Ticks (Acari: Ixodidae) as ectoparasites of Brazilian wild birds and their association with rickettsial diseases

Carrapatos (Acari: Ixodidae) como ectoprasitos de aves Brasileiras e sua associação com doenças riquetsiais

Maria OGRZEWALSKA[1]; Adriano PINTER[2]

[1] Fundação Oswaldo Cruz, Instituto Oswaldo Cruz, Laboratório de Hantaviroses e Rickettsioses, Rio de Janeiro – RJ, Brazil
[2] Superintendência de Controle de Endemias Sucen, Laboratório de Bioquímica e Biologia Molecular, São Paulo – SP, Brazil

Abstract

Ticks (Acari: Ixodidae) are obligatory hematophagous ectoparasites of a variety of vertebrate hosts and play an important role in the transmission and ecology of infectious pathogens causing diseases in humans and animals worldwide. Sixty-eight species of ticks exist in Brazil, and at least 23 are found parasitizing wild birds. This number is increasing with the advent of new studies highlighting the underestimated role of birds in the life cycle of these arthropods. In South America, many of these ticks are involved in epidemiology of the life-threatening spotted fever diseases caused by bacteria from the genus *Rickettsia* (Rickettsiales: Rickettsiaceae). The aim of this paper is to present up-to-date knowledge about the bird-tick fauna of Brazil and their association with rickettsioses. The available literature concerning ticks on birds and tick-borne diseases related to these ticks in Brazil has been revised. It could be concluded that birds play a primary role in life cycles of various tick species, especially during immature stages (larvae and nymphs). The best known is a bird-tick fauna from the Atlantic Forest and from Brazilian savannah called Cerrado in southern and central Brazil, respectively. On the other hand, the knowledge about bird tick parasitism from other Brazilian biomes such as the Amazon, Caatinga, Pantanal and Pampas regions is very scarce and requires further study. Moreover, no studies about the role of birds as mobile hosts for spreading ticks to new areas exist, nor has their role in the natural life cycle of *Rickettsia* been thoroughly examined.

Keywords: Ticks. Ectoparasites. *Rickettsia*. Disease. Birds. Brazil.

Resumo

Os carrapatos (Acari: Ixodoidea) são ectoparasitas obrigatórias de uma variedade de hospedeiros vertebrados e têm um papel importante na ecologia e transmissão de diversos patógenos causadores de doenças em humanos e animais no mundo todo. No Brasil existem 68 espécies de carrapatos e pelo menos 23 espécies são encontradas parasitando aves silvestres. Esse número tem crescido com o advento de novos estudos ressaltando o papel das aves nos ciclos de vida desses artrópodes. Na América do Sul alguns desses carrapatos estão envolvidos na epidemiologia de doenças graves para o ser humano, como a febre maculosa, causada por bactérias do gênero *Rickettsia* (Rickettsiales: Rickettsiaceae). O alvo desse artigo é apresentar o estado atual de conhecimento sobre a fauna de carrapatos encontrados em aves no Brasil e as associações estabelecidas com as riquetsioses. A literatura disponível sobre carrapatos em aves e ocorrência de riquétsias foi revisada e pôde ser concluído que aves têm um papel importante nos ciclos de vida de várias espécies de carrapatos, sendo especialmente importantes para os estágios imaturos (larvas e ninfas). A maior parte do conhecimento sabrecai na fauna de carrapatos de aves dos biomas Mata Atlântica e Cerrado no sudeste e centro-oeste do Brasil. Já o conhecimento sobre o parasitismo por carrapatos em aves dos outros biomas: Amazônia, Caatinga, Pantanal e Pampas é muito limitado. Além disso, não há estudos sobre o papel de aves como disseminadores de carrapatos entre áreas e também o papel de aves no ciclo de *Rickettsia* não está totalmente esclarecido.

Palavras-chave: Carrapatos. Ectoparasitas. *Rickettsia*. Doença. Aves. Brasil.

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Correspondence to:
Maria Ogrzewalska
Fundação Oswaldo Cruz, Instituto Oswaldo Cruz, Laboratório de Hantaviroses e Rickettsioses
Av. Brasil, 4365
CEP 21040-360, Rio de Janeiro, RJ, Brazil
e-mail: maria.ogrzewalska@ioc.fiocruz.br

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Introduction

Ticks (Acari: Ixodidae) are blood-feeding ectoparasites of wild and domestic terrestrial or semi-aquatic vertebrates. Ticks have a worldwide distribution and are capable of transmitting a broad range of human and animal pathogens. Currently the Brazilian tick fauna is represented by 68 species, 46 in the Ixodidae family and 22 in the Argasidae family (ARAGÃO 1936; DANTAS-TORRES et al., 2009a, 2012; LABRUNA; VENZAL 2009; NAVA et al., 2010a; 2014; BARROS-BATTESTI et al., 2015; KRAWCZAK et al., 2015). In Brazil, several species of ticks representing genera *Ornithodoros, Ixodes, Amblyomma,* and *Haemaphysalis* have been found parasitizing wild birds; however, insight derived from the latest investigations suggest that the Brazilian bird tick fauna is probably much more diverse than presently known. The recent increase in studies on ticks parasitizing birds is related with: (i.) Advent of molecular methods for identification of immature stages, especially larvae by amplifying fragments of mainly of 16S RNA gene (MANGOLD et al., 1998) and/or 12S RNA gene (BEATI; KEIRANS, 2001) and comparing the obtained sequences with those available in GenBank; (ii) Publication of identification key for nymphs of *Amblyomma* – the most commonly found genera on birds in Brazil (MARTINS et al., 2010). Before that, the only solution was to identify larvae and nymph of *Amblyomma* by rearing them on rabbits to adult stages (LABRUNA et al., 2002a; SZABÓ et al., 2007a,b; 2009; OGRZEWALSKA et al., 2009a), although this method was not very efficient, especially for larvae that usually died before reaching the adult stage.

About 60% of the bird species documented for South America are found in Brazil. Currently, 1,901 species (PIACENTINI et al., 2015) are registered, but this number is still increasing almost every year. This is due to new occurrences or new species being described, like a spectacular discovery of 15 new species in 2013 in Brazilian Amazon (DEL HOYO et al., 2013). Although Brazilian ornitofauna is rich and diverse, the involvement of wild birds in the epidemiology of diseases is poorly known. Most research investigating bird diseases focuses on viral zoonosis in direct contact with poultry, viral diseases affecting industrial aviculture or possible transmission of viruses by migratory birds, such as Avian influenza (ARAUJO et al., 2014), Newcastle Disease Virus (CUNHA; SILVA, 1955; OLIVEIRA et al., 2000; ORSI et al., 2010; THOMAZELLI et al., 2012), West Nile virus (OMETTO et al., 2013), Avian Bornavirus (ENCINAS-NAGEL et al., 2014) and little is known about the role of birds as disseminators of potentially infected ectoparasites such ticks or their role as potential reservoirs of pathogens harbored and transmitted by ticks. Outside of Brazil, mainly in Europe and North America, the role of birds as hosts and disseminators of ectoparasites such as ticks have been broadly studied. Birds were shown to be important mobile hosts responsible for the spread of one or more stages of ticks and tick-borne

pathogens such as *Rickettsia, Borrelia, Anaplasma* and *Ehrlichia* (ANDERSON et al., 1896; PARKER et al., 1933; HOOGSTRAAL, 1961; 1963; SOMOV; SOLDATOV, 1964 apud HUBÁLEK 2004; OLSEN et al., 1993; GERN et al., 1998; HUMAIR et al., 1998; ALEKSEEV et al., 2001; BJÖERSDORFF et al., 2001; DANIELS et al., 2002; SANTOS-SILVA et al., 2006; SMITH et al., 2006; OGDEN et al., 2008; HAMER et al., 2011; GELLER et al., 2013; NORTE et al., 2013; LITERAK et al., 2015). Migratory birds in particular have received much attention as they can transport potentially infected ticks across large areas and may account for the origin of some new foci of diseases (ANDERSON et al., 1986; OLSEN et al., 1995a; KLICH et al., 1996; SMITH et al., 1996; RAND et al., 1998; KINSEY et al., 2000; SCOTT et al., 2001, 2010, 2012; JONGEJAN et al., 2004; MORSHED et al., 2005; DUBSKA et al., 2009; ELFVING et al., 2010; HILDEBRANDT et al., 2010; KJELLAND et al., 2010; HASLE et al., 2011; HASLE, 2013; MOVILA et al., 2011; GELLER et al., 2013; CAPLIGINA et al., 2014), even introducing them to different continents (OLSEN et al., 1995b; MUKHERJEE et al., 2014; SCOTT; DURDEN, 2015). Although the role of birds as hosts and disseminators of ticks has received much attention over the past several years, there is a lack of studies in South America, including Brazil. The aim of this review is to present up-to-date knowledge about the bird-tick fauna of Brazil and their association with rickettsioses.

Ticks found parasitizing birds in Brazil

Family Argasidae

***Argas* (*Persicargas*) *miniatus* Koch 1844.** It is the only species representing the genera *Argas* in Brazil, until now only found on domestic fowls (LOUREIRO, 1966; EVANS et al., 2000; ARZUA et al., 2005; LOROSA et al., 2007). No records of human parasitism exist.

***Ornithodoros mimon* Kohls, Clifford and Jones 1969** parasitizes bats (Chiroptera) in Bolivia, Uruguay, Argentina and Brazil (KOHLS et al., 1969; VENZAL et al., 2004a; BARROS-BATTESTI et al., 2006; LABRUNA et al., 2014). Larvae were found parasitizing small mammals from the order Didelphimorphia and Rodentia collected in woodland fragments of Cerrado in the Mato Grosso do Sul, Brazil (SPONCHIADO et al., 2015). Recently, a few larvae were collected from wild Passeriformes birds in Mato Grosso (RAMOS et al., 2015). This species is aggressive to humans; however, its role in tick-borne diseases is still unknown (BARROS-BATTESTI et al., 2011; LANDULFO et al., 2012; LABRUNA et al., 2014).

***Ornithodoros* sp.** The sole larva has been also reported on swift *Streptoprocne zonaris* (Shaw, 1796) (Apodiformes) captured in Minas Gerais State (TOLESANO-PASCOLI et al., 2014).

Family Ixodidae

***Amblyomma aureolatum* (Pallas, 1772).** Distribution of *A. aureolatum* is restricted to the eastern area of South America, from Uruguay to Surinam, including northeastern Argentina, eastern Paraguay, southeastern to southern Brazil, and French Guiana (GUGLIELMONE et al., 2003). This tick species is typical of the Atlantic rainforest region, where it finds optimal conditions of high humidity and cool temperatures (PINTER et al., 2004; SZABÓ et al., 2009). Adults of *A. aureolatum* in natural conditions feed mainly on wild carnivore species, such as foxes *Cerdocyon thous* (Linnaeus, 1766) and *Lycalopex* spp. and raccoons *Procyon cancrivorus* (Cuvier, 1798) (GUGLIELMONE et al., 2003, LABRUNA et al., 2005b), but in the rural areas close to rainforest remnants, adult ticks feed mainly on domestic dogs (PINTER et al., 2004; MORAES-FILHO et al., 2009; OGRZEWALSKA et al., 2012a). Only a few host records have been reported for the immature stages (larvae and nymphs) of *A. aureolatum,*

including wild birds in southern Brazil (ARZUA et al., 2003; GUGLIELMONE et al., 2003; OGRZEWALSKA et al., 2012a; PACHECO et al., 2012), Uruguay (VENZAL et al., 2005), Paraguay (OGRZEWALSKA et al., 2014), and a few rodent species from families Echimyidae, Ctenomyidae, and Bradypodidae (GUGLIEMONE et al., 2003; 2014). This species is involved in the epidemiology of Brazilian spotted fever in Brazil transmitting to humans *Rickettsia rickettsii*. Moreover, Brazilian spotted fever has been found to be infected by *Rickettsia bellii,* (PINTER; LABRUNA, 2006; MORAES-FILHO et al., 2009; OGRZEWALSKA et al., 2012a).

***Amblyomma auricularium* (Conil, 1878).** This species has been found from northern Patagonia in Argentina throughout the Neotropics into the Nearctic region to southern USA (Texas, Florida), with records also from Belize, Bolivia, Brazil, Colombia, Costa Rica, French Guiana, Honduras, Mexico, Nicaragua, Panama, Paraguay, Trinidad and Tobago, Uruguay and Venezuela (GUGLIELMONE et al., 2014). Within its distribution area, all parasitic stages of *A. auricularium* are found feeding mainly on armadillos (Dasypodidae), although immature stages are also found feeding on small rodents (GUGLIELMONE et al., 2003; HORTA et al., 2011). However, Lugarini et al. (2015) recently found various immature stages (17 nymphs, 14 larvae) parasitizing birds sampled at a coastal Atlantic forest in Paraíba State and the xeric shrubland at Caatinga biome in Bahia State, Brazil. Although *A. auricularium* is not known to be a vector of pathogens causing diseases in humans or animals and no report of human infestation by these tick exists, it is important to point out that this species was recently found to be infected with '*Candidatus* Rickettsia amblyommii' and *R. bellii* (SARAIVA et al., 2013; LUGARINI et al., 2015).

***Amblyomma brasiliense* Aragão 1908** occurs in Brazil, Argentina and Paraguay (GUGLIELMONE et al., 2014). Under natural conditions, peccaries (*Tayassu* spp.) are considered the primary hosts for *A. brasiliense* ticks (ARAGÃO, 1936). However, this tick is also aggressive to humans (GUGLIELMONE et al., 2006). Although scarce records on parasitism of ground-dwelling birds (BARROS-BATTESTI et al., 2006) exist in literature, birds are rather accidental hosts and seem not to play an important role in the life cycle of this species.

***Amblyomma cajennense* complex.** Currently, *A. cajennense* is a complex of six species, *A. cajennense* sensu stricto (s.s) Fabricius, 1787, *Amblyomma tonelliae* Nava, Beati and Labruna (2014), *Amblyomma interandinum* Beati, Nava and Cáceres (2014), *Amblyomma patinoi* Labruna, Nava and Beati (2014), *Amblyomma mixtum* Koch, 1844 and *Amblyomma sculptum* Berlese, 1888 (BEATI et al., 2013; NAVA et al., 2014). In Brazil, two species are found: *A. sculptum* in coastal and central-western states of Brazil and *A. cajennense* s.s in the Amazonian region of South America. Adults are found on variety of animals; however, capybaras (*Hydrochoerus hydrochaeris* (Linnaeus, 1766), tapirs (*Tapirus terrestris* (Linnaeus, 1758)), peccaries (*Tayassu* spp.) and horses (*Equus caballus* Linnaeus, 1758) serve as main primary hosts for these ticks. Records of *A. cajennense* parasitizing birds in Brazil exist in literature; however, taking into account the recent *A. cajennense* complex division, almost all available records probably refer to *A. sculptum* (LABRUNA et al., 2007a; TEIXEIRA et al., 2008; OGRZEWALSKA et al., 2009a; 2011a; SANTOLIN et al., 2012; SILVEIRA et al., 2015; TOLESCANO-PASCOAL et al., 2014; RAMOS et al., 2015). Still, birds are considered accidental hosts, as even in areas where this tick is extremely abundant, birds are rarely found parasitized by this species (OGRZEWALSKA et al., 2011b). In Brazil, *A. sculptum* is a very aggressive tick to humans and the main vector of *R. rickettsii* to humans causing

the lethal disease known as Brazilian spotted fever (SZABÓ et al., 2013a; KRAWCZAK et al., 2014).

***Amblyomma calcaratum* Neumann, 1899** has been reported from Mexico to Argentina, where the adult stage is found feeding almost exclusively on anteaters (Myrmecophagidae) (JONES et al., 1972; CÀCERES et al., 2002; GUGLIELMONE et al., 2014; WITTER et al., 2016), but has also been found sporadically on other mammals: raccoon *P. cancrivorus*, sloths *Choloepus hoffmanni* Peters, 1858 and deer *Mazama americana* Erxleben, 1777. Although immature stages have been found on tapirs and anteaters (GUGLIELMONE et al., 2014), it seems that wild birds play important role in the life cycle of this species. In Brazil, *A. calcaratum*, mainly nymphs, have been found parasitizing birds in the region of the Atlantic Forest in the state of Paraná (PACHECO et al., 2012), São Paulo (LABRUNA et al., 2007a; OGRZEWALSKA et al., 2009a; 2011a; SANCHES et al., 2013), Bahia (OGRZEWALSKA et al., 2011a), a region of the Amazon Forest in the state of Pará (OGRZEWALSKA et al., 2010) and Amazonas (MARTINS et al., 2014b), the region of Pantanal in the state of Mato Grosso (RAMOS et al., 2015) and Cerrado in the state of Mato Grosso (RAMOS et al., 2015) and Mato Grosso do Sul (OGRZEWALSKA et al., 2013). Moreover, this species was found parasitizing wild birds in Peru (OGRZEWALSKA et al., 2012b), Paraguay (OGRZEWALSKA et al., 2014) and Costa Rica (OGRZEWALSKA et al., 2015). *Amblyomma calcaratum* is a species of potential medical importance because a spotted fever group bacterium, identified as *Rickettsia parkeri*-like agent, was recently reported infecting nymphs collected from birds in Brazil (OGRZEWALSKA et al., 2013). According to literature, this species has been found infesting humans (GUGLIELMONE et al., 2014).

***Amblyomma coelebs* Neumann, 1899** is established in the Neotropical and Nearctic regions (GUGLIELMONE et al., 2014). Adults almost exclusively parasitize tapirs (*Tapirus* sp.) (LABRUNA et al., 2010), but they are also periodically collected on other wild and domestic even-toed ungulates Artiodactyla (LABRUNA et al., 2005a). These ticks are frequently collected on vegetation and attached to humans (GUGLIELMONE et al., 2006). Few records of parasitism of immature stages exist; however, immature stages seem to have a broad range of hosts and have been found in Rodentia (MARTINS et al., 2011; MARTINS et al., 2014a; SPONCHIADO et al., 2015; WITTER et al., 2016), Didelphimorphia (LABRUNA et al., 2005a; SARAIVA et al., 2012; SPONCHIADO et al., 2015; WITTER et al., 2016), Cingulata (MARTINS et al., 2014a), Artiodactyla (LABRUNA et al., 2005a, 2010), Carnivora (LABRUNA et al., 2002a; 2005b; MARTINS et al., 2011; WITTER et al., 2016) and on humans (LABRUNA et al., 2005a; GARCIA et al., 2015). Although few records of immature *A. coelebs* exist in Brazil (OGRZEWALSKA et al., 2009a, 2010) and in Costa Rica (OGRZEWALSKA et al., 2015), birds are rather accidental host for this species. Ticks *A. coelebs* were shown to be infected with '*Ca.* Rickettsia amblyommii' in Brazil (LABRUNA et al., 2004a; SILVEIRA et al., 2015; WITTER et al., 2016) and French Guyana (PAROLA et al., 2007).

***Amblyomma dissimile* Koch, 1844** occurs in the Nearctic, Neotropical zoogeographic regions. Usual hosts of larvae, nymphs and adult ticks are amphibians (Anura, Bufonidae) and reptiles (Squamata: Boidae and Iguanidae). Infestations by *A. dissimile* on mammalian hosts, including humans, have occasionally been reported (GUGLIELMONE et al., 2014). Birds are considered exceptional hosts for this tick. In Brazil, only one record exists of *A. dissimile* nymph infesting a macaw, *Primolius maracana* Vieillot, 1816 held in captivity (SCOFIELD et al., 2011). In Colombia, *A. dissimile* ticks have been

found infected with *Rickettsia* sp. strain colombianensi (MIRANDA et al., 2012).

Amblyomma geayi **Neumann, 1899** is a Neotropical species. Principal hosts for adults are the sloths *Bradypus tridactylus* Linnaeus, 1758 and *C. hoffmanni* (Xenarthra, Pilosa, Folivora) but a few collections were taken from the porcupine *Coendou prehensilis* Linnaeus, 1758 (Rodentia, Erethizontidae). Human infestation is unknown (GUGLIELMONE et al., 2014). A few nymphs were collected on sloths *Bradypus variegatus* Schinz, 1825 (MARTINS et al., 2013) and on opossum (Didelphidae) (GUGLIELMONE et al., 2014). Although only a few records of parasitism of immature stages on wild birds exist, it was suggested that passeriform birds may play an important role in the life cycle of tick species in the Amazon forest region (OGRZEWALSKA et al., 2010; MARTINS et al., 2014b). Ticks collected form wild birds in the state of Pará have been found infected with '*Ca.* Rickettsia amblyommii' (OGRZEWALSKA et al., 2010).

Amblyomma humerale **Koch, 1844** is a Neotropical species. Usual hosts for adult ticks are tortoises *Chelonoidis* (Testudinidae) and mammals are considered exceptional hosts (LABRUNA et al., 2002b, 2005a; MARTINS et al., 2014a). Human infestation is unknown (GUGLIELMONE et al., 2014). Few records for immature stages exist. Nymphs were collected in lizards *Plica* Linnaeus, 1758, *Plica umbra* Linnaeus, 1758, *Kentropyx calcarata* Spix, 1825, anteater *Cyclopes didactylus* Linnaeus, 1758 and *D. marsupialis* (LABRUNA et al., 2002b, 2005a; WITTER et al., 2016) and armadillo (Cingulata) (MARTINS et al., 2014a; WITTER et al., 2016) and caiman *Paleosuchus trigonatus* (Schneider, 1801), coati *Nasua nasua* (Linnaeus, 1766) and anteater *Tamandua tetradactyla* (Linnaeus, 1758) (WITTER et al., 2016). It was recently suggested that wild birds may play an important role in the life cycle serving as hosts for larvae and nymphs of this species in the Amazon forest region, State of Pará (OGRZEWALSKA et al., 2010; MARTINS et al., 2014b). Adult *A. humerale* were shown to be infected with *R. bellii* in Brazil (LABRUNA et al., 2004a).

Amblyomma longirostre **Koch, 1844** is widely distributed throughout the Neotropical region (JONES et al., 1972; GUGLIELMONE et al., 2014; reviewed by NAVA et al., 2010b; NOVAKOVA et al., 2015). Known human infestation is scarce (ARZUA et al., 2005; GUGLIELMONE et al., 2006). The adult stage feeds primarily on rodents *Coendou*, *Chaetomys* and *Sphiggurus* (Erethizontidae) (JONES et al., 1972; LABRUNA et al., 2002a; 2004c; BARROS-BATTESTI et al., 2006; SILVEIRA et al., 2008; reviewed by NAVA et al., 2010b). Birds are the main host for immature stages and in Brazil it is the most prevalent species found on birds (ARAGÃO, 1936; LABRUNA et al., 2007a; SOARES et al., 2009; OGRZEWALSKA et al., 2008, 2009a, 2010, 2011a, 2012a; TOLESANO-PASCOLI et al., 2010; NAVA et al., 2010b; LUZ et al., 2012; LUGARINI et al., 2015; RAMOS et al., 2015; GRESSLER et al., 2016; WITTER et al., 2016). All stages (adults, nymphs and larvae) have been found infected with '*Ca. R. amblyommii*' or bacteria closely related to it (LABRUNA et al., 2004a; OGRZEWALSKA et al., 2008, 2010, 2011a, 2012a, 2015; MEDEIROS et al., 2011; PACHECO et al., 2012; LUGARINI et al., 2015; RAMOS et al., 2015; NOVAKOVA et al., 2015; Table1). Relevant association between species of birds are presented elsewhere (LUZ; FACCINI, 2013).

Table 1 – *Rickettsia* species found in immature *Amblyomma* ticks collected on Brazilian wild birds

***Rickettsia* species**	**Tick species**	**State**	**Bioma**	**Reference**
Rickettsia bellii	*Amblyomma auricularium*	BA	Caatinga	Lugarini et al., 2015
	Amblyomma nodosum	SP	Atlantic forest	Ogrzewalska et al., 2009b
'*Candidatus* Rickettsia andenae'	*Amblyomma parvum*	BA	Caatinga	Lugarini et al., 2015
'*Candidatus* Rickettsia amblyommii' or closely related strains	*Amblyomma auricularium*	BA	Caatinga	Lugarini et al., 2015
	Amblyomma geayi	PA	Amazon	Ogrzewalska et al., 2010
	Amblyomma longirostre	BA	Atlantic Forest	Ogrzewalska et al., 2011a
		MT	Pantanal and Cerrado	Ramos et al., 2015
		PB	Atlantic Forest	Lugarini et al., 2015
		PA	Amazonia	Ogrzewalska et al., 2010
		PR	Atlantic Forest	Pacheco et al., 2012
		SP	Atlantic Forest	Ogrzewalska et al., 2008, 2012a
	Amblyomma nodosum	SP	Atlantic Forest	this paper
	Amblyomma varium	SP	Atlantic Forest	this paper
Rickettsia parkeri-like strains	*Amblyomma calcaratum*	MS	Cerrado	Ogrzewalska et al., 2013
	Amblyomma longirostre	PR	Atlantic forest	Pacheco et al., 2012
	Amblyomma nodosum	MT	Cerrado	Ramos et al., 2015
		PB	Atlantic forest	Lugarini et al., 2015
		SP	Atlantic forest	Ogrzewalska et al., 2009b
	Amblyomma parkeri	PR	Atlantic forest	Pacheco et al., 2012
		SP	Atlantic forest	Ogrzewalska et al., 2012a
	Amblyomma sp. haplotype Nazare	SP	Atlantic forest	Ogrzewalska et al., 2012a

***Amblyomma naponense* (Packard, 1869)** is a Neotropical tick species. Usual hosts of adult ticks are peccaries (Tayassuidae). It is known to parasitize humans (GUGLIELMONE et al., 2006). Little is known about hosts for immature stages. Nymphs were found in Brazil on *C. thous* and *T. tajacu* captured in Emas National Park, Goiás State, Brazil (MARINS et al., 2011). Regarding birds, only three sporadic records exist of parasitism of nymphs in the southeastern part of Brazil (OGRZEWALSKA et al., 2009a).

***Amblyomma nodosum* Neumann, 1899** is a Neotropical tick species widely distributed throughout South and Central America. No known human infestation records exist (GUGLIELMONE et al., 2014). The adults of this species are commonly found in the anteaters (Xenarthra, Pilosa) (ARAGÃO, 1936; JONES et al., 1972; BECHARA et al., 2002; LABRUNA et al., 2002a; DANTAS-TORRES et al., 2010; MARTINS et al., 2014a). Subadults, especially nymphs, seem to feed primarily on birds (JONES et al., 1972; LABRUNA et al., 2007a; OGRZEWALSKA et al., 2009a, 2011a, 2012a; TOLESANO-PASCOLI et al., 2010; LUZ et al., 2012; MARTINS et al., 2013; PASCOAL et al., 2013; TORGA et al., 2013; LUGARINI et al., 2015; NOVAKOVA et al., 2015; RAMOS et al., 2015; WITTER et al., 2016). Ogrzewalska et al. (2011b) found higher prevalence of *A. nodosum* on wild birds in smaller and degraded forest fragments of Atlantic Forest in the interior of the São Paulo State than in preserved, more humid fragments. In Brazil, immature stages collected on wild birds have been found infected with *Rickettsia parkeri*-like agent (OGRZEWALSKA et al., 2009b; LUGARINI et al., 2015; RAMOS et al., 2015), *R. bellii* (OGRZEWALSKA et al., 2009b). Two nymphs of *A. nodosum* collected from *Thamnophilus doliatus* (Linnaeus, 1764) and *Herpsilochmus longirostris*

Pelzeln, 1868 (Passeriformes, Thamnophilidae) in Dracena, SP, were infected with '*Ca*. Rickettsia amblyommii', identical with strain AL (verbal information) (Table 1). Adults were recently found infected with undefined *Rickettsia* sp (ALMEIDA et al., 2012) and also with *Rickettsia parkeri*-like agent (WITTER et al., 2016).

***Amblyomma ovale* Koch, 1844** occurs in Nearctic and Neotropical zoogeographic regions. Adults mainly parasitize carnivores (LABRUNA et al., 2005b; WITTER et al., 2016), and domestic dogs (SABATINI et al., 2010; SZABÓ et al., 2013b). The tick is aggressive to humans (GUGLIELMONE et al., 2006; SZABÓ et al., 2006, 2013b). The main hosts for immature stages are rodents, especially Echimyidae (SARAIVA et al., 2012; SZABÓ et al., 2013b). The role of birds as host for this species is unclear. Some records do exist in Brazil (OGRZEWALSKA et al., 2009a; LUZ et al., 2012; PACHECO et al., 2012; RAMOS et al., 2015), Paraguay (OGRZEWALSKA et al., 2013), Argentina (FLORES et al., 2014), Panama (MURGAS et al., 2013), Costa Rica (OGRZEWALSKA et al., 2015); however, in areas of coastal rainforest of the São Paulo state, where *A. ovale* commonly parasitizes domestics dogs, wild birds seem not to be important for immature stages (OGRZEWALSKA, not published). Adults of *A. ovale* are the main vectors of *Rickettsia parkeri*-like strain responsible for a milder febrile human disease (SABATINI et al., 2010; SZABÓ et al., 2013a, b).

***Amblyomma pacae* Aragão, 1911** is a Neotropical tick whose usual hosts for adult and nymphs are Rodentia (Cuniculidae) (LABRUNA et al., 2005c; GUGLIELMONE et al., 2014). Records of human parasitism occur (GUGLIELMONE et al., 2014). Only one record exists of parasitism of birds *Cariama cristata* (Linnaeus, 1766) by larvae and nymphs; however, birds were maintained in captivity (TEIXEIRA et al., 2008).

***Amblyomma parkeri* Fonseca and Aragão, 1952** is a rare species, currently considered endemic to southeastern and southern Brazil. *Amblyomma parkeri* and *A. longirostre* are morphologically and ecologically closely related species. Their adult stages are commonly associated with porcupines from the family Erethizontidae (Rodentia) (LABRUNA et al., 2009; MARTINS et al., 2013). Immature stages were found on monkey *Alouatta guariba* Humboldt, 1812 (MARTINS et al., 2010, 2013), on *D. albiventris* (SPONCHIADO et al., 2015), *Didelphis marsupialis* Linnaeus, 1758 (WITTER et al., 2016), on porcupines (Erethizontidae) (GUGLIELMONE et al., 2014) and on birds in the Atlantic Forest region (OGRZEWALSKA et al., 2008, 2011a, 2012a; PACHECO et al., 2012). Additionally, Pacheco et al. (2012) found two and Ogrzewalska et al. (2012a) seven larvae of *A. parkeri* collected from wild birds infected with *Rickettsia* sp. ApPR, genotype of *R. parkeri* (Table 1). One record of parasitism of nymph on humans exists (MARTINS et al., 2013).

***Amblyomma parvum* Aragão, 1908** is a Neotropical species. There are records of *A. parvum* in the Amazon, Cerrado and Pantanal biomes in Brazil (MULLINS et al., 2004; SZABÓ et al., 2007a; CANÇADO et al., 2008; SARAIVA et al., 2012). Adult stages are frequently associated with a wide variety of wild and domestic mammals (LABRUNA et al., 2005b; NAVA et al., 2006, 2008b; SZABÓ et al., 2007a; MARTINS et al., 2011). Records exist of human parasitism (GUGLIELMONE et al., 2006). Despite the fact that immature stages seem to prefer small mammals (NAVA et al., 2006; HORTA et al., 2011; SARAIVA et al., 2012), birds also seem to take part in the life cycle for this tick in dry areas of the Cerrado and Caatinga biomes (LUZ et al., 2012; LUGARINI et al., 2015) and Chaco biome in Argentina (NAVA et al., 2006, 2008b). Parasitism of captive bird *Rhea americana* (Linnaeus, 1758) by adults was also reported (TEIXEIRA et al., 2008). Lugarini et al. (2015) found '*Canditatus* Rickettsia andenae' in *A. parvum* collected from birds in Caatinga, northeastern Brazil.

***Amblyomma triste* Koch, 1844** is distributed from south of United States to Argentina. It is a

member of the '*Amblyomma maculatum* group' which also include *Amblyomma maculatum* Koch, 1844 and *Amblyomma tigrinum* Koch, 1844 (GUGLIELMONE et al., 2014). Ecological studies of *A. triste* in Brazil and Uruguay indicated that this tick species is strongly associated with wetlands and environments prone to flooding and the deer *Blastocerus dichotomus* Illiger, 1815 has been pointed out as one of the main hosts for the adults of *A. triste.* However, other mammals such as domestic and wild carnivores, cattle, goat, horse were also recorded as hosts for *A. triste* adults (LABRUNA et al., 2003; SZABÓ et al., 2003, 2007b; VENZAL et al., 2008; MARTINS et al., 2011; NAVA et al., 2011). Larvae and nymphs of *A. triste* are common parasites of small rodents (LABRUNA et al., 2003; VENZAL et al., 2008; NAVA et al., 2011) and birds in Argentina (NAVA et al., 2011; FLORES et al., 2014) and in United States (MERTINS et al., 2010). In Brazil, there are only two records of parasitism of wild birds from flooded lowland grassland in the São Paulo State (SILVEIRA et al., 2015) and Mato Grosso State (RAMOS et al., 2015). This tick is of public health relevance as its species is frequently found biting humans (GUGLIELMONE et al., 2006) and involved in epidemiology of spotted fever caused by *R. parkeri* in Uruguay (VENZAL et al., 2004b; PACHECO et al., 2006; VENZAL et al., 2012), Argentina (NAVA et al., 2008a) and possibly in Brazil (SILVEIRA et al., 2007; MELO et al., 2015).

***Amblyomma varium* Koch, 1844**. This tick is widely distributed from southern Central America to Argentina (GUGLIELMONE et al., 2014). It is known in Brazil as the "sloth's giant" because during the adult stage, the tick presents a high host specificity and is found almost exclusively on the sloths from the families Bradypodidae and Megalonychidae (MARQUES et al., 2002; GUGLIELMONE et al., 2014). The hosts of immature stages are only limited to rare records on wild birds in Brazil (LUGARINI et al., 2015), Peru (OGRZEWALSKA et al., 2012b), and Costa Rica (OGRZEWALSKA et al., 2015). Two nymphs of *A. varium* collected from *Elaenia flavogaster* Thunberg, 1822 and from *Thamnophilus* sp. (Passeriformes, Thamnophilidae), Prado, Bahia, were infected with '*Ca. Rickettsia amblyommii*', identical with strain AL (data not published, Table 1). Lugarini et al. (2015) reported larvae of *A. varium* collected from the clothes and skin of the field team in costal Atlantic forest in Paraíba State, Brazil infected '*Ca. Rickettsia amblyommii*'-like agent. In Peru, two larvae collected from dove *Leptotila rufaxilla* Richard and Bernard, 1792 were found infected with *R. bellii* (OGRZEWALSKA et al., 2012b).

***Amblyomma* sp. haplotype Nazare**. Twelve *Amblyomma* sp. larvae were collected from forest Passeriformes birds, in the region of Nazaré Paulista, São Paulo State, Brazil and their DNA sequence of a fragment of the mitochondrial 16S rDNA was most similar (90%) to *A. parkeri* and (88%) to *A. longirostre*. Three larvae have been found infected with *R. parkeri*-like agent (OGRZEWALSKA et al., 2012a).

Haemaphysalis

***Haemaphysalis juxtakochi* Cooley, 1946.** This tick occurs in several different Nearctic and Neotropical ecoregions. Usual hosts for adult ticks are Artiodactyla: Cervidae but it is also found on other large mammals (GUGLIELMONE et al., 2014). Few records exist of bird parasitism in Brazil (ARZUA et al., 2005; OGRZEWALSKA et al., 2010), Uruguay (VENZAL et al., 2005), and in Argentina (BELDOMENICO et al., 2003; FLORES et al., 2014). *Rickettsia rhipicephali* was isolated from adult ticks in Rondônia (LABRUNA et al., 2005c), São Paulo (LABRUNA et al., 2007b) and *R. bellii* from São Paulo State (LABRUNA et al., 2007b).

***Haemaphysalis leporispalustris* Packard, 1869** has wide distribution across the American continent, from Alaska to Argentina (GUGLIELMONE et al., 2014). Usual hosts for larvae, nymphs and adult ticks are wild rabbits (Lagomorpha: Leporidae), and birds

appear to be alternative hosts for the immature stages in some areas (STAFFORD et al., 1995; BELDOMENICO et al., 2003; FLORES et al., 2014). A few records in Brazil on parasitism on birds are from the São Paulo, Paraná, Rio de Janeiro and Minas Gerais states (ARZUA et al., 2005; OGRZEWALSKA et al., 2012a; ZERINGÓTA et al., 2016). Although *H. leporispalustris* is not a classical human-biting tick, previous studies suggested that this tick is important in the enzootic maintenance of *R. rickettsii* in nature (HUN et al., 2008).

Ixodes

***Ixodes auritulus* Neumann, 1904** is a bird tick found in the Australian, Ethiopian, Nearctic and Neotropical zoogeographic regions with records in Ecuador, Chile, Peru, Costa Rica, Argentina, Colombia, Guatemala, Uruguay and Brazil (GUGLIELMONE et al., 2014). It was suggested that *I. auritulus* is a catchall name for a tick species group (GONZÁLEZ-ACUNA et al., 2005). In Brazil, the only records are from the states of Paraná, São Paulo and Rio de Janeiro (ARZUA; BARROS-BATTESTI, 1999; ARZUA et al., 1994, 2003, 2005; GONZÁLEZ-ACUNA et al., 2005). Males of *I. auritulus* are not commonly found on hosts. No *Rickettsia* was found. Although *I. auritulus* does not bite humans, this tick species helps to maintain *Borrelia burgdorferi* in the enzootic transmission cycles in Canada (MORSHED et al., 2005; SCOTT et al., 2015).

***Ixodes paranaensis* Barros-Battesti, Arzua, Pichorim and Keirans, 2003.** This species was found for the first time in a colony of swifts *Streptoprocne biscutata* Sclater, 1866 (Apodiformes, Apodidae), in caves in Paraná State, southern Brazil (BARROS-BATTESTI et al., 2003), and only two other records exist, both from the State of Minas Gerais, southeastern Brazil; the first one in a cave and breeding site for *S. biscutata* (DANTAS-TORRES et al., 2009b) and on swifts *S. zonaris* and *Cypseloides senex* Temminck, 1826 caught at waterfalls in Minas Gerais State (TOLESANO-PASCOLI et al., 2014). This tick species is probably nidicolous, meaning with its entire life cycle occurs in the nest with the bird as host (BARROS-BATTESTI et al., 2003). No records of pathogen infection exist.

***Ixodes* sp.** One, not identified nymph found on *Trichothraupis melanops* Vieillot, 1818 (Passeriformes, Thraupidae) in the São Paulo State (OGRZEWALSKA et al., 2012a).

Rhipicephalus

***Rhipicephalus sanguineus* Latreille, 1806.** In the Neotropical region, *R. sanguineus* has as its primary host dogs from urban or rural environments, but also wild carnivores associated with domestic dogs (LABRUNA et al., 2005a, b). However, recent studies based on phylogenetic analysis and laboratory crosses show the presence of at least two species under the taxon *R. sanguineus* in the New World (MORAES-FILHO et al., 2011). Sporadic records of parasitism of birds exist, but are unexpected and are rather related with habits of synanthropic birds sharing the environment with domestic dogs (DIOGO et al., 2003; SZABÓ et al., 2008; LUZ et al., 2012; LUGARINI et al., 2015). Worldwide ticks from *R. sanguineus* complex have been linked to tick-borne diseases such as spotted and boutonneuse fever and ehrlichiosis in humans, and canine babesiosis and ehrlichiosis (reviewed by GRAY et al., 2013); however, further work is required to clearly define the taxonomic status of *R. sanguineus* (NAVA et al., 2015).

Birds as part of the rickettsial life cycle

Rickettsia

Rickettsiae are rod-shaped, small (0.3 to 0.5 μm by 0.8 to 2.0μm), gram-negative, non-sporeforming bacteria. They are obligate intracellular bacteria, which means they can only reproduce within animal cells (RAOULT; ROUX, 1997). The members of the Rickettsiaceae family are maintained in nature through complex cycles involving reservoir in

mammals and arthropod vectors such as ticks, mites and lice (RAOULT; ROUX, 1997). Except for *R. prowazekii*, humans are only accidental hosts for rickettsiae and usually get infected through bites or feces of infected arthropods. Some of these diseases are benign for humans, while others may be fatal. Currently, 26 species with validated and published names within the genus *Rickettsia* exist. However, some species are divided into subspecies and more than 70 strains remain unidentified or incompletely described pathogens. Moreover, new species, or stains are discovered each year (reviewed by PAROLA et al., 2013). Until 2003, *R. rickettsii* was the only rickettsia that was reported infecting ticks in Brazil. During the last 12 years, there has been an increasing number of tick-associated rickettsiae in this country, with reports of various strains of *R. parkeri, R. rhipicephali, R. monteiroi, R. massiliae, R. bellii, 'Ca. R. amblyommii'* and *'Ca. Rickettsia andeanae'* infecting South American ticks (Reviewed by LABRUNA, 2009; NIERI-BASTOS et al., 2014).

It is noteworthy how birds play an import role as host to ticks. On the other hand, many questions still remain unsolved as to the role of avian hosts as reservoirs or amplifiers of *Rickettsia*. Randolph (1998) describes the important differences between ticks and insects with respect to competence of being a reservoir and vector of pathogens. In fact, when compared to haematophagus insects, hard ticks show a longer lifespan and fewer blood meals. In order to be successfully transmitted by ticks, a pathogen organism must use two main strategies: First, use a vertebrate animal as a reservoir in order to be accessed by ticks and, second, successfully use the tick female transovarian route combined with using vertebrate hosts as amplifiers in order to spread horizontally on tick population. Cooksey et al. (1990) describes that the *R. rickettsii* life cycle relies on the second strategy; therefore, at least one rickettsial amplifier host must be identified among the most sui tick hosts on determined localization, otherwise the bacteria would disappear from a ticks´ population. Moreover, Labruna (2009) postulates that the *R. rickettsii* amplifier hosts must fulfill five requirements: 1) It has to be abundant; 2) It has to be a major host for the tick vector; 3) It has to be sui to *R. rickettsia* infection; 4) Once infected, it must develop a rickettsemia period and be a source of infection to ticks; 5) It has to be a prolific species. In fact, birds suit at least three of the five requirements. Birds are abundant, prolific and major hosts for several tick species. Nevertheless, very few studies discuss the capacity of birds to be infected and to be a course of tick infection. Several studies were conducted in the United States in the mid-twentieth century to discover *Rickettsia* animal reservoirs, before the concept of amplifier was established. Vest et al. (1965) were not able to find rickettsial agents in tissue samples of 326 wild birds tested in Unites States. Although the spotted fever group antibodies were detected in sera of two birds, the authors suggest that these antibody titers are rather due to nonspecific factors in the sera, rather than indicative of rickettsial infection. Experimentally, Lundgren et al. (1966) inoculated *R. rickettsii* in different species of birds (chickens, pigeons, pheasants, sparrow hawks, red-tailed hawks, ravens, magpies, and a marsh hawk); only pigeons showed antibody titers, but all them presented rickettsemia that was weak and transient in some species. However, the capacity of the birds being an infection source was not accessed.

More recently, Moraru et al. (2013) tested laboratory infected cotton rats and quail as amplifier hosts for *R. parkeri*. While viable *R. parkeri* was re-isolated from blood, skin and spleen tissues of the cotton rats, none was found on quails. This experiment shows that in the same conditions of infection, *R. parkeri* was able to amplify in cotton-rats but not in quail. Maciel et al. (2013) tested 300 chickens that were maintained freely on an endemic area for rickettsial infected ticks, and only 1.33% of the animals yielded seropositive outcome.

Only a few studies so far identified a rickettsial agent in wild sampled birds. et al. (2010) recorded

Rickettsia infection in blood samples of wild Passeriformes birds *Periparus ater* (Linnaeus, 1758), *Parus major* Linnaeus, 1758, *Cyanistes caeruleus* (Linnaeus, 1758) and *Chloris chloris* (Linnaeus, 1758) that sampled from Slovakia, Austria and the Czech Republic. Ioannou et al. (2009) sampled 557 migratory birds in Cyprus and after processing the samples in 131 pools, found 3% positive in PCR for genus *Rickettsia*. Elfving et al. (2010) conducted a field study collecting birds in migratory route in Northern Europe, and found that the occurrence of infected ticks does not support the thesis that birds play a role as reservoir or amplifier host for rickettsial agents. Hornok et al. (2014) sampled 128 migratory birds in central Europe and found 4.7% of them PCR positive for *Rickettsia helvetica*. This finding points out that birds can be infected by *R. helvetica* and furthermore, infection does not prevent birds from migrating as much as non-infected birds. In the United States, Mukherjee et al. (2014) found birds naturally infected with rickettsial agents, but no correlation with the pathogens found on the ticks feeding on the same birds, supporting the thesis that the birds may not be a source of tick infection. In another study, Erwin et al. (2016) found *Rickettsia felis* in one among 55 *Caracara cheriway* (Jacquin, 1784) in Florida, USA, and concluded that the low prevalence of infections suggests the populations of *C. cheriway* likely do not function as an ecological reservoir. Berthová et al. (2016) found *Rickettsia* spp. in 8.9 % and *Rickettsia helvetica* in 4.2 % of 336 Passeriformes bird blood samples in Slovakia and suggested that further studies are necessary to define the role of birds in the circulation of rickettsiae in natural foci. In Brazil, there are unpublished results about possible infection of birds with *Rickettsia*; however, some studies show that ticks collected from wild birds are infected with some rickettsial agents.

Rickettsia species found in ticks parasitizing birds in Brazil

Rickettsia bellii is considered the most common *Rickettsia* in various tick species from the New World (reviewed by LABRUNA, 2009; BARBIERI et al., 2012). In Brazil, *R. bellii* has been isolated by Pinter and Labruna (2006) from *A. aureolatum* tick collected from a domestic dog in the São Paulo State. Later, this bacterium has been found infecting *A. aureolatum* ticks in other areas (SABATINI et al., 2010; OGRZEWALSKA et al., 2012a), *A. cajennense* (DE BARROS-LOPES et al., 2014), *A. dubitatum* (LABRUNA et al., 2004b; HORTA et al., 2007; PACHECO et al., 2009; BRITES-NETO et al., 2013; MOURA-MARTINIANO et al., 2015), *Amblyomma incisum* Neumann, 1906 (PACHECO et al., 2008; SABATINI et al., 2010), *A. ovale* (LABRUNA et al., 2004a; PACHECO et al., 2008; SABATINI et al., 2010; SZABÓ et al., 2013b), *A. longirostre* (MCINTOSH et al., 2015), *Amblyomma scalpturatum* Neumann, 1906, *Amblyomma oblongoguttatum* Koch, 1844, *Amblyomma rotundatum* Koch, 1844, and *A. humerale* (LABRUNA et al., 2004a), *H. juxtakochi* (LABRUNA et al., 2007b), *Ixodes loricatus* Neumann, 1899 (HORTA et al., 2006, 2007; OGRZEWALSKA et al., 2012a). Finally, *R. bellii* has been also found in immature ticks collected from wild birds: *A. auricularium* and *A. nodosum* (Table 1). Currently, *R. bellii* is considered non-pathogenic to humans (LABRUNA, 2009) and other animals (HORTA et al., 2007; PINTER et al., 2008).

'*Candidatus Rickettsia andenae*' is a spotted fever group agent infecting found infecting adults of *A. parvum* in Argentina (PACHECO et al., 2007), Brazil (NIERI-BASTOS et al., 2014), *A. maculatum* in Unites States (PADDOCK et al., 2010; FORNADEL et al., 2011; JIANG et al., 2012; FERRARI et al., 2013; NADOLNY et al., 2014) and Peru (BLAIR et al., 2004; JIANG et al., 2005; FLORES-MENDOZA et al., 2013), *Amblyomma pseudoconcolor* Aragão, 1908 in Argentina (TOMASSONE et al., 2010a), *A. triste* in Chile (ABARCA et al., 2012), *A. sculptum* in Brazil

(WITTER et al., 2016), *R. sanguineus* (FLORES-MENDOZA et al., 2013), and *Ixodes boliviensis* Neumann, 1904 (JIANG et al., 2005) in Peru. Nymphs of *A. parvum* collected from wild birds of were found infected with this *Rickettsia* in Paraguay (OGRZEWALSKA et al., 2014), and in Brazil (LUGARINI et al., 2015) (Table 1). The role of "*Ca. Rickettsia andeanae*" as a human pathogen is unknown.

'Candidatus Rickettsia amblyommii' is an incompletely characterized alphaproteobacterium in the spotted fever group (SFG) of organisms. This bacterium seems to have a wide distribution and has been found infecting various species of ticks across various countries in the Americas: Unites States (STROMDAHL et al., 2008; JIANG et al., 2010; MONCAYO et al., 2010; TROUT et al., 2010; WILLIAMSON et al., 2010), Honduras (NOVAKOVA et al., 2015), Costa Rica (HUN et al., 2011; OGRZEWALSKA et al., 2015), Panama (BERMUDEZ et al., 2011), French Guyana (PAROLA et al., 2007) and Argentina (LABRUNA et al., 2007c). In Brazil, this species was isolated in 2004 for the first time from ticks found in Rondônia State, Western Amazon. The strain isolated form adult male *A. longirostre* collected from a porcupine *Coendou prehensilis* Linnaeus, 1758, was designated as the strain Aranha (LABRUNA et al., 2004c). Later, closely related genotypes were found also in *A. auricularium* (SARAIVA et al., 2013), *A. cajennense* (LABRUNA et al., 2004a; DE BARROS-LOPES et al., 2014; WITTER et al., 2016), *A. coelebs* (LABRUNA et al., 2004b; SILVEIRA et al., 2015; WITTER et al., 2016) and *A. longirostre* (MEDEIROS et al., 2011; MCINTOSH et al., 2015). In 2006 Ogrzewalska et al. (2008) isolated "*Ca. Rickettsia amblyommii*" or closely related bacteria denominated strain AL from and adult ticks obtained from engorged nymph collected from *Conopophaga lineata* (Wied, 1831) (Passeriformes, Conopophagidae), State of São Paulo. Since then, "*Ca. Rickettsia amblyommii*" have been found frequently infecting immature ticks *A. longirostre* collected on birds (Table 1). Recently, immature *A. auricularim A. geay, A. nodosum, A. varium,* also collected from birds have been found infected with this or closely related bacteria (Table 1). The pathogenicity for humans of '*Ca. Rickettsia amblyommii*' remains unknown; however, there was serological evidence of exposure of humans and canines to this agent in the USA and in the Brazilian western Amazon (LABRUNA et al., 2007d), and recently it was associated in USA with a rash in humans (BILLETER et al., 2007). It was also proposed that some of the rickettsiosis cases reported as Rocky Mountain spotted fever in the USA may have been caused by "*Ca. Rickettsia amblyommii*" instead of *R. rickettsii* (APPERSON et al., 2008).

Rickettsia parkeri and *Rickettsia parkeri*-like strains

Rickettsia parkeri agent is responsible for spotted fever cases in humans in the United States where it is transmitted by *Amblyomma maculatum* Koch, 1844 (PADDOCK et al., 2004, 2008; WHITMAN et al., 2007; FORNADEL et al., 2011). This pathogen was also detected in *A. maculatum* in Peru (FLORES-MANDONZA et al., 2013), *A. triste* in Uruguay (VENZAL et al., 2004a, 2012; PACHECO et al., 2006; CONTI-DÍAZ et al., 2009), Argentina (NAVA et al., 2008a) and Brazil (SILVEIRA et al., 2007) and in *A. tigrinum* in Bolivia (TOMASSONE et al., 2010b). Closely related with *R. parkeri*, strain denominated *Rickettsia* sp. Atlantic Rainforest was also found in Brazilian populations of *A. ovale* and *A. aureolatum* ticks (SABATINI et al., 2010; MEDEIROS et al., 2011; BARIBIERI et al., 2014; WITTER et al., 2016) and was recently proven to cause a milder version of Brazilian spotted fever caused by *R. rickettsii* (SPOLIDORIO et al., 2010; SILVA et al., 2011). Moreover, in Brazil, various other strains of *R. parkeri*-like have been found, including ticks collected on wild birds; in *A. nodosum*: *Rickettsia* sp strain NOD (OGRZEWALSKA et al., 2009b; WITTER et al.,

2016), strain PNCG (RAMOS et al., 2015), strain Paraiba (LUGARINI et al., 2015), in *A. longirostre*: strain ApPR (PACHECO et al., 2012), and in *A. calcaratum R. parkeri*-like (OGRZEWALSKA et al., 2013) (Table 1). The role of these bird ticks in the cycle of *Rickettsia* and its possible impact on public health remains unknown.

Final Considerations

Although information about the role of wild birds in the life cycle of South American ticks has increased in recent years, little is still known. Most of the available studies concern the role of birds as possible host in the life cycle of ticks, and it seem that for at least six species such as *A. calcaratum, A. longirostre A. nodosum, I. auritulus* and *I. paranaensis,* birds are essential host for immatures stages. For others, such as *A. parvum, A. triste, H. juxtakochi, H. leporispalustris,* birds are important, but not essential and rather alternative hosts. For other tick species *A. aureolatum, A. auricularium, A. geayi, A. humerale, A. ovale, A. parkeri, A. varium, O. mimon,* birds are possibly important hosts; however, data are very limited and require further investigations. And finally, for *A. brasiliense, A. sculptum, A. coelebs, A. dissimile, A. naponense, A. pacae* and *R. sanguineus,* birds seem rather accidental hosts.

Bird tick fauna is the best known from the region of Atlantic Forest and Cerrado, and there is a lack of knowledge about bird parasitism in other Brazilian biomes. It is important to highlight that even the available data are mainly obtained by capturing birds by mist nests; thus, data are not completely representative. Mist nets were invented over 300 years ago in Japan for capturing birds for food (SPENCER, 1972) and remain the most commonly used method for capturing birds for research. However, netting is usually used for sampling small to medium-sized wild birds such as passerines and shorebirds and is known to under-sample or completely miss birds living in canopy stratum (e.g. parrots, raptors, toucans) and large terrestrial birds (e.g. tinamous, curassows guans) (WANG; FINCH, 2002). For capturing these groups, other methods such as baited traps are indicated (BUB, 1991). Thus, caution should always be taken when making conclusions based only on this selective data. The important group of midsize to large terrestrial birds are not accessed often in parasitology studies. It is expected that terrestrial birds are exposed to larger burden of subadult ticks, and because of the closer and constant contact, it would be expected that most of the records of ticks on birds would come from this group. However, more studies with this group of birds must be taken in order to fill the knowledge gaps.

It seems very unlikely that birds play a major role as amplifier hosts for rickettsial agents, even though this hypothesis has yet to be more extensively tested. On the other hand, birds may be an important source of spatial dispersion of rickettsial agents alongside the tick population itself; however, the dynamic of dispersion of tick by birds is not well known in South America. Although most Brazilian birds are resident, not migratory species (CBRO, 2014), it is likely that birds are essential in spreading ticks and pathogens within ecosystems they habit. Further studies must be carried out in order to quantifiably measure this hypothesis and interaction among birds, ticks and rickettsial agents as this is an import concern for public health, and continues to be an open field for research.

Some examples of parasitism of wild birds by *Amblyomma* ticks in Atlantic Forest region, São Paulo State, Brazil

Figure 1 – Nymph of *Amblyomma sculptum* on *Penelope superciliaris* (Galliformes, Cracidae)

Figure 2 – More than 500 larvae of *Amblyomma nodosum* on *Conopophaga lineata* (Passeriformes, Conopophagidae)

Figure 3 – Larvae of *Amblyomma longirostre* on *Schiffornis virescens* (Passeriformes, Tityridae)

Figure 4 – Larvae (above the eye) of *Amblyomma* spp and nymph (neck) of *Amblyomma longirostre* on *Lanio* (*Trichothraupis*) *melanops* (Passeriformes, Thraupidae)

Figure 5 – Nymph of *Amblyomma coelebs* on *Baryphthengus ruficapillus* (Coraciiformes, Momotidae)

Figure 6 – Nymphs of *Amblyomma nodosum* on the neck of *Thamnophilus pelzelni* (Passeriformes, Thamnphilidae)

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