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










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Ticks (Parasitiformes: Ixodida) on new world wild primates in Brazil

Thiago F. Martins ^{a,b}, Rodrigo H. F. Teixeira ^{c,d}, Julio C. Souza Jr ^e, Hermes R. Luz ^f, Mônica M. Montenegro ^g, Leandro Jerusalinsky ^g, Marina G. Bueno ^h, Valeria C. Onofrio ^{i,j}, Marinete Amorim ^k, Gilberto S. Gazêta ^k, Paula De J. Da Silva ^k, Karla Bitencourth ^k, Ana B. P. Borsoi ^k, Sandro Marques ^l, Marco O. Mattos Jr ^l, Leandra S. I. Hernandez ^l, Alessandra Scofield ^m, Rafael F. C. Vieira ^{n,o}, Richard C. Pacheco ^p, Maurício C. Horta ^q, Valéria P. da Silva ^r, Patrícia W. Silva ^s, Claudia A. Igaraya ^t, Thais C. Sanches ^{tu}, Marcello S. Nardi ^u, Camile Lugarini ^v, Natasha L. Maia ^w, Cláudio L. M. de Siqueira ^w, Juliana M. Ferreira ^x, João F. Soares ^y and Marcelo B. Labruna ^a

^aDepartamento De Medicina Veterinária Preventiva E Saúde Animal, Faculdade De Medicina Veterinária E Zootecnia, Universidade De São Paulo, São Paulo, SP, Brazil; ^bSuperintendência De Controle De Endemias, São Paulo, SP, Brazil; ^cParque Zoológico Municipal “Quinzinho De Barros”, Sorocaba, SP, Brazil; ^dUniversidade De Sorocaba “UNISO”, Sorocaba, SP, Brazil; ^eUniversidade Regional De Blumenau, Blumenau, SC, Brazil; ^fCentro De Ciências Biológicas E Da Saúde, Departamento De Patologia, Universidade Federal Do Maranhão, São Luís, MA, Brazil; ^gCentro Nacional De Pesquisa E Conservação De Primatas Brasileiros, Instituto Chico Mendes De Conservação Da Biodiversidade, João Pessoa, PB, Brazil; ^hLaboratório De Virologia Comparada E Ambiental, Instituto Oswaldo Cruz, Rio De Janeiro, RJ, Brazil; ⁱMestrado Em Medicina E Bem Estar Animal, Doutorado Em Saúde Única, Universidade Santo Amaro, São Paulo, SP, Brazil; ^jLaboratório De Coleções Zoológicas, Instituto Butantan, São Paulo, SP, Brazil; ^kLaboratório De Referência Nacional Em Vetores Das Riquetsioses, Instituto Oswaldo Cruz, Rio De Janeiro, RJ, Brazil; ^lLaboratório De Identificação E Pesquisa De Fauna Sinantrópica Da Prefeitura Municipal De São Paulo, São Paulo, SP, Brazil; ^mPrograma De Pós-graduação Em Saúde Animal Na Amazônia, Instituto De Medicina Veterinária, Universidade Federal Do Pará, Castanhal, PA, Brazil; ⁿLaboratório De Doenças Transmitidas Por Vetores, Departamento De Medicina Veterinária, Universidade Federal Do Paraná, Curitiba, PR, Brazil; ^oGlobal One Health Initiative “Gohi”, The Ohio State University, Columbus, OH, USA; ^pPrograma De Pós-graduação Em Ciências Veterinárias, Faculdade De Medicina Veterinária Da Universidade Federal De Mato Grosso, Cuiabá, MT, Brazil; ^qColegiado De Medicina Veterinária, Universidade Federal Do Vale Do São Francisco, Petrolina, PE, Brazil; ^rCentro De Triagem De Animais Silvestres, Parque Ecológico Do Tietê, Departamento De Águas E Energia Elétrica, São Paulo, SP, Brazil; ^sMuseu De História Natural Capão Da Imbuía, Prefeitura Municipal De Curitiba, Curitiba, PR, Brazil; ^tZoológico Municipal De Guarulhos, Guarulhos, SP, Brazil; ^uDivisão Da Fauna Silvestre, Secretaria Municipal Do Verde E Do Meio Ambiente Da Prefeitura Municipal De São Paulo, São Paulo, SP, Brazil; ^vCentro Nacional De Pesquisa E Conservação De Aves Silvestres, Estação Ecológica De Carijós, Florianópolis, SC, Brazil; ^wDepartamento De Bioquímica E Biologia Molecular, Universidade Federal De Viçosa, Viçosa, MG, Brazil; ^xUniversidade Vila Velha, Vila Velha, ES, Brazil; ^yLaboratório Protozoologia E Rickettsioses Vetoriais, Departamento De Patologia Clínica Veterinária, Faculdade De veterinária Da Universidade Federal Do Rio Grande Do Sul, Porto Alegre, RS, Brazil

ABSTRACT

Brazil concentrates the largest number of primate species in the world. In the present study, an extensive literature review of ticks on New World wild monkeys has been carried out, demonstrating that between the years 1912 to 2018, 182 larvae, 137 nymphs and 31 adult ticks (10 males and 21 females) were collected on 78 primates (from 12 different species) in 28 distinct localities in the Brazilian territory. Additionally, examination of allotments of 11 tick collections of Brazil revealed that from 1919 to 2019, 93 larvae, 91 nymphs and 175 adult ticks (62 males and 113 females) were collected from 100 monkeys (among 20 different species) from 43 localities in distinct Brazilian biomes. Overall, 19 tick species were identified on wild primates in the country: *Amblyomma aureolatum* (Pallas, 1772), *Amblyomma cajenense* (Fabricius, 1787) *sensu stricto*, *Amblyomma coelebs* Neumann, 1899, *Amblyomma dubitatum* Neumann, 1899, *Amblyomma geayi* Neumann, 1899, *Amblyomma incisum* Neumann, 1906, *Amblyomma longirostre* (Koch, 1844), *Amblyomma naponense* (Packard, 1869), *Amblyomma nodosum* Neumann, 1899, *Amblyomma ovale* Koch, 1844, *Amblyomma parkeri* Fonseca & Aragão, 1952, *Amblyomma romarioi* Martins, Luz & Labruna, 2019, *Amblyomma rotundatum* Koch, 1844, *Amblyomma sculptum* Berlese, 1888, *Haemaphysalis juxtakochi* Cooley, 1946, *Ixodes fuscipes* Koch, 1844, *Rhipicephalus microplus* (Canestrini, 1888), *Rhipicephalus sanguineus* (Latreille, 1806) *sensu lato*, and *Ornithodoros rosstratus* Aragão, 1911. The presence of *A. incisum*, *A. naponense*, *A. nodosum*, *A. rotundatum* and *I. fuscipes* on monkeys is recorded for the first time. This research is therefore a significant contribution to the knowledge of tick species associated with non-human primates in the Neotropical region.

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Introduction

Ticks are arthropods belonging to the class of Arachnids, which also include scorpions, spiders, and several species of mites (Guimarães et al. 2001). Currently, the Brazilian tick fauna is composed of 75 species, which are divided into the Ixodidae family (51 species), popularly known hard ticks, and the Argasidae family (24 species), commonly known soft ticks. Ixodidae are distributed into five genus: *Amblyomma* (33 species), *Ixodes* (12 species), *Haemaphysalis* (three species), *Rhipicephalus* (two species), and

Dermacentor (one species). The Argasidae are distributed in four genus: *Ornithodoros* (18 species), *Antricola* (three species), *Nothoaspis* (two species), and *Argas* (one species) (Barros-Battesti et al. 2006; Dantas-Torres et al. 2019; Martins et al. 2019; Muñoz-Leal et al. 2019, 2020; Labruna et al. 2020; Onofrio et al. 2020).

In Brazil, hard and soft ticks are important vectors of pathogenic bacteria (e.g., *Anaplasma*, *Borrelia*, *Ehrlichia*, *Rickettsia*) and protozoa (e.g., *Babesia*, *Hepatozoon*, *Rangelia*, *Theileria*) to humans, domestic and wild animals, being therefore considered relevant

to veterinary and public health (Guimarães et al. 2001; Barros-Battesti et al. 2006). Due to Brazilian territorial extension, the country presents a great biological diversity including amphibians, reptiles, birds, and mammals that are frequently parasitized by ticks (Aragão 1936; Martins 2018). The species of ticks that parasitize domestic animals are the most studied due to their sanitary importance. In contrast, the vast majority of tick species that parasitizes wild fauna are still little known in relation to taxonomy, biology, ecology, geographic distribution, habitual hosts, and vector competence for pathogenic agents (Barros-Battesti et al. 2006; Martins et al. 2011, 2015, 2017a, 2020). To our knowledge, reports of agents related to tick-borne diseases in non-human primates in Brazil have been restricted to the detection of *Babesia*-like structures in blood smears of black-and-gold howler monkeys (*Alouatta caraya*) (Ortunho et al. 2014), *Ehrlichia canis* DNA in the blood of a marmoset of the genus *Callithrix* (Mafra et al. 2015), and *Borrelia burgdorferi* DNA in the blood of 32 golden-headed lion tamarins (*Leontopithecus chrysomelas*) (Santos et al. 2018).

According to the National Centre for Research and Conservation of Brazilian Primates and the Brazilian Society of Primatology, there are 119 primate species in the country, distributed into five families: Callitrichidae (41 species), Pitheciidae (39 species), Cebidae (19 species), Atelidae (15 species) and Aotidae (five species) (Paglia et al. 2012; SBPr 2019; CPB-ICMBio 2020). Primate species are present in the six Brazilian biomes (Amazon, Atlantic Forest, Caatinga, Cerrado, Pampa, and Pantanal), occurring mainly in the Amazon (93 species) and in the Atlantic Forest (21 species), playing a fundamental role in the structure of forests, in addition to participating in the food chain in the ecosystem in which they live (Paglia et al. 2012; CPB-ICMBio 2020). About 55% of monkey species are endemic in Brazil and 35 are threatened with extinction, according to the Official National List of Endangered Species of Fauna (ICMBio 2014). According to previous studies, the main threats for this group are the loss, fragmentation and degradation of habitats, hunting and harvesting, the introduction of invasive species and vector-borne diseases, impacts related to human actions such as agricultural and urban expansion, projects of infrastructure, and climate change (Fonseca et al. 1996; Reis et al. 2011; Romano 2014; Sevá et al. 2019; CPB-ICMBio 2020).

Brazil concentrates the largest number of primate species in the world (Fonseca et al. 1996; Reis et al. 2011; Paglia et al. 2012; SBPr 2019; CPB-ICMBio 2020). Despite the diversity of ticks and monkeys, previous reports of ticks on non-human primates in Brazil have been restricted to sporadic records, each of which usually included a single tick species on one primate species (Aragão 1913, 1936; Ferreira d'Almeida 1937; Wilson et al. 1989; Barros and Baggio 1992; Catão-Dias 2001; Guimarães et al. 2001; Labruna et al. 2002, 2004, 2009; Arzua et al. 2005; Martins et al. 2006, 2010, 2011, 2013, 2015, 2016, 2017a, 2017b, 2019; Lavina et al. 2011; Soares et al. 2015; Bastos et al. 2016; Witter et al. 2016; Gonzalez et al. 2017; Teixeira et al. 2017; Gianizella et al. 2018; Zimmermann et al. 2018; Peckle et al. 2019). Therefore, considering the gaps in the knowledge of the tick fauna parasitizing non-human primates in their natural habitats, in this study we provide a compilation of data of ticks infesting New World wild monkeys in the six Brazilian biomes, based on data from previous reports, and unpublished data from the largest tick collections of Brazil.

Materials and methods

In the present study, an extensive literature review of ticks on wild primates in the Brazilian territory has been carried out. The review of published articles was conducted through a computerized search in the PubMed (<http://www.ncbi.nlm.nih.gov/pubmed>) and SciELO (<http://www.scielo.org/>) electronic databases, using the following general descriptors (keywords): ticks, Ixodida, Ixodidae, Argasidae, *Amblyomma*, *Haemaphysalis*, *Ixodes*, *Rhipicephalus*, *Ornithodoros*, Primates, monkeys, and Brazil. The

same descriptors in English were also searched for in the SciELO database, with additional Portuguese translations as keywords. The reference list of every selected manuscript was also considered for our literature survey.

Additionally, specimens of ticks collected on wild monkeys in the country deposited in the 11 largest tick collections of Brazil were accessed and re-examined during the years 2015 and 2016. The visited collections were: "Coleção Nacional de Carrapatos Danilo Gonçalves Saraiva da Universidade de São Paulo" (CNC) São Paulo, SP; "Coleção Acarológica do Instituto Butantan" (IBSP) São Paulo, SP; "Coleção de Fauna Sinantrópica do Município de São Paulo, Coordenação de Vigilância em Saúde, Secretaria Municipal da Saúde" (CFS-MSP-COVISA-SMS) São Paulo, SP; "Coleção de Chelicerata do Museu de Zoologia da Universidade de São Paulo" (MZ-USP), São Paulo, SP; "Coleção de Artrópodes Vetores Ápteros de Importância em Saúde das Comunidades do Instituto Oswaldo Cruz-Fiocruz, seção Ixodológica" (CAVAISC-IOC-IXO) Rio de Janeiro, RJ; "Coleção de Parasitos do Museu de História Natural Capão da Imbuia" (MHNCI), Curitiba, PR; "Coleção do Laboratório de Zoonoses e Epidemiologia Molecular da Universidade Federal do Paraná" (LAZEM), Curitiba, PR; "Coleção de Invertebrados do Instituto Nacional de Pesquisas da Amazônia" (INPA), Manaus, AM; "Coleção do Laboratório de Parasitologia Animal da Universidade Federal do Pará" (UFPA), Castanhal, PA; "Coleção do Laboratório de Parasitologia e Doenças Parasitárias dos Animais Domésticos e Silvestres da Universidade Federal de Mato Grosso" (UFMT) Cuiabá, MT; and "Coleção Nacional de Ectoparasitas e Vetores da Universidade Federal do Vale do São Francisco" (UNIVASF) Petrolina, PE.

All ticks preserved in 70% ethanol were identified using a stereomicroscope and taxonomic keys, identifying the stages (larva, nymph and adult, male and female), the genus and, the species according to the literature: Barros-Battesti et al. (2006), Martins et al. (2016), Labruna et al. (2020) and Onofrio et al. (2020) for adult ticks of the genera *Amblyomma*, *Haemaphysalis*, *Ixodes*, and *Rhipicephalus*; Martins et al. (2010, 2013, 2016) and Nava et al. (2017) for *Amblyomma* and *Haemaphysalis* nymphs. Many of the larvae of the genus *Amblyomma* and one nymph of the genus *Ixodes* could not be identified to the species level because there is insufficient literature available. However, some larvae or nymphs listed in the visited collections had information that were collected as engorged specimens, which moulted to nymphs and adults, respectively, in the laboratory, allowing identification at species level following the same methodology as established in previous studies (Labruna et al. 2002, 2004). One nymph was identified by molecular analysis, following the same protocol used in other studies with ticks collected on wild primates in Brazil (Soares et al. 2015; Martins et al. 2019).

Results

Data on ticks infesting wild primates were obtained by two ways: (i) review of literature records; and (ii) examination of unpublished data from tick collections. Based on literature records of ticks on wild primates in Brazil, 182 larvae, 137 nymphs, and 31 adult ticks (10 males and 21 females) were collected on 78 monkeys (at least 12 different species) at 28 distinct localities from the country, between the years 1912 to 2018. On the other hand, analysing the 11 tick collections, 93 larvae, 91 nymphs, and 175 adult ticks (62 males and 113 females) were collected on 100 primates specimens (at least 20 different species) in 43 distinct localities from Brazil, from 1919 to 2019. All results of the present study are detailed in Tables 1 and Tables 2.

The tick species reported on wild monkeys in the literature review were *Amblyomma aureolatum* (Pallas, 1772), *Amblyomma cajennense* (Fabricius, 1787) sensu lato (s. l.), *Amblyomma coelebs* Neumann, 1899, *Amblyomma dubitatum* Neumann, 1899, *Amblyomma geayi* Neumann, 1899, *Amblyomma longirostre* (Koch, 1844), *Amblyomma*

Table 1. Literature records for ticks on wild primates in Brazil sampled between the years 1912 and 2018.

Host species / Families	Municipalities or localities / States	Years	Tick species / Number and stages	Chronological references
<i>Mycetes</i> sp. [†] / At	ND / PI	1912	<i>Amblyomma cajennense</i> [∞] / 2 L, 10 N	Aragão (1913)
<i>Alouatta</i> sp. / At	ND / ND	ND	<i>A. cajennense</i> [∞] / ND	Aragão (1936)
<i>Cebus</i> sp. / Ce	ND / ND	ND	<i>A. cajennense</i> [∞] / ND	
Monkey [‡] / ND	ND / ND	ND	<i>Ornithodoros rostratus</i> / ND	
Marmoset [‡] / Ca	ND / ND	ND	<i>O. rostratus</i> / ND	
<i>Ateles paniscus</i> / At	ND [‡] / PA	1936	<i>A. cajennense</i> [*] / 1 N	Ferreira d'Almeida (1937)
<i>Leontopithecus rosalia</i> / Ca (26)	Silva Jardim / RJ	1984 / 1985	<i>Amblyomma</i> sp. / 145 L, 3 N	Wilson et al. (1989)
<i>Cebus apella</i> [‡] / Ce	Foz do Iguaçu / PR	ND	<i>Amblyomma ovale</i> / 1 F	Barros and Baggio (1992)
<i>Alouatta caraya</i> / At	ND / ND	1999	<i>Amblyomma oblongoguttatum</i> [∞] / ND	Catão-Dias (2001)
<i>Cebus</i> sp. / Ce	ND / ND	ND	<i>Amblyomma longirostre</i> / ND	Guimarães et al. (2001)
<i>A. caraya</i> / At (3)	PPHPS / MS, SP	2000 / 2001	<i>A. cajennense</i> [∞] / 18 N *	Labruna et al. (2002)
<i>C. apella</i> [‡] / Ce (3)	PPHPS / MS, SP	2000 / 2001	<i>Amblyomma</i> sp. / 1 L, 20 N <i>A. cajennense</i> [∞] / 19 N *	
<i>A. caraya</i> / At	ND [‡] / SP	ND	<i>Amblyomma dubitatum</i> / 1 N *	Labruna et al. (2004b)
<i>C. apella</i> [‡] / Ce	Foz do Iguaçu / PR	1988	<i>A. ovale</i> / 1 F [‡]	Arzua et al. (2005)
<i>Alouatta guariba</i> / At	Cachoeira do Sul / RS	2006	<i>Amblyomma aureolatum</i> / 1 F	Martins et al. (2006)
<i>Alouatta</i> sp. / At	ND / SP	2002	<i>Amblyomma parkeri</i> / 1 F	Labruna et al. (2009)
<i>Alouatta</i> sp. / At	São Paulo / SP	2004	<i>A. parkeri</i> / 3 F	
<i>Alouatta fusca</i> [⊖] / At	São Paulo / SP	2010	<i>A. parkeri</i> / 1 N	Martins et al. (2010)
<i>Alouatta clamitans</i> [⊖] / At (5)	Blumenau, Garuva, Indaial, Jaraguá do Sul / SC	2005 / 2007	<i>A. aureolatum</i> / 2 M, 1 F <i>A. ovale</i> / 1 M, 5 F <i>Amblyomma</i> sp. / 3 L, 4 N	Lavina et al. (2011)
<i>C. apella</i> [⊖] / Ce	ENP / GO	1999 / 2008	<i>A. cajennense</i> [∞] / 1 N	Martins et al. (2011)
<i>A. guariba</i> / At	Blumenau / SC	2012	<i>A. parkeri</i> / 2 N	Martins et al. (2013)
<i>A. guariba</i> / At	São Paulo / SP	2010	<i>A. parkeri</i> / 4 N	
<i>A. guariba</i> / At	Sorocaba / SP	2012	<i>Amblyomma sculptum</i> / 1 N	Martins et al. (2015)
<i>Alouatta nigerrima</i> / At	TNF / PA	2009 / 2011	<i>Amblyomma geayi</i> / 1 L [§]	Soares et al. (2015)
<i>A. guariba</i> / At	Goiânia / GO	2013	<i>A. sculptum</i> / 1 N	Bastos et al. (2016)
<i>A. guariba</i> / At	São Paulo / SP	2006	<i>A. sculptum</i> / 1 F	Martins et al. (2016)
<i>Sapajus nigrinus</i> / Ce	Bebedouro / SP	1950	<i>A. cajennense sensu lato</i> [∞] / 1 M	
<i>Mico melanurus</i> / Ca	Cuiabá / MT	2014	<i>Rhipicephalus sanguineus sensu lato</i> / 1 M	Witter et al. (2016)
<i>A. guariba clamitans</i> / At (3)	São Paulo / SP	2012 / 2014 / 2015	<i>A. aureolatum</i> / 1 F <i>A. parkeri</i> / 1 N <i>Amblyomma</i> sp. / 5 L	Gonzalez et al. (2017)
<i>A. guariba</i> / At	Arujá / SP	2007	<i>A. sculptum</i> / 1 F	Martins et al. (2017a)
<i>A. guariba</i> / At	São Paulo / SP	2014	<i>A. aureolatum</i> / 1 F <i>A. sculptum</i> / 1 N	Martins et al. (2017b)
<i>A. guariba</i> / At	Mairiporã / SP	2014	<i>A. parkeri</i> / 2 N	
<i>A. guariba</i> / At (2)	Itapeerica da Serra / SP	2013	<i>A. aureolatum</i> / 1 M, 1 F <i>A. sculptum</i> / 1 N	
<i>A. guariba</i> / At (2)	São Paulo / SP	2015	<i>A. dubitatum</i> / 1 N <i>A. sculptum</i> / 24 N, 1 M <i>Amblyomma</i> sp. / 1 L	
<i>Callicebus nigrifrons</i> / Pi	Nazaré Paulista / SP	2013	<i>A. parkeri</i> / 3 N	
<i>A. guariba</i> / At	São Roque / SP	2016	<i>A. sculptum</i> / 1 N	Teixeira et al. (2017)
<i>Saguinus bicolorbicolor</i> / Ca	Manaus / AM	2012	<i>A. geayi</i> / 2 N <i>Amblyomma</i> sp. / 24 L <i>Amblyomma coelebs</i> / 1 F	Gianizella et al. (2018)
<i>Sapajus macrocephalus</i> / Ce	Santa Isabel do Rio Negro / AM	2012	<i>Rhipicephalus (Boophilus) microplus</i> / 1 F	Zimmermann et al. (2018)
<i>Alouatta puruensis</i> / At	Ariquemes / RO	2014 / 2015	<i>Amblyomma</i> sp. haplotype Nazaré / 8 N [⊚]	Peckle et al. (2019)
<i>C. nigrifrons</i> / Pi	Barbacena / MG	2014	<i>Amblyomma romarioi</i> / 3 M	Martins et al. (2019)
<i>C. nigrifrons</i> / Pi	Nazaré Paulista / SP	2013	<i>A. romarioi</i> / 2 F	
<i>C. nigrifrons</i> / Pi	Atibaia / SP	2018	<i>A. romarioi</i> / 2 F	
<i>C. nigrifrons</i> / Pi	Barbacena / MG	2014	<i>A. romarioi</i> / 6 N [§]	

(Number of examined animals).

At: Atelidae; Ca: Callitrichidae; Ce: Cebidae; Pi: Pitheciidae.

ND: Not determined.

[‡]The scientific name of these hosts was not reported.[†]*Alouatta* sp.[‡]*Sapajus nigrinus*.[⊖]*Alouatta guariba clamitans*.[⊖]*Sapajus libidinosus*.[‡] River banks (Cuminá and Trombetas in Pará state).

PPHPS: Porto-Primavera Hydroelectric Power Station (Municipalities: Anaurilândia, Bataguassu, Bataiporã, Brasilândia and Santa Rita do Pardo located in the state of Mato Grosso do Sul; Presidente Epitácio, Primavera and Rosana located in the state of São Paulo).

[‡] This location was later reported as the municipality of Jundiá in São Paulo state by Nava et al. (2010).

ENP: Emas National Park (Municipalities: Chapadão do Céu, Mineiros and Serranópolis in Goiás state).

TNF: Tapajós National Forest (Municipality: Rurópolis in Pará state).

[∞]*Amblyomma cajennense sensu lato*.^{*}*Amblyomma cajennense sensu stricto*.[∞]*Amblyomma sculptum*.

L: Larva; N: Nymph; M: Male; F: Female.

[‡] This same female probably was a reiteration of Barros and Baggio (1992).[∞]This tick species was re-examined during the review of tick collections and was identified as *Amblyomma sculptum* in the present study.^{*} These ticks were collected as engorged nymphs that moulted to adults in the laboratory for identification.[§] These immatures (larva and nymphs) were identified by molecular analysis.[⊚] These same nymphs were later identified as *Amblyomma romarioi* by Martins et al. (2019).

Table 2. Ticks identified on wild primates from different locations in Brazil sampled between the years 1919 and 2019.

Host species	Municipalities / States	Years	Tick species / Number and stages
Family Aotidae			
<i>Aotus infulatus</i>	Cuiabá / MT	2016	<i>Amblyomma sculptum</i> / 1 F
<i>A. infulatus</i> (2)	Marabá / PA	2017	<i>Amblyomma cajennense</i> sensu stricto / 5 N, 1 N *
Family Atelidae			
<i>Alouatta belzebul</i>	Tucuruí / PA	1984	<i>A. cajennense</i> s. s. / 3 F
<i>A. belzebul</i>	ND / PA	1919	<i>Amblyomma rotundatum</i> / 1 N
<i>Alouatta caraya</i> (2)	Brasília / MS	1998	<i>Amblyomma incisum</i> / 1 N *
<i>A. caraya</i>	Santa Rita do Pardo / MS	2000	<i>A. sculptum</i> / 14 N, 4 F
<i>A. caraya</i>	Campo Formoso / BA	2012	<i>A. sculptum</i> / 14 N
<i>Alouatta guariba clamitans</i>	São Paulo / SP	1982	<i>Rhipicephalus sanguineus</i> sensu lato / 1 F
<i>A. guariba clamitans</i>	Itapeçerica da Serra / SP	1994	<i>Amblyomma parkeri</i> / 1 N
<i>A. guariba clamitans</i>	Sorocaba / SP	1997	<i>Amblyomma aureolatum</i> / 1 F
<i>A. guariba clamitans</i>	São Paulo / SP	2001	<i>A. sculptum</i> / 2 N
<i>A. guariba clamitans</i> (2)	Mairiporã / SP	2002	<i>A. parkeri</i> / 1 N
<i>A. guariba clamitans</i>	São Paulo / SP	2002	<i>A. aureolatum</i> / 1 M
<i>A. guariba clamitans</i>	São Paulo / SP	2002	<i>A. parkeri</i> / 1 N
<i>A. guariba clamitans</i>	São Paulo / SP	2002	<i>Amblyomma</i> sp. / 8 L
<i>A. guariba clamitans</i>	Tijucas do Sul / PR	2003	<i>Amblyomma</i> sp. / 3 L
<i>A. guariba clamitans</i>	Ibiúna / SP	2004	<i>A. parkeri</i> / 1 N
<i>A. guariba clamitans</i>	São Paulo / SP	2004	<i>Ixodes</i> sp. / 1 N
<i>A. guariba clamitans</i>	Sorocaba / SP	2006	<i>A. parkeri</i> / 1 N
<i>A. guariba clamitans</i>	Sorocaba / SP	2006	<i>A. sculptum</i> / 3 M
<i>A. guariba clamitans</i>	Indaial / SC	2007	<i>A. sculptum</i> / 1 N
<i>A. guariba clamitans</i> (2)	São Paulo / SP	2007	<i>A. aureolatum</i> / 1 F
<i>A. guariba clamitans</i>	São Paulo / SP	2007	<i>A. aureolatum</i> / 1 F
<i>A. guariba clamitans</i>	São Paulo / SP	2007	<i>A. parkeri</i> / 7 F
<i>A. guariba clamitans</i>	São Bento do Sul / SC	2009	<i>A. parkeri</i> / 1 N
<i>A. guariba clamitans</i>	São Paulo / SP	2009	<i>A. parkeri</i> / 1 F
<i>A. guariba clamitans</i>	São Paulo / SP	2009	<i>A. aureolatum</i> / 1 F
<i>A. guariba clamitans</i>	Ibiúna / SP	2010	<i>A. aureolatum</i> / 1 F
<i>A. guariba clamitans</i>	Indaial / SC	2010	<i>Amblyomma ovale</i> / 1 F
<i>A. guariba clamitans</i>	São Paulo / SP	2010	<i>A. aureolatum</i> / 1 M, 1 F
<i>A. guariba clamitans</i>	Lapa / PR	2012	<i>A. parkeri</i> / 2 N
<i>A. guariba clamitans</i>	São Paulo / SP	2012	<i>A. sculptum</i> / 21 L [♂]
<i>A. guariba clamitans</i> (2)	Indaial / SC	2013	<i>Amblyomma</i> sp. / 6 L
<i>A. guariba clamitans</i>	Guarulhos / SP	2014	<i>Haemaphysalis juxtakochi</i> / 1 L [♂]
<i>A. guariba clamitans</i> (2)	Blumenau / SC	2015	<i>A. aureolatum</i> / 1 M
<i>A. guariba clamitans</i>	Guarulhos / SP	2015	<i>Amblyomma longirostre</i> / 1 F
<i>A. guariba clamitans</i>	Joinville / SC	2015	<i>A. parkeri</i> / 1 N
<i>A. guariba clamitans</i>	Blumenau / SC	2016	<i>A. aureolatum</i> / 1 F
<i>A. guariba clamitans</i>	Pomerode / SC	2016	<i>A. parkeri</i> / 1 N
<i>A. guariba clamitans</i> (2)	Blumenau / SC	2017	<i>A. longirostre</i> / 1 F
<i>A. guariba clamitans</i>	Franco da Rocha / SP	2017	<i>Rhipicephalus microplus</i> / 1 M, 4 F
<i>A. guariba clamitans</i> (2)	São Paulo / SP	2017	<i>A. longirostre</i> / 1 F
<i>A. guariba clamitans</i>	Anita Garibaldi	2018	<i>A. parkeri</i> / 1 F
<i>A. guariba clamitans</i>	Blumenau / SC	2018	<i>A. aureolatum</i> / 1 M
<i>A. guariba clamitans</i>	Curitiba / PR	2018	<i>A. parkeri</i> / 1 M, 1 F
<i>A. guariba clamitans</i> (3)	Blumenau / SC	2019	<i>A. parkeri</i> / 1 N
<i>A. guariba clamitans</i>	Mairiporã / SP	2019	<i>A. aureolatum</i> / 2 F
<i>A. guariba clamitans</i>	Porto Alegre / RS	2019	<i>Amblyomma dubitatum</i> / 1 N
<i>A. guariba clamitans</i>	São José dos Pinhais / PR	2019	<i>A. ovale</i> / 2 F
<i>A. guariba clamitans</i>	São Paulo / SP	2019	<i>R. sanguineus</i> s. l. / 1 M
<i>Alouatta nigerrima</i>	Itacoatiara / AM	1919	<i>A. parkeri</i> / 1 N
<i>Alouatta seniculus</i>	Tefé / AM	1992	<i>A. aureolatum</i> / 1 F
<i>Ateles paniscus</i>	Natal / RN	1992	<i>A. parkeri</i> / 2 N
Family Callitrichidae			
<i>Callithrix aurita</i> (3)	Salesópolis / SP	2004	<i>H. juxtakochi</i> / 3 N, 4 M, 2 F
<i>Callithrix penicillata</i>	Viçosa / MG	2010	<i>Ixodes fuscipes</i> / 2 M
<i>C. penicillata</i>	Juazeiro / BA	2012	<i>A. cajennense</i> s. s. / 1 N
<i>Callitrix</i> sp. ^a	Arujá / SP	2014	<i>Amblyomma geayi</i> / 1 N
<i>Callitrix</i> sp. ^a	Cajamar / SP	2019	<i>R. sanguineus</i> s. l. / 6 N, 42 M, 69 F
<i>Callitrix</i> sp. ^a	São Paulo / SP	2019	<i>A. aureolatum</i> / 1 M, 1 F
<i>Leontopithecus chrysomelas</i>	Niterói / RJ	2012	<i>Amblyomma</i> sp. / 1 L
<i>Leontopithecus chrysopygus</i>	Teodoro Sampaio / SP	2005	<i>A. sculptum</i> / 7 N
<i>Leontopithecus rosalia</i> (8)	Silva Jardim / RJ	2003	<i>A. sculptum</i> / 1 N
<i>Mico melanurus</i>	Cuiabá / MT	2017	<i>R. sanguineus</i> s. l. / 1 M

(Continued)

Table 2. (Continued).

Host species	Municipalities / States	Years	Tick species / Number and stages
Family Cebidae			
<i>Sapajus apella</i>	Tucuruí / PA	1980	<i>Amblyomma naponense</i> / 1 N
<i>Sapajus flavius</i> (8)	Santa Rita / PB	2010	<i>Amblyomma</i> sp. / 25 L
<i>Sapajus nigrinus</i>	Sorocaba / SP	1999	<i>Amblyomma</i> sp. / 2 L
<i>S. nigrinus</i>	Santa Rita do Pardo / MS	2000	<i>A. sculptum</i> / 3 N
<i>S. nigrinus</i>	Resende / RJ	2015	<i>A. longirostre</i> / 1 N *
Family Pitheciidae			
<i>Cacajao calvus</i>	Tefé / AM	1992	<i>A. geayi</i> / 1 N
<i>Callicebus nigrifrons</i>	Itabira / MG	2010	<i>A. sculptum</i> / 1 N
<i>C. nigrifrons</i>	Santo Antônio do Grama / MG	2012	<i>Amblyomma romarioi</i> / 1 N [§]
<i>C. nigrifrons</i>	Cajamar / SP	2014	<i>A. parkeri</i> / 1 N
<i>Callicebus personatus</i>	Santa Teresa / ES	2017	<i>Amblyomma</i> sp. / 3 L
<i>Pithecia monachus</i> (2)	Juruá / AM	1919	<i>A. longirostre</i> / 4 N <i>A. cajennense</i> s. s. / 2 N
Order Primates			
Monkey ‡	São Paulo / SP	1937	<i>A. parkeri</i> / 1 N
Monkey ‡	ND / GO	ND	<i>A. sculptum</i> / 1 N

(Number of examined animals).

^aHybrid animals.

[‡]The scientific names of these hosts was not identified.

ND: Not determined.

L: Larva; N: Nymph; M: Male; F: Female.

* These ticks were collected as engorged nymphs that moulted to adults in the laboratory for identification.

[§] These ticks were collected as engorged larvae that moulted to nymphs in the laboratory for identification.

[§]This nymph was identified by molecular analysis.

oblongoguttatum Koch, 1844, *Amblyomma ovale* Koch, 1844, *Amblyomma parkeri* Fonseca & Aragão, 1952, *Amblyomma romarioi* Martins, Luz & Labruna, 2019, *Amblyomma sculptum* Berlese, 1888, *Rhipicephalus microplus* (Canestrini, 1888), *Rhipicephalus sanguineus* (Latreille, 1806) sensu lato (s. l.), and *Ornithodoros rostratus* Aragão, 1911. Several immature ticks (larvae and nymphs) were classified solely as *Amblyomma* sp. (Table 1).

Through the examination of unpublished data in the tick collections, the following tick species were identified on wild primates: *A. aureolatum*, *A. cajennense* sensu stricto (s. s.), *A. coelebs*, *A. dubitatum*, *A. geayi*, *Amblyomma incisum* Neumann, 1906, *A. longirostre*, *Amblyomma naponense* (Packard, 1869), *Amblyomma nodosum* Neumann, 1899, *A. ovale*, *A. parkeri*, *A. romarioi*, *Amblyomma rotundatum* Koch, 1844, *A. sculptum*, *Haemaphysalis juxtakochi* Cooley, 1946, *Ixodes fuscipes* Koch, 1844, *R. microplus* and *R. sanguineus* s. l. In addition, several *Amblyomma* larvae and one nymph of *Ixodes* could not be identified at species level (Table 2). The diversity of tick species found in the literature review and in the tick collections in the different families of non-human primates are shown in Figure 1.

Ticks were found in the five primate families, and in 11 out of the 22 primate genera registered in Brazil. However, ticks were identified in only about 23 out of the 119 monkey species reported in the Brazilian territory (Tables 1 and Tables 2). Altogether, the present records of ticks on wild primates are originated from 64 Brazilian localities, including undetermined locations in some states (Tables 1 and Tables 2). The only Brazilian biome where there was not record of tick infestation on monkeys was the Pantanal. Among the other five biomes, there was a single record in the Pampa, few records in the Caatinga and Cerrado, and the majority of tick records distributed in the Amazon and the Atlantic Forest biomes (Figure 2).

Discussion

In the literature review, the only species of soft tick found on primates was *O. rostratus*, but neither the stage nor the number of ticks was reported, as well the location in Brazil and primate species, which were reported only as monkey and marmoset (Aragão 1936). Therefore, these data should be interpreted with

caution, since they may be animals raised and kept in laboratory conditions and used for scientific studies in the past century.

In the tick collections, all stages of *H. juxtakochi* were identified on two specimens of brown howler monkey (*Alouatta guariba clamitans*), and a larva on marmoset (*Callitrix* sp.), all of them from the Atlantic Forest biome in the Southeastern region of the Brazilian territory. The finding in the present study of adult ticks on *A. guariba clamitans* in Brazil is in agreement with another study carried in Venezuela, where a male of *H. juxtakochi* was reported on another monkey species, a weeper capuchin (*Cebus olivaceus*), published as *Cebus nigrivittatus* (Jones et al. 1972). Deer of the family Cervidae are the most common hosts for *H. juxtakochi* adults, but they were also found on a variety of mammals and occasionally on birds (Guglielmone et al. 2014). Large wild and domestic mammals are also hosts for immature stages of *H. juxtakochi*, but larvae and nymphs were found as well on small rodents and birds (Nava et al. 2017).

Two males of the tick species *I. fuscipes* and a nymph of *Ixodes* sp. were identified in the tick collections analysed in the present study on two *A. guariba clamitans* in the Atlantic Forest, Southeastern Brazil. On the other hand, the nymph of *Ixodes* sp. has not been identified at the species level because there are no taxonomic keys for nymphs of the genus *Ixodes* that occur in the Brazilian territory, and some of the nymphs have not yet been described or even collected, so they are unknown. The tick *I. fuscipes* was recently re-described, showing that domestic mammals (dog and horse) are hosts for adults, but deer of the genus *Mazama* appear to be the main hosts of this stage in Brazil (Labruna et al. 2020).

The hard tick *R. sanguineus* s. l. was identified in the tick collections analysed in the present study on *A. caraya*, *A. guariba clamitans*, red-faced spider monkey (*Ateles paniscus*), *Callitrix* sp. (2 specimens) and black-tailed marmoset (*Mico melanurus*), corroborating the report of the literature review, which records a male of *R. sanguineus* s. l. on *M. melanurus* (Witter et al. 2016). An intense infestation was found exclusively by *R. sanguineus* s. l. on an *A. paniscus* (6 nymphs, 42 males, and 69 females) in the Northeastern region, probably a captive animal, since this monkey species occurs only in Northern Brazil. Ectoparasites are rare on non-human primates due to their picking habits, but mainly in captivity, animals that are debilitated, solitary, or excluded from

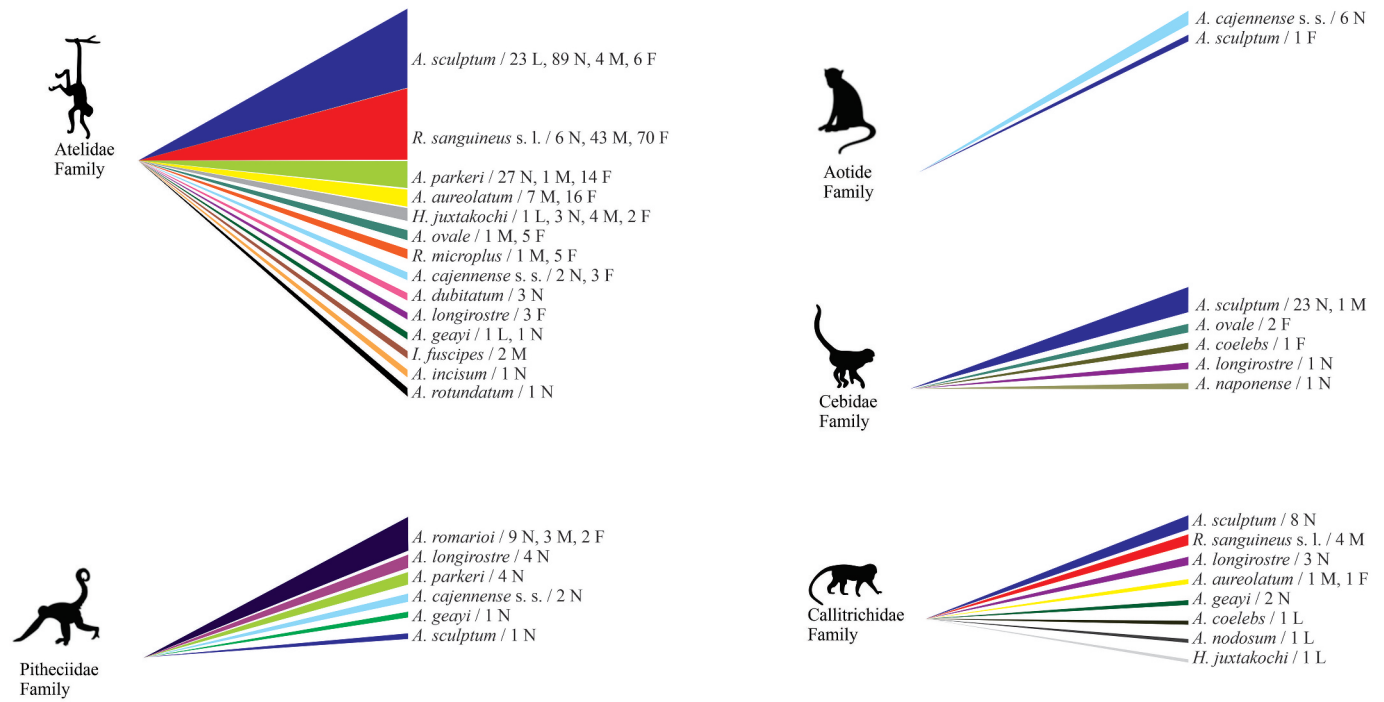


Figure 1. Diversity of tick species found in the present study in different families of Brazilian wild primates

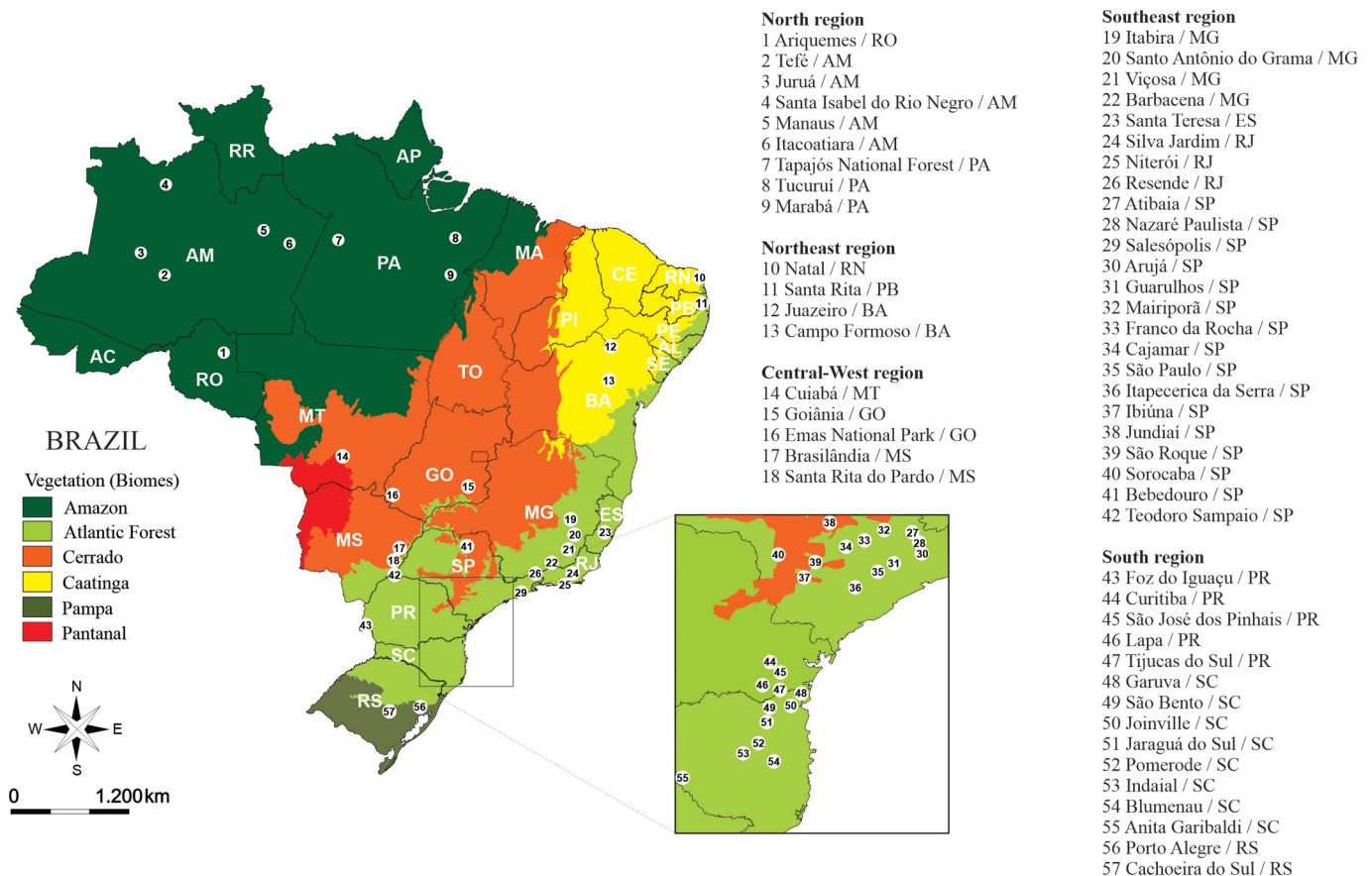


Figure 2. Geopolitical map of Brazil, showing the localities of the ticks found and identified in the present study, according to the six major biomes (Amazon, Atlantic Forest, Caatinga, Cerrado, Pantanal and Pampa) that compose the Brazilian landscape.

groups can be more easily infested. Therefore, the finding of this tick species on primates suggests captive animals or monkeys that lived in forest fragments with some degree of anthropization, although, more evidence is needed to substantiate this statement.

The domestic dog is the primary host for all stages of *R. sanguineus* s. l., which has an Old-World origin and does not occur in natural areas of Brazil (Guimarães et al. 2001; Barros-Battesti et al. 2006). Other species of wild animals might maintain this ectoparasite

only at captivity conditions, since this tick species predominates widely in urban areas of all Brazilian regions (Martins et al. 2017a; Martins 2018).

In the analysed tick collections, a male and females of *R. microplus* were identified on one *A. guariba clamitans* in the Atlantic Forest, Southern Brazil. However, in the literature review, a female of *R. microplus* was reported on an Purús red howler monkey (*Alouatta puruensis*). According to the authors, it was possibly an accidental encounter, since this tick was found fixed on a young specimen found separated from its mother on the forest floor during a fauna rescue in a construction area of a hydroelectric dam in the Amazon biome, Northern region of the country (Zimmermann et al. 2018). In fact, monkey parasitism in the Brazilian territory is often associated with young or injured animals that exhibit altered behaviour, including prolonged presence in the soil caused by some physical debility and decreased hygiene (Martins et al. 2006; Lavina et al. 2011). The exotic cattle tick, *R. microplus*, is a species introduced in Brazil with cattle from Asia, and today it is widely distributed in almost all the national territory (including areas of deforested Amazon), where it is closely linked to domestic cattle (Guimarães et al. 2001; Labruna et al. 2005; Barros-Battesti et al. 2006).

Both in the literature review and in the analysis of tick collections, immature ticks of the genus *Amblyomma* were found and identified parasitizing primates in Brazil, e.g., Northern masked titi monkey (*Callicebus personatus*) in Table 2 (Wilson et al. 1989; Labruna et al. 2002; Lavina et al. 2011; Gonzalez et al. 2017; Martins et al. 2017b; Gianizella et al. 2018). These findings corroborate two studies conducted in Venezuela and French Guiana that reported red howler monkey (*Alouatta seniculus*) parasitized by larvae and nymphs of *Amblyomma* spp. (Jones et al. 1972; Thoisy et al. 2001).

In the literature review, *A. oblongoguttatum* was found on *A. caraya* in the Brazilian territory (Catão-Dias 2001). However, this tick species was re-examined during the review of tick collections and was identified as *A. sculptum* in the present study. On the other hand, adults of *A. oblongoguttatum* were reported on Colombian white-faced capuchin (*Cebus capucinus*) in Panama (Fairchild et al. 1966).

The identification of a *A. coelebs* larva on black lion tamarin (*Leontopithecus chrysopygus*) in the Atlantic Forest, found in the tick collection, is in agreement with the literature report of an adult of *A. coelebs* in another monkey species, a large-headed capuchin (*Sapajus macrocephalus*) in the Brazilian Amazon (Gianizella et al. 2018). New World tapirs are considered usual hosts for adults of *A. coelebs* (Labruna and Guglielmone 2009). However, adults and immature stages of this tick present low host specificity, adults were recorded on different mammal species, and larvae and nymphs were also found on wild birds (Nava et al. 2017). Ticks that have a low parasitic specificity end up parasitizing a larger range of hosts, so the present found is in agreement with another tick with a low host specificity, *Amblyomma parvum* Aragão, 1908, that was reported in Argentina parasitizing another species of primate, a capuchin monkey (*Sapajus* sp.), published as *Cebus apella* (Guglielmone et al. 1990).

A nymph of the tick *A. dubitatum* was identified in the review of tick collections on *A. guariba clamitans* in the Atlantic Forest, Southern Brazil. This identification corroborates the literature review that includes two studies carried in the same biome, however, in the Southeastern region of the country, where two nymphs of *A. dubitatum* were reported on monkeys of the species *A. caraya* and *A. guariba clamitans* (Labruna et al. 2004; Martins et al. 2017b). The capybaras are the most common hosts for all stages of *A. dubitatum* (Labruna et al. 2004). However, larvae, nymphs, and adults of this tick were also collected on several mammal species belonging to different orders, and the immature stages were found on a few species of wild birds (Nava et al. 2010, 2017).

In the tick collection, a nymph of *A. incisum* was found on *A. caraya* in the Atlantic Forest from transition area with the Cerrado, Central-West region. This nymph moulted incompletely to an adult male, and by morphological analysis, some of us (G.S.G., T.F.M.) concluded that this incompletely formed adult has several features compatible with a male of *A. incisum*. On the other hand, there have had several recent studies that did not find the species *A. incisum* in the same region, despite of extensive field work (Labruna et al. 2002; Szabó et al. 2003, 2007; Silveira et al. 2007, 2015; Ogrzewalska et al. 2009a, 2009b, 2011). Therefore, future studies should be carried out in this Atlantic Forest-Cerrado transition area to confirm the establishment of *A. incisum* in the region. South American tapirs are considered usual hosts for adults of *A. incisum*, but they have also been collected from rodents (Labruna and Guglielmone 2009; Guglielmone and Robbins 2018). There are records of nymphs of this tick from perissodactyls, artiodactyls, and carnivorous (Nava et al. 2017; Guglielmone and Robbins 2018).

During the review of the tick collections, a nymph of *A. naponense* was identified on brown tufted capuchin (*Sapajus apella*) from the Amazon, Northern Brazil. Adults and nymphs of *A. naponense* have been found on artiodactyls, carnivores, pilosans, and rodents. However, adult ticks have been collected from rodents, while immature stages were identified on carnivores, didelphimorphs, rodents, and wild birds (Guglielmone et al. 2014; Soares et al. 2015; Witter et al. 2016; Guglielmone and Robbins 2018).

In the tick collection, a larva of *A. nodosum* was identified on *L. chrysomelas* in the Atlantic Forest, Southeastern Brazil. Passerine birds are the principal hosts for immature stages of *A. nodosum* (Barros-Battesti et al. 2006). Differently, anteaters are the principal hosts for adult stage of *A. nodosum* (Muñoz-García et al. 2019). The host range for adults of *A. nodosum* also includes species belonging to different orders of mammals, and immature stages were found in other three orders of birds besides Passeriformes (Nava et al. 2017).

The identification of an *A. rotundatum* nymph on red-handed howler monkey (*Alouatta belzebul*) from the Amazon, in the analysed tick collection can be considered accidental, since the associations of this tick species with their usual hosts are well known. Amphibians and reptiles are the principal hosts for all parasitic stages of *A. rotundatum* (Guglielmone and Nava 2010). However, there have been sporadic records of *A. rotundatum* on mammals belonging to different orders (Nava et al. 2017).

The present identification in the tick collections of an *A. geayi* nymph on *A. seniculus* and a nymph on bald-headed uakari (*Cacajao calvus*) in the Amazon is in agreement with the literature review, that includes *A. geayi* larva on black howler monkey (*Alouatta nigerrima*) and nymphs on pied tamarin (*Saguinus bicolor*), also in the Brazilian Amazon (Soares et al. 2015; Gianizella et al. 2018). The finding in the present study of *A. geayi* immature ticks on primates is also in agreement with another study carried in Panama, where a nymph of *A. geayi* was reported on a mantled howler monkey (*Alouatta palliata*) (Esser et al. 2016). On the other hand, another tick species, *Amblyomma humerale* Koch, 1844 (published as *A. humeralae*) was reported on another monkey species of the genus *Saguinus*, red-handed tamarin (*Saguinus midas*), in French Guiana (Thoisy et al. 2001). However, this record should be considered doubtful, since there was no taxonomic support for the identification of this tick species in that study. Adults of *A. geayi* are usually found on pilosans and rodents, with some records from other pilosan hosts and didelphimorphs. On the other hand, larvae and nymphs are mostly found on wild birds, with a few records on mammals (Martins et al. 2013; Guglielmone et al. 2014; Guglielmone and Robbins 2018).

In the review of the tick collections, *A. longirostre* nymphs were identified on monk saki (*Pithecia monachus*) in the Amazon, adults on *A. guariba clamitans*, nymph on *L. chrysomelas*, nymphs on golden lion tamarin (*Leontopithecus rosalia*), and nymph on black-horned

tufted capuchin (*Sapajus nigritus*) in the Brazilian Atlantic Forest. In the literature review, it was also found a report of *A. longirostre* on capuchin monkey (*Cebus* sp.); however, the tick stage was not reported (Guimarães et al. 2001). These findings are in agreement with other two studies that reported *A. longirostre* on white-faced saki (*Pithecia pithecia*), on *S. midas*, and on *Cebus* sp. in French Guiana (Floch and Fauran 1959; Thoisy et al. 2001). The records on *P. pithecia* and *S. midas* (published as *A. longirostris*) should be considered doubtful, since there was no taxonomic support for the identification of this tick species in Thoisy et al. (2001). Neotropical porcupines and passerine birds are the principal hosts for adults and immature stages, respectively, of *A. longirostre* (Barros-Battesti et al. 2006). Adults and nymphs of *A. longirostre* were also found on mammals belonging to different orders, and there have been records of larvae, nymphs, and adults on non-passerine birds (Nava et al. 2017).

During the review of tick collections, a nymph of *A. parkeri* was identified on a black-fronted titi (*Callicebus nigrifrons*) and several nymphs and some adults were identified on 19 *A. guariba clamitans* in the Atlantic Forest of the Southern and Southeastern regions of Brazil. Therefore, these findings indicate the importance of monkeys as usual hosts, and corroborate the other studies in the literature review that also included *A. parkeri* on these two primate species in the same biome and in these two regions of the country (Labruna et al. 2009; Martins et al. 2010, 2013, 2017b, 2019; Gonzalez et al. 2017). Interestingly, a nymph of *A. parkeri* was collected inside the nostril of *A. guariba clamitans* (Martins et al. 2013). This unusual encounter may be related to the monkeys' effective self-cleaning behaviour, which uses ectoparasites picking in the groups in which they live to get rid of ticks, suggesting a strategy for the tick survival in nature, during parasitic stages. Adults of *A. parkeri* are usually found on South American porcupines, while larvae and nymphs have been collected from these rodents, but most records of immatures are from several families of passerine birds (Guglielmo and Robbins 2018). Adults and nymphs have also been found on carnivores and didelphimorphs, respectively (Martins et al. 2017b; Guglielmo and Robbins 2018).

The tick species *A. romarioi* was recently described in the Brazilian Atlantic Forest, demonstrating that until now, the only known host for nymphs and adults is the *C. nigrifrons* that occurs in the Southeastern region of the national territory (Martins et al. 2019). A nymph of *A. romarioi* was identified on another *C. nigrifrons* in the one of tick collections analysed in the present study, thus confirming that this species of monkey is important for the nymphal stage of *A. romarioi* in the nature. *Amblyomma romarioi* is the only Neotropical tick whose nymphs and adults have only been found on Brazilian monkeys, suggesting a tick-monkey specific interaction unique in the Neotropical region. On the other hand, some hard tick species (i.e., *Haemaphysalis lemuris* Hoogstraal 1953, *Ixodes lemuris* Arthur 1958, *Ixodes rageaui* Arthur 1958, *Ixodes schillingsi* Neumann 1901) are also known to be primarily associated with wild primates in the Afrotropical region (Arthur 1958; Hoogstraal and Theiler 1959; Durden et al. 2010; Blanco et al. 2013; Guglielmo et al. 2014).

The species *A. geayi*, *A. longirostre*, *A. parkeri* and *A. romarioi* form a natural group of genetically, morphologically and ecologically related Neotropical ticks (Labruna et al. 2009; Martins et al. 2013, 2019; Luz et al. 2018). In this context, these four species are considered possibly arboreal ticks, with the possibility that they use the tree canopy for the free-living developmental stages, and the Brazilian primates in their parasitic life cycle. This "arboreal life-cycle" is yet to be demonstrated in further studies.

In the analysed tick collections, females of *A. cajennense* s. s. were identified on *A. belzebul* and nymphs on feline night monkey (*Aotus infulatus*), *A. nigerrima* and *P. monachus* in the Amazon, Northern Brazil. The finding in the present study of this tick species on primates is also in agreement with the literature review, where another study conducted in the same region and biome reported a nymph of *A. cajennense* s. s. (published as *A. cajennense*) on *A. paniscus* (Ferreira d'Almeida 1937). In Venezuela, a female of *A. cajennense*

s. l. was identified on another monkey species, *A. seniculus* (Jones et al. 1972). In the Brazilian territory, wild and domestic medium to large-sized mammals, including tapirs, anteaters, dogs, horses, and cattle, are considered principal hosts for adults of *A. cajennense* s. s. (Martins et al. 2016). However, immature stages feed on a much broader range of mammals of several orders, as well as on wild birds (Guglielmo and Robbins 2018).

Regarding the *A. sculptum* identified in the tick collections, nymphs were found on two black tufted-ear marmoset (*Callithrix penicillata*) in the Atlantic Forest and Caatinga, in the Southeastern and Northeastern regions of Brazil, respectively. Nymphs were also identified on *S. nigritus* and *C. nigrifrons* in the Atlantic Forest and Cerrado biomes. Nymphs and adults have also been identified on three *A. caraya* in the Atlantic Forest-Cerrado transition area, Central-West of the country. On the other hand, only the adult stage was identified on an *A. infulatus* in the Cerrado. Finally, all parasitic stages were identified on five *A. guariba clamitans* in the Atlantic Forest. All these findings on brown howler monkey are in agreement with literature review, which includes several studies conducted in the Brazil, that also found nymphs and adults of *A. sculptum* on this same host species (Martins et al. 2015, 2016, 2017a, 2017b; Bastos et al. 2016; Teixeira et al. 2017). Other studies carried in the country also found *A. sculptum* on primates in the Atlantic Forest, Cerrado and Caatinga biomes. However, larvae and nymphs were found on *Aloatta* sp., nymphs on *A. caraya*, bearded capuchin (*Sapajus libidinosus*) and *S. nigritus* (all published as *A. cajennense*) and adults on *S. nigritus* (published as *A. cajennense* s. l.) (Aragão 1913; Labruna et al. 2002; Martins et al. 2011, 2016). Adults and immature stages of *A. sculptum* present low host specificity (Nava et al. 2017). In the Brazilian territory, wild and domestic medium to large-sized mammals are considered usual hosts for adults and immatures of this tick species, including capybaras, tapirs, anteaters, jaguars, horses, and dogs (Martins et al. 2016), in addition to a few records on wild birds (Nava et al. 2017).

In the tick collections, adults of *A. aureolatum* were identified on two buffy tufted-ear marmoset (*Callithrix aurita*) in the Atlantic Forest, Southeastern Brazil, and several adults were identified on thirteen *A. guariba clamitans* in this same biome of the Southern and Southeastern regions of the country. Therefore, these findings on brown howler monkey corroborate the literature review, in which other studies also found *A. aureolatum* on several *A. guariba clamitans* in these two regions of the national territory (Martins et al. 2006; Lavina et al. 2011; Gonzalez et al. 2017; Martins et al. 2017b). The principal hosts for adult and immature stages of *A. aureolatum* are carnivorous and passerine birds, respectively, but the range of hosts is wide, especially for adult ticks, that includes several orders of mammals (Guimarães et al. 2001; Barros-Battesti et al. 2006; Nava et al. 2017).

Adults of *A. ovale* were identified on three *A. guariba clamitans* from the Atlantic Forest, Southern Brazil, during the analysis of the tick collections. These identifications corroborate the literature review, in which two studies carried in the same biome and region of the country also found adults on the primates *A. guariba clamitans* and *S. nigritus* (Barros and Baggio 1992; Arzua et al. 2005; Lavina et al. 2011). The principal hosts for *A. ovale* adults are carnivorous, while wild rodents are the most common hosts for immatures (Guimarães et al. 2001; Barros-Battesti et al. 2006). It is also considerable the contribution of tapirs and carnivorous animals as hosts for adults and immatures, respectively, and in a lesser extent other types of hosts, although wild birds have been found increasingly relevant as hosts for immature stages (Nava et al. 2017).

It is worth to mention that *A. sculptum* and *A. aureolatum* are considered important vectors of the bacterium *Rickettsia rickettsii*, the aetiological agent of Brazilian spotted fever, whereas *A. ovale* is the vector of *Rickettsia parkeri* strain Atlantic Forest, a milder rickettsiosis affecting humans in Brazil (Szabó et al. 2013).

In the present study, out of the 19 tick species found on nonhuman primates, at least 15 species (*A. aureolatum*, *A. cajennense* s. s., *A. coelebs*, *A. dubitatum*, *A. incisum*, *A. longirostre*, *A. naponense*, *A. ovale*, *A. parkeri*, *A. rotundatum*, *A. sculptum*, *H. juxtakochi*, *R. microplus*, *R. sanguineus* s. l. and *O. rostratus*) have already been reported parasitizing humans in Brazil (Aragão 1936; Lima et al. 1995; Famadas et al. 1997; Figueiredo et al. 1999; Arzua et al. 2005; Labruna et al. 2005; Guglielmone et al. 2006; Szabó et al. 2006; Labruna et al. 2007; Martins et al. 2013; 2016; Garcia et al. 2015; Acosta et al. 2017; Gianizella et al. 2018; Guglielmone and Robbins 2018; Jaguizeski et al. 2018; Reck et al. 2018; Sevá et al. 2019; Szabó et al. 2020).

Additionally, the presence of *A. incisum*, *A. naponense*, *A. nodosum*, *A. rotundatum* and *I. fuscipes* on monkeys is recorded for the first time in the present research, thus contributing to the knowledge of ticks associated with New World wild primates.

Finally, it is important to note that the data available to date have been obtained mainly by receiving injured and weakened monkeys for treatment in institutions (zoological parks and wildlife rescue centres) or even captured primates found wandering in urban areas. Thus, the collection of ticks for the taxonomic studies is important to know the parasitic fauna of this order, which is still little investigated. Therefore, primates newly arrived from the nature in institutions must be carefully observed and suspects examined to prevent tick infestations in the enclosures or other groups of monkeys. Such measures should be combined with the quarantine period, routine management, and sanitary control of ectoparasites in each institution, avoiding veterinary problems. Further studies should investigate the role of ticks as vector of pathogenic microorganisms to Brazilian non-human primates.

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ORCID

Thiago F. Martins  <http://orcid.org/0000-0002-7325-3362>
 Rodrigo H. F. Teixeira  <http://orcid.org/0000-0001-8219-0845>
 Julio C. Souza Jr  <http://orcid.org/0000-0002-9122-7336>
 Hermes R. Luz  <http://orcid.org/0000-0002-8200-6427>
 Mônica M. Montenegro  <http://orcid.org/0000-0001-6574-819X>
 Leandro Jerusalinsky  <http://orcid.org/0000-0003-0744-1987>
 Marina G. Bueno  <http://orcid.org/0000-0001-7903-4147>
 Valeria C. Onofrio  <http://orcid.org/0000-0002-2734-7800>
 Marinete Amorim  <http://orcid.org/0000-0003-4311-3374>
 Paula De J. Da Silva  <http://orcid.org/0000-0002-9503-892X>
 Karla Bitencourth  <http://orcid.org/0000-0002-7812-9336>
 Ana B. P. Borsoi  <http://orcid.org/0000-0003-4499-5401>
 Sandro Marques  <http://orcid.org/0000-0002-7046-7330>
 Marco O. Mattos Jr  <http://orcid.org/0000-0002-7342-0490>
 Leandra S. I. Hernandez  <http://orcid.org/0000-0002-4544-9675>
 Rafael F. C. Vieira  <http://orcid.org/0000-0001-6613-0287>
 Richard C. Pacheco  <http://orcid.org/0000-0002-7135-1516>
 Maurício C. Horta  <http://orcid.org/0000-0003-3834-8398>
 Valéria P. da Silva  <http://orcid.org/0000-0001-7279-6229>
 Claudia A. Igayara  <http://orcid.org/0000-0002-1107-2435>
 Thais C. Sanches  <http://orcid.org/0000-0001-8319-1719>
 Marcello S. Nardi  <http://orcid.org/0000-0002-0195-9016>
 Camile Lugarini  <http://orcid.org/0000-0001-7589-7113>
 Cláudio L. M. de Siqueira  <http://orcid.org/0000-0003-0101-4212>
 João F. Soares  <http://orcid.org/0000-0002-7967-6569>
 Marcelo B. Labruna  <http://orcid.org/0000-0002-9675-3132>

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