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Blood parasites in passerine birds from the Brazilian Atlantic Forest

Hemoparasitos em passeriformes da Mata Atlântica Brasileira

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Abstract

Parasites may lead bird species to extinction, affect host temporal and spatial population dynamics, alter community structure and alter individuals' social status. We evaluated blood parasite prevalence and intensity according to bird families and species, among 925 birds that were caught in 2000 and 2001, in the Atlantic Forest in the State of Minas Gerais, Brazil. We applied Giemsa staining to thin blood smears, to detect blood parasites. The birds (n = 15.8%) in 11 families, were infected by at least one parasite genus, especially Muscicapidae (28.3%) and Conopophagidae (25%). Among the 146 infected birds, *Plasmodium* was detected in all bird families and had the highest prevalence (54.8%). *Trypanosoma*, *Haemoproteus* and microfilaria had lower prevalence rates (23.3, 23.3 and 2.1%, respectively). Birds caught during the rainy season were more infected than birds caught during the dry season. The overall low prevalence of blood parasites in birds is similar to the patterns found elsewhere in the Neotropical region.

Keywords: Brazil, microscopy, parasites, *Plasmodium*, *Trypanosoma*, *Haemoproteus*.

Resumo

Parasitos podem levar espécies de aves à extinção, afetar as dinâmicas temporais e espaciais dos hospedeiros, alterar a estrutura de comunidades e o *status* social de indivíduos. Avaliou-se a prevalência e a intensidade de parasitos em famílias e espécies de 925 aves capturadas, entre 2000 e 2001, na Mata Atlântica de Minas Gerais. Foram coradas com Giemsa extensões de sangue para detectar parasitos hematozoários. As aves (n= 15,8%) 11 famílias estavam infectadas por pelo menos um gênero de parasito, especialmente Muscicapidae (28,3%) e Conopophagidae (25%). Entre as 146 aves infectadas, *Plasmodium* foi detectado em todas as famílias e possuiu a maior prevalência (54,8%). *Trypanosoma, Haemoproteus* e microfilaria possuíram baixas prevalências (23,3, 23,3 e 2,1%, respectivamente). Aves capturadas durante a estação chuvosa estavam mais infectadas do que aves capturadas durante a estação seca. A baixa prevalência geral de parasitos do sangue das aves é semelhante aos padrões encontrados em outras localidades da região Neotropical.

Palavras-chave: Brasil, microscopia, parasitos, *Plasmodium*, *Trypanosoma*, *Haemoproteus.*

Introduction

Haematozoa, or blood parasites, may lead bird species to extinction (VAN RIPER III et al., 1986), and alter sexual selection and the evolution of plumage color (HAMILTON; ZUK, 1982; PRUETT-JONES et al., 1990; KIRKPATRICK; RYAN, 1991). Infected individuals may be more susceptible to predators and less able to establish territories (ANDERSON; MAY, 1979). Parasite infections may determine avian death, but the cause of mortality is usually identified *a posteriori* (McCALLUM; DOBSON, 1995). Moreover, pathogens are usually considered to be regulators of host population size.

Several studies focusing on occurrence, prevalence or incidence of blood parasites in birds have been conducted (YOUNG et al., 1993; GILARDI et al., 1995). Within the Apicomplexa phylum, *Haemoproteus*, *Leucocytozoon* and *Lankesterella* are the most prevalent genera infecting birds (BENNETT; BORRERO, 1976; ATKINSON; VAN RIPER III, 1991). *Plasmodium* has received most attention, including in relation to its evolutionary ecology (PAUL et al., 2003), but its distribution has not been fully

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documented yet. *Plasmodium*, *Haemoproteus* and *Leucocytozoon* have been recorded in several parts of the world, with the exception of Antarctica, where the low temperatures do not allow the vectors to survive (FRIEND; FRANSON, 1999). As well as in the Apicomplexa, the blood parasite *Trypanosoma* has also been reported in a wide array of bird hosts (PEIRCE, 1989). However, there is still little evidence to show that this parasite genus is pathogenic in birds (BAKER, 1976).

Most studies on the prevalence of blood parasites in birds have been conducted in the Neartic region (GREINER et al., 1975; KIRKPATRICK; SUTHERS, 1988) and few have been performed in the Neotropical region (DURRANT et al., 2006; FECCHIO et al., 2007; FECCHIO et al., 2011). Some studies have found high prevalence of *Haemoproteus* and low prevalence of *Plasmodium* in the state of São Paulo, Brazil (BENNETT; SOUZA, 1980; WOODWORTH-LYNAS et al., 1989). However, very low prevalence values have been found in the Cerrado (savanna) region of central Brazil (FECCHIO et al., 2007, 2011). The prevalence of blood parasites and the diversity of haematozoan haplotypes have been found to be higher in Guyana than in Uruguay (DURRANT et al., 2006). Although no relationship has been found between blood parasite diversity and latitude in Chile, a positive relationship between prevalence and latitude has been shown for *Leucocytozoon*, and negative relationships for *Haemoproteus*, *Plasmodium* and mixed infections (MERINO et al., 2008). Considering the poor knowledge about blood parasitism among wild birds in Brazil, this study had the aims of evaluating the prevalence of avian blood parasites in several areas of the Atlantic Forest, and estimating their occurrence and intensities in different seasons.

Materials and Methods

Between August and October 2000 and between June and November 2001, birds were caught in Brazilian Atlantic forest fragments, in the following areas of the state of Minas Gerais: 1) Sossego Forest Private Natural Heritage Reserve (Reserva Particular do Patrimônio Natural Mata do Sossego; RPPN Mata do Sossego), located in the municipality of Simonésia (20° 07' S; 42° 00' W); 2) Dark Forest Farm (Fazenda da Mata Escura), located on the left bank of the Jequitinhonha River (16° 20' S; 41° 00' W); 3) Brigadeiro Range State Park (Parque Estadual Serra do Brigadeiro; PESB), located within the Mantiqueira mountain range (Serra da Mantiqueira) (20° 20' and 21° 00' S; 42° 20' and 42° 40' W): 4) Jambreiro Forest Private Natural Heritage Reserve (Reserva Particular do Patrimônio Natural Mata do Jambreiro; RPPN Mata do Jambreiro), located in the municipality of Nova Lima (19° 58' S; 43° 55' W); 5) Santana Farm (Fazenda Santana), located on the left bank of the Jequitinhonha River (16° 05' S; 40° 02' W); and 6) Caratinga Private Natural Heritage Reserve (Reserva Particular do Patrimônio Natural de Caratinga; RPPN de Caratinga), located in the municipality of Caratinga (20° 06' S; 41° 21' W) (Figure 1). Birds were caught in two forest fragments in each of these areas: one large fragment (>1000 ha) and one small fragment (up to 30 ha). The fragments were isolated from

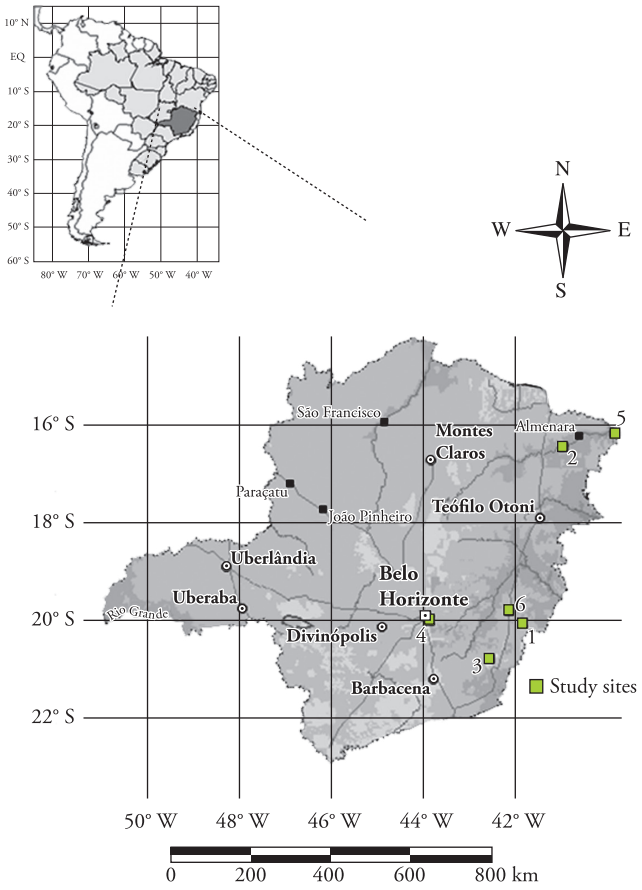

Figure 1. Study sites visited in the Brazilian Atlantic Forest domain within the state of Minas Gerais. 1) Sossego Forest Private Natural Heritage Reserve (Simonésia); 2) Dark Forest Farm (Jequitinhonha); 3) Brigadeiro Range State Park (Ervália); 4) Jambreiro Forest Private Natural Heritage Reserve (Nova Lima); 5) Santana Farm (Salto da Divisa); 6) Caratinga Private Natural Heritage Reserve (Caratinga). Map source: SOS Atlantic Forest Foundation (Fundação SOS Mata Atlântica), INPE.

each other or from any other forested area by at least 1 km of open land, mostly used for crops and pasture.

The birds were caught using up to 20 mist nets, which were left open from sunrise until 5:00 PM, with a mean total of 640 mist-net hours for each area. The birds were identified using field guides. The individuals that were caught were then banded with a metal ring from the Brazilian birding agency (CEMAVE/IBAMA), to ensure that we were not sampling the same individual twice. The birds were released after banding and after blood samples had been collected in order to prepare the thin blood smears. The species nomenclature used followed the prescriptions of the Brazilian Ornithological Records Committee (Comitê Brasileiro de Registros Ornitológicos) (CBRO, 2007), and the family nomenclature followed Comitê Brasileiro de Registros Ornitológicos (2006), so as to allow statistical analyses, because of the small samples sizes of several families.

In the field, we prepared one thin blood smear from each bird, using disposable lancets to make a small perforation in the left tarsus to collect a drop of blood. The smears were air dried and

fixed with methanol. They were then stained with Giemsa solution in buffered water (pH 7.2-7.4), diluted at 1:10, in the Malaria Laboratory of the Federal University of Minas Gerais (UFMG).

We searched for blood parasites in the blood smears using an optical microscope (Olympus 3H). We inspected at least two hundred fields on each smear, and the number of parasitized cells or the number of parasites was counted at 1,000× magnification under oil immersion.

We estimated three blood parasite infection parameters: prevalence, mean intensity and relative intensity (MARGOLIS et al., 1982). We used Spearman rank correlations to evaluate the relationships between blood parasite prevalence rates and mean and relative intensities for species or families with prevalence values differing from zero. We used Kruskal-Wallis to test for differences in parasite intensities among months and between the dry season (June, July, August and September) and rainy season (October and November). This test was also used to compare the infection intensity between the dry and rainy seasons, considering each parasite separately. We used a chi-square test for pairs of independent samples to ascertain whether the prevalence rates for parasite genera were independent between the seasons. We considered statistical differences to be significant at the 0.05 level. All statistical analyses were run using the STATISTICA (version 5.1), MINITAB or EPIINFO (version 6.0) computer packages.

Results

We analyzed 925 birds belonging to 109 species and 11 families (Table 1). A total of 146 birds (15.8%) from 62 species and all 11 families (Figure 2) had at least one parasite specimen of *Plasmodium*, *Trypanosoma*, *Haemoproteus* or microfilaria. The total prevalence values for these four parasites were 9.2, 3.8, 3.2 and 0.03%, respectively (Table 1). Among the 146 infected individuals, we observed the following prevalence rates: *Plasmodium* (54.8%), *Trypanosoma* (23.3%), *Haemoproteus* (23.3%) and microfilaria (2.1%). For several birds, this was the first report showing them to be new hosts for some blood parasites. Of the 62 bird species parasitized, 31 were new host records for *Plasmodium*, eight for *Haemoproteus* and two each for *Trypanosoma* and microfilaria (Table 1).

The parasite prevalence rates were not homogeneous among the bird families. *Plasmodium* was detected in all 11 bird families, with very high incidence in Muscicapidae (24.5%). The prevalences of *Trypanosoma* and *Haemoproteus* were low, compared with the prevalence of *Plasmodium*. *Trypanosoma* was detected in 14 species of eight bird families. Conopophagidae was the bird family with the highest prevalence (13.8%) of *Trypanosoma*, whereas Troglodytidae and Dendrocolaptidae had no birds infected with *Trypanosoma*. *Haemoproteus* was detected in only five families: Tyrannidae (n = 226; 9.7%), Emberizidae (n = 173; 2.3%), Muscicapidae (n = 53; 1.9%), Conopophagidae (n = 80; 1.3%) and Thamnophilidae (n = 165; 1.2%) (Table 1).

The bird families and species with the highest parasite prevalence also generally had the highest parasite intensity. Prevalence was positively and significantly correlated with relative intensity for all three parasites: *Plasmodium* (n = 11; r = 0.998; p < 0.001), *Trypanosoma* (n = 9; r = 0.989; p < 0.001) and *Haemoproteus* (n = 5; r = 0.983; p = 0.026). However, the correlation between specific prevalence and mean intensity was positive and significant for the bird families infected with *Plasmodium* (n = 11 bird families; r = 0.768; p = 0.001), but was not significant for *Trypanosoma* (n = 9; r = 0.002; p = 0.996) or *Haemoproteus* (n = 5; r = 0.290; p = 0.255).

Prevalence and mean parasite intensity did not show any correlation at the species level: *Plasmodium* (n = 48 bird species; r = 0.137; p = 0.351), *Trypanosoma* (n = 14; r = 0.432; p = 0.123) and *Haemoproteus* (n = 17; r = –0.090; p = 0.724). However, prevalence and relative parasite intensity were significantly correlated for *Plasmodium* (n = 48; r = 0.546; p < 0.001) and *Trypanosoma* (n = 14; r = 0.928; p < 0.001), but not for *Haemoproteus* (n = 17; r = 0.436; p = 0.079).

The prevalence of parasitism was higher during the rainy months than during the dry months sampled. The rainy months had significantly (χ^2 = 9.9; p = 0.002) higher numbers of infected birds (618 individuals analyzed, 21.2% prevalence) than the dry months (307 individuals analyzed, 13% prevalence). However, the prevalence varied greatly within the dry season, with the highest prevalence occurring in July (n = 78 birds sampled; 33.3% parasitized) (Figure 3). September was the month with most birds sampled (n = 302), but with the lowest parasite prevalence (6.9%). The prevalence of *Plasmodium* varied irregularly along the months (Figure 4), being highest in July (n = 78 birds sampled; 25.6% infected) and lowest in June (n = 38; 2.6%). However, no difference was detected between the dry months (n = 51; 8.4%) and rainy months (n = 34; 10.8%) in relation to prevalence (χ^2 = 1.15; p = 0.28) or intensity (H = 14.90; p = 0.136). *Trypanosoma* had the highest prevalence values in July and August and the lowest in the other months. There was no significant difference (χ^2 = 0.80; p = 0.370) between the dry months (n = 26; 4.3%) and the rainy months (n = 9; 2.8%). For *Haemoproteus,* there was no significant difference (H = 6.44; p = 0.27) in parasite intensity between the dry and the rainy months (Figure 4). *Haemoproteus* had low prevalence in all the months sampled, except in November (n = 100; 23%). Comparing the two seasons, dry (n = 4; 0.70%) and rainy (n = 26; 8.2%), there was significantly higher prevalence (χ^2 = 35.63; p < 0.001) and higher parasite intensity (H = 38.16; p < 0.001) in the rainy season than in the dry season (Figure 4).

Discussion

Birds from most Neotropical regions seem to have low blood parasite prevalence rates, independent of the type of habitat or region (WHITE et al., 1978; FECCHIO et al., 2007, 2011). Our study showed that the overall blood parasite prevalence was 15.8% among 925 birds sampled, similar to other Neotropical areas (WHITE et al., 1978). A study on the prevalence of parasites in birds from several habitats, including open areas, in southeast Brazil, found similar prevalence values for different habitats (WOODWORTH-LYNAS et al., 1989). Similarly, the prevalence values for blood parasites in passerines from several habitats (capoeira, 'terra firme' forest and várzea) in the Brazilian Amazon region were low (10%) (LAINSON et al., 1970).

Table 1. Total number of birds examined, total number of infected birds and number of birds infected by each blood parasite in the Brazilian Atlantic Forest sites of the state of Minas Gerais between 2000 and 2001.

Bird taxa	Nº of birds examined	Nº of infected birds	Nº of infected birds according to parasite taxa[2]			
			Haem.	*Plasm.*	*Tryp.*	Micro.
Mackenziaena leachii[1]	1	1		1		
Mackenziaena severa	1	0	1			
Thamnophilus pelzelni	33	4		2		1
Thamnophilus caerulescens[1]	27	6		3	3	
Thamnophilus ambiguus	4	0				
Dysithamnus mentalis	6	0				
Dysithamnus plumbeus[1]	9	1		1		
Myrmotherula gularis	1	0				
Formicivora serrana	2	0				
Drymophila ferruginea	4	0				
Drymophila ochropyga[1]	8	1		1		
Drymophila squamata	15	0				
Pyriglena leucoptera[3]	36	9	1	1	8	
Rhopornis ardesiacus	7	0				
Myrmeciza loricata[1]	10	2		1	1	
Myrmeciza ruficauda	1	0				
Chamaeza campanisona[1,3]	1	1		1	1	
Conopophaga melanops[1]	7	2	1	1		
Conopophaga lineata[4]	73	18		9	11	
Dendrocincla turdina[1]	8	1		1		
Sittasomus griseicapillus[1]	13	2		2		
Xiphocolaptes albicollis[1]	2	1		1		
Dendrocolaptes platyrostris	2	0				
Lepidocolaptes squamatus	2	0				
Xiphorhynchus fuscus	18	1		1		
Campylorhamphus falcularius	5	0				
Sclerurus scansor	3	0				
Furnarius leucopus	6	0				
Synallaxis spixi	2	0				
Synallaxis ruficapilla[1]	14	2		2		
Synallaxis cinerea	1	0				
Synallaxis frontalis[1]	9	2		2		
Synallaxis cinerascens[1]	3	1		1		
Synallaxis scutata	2	0				
Phacellodomus rufifrons	1	0				
Anabazenops fuscus[1]	11	1		1		
Syndactyla rufosuperciliata	4	1			1	
Philydor lichtensteini	1	0				
Philydor rufum[1]	8	2		2		
Automolus leucophthalmus	6	1		1	1	
Heliobletus contaminatus	1	0				
Lochmias nematura [1]	11	1		1	1	
Myiopagis viridicata[1]	2	1		1		
Myiopagis caniceps[1]	2	1	1			
Phaeomyias murina[1]	2	1				
Elaenia obscura[1]	4	1		2		
Euscarthmus meloryphus	2	0		1		

[1]New host record, [2]*Haem.* = *Haemoproteus*; *Plasm.* = *Plasmodium*; *Tryp.* = *Trypanosoma*; Micro = Microfilaria, [3]One bird with double infection by *Haemoproteus* and *Trypanosoma*, [4]One bird with double infection by *Plasmodium* and *Trypanosoma.*

Table 1. Continued...

Bird taxa	Nº of birds examined	Nº of infected birds	Nº of infected birds according to parasite taxa[2]			
			Haem.	***Plasm.***	***Tryp.***	**Micro.**
Mionectes rufiventris	7	0				
Leptopogon amaurocephalus[1]	29	3	1	4		
Phylloscartes ventralis[1]	2	1				
Capsiempis flaveola	5	2	2			
Hemitriccus diops[1]	26	4				
Hemitriccus obsoletus	1	0		1		
Todirostrum cinereum	2	0		2		
Tolmomyias sulphurescens	6	0				
Tolmomyias flaviventris[1]	22	7	6			
Platyrinchus mystaceus	35	4			2	
Myiobius barbatus	3	0		2		
Myiobius atricaudus	2	0				
Myiophobus fasciatus	2	1	1			
Lathrotriccus euleri[1]	27	2				
Cnemotriccus fuscatus[1]	5	1				1
Knipolegus cyanirostris	2	0				
Attila rufus	4	0				
Casiornis fuscus[1]	5	1	1			
Myiarchus ferox	2	0				
Myiarchus tyrannulus	8	1	1			
Myiarchus swainsoni	1	0		1		
Myiarchus tuberculifer	3	0		4		
Myiodynastes maculatus	3	1	1	1		
Antilophia galeata[1]	1	1		2		
Chiroxiphia caudata	20	5			1	
Ilicura militaris[1]	12	1				
Manacus manacus[1]	37	2				
Pachyramphus polychopterus	10	10	8		2	
Schiffornis virescens	2	0				
Cyclarhis gujanensis	5	1		1		
Vireo olivaceus	1	1		**1**	1	
Hylophilus poicilotis	5	0				
Hylophilus amaurocephalus	2	0				
Pheugopedius genibarbis[1]	9	1				
Ramphocaenus melanurus	1	0				
Turdus flavipes	1	0				
Turdus rufiventris	18	9	1	8		
Turdus leucomelas	13	3		3		
Turdus amaurochalinus	7	0				
Turdus albicollis	13	3		2	1	
Basileuterus flaveolus	16	0				
Basileuterus culicivorus[1]	26	1		1		
Basileuterus leucoblepharus[1]	11	1		1		
Basileuterus hypoleucus	9	1		1		
Nemosia pileata[1]	2	1	1			
Tachyphonus coronatus	13	0				
Tachyphonus rufus	1	1	1			
Trichothraupis melanops	41	4		3	1	

[1]New host record, [2]*Haem.* = *Haemoproteus*; *Plasm.* = *Plasmodium*; *Tryp.* = *Trypanosoma*; Micro = Microfilaria, [3]One bird with double infection by *Haemoproteus* and *Trypanosoma*, [4]One bird with double infection by *Plasmodium* and *Trypanosoma.*

Table 1. Continued...

Bird taxa	Nº of birds examined	Nº of infected birds	Nº of infected birds according to parasite taxa[2]			
			Haem.	***Plasm.***	***Tryp.***	**Micro.**
Habia rubica	6	0				
Tangara desmaresti	6	2	1	1		
Tangara cyanoventris[1]	1	1	1			
Conirostrum speciosum	1		0			
Haplospiza unicolor[1]	7		1	1		
Amaurospiza moesta	1		0			
Tiaris fuliginosus	3		1	1		
Arremon flavirostris	2		0			
Arremon franciscanus	2		0			
Arremon cf. *semitorquatus*	2		0			
Saltator maximus	1		1	1		
Saltator similis	18		0			
Euphonia violacea[3]	4		1	1		1
Euphonia pectoralis	2		1	1		
Total	925	146	31	80	34	3
Frequencies		15.8	3.4	8.7	3.7	0.3

[1]New host record, [2]*Haem.* = *Haemoproteus*; *Plasm.* = *Plasmodium*; *Tryp.* = *Trypanosoma*; Micro = Microfilaria, [3]One bird with double infection by *Haemoproteus* and *Trypanosoma*, [4]One bird with double infection by *Plasmodium* and *Trypanosoma.*

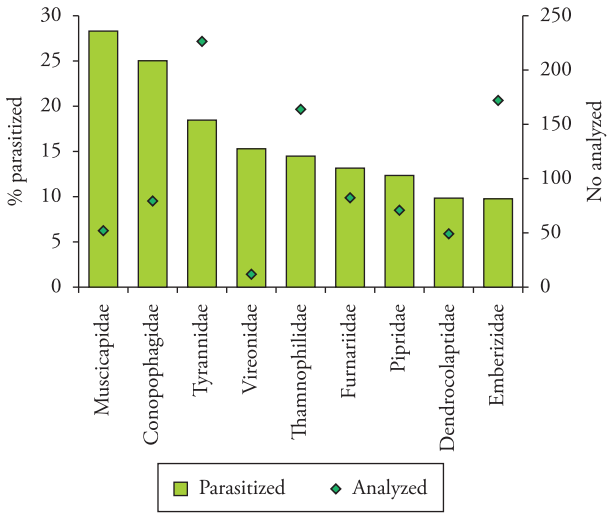

Figure 2. Total prevalence of parasitized birds and number of individuals sampled according to bird family (minimum of 13 individuals per family) in the Atlantic Forest, state of Minas Gerais, during 2000 and 2001.

It is difficult to identify nematode microfilariae at species level because of their high degree of morphological and morphometric similarities (McKEAND, 1998). Sehgal et al. (2005), for example, found eight forms of microfilaria in 12 African passerines based on morphological characteristics, but they were not able to assign them with certainty to any species. Similarly, Silveira et al. (2010) reported on two microfilarial forms from central Brazil, also with insufficient information to allow the identification of the specimens. However, one filarial species of Splendidofilariinae, *Cardiofilaria pavlovskyi,* has been reported in several birds, including Passeriformes (ANDERSON, 2000).

Plasmodium was the most prevalent parasite genus, and was detected in 9.2% of the 925 individuals sampled. This pattern is the rule for most Neotropical regions (WHITE et al., 1978; FECCHIO et al., 2007). However, *Haemoproteus* was the most prevalent parasite, infecting 38.9% of the birds sampled in a region in southeastern Brazil, whereas in our study, this parasite was 10 times less prevalent than what they found (WOODWORTH-LYNAS et al., 1989). One explanation might be related to the fact that our study was restricted to forest birds of the order Passeriformes. Columbidae, for example, which is the most important host of *Haemoproteus*, was not considered in our study. Moreover, these two studies differed in relation to the time of the year when blood samples were taken in the Atlantic Forest region, and the authors did not mention the level of disturbance in their study sites, a factor that could also explain part of the differences in the samples that were collected. Nonetheless, the prevalence of both of these blood parasites varied considerably among the bird families and species that we studied. The reasons for these differences are unknown, but might involve the behavioral and ecological traits of the species. These bird-specific characteristics, such as type of nest constructed and reproductive behavior, might facilitate or prevent contact between birds and their vectors (MARINI et al., 1996; FECCHIO et al., 2011). Interspecies differences between blood parasites in terms of parasitemia might be influenced by the distribution of habitat-dependent vectors, at both micro and macro habitat scale (GARVIN; REMSEN, 1997; PIERSMA, 1997). Host specificity and host-parasite co-evolution are also factors that can affect parasite prevalence (WOODWORTH-LYNAS et al., 1989). The detection of *Plasmodium* in all 11 bird families suggests that the genus is not host-specific, as has also been found by Bennett et al. (1982). However, *Haemoproteus* is more host-specific and is restricted to some species of bird families (FALLIS et al., 1974; ATKINSON et al., 1986). *Trypanosoma* was

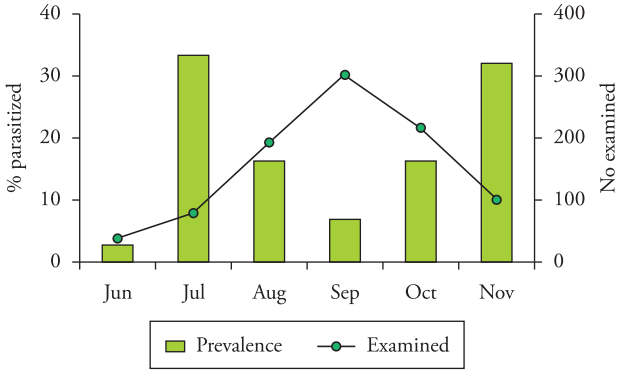

Figure 3. Percentage of individuals parasitized for each month sampled in the Atlantic Forest, state of Minas Gerais, during 2000 and 2001.

found in a small percentage of infected birds in spite of having a wide variety of vectors (PEIRCE, 1989). Its detection is difficult because of its low parasitemia and high polymorphism levels, which might explain the low prevalence that we found.

Prevalence and parasite intensity were positively correlated at both family and species levels. This has also been found for bird ectoparasites (PRUETT-JONES et al., 1991; MARINI et al., 1996). Factors relating to gender, age structure, behavior, season of the year and body condition of the populations studied might be important in explaining the parasitism levels. For example, birds with high infection by *Plasmodium* and *Haemoproteus* might exhibit signs such as appetite loss, apathy, shortness of breath and weakness in one or both legs (FRIEND; FRANSON, 1999). On the other hand, some studies have shown that low levels of parasitemia in the blood or tissue of a bird stimulate some protection against infection (WILSON et al., 2002). Thus, some birds might not show signs of diseases, but keep an infection, thus allowing the parasite population to survive through the dry season when vector populations are low (FRIEND; FRANSON, 1999).

Some blood parasites might change their loads or occur seasonally in the Atlantic Forest birds. In general, we found fewer parasites during the dry season than during the rainy season, even though the sample sizes were better during the rainy season. This pattern was due to the high prevalence of *Haemoproteus* during the rainiest months. Lower blood parasite prevalence during the dry season than during the rainy season was found in forest birds from Costa Rica and Jamaica (BENNETT et al., 1980; YOUNG et al., 1993). This pattern is in agreement with the North American model, in which it was proposed that blood parasite recurrence would be seen during the reproductive season (BEAUDOIN et al., 1971). The low prevalence during the dry months, a period when most birds are not reproducing, occurs mostly in tropical areas (BENNETT et al., 1991). During the reproductive season, nestlings still lack feathers and are more vulnerable to vectors and, thus, have high seasonal transmission. When we analyzed the results on a monthly basis, however, we detected similar peaks in both the seasons. This can be explained by the fact that even though all the data were gathered within the Atlantic Forest biome, they came from six different localities in the state of Minas Gerais. Data gathering in the same area throughout the year would enable better evaluation of this pattern.

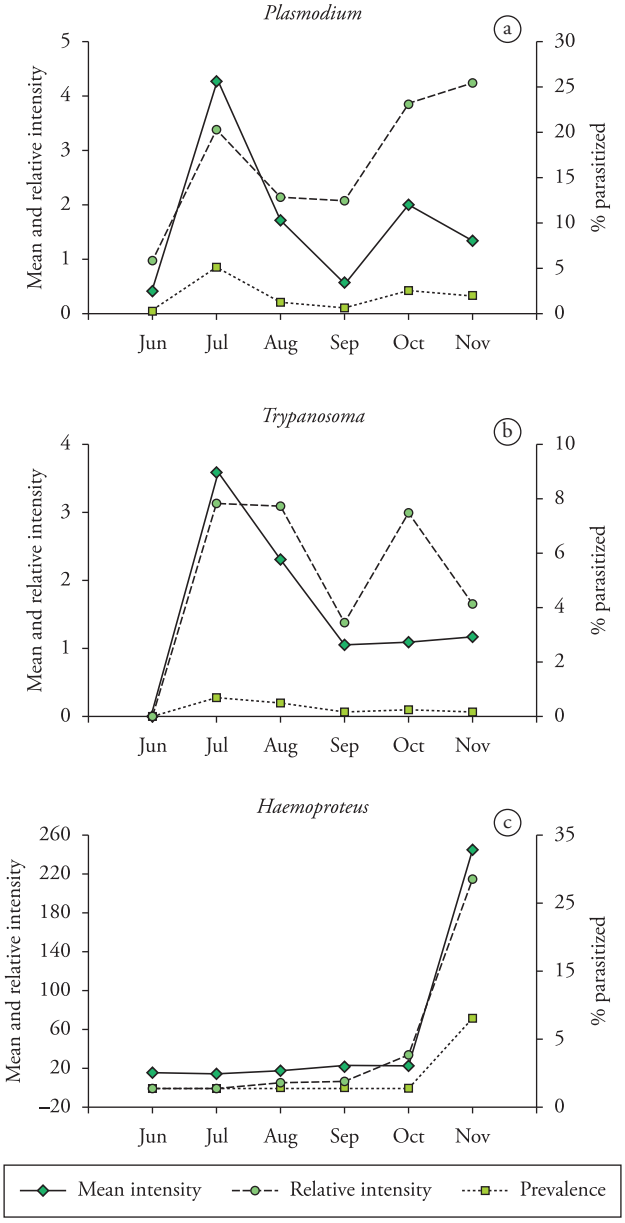

Figure 4. Parasite intensity and percentage of individuals parasitized for each month in the Atlantic Forest, state of Minas Gerais, during 2000 and 2001.

Overall, this study revealed that Atlantic Forest birds might be infected by several blood parasites at levels similar to what has been found in other Neotropical regions. The findings of differences in prevalence rates among hosts and for different parasites, and of temporal variation in prevalence values, reveal that blood parasite-bird interactions are very complex and poorly understood. Long-term population and community-based studies are required at both local and regional scales. The high number of new host species described in this study reflects the scarcity of studies of bird parasites in Brazil. We found more new hosts in bird families with more species sampled. This constitutes evidence of the need to acquire more knowledge of blood parasite bird hosts and their ecology and behavior.

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References

Anderson RC. *Nematode parasites of vertebrates: their development and transmission*. New York: CABI Publishing; 2000. http://dx.doi.org/10.1079/9780851994215.0000

Anderson RM, May RM. Population biology of infectious diseases, part I. *Nature* 1979; 280: 361-367. PMid:460412. http://dx.doi.org/10.1038/280361a0

Atkinson CT, Van Riper III C. Pathogenicity and epizootiology of avian haematozoa: *Plasmodium*, *Leucocytozoon*, and *Haemoproteus*. In: Loye JE, Zuk M. *Bird-Parasite interactions*: ecology, evolution and behaviour. Oxford: Oxford University Press; 1991. p. 19-48.

Atkinson CT, Greiner EC, Forrester DJ. Pre-erythrocytic development and associated host responses to *Haemoproteus meleagridis* (Haemosporina: Haemoproteidae) in experimentally infected domestic turkeys. *J Protozool* 1986; 33(3): 375-381. PMid:3091815.

Baker JR. Biology of the trypanosomes of birds. In: Lumsden WHR, Evans DA. *Biology of the Kinetoplastida*. New York: Academic Press; 1976. p. 131-174.

Beaudoin RL, Applegate JE, Davis DE, McLean RG. A model for the ecology of avian malaria. *J Wildl Dis* 1971(1); 7: 5-13. PMid:4400360.

Bennett GF, Borrero JIH. Blood parasites of some birds from Colombia. *J Wildl Dis* 1976; 12(3): 454-458. PMid:16498894.

Bennett GF, Souza O. Blood parasites of some birds from São Paulo, Brazil. *Mem Inst Oswaldo Cruz* 1980; 75(1-2): 117-134. http://dx.doi.org/10.1590/S0074-02761980000100012

Bennett GF, Aguirre AA, Cook RS. Blood parasites of some birds from northeastern Mexico. *J Parasitol* 1991; 77(1): 38-41. PMid:1992093. http://dx.doi.org/10.2307/3282552

Bennett GF, Whiteway MA, Woodworth-Lynas CB. Host-parasite catalogue of the avian haematozoa. *Mem Univ Newfoundland Occ Pap Biol* 1982; 5: 1-243.

Bennett GF, Witt H, White EM. Blood parasites of some Jamaican birds. *J Wildl Dis* 1980; 16(1): 29-38. PMid:6768902.

Comitê Brasileiro de Registros Ornitológicos. CBRO 2006 [cited 2008 Fev. 04]. Available from: http://www.cbro.org.br/CBRO/index.htm

Comitê Brasileiro de Registros Ornitológicos. CBRO 2007 [cited 2008 Fev. 04]. Available from: http://www.cbro.org.br/CBRO/index.htm

Durrant KL, Beadell JS, Ishtiaq F, Graves GR, Olson SL, Gering E, et al. Avian hematozoa in South America: a comparison of temperate and tropical zones. *Ornithol Monogr* 2006; 60: 98-111. http://dx.doi.org/10.1642/0078-6594(2006)60[98:AHISAA]2.0.CO;2

Fallis AM, Desser SS, Kahn RA. On species *Leucocytozoon*. *Adv Parasitol* 1974; 12: 1-67. http://dx.doi.org/10.1016/S0065-308X(08)60386-3

Fecchio A, Marini MÂ, Braga ÉM. Baixa prevalência de hemoparasitos em aves silvestres no Cerrado do Brasil Central. *Neotrop Biol Conserv* 2007; 2(3): 127-135.

Fecchio A, Lima MR, Silveira P, Braga ÉM, Marini MÂ. High prevalence of blood parasites in social birds from a neotropical savanna in Brazil. *Emu* 2011; 111: 132-138. http://dx.doi.org/10.1071/MU10063

Friend M, Franson JC. *Field manual of wildlife diseases*: general field procedures and disease of birds. Madison: U. S. Geological Survey Information and Technology Report; 1999.

Garvin MC, Remsen Junior JV. An alternative hypothesis for heavier parasite loads of brightly colored birds: exposure at the nest. *Auk* 1997; 114(2): 179-191.

Gilardi KVK, Lowenstine LJ, Gilardi JD, Munn CA. A survey for selected viral, chlamydial, and parasitic diseases in wild Dusky-headed Parakeets (*Aratinga weddellii*) and Tui Parakeets (*Brotogeris sanctithomae*) in Peru. *J Wildl Dis* 1995; 31(4): 523-528. PMid:8592384.

Greiner EC, Bennett GF, White E, Coombs RF. Distribution of the avian haematozoa of North America. *Can J Zool* 1975; 53: 1762-1787. PMid:1212636. http://dx.doi.org/10.1139/z75-211

Hamilton WD, Zuk M. Heritable true fitness and bright birds: A role for parasites? *Science* 1982(4570); 218: 384-387. PMid:7123238. http://dx.doi.org/10.1126/science.7123238

Kirkpatrick CE, Suthers HB. Epizootiology of blood parasite infections in passerine birds from central New Jersey. *Can J Zool* 1988; 66(11): 2374-2382. http://dx.doi.org/10.1139/z88-352

Kirkpatrick M, Ryan MJ. The evolution of mating preferences and the paradox of the lek. *Nature* 1991; 350: 33-38. http://dx.doi.org/10.1038/350033a0

Lainson R, Shaw JJ, Humphrey PS. Preliminary survey of blood-parasites of birds of the Area de Pesquisas Ecológicas do Guamá. Belém, Pará, Brasil. *J Parasitol* 1970; 56 (Sect. II, Part I): 197-198.

McCallum H, Dobson H. Detecting disease and parasite threats to endangered species and ecosystems. *Trends Ecol Evol* 1995; 10(5): 190-194. http://dx.doi.org/10.1016/S0169-5347(00)89050-3

McKeand JB. Molecular diagnosis of parasitic nematodes. *Parasitology* 1998; 117: 87-96. http://dx.doi.org/10.1017/S0031182099004096

Margolis LG, Esch W, Holmes JC, Kuris AM, Schad G. The use of ecological terms in parasitology. *J Parasitol* 1982; 68: 131-133. http://dx.doi.org/10.2307/3281335

Marini MÂ, Reinert BL, Bornschein MR, Pinto JC, Pichorim MA. Ecological correlates of ectoparasitism on Atlantic Forest birds, Brazil. *Ararajuba* 1996; 4: 93-102.

Merino S, Moreno J, Vásquez RA, Martínez J, Sánchez-Monsálvez I, Estades CF, et al. Haematozoa in forest birds from southern Chile: Latitudinal gradients in prevalence and parasite lineage richness. *Austr Ecol* 2008; 33(3): 329-340. http://dx.doi.org/10.1111/j.1442-9993.2008.01820.x

Paul REL, Ariey F, Robert V. The evolutionary ecology of *Plasmodium*. *Ecol Let* 2003; 6: 866-880.

Peirce MA. The significance of avian haematozoa in conservation strategies. In: Cooper J E. *Disease and threatened birds*. Cambridge: ICBP Technical Publication; 1989. p. 69-76.

Piersma T. Do global patterns of habitat use and migration strategies co-evolve with relative investments in immunocompetence due to spatial variation in parasite pressure? *Oikos* 1997; 80(3): 623-631. http://dx.doi.org/10.2307/3546640

Pruett-Jones SG, Pruett-Jones MA, Jones HI. Parasites and sexual selection in birds of paradise. *Amer Zool* 1990; 30(2): 287-298.

Pruett-Jones SG, Pruett-Jones MA, Jones HI. Parasites and sexual selection in a New Guinea avifauna. In: Johnston RF *Current Ornithology.* New York: Plenum Press; 1991. v. 8, p. 213-245.

Sehgal RNM, Jones HI, Smith TB. Molecular evidence for host specificity of parasitic nematode microfilariae in some African rainforest birds. *Mol Ecol* 2005; 14(13): 3977-3988. PMid:16262853. http://dx.doi.org/10.1111/j.1365-294X.2005.02555.x

Silveira P, Belo NO, Rodello D, Pinheiro RT, Braga ÉM. Microfilariae infection in wild birds from the Brazilian Cerrado. *J Wildl Dis* 2010; 46: 1305-1309. PMid:20966285.

Van Riper III C, Van Riper SG, Goff ML, Laird M. The epizootiology and ecological significance of malaria in Hawaiian land birds. *Ecol Monogr* 1986; 56: 327-344. http://dx.doi.org/10.2307/1942550

White EM, Greiner EC, Bennett GF, Herman CM. Distribution of the haematozoa of Neotropical birds. *Rev Biol Trop* 1978; 26: 43-102. PMid:108771.

Wilson K, Bjornstad ON, Dobson AP, Merler S, Poglayen G, Randolph SE, et al. Heterogeneities in macroparasites infections: patterns and processes. In: Hudson PJ, Rizzoli A, Grenfell BT, Heesterbeek H, Dobson AP. *The ecology of wildlife diseases*. Oxford: Oxford University Press; 2002. p. 6-44.

Woodworth-Lynas CB, Caines JR, Bennett GF. Prevalence of avian haematozoa in São Paulo, Brazil. *Mem Inst Oswaldo Cruz* 1989; 84: 515-526. http://dx.doi.org/10.1590/S0074-02761989000400009

Young BE, Garvin MC, McDonald B. Blood parasites in birds from Monteverde, Costa Rica. *J Wildl Dis* 1993; 29(4): 555-560. PMid:8258853.