), 11268–11270 (skin and skull; male), 11271 (skin and skull; female), 11297 (skin and skull; male), 11302 (skin and skull; male), 11303–11304 (skin and skull; female), 11332 (skin and skull; male), 11333 (skin and skull; female); Transamazônica, km 62, near Itaituba: 18866 (skin and skull; male); Urucurituba, Rio Tapajós: 10095–10099 (skin and skull; male); 11249–11253 (skin and skull; male), 11255 (skin and skull; female), 11256 (skin and skull; male), 11257–11258 (skin and skull; female), 11259 (skin and skull; male), 11260 (skin and skull; female), 11261–11262 (skin and skull; male), 11263 (skin and skull; female), 11356–11358 (skin and skull; female).

Conservation status: ICMBio (2018): LC; IUCN (2019): DD.

*Mico leucippe* Thomas, 1922

Common names: *sagui-de-orelha-nua-branco* (Port.); white marmoset, golden-white bare-ear marmoset (Eng.).

Records (6 localities and 22 specimens): Fordlândia: MZUSP 10093 (skin and skull; male), 11248 (skin and skull; female), 11279–11280 (skin and skull; male), 11281 (skin and skull; female), 11291 (skin and skull; male), 11295–11296 (skin and skull; female), 11305 (skin and skull; female), 11311 (skin and skull; male); Fordlândia, Fazenda Nova: 11402 (skin; male), 11403 (skin and skull; female); Lago Araipá, Rio Tapajós: 9965 (skin; male); Monte Cristo, Rio Tapajós: 3598–3599 (skin and skull; male), 3600 (skin and skull; female), 3602–3603 (skin and skull; female), 11361 (skin and skeleton; female); Pedreira, Rio Tapajós: 9964 (skin; male); Tavio, Rio Tapajós: 10094 (skin and skull; female), 11394 (skin; male).

Conservation status: ICMBio (2018): LC; IUCN (2019): VU A2c.

### Genus *Saguinus* Hoffmannsegg, 1807
### Subgenus *Saguinus* Hoffmannsegg, 1807

*Saguinus midas* (Linnaeus, 1758)

Common names: *sagui-de-mãos-douradas*, *sagui-de-mãos-amarelas* (Port.); golden-handed tamarin, red-handed tamarin, Midas tamarin (Eng.).

Records (8 localities and 46 specimens): Boiuçu: MZUSP 4830 (skin and skull; female), 4834 (skin and skull; male), 4863 (skin and skull; male), 4868 (skin; male), 4869 (skin and skull; male), 4872 (skin and skull; female), 4877 (skin and skull; male), 4930 (skin and skull; male), 4935–4936 (skin and skull; male), 4941 (skin and skull; female), 4944 (skin and skull; female), 4948 (skin and skull; female), 5000 (skin and skull; male), 5013 (skin and skull; male), 5021 (skin and skull; female); Igarapé Bravo, Rio Amazonas: 4866 (skin and skull; female), 4867 (skin and skull; male), 4870 (skin and skull; female), 4871 (skin and skull; male), 4873–4875 (skin and skull; female), 4876 (skin and skull; male), 4878–4879 (skin and skull; male), 4958 (skin and skull; male), 4960 (skin and skull; female), 4961 (skin and skull; male), 4962 (skin; male), 4963 (skin and skull; female); Cacaoal Grande: 3604 (skin and skull; male), 3605 (skin and skull; female); Curuá, Lago Cuiteuá, Rio Amazonas: 4306 (skin; female); Óbidos: 3606–3607 (skin and skull; female), 3608–3610 (skin and skull; male), 3611–3612 (skull; male); Oriximiná: 11343–11344 (skin and skeleton; female); Paissandu, Igarapé Bom Jardim: 7170 (skull; female); Rio Cuminá-Miri (mouth): 11341 (skin and skull; male), 11342 (skin and skull; unknown sex).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC.

Comments: Gregorin & de Vivo (2013) examined two specimens (MZUSP 2867 and 7170) from Bom Jardim, Pará state, identifying them as *Saguinus ursula* Hoffmannsegg, 1807, but this locatity falls within the geographical distribution of *S. midas*. One of these specimens cited by Gregorin & de Vivo (2013), MZUSP 2867, was not found in the collection and this registration number is occupied by a *Didelphis aurita* Wied, 1826 (from Bauru, São Paulo state), which was discarded decades ago due to damages on the skin.

*Saguinus niger* (É. Geoffroy, 1803)

Common names: *sagui-una*, *sagui-preto* (Port.); Western black tamarin, Western black-handed tamarin (Eng.).

Records (5 localities and 24 specimens): Cametá, Rio Tocantins: MZUSP 4749 (skin; male), 4750 (skin and skull; male), 4790 (skin and skull; male), 4792–4793 (skin and skull; female), 4794 (skin and skull; male), 4795–4796 (skin and skull; female), 4825 (skin and skull; male), 4922 (skin and skull; male), 4926 (skin and skull; male), 4933 (skin and skull; female), 4937 (skin and skull; female), 4946 (skin and skull; male), 4950 (skin and skull; male), 4951 (skin and skull; female), 4954 (skin and skull; male), 4955 (skin and skull; female), 20042 (skin and skull; female); Cachoeira do Espelho, Rio Xingu: 21321 (skin and skeleton; female), 21322 (skin and skeleton; male); Rio Bacajá (mouth): 25447 (skin, skull and skeleton; male); Santana do Araguaia, Fazenda Fartura: 35403 (skin; female); Santo Antonio, Rio Tocantins: 13471 (skin and skull; unknown sex).

Conservation status: ICMBio (2018): VU A4c; IUCN (2019): VU A2c.

*Saguinus ursula* Hoffmannsegg, 1807

Common names: *sagui-una*, *sagui-preto* (Port.); Eastern black tamarin, Eastern black-handed tamarin (Eng.).

Records (2 localities and 43 specimens): Belém: MZUSP 10658 (skin and skull; female), 11247 (skin and skull; male), 19035–19061 (skull; unknown sex), 19076 (skull; unknown sex); BR-010, km 93: 8923–8928 (skin and skull; male), 8929–8933 (skin and skull; female), 8934 (skin and skull; male), 8935 (skin and skull; female).

Conservation status: ICMBio (2018): VU A4c (as part of *S. niger*); IUCN (2019): VU A2c (as part of *S. niger*). Due to its being recently split from *Saguinus niger*, this species was not included in the assessments of ICMBio (2018) and IUCN (2019).

Comments: this species was revalidated by Gregorin & de Vivo (2013). We follow Garbino & Martins-Junior (2018, p. 168) in using *Saguinus ursula* instead of *Saguinus ursulus* because "this species was named after a proper noun and treat it as a noun in apposition".

### Subfamily Cebinae Bonaparte, 1841

### Genus *Cebus* Erxleben, 1777

### Subgenus *Cebus* Erxleben, 1777

*Cebus* (*Cebus*) *kaapori* Queiroz, 1992

Common names: *caiarara*, *caiara* (Port.); Kaapori capuchin (Eng.).

Records (1 locality and 1 specimen): Bragança: MZUSP 8252 (skin and skull; unknown sex).

Conservation status: ICMBio (2018): CR A2acd; IUCN (2019): CR A2cd.

Comments: MZUSP 8252 was originally labeled and identified as *Cebus olivaceus nigrivittatus* (Wagner, 1848) by C.O.C. Vieira. However, it was considered as *C.* (*Cebus*) *kaapori* by Silva Jr. (2001). Furthermore, Silva Jr. *et al.* (2010) reported that the specimen was acquired at a street fair in Belém and the original locality, indicated as Bragança, is doubtful.

*Cebus* (*Cebus*) *unicolor* Spix, 1823

Common names: *caiarara*, *caiara* (Port.); Spix's white-fronted capuchin (Eng.).

Records (2 localities and 2 specimens): Aruã, Rio Arapiuns: MZUSP 5133 (skin and skull; female); Sumaúma, Rio Tapajós: 7175 (skin and skull; female).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC [as a synonym of *Cebus albifrons* (Humboldt, 1812)].

Comments: Silva Jr. (2001) did not recognize *C. unicolor* as a distinct species, treating it as a junior synonym of *C. albifrons.* In his revision, Silva Jr. (2001) identified MZUSP 5133 as *C. apella* (Linnaeus, 1758) and MZUSP 7175 as *C. albifrons*, following the identification on the labels by C.O.C. Vieira. Here we follow Mittermeier *et al.* (2013) in recognizing *C. unicolor* as a valid species. We identified both MZUSP 5133 and 7175 as *C. unicolor*.

### Subgenus *Sapajus* Kerr, 1792

*Cebus* (*Sapajus*) *apella* (Linnaeus, 1758)

Common names: *macaco-prego* (Port.); tufted capuchin (Eng.).

Records (26 localities and 113 specimens): Aruã, Rio Arapiuns: MZUSP 5674 (skin and skull; male), 5675 (skin and skull; female); Barreira, Rio Tapajós: 19562 (skin and skull; female); Belém: 24250 (skull; unknown sex); Boim: 4291 (skin and skull; male); Boiçu: 5126 (skin and skull; female), 5134 (skin and skull; male); Bom Jardim, Rio Amazonas: 5128 (skin and skull; male), 5132 (skin and skull; male); Capim, BR-010, km 93: 8920 (skin and skull; male); Brasília Legal, Rio Tapajós: 19561 (skin and skull; male); Igarapé Bravo, Rio Amazonas: 5114 (skin; male), 5115 (skin and skull; male), 5116–5117 (skin and skull; female), 10546 (skull; male); Cachoeira do Espelho, Rio Xingu: 21325 (skin and skull; male), 22794 (skeleton; unknown sex); Caxiricatuba, Rio Tapajós: 5118 (skin and skull; female), 5119 (skin; female), 5120–5121 (skin and skull; male), 5122–5123 (skin; male), 5752–5753 (skin and skull; male), 10535 (skull; female), 10537 (skull; male), 10540–10541 (skull; male), 19560 (skin; male); Curral Grande: 3636 (skin and skull; female); Fordlândia: 19564 (skin and skull; male), 19565 (skin and skull; female), 19566 (skin and skull; male), 19567 (skin and skull; female), 19568–19573 (skin and skull; male), 19574 (skin and skull; female), 19575–19577 (skin and skull; male), 19578 (skin and skull; female), 19579 (skin and skull; male), 19580 (skin and skull; female), 19581 (skin and skull; male), 19582 (skin and skull; female), 19583–19585 (skin and skull; male), 19586 (skin and skull; unknown sex), 19587–19588 (skin and skull; male), 19589 (skin and skull; female), 19590–19593 (skin and skull; male), 19594–19595 (skin and skull; female), 19596 (skin and skull; male), 19597–19599 (skin and skull; female), 19645 (skeleton; female), 19646 (skull; female); Ilha de Nova Olinda, Rio Tapajós: 24252 (skull; unknown sex); Itupiranga, Rio Tocantins: 19617 (skin and skull; male); Largo do Souza, Rio Iriri: 25446 (skin, skull and skeleton; male); Monte Cristo, Rio Tapajós: 19563 (skin and skull; female); Paissandu, Igarapé Bom Jardim: 8956 (skin and skull; female), 8957–8959 (skin and skull; male); Piquiatuba, Rio Tapajós: 10503 (skull; female); Rio Bacajá (mouth): 25451 (skin, skull and skeleton; male), 25452 (skin and skull; male); Rio Curuá (mouth): 5127 (skin; unknown sex), 5129 (skin and skull; male), 5130 (skin and skull; female), 5131 (skin; female), 5464 (skin; female), 5466 (skin; female), 10499 (skull; female), 10536 (skull; male), 10538 (skull; female), 10544 (skull; female); Rio Pucuruí, tributary of Rio Tocantins: 13482 (skin and skull; unknown sex); Santarém, Fazenda Maruá: 3633–3634 (skin; male); Santa Rosa, Ilha de Urucurituba: 19602–19603 (skin and skull; female); Santo Antônio, Rio Tocantins: 13480 (skin and skull; male); Urucurituba, Rio Tapajós: 19600–19601 (skin and skull; male), 19604–19606 (skin and skull; male), 19607–19608 (skin and skull; female), 19609 (skin and skull; male), 19610 (skin and skull; female), 19611–19612 (skin and skull; male), 19613 (skin and skull; female), 19614 (skin and skull; male), 19615 (skull and skeleton; female), 19616 (skull and skeleton; male), 19644 (skin and skull; female).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC.

## Subfamily Saimiriinae Miller, 1912

### Genus *Saimiri* Voigt, 1831

*Saimiri collinsi* Osgood, 1916

Common names: *macaco-de-cheiro*, *mico-de-cheiro*, *macaco-mão-de-ouro* (Port.); Collins' squirrel monkey (Eng.).

Records (15 localities and 105 specimens): Belém: MZUSP 19137 (skin and skull; female), 19138–19140 (skin; female); Bom Jardim, Rio Amazonas: 5517 (skin and skull; male), 5519 (skin and skull; female), 5520–5521 (skin and skull; male); Capim, BR-010, km 93: 8921 (skin and skull; male), 8922 (skin and skull; female); Cachoeira do Espelho, Rio Xingu: 25435 (skin, skull and skeleton; male); Cametá: 5531 (skin and skull; male); Caxiricatuba, Rio Tapajós: 5523 (skin and skull; male), 5525–5526 (skin and skull; male), 5527 (skin and skull; female), 5528 (skin; unknown sex), 5529 (skin and skull; male), 5530 (skin and skull; unknown sex), 10515 (skull; female); Curral Grande: 3616 (skull; unknown sex), 3618 (skull; male), 3619 (skull; female), 3620 (skin and skull; female); Fordlândia: 10101–10102 (skin and skull; female), 19142 (skin and skull; female), 19143–19144 (skin and skull; male), 19145 (skin and skull; female), 19146–19150 (skin and skull; male), 19151–19153 (skin and skull; female), 19711–19714 (skin and skull; male), 19715 (skin; female), 19717 (skull and skeleton; female), 19718–19719 (skull and skeleton; male), 19722 (skull; unknown sex), 19723 (skin; male), 19724–19725 (skin and skull; male); Igarapé Taperebá, Ilha de Marajó: 8677 (skin and skull; female), 8678 (skin and skeleton; male), 19704–19705 (skull; male); Itapoama, Rio Tapajós: 10100 (skin and skull; female); Monte Cristo, Rio Tapajós: 3613–3614 (skin and skull; male); Posto DNERu (Departamento Nacional de Endemias Rurais), Rio Tocantins: 19709 (skin; male); Posto DNERu (Departamento Nacional de Endemias Rurais), Rio Tracajuba: 19710 (skin and skull; unknown sex); Piquiatuba, Rio Tapajós: 10531 (skull; female); Rio Bacajá (mouth): 25436–25438 (skin, skull and skeleton; male); Santo Antônio, Rio Tocantins: 13473 (skin and skull; unknown sex); Taperinha: 3615 (skin and skull; female).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC [as a synonym of *S. sciureus* (Linnaeus, 1758)].

Comments: MZUSP 5521 from Bom Jardim has the same catalog number as a specimen of *Saimiri sciureus* from Boiuçu.

*Saimiri sciureus* (Linnaeus, 1758)

Common names: *macaco-de-cheiro*, *mico-de-cheiro*, *macaco-mão-de-ouro* (Port.); Guianan squirrel monkey, common squirrel monkey (Eng.).

Records (6 localities and 17 specimens): Boiuçu: MZUSP 5219 (skin and skull; male), 5220 (skin and skull; female), 5221 (skin and skull; male), 5224 (skin; male), 5225 (skin and skull; female), 5226 (skin and skull; male), 5227 (skin and skull; female); Igarapé Bravo, Rio Amazonas: 5222 (skin and skull; female), 5523 (skin and skull; female); Igarapé Piaba: 4315 (skin and skull; male); Jaguara: 8899 (skin and skull; male), 8900–8901 (skin and skull; female), 8902 (skin and skull; male); Lago Paru, Rio Trombetas: 19135 (skin and skull; female), 19141 (skin and skull; male); Paissandu, Igarapé Bom Jardim: 8955 (skin and skull; male).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC.

Comments: The MZUSP 5521 from Boiuçu has the same catalog number as a specimen of *Saimiri collinsi* from Bom Jardim.

*Saimiri* sp.

Common names: *macaco-de-cheiro*, *mico-de-cheiro*, *macaco-mão-de-ouro* (Port.); squirrel monkey (Eng.).

Records (*Unknown locality and 1 specimen*): MZUSP 6786 (skin and skull; male).

Conservation status: not applicable.

Comments: identification remains as indeterminate due to the lack of detailed information regarding this specimen. No precise collection locality provided. The specimen is an old skin, which lost its original coloration, an important diagnostic character (Mercês *et al.*, 2015).

### Family Aotidae Elliot, 1913

### Genus *Aotus* Illiger, 1811

*Aotus infulatus* (Kuhl, 1920)

Common names: *macaco-da-noite*, *macaco-da-noite-de-pescoço-vermelho* (Port.); feline night monkey (Eng.).

Records (8 localities and 38 specimens): BR-010, km 92: MZUSP 10468 (skin and skull; female); Cachoeira do Espelho, Rio Xingu: 21326 (skin, skull and skeleton; male); Caxiricatuba, Rio Tapajós: 5046 (skin and skull; male); Fordlândia: 10156 (skin and skull; male), 10157 (skin and skull; female), 11513–11515 (skin and skull; female), 11516 (skin and skull; male), 11517 (skin and skull; female), 11518 (skin and skull; male), 11519–11520 (skin and skull; female), 11521–11523 (skin and skull; male), 11524–11527 (skin and skull; female), 11528 (skin and skull; male), 11530 (skull and skeleton; female), 11532 (skull and skeleton; unknown sex), 11533 (skull and skeleton; female); Largo do Souza, Rio Iriri: 25439 (skin and skull; female), 25440 (skin and skull; male); Monte Cristo, Rio Tapajós: 11504 (skin and skull; female), 11505–11506 (skin, skull and skeleton; female), 11507 (skin and skull; female), 11508 (skin, skull and skeleton; female), 11509 (skin and skull; male), 11510–11511 (skin, skull and skeleton; female), 11512 (skin and skull; female); Piquiatuba, Rio Tapajós: 5045 (skin and skull; female); Santo Antônio, Rio Tocantins: 13477 (skin and skull; male).

Conservation status: ICMBio (2018): LC; IUCN (2019): NT [as *Aotus azarae infulatus* (Kuhl, 1820)]. The recent taxonomic changes (see Comments) were not included in the latest conservation assessments by ICMBio (2018) and IUCN (2019). Therefore, this species was classified by these agencies as *Aotus azarae infulatus*.

Comments: Hershkovitz (1983) recognized *Aotus infulatus* as a full species, but Rylands *et al.* (2000), Groves (2001) and Fernandez-Duque *et al*. (2013) classified it as a subspecies of *Aotus azarae*. However, Paglia *et al*. (2012) followed the opinion of Hershkovitz (1983).

## Family Pitheciidae Mivart, 1865

### Subfamily Callicebinae Pocock, 1925

### Genus *Callicebus* Thomas, 1903

### Subgenus *Plecturocebus* Byrne, Rylands, Carneiro, Lynch-Alfaro, Bertuol, da Silva, Messias, Groves, Mittermeier, Farias, Hrbek, Schneider, Sampaio & Boubli, 2016

*Callicebus* (*Plecturocebus*) *hoffmannsi* (Thomas, 1908)

Common names: *guigó*, *sauá*, *zogue-zogue* (Port.); Hoffmanns's titi (Eng.).

Records (6 localities and 20 specimens): Aruã, Rio Arapiúns: MZUSP 5091 (skin and skull; male); Brasília Legal, Rio Tapajós: 11715 (skin and skull; male), 11721 (skin and skull; female), 11726 (skin and skull; male); Fordlândia: 11731 (skin and skull; female), 11839 (skin and skull; unknown sex); Itaituba: 3574 (skull; female), 3575 (skin and skull; female), 3576 (skin and skull; male); Sumaúma, Rio Tapajós: 11741 (skin and skull; female), 11745 (skin and skull; female); Urucurituba, Rio Tapajós: 19534 (skull; unknown sex); 10154–10155 (skin and skull; female), 11743 (skin and skull; female), 11815 (skin and skull; female), 11833 (skin and skull; male), 11834 (skin and skull; female), 11835–11836 (skin and skull; male).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC.

Comments: according to Hershkovitz (1990), this species does not occur on the east bank of Rio Tapajós. Therefore, the two specimens from Fordlândia, a district located on the east bank of the river, are probably mislabeled or had been transferred to this bank in an oxbow cutoff (Hershkovitz, 1990).

*Callicebus* (*Plecturocebus*) *moloch* (Hoffmannsegg, 1807)

Common names: *zogue-zogue*, *sauá-de-barriga-vermelha*, *sauá-moreno* (Port.); red-bellied titi, dusky titi, red-bellied titi (Eng.).

Records (14 localities and 73 specimens): Bom Jardim, Rio Amazonas: MZUSP 5198 (skin; female); 5200 (skin and skull; female); Cachimbo: 8062 (skin and skull; male); Caxiricatuba, Rio Tapajós: 5143 (skin and skull; male), 5144 (skin and skull; female), 5146 (skin and skull; female), 5147 (skull; female), 5148 (skull; male), 5149 (skull; female), 5150–5151 (skull; male), 5152 (skull; female), 5157 (skull; female), 5159 (skin and skull; male), 5165 (skin and skull; male), 5166 (skin and skull; female), 5167 (skin and skull; male), 5169 (skin and skull; female), 24735 (skin and skull; male); Fordlândia: 10151 (skin and skull; female), 10153 (skin and skull), 11716–11718 (skin and skull; male), 11719–11720 (skin and skull; female), 11723 (skin and skull; female), 11724 (skin and skull; male), 11725 (skin and skull; female), 11727 (skin and skull; female), 11728 (skin; female), 11729 (skin and skull; female), 11730 (skin and skull; male), 11732 (skin and skull; male), 11733 (skin and skull; female), 11734 (skin and skull; male), 11735 (skin and skull; female), 11736 (skin and skull; male), 11737 (skin and skull; female), 11738–11739 (skin and skull; male), 11740 (skin and skull; female), 11742 (skin and skull; female), 11744 (skin and skull; female), 11813–11814 (skin and skull; female), 11816 (skin and skull; female), 11837 (skin; male), 11838 (skin and skull; male), 11840 (skin and skull; female), 11841 (skin; female), 19690 (skull; female); Itaituba: 3566 (skin and skull; male); Itapoama, Rio Tapajós: 10152 (skin and skull; male); Monte Cristo, Rio Tapajós: 3567 (skin and skull; male), 3568 (skin; female); 3569 (skin and skull; female), 11817 (skin and skull, male); Piquiatuba, Rio Tapajós: 5142 (skin and skull; female), 5153 (skin; male), 5155 (skin; female), 5156 (skin and skull; female), 5158 (skin and skull; female), 5160 (skin and skull; male); Rio Bacajá (mouth): 25444 (skin and skull; female), 25445 (skin and skull; male); Rio Curuá (mouth): 5196–5197 (skin and skull; female), 5202 (skin and skull; female); Santana do Araguaia, Fazenda Fartura: 35406 (skin; female); Santarém, Fazenda Marucu: 3571 (skin and skull; female), 3572 (skin and skull; male); Santo Antônio, Rio Tocantins: 13472 (skin and skull; unknown sex); Taperinha: 3570 (skin and skull; male).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC.

*Callicebus* (*Plecturocebus*) *vieirai* (Gualda-Barros, Nascimento & Amaral, 2012)

Common names: *guigó-de-vieira*, *sauá-de-vieira*, *zogue-zogue-de-vieira* (Port.); Vieira's titi (Eng.).

Records (1 locality and 3 specimens): Largo do Souza, Rio Iriri: MZUSP 25441 (skin and skull; female), 25442–25443 (skin and skull; male) [paratypes].

Conservation status: ICMBio (2018): DD; IUCN (2019): DD.

Comments: this species was described based on specimens held in the MZUSP since 1997. Gualda-Barros *et al.* (2012) named the species after Dr. Octaviano da Cunha Vieira, former Curator of the Mammal Collection of the MZUSP from 1941 to 1958.

### Subfamily Pitheciinae Mivart, 1865

### Genus *Chiropotes* Lesson, 1840

*Chiropotes albinasus* (I. Geoffroy & Deville, 1848)

Common names: *cuxiú-de-nariz-vermelho* (Port.); red-nosed bearded saki, red-nosed saki, white-nosed bearded saki, white-nosed saki (Eng.).

Records (8 localities and 31 specimens): Aruã, Rio Arapiuns: MZUSP 5304 (skin and skull; female), 5305 (skin and skull; male), 5307 (skin; male), 5309 (skin and skull; male), 5310 (skin and skull; female), 5313 (skin and skull; female); Barreira, Rio Tapajós: 19653 (skin; male); Cachimbo: 8008 (skin; female), 8009 (skin and skull; female), 8069 (skin and skull; female); Caxiricatuba, Rio Tapajós: 5311–5312 (skin and skull; female); Fordlândia: 12885 (skin and skull; female), 12886 (skin; female), 19660 (skin and skull; female), 19661–19662 (skin and skull; male), 19664–19667 (skin and skull; female), 19668 (skin; male); Monte Cristo, Rio Tapajós: 3626 (skin and skull; male), 19654 (skin, skull and skeleton; female), 19655–19656 (skin, skull and skeleton; male), 19657–19658 (skin and skull; female), 19659 (skin, skull and skeleton; male); Piquiatuba, Rio Tapajós: 5308 (skin and skull; female); Sumaúma, Rio Tapajós: 19663 (skin and skull; female).

Conservation status: ICMBio (2018): NT; IUCN (2019): EN A3cd.

*Chiropotes sagulatus* (Trail, 1821)

Common names: *cuxiú-de-humboldt* (Port.); Guianan bearded saki (Eng.).

Records (2 localities and 2 specimens): Cachoeira da Porteira, Rio Nhamundá: MZUSP 13632 (skull; male); Oriximiná: 19669 (skin, skull and skeleton; female).

Conservation status: ICMBio (2018): LC; IUCN (2019): NA.

*Chiropotes satanas* (Hoffmannsegg, 1807)

Common names: *cuxiú-preto* (Port.); black-bearded saki (Eng.).

Records (1 locality and 8 specimens): Capim, BR-010, km 93: MZUSP 8912–8913 (skin and skull; female), 8914–8915 (skin and skull; male), 8916–8917 (skin and skull; female), 8918 (skin, skull and skeleton; female), 8919 (skin and sull; unknown sex).

Conservation status: ICMBio (2018): CR A2cd; IUCN (2019): CR A2c+3c.

*Chiropotes utahicki* Hershkovitz, 1985

Common names: *cuxiú-de-uta-hick* (Port.); Uta Hick's bearded saki (Eng.).

Records (4 localities and 5 specimens): Cachoeira do Espelho, Rio Xingu: MZUSP 21323 (skin and skeleton; female), 21324 (skin and skeleton; male); Igarapé Águas da Saúde, Rio Tocantins: 23484 (skin and skull; male); Itupiranga, Rio Tocantins: 13523 (skin; male); Remansinho, Rio Tocantins: 23485 (skin and skull; female).

Conservation status: ICMBio (2018): VU A4cd; IUCN (2019): EN A3cd.

Comments: the specimen MZUSP 13523 was identified as *Chiropotes satanas satanas* by Philip Hershkovitz in 1987, when he visited the MZUSP. However, in his previous work (Hershkovitz, 1985) he had identified the same specimen as *C. s. utahicki*. The pelage characters of specimen MZUSP 13523 have allowed us to identify it as *Chiropotes utahicki*.

### Genus *Pithecia* Desmarest, 1804

*Pithecia irrorata* Gray, 1843

Common names: *parauacu*, *macaco-velho*, *macaco-cabeludo* (Port.); Gray's bald-faced saki (Eng.).

Records (2 localities and 2 specimens): Aruã, Rio Arapiuns: MZUSP 5549 (skin and skull; male) [Paratype of *Pithecia mittermeieri* Marsh, 2014]; Santarém, Fazenda Mararu, Rio Tapajós: 3632 (skin and skull; female).

Conservation status: ICMBio (2018): DD (as *Pithecia irrorata irrorata*); IUCN (2019): DD.

Comments: Hershkovitz (1987) recognized two subspecies for *Pithecia irrorata*: *P. i. irrorata* (Gray, 1843) and *P. i. vanzolinii* Hershkovitz, 1987. Subsequently Marsh (2014) raised these subspecies to species level and additionally proposed three putative new species from *P. irrorata*: *P. mittermeieri*, *P. pissinattii* Marsh, 2014 and *P. rylandsi* Marsh, 2014. However, Serrano-Villavicencio *et al*. (2019) concluded that these new putative species are not distinguished from each other and from *P. irrorata*, considering them junior synonyms of the latter.

*Pithecia pithecia* (Linnaeus, 1766)

Common names: *parauacu*, *parauacu-de-cara-branca*, *macaco-velho*, *macaco-cabeludo* (Port.); white-faced saki (Eng.).

Records (3 localities and 18 specimens): Boiuçu: MZUSP 5580 (skin and skull; male), 5582 (skin and skull; male), 5584–5585 (skin and skull; male), 5587 (skin and skull; female), 5591 (skin and skull; female), 5592 (skin and skull; male); Igarapé Bravo, Rio Amazonas: 5581 (skin and skull; male), 5583 (skin and skull; male), 5586 (skin and skull; male), 5588 (skin and skull; female), 5589 (skin and skull; male), 5590 (skin and skull; female); Óbidos: 3621 (skin and skull; male), 3622–3623 (skin and skull; female), 3624–3625 (skin and skull; male).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC.

Comments: two subspecies are traditionally recognized, *P. p. pithecia* (Linnaeus, 1766) and *P. p. chrysocephala* (I. Geoffroy, 1850). Hershkovitz (1987) identified specimens from Pará as *P. p. crysocephala*, but subsequent studies (Silva Jr. *et al.*, 2013) suggested that this taxon it is restricted to the Amazonas state (Negro-Nhamundá interfluvium), while *P. p. pithecia* is present in Pará (according to Hershkovitz, *P. p. pithecia* would present in the Guianas). Moreover, there is evidence of the existence of intermediate morphotypes in the region between the Rio Nhamundá and Rio Jari, supporting the recognition of subspecies (Silva Jr. *et al.*, 2013). On the other hand, Marsh (2014) elevated these two subspecies to full species status. Here we follow Silva Jr. *et al.* (2013).

## Family Atelidae Gray, 1825

## Subfamily Alouattinae Trouessart, 1897

### Genus *Alouatta* Lacépède, 1799

*Alouatta belzebul* (Linnaeus, 1766)

Common names: *bugio-de-mãos-vermelhas*, *guariba-de-mãos-vermelhas*, *bugio-de-mãos-ruivas*, *guariba-de-mãos-ruivas* (Port.); red-handed howler (Eng.).

Records (8 localities and 22 specimens): Belém: MZUSP 19004 (skin and skull; male); Capim, BR-010, km 93: 8910 (skin, skull and hyoid; female), 8911 (skin and skull; female), 8936 (skin, skull and hyoid; female), 8937 (skin and skull; female), 8938 (skin and skull; male), 8939 (skull; male); Cametá, Rio Tocantins: 5256 (skin; female), 5405 (skin; male), 5406 (skin and skull; male), 5407 (skin, skull and hyoid; male), 5408 (skin, skull; female); 10489 (skull; female), 26831 (skull; male); Cachoeira do Espelho, Rio Xingu: 20927 (skin and skull; male), 20928 (skin; female), 20929 (skin and skull; male); Largo do Souza, Rio Iriri: 25448 (skin, skull and skeleton; male); Rio Amazonas:

19511 (fetus in formalin); Rio Bacajá (mouth): 25449 (skin, skull and hyoid; male), 25450 (skull, hyoid and skeleton; female); Santo Antônio, Rio Tocantins: 13483 (skin, skull and hyoid; female).

Conservation status: ICMBio (2018): VU A2cd; IUCN (2019): VU A2cd.

*Alouatta discolor* (Spix, 1823)

Common names: *bugio-de-mãos-vermelhas*, *guariba-de-mãos-vermelhas*, *bugio-de-mãos-ruivas*, *guariba-de-mãos-ruivas* (Port.); Spix red-handed howler (Eng.).

Records (10 localities and 68 specimens): Barreira: MZUSP 18972 (skin and skull; female); Boiuçú: 5472 (skin; male); Bom Jardim, Rio Amazonas: 5409–5410 (skin and skull; female), 5411 (skull; male), 5568 (skin and skull; male), 5572 (skin; female), 5573 (skin and skull; male), 5747 (skin and skull; female), 5748 (skin; female), 7110 (skull; female), 18996 (skull; male), 24833 (skin and skull; male); Caxiricatuba, Rio Tapajós: 5328 (skin and skull; female), 5565 (skin and skull; male), 5566 (skin, skull and hyoid; male), 5567 (skin and skull; male), 5570 (skin and skull; female), 6022 (skull; male), 10563 (skull; male), 10565 (skull; male), 18997 (skin; unknown sex), 19032 (skin; male), 19118 (skull; male); Fordlândia: 18966 (skin and skull; female), 18967 (skin, skull and hyoid; male), 18968–18970 (skin and skull; female), 18971 (skin, skull and hyoid; female), 18973–18974 (skin, skull and hyoid; female), 18975 (skin and skull; male), 18976 (skin, skull and hyoid; male), 18977 (skin, skull and hyoid; female), 18978 (skin and skull; female), 18979 (skin, skull and hyoid; male), 18981 (skin, skull and hyoid; female), 18982 (skin and skull; male), 18983 (skin, skull and hyoid; male), 18984 (skin, skull and hyoid; female), 18985 (skin, skull and hyoid; male), 18986 (skin, skull and hyoid; female), 18987 (skin, skull and hyoid; male), 18988 (skin and skull; male), 18989 (skin, skull and hyoid; female), 18991 (skin, skull and hyoid; male), 18992 (skin, skull and hyoid; female), 18993 (skin, skull and hyoid; male), 18994–18995 (skin, skull and hyoid; female), 18998 (skin; female), 18999–19000 (skin, skull and hyoid; male); Monte Cristo, Rio Tapajós: 3645 (skin; skin, skull and hyoid; female); Piquiatuba, Rio Tapajós: 5329–5330 (skin and skull; male), 5333 (skin and skull; male), 5574 (skin and skull; male), 10495 (skull and hyoid; male); Rio Tapajós: 3644 (skin, skull and hyoid; male), 24256 (skull and hyoid; male); Serra do Cachimbo: 8063 (skin, skull and hyoid; male), 8066 (skin, skull and hyoid; male), 8067 (skull; male), 8068 (skin; female), 8071 (skin and skull; female); Taperinha: 18935 (skin, skull and hyoid; male).

Conservation status: ICMBio (2018): VU A4cd; IUCN (2019): VU A2c.

*Alouatta macconnelli* (Linnaeus, 1766)

Common names: *bugio-vermelho*, *guariba-vermelho* (Port.); Guianan red howler (Eng.).

Records (8 localities and 33 specimens): Boiuçu: MZUSP 5095 (skin and skull; female), 5096 (skin, skull and hyoid; male), 5473 (skin and skull; male), 5474 (skin and skull; male), 19088 (skull and hyoid; male); Igarapé Bravo, Rio Amazonas: 5094 (skin and skull; male), 5435 (skin; female), 5470 (skin and skull; male), 5471 (skin and skull; female), 5476 (skin and skull; female), 5478 (skin and skull; male), 5480 (skin and skull; female), 5481 (skin and skull; male), 7113 (skull; female), 10496 (skull; male), 19123 (skull; female); Faro: 9955 (skin, skull and hyoid; female), 9956 (skin, skull and hyoid; male); Jaguara: 19121 (skull and hyoid; male); Óbidos: 3637 (skin and skull; male), 3638–3639 (skin and skull; female), 3640 (skin and skull; male), 19086 (skull; male); Paissandu, Igarapé Bom Jardim: 9949 (skin; male), 9950 (skin; unknown sex), 9951–9952 (skin, skull and hyoid; male), 9953–9954 (skin and skull; male), 9957–9958 (skin, skull and hyoid; female), 19085 (skull and skeleton; male).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC.

*Alouatta nigerrima* Lönnberg, 1941

Common names: *bugio-preto*, *guariba-preto* (Port.); Amazon black howler (Eng.).

Records (6 localities and 7 specimens): Itaituba: MZUSP 3646 (skin, skull and hyoid; male); Samaúma: MZUSP: 19003 (skin, skull and skeleton; male); Óbidos: 3643 (skull; male); Parque Nacional da Amazônia, Igarapé do Cotovelo: 24603 (skull; unknown sex); Parque Nacional da Amazônia, Uruá: 19119 (skull and skeleton; male); Urucurituba, Rio Tapajós: 19001 (skin; male), 19002 (skin, skull and hyoid; female).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC.

### Subfamily Atelinae Gray, 1825

### Genus *Ateles* É. Geoffroy, 1806

*Ateles chamek* (Humboldt, 1812)

Common names: *macaco-aranha-de-cara-preta*, *coatá-de-cara-preta* (Port.); Peruvian spider monkey (Eng.).

Records (2 localities and 2 specimens): Barreira, Rio Tapajós: MZUSP 19326 (skin and skull; male); Urucurituba, Rio Tapajós: 19543 (skeleton; female).

Conservation status: ICMBio (2018): VU A4cd; IUCN (2019): EN A2cd.

*Ateles marginatus* É. Geoffroy, 1809

Common names: *macaco-aranha-de-cara-branca*, *coatá-de-cara-branca* (Port.); white-cheeked spider monkey (Eng.).

Records (9 localities and 47 specimens): Cachimbo: MZUSP 8064 (skull; male), 8070 (skull; unknown sex), 19331 (skin; female), 19332 (skin; unknown sex); Caxiricatuba, Rio Tapajós: 5281–5282 (skin and skull; female), 5284–5285 (skin and skull; female), 5287 (skin and skull; female), 5603 (skin; male), 5604 (skin; unknown sex), 5605 (skin and skull; female); Fordlândia: 10158 (skin and skull; female), 19313 (skin and skull; male), 19314–19316 (skin and skull; female), 19317–19322 (skin and skull; male), 19323 (skin and skull; female), 19324 (skin and skull; male), 19325 (skin and skull; female), 19327 (skin and skull; female), 19329 (skin and skull; female), 19330 (skin and skull; male); Piquiatuba, Rio Tapajós: 5279 (skin and skull; female), 5286 (skin and skull; female), 5606 (skin and skull; female), 5607 (skin and skull; male), 7104–7105 (skull; female), 19188 (skin; female); Rio Curuá do Sul (mouth): 7101–7102 (skull; female), 19335 (skull; female); Rio Curuá-Una (mouth): 5288 (skin and skull; male), 5600 (skin and skull; female); Santarém: 19328 (skin and skull; female); Tapaiúna, Rio Tapajós: 10159 (skin and skull; female); Taperinha: 3565 (skin and skull; female).

Conservation status: ICMBio (2018): EN A4cd; IUCN (2019): EN A4cd.

*Ateles paniscus* (Linnaeus, 1758)

Common names: *macaco-aranha-de-cara-vermelha*, *coatá-de-cara-vermelha* (Port.); red-faced spider monkey, red-faced black spider monkey, Guiana spider monkey (Eng.).

Records (3 localities and 6 specimens): Igarapé Bravo, Rio Amazonas: MZUSP 5277 (skin and skull; male), 5278 (skull; female), 25777 (skin; female); Óbidos: 3641–3642 (skin and skull; female); Rio Cuminá-Miri (mouth): 19334 (skull; unknown sex).

Conservation status: ICMBio (2018): LC; IUCN (2019): VU A4cd.

### Order Lagomorpha Brandt, 1855
### Family Leporidae Fischer, 1817

### Genus *Sylvilagus* Gray, 1867

*Sylvilagus minensis* Thomas, 1901

Common names: *tapiti*, *coelho-do-mato* (Port.); tapeti, Brazilian cottontail, forest cottontail (Eng.).

Records (3 localities and 3 specimens): Barreirinha, Rio Tapajós: MZUSP 26750 (skin and skull; male); Cachoeira do Espelho, Rio Xingu: 21304 (skin and skull; female); Fordlândia: 26751 (skin and skull; male).

Conservation status: ICMBio (2018): LC (as *S. brasiliensis*); IUCN (2019): NA.

Comments: the taxonomy of *Sylvilagus brasiliensis* (Linnaeus, 1758) is undergoing profound changes, and some of the subspecies and synonyms are now treated as a full species (Ruedas, 2017; Ruedas *et al.*, 2017). Tapetis found in the state of Pará are now classified as *S. minensis* (see Ruedas, 2017; Ruedas *et al.*, 2017).

### Order Rodentia Bowdich, 1821
### Family Caviidae Fischer, 1817
### Subfamily Hydrochoerinae gray, 1825

### Genus *Hydrochoerus* Brisson, 1762

*Hydrochoerus hydrochaeris* (Linnaeus, 1766)

Common names: *capivara* (Port.); capybara (Eng.).

Records (1 locality and 1 specimen): Cachoeira do Espelho, Rio Xingu: MZUSP 20925 (skin and skull; male).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC.

### Family Cuniculidae Miller & Gidley, 1918

### Genus *Cuniculus* Brisson, 1762

*Cuniculus paca* (Linnaeus, 1766)

Common names: *paca* (Port.); lowland paca, spotted paca (Eng.).

Records (11 localities and 29 specimens): As Pedras, Rio Cuminá-Miri: MZUSP 25462 (skin and skull; male), 25463 (skin and skull; female), 25464 (skin and skull; male); Igarapé Bravo, Rio Amazonas: 5263 (skin and skull; female); Capim, BR-010, km 94: 9616 (skin and skull; male), 9617–9618 (skin and skull; female and fetus), 9619 (skull; female), 9620 (skull; male), 9621 (skull; unknown sex), 9622 (skull; female), 9623–9626 (skull; male); Cachoeira do Escalaço, Rio Xingu: 25457 (skin and skull; male); Cachoeira do Espelho, Rio Xingu: 21331 (skin and skull; female and embryo), 21335 (skull; male); Ilha de Nova Olinda, Rio Tapajós: 25466 (skull; unknown sex); Lago Jacaré, Rio Trombetas: 10709 (skin and skull; female), 10710 (skin and skull; female), 10711 (skin and skull; pregnant female), 10712 (skin and skull; male), 26840 (fetus of female 10709; in alcohol); Oriximiná, Açaizinho: 24919 (fetus in alcohol); Parque Nacional da Amazônia: 25465 (skull; unknown sex), 25467 (partial skeleton; unknown sex); Piquiatuba, Rio Tapajós: 5267 (skin and skull; female); Rio Curuá (mouth): 5265 (skin and skull; male).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC.

### Family Dasyproctidae Bonaparte, 1838

### Genus *Dasyprocta* Illiger, 1811

*Dasyprocta croconota* Wagler, 1831

Common names: *cutia* (Port.); orange agouti (Eng.).

Records (9 localities and 67 specimens): Bom Jardim, Rio Amazonas: MZUSP 5373 (skin and skull; female), 5377 (skin and skull; female), 5378–5379 (skin and skull; male), 5384 (skin and skull; female); Cametá, Rio Tocantins: 5363 (skin; unknown sex), 5478–5479 (skin; male), 5475–5477 (skull; male), 25558 (skull; male), 25564 (skull; unknown sex), 25568 (skull; male); Caxiricatuba, Rio Tapajós: 5356–5357 (skin and skull; male), 5359–5360 (skin; female), 5361 (skin and skull; female), 5365 (skin and skull; male), 5366 (skin and skull; female), 5368 (skin and skull; unknown sex), 5371–5372 (skin and skull; female), 5374 (skin and skull; male), 5376 (skin; female), 5383 (skin and skull; male); Fordlândia: 10146–10147 (skin and skull; male), 10148 (skin and skull; female), 10149 (skin and skull; male), 25477 (skin and skull; female), 25478–25480 (skin and skull; male), 25481 (skin and skull; unknown sex), 25482–25483 (skin and skull; female), 25484–25487 (skin and skull; male), 25488 (skin and skull; female), 25489–25490 (skin and skull; male), 25491–25492 (skin and skull; female), 25534 (skin and skull; female), 25535 (skull and skeleton; female); Piquiatuba, Rio Tapajós: 5355 (skin and skull; female), 5358 (skin and skull; female), 5364 (skin and skull; male), 5367 (skin and skull; female), 5369 (skin and skull; female), 5381 (skin and skull; male), 5382 (skin and skull; male), 5438 (skin and skull; male); Rio Curuá (mouth): 5353 (skin and skull; female), 5354 (skin and skull; male), 5362 (skin and skull; female), 5380 (skin and skull; male), 25493 (skin and skull; male), 25559 (skin and skull; male), 25560 (skin and skull; male); Taperinha: 3789 (skin and skull; female); Urucurituba, Rio Tapajós: 25476 (skin and skull; female); Santarém: 3790 (skin; male); Santarém, Fazenda Marucu: 25530 (skin; male).

Conservation status: ICMBio (2018): LC; IUCN (2019): DD.

*Dasyprocta leporina* (Linnaeus, 1758)

Common names: *cutia* (Port.); red-rumped agouti (Eng.).

Records (6 localities and 10 specimens): Igarapé Bravo, Rio Amazonas: MZUSP 5324–5325 (skin and skull; female), 5331 (skin and skull; female); Cachoeira do Espelho, Rio Xingu: 20930 (skin and skull; male), 21332 (skin and skull; male); Gorotire: 25515 (skin; unknown sex); Lago Jacaré, Rio Trombetas: 10714 (skin and skull; female), 26742 (fetus of 10714); Óbidos: 3788 (skin and skull; unknown sex); Parque Nacional da Amazônia, Rio Tapajós: 25514 (skin and skull; unknown sex).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC.

Comments: Iack-Ximenes (1999) considered specimens south of the Rio Amazonas as *D. aguti* Linnaeus, 1766, while those in the north of this river and the Guianas were recognized as *D. leporina*.

*Dasyprocta prymnolopha* Wagler, 1831

Common names: *cutia* (Port.); black-rumped agouti (Eng.).

Records (3 localities and 10 specimens): Capim, BR-010, km 93: MZUSP 8943 (skull; unknown sex), 8944–8945 (skin and skull; male), 8946–8947 (skin and skull; female), 8948 (skin and skull; unknown sex), 8949 (skin and skull; male), 8952 (skin and skull; male); Belém: 8641 (skin; male); Paraná do Samaúma, Rio Tocantins: 25516 (skin and skull; unknown sex).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC.

### Genus *Myoprocta* Thomas, 1903

*Myoprocta acouchy* (Erxleben, 1777)

Common names: *cutiara*, *cutia-de-rabo* (Port.); red acouchi (Eng.).

Records (4 localities and 9 specimens): Igarapé Bravo, Rio Amazonas: MZUSP 4709 (skin and skull; female), 4821 (skin; female); Boiuçu: 4710 (skin and skull; skin and skull; female); Curuá, Lago Cuiteuá, Rio Amazonas: 4635 (skin and skull; female), 4832 (skin and skull; female); Óbidos: 3688 (skin and skull; female), 3689 (skin and skull; unknown sex), 3690 (skin and skull; male), 4204 (skin and skull; male).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC.

Comments: two species of *Myoprocta* are recognized, the red acouchi *M. acouchy*, found in the Guianas and northern Brazil (north bank of the Rio Amazonas), and the green acouchi *M. pratti* Pocock, 1913, distributed in the western Amazon, from Venezuela and Colombia to northern Bolivia (Voss *et al.*, 2001; Patton & Emmons, 2015; Teta, 2019). Iack-Ximenes (1999) identified the specimens distributed in the Negro-Trombetas interfluvium as *M. exilis* (Wagler, 1831), while those found east of the Rio Trombetas as *M. demararae* (Tate, 1939), both considered junior synonyms of *M. acouchy* by other authors.

## Family Erethizontidae Bonaparte, 1845

### Genus *Coendou* Lacépède, 1799

*Coendou nycthemera* (Olfers, 1818)

Common names: *ouriço-cacheiro*, *porco-espinho* (Port.); Eastern Amazonian dwarf porcupine (Eng.).

Records (4 localities and 10 specimens): Belém: MZUSP 13519–13520 (skin and skull; male); BR-010, km 87-94: 25591 (skull; unknown sex); Cametá, Rio Tocantins:

5031–5034 (skin and skull; unknown sex), 5036–5037 (skin and skull; unknown sex), 5038 (skin; female), 5039 (skin and skull; unknown sex); Caxiricatuba, Rio Tapajós: 5035 (skin and skull; female).

Conservation status: ICMBio (2018): LC; IUCN (2019): DD.

*Coendou prehensilis* (Linnaeus, 1758)

Common names: *ouriço-cacheiro*, *porco-espinho* (Port.); Brazilian porcupine (Eng.).

Records (5 localities and 8 specimens): Barreira, Rio Tapajós: MZUSP 25232 (skin and skull; female); Cachoeira do Espelho, Rio Xingu: 20931 (skin, skull and skeleton; unknown sex), 21302 (skin, skull and skeleton; male), 21303 (skin, skull and skeleton; female); Cametá, Rio Xingu: 5042 (skin and skull; male); Parque Nacional da Amazônia, Uruá, km 65: 25230 (partial skeleton; unknown sex), 25231 (skull; unknown sex); Santo Antônio, Rio Tocantins: 13486 (skin and skull; unknown sex).

Conservation status: ICMBio (2018): LC; IUCN (2019): LC.

## SPECIES RECORDED FOR THE STATE OF PARÁ WITHOUT VOUCHER SPECIMENS IN THE MZUSP

Table 1 contains the species of medium and large-sized mammals that have records in the literature for the state of Pará, but do not have voucher specimens deposited in the MZUSP.

## SAMPLING RICHNESS

The MZUSP houses 1,910 specimens representing 79 species of mammals from Pará state. These species correspond to nine of the 10 orders recognized for the state (Percequillo & Gregorin, 2019), emphasizing the importance of the MZUSP collection. However, this representativeness is not equal in terms of the number of specimens for each genus (Figure 1).

Table 1. List of medium and large-sized mammal species (scientific and popular names in Portuguese and English) recorded for the state of Pará, Brazil, but without voucher specimens deposited in the MZUSP. In the right column are the bibliographic sources of the species records. References: 1 = Andrade *et al.* (2018); 2 = Boubli *et al.* (2008); 3 = Brandão *et al.* (2015); 4 = Duarte *et al.* (2012); 5 = Emin-Lima *et al.* (2010); 6 = Faria & Melo (2017); 7 = Goeldi & Hagmann (1904); 8 = González *et al.* (2010); 9 = Hrbek *et al.* (2014); 10 = Mendes-Oliveira *et al.* (2011); 11 = Oliveira, L. *et al.* (2009); 12 = Pimenta & Silva Jr. (2005); 13 = Rossi *et al.* (2017); 14 = Siciliano *et al.* (2016); 15 = Silva Jr. *et al.* (2010); 16 = de Vivo (1991); 17 = Voss *et al.* (2001); 18 = Voss *et al.* (2018); 19 = Wetzel *et al.* (2008).

(Continue)

| *Taxa* | Common name | | References |
|---|---|---|---|
| | Portuguese | English | |
| **Didelphimorphia Gill, 1872** | | | |
| **Didelphidae Gray, 1821** | | | |
| *Didelphis* Linnaeus, 1758 | | | |
| *D. imperfecta* Mondolfi & Pérez-Hernàndez, 1984 | *Gambá, mucura, saruê, sarigueia* | Guianan white-eared opossum | 3, 6, 13 |
| *Philander* Brisson 1762 | | | |
| *P. canus* (Osgood, 1913) | *Cuíca-de-quatro-olhos* | Gray four-eyed opossum | 17 |
| **Cingulata Illiger, 1811** | | | |
| **Chlamyphoridae Bonaparte, 1850** | | | |
| *Cabassous* McMurtrie, 1831 | | | |
| *C. unicinctus* (Linnaeus, 1758) | *Tatu-de-rabo-mole-pequeno* | Southern naked-tailed armadillo | 19 |

Table 1. (Conclusion)

| *Taxa* | Common name | | References |
|---|---|---|---|
| | Portuguese | English | |
| **Sirenia Illiger, 1811** | | | |
| **Trichechidae Gill, 1872** | | | |
| *Trichechus* Linnaeus, 1758 | | | |
| *T. manatus* (Linnaeus, 1758) | *Peixe-boi-marinho* | West Indian manatee | 5 |
| **Carnivora Bowdich (1821)** | | | |
| **Mustelidae Fischer, 1817** | | | |
| *Lontra* Gray, 1843 | | | |
| *L. longicaudis* (Olfers, 1818) | *Lontra* | Neotropical otter | 5, 15 |
| **Artiodactyla Owen, 1848** | | | |
| **Cervidae Goldfuss, 1820** | | | |
| *Blastocerus* Wagner, 1844 | | | |
| *B. dichotomus* (Illiger, 1815) | *Cervo-do-pantanal, suaçuetê* | Marsh deer | 4 |
| *Odocoileus* Rafinesque, 1832 | | | |
| *O. virginianus* (Zimmermann, 1780) | *Veado-galheiro, cariacu* | White-tailed deer | 10 |
| *Ozotoceros* Ameghino, 1891 | | | |
| *O. bezoarticus* (Linnaeus, 1758) | *Veado-campeiro, veado-branco* | Pampas deer | 7, 8, 15 |
| **Iniidae Gray, 1846** | | | |
| *Inia* d'Orbigny, 1834 | | | |
| *I. araguaiaensis* Hrbek *et al.*, 2014 | *Boto-do-araguaia* | Araguian river dolphin | 9, 14 |
| **Primates Linnaeus, 1758** | | | |
| **Callitrichidae Thomas, 1903** | | | |
| *Mico* Lesson, 1840 | | | |
| *M. emiliae* (Thomas, 1920) | *Sagui-de-snethlage, mico-de-snethlage* | Emilia's marmoset, Snethlage's marmoset | 1, 12, 16 |
| *Saguinus* Hoffmannsegg, 1807 | | | |
| *S. (S.) martinsi* (Thomas, 1912) | *Sauim* | Martins's tamarin | 11 |
| **Cebidae Bonaparte, 1831** | | | |
| *Cebus* Erxleben, 1777 | | | |
| *C. (C.) olivaceus* (Schomburgk, 1848) | *Caiarara, caiara* | Wedge-capped capuchin | 15 |
| **Atelidae Gray, 1825** | | | |
| *Lagothrix* É. Geoffroy, 1812 | | | |
| *Lagothrix cana* (É. Geoffroy, 1812) | *Macaco-barrigudo* | Peruvian wolly monkey | 2 |
| **Rodentia Bowdich, 1821** | | | |
| **Erethizontidae Bonaparte, 1845** | | | |
| *Coendou* Lacépède, 1799 | | | |
| *C. melanurus* (Wagner, 1842) | *Ouriço-cacheiro* | Black-tailed hairy dwarf porcupine | 17 |

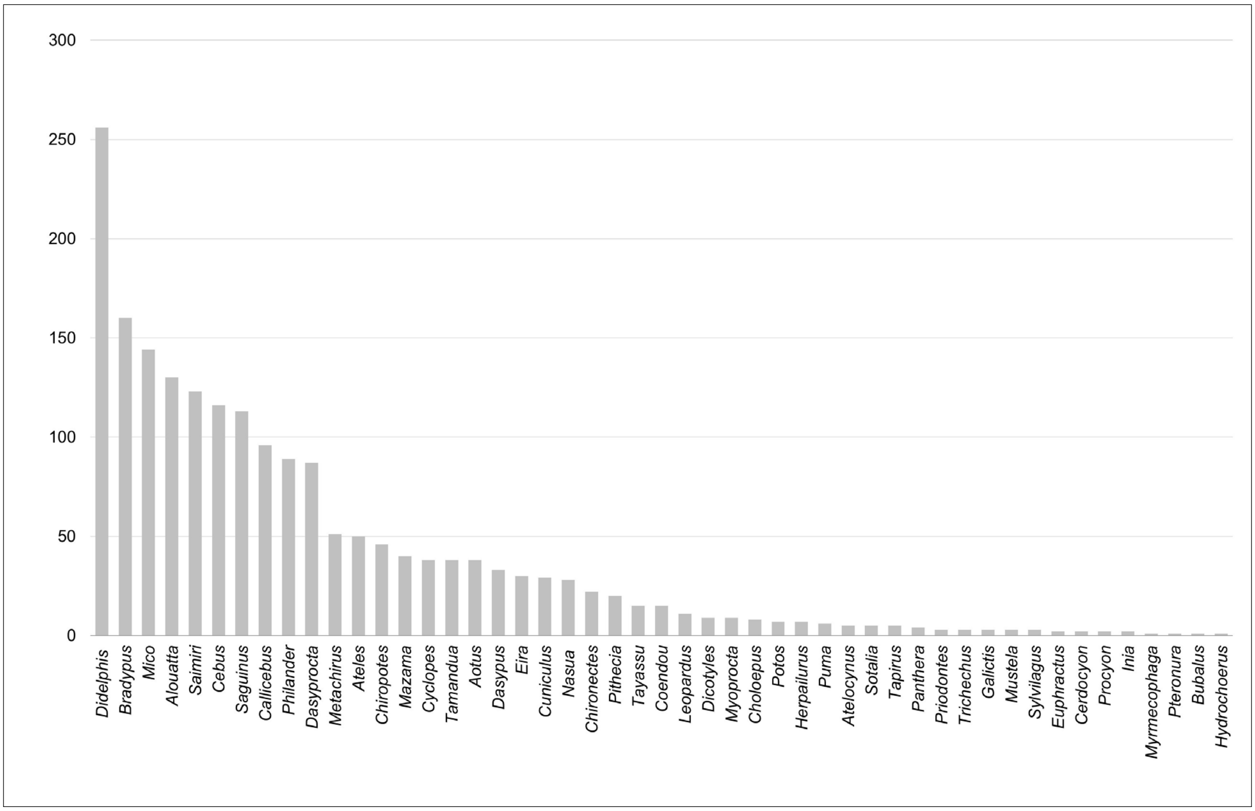

Figure 1. Number of specimens per genus collected in the state of Pará, Brazil, and housed in the Mammal Collection of the *Museu de Zoologia da Universidade de São Paulo*, SP, Brazil.

The most represented genus in the collection is *Didelphis*, with 216 specimens, corresponding to 13% of all specimens from Pará state. *Bradypus* and some primate genera (*Mico*, *Alouatta*, *Saimiri*, *Cebus*, and *Saguinus*), also have large number of specimens (> 100). On the other hand, 46% of the genera found in MZUSP are represented by less than 10 specimens, demonstrating a possible collection bias in favor of the first-mentioned taxa.

Regarding the geographical distribution of the samples (Figure 2), there are four areas of denser collection: (1) a large concentration in the west of the state, which encompasses the Lower Rio Tapajós, Lower Rio Trombetas, and the Rio Amazonas between the mouth of Rio Nhamundá and mouth of Rio Curuá-Una; (2) Lower Rio Xingu, between the mouth of Rio Iriri and the mouth of Rio Bacajá; (3) Rio Tocantins in the Tucuruí region; and (4) the northeastern portion of Pará, which encompasses the mouth of the Rio Tocantins, Ilha de Marajó, and Belém municipality area. On the Tucuruí region, it is worth mentioning that many collection localities are currently submerged by a giant reservoir (> 2,400 km$^2$) caused by the Tucuruí Dam, which was completed in the mid-1980s (Goulding *et al.*, 2003; Pinto, L., 2012).

On the other hand, there is a lack of specimen representation mainly in the central and southern regions of the state, as well as the region on the left bank of the Rio Amazonas. Most of the specimens were collected in forested areas of the Amazon biome, and only a few in Cerrado patches or Amazon-Cerrado transition areas, such as Serra do Cachimbo, Formiga, Canaã dos Carajás, Gorotire, and Santana do Araguaia. These large concentrations of collection points in certain areas of the

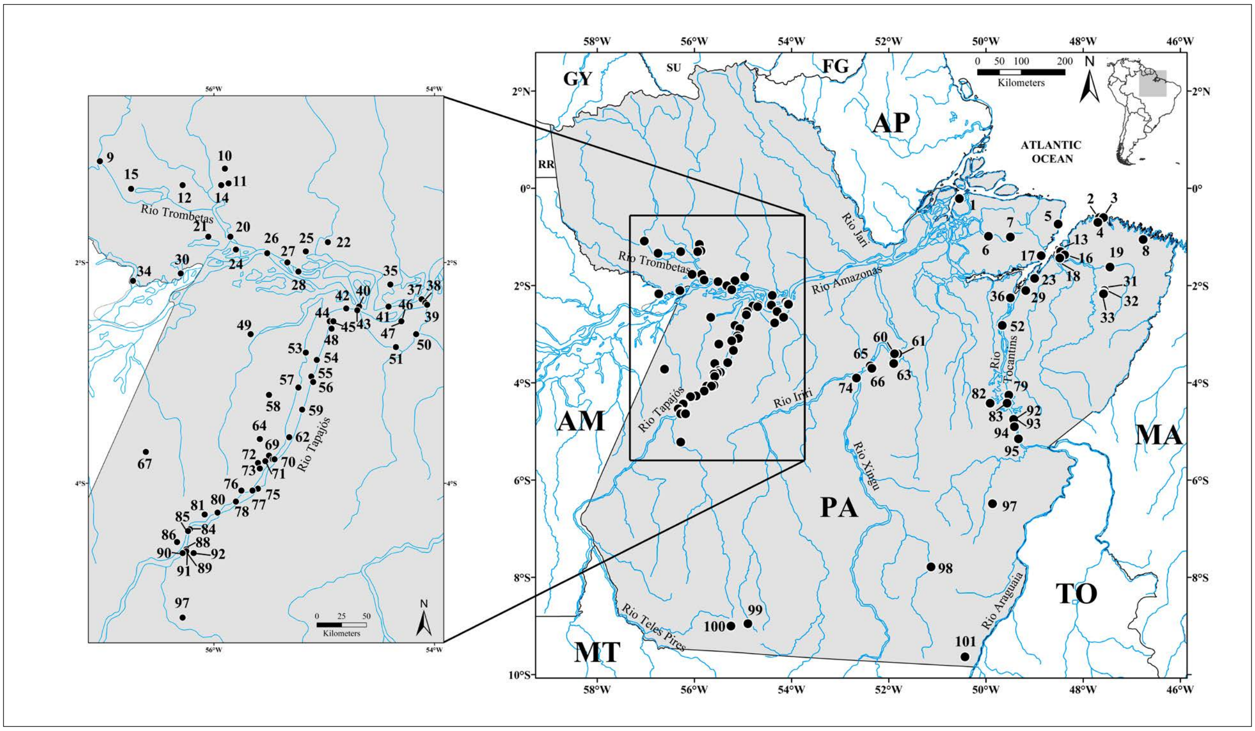

Figure 2. Collection localities (black dots) of the specimens of medium and large-sized mammals from Pará state (in gray) housed in the Mammal Collection of the *Museu de Zoologia da Universidade de São Paulo*, SP, Brazil. Numbers correspond to collection localities listed in the gazetteer (see Appendix 1). Legend: AM = state of Amazonas, Brazil; AP = state of Amapá, Brazil; FG = French Guiana; GY = Guyana; MA = state of Maranhão, Brazil; MT = state of Mato Grosso, Brazil; PA = state of Pará, Brazil; RR = state of Roraima, Brazil; SU = Suriname; TO = state of Tocantins, Brazil.

state reflect the history of collection expeditions, which were conducted along major rivers and near municipalities or localities with a higher concentration of human population at the time [for example, see Pinto, O. (1945) who reported in detail the routes and collection localities of the MZUSP expeditions in the Amazon in the first half of the last century].

As pointed out by de Vivo *et al.* (2014), even the best museums in terms of geographical representation cannot provide, alone, sufficient data about the distribution of a single taxon. Therefore, for more comprehensive studies about mammals of Pará state, it is crucial to consult additional Mammalogy collections, such as *Museu Paraense Emílio Goeldi*, Belém, Pará state, and the *Museu Nacional/Universidade Federal do Rio de Janeiro*, Rio de Janeiro state. In this context, museum catalogs, such as Vieira (1944, 1945, 1946, 1949, 1951, 1953a, 1953b, 1957), Ávila-Pires (1968), Napier (1976), Lawrence (1993), Fisher & Ludwig (2014), Bezerra & Bordallo (2018), and the present contribution, are important references for the mammal richness represented in scientific collections. For medium and large-sized mammals, especially, these catalogs should be considered as primary sources to found specimens, since they cannot be collected as it was in the first half of the 20th century (Pinto, O., 1945; Nascimento, 2014), and the number of samples housed in scientific collections are usually small (Rossi, 2000).

Among the species listed here, 24 are currently threatened (VU: 18; EN: 4; CR: 2, following the classification of ICMBio, 2018) according to the definitions proposed by Portaria MMA (Brasil, 2014, Art. 6° § 2°). One of the greatest threats for mammals in Brazil is habitat loss and fragmentation (Costa *et al.*, 2005). The eastern, southern and southeastern state of Pará, for being insert in the arc of deforestation, suffers of a heavy human pressure, resulting in a few and sparsely forested areas surrounded by agricultural farms (Negrões *et al.*, 2011; Aldrich *et al.*, 2012). Additionally, medium and large-sized mammals are heavily affected by the hunting pressure in the remaining forests, even in the protected ones, resulting in population decline or local extinction (Costa *et al.*, 2005; Peres *et al.*, 2016). Two critically endangered species present in the MZUSP, *Cebus* (*Cebus*) *kaapori* and *Chiropotes satanas*, are examples of population reduction due to these threats. These primate species were originally distributed through the Belém area of endemism (ICMBio, 2018). In this area, deforestation has reached 76%, remaining only few fragments of primary and secondary forest (Almeida & Vieira, 2010), leading to the population decline of these two species to an estimated 80% during the last 30-40 years (ICMBio, 2018).

In this scenario, the MZUSP, as well as other scientific collections, are of great importance to preserve samples of the biodiversity, especially of the threatened and extinct species. The relevance of scientific collections transcends time and space. Thus, MZUSP holds an important and priceless part of the Brazilian mammalogy that will be the legacy to be used by the next generations of scientists worldwide.

## CONCLUSIONS

The present catalog demonstrates that most of the medium and large-sized mammal richness of Pará state is represented in the MZUSP. The majority of the preserved material was collected in a few areas of the state, leaving many areas unsampled. These results reflect the history of the collection over the years and allow the researcher to make projections of the main areas of study and possible important regions for sample collection. In this context, this catalog plays an important role in presenting the currently known biodiversity of medium and large-sized mammals of Pará, also acting as a primary source for systematics, ecological, conservation and biogeographic studies.

## ACKNOWLEDGMENTS

We are grateful to Luís Fábio Silveira and Juliana Gualda-Barros for permission to examine the specimens and the collection catalogs; José Eduardo Serrano-Villavicencio and Guilherme Siniciato Terra Garbino for valuable suggestions; Dione Seripierri for valuable effort in obtaining some important references; and Alexandra Bezerra for the invitation to participate in this special edition. Finally, we are also grateful to Ricardo Moratelli and one anonymous reviewer for critically commenting on earlier versions of this contribution. RLV is supported by *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* (CAPES).

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Appendix 1. Geographic coordinates of the collections localities. (Continue)

BRAZIL

**Pará state**

1. Igarapé Taperebá, Ilha de Marajó. 00° 13' S, 50° 33' W
2. Alegre, 15 km NE Marapanim. 00° 36' S, 47° 40' W
3. Maracanã, Ilha de Maiandeua, Algodoal. 00° 36' S, 47° 35' W
4. Marapanim, Marudá. 00° 42' S, 47° 42' W
5. Soure, Fazenda Teso, Ilha de Marajó. 00° 44' S, 48° 31' W
6. Anajás. 00° 59' S, 49° 57' W
7. Ilha de Marajó. 01° 00' S, 49° 30' W
8. Bragança. 01° 03' S, 46° 46' W
9. Cachoeira da Porteira, Rio Nhamundá. 01° 05' S, 57° 02' W
10. Igarapé Jaramacaru. 01° 09' S, 55° 54' W
11. As Pedras, Rio Cuminá-Miri. 01° 17' S, 55° 52' W
12. Lago Jacaré, Rio Trombetas. 01° 18' S, 56° 17' W
13. Icoaraci. 01° 18' S, 48° 28' W
14. Rio Cuminá-Miri (mouth). 01° 18' S, 55° 56' W
15. Reserva Biológica do Rio Trombetas. 01° 20' S, 56° 45' W
16. Ananindeua. 01° 22' S, 48° 23' W
17. Ponta de Pedras, Ilha de Marajó. 01° 23' S, 48° 52' W
18. Belém. 01° 26' S, 48° 29' W
19. São Miguel do Guamá. 01° 37' S, 47° 27' W
20. Oriximiná. 01° 46' S, 55° 51' W
21. Lago Sapucuá, Rio Trombetas. 01° 46' S, 56° 03' W
22. Curuá, Lago Cuiteuá, Rio Amazonas. 01° 49' S, 54° 58' W
23. Paraná do Samaúma, Rio Tocantins. 01° 51' S, 49° 00' W
24. Lago Paru, Rio Trombetas. 01° 53' S, 55° 48' W
25. Igarapé Bravo, Rio Amazonas. 01° 54' S, 55° 10' W
26. Óbidos. 01° 55› S, 55° 31› W
27. Igarapé Piaba. 02° 00' S, 55° 20' W
28. Boiuçu. 02° 05' S, 55° 14' W
29. Arimateua, Rio Tocantins. 02° 06' S, 49° 11' W
30. Paissandu, Igarapé Bom Jardim. 02° 06' S, 56° 18' W
31. BR-010, km 87-94. 02° 06' S, 47° 34' W
32. BR-010, km 92 / São Domingos do Capim, BR-10, km 92. 02° 09' S, 47° 35' W
33. Capim, Rodovia BR-14, km 93 / Capim, BR-010, km 93 / Capim, BR-010, km 94 / Capim. 02° 10' S, 47° 35' W
34. Faro. 02° 10' S, 56° 44' W
35. Jaguara. 02° 12' S, 54° 24' W

Appendix 1. (Continue)

36. Cametá, Rio Tocantins. 02° 15' S, 49° 30' W
37. Curral Grande. 02° 20' S, 54° 07' W
38. Rio Curuá (mouth). 02° 22' S, 54° 05' W
39. Rio Curuá-Una (mouth). 02° 23' S, 54° 04' W
40. Rio Tapajós. 02° 24' S, 54° 41' W
41. Cacaoal Grande. 02° 24' S, 54° 25' W
42. Santarém. 02° 25' S, 54° 48' W
43. Santarém, Fazenda Mararu, Rio Tapajós. 02° 26' S, 54° 42' W
44. Santarém, Alter do Chão. 02° 32' S, 54° 57' W
45. Santarém, Fazenda Marucu. 02° 32' S, 54° 55' W
46. Taperinha. 02° 32' S, 54° 18' W
47. Os Patos. 02° 32' S, 54° 18' W
48. Caxiricatuba, Rio Tapajós. 02° 36' S, 54° 56' W
49. Aruã, Rio Arapiuns. 02° 39' S, 55° 40' W
50. Rio Curuá do Sul (mouth). 02° 39' S, 54° 10' W
51. Bom Jardim, Rio Amazonas. 02° 46' S, 54° 21' W
52. Santo Antônio, Rio Tocantins. 02° 49' S, 49° 40' W
53. Boim. 02° 49' S, 55° 10' W
54. Tapaiúna, Rio Tapajós. 02° 53' S, 55° 04' W
55. Piquiatuba, Rio Tapajós. 03° 02' S, 55° 07' W
56. Tauari, Rio Tapajós. 03° 05' S, 55° 06' W
57. Pau de Letra, Rio Tapajós. 03° 08' S, 55° 14' W
58. Urucurituba, Rio Tapajós. 03° 12' S, 55° 30' W
59. Itapoama, Rio Tapajós. 03° 20' S, 55° 12' W
60. Ilha do Limão, Rio Xingu. 03° 24' S, 51° 49' W
61. Juruá, Rio Xingu. 03° 24' S, 51° 53' W
62. Aveiro. 03° 35' S, 55° 19' W
63. Rio Bacajá (mouth). 03° 36' S, 51° 54' W
64. Samaúma. 03° 36' S, 55° 35' W
65. Cachoeira do Espelho, Rio Xingu. 03° 39' S, 52° 23' W
66. Cachoeira do Escalaço, Rio Xingu. 03° 42' S, 52° 21' W
67. Terra Santa, Rio Jamari. 03° 43' S, 56° 37' W
68. Santa Rosa, Ilha de Urucurituba. 03° 45' S, 55° 30' W
69. Tavio, Rio Tapajós. 03° 47' S, 55° 27' W
70. Fordlândia / Fordlândia, Fazenda Nova. 03° 47' S, 55° 28' W
71. Sumaúma, Rio Tapajós. 03° 48' S, 55° 32' W
72. Brasília Legal, Rio Tapajós. 03° 49' S, 55° 36' W
73. Arara, Rio Tapajós. 03° 52' S, 55° 35' W

Appendix 1. (Conclusion)

74. Largo do Souza, Rio Iriri. 03° 54' S, 52° 40' W
75. Pedreira, Rio Tapajós. 04° 03' S, 55° 36' W
76. Barreira, Rio Tapajós. 04° 04' S, 55° 45' W
77. Monte Cristo, Rio Tapajós. 04° 04' S, 55° 39' W
78. Lago Araipá, Rio Tapajós. 04° 10' S, 55° 48' W
79. Vila Bravo, Rio Tocantins. 04° 15' S, 49° 32' W
80. Transamazônica km 46 / Transamazônica km 50, near Itaituba / Transamazônica km 75, near Itaituba / Transamazônica km 62, near Itaituba / Transamazônica km 58, near Itaituba / Transamazônica km 80, near Itaituba / Transamazônica km 100 / Itaituba / Itaituba, Parque Nacional da Amazônia / Parque Nacional da Amazônia / Parque Nacional da Amazônia, Rio Tapajós / Transamazônica km 66, Parque Nacional da Amazônia / Parque Nacional da Amazônia, Igarapé do Cotovelo. 04° 16' S, 55° 58' W
81. Transamazônica km 15, near Itaituba. 04° 17' S, 56° 05' W
82. Rio Pucuruí, tributary of Rio Tocantins. 04° 25' S, 49° 55' W
83. Remansinho, Rio Tocantins. 04° 25' S, 49° 34' W
84. Barreirinha, Rio Tapajós. 04° 25' S, 56° 13' W
85. São Luís, Rio Tapajós. 04° 26' S, 56° 14' W
86. Morro da Terra Preta, Transamazônica km 60, near Itaituba. 04° 32' S, 56° 20' W
87. Pimental. 04° 36' S, 56° 15' W
88. Uruá, Rio Tapajós / Parque Nacional da Amazônia, Uruá / Parque Nacional da Amazônia, Uruá, km 65. 04° 37' S, 56° 15' W
89. Igarapé São José, near Itaituba. 04° 38' S, 56° 11' W
90. Ilha de Nova Olinda, Rio Tapajós. 04° 38' S, 56° 17' W
91. Boa Fé, Parque Nacional do Tapajós. 04° 38' S, 56° 11' W
92. Bagagem, Rio Tocantins. 04° 45' S, 49° 26' W
93. Igarapé Águas da Saúde, Rio Tocantins. 04° 45' S, 49° 26' W
94. Puraquecuara, Rio Tocantins. 04° 54' S, 49° 25' W
95. Itupiranga, Rio Tocantins. 05° 09' S, 49° 20' W
96. Ilha de Santa Helena, Rio Pará. 05° 13' S, 56° 17' W
97. Canaã dos Carajás. 06° 29' S, 49° 52' W
98. Gorotire. 07° 47' S, 51° 08' W
99. Cachimbo / Cachimbo, Formiga. 08° 57' S, 54° 54' W
100. Serra do Cachimbo. 09° 00' S, 55° 15' W
101. Santana do Araguaia, Fazenda Fartura. 09° 38' S, 50° 26' W

# Mammals collected by Johann Jakob von Tschudi in Peru during 1838-1842 for the *Muséum d'Histoire Naturelle de Neuchâtel*, Switzerland

# Mamíferos coletados por Johann Jakob von Tschudi no Peru, durante 1838-1842, para o Museu de História Natural de Neuchâtel, Suíça

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**Abstract:** During his first trip to Latin America (1838-1842), the Swiss naturalist Johann Jakob von Tschudi collected a large series of Peruvian fauna, including birds, reptiles, fish, amphibians, and mammals. On this last group, Tschudi published two pioneering works, "Mammalium conspectus" and "Untersuchungen über die Fauna Peruana", in which he described new species and presented the first systematic lists of the Peruvian fauna. Despite the relevance of Tschudi's work, his lists of mammals have been poorly consulted in contemporary research. In order to rectify and update these lists, we reviewed all of Tschudi's writings on mammals, situating his expedition in its global context. Additionally, we looked and reviewed the material collected by Tschudi, including types, held at the *Muséum d'Histoire Naturelle de Neuchâtel* (Neuchâtel, Switzerland). Of the 119 species listed by Tschudi, approximately 87 are currently recognized as valid. Furthermore, at least 21 type specimens representing 14 of the 24 species described by Tschudi are still held at Neuchâtel's collection. We finally corrected and clarified the date of publication of Tschudi's new species. Tschudi's Peruvian expedition drew international recognition in his days, being a milestone in the history of scientific institutionalization in Switzerland, and remains as a relevant legacy for the study of Peruvian biodiversity.

**Keywords:** History. Mammalogy. Scientific collections. Travels in Peru. Type material.

**Resumo:** Durante sua primeira viagem à América Latina (1838-1842), o naturalista suíço Johann Jakob von Tschudi coletou uma grande amostra da fauna peruana, incluindo aves, répteis, peixes, anfíbios e mamíferos. Sobre o último grupo, publicou dois trabalhos pioneiros, "Mammalium conspectus" e "Untersuchungen über die Fauna Peruana", nos quais descreveu novas espécies e apresentou as primeiras listas sistemáticas da fauna peruana. Apesar da relevância destas obras, suas listas de mamíferos foram pouco consultadas por autores modernos. Objetivando retificar e atualizar essas listas, revisamos toda a literatura relacionada aos mamíferos de Tschudi, situando sua expedição em um contexto global. Adicionalmente, examinamos e revisamos o material de Tschudi, incluindo os tipos depositados no *Muséum d'Histoire Naturelle de Neuchâtel* (Neuchâtel, Suíça). Das 119 espécies listadas por Tschudi, aproximadamente 87 são consideradas válidas atualmente. Além disso, pelo menos 21 espécimes-tipo representando 14 das 24 espécies descritas por Tschudi ainda estão depositados na coleção de Neuchâtel. Finalmente, corrigimos e esclarecemos as datas de publicação das novas espécies de Tschudi. A expedição peruana de Tschudi obteve reconhecimento internacional da elite científica em seus dias, sendo um marco na história da institucionalização científica na Suíça e permanece como legado relevante para o estudo da biodiversidade peruana.

**Palavras-chave:** História. Mastozoologia. Coleções científicas. Viagens no Peru. Material-tipo.

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SERRANO-VILLAVICENCIO, J. E., T. BARTOLETTI & C. BUENO, 2020. Mammals collected by Johann Jakob von Tschudi in Peru during 1838-1842 for the *Muséum d'Histoire Naturelle de Neuchâtel*, Switzerland. **Boletim do Museu Paraense Emílio Goeldi. Ciências Naturais** 15(3): 905-931. DOI: http://doi.org/10.46357/bcnaturais.v15i3.249.

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Recebido em 21/12/2019
Aprovado em 12/11/2020
Responsabilidade editorial: Alexandra Maria Ramos Bezerra

## INTRODUCTION

The histories of zoological collections assembled in the 19th century tend to be reconstructed from the standpoint of programmatic motivations. Various museums and university institutions needed to expand their inventory with the desire —first of a fixist nature then later evolutionist (Robert *et al.*, 2017; Wilkins, 2018)—to broaden the number of specimens in the Book of Nature (Forgan, 1994; Outram, 1997; Alberti, 2005, 2018). Other communities took an interest in the conservation of local natural heritage (Kohler, 2006). Although this expansion generally occurred in European museums due to their connections with (post) colonial territories, collections also emerged in non-European territories that emulated these 19th century "cathedrals of science" (Sheets-Pyenson, 1988), particularly in Latin America (Horta Duarte, 2013), making it possible to establish fluent exchanges in global scientific networks (*cf*. Gänger, 2017). Extraordinary factors can be identified in these histories, typical of the 19th century and its dynamic global order, including developments in transport and communication, and key political events occurring in African and southern Asian colonies and in the emergent South American independent states (Bayly, 2004; Osterhammel, 2014). Without possessing colonies, Switzerland actively participated in this European expansion by collaborating with transimperial projects of different kinds (Purtschert *et al.*, 2012; Purtschert & Fischer-Tiné, 2015; Eichenberger *et al.*, 2017). This participation was by means of mercenaries and missionaries networks, but also by means of scientific expeditions (Harries, 2007; Zangger, 2011; Kupper & Schär, 2015; Schär, 2015). One paradigmatic case is the collection currently in the *Muséum d'Histoire Naturelle de Neuchâtel*, gathered by Johann Jakob von Tschudi (born in Glarus 1818-died in Wiener Neustadt 1889; see Schazmann, 1956; Kaulicke, 2001) in Peru during 1838-1842, whose fundamental legacy for South American Zoology is the motivation for this article.

The collection of the *Muséum d'Histoire Naturelle de Neuchâtel* originated in a donation from General Charles-Daniel de Meuron, founder of a Swiss mercenary regiment that served first in the Dutch East India Company and later in the British East India Company (Meuron, 1982; Schlup, 1996; Fässler, 2007, p. 133-134, 159-160). During his military campaigns in southern India and Cape Town in the late 18th century, de Meuron collected animals and cultural objects belonging to the natives in the region, thus creating a natural history cabinet and gaining prestige in the Swiss intellectual scene (Kaehr, 2000). The transformation of the cabinet into an actual museum was the responsibility of the de Coulon family, especially Louis, who signed on as director in 1835 (Favre, 1893-1894; *cf*. Schubiger, 2008). The expedition that took Tschudi to further map South American biogeography (Browne, 1983, 1992), a project begun on Alexander von Humboldt's famous voyage, was initially sponsored by the de Grenus banking family of Geneva, who arranged for a ship to sell Swiss products abroad and invited different museums to send scientists on the voyage (Godet, 1901). The professor Louis Agassiz, who had already made an international name for himself for his work with fossil fish (Agassiz, 1833-1843), passed up the trans-Atlantic adventure due to his planned visit to the northern region of the Americas (Lurie, 1960, p. 72-121). He gave his backing to Tschudi, a young naturalist from Glarus no doubt due to his academic record, but also because of his skills 'in the field' (fishing, hunting, riding, taxidermy). Prior to his Peruvian journey, he had already published works on Swiss reptiles (Tschudi, 1837) and the classification of batrachians (Tschudi, 1838). Furthermore, the 'von' in Tschudi's surname refers to the patrician lineage of the Glarus canton that goes back to the first chronicler of the early Swiss Confederation, Aegidius Tschudi. Practical knowledge of hunting was part of the patrician elite's social capital and influenced him throughout his life, as evidenced by the two decades he devoted to editing a hunting manual (Winkell, 1858-1878). Hunting as a practice of the Central European elite may go back as far as the Middle Ages or even Ancient times. Until the mid-19th century (early 19th century in Switzerland) it was a privilege of the nobility and in the imperial context this practice was passed on to the African and Asian colonies (Thompsell, 2015; Gissibl, 2016), especially stressing their 'scientific' dimension, as MacKenzie (1988, p. 300) described it:

> The true sportsman was a natural historian and a scientist. Killing was in a sense legitimated by his understanding of his quarry, its environment and its anatomy, and his knowledge of firearms and ballistics added an extra scientific dimension. The hunter had become a member of an exclusive club, its rules defined by Western technology and science.

This biographical summary of Tschudi's practical skills aims to indicate what historians of science have emphasized during the last decades: the fundamental role of socio-historic conditions in the production of scientific knowledge. Following these canonical studies, Tschudi's Peruvian collections are a paradigmatic case of the formation of scientific knowledge and Central European elites in the 19th century (Browne, 1995, 2002; Shapin, 2010). That is, both in the cabinet that Meuron collected on his mercenary campaigns and in the scientific education Agassiz gave to the young patrician Tschudi, it is possible to identify the social context of Swiss museums and universities, their colonial ties and the global circulation of knowledge, from Ceylon to Peru, via Neuchâtel. Consequently, the history of zoological collections in general and of the *Muséum d'Histoire Naturelle de Neuchâtel* in particular should be read as a 'social and global' history of science (Chambers & Gillespie, 2000; Roberts, 2009; Sivasundaram, 2010; Habermas & Przyrembel, 2013; Finnegan & Wright, 2015).

The extraordinary circumstances of this expedition were the events that caused the ship l'Edmond to divert its course after crossing the Atlantic Ocean, reaching Peru via the Strait of Magellan. The war between Peru and Chile prevented the free movement of ships, with some temporary exceptions (Godet, 1901, p. 44), with the result that l'Edmond had to set sail from the port of Callao (near Lima, Peru), before Tschudi could finish his research. Consequently, Tschudi stayed four years longer than expected in Peru, but also had time to accumulate a monumental collection of over 665 specimens. The diversity of the specimens is not only associated with their variety, but also the regions he travelled across. Tschudi's journeys covered the coast and the Andes to the pre-Amazon jungle. In "Untersuchungen über die Fauna Peruana" (Tschudi, 1844b, 1845) and "Peru: Reiseskizzen, 1838–1842" (Tschudi, 1846), the locations are clarified with some approximation, be it the surroundings of Lima, the Quebrada de Huaytara, the Huascacocha lagoon, the Cerro Pasco, the Chanchamayo River, or the Monte San Carlos de Vitoc. Tschudi's expedition and the unexpected abandonment by l'Edmond had logistical consequences that he details in his books and some correspondence. Among the descriptions of the social life in Lima and impressions of Inca antiquities, he recounts how he worked as a doctor to cover his costs and an accident with his mule in which he lost a large part of his instruments and notes from the first years. However, the true difficulties and needs of Tschudi's scientific expedition can be read in the letters that he sent home from Peru[1]. Particularly, letters from 1839 addressed to his friend Alfred Escher and Louis de Coulon from the foothills of Montaña de Vitoc show successive requests for money, weapons, gunpowder, dissection instruments, and several artifacts to trade with the locals. He also outlines the logistics and number of specimens he had sent so far. The requested money was not only for his subsistence, but also that of the Prussian sailor Eduard Klee, who accompanied Tschudi during his travels in order to hunt animals for the collection (Tschudi, 1846, II, p. 270-286) (Figure 1). The Grey Tinamou *Tinamus tao kleei* (Tschudi, 1845) (Aves: Tinamidae), originally described as *Crypturus kleei*, was named after him (see Tschudi, 1845, p. 284-286). All these

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[1] Some of these letters were published and translated into Spanish in *Boletín de Lima* 117 (Zennibar, 1999). Letters from this period are found in the historical archive of the Museum in Neuchâtel and in the digital edition of Alfred Escher's letters (Alfred Escher-Stiftung, n. d.).

data document the logistical factors in assembling zoological collections in the context of expanding global trade in the 19th century (Coote *et al.*, 2017).

Tschudi did not rely only on his European practice of hunting with scientific ends. Other species, such as camelids, were taken using the traditional Andean method of domestication called *chacu*, herding them into funnel traps (Custred, 1979). Tschudi participated in this way of domesticating camelids and, as he detailed in one of his last publications (Tschudi, 1885), he developed an ethnozoological perspective to explain the Andean attitudes towards the fauna. The vicuñas currently in the Neuchâtel were collected in a *chacu* (Tschudi, 1845, p. 223-238), and are one of the most significant pieces. He had already covered some of this ethnozoological perspective in "Peru: Reiseskizzen, 1838–1842" (Tschudi, 1846, p. 79-112) and in "Untersuchungen über die Fauna Peruana" (Tschudi, 1844b, 1845), a summary of his scientific work in Peru, over 800 pages long and featuring 70 illustrations. Composed on his return in 1843 and after visiting the collections of Paris, Berlin, Munich, and Vienna, "Untersuchungen über die Fauna Peruana" is the first systematic study of the Peruvian fauna associated with his geognostic understanding, a focus typical of "Humboldtian Science" (Nicolson, 1987; Böhme, 1999). In it we can see the contemporary state of zoology in the mid-19th century and also identify a certain culturalist perspective, as Tschudi explains domestic uses of the animals and different local hunting forms. "Untersuchungen über die Fauna Peruana" was explicitly dedicated to Alexander von Humboldt, whom Tschudi met in Berlin in 1844, and who provided Tschudi with sketches of illustrations from his first journey. The famous London ornithologist John Gould would also remark on the birds collected by Tschudi, one of the Neuchâtel museum's most valuable collections. With the interest of broadening the late Joseph Blumenbach's renowned collection, Rudolf Wagner wrote to Tschudi from Göttingen about the mummies and skulls he brought back from Peruvian *huacas* (see Rivero y Ustáriz & Tschudi, 1851, p. 22-37). It can be said then that Tschudi and his South American journey along with his extensive "Fauna Peruana" and the zoological collection connected to it drew international recognition in his day from the scientific elite. Tschudi's laborious expedition retains to this day a relevant legacy in the *Muséum d'Histoire Naturelle de Neuchâtel* for the study of Peruvian biodiversity in the mid-19th century.

Figure 1. Refuge inhabited by J. J. von Tschudi and Eduard Klee during their stay in the Montaña de Vitoc, Peru (Tschudi, 1846, p. 279).

As part of a collective multi-local and interdisciplinary work, this research seeks to reconstruct the historical and epistemological material collected by Tschudi during his first travel to Peru (1838-1842) for the *Muséum d'Histoire Naturelle de Neuchâtel* (MHNN, Switzerland). For this purpose, we reassembled the historical material from the archives and publications together with the mammal collection. We also updated the taxonomy of Tschudi's (1844a, 1844b, 1845) lists by contrasting his original descriptions and illustrations with the material store at the MHNN collected by this author and with recent literature. This represents a first step towards the complete reassembly of the materials in the *Muséum d'Histoire Naturelle de Neuchâtel* linked to Tschudi's expedition in a context of global formation of natural history collections during the 19th century.

## MATERIALS AND METHODS

In order to update and reinterprate the lists given by Tschudi in his "Mammalium conspectus" (Tschudi, 1844a) and "Untersuchungen über die Fauna Peruana" (Tschudi, 1844b, 1845, hereafter "Fauna Peruana"), we reviewed the material collected by Tschudi in Peru, which is held in the *Muséum d'Histoire Naturelle de Neuchâtel* (hereafter MHNN). Additionally, we reviewed Tschudi's publications and accounts regarding mammals and compared them with historical and recent literature of Peruvian mammals. The taxonomic arrangement of Primates follows Schneider & Sampaio (2015) and Garbino & Martins-Junior (2017) for genera and families, and Mittermeier *et al.* (2013) for species with some modifications. We followed Hershkovitz's (1987a) taxonomic arrangement of *Pithecia* Desmarest, 1804. The new genera of titi monkeys proposed by Byrne *et al.* (2016), *Cheracebus* and *Plecturocebus*, are here treated as subgenera following Serrano-Villavicencio *et al.* (2017), Gutiérrez & Marinho-Filho (2017), Garbino & Aquino (2018), and Brandão *et al.* (2019). In the same way, we recognize all capuchin monkeys as *Cebus*, with the subgenera *Cebus* Erxleben, 1777 (gracile species) and *Sapajus* Kerr, 1792 (robust species), following Feijó & Langguth (2013), Garbino (2015), Gutiérrez & Marinho-Filho (2017), and Teta *et al.* (2018); we followed Hershkovitz's (1949) arrangement for gracile capuchin species. The taxonomy of Didelphimorphia, Pilosa, Cingulata, and Chiroptera follows authors in Gardner (2008 [2007]), with the update of Miranda *et al.* (2017) for the silky anteaters (*Cyclopes*). The taxonomy of Rodentia follows authors in Patton *et al.* (2015), and Carnivora and Artiodactyla following Wozencraft (2005) and Grubb (2005), respectively, and Acosta, L. *et al.* (2020) for Tayassuidae.

## RESULTS AND DISCUSSION

### TSCHUDI'S COLLECTION AT THE *MUSÉUM D'HISTOIRE NATURELLE DE NEUCHÂTEL*

Over 665 specimens collected by Tschudi are preserved at the MHNN. His contributions not only cover birds (407 specimens), reptiles (116), and mammals (93), but also amphibians (46), bony fishes (two), and at least one mollusk. This collection includes over 200 type specimens, mostly of birds. The 93 mammals include 21 type specimens covering 14 species described by Tschudi. Six type specimens were reviewed by specialists: holotype of *Rhipidomys leucodactylus* (MHNN-94.2043F) by Christopher J. Tribe in 1990, Syntypes of *Phyllostoma erythromos* (MHNN-94.2539), *Phyllostoma oporaphilum* (MHNN-94.2540 and MHNN-94.2540A) by Timothy J. McCarthy in 1989, and the lectotypes of *Oligoryzomys destructor* (MHNN 94.2043A) and *Oligoryzomys melanostoma* (MHNN-94.2043B) (Gyldenstolpe, 1932; Serrano-Villavicencio, 2019).

Type specimens for another eight mammal species might be mislabeled and still remain to be located upon further revision of the Tschudi's collection at the MHNN. These unlocated type specimens belong to the following species: *Glossophaga* (*Choeronycteris*) *peruana*, *Ursus frugilegus*, *Nasua leucorhynchos*, *N. vittata*, *Mustela agilis*, *Lutra montana*, *Didelphys* (*sic*) *impavida*, *Molossus anonymus*. The two remaining species described by Tschudi, *Phyllostoma innominatum* and *Glossophaga* (*Choeronycteris*) *mexicana* have their type specimens inexistent, lost, or deposited elsewhere outside the MHNN. The available material collected by Tschudi can be found at the MHNN's online database (MHNN, n. d.).

### PUBLICATION DATES OF THE MAMMAL SPECIES DESCRIBED BY TSCHUDI

There has been a persistent confusion about the year of authorship of some mammals described by Tschudi. This confusion was mainly caused by three factors: (1) the publication of Tschudi's "Mammalium conspectus" (Tschudi, 1844a) dated December 1843 but published in 1844, which included the names of the new species later described by him; (2) the list of species presented at the beginning of Tschudi's "Fauna Peruana" (Tschudi, 1844b, p. 6-20) also containing the names of his new species without descriptions; and (3) the different years in which the sections of the "Fauna

Peruana" were published, although the section of mammals is dated 1844 in the cover. Tribe (2015, p. 586) gave an accurate explanation in order to solve the problems concerning the availability of Tschudi's new names. In agreement with Tribe (2015), the names that appeared in Tschudi's (1844a) "Mammalium conspectus" and in "Fauna Peruana"'s lists represent *nomina nuda* since they do not present a proper definition nor description as dictated by Article 12 of the International Code of Zoological Nomenclature (ICZN).

Point (3) is harder to ascertain. Tribe (2015) argued that Sherborn (1922, p. cxxiv) would arrange this confusion surrounding the dates of the "Fauna Peruana"'s sections. This is in part accurate. C. D. Sherborn allowed B. B. Woodward to use his ongoing manuscripts into the "Catalogue of the Books, Manuscripts, Maps and Drawings: In the British Museum (Natural History)" (see British Museum, 1903, p. viii). The information regarding Tschudi's publications given by Sherborn was first published in British Museum (1915, p. 2147). Sherborn's amendments were based on data published in Lorenz Oken's journal Isis. According to Oken (1844, 1845, 1846, 1847), Tschudi's "Fauna Peruana" was published between 1844 and 1846 in 12 parts as follows: Mammals (Therologie) (1) pp. 1-20, 1844; (2) pp. 21-76, 1844; (3) pp. 77-132, 1845; (4) pp. 133-188, 1845; (5) pp. 189-244, 1845; (6) pp. 245-262 and Birds (Ornithologie), pp. 1-32, 1846; (7-12) and end of Birds, Reptiles (Herpetologie), pp. 1-80 and Fish (Ichthyologie), pp. 1-35, 1846.

According to Oken (1845, p. 875), the species of mammals Tschudi described in 1844 were *Phyllostoma erythromos*, *Phyllostoma oporaphilum*, *Phyllostoma innominatum*, *Glossophaga* (*Choeronycteris*) *peruana*, and *Glossophaga* (*Choeronycteris*) *mexicana*, whereas Tschudi described the following species in 1845: *Molossus naso*, *Molossus anonymus*, *Molossus myosuros*, *Ursus frugilegus*, *Nasua leucorhynchos*, *Nasua vittata*, *Nasua montana*, *Mustela agilis*, *Lutra montana*, *Otaria ulloae*, *Didelphys* (*sic*) *ornata*, *Didelphys* (*sic*) *noctivaga*, *Didelphys* (*sic*) *impavida*, *Drymomys parvulus*, *Hesperomys destructor*, *Hesperomys melanostoma*, *Hesperomys leucodactylus*, *Sphingurus bicolor*, and *Dasyprocta variegata* (see Oken, 1845, p. 935; 1846, p. 312; 1847, p. 880). Likewise, the 18 plates of mammals presented by Tschudi in "Fauna Peruana" were also published on different dates as indicated by Oken. Plates 1-12 were published in 1844 (see Oken, 1844, p. 938; 1845, p. 875), whereas plates 13-18 appeared in 1845 (see Oken, 1847, p. 880)

Although this publication issue has been explained and corrected by several authors (see Sherborn, 1922; Patton & Emmons, 2015; Tribe, 2015), this confusion still persists. One example of this confusion is Pacheco *et al.* (2009, p. 20), who listed *Marmosops impavidus* and *M. noctivagus* as authored by Tschudi, 1845 and Tschudi, 1844, respectively. However, both species were described in the same section (Therologie, section 4 according to Oken), hence are attributable to Tschudi, 1845. As a recent example, we present the case of *Oligoryzomys destructor* and *O. melanostoma.* Since both species were properly described on page 182 of "Fauna Peruana" and, as in the previous example, their correct publication date is Tschudi, 1845. Nonetheless, *Oligoryzomys destructor* and *O. melanostoma* have been recently assessed and the names have been mistakenly attributed to Tschudi, 1844 (see Weksler & Bonvicino, 2015; Hurtado & D'Elía, 2019; Serrano-Villavicencio, 2019).

## MAMMALS OF PERU ACCORDING TO TSCHUDI

Tschudi presented the first lists of Peruvian mammals in his (1) "Mammalium conspectus" (Tschudi, 1844a) and (2) "Fauna Peruana" (Tschudi, 1844b). In (1), 119 species of mammals were listed; although Tschudi's new species were not properly described. On the other hand, in (2) the list was reduced to 109 mammal species. In addition to the disparity in number of species, there are other differences between these two works. For instance, *Molossus longimanus* (Wagner, 1843) was considered as a species in (1) but as a synonym of *M. ferox* Poeppig, 1832 in (2). *Lagidium pallipes* Bennett, 1835 appeared only in (2); in (1) *Myrmecophaga* Linnaeus, 1758 has two species: *M. tetradactyla* Linnaeus, 1758 and *M. didactyla* Linnaeus, 1758 whereas in (2) the two species are *M. tamandua* Cuvier, 1798 and *M. didactyla*.

Besides the differences among the lists published by Tschudi in "Mammalium conspectus" and "Fauna Peruana", there are also discrepancies related to the number of species presented in the list and in the body of the latter work. Some of these discrepancies are: *Glossophaga* (*Choeronycteris*) *mexicana* Tschudi, 1845 appears in the body but not in the list. In the list, there are only two species of the genus *Nasua* Storr, 1780, *N. socialis* Wied, 1826 and *N. montana* Tschudi, 1845; nonetheless, in the body are listed five species: *N. socialis*, *N. solitaria* Schinz, 1821, *N. leucorhynchos* Tschudi, 1845, *N. vittata* Tschudi, 1845, and *N. montana*. In the list, four species of *Canis* appear: *C. familiaris* Linnaeus, 1758, *C. caraibicus* (*sic*) Lesson, 1827, *C. ingae* Tschudi, 1845, and *C. azarae* Wied, 1824; however, in the body only the last species is listed. The genus *Myopotamus* É. Geoffroy Saint-Hilaire, 1805 is in the list but it was removed from the body due to uncertainty regarding its presence in Peru. The genera *Equus* Linnaeus, 1758, *Sus* Linnaeus, 1758, *Bos* Linnaeus, 1758, *Capra* Linnaeus, 1758, and *Ovis* Linnaeus, 1758 are only in the list, not in the body.

Tschudi (1844b) separated wild and native species from the introduced or domestic ones, describing them in the section "Über die Haussäugethiere in Peru" (= about the domestic animals in Peru). In this section, the author described species of domestic dogs as *Canis caraibicus* (*sic*) (Peruvian hairless dog) or *Canis ingae* (mongrel dog from the Andes). Other animals described in this section are the domestic cat, *Felis silvestris catus* Linnaeus, 1758; the *cuy* or guinea pig, *Cavia porcellus* Blumenbach, 1779, which Tschudi wrote was widely consumed in the Andes; pigs, *Sus scrofa domesticus* Linnaeus, 1758; cattle, *Bos taurus* Linnaeus, 1758; sheep, *Ovis orientalis aries* Linnaeus, 1758; goats, *Capra aegagrus hircus* Linnaeus, 1758; llamas, *Lama glama* Linnaeus, 1758; and alpacas, *Vicugna pacos* (Linnaeus, 1758).

Regarding cetaceans, Tschudi (1844a, 1844b) noted the difficulty of elaborating a detailed list of these mammals due to the lack of material. Tentatively, Tschudi listed *Manatus americanus* (= *Trichechus manatus* Linnaeus, 1758), *Catodon macrocephalus* (= *Physeter catodon* Linnaeus, 1758), *Balaena mysticeta* (*sic*) (= *Balaena mysticetus* Linnaeus, 1758) and *B. lunulata* [= *Eubalaena japonica* (Lacepède, 1818)], and *Balaenoptera punctata* (= *Balaenoptera* sp.). In addition to this list, Tschudi (1844b, p. 20) gives a brief account about a beached whale (*Balaenoptera* sp.) of approximately 17 meters on the coast of Miraflores (Lima) in January 1839. Although Tschudi thought that this individual may represent a new species of *Balaenoptera*, he stated that there was no comparative material and never described it as such.

In addition to the above mentioned accounts of mammals presented by Tschudi, there are numerous illustrations that he published in "Fauna Peruana". They represent relevant visual evidence for our collation with the existing collection in MHNN, as well as the media through which the naturalists were circulating and exchanging their knowledge (Heßler, 2006; Mersch, 2006). Those illustrations published by Tschudi followed the trend of his time. Animal illustrations did not have a single process of creation and each particular case should be analyzed separately. What can be assured is that scientific illustrations had different stages as sketches in the field, comparison with specimens from other collections, comparison with other illustrations and/or sketches made by other naturalists, and precisely the illustration from the taxidermied specimen itself (Wittmann, 2008). Moreover, some authors replicated original illustrations and published them with lesser quality and details. For instance, Reichenbach (1862, Plate IV, V) presented plates of several Neotropical primates copied from other authors, between them, we found replicas of Spix's (1823) *Pithecia inusta* and *P. capillamentosa* or I. Geoffroy Saint-Hilaire & Deville's (1848) *Callicebus discolor* original illustrations. A paradigmatic case is that of Tschudi's *Otaria ulloae*, which was based both on the specimen he sent from Peru to Neuchâtel and on a sketch that Alexander von Humboldt gave as a present to him in 1844 (Bayerl, 2017).

The lists of Peruvian mammals presented by Tschudi (1844a, 1844b) were analyzed and interpreted by Hershkovitz (1987b). This latter author identified 119 species in 48 genera, including some duplicated names of native species and others not known to occur in Peru. Hershkovitz (1987b, p. 68, table 9) presented a list with the names given by Tschudi and the current names of each species at that time. After reviewing Tschudi's accounts, we believe that, although Tschudi misapplied some scientific names, he was actually referring to mammals that occur in Peru. The descriptions of some species listed by Tschudi were based on communications with natives and local hunters (as probably in the case of *Ursus frugilegus*) or literature available at that time (e.g. *Mycetes flavicaudatus* based on Humboldt's *Simia flavicauda*). In Table 1, we present an updated list of the Peruvian mammals recorded by Tschudi. The identification of some species remains as tentative due to the lack of details in Tschudi's accounts. Our list follows the order established by Tschudi in "Fauna Peruana".

## PHOTOGRAPHIC RECORDS OF TSCHUDI'S TYPE MATERIAL

Although the material collected by Tschudi has been mentioned by some authors (see Thomas, 1908, 1927; Gyldenstolpe, 1932; Hershkovitz, 1987b), its plates have appeared in few works. Hershkovitz (1987b, p. 66) reproduced Tschudi's plates of *Auchenia vicunia*, *Didelphys* (*sic*) *ornata*, *Dasyprocta variegata*, and *Nasua montana*. Similarly, Zennibar (1999, p. 57) presented Tschudi's plate of *Cervus antisiensis* (= *Hippocamelus antisensis*) accompanied by a photo of the specimen in Neuchâtel, MHNN-94.1588A. Velazco & Cornejo (2014) also presented Tschudi's plate of *Dasyprocta variegata*. Finally, Serrano-Villavicencio (2019) presented the lectotypes of *Hesperomys destructor* (MHNN-94.2043A) and *H. melanostoma* (MHNN-94.2043A), held at the MHNN. For this reason, we found relevant and necessary to present the first photographic catalog of the type material collected by Tschudi in Peru. We expect that this catalog will be useful for future assessments of the Peruvian mammal fauna. When possible, we present the photograph of the specimen alongside the plates published by Tschudi (1844-1845) (Figures 2-14).

## CONCLUSION

As part of interdisciplinary research, we demonstrate the novel relevance of natural history museums in reconstructing the species richness and uniqueness of Peruvian mammals. In this sense, natural history museums can be considered as 'archives of biodiversity'. Research in 'archives of biodiversity' implies an understanding of the collections as natural, social and historical assemblages, which necessarily includes an insight into the biographical and social aspects of the collector (Johann Jakob von Tschudi) and the institution (*Muséum d'Histoire Naturelle de Neuchâtel*). This interdisciplinary engagement between the natural and social sciences in natural history museums therefore provides convincing arguments against their dispersal or deactivation and in favour of their conservation and improved accessibility for researchers.

The legacy of Johann Jakob von Tschudi has been investigated only on the surface. His more complete work regarding the Peruvian fauna, "Fauna Peruana", is full of details and valuable information that has not been properly dissected nor used. Nonetheless, his contributions could and should be considered as the starting point of the scientific study on the Peruvian mammals (Velazco & Cornejo, 2014). Tschudi's works were the first attempt to make a systematized compendium of Peruvian mammals, for which he reviewed not only European literature but also had the merit of worrying about understanding the Peruvian fauna in a regional context. This concern is evidenced in the colonial literature he cited as José de la Acosta's (1590) "Historia natural y moral de las Indias", or even Inca Garcilaso de la Vega's (1609) "Los comentarios reales de los incas", a fact rarely seen before. Tschudi's impetus for integrating the fauna with its natural history could only be realized because of his commitment to the Peruvian culture. Tschudi did not only study the Peruvian fauna, but also engaged in indigenous and local management with animals, which provides a relevant source for further ethnozoological research.

Table 1. Peruvian mammals according to J. J. von Tschudi. Current scientific names were inferred from Tschudi's (1844a, 1844b, 1845) descriptions; when relevant, we provide comments for some species. In the case of type material, its corresponding museum information is provided. '?' represents uncertainty on identification due to lack of detailed information.

(Continue)

| Order/Current name | Name in Tschudi's list | Comments |
|---|---|---|
| Primates | | |
| *Ateles belzebuth* É. Geoffroy Saint-Hilaire, 1806 | *Ateles marginatus* É. Geoffroy Saint-Hilaire, 1809 | *Ateles marginatus* is endemic to Brazil (Rylands *et al*., 2013b). Tschudi described this spider monkey as having a white part in the front of the head and white belly. In Peru the only species of *Ateles* presenting these characters is *A. belzebuth.* |
| *Ateles chamek* (Humboldt, 1812) | *Ateles ater* F. Cuvier, 1823 | *Ateles ater* and *A. pentadactylus* are currently considered as junior synonyms of *A. paniscus.* Hill (1962) considered *A. chamek* as subspecies *of A. paniscus.* Due to the morphological similarity of these two species and because *A. paniscus* does not occur in Peru, we consider that Tschudi referred to *A. chamek.* |
| | *Ateles paniscus* (Linnaeus, 1758) | |
| | *Ateles pentadactylus* É. Geoffroy Saint-Hilaire, 1806 | |
| *Lagothrix lagothricha poeppigii* Schinz, 1844 | *Lagothrix humboldtii* É. Geoffroy Saint-Hilaire, 1812 | According to Fooden (1963), *Lagothrix humboldtii* is a synonym of *Lagothrix lagothricha lagothricha*, *L. l. cana*, and *L. l. poeppigii.* Tschudi described a brownish monkey with black head which matches the phenotype of *L. l. poeppigii.* |
| *Lagothrix lagothricha cana* (É. Geoffroy Saint-Hilaire, 1812) | *Lagothrix canus* (É. Geoffroy Saint-Hilaire in Humboldt, 1812) | |
| *Alouatta seniculus* (Linnaeus, 1766) | *Mycetes stramineus* (É. Geoffroy Saint-Hilaire in Humboldt, 1812) | According to Gregorin (2006), *Mycetes stramineus* is a current synonym of two species of *Alouatta: A. caraya* and *A. macconnelli.* Tschudi (1844b, p. 39) stated that he saw a live specimen of *M. stramineus* in captivity that was captured in the woods east of Moyobamba (San Martín, Peru). He also affirmed that another species of *Mycetes* inhabited further south, *M. rufimanus*. Pacheco *et al.* (2020) listed two species of reddish howler monkeys, *A. seniculus,* inhabiting northeastern Peru and *A. sara* in the southeastern, which agrees with Tschudi's statement. For these reasons, *A. seniculus* is the most suitable option. |
| *Alouatta sara* Elliot, 1910 | *Mycetes rufimanus* Kuhl, 1820 | *Mycetes rufimanus* is a current synonym of *Alouatta belzebul* (Gregorin, 2006). *Alouatta sara* matches the description and the coordinates given by Tschudi. |
| *Lagothrix flavicauda* (Humboldt, 1812) | *Mycetes flavicaudatus* (Humboldt, 1812) | Based on Humboldt's (1812) *Simia flavicauda.* It is highly probable that Tschudi never saw individuals of this species. |
| *Cebus* (*Sapajus*) *apella* (Linnaeus, 1758) | *Cebus robustus* Kuhl, 1820 | This is a species which does not occur in Peru only in the Brazilian Atlantic forest (Lynch Alfaro *et al*., 2012; Rylands *et al*., 2013a). It is probable that Tschudi referred to *Cebus apella.* |

Table 1. (Continue)

| Order/Current name | Name in Tschudi's list | Comments |
|---|---|---|
| *Cebus* (*Cebus*) *albifrons unicolor* Spix, 1823<br>*Cebus* (*Cebus*) *albifrons yuracus* Hershkovitz, 1949<br>*Cebus* (*Cebus*) *albifrons cuscinus* Thomas, 1901 | *Cebus capucinus* (Linnaeus, 1758) | *Cebus capucinus* inhabits the eastern portion of Panama and the north-western portion of South America, which does not occur in Peru (Lynch Alfaro *et al*., 2012; Rylands *et al*., 2013a). The description given by Tschudi lacks of diagnostic specific characters and matches any of the three subspecies of *Cebus albifrons* proposed by Hershkovitz (1949) for Peru. |
| *Cebus* (*Cebus*) *albifrons unicolor* Spix, 1823<br>*Cebus* (*Cebus*) *albifrons yuracus* Hershkovitz, 1949<br>*Cebus (Cebus) albifrons cuscinus* Thomas, 1901 | *Cebus albifrons* (Humboldt, 1812) | As in the case above, Tschudi's description does not allow us to determine the species he was referring to. *Cebus albifrons unicolor*, *C. a. yuracus*, and *C. a. cuscinus* are equally likely options. |
| *Callicebus* (*Plecturocebus*) sp. | *Callithrix personatus* (É. Geoffroy Saint-Hilaire in Humboldt, 1812) | *Callithrix personatus* is a current synonym of *Callicebus (Callicebus) personatus*. This species is endemic to the Brazilian Atlantic Forest (Hershkovitz, 1990). *Callicebus cupreus*, *C. toppini*, or *C. urubambensis* match Tschudi's description. |
| *Callicebus* (*Cheracebus*) *torquatus* (Hoffmannsegg, 1807) | *Callithrix amictus* É. Geoffroy Saint-Hilaire, 1812 | |
| *Saimiri boliviensis peruviensis* Hershkovitz, 1984 | *Chrysothrix sciureus* (Linnaeus, 1758) | |
| *Aotus nigriceps* Dollman, 1909 | *Nyctipithecus trivirgatus* (Humboldt, 1812) | |
| *Pithecia monachus* (É. Geoffroy Saint-Hilaire, 1812) | *Pithecia satanas* (Hoffmannsegg, 1807) | *Pithecia satanas* is a synonym of *Chiropotes satanas*. The genus *Chiropotes* does not occur in Peru (Hershkovitz, 1985). Based on the description and the coordinates given by Tschudi, the recorded species might be *Pithecia monachus.* |
| *Saguinus* (*Leontocebus*) *fuscicollis* (Spix, 1823) | *Midas rufimanus* É. Geoffroy Saint-Hilaire, 1812 | Although *Midas rufimanus* is a current synonym of *Saguinus midas*, the description given by Tschudi does not match the phenotype of the latter species; he probably mentioned a species of the *S. fuscicollis* group. |
| *Saguinus* (*Leontocebus*) *labiatus* (É. Geoffroy Saint-Hilaire, 1812) | *Midas labiatus* É. Geoffroy Saint-Hilaire, 1812 | |
| *Callicebus* (*Plecturocebus*) *discolor*? (I. Géoffroy Saint-Hilaire & Deville, 1848) | *Midas chrysomelas* (Kuhl, 1820) | Clearly Tschudi did not see a specimen of *Leontopithecus chrysomelas* at that time which is a species endemic to the Brazilian Atlantic Forest (Hershkovitz, 1977; Rylands *et al*., 1993). From the characters given, it is probable that he referred to *C. discolor*. |
| Chiroptera | | |
| *Phyllostomus elongatus* (É. Geoffroy Saint-Hilaire, 1810) | *Phyllostoma* (*Phyllostoma*) *elongatum* É. Geoffroy Saint-Hilaire, 1810 | |
| *Phyllostomus hastatus* (Pallas, 1767) | *Phyllostoma (Phyllostoma) hastatum* (Pallas, 1767) | |

Table 1. (Continue)

| Order/Current name | Name in Tschudi's list | Comments |
|---|---|---|
| *Phyllostomus discolor* (Wagner, 1843) | *Phyllostoma (Phyllostoma) innominatum* Tschudi, 1844 | This species is attributed to Tschudi. Nonetheless, Tschudi did not pretend to describe it as a new taxon. The specific epithet *innominatum* (= nameless) was a provisional name because Tschudi expected that E. F. Poeppig eventually describe it as new, although that never happened. Kwiecinski (2006) and Williams & Genoways (2008 [2007]) recognized *P. innominatum* as synonym of *Phyllostomus discolor.*<br>Type material non-existent. This species was based on the description provided by Poeppig using material collected by himself in Maynas (Loreto, Peru). |
| *Artibeus glaucus* Thomas, 1893 | *Phyllostoma* (*Artibeus*) *pusillum* Wagner, 1843 | *Phyllostoma pusillum* is a synonym of *Vampyressa pusilla*, a species that does not occur in Peru (Arroyo-Cabrales, 2008 [2007]). *Artibeus glaucus* matches Tschudi's description of *P. pusillum* and the collection locality falls within *A. glaucus*'s distribution. |
| *Sturnira erythromos* (Tschudi, 1844) | *Phyllostoma (Sturnira) erythromos* Tschudi, 1844 | Type material: MHNN-94.2539 here selected as lectotype (Figure 2 this work). |
| *Sturnira oporaphilum* (Tschudi, 1844) | *Phyllostoma (Sturnira) oporaphilum* Tschudi, 1844 | Type material: syntypes MHNN-94.2540 (Figure 3 this work) and MHNN-94.2540A. |
| *Glossophaga soricina valens*? Miller, 1913 | *Glossophaga* (*Glossophaga*) *amplexicaudata* (Spix, 1823) | According to Hershkovitz (1987b), Tschudi referred to *Glossophaga soricina* when listed *G. amplexicaudata.* Griffiths & Gardner (2008 [2007]) recognized three subspecies of *G. soricina: G. s. mutica, G. s. soricina*, and *G. s. valens.* According to these authors, only the latter inhabits Peru. We could not confirm this identification due to lack of material collected by Tschudi. |
| *Anoura peruana* (Tschudi, 1844) | *Glossophaga* (*Choeronycteris*) *peruana* Tschudi, 1844 | Griffiths & Gardner (2008 [2007]) proposed this Tschudi's species as subspecies of *Anoura geoffroyi*, *A. g. peruana.* Mantilla-Meluk & Baker (2010), based on morphological and ecological evidence, elevated it to the species level. This species was named as *Choeronycteris peruanus* (not *peruana*) in its plate (see Tschudi, 1844b, Plate 3, figures 1 and 2).<br>Type material: not yet located. |
| *Choeronycteris mexicana* (Tschudi, 1844) | *Glossophaga* (*Choeronycteris*) *mexicana* Tschudi, 1844 | It seems that Tschudi included this species after reviewing material coming from Mexico housed at the "Museum von Berlin". Although Tschudi described its morphology, he did not provide further information of this species or if would inhabit Peru. We do not know the reasons why Tschudi included this species in his works of Peruvian fauna. This species was named as *Choeronycteris mexicanus* (not *mexicana*) in its plate (see Tschudi, 1844b, Plate 3, figure 3)<br>Type material was not deposited at the MHNN and we do not know about its current existence. |
| *Eptesicus innoxius* (Gervais, 1841) | *Vespertilio* (*Vesperus*) *innoxius* Gervais, 1841 | |

Table 1. (Continue)

| Order/Current name | Name in Tschudi's list | Comments |
|---|---|---|
| *Histiotus velatus* (I. Geoffroy Saint-Hilaire, 1824) | *Vespertilio* (*Vesperugo*) *velatus* (I. Geoffroy Saint-Hilaire, 1824) | |
| *Noctilio leporinus leporinus* (Linnaeus, 1758) | *Noctilio unicolor* Desmarest, 1818 | |
| *Noctilio albiventris albiventris* Desmarest, 1818 | *Noctilio affinis* d'Orbigny, 1837 | |
| *Tadarida brasiliensis brasiliensis* (I. Geoffroy Saint-Hilaire, 1824) | *Molossus naso* Tschudi, 1845 | Type material: syntype MHNN-94.2547 (Figure 4 this work) |
| *Molossus molossus crassicaudatus* É. Geoffroy Saint-Hilaire, 1805 | *Molossus velox* (Temminck, 1826) | Gray (1843) considered *Molossus velox* a valid species with *Dysopes velox* as synonym. We follow Eger (2008 [2007]) which considered *Dysopes velox* as junior synonym of *Molossus molossus crassicaudatus.* The description given by Tschudi also matches this species. |
| *Molossus* sp. | *Molossus fumarius* Spix, 1823 | *Molossus fumarius* is a current synonym of *Promops nasutus*, species which does not occur in Peru (Eger, 2008 [2007]). Due to the vague description of both species given by Tschudi, we could not identify which species this author was referring to. |
| | *Molossus anonymus* Tschudi, 1845 | |
| *Eumops glaucinus* (Wagner, 1843) | *Molossus ferox* Poeppig, 1832 | There are some inaccuracies regarding the authorship of *Molossus ferox*. Best *et al.* (1997) and Eger (2008 [2007]) attributed this species to Gundlach in W. Peters (1861, p. 149) with type locality "Cuba". Nonetheless, this species was originally described by Poeppig (1832, p. 230) based on bats he saw in Peru. Tschudi stated that he based his *M. ferox*'s description on the original work of E. F. Poeppig. It is probable that *ferox* has priority over *glaucinus*, a revision is needed. |
| *Molossus rufus* É. Geoffroy Saint-Hilaire, 1805 | *Molossus myosuros* Tschudi, 1845 | Type material: syntype MHNN-94.1203 (Figure 5 this work). |
| Carnivora | | |
| *Tremarctos ornatus* (Cuvier, 1825) | *Ursus ornatus* Cuvier, 1825 | |
| | *Ursus frugilegus* Tschudi, 1845 | There is no reference of any material collected by Tschudi of *U. frugilegus*. He only stated that, due to the climate, preserving skins of this species was a difficult task. It is most likely that Tschudi's description of *U. frugilegus* was based on information provided by natives.<br>Type material: not yet located. |
| *Nasua nasua montana* Tschudi, 1845 | *Nasua socialis* Wied-Neuwied, 1826 | |
| | *Nasua solitaria* Schinz, 1821 | |
| | *Nasua leucorhynchos* Tschudi, 1845 | Type material: not yet located. |
| | *Nasua montana* Tschudi, 1845 | Gompper & Decker (1998) recognized *Nasua nasua montana* as a valid subspecies with *Nasua monticola* Schinz, 1844 as synonym. Nonetheless, these authors claimed that the specific epithet *monticola* may have priority over *montana*. A taxonomic reassessment of the current recognized subspecies is needed.<br>Type material: holotype MHNN-94.1383A by monotypy (Figure 6 this work). |

Table 1. (Continue)

| Order/Current name | Name in Tschudi's list | Comments |
|---|---|---|
| *Nasua nasua vittata* Tschudi, 1845 | *Nasua vittata* Tschudi, 1845 | Type material: not yet located. |
| *Potos flavus* (Schreber, 1774) | *Cercoleptes caudivolvulus* (Pallas in Schreber, 1777) | Tschudi (1845, p. 106) stated that natives from the "Montana von Uchubamba" brought to him a specimen in bad condition. The skin had a blackish shade in the back and brown-reddish belly. The specimen would have been collected in the "Montana von Moyobamba", where this animal was said to be common. *Potos flavus* in Peru and throughout its distribution need taxonomic reassessment, subspecies limits are unknown (Ford & Hoffmann, 1988). |
| *Eira barbara* (Linnaeus, 1758) | *Galictis barbara* (Linnaeus, 1758) | |
| *Mustela frenata agilis* Tschudi, 1845 | *Mustela agilis* Tschudi, 1845 | Type material not yet located. |
| *Conepatus* sp. | *Mephitis mapurito* Lesson, 1827 | |
| | *Mephitis furcata* Wagner in Schreber, 1840 | |
| | *Mephitis amazonica* Lichtenstein, 1836 | |
| *Lontra felina* (Molina, 1782) | *Lutra chilensis* Bennett, 1832 | |
| *Lontra longicaudis* (Olfers, 1818) | *Lutra montana* Tschudi, 1845 | According to Thomas (1908, p. 393) and Cabrera (1958, p. 273) *Lutra montana* is an undetermined species. Both authors agreed that *L. montana*'s description could have been based on an *Eira barbara* specimen. We disagree. Tschudi clearly stated that *L. montana* was a freshwater otter whereas *Lutra chilensis* was a sea otter. Additionally, Tschudi reported *Eira barbara* as a completely different species. Here we propose that this author recorded a dark variation of *Lontra longicaudis*.<br>Type material not yet located. |
| *Lycalopex culpaeus andinus* (Thomas, 1914) | *Canis azarae* Wied-Neuwied, 1824 | *Canis azarae* is a current synonym of *Cerdocyon thous azarae*, species that does not occur in Peru (Wozencraft, 2005). The description given by Tschudi matches that of the Andean fox, *Lycalopex culpaeus andinus*. |
| *Puma concolor* (Linnaeus, 1771) | *Felis concolor* Linnaeus, 1771 | |
| *Panthera onca* (Linnaeus, 1758) | *Felis onza* Linnaeus, 1758 | |
| *Leopardus wiedii* (Schinz, 1821) | *Felis macrura* (*sic* = *Felis macroura*) Wied-Neuwied, 1822 | |
| | *Felis celidogaster* Temminck, 1824 | |
| *Leopardus pardalis* (Linnaeus, 1758) | *Felis pardalis* Linnaeus, 1758 | |
| *Puma yagouaroundi* (É. Geoffroy Saint-Hilaire, 1803) | *Felis yaguarundi* (É. Geoffroy Saint-Hilaire, 1803) | |
| *Otaria flavescens* (Shaw, 1800) | *Otaria jubata* (Schreber, 1776) | |
| | *Otaria ulloae* Tschudi, 1845 | Type material: syntypes MHNN-94.1513 (Figure 7 this work) and MHNN-94.1514. |

Table 1. (Continue)

| Order/Current name | Name in Tschudi's list | Comments |
|---|---|---|
| *Otaria flavescens* (Shaw, 1800) | *Otaria aurita* Humboldt in Tschudi, 1845 | |
| Didelphimorphia | | |
| *Didelphis pernigra* Allen, 1900 | *Didelphys* (*sic*) *azarae* Temminck, 1824 | Tschudi (1845, p. 144) informed that this species was known as "Muca" or "Mucamuca" on the coast of Peru, whereas in the Andes as "*Jarachupa*" (hairless tail, in Quechua). He also stated that *Didelphis azarae* had a very wide distribution area, occuring in all regions of Peru, but especially in the western part of the Andes. According to Cerqueira & Tribe (2008 [2007]), *D. azarae* is a synonym of three species: *D. albiventris*, *D. aurita*, and *D. pernigra*. Due to its morphology and distribution, *D. pernigra* is the most suitable option. |
| *Philander canus* (Osgood, 1913) | *Didelphys* (*sic*) *opossum* Linnaeus, 1758 | Voss *et al.* (2018) reassessed the taxonomy of *Philander.* These authors proposed that two species of *Philander* would occur in Peru, the revalidated *P. canus* and the new species *P. pebas.* The distribution of *P. canus* proposed by these authors agrees with *D. opossum*'s distribution informed by Tschudi. |
| *Metachirus myosuros* (Temminck, 1824) | *Didelphys* (*sic*) *myosuros* Temminck, 1824 | Hershkovitz (1959, 1976, 1997) claimed that *Didelphis myosuros* was a synonym of *Philander opossum.* On the other hand, Patton & da Silva (2008 [2007]) located *D. myosuros* into the synonymy of *Metachirus nudicaudatus.* Recently, Voss *et al.* (2019), using morphological and molecular data, recognized *Metachirus myosuros* as a valid species and distinct from *M. nudicaudatus.* |
| *Marmosa murina* (Linnaeus, 1758) | *Didelphys* (*sic*) *murina* Linnaeus, 1758 | |
| *Caluromys lanatus ornatus* (Tschudi, 1845) | *Didelphys* (*sic*) *ornata* Tschudi, 1845 | Type material: holotype MHNN-94.1008D by monotypy (Figure 8 this work). |
| *Marmosops noctivagus* (Tschudi, 1845) | *Didelphys* (*sic*) *noctivaga* Tschudi, 1845 | Gardner & Creighton (2008 [2007]) treated *Marmosops noctivagus* as monotypic, arguing that a taxonomic revision is pending. Type material: syntypes MHNN-94.1008A, MHNN-94.1008B, MHNN-94.1008C (Figure 9 this work). |
| *Marmosops impavidus* (Tschudi, 1845) | *Didelphys* (*sic*) *impavida* Tschudi, 1845 | Type material not yet located. |
| Rodentia | | |
| *Notosciurus pucheranii* (Fitzinger, 1867) | *Sciurus variabilis* I. Geoffroy Saint-Hilaire, 1832 | *Sciurus variabilis* is a synonym of several species. Nevertheless, Tschudi gave a detailed description of this species which exactly matches the description of *Notosciurus pucheranii* given by de Vivo & Carmignotto (2015, p. 40). |
| *Hadrosciurus spadiceus tricolor* (Tschudi, 1845) | *Sciurus tricolor* Poeppig in Tschudi, 1845 | |
| *Guerlinguetus aestuans* (Linnaeus, 1766) | *Sciurus aestuans* Linnaeus, 1766 | |

Table 1. (Continue)

| Order/Current name | Name in Tschudi's list | Comments |
|---|---|---|
| *Simosciurus nebouxii* (I. Geoffroy Saint-Hilaire, 1855) | *Sciurus stramineus* Gervais in Vaillant, 1841 | Based on the morphological and geographical description given by Tschudi and as the only species occurring in the West of the Andes in northern Peru at Amatope, *Simosciurus nebouxii* is the most suitable species to be chosen (see de Vivo & Carmignotto, 2015, p. 44). |
| *Chinchilla chinchilla* (Lichtenstein, 1830) | *Eriomys chinchilla* Lichtenstein, 1830 | |
| *Lagidium viscacia* (Molina, 1782) | *Lagidium peruvianum* (*sic*) Meyen, 1835 | |
| | *Lagidium pallipes* Bennett, 1835 | |
| *Octodon degus* (Molina, 1782) | *Octodon cummingii* (*sic*) Bennett, 1832 | Species of the genus *Octodon* are mainly distributed in Chile but also in part of Argentina (Verzi *et al*., 2015). Nonetheless, Tschudi collected one specimen of *Octodon* (MHNN 94.2459A) at the "Quebrada von San Mateo, in der Nähe des Dorfes San Juan de Matucana, etwa 9000' ü. M", Lima, Peru. Thomas (1927, p. 557) stated that this specimen was probably an escaped pet. How the animal reached that locality is unknown. |
| *Proechimys* sp. | *Echinomys leptosoma* Wagner in Schreber, 1842 | *Echinomys leptosoma* is a current synonym of *Trinomys setosus setosus,* a species that does not occur in Peru (Pessôa *et al.*, 2015). Based on Tschudi's description, this taxon may be a species of *Proechimys*. |
| *Mus musculus* Linnaeus, 1758 | *Mus musculus* Linnaeus, 1758 | |
| | *Mus decumanus* Pallas, 1779 | |
| *Akodon boliviensis* Meyen, 1833 | *Acodon* (*sic*) *boliviense* Meyen, 1833 | Tschudi (1845, p. 178) wondered why Meyen named this is species "*boliviense*" since the latter never visited Bolivia and its type material was collected in the Chucuito Province (Puno, Peru) (see Myers *et al.*, 1990, p. 49-50). |
| *Mus musculus*? Linnaeus, 1758 | *Drymomys parvulus* Tschudi, 1845 | According to Carleton & Musser (2005) this name would be a synonym of *Mus* (*Mus*) *musculus domesticus*. We could not confirm its identity.<br>Type material: syntype MHNN-94.2043E labeled as *Acodon* (*sic*) *parvulus* (Figure 10 this work). |
| *Phyllotis limatus* Thomas, 1912 | *Hesperomys* (*Hesperomys*) *darwinii* (Waterhouse, 1837) | *Hesperomys darwinii* is a current synonym of *Phyllotis darwini* but this species does not occur in Peru (Steppan & Ramírez, 2015). Based on the geographical and morphological description given by Tschudi (1845, p. 181), we propose *Phyllotis limatus* as the most likely option. |
| *Oligoryzomys destructor* (Tschudi, 1845) | *Hesperomys* (*Hesperomys*) *destructor* Tschudi, 1845 | Hurtado & D'Elía (2019), arguing that Tschudi's original material does not longer exist, mistakenly designated neotypes for *H. destructor* and *H. melanostoma* selecting specimens from a locality that Tschudi never visited. This designation was invalidated by Serrano-Villavicencio (2019), who presented evidence against Hurtado & D'Elía's (2019) argument.<br>Type material: lectotype MHNN-94.2043A designated by Serrano-Villavicencio (2019) (Figure 11 this work). |

Table 1. (Continue)

| Order/Current name | Name in Tschudi's list | Comments |
|---|---|---|
| *Oligoryzomys melanostoma* (Tschudi, 1845) | *Hesperomys* (*Hesperomys*) *melanostoma* Tschudi, 1845 | Hurtado & D'Elía (2019) regarded *O. melanostoma* as a synonym of *O. destructor*, but this could be a result of the improper designation of neotypes for the two species.<br>Type material: lectotype MHNN-94.2043B designated by Serrano-Villavicencio (2019) (Figure 11 this work). |
| *Rhipidomys leucodactylus* (Tschudi, 1845) | *Hesperomys* (*Rhipidomys*) *leucodactylus* Tschudi, 1845 | Tribe (2015, p. 602), based on Tschudi's itinerary, invalidated the "upper Huallaga" restriction of the type locality made by Cabrera (1961, p. 421), stating that the area proposed by this author as type locality was never visited by Tschudi. Tribe (2015) proposed the Montaña de Vitoc area, a region widely sampled by Tschudi, as type locality.<br>Type material: syntypes MHNN-94.2043C, MHNN-94.2043D (Figure 12 this work), and MHNN-94.2043F. |
| *Coendou bicolor* (Tschudi, 1845) | *Sphingurus bicolor* Tschudi, 1845 | Tschudi (1845) stated that the specimen that he sent to Neuchâtel was a female individual collected by a native in the jungle between the Tullumayo and Chanchamayo rivers. He also stated that the specimen was used to describe and illustrate this species (see Tschudi, 1845, Plate XV).<br>Type material: holotype MHNN-94.2432A by monotypy (Figure 13 this work). |
| *Myoprocta pratti* Pocock, 1913 | *Dasyprocta aguti* Linnaeus, 1766 | *Dasyprocta aguti* is a current synonym of *D. leporina*, a species not present in Peru (Patton & Emmons, 2015). The description given by Tschudi matches that of *Myoprocta pratti*. |
| *Dasyprocta variegata* Tschudi, 1845 | *Dasyprocta variegata* Tschudi, 1845 | Type material: syntypes MHNN-94.2445A and MHNN-94.2445B (Figure 14 this work). |
| *Cuniculus paca* (Linnaeus, 1766) | *Coelogenys fulvus* Cuvier, 1807 | |
| *Hydrochoerus hydrochaeris* (Linnaeus, 1766) | *Hydrochoerus capybara* Erxleben, 1777 | |
| *Cavia tschudii tschudii* Fitzinger, 1867 | *Cavia cuttleri* (*sic*) Bennett, 1836 | A misspelling of *Cavia cutleri* Bennet, 1836. Nonetheless, Bennet's *C. cutleri* referred to the domestic form of Guinea pig, *Cavia porcellus* whereas Tschudi to the wild populations. |
| *Sylvilagus brasiliensis* (Linnaeus, 1758) | *Lepus brasiliensis* Linnaeus, 1758 | Tschudi never saw this species in Peru. He based his description on observations made by E. F. Poeppig in Maynas (Loreto, Peru) and the lower Marañon river. |
| Pilosa | | |
| *Bradypus variegatus* Schinz, 1825 | *Bradypus infuscatus* Wagler, 1831 | |
| *Bradypus torquatus* Illiger, 1811 | *Bradypus torquatus* Illiger, 1811 | Perhaps an incorrect inference based on bibliography and comments of locals. |
| *Tamandua tetradactyla* (Linnaeus, 1758) | *Myrmecophaga tetradactyla* Linnaeus, 1758 | |

Table 1. (Conclusion)

| Order/Current name | Name in Tschudi's list | Comments |
|---|---|---|
| *Cyclopes thomasi*? Miranda, Casali, Perini, Machado & Santos, 2017 | *Myrmecophaga didactyla* Linnaeus, 1758 | Following Miranda *et al.* (2017), *Cyclopes thomasi* occurs in western Amazon, from its northern limit on the Juruá River to the southwest, in the Ucayali River region, in the provinces of Pasco and Ucayali (Peru). Tschudi (1845, p. 209) stated that he saw skins of *M. didactyla* with a longitudinal line on both dorsum and ventrum. According to Miranda *et al.* (2017), *C. thomasi* does not possess these lines and the coloration of this new taxon does not match that of Tschudi's description. This identification remains as tentative. |
| Cingulata | | |
| *Cabassous unicinctus* (Linnaeus, 1758) | *Dasypus tatuay* (*sic* = *tatouay*) (Desmarest, 1804) | |
| *Dasypus novemcinctus* Linnaeus, 1758 | *Dasypus novemcinctus* Linnaeus, 1758 | |
| Artiodactyla | | |
| *Tapirus terrestris* (Linnaeus, 1758) | *Tapirus americanus* (Gmelin in Linnaeus, 1758) | |
| *Tapirus pinchaque* (Roulin, 1829) | *Tapirus villosus* Wagner in Schreber, 1835 | |
| *Dicotyles tajacu* (Linnaeus, 1758) | *Dicotyles torquatus* Cuvier, 1817 | Ramírez-Pulido *et al.* (2014) and Acosta, L. *et al.* (2020) showed that *Dicotyles* Cuvier, 1817 is the oldest available generic name for the collared peccary, with *Pecari* Reichenbach, 1835 as a junior synonym. |
| *Tayassu pecari* (Link, 1795) | *Dicotyles labiatus* Cuvier, 1817 | |
| *Lama glama* (Linnaeus, 1758) | *Auchenia lama* Frisch, 1775 | |
| *Lama guanicoe* (Müller, 1776) | *Auchenia huanaco* (C. H. Smith, 1827) | |
| *Vicugna pacos* (Linnaeus, 1758) | *Auchenia paco* Desmarest, 1822 | |
| *Vicugna vicugna* (Molina, 1782) | *Auchenia vicunia* Fischer, 1829? | The authorship of *Auchenia vicunia* is debatable. According to Cabrera (1958) the author of this name would be Tschudi (1845, p. 223). Nonetheless, Tschudi (1845) attributed the authorship of *A. vicunia* to Fischer (1829) without any further references, whereas the latter listed *Auchenia vicunna* (*sic*) Desmarest, 1822 within the synonymy of *Lama vicugna*. A nomenclatural clarification becomes urgent. |
| *Mazama americana* (Erxleben, 1777) | *Cervus rufus* Illiger, 1811 | |
| *Mazama gouazoubira nemorivaga* (Cuvier, 1817) | *Cervus nemorivagus* Cuvier, 1817 | |
| *Hippocamelus antisensis* (d'Orbigny, 1834) | *Cervus antisiensis* d'Orbigny, 1843 | |

Figure 2. Type material of *Phyllostoma* (*Sturnira*) *erythromos* Tschudi, 1844: A) lectotype MHNN-94.2539; B) original illustration of *P. erythromos* edited from Tschudi (1844b, Plate I).

Figure 3. Type material of *Phyllostoma* (*Sturnira*) *oporaphilum* Tschudi, 1844: A) syntype MHNN-94.2540; B) Original illustration of *P. oporaphilum* edited from Tschudi (1844b, Plate II).

Figure 4. Syntype of *Molossus naso* Tschudi, 1845, MHNN-94.2547.

Figure 5. Type material of *Molossus myosuros* Tschudi, 1845: A) syntype MHNN-94.1203; B) original illustration of *M. myosuros* edited from Tschudi (1844b, Plate IV).

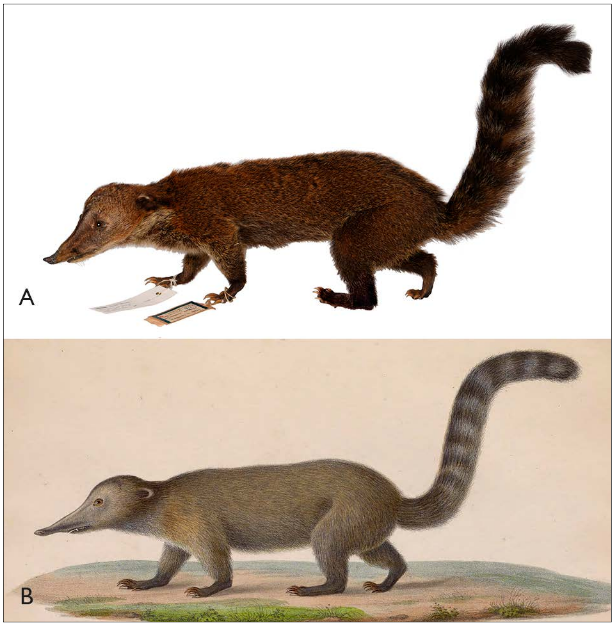

Figure 6. Type material of *Nasua montana* Tschudi, 1845: A) holotype MHNN-94.1383A; B) original illustration of *N. montana* edited from Tschudi (1844b, Plate V).

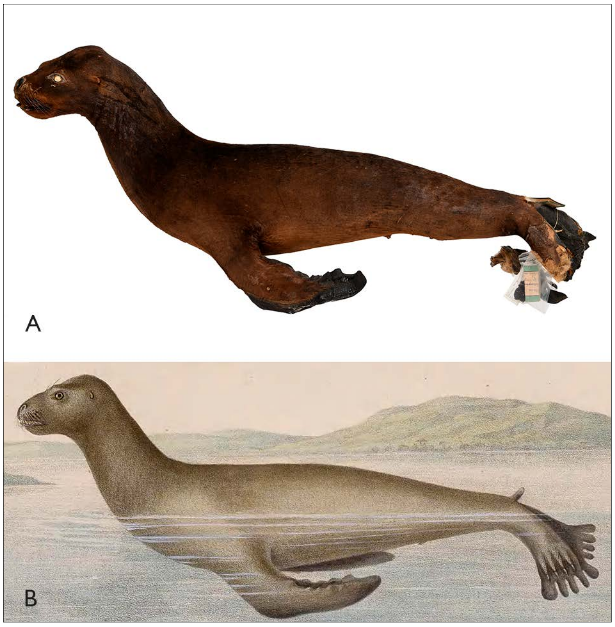

Figure 7. Type material of *Otaria ulloae* Tschudi, 1845: A) syntype MHNN-94.1513; B) original illustration of *O. ulloae* edited from Tschudi (1844b, Plate VI).

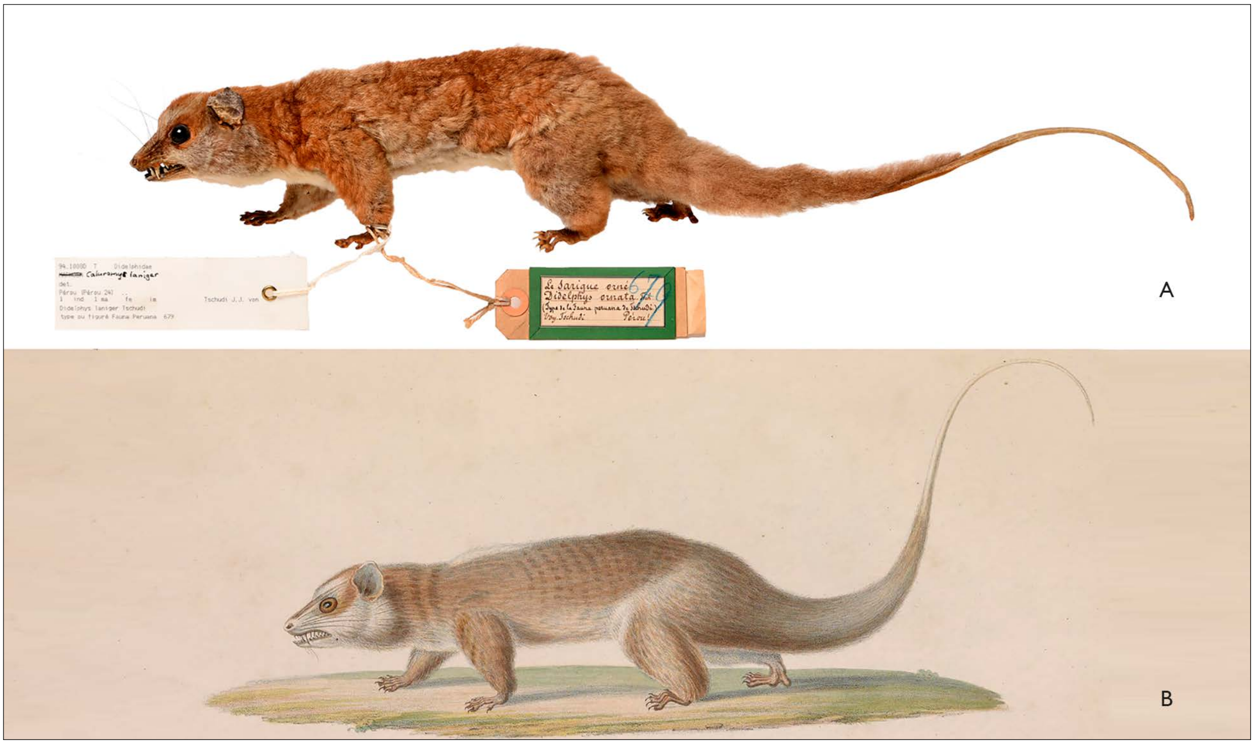

Figure 8. Type material of *Didelphys* (*sic*) *ornata* Tschudi, 1845: A) holotype MHNN-94.1008D; B) original illustration of *D. ornata* edited from Tschudi (1844b, Plate VII).

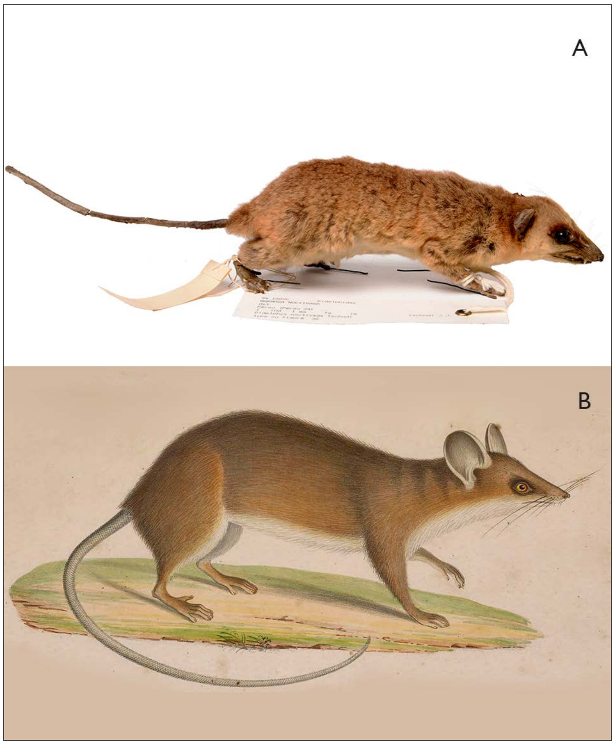

Figure 9. Type material of *Didelphys* (*sic*) *noctivaga* Tschudi, 1845: A) syntype MHNN-94.1008C; B) original illustration of *D. noctivaga* edited from Tschudi (1844b, Plate VIII).

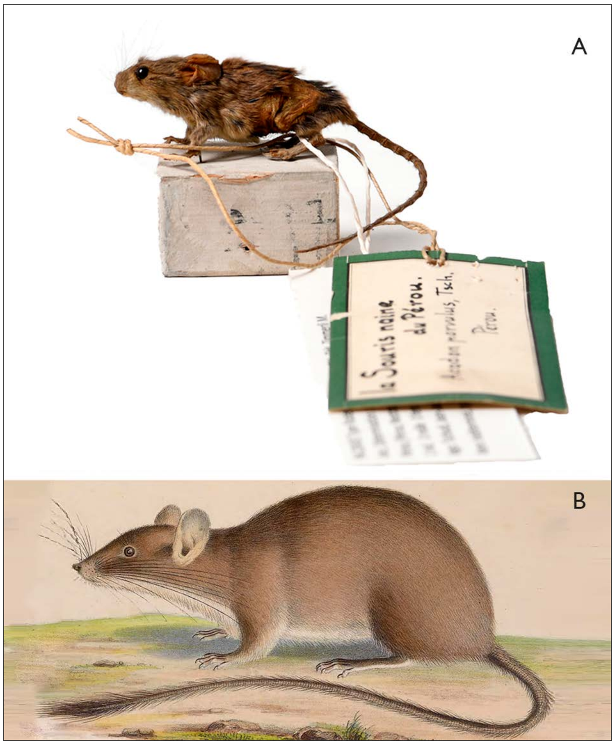

Figure 10. Type material of *Drymomys parvulus* Tschudi, 1845: A) syntype MHNN-94.2043E; B) original illustration of *D. parvulus* edited from Tschudi (1845, Plate X, figure 2).

Figure 11. Type material of *Hesperomys destructor* Tschudi, 1845 and *H. melanostoma* Tschudi, 1845: A) left, lectotype of *H. destructor* MHNN-94.2043A; right, lectotype of *H. melanostoma* MHNN-94.2043B; B) original illustration of *H. destructor* (left) and *H. melanostoma* (right), edited from Tschudi (1845, Plate XI, figures 1 and 2).

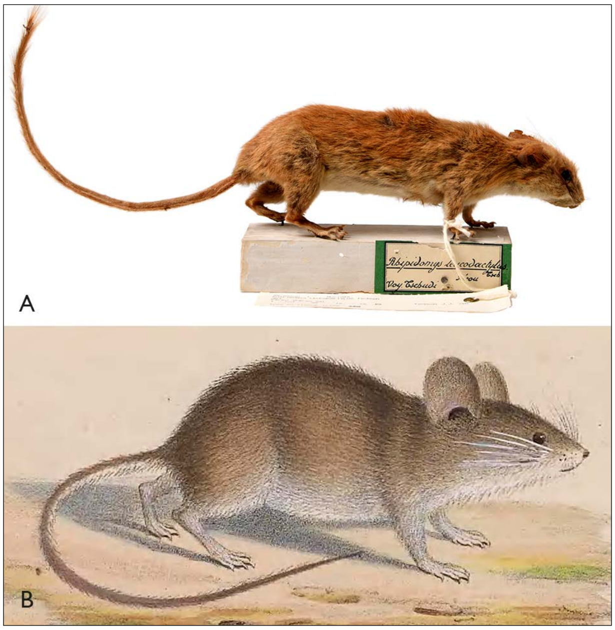

Figure 12. Type material of *Hesperomys* (*Rhipidomys*) *leucodactylus* Tschudi, 1845: A) syntype MHNN-94.2043D; B) original illustration of *H. leucodactylus* edited from Tschudi (1845, Plate X, figure 1).

Figure 13. Type material of *Sphingurus bicolor* Tschudi, 1845: A) holotype MHNN-94.2432A; B) original illustration of *S. bicolor* edited from Tschudi (1845, Plate XV).

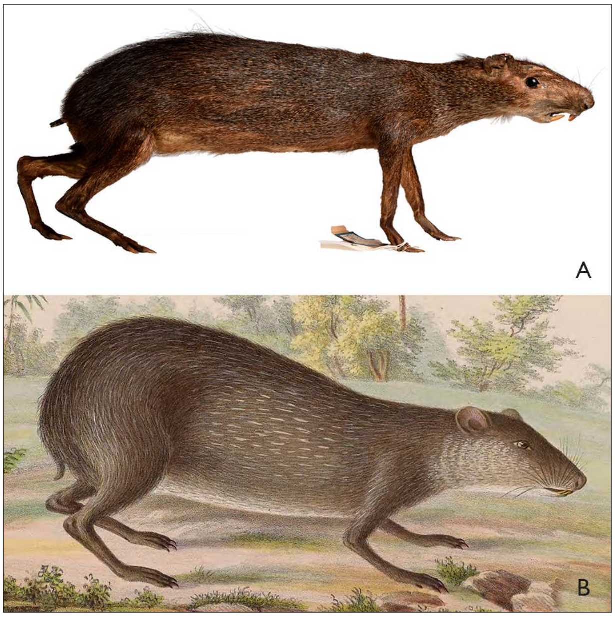

Figure 14. Type material of *Dasyprocta variegata* Tschudi, 1845: A) syntype MHNN-94.2445B; B) original illustration of *D. variegata* edited from Tschudi (1845, Plate XVI).

## ACKNOWLEDGMENTS

We would like to thank Louise Robert and Théa Bilat for taking the pictures of the type specimens at MHNN and for their care of its scientific collection. Dione Seripierri from the *Museu de Zoologia - Universidade de São Paulo*, is acknowledged for her willingness to help us search literature and clarify the problems of when Tschudi's works were published.

Alexandre R. Percequillo and Edgar Rengifo offered help identifying rodents. Fábio Oliveira do Nascimento, Rafaela L. Vendramel, Guilherme Garbino, and Rafael Nascimento made comments of the manuscript. We thank Malika Gottstein for helping us with translations from German and for reviewing the manuscript. We thank Bruce D. Patterson, the three anonymous reviewers, and Alexandra Bezerra for their suggestions and comments that clearly improved the quality of the manuscript. Finally, we thank Alexandra Bezerra for inviting us to participate in this special edition. JES-V received financial support from the Brazilian Federal Agency for Support and Evaluation of Graduate Education (CAPES). This study was financed in part by the *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* – Brasil (CAPES) – Finance Code 001.

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# BOLETIM DO MUSEU PARAENSE EMÍLIO GOELDI. CIÊNCIAS NATURAIS

## INSTRUÇÕES AOS AUTORES

### Objetivos e política editorial

O **Boletim do Museu Paraense Emílio Goeldi. Ciências Naturais** tem como missão publicar trabalhos originais em biologia (zoologia, botânica, biogeografia, ecologia, taxonomia, anatomia, biodiversidade, vegetação, conservação da natureza) e geologia. A revista aceita colaborações em português, espanhol e inglês (Inglaterra) para as seguintes seções:

**Artigos Científicos** – textos analíticos originais, resultantes de estudos e pesquisas com contribuição efetiva para o avanço do conhecimento. Até 50 laudas.

**Notas de Pesquisa** – relato preliminar sobre observações de campo, dificuldades e progressos de pesquisa em andamento, ou em fase inicial, enfatizando hipóteses, comentando fontes, resultados parciais, métodos e técnicas utilizados. Até 15 laudas.

**Memória** – seção que se destina à divulgação de acervos ou seus componentes que tenham relevância para a pesquisa científica; de documentos transcritos parcial ou integralmente, acompanhados de texto introdutório; e de ensaios biográficos, incluindo obituário ou memórias pessoais. Até 15 laudas.

**Resenhas Bibliográficas** – texto descritivo e/ou crítico de obras publicadas na forma impressa ou eletrônica. Até cinco laudas.

**Teses e Dissertações** – descrição sucinta, sem bibliografia, de dissertações de mestrado, teses de doutorado e livre-docência. Uma lauda.

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Os originais devem ser encaminhados ao Editor Científico por meio de mensagem eletrônica (boletim.naturais@museu-goeldi.br), contendo, obrigatoriamente, o título do trabalho, o nome completo, por extenso, do autor principal e dos demais autores, a indicação de autor para correspondência (com endereço completo, CEP, telefones, fax, e-mail) e uma declaração de que o autor principal se responsabiliza pela inclusão dos coautores.

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1. Lagarto com 4 patas minúsculas........................................2
   Lagarto com 4 patas bem desenvolvidas........................................3
2. Dígitos geralmente sem unhas, dorsais lisas........................................*Bachia flavescens*
   Dígitos com unhas, dorsais quilhadas........................................*Bachia panoplia*
3. Mãos com apenas 4 dedos........................................4
   Mãos com 5 dedos........................................5
4. Escamas dorsais lisas........................................*Gymnophthalmus underwoodii*
   Escamas dorsais quilhadas........................................*Amapasaurus tetradactylus*
5. Cabeça com grandes placas........................................6
   Cabeça com escamas pequenas ........................................7
6. Placas posteriores da cabeça formam uma linha redonda........................................*Alopoglossus angulatus*
   Placas posteriores da cabeça formam uma linha reta........................................ *Arthrosaura kockii*
7. Etc.
   Etc.

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   Hands with 5 fingers..........5
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   Head with small scales..........7
6. Posterior scales of head forming a rounded line..........*Alopoglossus angulatus*
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7. Etc.
   Etc.

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