Int J Primatol (2017) 38:1017–1031
DOI 10.1007/s10764-017-9994-5

Infectious Diseases in Free-Ranging Blonde Capuchins, *Sapajus flavius,* in Brazil

Marina Galvão Bueno[1,2] · José Luiz Catão-Dias[3] · Plautino de Oliveira Laroque[4] · Silvio Arruda Vasconcellos[5] · José Soares Ferreira Neto[5] · Solange Maria Gennari[5] · Fernando Ferreira[5] · Marcia Dalastra Laurenti[6] · Eufrosina Setsu Umezawa[7] · Norival Kesper[7] · Karin Kirchgatter[8] · Lilian Oliveira Guimarães[8] · Heloise Julião Pavanato[2,9] · Mônica Mafra Valença-Montenegro[4]

Received: 21 March 2017 / Accepted: 3 August 2017 / Published online: 4 November 2017

Abstract The main threats to primates worldwide are the degradation, fragmentation, and loss of their habitats; hunting (especially for bushmeat); and illegal trade. For many species, the most important threat is forest fragmentation, resulting in small populations that are restricted to isolated forest patches. In this situation, primates are particularly vulnerable to disease. The Endangered blonde capuchin (*Sapajus flavius*) is now restricted to a few forest patches in Northeast Brazil.

Handling Editor: Joanna M. Setchell

✉ Marina Galvão Bueno
buenomg@gmail.com

[1] Fundação Oswaldo Cruz – Plataforma Institucional Biodiversidade e Saúde Silvestre - Presidência, Rio de Janeiro 21.040-361, Brasil

[2] Instituto de Desenvolvimento Sustentável Mamirauá – IDSM/MCTI, Tefé, Amazonas 69.553-225, Brasil

[3] Laboratório de Patologia Comparada de Animais Selvagens – LAPCOM, Departamento de Patologia, Faculdade de Medicina Veterinária e Zootecnia, Universidade de São Paulo, São Paulo 05.508-270, Brasil

[4] Centro Nacional de Pesquisa e Conservação de Primatas Brasileiros – CPB, Instituto Chico Mendes de Conservação da Biodiversidade, João Pessoa, Paraíba 58.010-480, Brasil

[5] Departamento de Medicina Veterinária Preventiva e Saúde Animal, Faculdade de Medicina Veterinária e Zootecnia, Universidade de São Paulo, São Paulo 05.508-270, Brasil

We investigated the occurrence of parasites and bacterial diseases in one of three free-ranging groups of *S. flavius* in a small forest patch in Paraíba state, Northeast Brazil. We tested for antibodies against *Leishmania* spp., *Trypanosoma cruzi*, *Toxoplasma gondii*, *Leptospira* spp. (24 strains), and *Brucella* spp.. We used molecular analysis to detect *Plasmodium* spp., and evaluated blood smears for the presence of hemoparasites. All individuals tested negative for *Leptospira* spp. and *B. abortus*, but 8 of 48 (16%) presented antibodies for both *Leishmania* spp. and *T. cruzi*. We identified antibodies to *T. gondii* in 12% of the individuals tested. *Plasmodium brasilianum* infection was present in 4% of the individuals tested, and blood smears showed microfilariae parasites in 46% of the individuals tested. The occurrence of these infectious diseases in *S. flavius* may pose a significant threat in terms of reduced recruitment and poor survival rates, and an understanding of the influence of pathogens is crucial for the management of small populations of primates.

Keywords Atlantic Forest · Blonde capuchin monkey · Conservation · Pathogens

Introduction

Of the 504 species of nonhuman primates currently recognized, *ca.* 60% are threatened (Estrada *et al.* 2017). The main threats to primates are degradation, fragmentation, and loss of habitat; hunting; and illegal trade. For many primates, the main threat is forest fragmentation, resulting in small populations that are restricted to isolated forest patches. Habitat loss and fragmentation diminish species diversity and ecosystem function. They may also influence pathogen–host–environment dynamics. Primates in fragmented habitats are particularly vulnerable to disease epidemics, because of their small populations (Smith *et al.* 2009) and because translocation and reintroduction are increasingly used to maintain their genetic diversity, promoting animal movement, which may favor disease transmission (Kock *et al.* 2010).

Moreover, small forest patches are often surrounded by agriculture, livestock pasture, and settlements, which increases contact between people, wildlife, and domestic animals, with the consequent possibilities of disease spillover (Mackenstedt *et al.* 2015; Osofsky *et al.* 2005; Wolfe *et al.* 1998).

Wild primates have a great diversity of parasites, including viruses, fungi, bacteria, and micro- and macroparasites (Nunn and Gillespie 2016). Several pathogens cause

[6] Laboratório de Patologia de Moléstias Infecciosas, Faculdade de Medicina, Universidade de São Paulo, São Paulo 01.246-903, Brasil

[7] Laboratório de Protozoologia, Instituto de Medicina Tropical, Universidade de São Paulo, São Paulo 05.403-000, Brasil

[8] Núcleo de Estudos em Malária, Superintendência de Controle de Endemias/Instituto de Medicina Tropical, Universidade de São Paulo, São Paulo 05.403-000, Brasil

[9] Department of Mathematics and Statistics, University of Otago, PO Box 56, Dunedin 9054, New Zealand

disease and promote morbidity and, in some cases, mortality, in primates. These include malaria, Chagas disease, leishmaniasis, leptospirosis, brucellosis, toxoplasmosis, and filariasis (Baitchman *et al.* 2006; Epiphanio *et al.* 2003; Percy *et al.* 1972; Toft and Eberhard 1998). Little is known, however, of the diversity of pathogens in wildlife populations. This is especially so in large, tropical, megadiverse countries. Factors such as population density, relative abundance, geographic distribution, and loss of species diversity can also influence the pathogen transmission cycle and disease occurrence (Cook and Karesh 2008; Suzán *et al.* 2012). In addition, the sex, age, and social status of individuals can influence the exposure and transmission of parasites, affecting disease occurrence in a population. Young animals, for example, are more susceptible than older ones to many infectious diseases because of low immunity (Cross *et al.* 2009).

Studies of pathogen occurrence in endangered populations are of great importance for conservation, and epidemiological studies of pathogens in wild animals are also important for the prevention, control, and monitoring of diseases and to develop public and animal health policies (Daszak *et al.* 2000; Deem *et al.* 2001). Connections between vertebrate species through the human–animal–ecosystem interface may have consequences for human, animal, and ecosystem health. The majority (60%) of etiological agents circulate between animals and humans (anthropozoonosis), and 72% of emerging diseases are caused by pathogens originating from wildlife (Jones *et al.* 2008).

Thirty-five of Brazil's 150 primates are classified as Threatened, and 17 of these live in Brazil's Atlantic Forest (Brazil, Ministério do Meio Ambiente 2014). Of these threatened species, the blonde capuchin (*Sapajus flavius*) is restricted to a few forest patches in the Atlantic Forest of Northeast Brazil in the states of Alagoas, Pernambuco, Paraíba, and Rio Grande do Norte (Fialho *et al.* 2014; Oliveira and Langguth 2006; Pontes *et al.* 2006), and classified as Endangered (Brazil, Ministério do Meio Ambiente 2014; de Oliveira *et al.* 2015). In 2006, the total wild population of *S. flavius* was estimated to be 180 individuals, living in *ca.* 24 subpopulations (de Oliveira *et al.* 2015). Subsequent studies, between 2011 and 2014, indicated a wild population of around 1000 individuals, in at least 29 subpopulations (Fialho *et al.* 2014; Valença-Montenegro 2011). Group sizes are 9–90 individuals (Valença-Montenegro *et al.* 2015).

In Paraíba state, *Sapajus flavius* occurs in 19 small forest fragments (Fialho *et al.* 2014). These remnant subpopulations face severe deforestation, both past and present, mainly as a result of cattle ranching, agriculture (sugar cane), and logging. The remaining forest fragments together comprise just 0.4% of Paraíba state (Barbosa 1996; Tabarelli *et al.* 2006). Deforestation and hunting are the main overt threats to *S. flavius*, but considering the overall low numbers, and that the populations are severely fragmented, infectious diseases may pose an additional threat, as they may increase mortality/morbidity (Osofsky *et al.* 2005; Smith *et al.* 2009).

We examined the prevalence of zoonotic infectious parasites and bacteria in *Sapajus flavius* living in a small, isolated forest, at an unusually high density of 12 individuals/km^2, a factor that we assumed to be favorable to disease transmission. We also evaluated the influence of sex and age on risk of infection.

Methods

Study Site, Study Group, and Selected Diseases

We conducted our study in the Private Natural Heritage Reserve of Engenho Gargau, in Santa Rita municipality, 25 km from João Pessoa, the capital of Paraíba state, in Northeast Brazil (07°00′43.84″S, 34°57′24.96″W) (Fig. 1). The 1500-ha site is a privately owned protected area, with secondary forest in different stages of succession immersed in a matrix of sugar cane plantations. The forest is affected by hunting and firewood harvesting (Valença-Montenegro 2011). Annual mean temperature is 22–26 °C and annual mean rainfall is 1600–1800 mm (Lima and Heckendorff 1985).

Three species of primates inhabit the reserve: the common marmoset (*Callithrix jacchus*), the red-handed howler (*Alouatta belzebul*), and *Sapajus flavius* (Fialho and Gonçalves 2008). We estimated the population of *S. flavius* to be 180 individuals living in three groups (30, 60, and 90), among the largest groups ever recorded for *Sapajus*. *S. flavius* are largely frugivore-insectivores, and at this site palm fruits and sugar cane are key resources (Valença-Montenegro 2011).

We selected the following infectious agents for investigation, based on their capacity to affect or induce disease and death in primates, and their reported occurrence in domestic animals and/or humans in the area: *Leishmania* spp., *Trypanosoma cruzi*, *Toxoplasma gondii*, *Plasmodium* spp., filarial nematodes, *Leptospira* spp. (24 strains), and *Brucella* spp..

Sample Collection

We captured 48 *Sapajus flavius* using Tomahawk traps, removed them from the traps using dip nets, and anesthetized them with ketamine hydrochloride (30 mg/kg) in

Fig. 1 The study site. The Private Natural Heritage Reserve of Engenho Gargau, Paraíba state, Brazil, is outlined in white. Note the extensive agricultural and farming activities, and the reserve's proximity to an urban area on the right.

August 2009, March 2010, September 2010, and August 2012. We carried out a clinical evaluation of each individual and collected blood samples from the femoral vein. We classed monkeys as infants, young, or adults, based on body size (Fragaszy *et al.* 2004). We released all individuals where we captured them on the same day or the next morning if they had not fully recovered from anesthesia before dusk.

Laboratory Analysis

We examined samples from 48 individuals: 32 males and 16 females (28 adults and 20 young). We did not test all individuals for *Plasmodium* and filariasis because there was insufficient blood for some analyses. We tested for antibodies against *Leishmania* spp., *Trypanosoma cruzi*, *Toxoplasma gondii*, *Leptospira* spp. (24 serovars), and *Brucella* spp. using in-house diagnostic tests, and performed molecular analysis for *Plasmodium* spp. diagnosis. We also tested for the presence of *T. cruzi*, *Leishmania* spp., *Plasmodium* spp., and filaria by examining blood smears (Table I).

Statistical Analysis

We calculated Fisher exact 95% confidence intervals (CI) for the prevalence of each infectious disease using OpenEpi (Dean *et al.* 2013). We used a logistic regression to evaluate the influence of sex (female and male) and age (young and adult) on risk of infection (Dobson and Barnett 2002). We considered one model per disease (whenever the number of infected individuals exceeded one) using both predictors as factors. Whenever the predictors were significant at $\alpha = 0.1$, we predicted the risk of infection, i.e., probability of subjects being infected, by sex and/or age. We conducted analyses in R, version 3.3.1 (R Core Team 2015).

Ethical Note

All procedures were in full compliance with federal permits issued by the Brazilian Government (License SISBIO 19927). The authors declare that they have no conflict of interest.

Results

Risk of Infection

All subjects showed negative results for *Leptospira* spp. and *Brucella abortus*. However, the estimated prevalence of antibodies against *Leishmania* spp. and *Trypanosoma cruzi* was 16% (8/48; 95% CI: 9–30%). Five individuals presented antibodies for both pathogens, three were positive only for *Leishmania* spp., and another three only for *T. cruzi.* We identified antibodies to *Toxoplasma gondii* in 12% of animals tested (6/48; 95% exact CI: 6–25%), with titers of 25 (4 individuals), 400 (1 individual), and 3200 (1 individual). *Plasmodium* spp. infection was present in 4% of subjects (1/24; 95% CI: 1–20%) and molecular analysis of the *Plasmodium* isolate showed SSU rRNA and cytochrome *b* sequences of *Plasmodium brasilianum* (GenBank KX618475 and

Table I Prevalence, tests, antigens, and primers used to evaluate the presence of selected pathogens in *Sapajus flavius*, in the Private Natural Heritage Reserve of Engenho Gargau, Paraíba state, Brazil, 2009–2012

Pathogen	Prevalence (%)	No positive/ no examined	Test performed	Antigen/primer	Reference
Leishmania spp.	16	8/48	ELISA	*Leishmania* (*L.*) *amazonensis* promastigotes	Bueno (2012)
Trypanosoma cruzi	16	8/48	TESA-blot	Secreted/excreted *T. cruzi* trypomastigote antigens	Umezawa *et al.* (1996)
Leptospira spp.	0	0/48	Microscopic seroagglutination test	Castellonis, Bataviae, Canicola, Whitcombi, Cynopteri, Grippotyphosa, Hebdomadis, Copenhageni, Sentot, Patoc, Tarassovi, Shermani, Hardjo (Hardjobovis), Pomona, Panama, Javanica, Icterohaemorrhagiae, Wolffi, Hardjo (Hardjoprajitno), Pyrogenes	Alves (1995)
Brucella spp.	0	0/48	Rose Bengal plate test	*B. abortus* cells	Brazil (2006)
Toxoplasma gondii	12	6/48	Modified agglutination test	Tachyzoites of *T. gondii* (we considered results equal to or greater than 25 positive)	Dubey and Desmonts (1987)
Plasmodium spp.	4	1/24	PCR SSU	rPLU1/rPLU6R and rPLU3/rPLU4	dos Santos *et al.* (2009)
			PCR cyt*b*	DW2/DW4 and DW1/DW6	Perkins and Schall (2002)
Filarial nematoide	46	18/39	Blood smear	Direct evaluation	Brazil (2005)

ELISA = enzyme-linked immunosorbent assay; TESA-Blot = immunoblot assay; PCR SSU = polymerase chain reaction of the small subunit ribosomal RNA; PCR cyt*b* = polymerase chain reaction of the fragment of cytochrome *b* gene

KX618476, respectively). Blood smears were negative for *Plasmodium* spp., *Trypanosoma* spp., and *Leishmania* spp. parasites, but we found microfilariae in 46% of the individuals we evaluated (18/39; 95% exact CI: 30–63%). Clinical evaluation showed that all subjects in this study were apparently healthy when captured.

The predictor sex was significant only for *Toxoplasma gondii* (Table II), in which females had a higher chance of infection (0.25, SE = 0.11) than males (0.03, SE = 0.03), with an odds ratio of 8, i.e., chance of infection for females was eight times higher than for males. Age was not a significant factor in any infectious disease model.

Discussion

We found that wild populations of *Sapajus flavius* in Engenho Gargau were infected with *Leishmania* spp., *Trypanosoma cruzi*, *Toxoplasma gondii*, *Plasmodium* spp., and microfilariae and that *S. flavius* had no contact with *Leptospira* spp. and *Brucella* spp.. Females had a higher chance of *T. gondii* infection than males and age was not a significant factor in any infectious disease we investigated.

Our analyses indicated that the population of *Sapajus flavius* has had no contact with the following species of *Brucella*: *B. abortus*, *B. melitensis*, *B. suis*, *B. neotomae*, *B. pinnipedialis*, *B. ceti*, *B. microti*, and *B. inopinata*. Experimental studies have demonstrated that some primate species produce antibodies for, and can be affected by, these pathogens, causing disease

Table II Results of logistic regression testing the influence of sex and age on infectious disease in *Sapajus flavius* in the Private Natural Heritage Reserve of Engenho Gargau, Paraíba state, Brazil, 2009–2012

Coefficients	Point estimate	Standard error	*P*-value
Leishmania spp.			
Intercept	−0.753	0.551	–
Sex[a]	−1.355	0.991	0.132
Age[b]	−0.302	0.900	0.760
Trypanosoma cruzi			
Intercept	−1.029	0.585	–
Sex[a]	−0.590	0.859	0.492
Age[b]	−0.651	0.956	0.496
Toxoplasma gondii			
Intercept	−1.085	0.599	–
Sex[a]	−2.288	1.296	0.077
Age[b]	−0.111	1.342	0.934
Filarial nematoide			
Intercept	−0.217	0.599	–
Sex[a]	0.601	0.782	0.442
Age[b]	−0.774	0.723	0.285

[a] Corresponds to the coefficient of male. The intercept corresponds to the risk of infection for females and adults

[b] Corresponds to the coefficient of young

(Mense *et al.* 2004; Percy *et al.* 1972; Schlabritz-Loutsevitch *et al.* 2009; Thorne 2001; Wilson 1936; Yingst *et al.* 2010). Brucellosis is widely distributed in bovine herds throughout Paraíba and could be transmitted to *S. flavius* inhabiting remnants surrounded by cattle farms (Leite *et al.* 2003). More studies are needed to determine the susceptibility of Neotropical primates to these pathogens.

The negative results for anti-*Leptospira* antibody serovars may reflect the absence of this pathogen in the population but may also be due to its virulence. Several outbreaks of leptospirosis have been described in captive primates, causing jaundice, lethargy, and abortion (Gibson 1998; Karesh *et al.* 1998; Leighton and Kuiken 2001). The disease is often characterized as acute, mortality is usually high, and infected individuals may die without being detected (Baitchman *et al.* 2006; Perolat *et al.* 1992). Studies in Brazil have demonstrated the occurrence of antibodies to *Leptospira* in *Cebus* and *Sapajus*, including *S. flavius*, but most of these were conducted on captive individuals or in rescue centers (Ferreira *et al.* 2011). Serological studies of free-ranging Neotropical primates showed positive results to different serovars, such as Pomona, Brasiliensis, Mini, Swajizak, Grippothyphosa, Sarmin, Fluminense, and Autumnalis in *Cebus paella*; Mangus and Fluminense in *Alouatta caraya*; Australis and Pomona in *Callithrix penicillata*; and Grippotyphosa in *Ateles paniscus chamek* (Dória *et al.* 1974; Karesh *et al.* 1998; Souza *et al.* 2006).

Our analysis showed that the chances of infection with *Leishmania* spp. were high for *Sapajus flavius* at our study site, with an infection probability of 0.56. There are autochthonous human cases of infection in the study area, and leishmaniasis, especially the cutaneous form, is considered endemic in Paraíba state (Brandão-Filho *et al.* 1999).

The epidemiology of *Leishmania* in Neotropical primates is not well studied; however, experimental studies show that *Leishmania* sp. can affect primates, which manifest symptoms similar to those shown by humans (Silveira *et al.* 1990; WHO 2010). *Leishmania* has been described in different primate species for Brazil and other countries, e.g., *Callithrix* spp., *Cebus* sp., *Chiropotes satanas*, *Saguinus* spp., *Papio cynocephalus*, *Chlorocebus aethiops*, and *Cercopithecus mitis* (Bueno 2012; Gicheru *et al.* 2009; Ashford 1996). Nevertheless, the effect of this pathogen on primate populations is still poorly known. So far, one study described antibodies and infection with *Leishmania* in Brazilian wild *Sapajus* using serology and molecular methods, and a report showed a fatal natural case of visceral leishmaniasis in a captive black-fronted titi monkey in Southeast Brazil (*Callicebus nigrifrons*), with the development of clinical signs and lesions that were typical of visceral leishmaniasis (Bueno 2012; Malta *et al.* 2010).

The infection rate for *Trypanosoma cruzi* in *Sapajus flavius* was 16%. Natural *T. cruzi* infection occurs in numerous Neotropical primate species, including *Cebus*. The lesions mentioned most frequently in naturally occurring *T. cruzi* infections in primates are myocarditis and generalized edema without necrosis or hemorrhage (Toft and Eberhard 1998). Changes in electrocardiographic patterns were reported for Cebinae (Monteiro *et al.* 2006; Toft and Eberhard 1998), and captive individuals in the United States have died from locally acquired *T. cruzi* infection (Bern *et al.* 2011). *T. cruzi* transmission can occur by the bite or oral ingestion of infected hematophagous triatomid bugs that inhabit palm trees or sugar cane (Shikanai-Yasuda *et al.* 1991). For example, infection in lion tamarins (*Leontopithecus*) in Southeast Brazil is related to oral transmission and correlates with cardiac disorders (Benchimol 2006;

Monteiro *et al.* 2006). *Sapajus flavius* is a frugivore-insectivore and its diet includes a wide variety of fruits, seeds and arthropods, frogs, nestlings, and even small mammals (de Oliveira *et al.* 2015). Sugar cane is a fallback item in their diet (Valença-Montenegro 2011). Besides transmission by blood-sucking triatomids, the extractive and manipulative foraging typical of these monkeys indicates that they may also ingest infected triatomids. Supporting this potential source of infection, a human case of acute infection of *T. cruzi* was reported in Paraíba state via oral contamination due to eating cane juice contaminated with crushed infected bugs or possibly excretions from naturally infected marsupials (Shikanai-Yasuda *et al.* 1991).

We found the same prevalence of *Trypanosoma cruzi* infection for antibodies to *Leishmania* spp., and 62.5% of subjects (5/8) had antibodies against both *Leishmania* spp. and *T. cruzi.* This may be evidence of coinfection, or may be due to serological cross-reaction between *Leishmania* and other microorganisms (de Lima *et al.* 2010; Zanette *et al.* 2014). According to the Brazilian Ministry of Health Diseases Information System Notification (SINAN), 475 people in the state of Paraíba died of Chagas disease (*T. cruzi* infection) from 1996 to 2013; 142 were diagnosed with visceral leishmaniasis, and 319 with cutaneous leishmaniasis from 2007 to 2013 (Brazil, Ministério da Saúde 2016). These data show the circulation of these pathogens in Paraíba state, which corroborates the results mentioned in the preceding text for the population of *Sapajus flavius*.

We detected antibodies to *Toxoplasma gondii* in 12.5% of sera analyzed, and a higher chance of infection for females than males. Transmission of *T. gondii* can occur horizontally through ingestion of environmental oocysts in contaminated prey, soil, or water (Catão-Dias *et al.* 2013; Robert-Gangneux and Dardé 2012); thus this result can be explained by the monkeys' foraging behavior. More studies are needed, however, to determine whether the sex difference relates to females having greater access to, or a greater predilection for, vertebrate hosts, or more contact with soil than males, where there is greater likelihood of contact with feline feces (felids are the only animals capable of shedding oocysts in their feces and transmitting the parasite to the environment). *Cebus* and *Sapajus* do not show high mortality from *T. gondii* infection, unlike callitrichids, which show acute to hyperacute disease (Catão-Dias *et al.* 2013). Nevertheless, *Cebus* and *Sapajus* can show mild and nonspecific clinical signs, such as abortion and premature birth, with high and persistent IgG antibody titers (Catão-Dias *et al.* 2013; Epiphanio *et al.* 2003; Ferreira *et al.* 2015; Resing and Oerke 2005; Santos *et al.* 2014; Toft and Eberhard 1998). This pathogen could therefore affect recruitment and the population growth rate directly.

Primates show three distinct responses to *Toxoplasma gondii* (Catão-Dias *et al.* 2013). Pattern I, in which the disease is markedly severe with mortality close to 100% mortality, is observed mainly in the Callitrichinae (*Saguinus*, *Leontopithecus*, and *Callithrix*); pattern II is characterized by severe outbreaks, with variable mortality (described for Cebidae family); and pattern III is characterized by the induction of high and persistent IgG titers, mild clinical presentation, and low mortality. Pattern III could explain our findings, especially the presence of high titers found in one individual (>3200), but we should also consider host susceptibility, contact rates, and time since exposure. Contact with *T. gondii* may have occurred via interactions with feline feces, because *Sapajus flavius* frequently goes down to the understory or to the ground during both travel and feeding (Catão-Dias *et al.* 2013). Wild and domestic cats can enter the

forest and spread the protozoa, especially given that this area is fragmented and surrounded by agricultural farms (Molina *et al.* 2014). Another possibility is related to the feeding habits of *S. flavius*. *Sapajus* and *Cebus* have the most eclectic diets of all the Neotropical genera (Fragaszy *et al.* 2004). Their diets include a wide range of fruits and nuts and other plant parts, invertebrates, and small vertebrates. A study of feeding behavior of *S. flavius* in Gargau showed that 15% of the group's diet was made up of prey animals, such as marsupials (Rodrigues 2013), and some small mammals act as a reservoir for *T. gondii* (Siqueira *et al.* 2013). Thus, *T. gondii* infection in the population of *S. flavius* studied was probably due to food contamination.

Infection surveillance in primates, including Neotropical species, is important for public health malaria screening and control programs (Duarte *et al.* 2008; Guimarães *et al.* 2015; Hayakawa *et al.* 2009). Some studies indicate that some species, principally of the genera *Alouatta*, *Sapajus*, and *Cebus*, can be reservoirs for malaria in extra-Amazonian regions and especially in Atlantic Forest remnants (Alvarenga *et al.* 2015; Fandeur *et al.* 2000). Our findings show that despite the low prevalence (4%) and low risk of infection by *Plasmodium* (0.05), *P. brasilianum* occurs in *Sapajus flavius* in Engenho Gargau, but little is known of its impact on the monkeys. In general, *Plasmodium* does not manifest severe clinical symptoms in primates; however, it may be debilitating and stress can lead to overt disease (Toft and Eberhard 1998). Slight anemia may be associated with low-grade parasitemia in some individuals, but they appear outwardly normal (Bueno 2012; Bueno *et al.* 2013; Deane 1992; Tazi and Ayala 2011; Toft and Eberhard 1998). Clinical signs reported in primates infected with malaria consist of irritability, cyclic fever, depression, listlessness, anorexia, and weight loss (Toft and Eberhard 1998). However, this pathogen may have epidemiological importance for public health, as *Plasmodium* species infecting primates, namely *P. brasilianum* and *P. simium*, are genetically and morphologically similar to those affecting humans, *P. malariae* and *P. vivax*, respectively (Escalante *et al.* 1995; Fandeur *et al.* 2000; Tazi and Ayala 2011). To date, the malaria cases in humans in the state of Paraíba that are reported by Brazil's Ministry of Health are imported from endemic regions elsewhere (Brazil, Ministério da Saúde 2015). *Plasmodium malariae* is difficult to diagnose by examination of blood smears in humans, owing to low parasitemia and morphological similarity to *P. vivax* (Pina-Costa *et al.* 2014). Nevertheless, we found a *Plasmodium*-positive primate, which serves as an alert for the region and for people who live in the area, especially those in similarly fragmented and disturbed habitats.

There was a high prevalence of microfilariae infection in the population of *Sapajus flavius* in Engenho Gargau, with an infection risk of 0.46. More than 40 microfilariae species (*Dipetalonema* sp., *Dirofilaria immitis*, *Tetrapetalonema* sp., *Wuchereria* sp., and *Edesonfilaria* sp.) have been described in primates (Orihel and Seibold 1972). Of these, at least 14 species, 5 species of *Dipetalonema* and 9 species of *Mansonella*, occur in Neotropical primates, including marmosets, capuchins, squirrel monkeys, and owl monkeys (Toft and Eberhard 1998). The presence of microfilariae caused subclinical changes in infected *Callithrix jacchus*, despite the absence of clinical signs (Verona 2008), and some *Dipetalonema* species cause inflammatory responses in serous cavities (Orihel and Seibold 1972). However, few studies have examined the effect of this parasite on primates. More studies are necessary to understand which microfilaria species infect the population of *S. flavius* in our study site and if there is a risk for the study species or for public health.

Considering the small numbers of *Sapajus flavius* in the wild, and severely fragmented population, infectious diseases may pose an additional significant threat to their survival. The high density of *S. flavius* in this isolated small reserve (12 individuals/km^2) is propitious for conservation, but may favor disease transmission. More comparative data are needed to determine how representative the incidence of pathogens in this population is for the study species, and the likelihood of an epizootic event. Knowledge of the prevalence of zoonotic infectious diseases is essential for future management actions, such as translocations and reintroductions.

In conclusion, our results confirmed the existence of microfilariae, *Toxoplasma gondii*, *Trypanosoma cruzi*, *Leishmania* spp., and *Plasmodium brasilianum* (in order of infection risk) in *Sapajus flavius* in Engenho Gargau. We hope that our findings will inspire further long-term research on the clinical aspects and epidemiology of these pathogens on the demography of the few remaining populations of this species, contributing to efforts for their conservation as well to public health in the rural communities in the state of Paraíba, Brazil.

Data Availability

The datasets analyzed during the current study are available from the corresponding author on reasonable request.

Acknowledgments The authors thank the financial support by Fundação de Amparo à Pesquisa do Estado de São Paulo-FAPESP (09/51466-4; 09/53561-4) and Instituto Chico Mendes de Conservação da Biodiversidade (ICMBIO/CPB). We are grateful to Livia Abdalla (Programa Institucional Biodiversidade e Saúde, Fundação Oswaldo Cruz) for creating the map (Fig. 1). J. L. Catão-Dias, M. D. Laurenti, and S. M. Gennari are recipients of a fellowship from Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq). We are also grateful for the constructive comments made by the editor and reviewer and for the corrections and suggestions made by Dr. Anthony B. Rylands (Conservation International) for improving the paper.

References

Alvarenga, D. A. M., Pina-Costa, A., Sousa, T. N., Pissinatti, A., Zalis, M. G., et al (2015). Simian malaria in the Brazilian Atlantic Forest: First description of natural infection of capuchin monkeys (Cebinae subfamily) by *Plasmodium simium*. *Malaria Journal, 14*(81), 1–9.

Alves, C. J. (1995). *Influência de fatores ambientais sobre a Proporção de Caprinos Soro-reatores para a leptospirose em cinco centros de criação do Estado da Paraíba, Brasil*. Doctoral dissertation, Faculdade de Medicina Veterinária e Zootecnia da Universidade de São Paulo.

Ashford, R. W. (1996). Leishmaniasis reservoir and their significance in control. *Clinics in Dermatology, 14*, 523–532.

Baitchman, E. J., Calle, P. P., James, S. B., Linn, M. J., & Raphael, B. L. (2006). Leptospirosis in Wied's marmosets (*Callithrix kuhlii*). *Journal of Zoo and Wildlife Medicine, 37*, 182–185.

Barbosa, M. R. V. (1996). *Estudo florístico e fitossociológico da mata do Buraquinho, remanescente de Mata Atlântica em João Pessoa, PB*. Doctoral dissertation, Universidade Estadual de Campinas, São Paulo. Available from Universidade Estadual de Campinas; Biblioteca Digital da Unicamp; vtls000107407.

Benchimol, B. P. R. (2006). The oral transmission of Chagas' disease: An acute form of infection responsible for regional outbreaks. *International Journal of Cardiology, 112*(1), 132–133.

Bern, C., Kjos, S., Yabsley, M. J., & Montgomery, S. P. (2011). *Trypanosoma cruzi* and Chagas' disease in the United States. *Clinical Microbiology Reviews, 24*(4), 655–681.

Brandão-Filho, P., Campbell-Lendrum, D., Brito, M. E., Shaw, J. J., & Davies, C. R. (1999). Epidemiological surveys confirm an increasing burden of cutaneous leishmaniasis in northeast Brazil. *Transactions of the Royal Society of Tropical Medicine and Hygiene, 93*(5), 488–494.

Brazil, MAPA/SDA/DSA. (2006). Programa Nacional de Controle e Erradicação da Brucelose e da Tuberculose – PNCEBT 2006. Brasília: Ministério da Agricultura, Pecuária e Abastecimento (MAPA), Secretaria de Defesa Agropecuária (SDA), Departamento de Saúde Animal (DSA). www.adaptar.pr.gov.br/rquivos/File/GSA/PECEBT/MANUAL_PNCET.pdf. Accessed 16 June 2016.

Brazil, Ministério da Saúde. (2005). *Manual de diagnóstico laboratorial da malária*. Brasília: Secretaria de Vigilância em Saúde http://bvsms.saude.gov.br/bvs/publicacoes/malaria_diag_manual_final.pdf (Accessed Apr 11, 2016.

Brazil, Ministério da Saúde. (2015). Sistema de Informação de Agravos de Notificação. Brasília. http://dtr2004.saude.gov.br/sinanweb/tabnet/dh?sinannet/malaria/bases/malabrnet.def (Accessed Dec 15, 2015).

Brazil, Ministério da Saúde. (2016). Sistema de Informação de Agravos de Notificação. Brasília: Ministério da Saúde. http://www.datasus.gov.br/DATASUS/index.php?area=0203&id=29878153 (Accessed Mar 16, 2016).

Brazil, Ministério do Meio Ambiente. (2014). Portaria n° 444, de 17 de Dezembro de 2014. Atualização da lista nacional oficial de espécies da fauna ameaçadas de extinção. *Diário Oficial da União, Poder Executivo* 18 dezembro 2014. Seção 1, pp. 121–130.

Bueno, M. G. (2012). *Pesquisa de* Leishmania *spp. e* Plasmodium *spp. em primatas neotropicais provenientes de regiões de Mata Atlântica e Amazônia impactadas por ações antrópicas: Investigação* in situ e ex situ. Doctoral dissertation, Departamento de Patologia Faculdade de Medicina Veterinária e Zootécnica – Universidade de São Paulo.

Bueno, G. B., Rohe, F., Kirchgatter, K., Di Santi, S. M., Guimarães, L. O., et al (2013). Survey of *Plasmodium* spp. in free-ranging Neotropical primates from the Brazilian Amazon region impacted by anthropogenic actions. *EcoHealth, 10*, 48–53.

Catão-Dias, J. L., Epiphanio, S., & Kierulff, M. C. M. (2013). Neotropical primates and their susceptibility to *Toxoplasma gondii*: New insights for an old problem. In J. F. Brinkworth & E. Pechenkina (Eds.), *Primates, pathogens, and evolution* (pp. 253–289). Developments in Primatology: Progress and Prospects. New York: Springer Science + Business Media.

Cook, R. A., & Karesh, W. B. (2008). Emerging diseases at the interface of people, domestic animals and wildlife. In M. E. Fowler & R. E. Miller (Eds.), *Zoo and wild animal medicine: Current therapy* (pp. 55–65). St. Louis: Saunders-Elsevier.

Cross, P. C., Drewe, J., Patrek, V., Pearce, G., Samuel, M. D., & Delahay, R. J. (2009). Wildlife population structure and parasite transmission: Implications for disease management. In R. J. Delahay, G. C. Smith, & M. R. Hutchings (Eds.), *Management of disease in wild mammals* (pp. 1–15). Tokyo: Springer.

Daszak, P., Cunningham, A. A., & Hyatt, A. D. (2000). Emerging infectious diseases of wildlife: Threats to biodiversity and human health. *Science, 287*, 443–449.

de Lima, V. M., Fattori, K. R., Michelin, A. F., Silveira, D., Neto, L., & Vasconcelos, R. O. (2010). Comparison between elisa using total antigen and immunochromatography with antigen rK39 in the diagnosis of canine visceral leishmaniasis. *Veterinary Parasitology, 173*(3–4), 330–333.

de Oliveira, M. M., Boubli, J. P., & Kierulff, M. C. M. (2015). *Cebus flavius*. The IUCN Red List of Threatened Species. Version 2014.3. www.iucnredlist.org (Accessed Mar 20, 2016).

Dean, A. G., Sullivan, K. M., & Soe, M. M. (2013). OpenEpi: Open source epidemiologic statistics for public health, version. http://www.openepi.com/Menu/OE_Menu.htm (Updated April 5, 2013; accessed Feb 16, 2017).

Deane, L. M. (1992). Simian malaria in Brazil. *Memórias do Instituto Oswaldo Cruz, 87*(3), 1–20.

Deem, S. L., Karesh, W. B., & Weisman, W. (2001). Putting theory into practice: Wildlife health in conservation. *Conservation Biology, 15*, 1224–1233.

Dobson, A. J., & Barnett, A. G. (2002). *An introduction to generalized linear models*. Boca Raton: Chapman & Hall/CRC.

Dória, J. D., Silva, A. G., & Costa, A. R. (1974). Leptospirose: Presença de aglutininas anti-leptospira no soro de saguis (*Callithrix penicillata*) no Estado da Bahia. *Boletim do Instituto de Biologia da Bahia, 13*, 148–149.

dos Santos, L. C., Curotto, S. M. R., & Moraes, W. (2009). Detection of *Plasmodium* sp. in capybara. *Veterinary Parasitology, 163*, 148–151.

Duarte, A. M. R. C., Malafronte, R. S., Cerutti Jr., C., Curado, I., Paiva, B. R., et al (2008). Natural *Plasmodium* infections in Brazilian wild monkeys: Are reservoirs for human infections? *Acta Tropica, 107*(2), 179–185.

Dubey, J. P., & Desmonts, G. (1987). Serological responses of equids fed *Toxoplasma gondii* oocysts. *Equine Veterinary Journal, 19*, 337–339.

Epiphanio, S., Sa, L. R. M., Teixeira, R. H. F., & Catão-Dias, J. L. (2000). Toxoplasmosis in a wild caught black lion tamarin (*Leontopithecus chrysopygus*). *Veterinary Records, 149*, 627–628.

Epiphanio, S., Sinhorini, I. L., & Catão-Dias, J. L. (2003). Pathology of toxoplasmosis in captive New World primates. *Journal of Comparative Pathology, 129*, 196–204.

Escalante, A. A., Barrio, E., & Ayala, F. J. (1995). Evolutionary origin of human and primate malarias: Evidence from the circumsporozoite protein gene. *Molecular Biology and Evolution, 12*(4), 616–626.

Estrada, A., Garber, P., Rylands, A. B., Roos, C., Fernandez-Duque, E., et al (2017). Impending extinction crisis of the world's primates: Why primates matter. *Science Advances, 3*, e1600946.

Fandeur, T., Volney, B., Peneau, C., & De Thoisy, B. (2000). Monkeys of the rainforest in French Guiana are natural reservoirs for *P. brasilianum/P. malariae* malaria. *Parasitology, 120*, 11–21.

Ferreira, D. R. A., Laroque, P. O., Wagner, G. C., Higino, S. S. S., Azevedo, S. S., et al (2011). Occurrence of antibodies and risk factors associated with *Leptospira* spp. infection in capitivity *Cebus* spp. from Northeast of Brazil. *Pesquisa Veterinária Brasileira, 31*(11), 1019–1023.

Ferreira, D. R. A., Ribeiro, V. O., Laroque, P. O., Wagner, P. G. C., Pinheiro Júnior, J. W., et al (2015). Risk factors associated with *Toxoplasma gondii* infection in captive *Sapajus* spp. *American Journal of Primatology, 7*(5), 558–562.

Fialho, M. S., & Gonçalves, G. F. (2008). Primatas da RPPN Gargaú, Paraíba, Brasil. *Neotropical Primates, 15*(2), 50–54.

Fialho, M. S., Valença-Montenegro, M. M., da Silva, T. C. F., Ferreira, J. G., & Laroque, P. O. (2014). Ocorrência de *Sapajus flavius* e *Alouatta belzebul* no Centro de Endemismo Pernambuco. *Neotropical Primates, 21*(2), 214–218.

Fragaszy, D. M., Visalberghi, E., & Fedigan, L. M. (2004). *The complete capuchin: The biology of the genus Cebus*. Cambridge: Cambridge University Press.

Garcia, J. L., Svoboda, W. K., Chryssafidis, A. L., Malanski, L. S., Shiozawa, M. M., et al (2005). Sero-epidemiological survey for toxoplasmosis in wild New World monkeys (*Cebus* spp.; *Alouatta caraya*) at the Paraná river basin, Paraná State, Brazil. *Veterinary Parasitology, 133*, 307–311.

Gibson, S. V. (1998). Bacterial and mycotic disease of nonhuman primates. In T. Bennett, C. R. Abee, & R. Henrickson (Eds.), *Nonhuman primates in biomedical research*, *Diseases* (Vol. 2, pp. 105–172). London: Elsevier Academic Press.

Gicheru, M. M., Jeneby, M. M., Macharia, J. C., Carlsson, H. E., & Suleman, M. A. (2009). Prevalence of antibodies and cell mediated immune response against *Leishmania major* in feral nonhuman primates from Kenya. *Acta Tropica, 109*, 136–140.

Guimarães, L. O., Wunderlich, G., Alves, J. M., Bueno, M. G., Röhe, F., et al (2015). Merozoite surface protein-1 genetic diversity in *Plasmodium malariae* and *Plasmodium brasilianum* from Brazil. *BMC Infectious Diseases, 15*, 529.

Hayakawa, T., Nobuko, A., Toshifumi, U., Hiroshisa, H., Sattabongkot, J., et al (2009). Identification of *Plasmodium malariae*, a human malaria parasite, in imported chimpanzees. *PLoS ONE, 4*(10), e7412.

Hershkovitz, P. (1987). A history of the recent mammalogy of the Neotropical region from 1492 to 1850. *Fieldiana, Zoology, New Series, 39*, 11–98.

Jones, K. E., Patel, N. G., Levy, M. A., Storeygard, A., Balk, D., et al (2008). Global trends in emerging infectious diseases. *Nature, 451*, 990–993.

Karesh, W. B., Wallace, R. B., Painter, R. L. E., Rumiz, D., Braselton, W. E., et al (1998). Immobilization and health assessment of free-ranging black spider monkeys (*Ateles paniscus chamek*). *American Journal of Primatology, 44*, 107–123.

Kock, R. A., Woodford, M. H., & Rossiter, P. B. (2010). Disease risk associated with the translocation of wildlife. *Revue Scientifique et Technique, 29*(2), 329–350.

Leighton, F. A., & Kuiken, T. (2001). Leptospirosis. In E. S. Williams & I. K. Barker (Eds.), *Infectious diseases of wild mammals* (pp. 498–501). Ames: Iowa State University Press.

Leite, R. M. H., Thompson, I. A., Gonçalves, V. S. P., Leite, R. C., Bandeira, D. A., & Lage, A. P. (2003). A random sample survey of bovine brucellosis in the State of Paraíba, Brazil. *Brazilian Journal of Veterinary Research and Animal Science, 40*, 170–174.

Lima, P. J., & Heckendorff, W. D. (1985). Climatologia. In Governo do Estado da Paraíba, Secretaria de Educação, Universidade Federal da Paraíba (Ed.), *Atlas geográfico do estado da Paraíba* (pp. 34–44). João Pessoa: Grafset.

Lynch Alfaro, J., Silva Jr., J. S., & Rylands, A. B. (2012). How different are robust and gracile capuchin monkeys? An argument for the use of *Sapajus* and *Cebus*. *American Journal of Primatology, 74*, 273–286.

Mackenstedt, U., Jenkins, D., & Romig, T. (2015). The role of wildlife in the transmission of parasitic zoonoses in peri-urban and urban areas. *International Journal for Parasitology: Parasites and Wildlife, 4*(1), 71–79.

Malta, M. C., Tinoco, H. P., Xavier, M. N., Vieira, A. L., Costa, E. A., & Santos, R. L. (2010). Naturally acquired visceral leishmaniasis in non-human primates in Brazil. *Veterinary Parasitology, 169*, 193–197.

Marcgrave, G. (1648). *Historiae rerum naturalium Brasiliae*, Libro VI (pp. 221–244). Leiden: Ioanes de Laet, Elzevier.

Mense, M. G., Borschel, R. H., Wilhelmsen, C. L., Pitt, M. L., & Hoover, D. L. (2004). Pathologic changes associated with brucellosis experimentally induced by aerosol exposure in rhesus macaques (*Macaca mulatta*). *American Journal of Veterinary Research, 65*, 644–652.

Molina, C. V., Catão-Dias, J. L., Ferreira Neto, J. S., Vasconcellos, S. A., Gennari, S. M., et al (2014). Sero-epidemiological survey for brucellosis, leptospirosis, and toxoplasmosis in free-ranging *Alouatta caraya* and *Callithrix penicillata* from São Paulo state, Brazil. *Journal of Medical Primatology, 43*, 197–201.

Monteiro, R. V., Baldez, J., Dietz, J., Baker, A., Lisboa, V. C., & Jansen, A. M. (2006). Clinical, biochemical, and electrocardiographic aspects of *Trypanosoma cruzi* infection in free-ranging golden lion tamarins (*Leontopithecus rosalia*). *Journal of Medical Primatology, 135*, 48–55.

Nunn, C. L., & Altizer, S. M. (2005). The global mammal parasite database: An online resource for infectious disease records in wild primates. *Evolutionary Anthropology, 14*, 1–2.

Nunn, C. L., & Gillespie, T. R. (2016). Infectious disease and primate conservation. In S. A. Wich & A. J. Marshall (Eds.), *An introduction to primate conservation* (pp. 157–173). Oxford: Oxford University Press.

Oliveira, M. M., & Langguth, A. (2006). Rediscovery of Marcgrave's capuchin monkey and designation of a neotype for *Simia flavia* Schreber, 1774 (Primates, Cebidae). *Boletim do Museu Nacional, 523*, 1–16.

Orihel, T. C., & Seibold, H. R. (1972). Nematodes of the bowel and tissues. In R. N. T. W. Fiennes (Ed.), *Pathology of simian primates. Part II: Infectious and parasitic diseases (pp. 76–103). London: S.* Karger.

Osofsky, S. A., Kock, R. A., Kock, M. D., Kalema-Zikusoka, G., Grahn, R., *et al.* (2005). Building support for protected areas using a 'one health' perspective. In J. A. McNeely (Ed.), *Friends for life: New partners in support of protected areas (pp. 65–79).* Gland: IUCN.

Percy, D. H., Egwu, N., & Jonas, A. M. (1972). Experimental *Brucella canis* infection in the monkey (*Macaca arctoides*). *Canadian Journal of Comparative Medicine, 36*, 221–225.

Perkins, S. L., & Schall, J. J. (2002). A molecular phylogeny of malarial parasites recovered from cytochrome *b* gene sequences. *Journal of Parasitology, 88*, 972–978.

Perolat, P., Poingt, J. P., Vie, J. C., Jouaneau, C., Baranton, G., et al (1992). Occurrence of severe leptospirosis in a breeding colony of squirrel monkeys. *The American Journal of Tropical Medicine and Hygiene, 46*, 538–545.

Pina-Costa, A., Brasil, P., Di Santi, S. M., Araujo, M. P., Suárez-Mutis, M. C., et al (2014). Malaria in Brazil: What happens outside the Amazonian endemic region. *Memórias do Instituto Oswaldo Cruz, 109*(5), 618–633.

Pontes, A. R. M., Malta, A., & Asfora, P. H. (2006). A new species of capuchin monkey, genus *Cebus erxleben* (Cebidae, Primates): Found at the very brink of extinction in the Pernambuco Endemism Centre. *Zootaxa, 1220*, 1–12.

R Core Team. (2015). R: A language and environment for statistical computing. Vienna: R Foundation for Statistical Computing. http://www.R-project.org/ (Accessed May 20, 2016).

Resing, S., & Oerke, A. K. (2005). Husbandry and management of New World species: Marmosets and tamarins. In S. Wolfe-Coote (Ed.), *The laboratory primate* (pp. 145–162). London: Elsevier Academic Press.

Robert-Gangneux, F., & Dardé, M. L. (2012). Epidemiology of and diagnostic strategies for toxoplasmosis. *Clinical Microbiology Reviews, 25*, 264–296.

Rodrigues, K. C. (2013). *Padrão de atividades, comportamento alimentar, exploração de habitat e área de vida de Um grupo de* Sapajus flavius *(Schreber, 1774) (Primates, Cebidae)*. Dissertation, Universidade Federal da Paraíba. http://tede.biblioteca.ufpb.br:8080/handle/tede/7631 (Accessed May 10, 2016).

Santos, S. V., Strefezzi, R. F., Pissinatti, A., Kanamura, C. T., Takakura, C. F. H., et al (2014). Detection of *Toxoplasma gondii* in two southern wooly spider monkeys (*Brachyteles arachnoides* – Geoffroy, 1806) from the Rio de Janeiro Primate Center, Brazil. *Journal of Medical Primatology, 43*, 125–129.

Schlabritz-Loutsevitch, N. E., Whatmore, A. M., Quance, C. R., Koylass, M. S., Cummins, L. M., et al (2009). A novel *Brucella* isolate in association with two cases of still-birth in non-human primates: First report. *Journal of Medical Primatology, 38*, 70–73.

Schreber, J. C. D. (1774). *Die Säugthiere in Abbildungen nach der Natur mit Beschreibungen.* Erlangen: Theil 1, Heft 4, pp. 57–64, pls. 27–34.

Shikanai-Yasuda, M. A., Marcondes, C. B., Guedes, L. A., Siqueira, G. S., Barone, A. A., et al (1991). Possible oral transmission of acute Chagas' disease in Brazil. *Revista do Instituto de Medicina Tropical de São Paulo, 33*(5), 351–357.

Silveira, T. F., Moraes, M. A. P., Lainson, R., & Shaw, J. J. (1990). Leishmaniose cutânea experimental III: Aspectos histopatológicos do comportamento evolutivo da lesão cutânea produzida em *Cebus apella* (Primates: Cebidae) por *Leishmania* (*Viannia*) *lainsoni*, *L.* (V.) *braziliensis* e *L. (Leishmania*) *amazonensis*. *Revista de Medicina Tropical, 32*(6), 387–394.

Siqueira, D. B., Aléssio, F. M., Mauffrey, J. F., Marvulo, M. F., Ribeiro, V. O., et al (2013). Seroprevalence of *Toxoplasma gondii* in wild marsupials and rodents from the Atlantic Forest of Pernambuco state, Northeastern Region, Brazil. *Journal of Parasitology, 99*(6), 1140–1143.

Smith, K. F., Acevedo-Whitehouse, K., & Pedersen, A. B. (2009). The role of infectious diseases in biological conservation. *Animal Conservation, 12*, 1–12.

Souza Jr., M. F., Lobato, Z. I. P., Lobato, F. C. F., Moreira, E. C., Oliveira, R. R., et al (2006). Presença de anticorpos da classe IgM de *Leptospira interrogans* em animais silvestres do Estado do Tocantins. *Revista da Sociedade Brasileira de Medicina Tropical, 39*(3), 292–294.

Suzán, G., Esponda, F., Carrasco-Hernández, R., & Aguirre, A. (2012). Habitat fragmentation and infection disease ecology. In A. A. Aguirre, R. O. Ostfeld, & P. Daszak (Eds.), *New directions in conservation medicine, applied cases of ecological health* (pp. 135–150). Oxford: Oxford University Press.

Tabarelli, M., Melo, M. D. V. C., & Lira, O. C. (2006). Nordeste e Estados do Nordeste, menos Sergipe. In M. Campanili & M. Prochnow (Eds.), *Mata Atlântica: Uma rede pela floresta* (pp. 149–164). Brasília: Rede de ONGs da Mata Atlântica (RMA).

Tazi, L., & Ayala, F. J. (2011). Unresolved direction of host transfer of *Plasmodium vivax* v. *P. simium* and *P. malariae* v. *P. brasilianum*. *Infection*. *Genetics and Evolution, 11*, 209–221.

Thorne, E. T. (2001). Brucellosis. In E. S. Williams & I. K. Barker (Eds.), *Infectious diseases of wild mammals* (pp. 372–395). Ames: Iowa State University Press.

Toft, J. D., & Eberhard, M. L. (1998). Parasitic diseases. In T. Bennett, C. R. Abee, & R. Henrickson. *Nonhuman primates in biomedical research*, Vol. 2: *Diseases* (pp. 111–206). London: Elsevier Academic Press.

Umezawa, E. S., Nascimento, M. S., Kesper, J. R., Coura, J. R., Borges-Pereira, J., et al (1996). Immunoblot assay using excreted-secreted antigens of *Trypanosoma cruzi* in serodiagnosis of congenital, acute, and chronic Chagas' disease. *Journal of Clinical Microbiology, 34*(9), 2143–2147.

Valença-Montenegro, M. (2011). *Ecologia de* Cebus flavius *(Schreber, 1774) em Remanescentes de Mata Atlântica no Estado da Paraíba*. Doctoral dissertation, Universidade de São Paulo, Piracicaba. http://www.teses.usp.br/teses/disponiveis/91/91131/tde-20122011-143229/pt-br.php (Accessed Mar 14, 2016).

Valença-Montenegro, M. M., Bezerra, B. M., Martins, A. B., & Fialho, M. S. (2015). Avaliação do Risco de Extinção de *Sapajus flavius* (Schreber, 1774) no Brasil. Processo de avaliação do risco de extinção da fauna brasileira. ICMBio. http://www.icmbio.gov.br/portal/biodiversidade/fauna-brasileira/lista-de-especies/7272-mamiferos-sapajus-flavius-macaco-prego-galego.html (Accessed Feb 24, 2017).

Verona, C. E. S. (2008). *Parasitos em sagüi-de-tufo-branco* (Callithrix jacchus) *no Rio de Janeiro*. Doctoral dissertation, Fundação Oswaldo Cruz, Escola Nacional de Saúde Pública Sérgio Arouca, Rio de Janeiro. http://arca.icict.fiocruz.br/handle/icict/4462 (Accessed Mar 14, 2016).

WHO. (2010). Control of the leishmaniases: Report of a meeting of the WHO Expert Committee on the Control of Leishmaniasis, Geneva, 22–26 March. Rome: World Health Organization (WHO). http://whqlibdoc.who.int/trs/WHO_TRS_949_eng.pdf (Accessed Mar 17, 2016).

Wilson, D. E. (1936). The pathogenicity of Tanganyika strains of *Brucella abortus* and *B. melitensis* for a local species of monkey (*Cercopithecus* sp.) *Journal of Hygiene, 36*(1), 125–127.

Wolfe, N. D., Escalante, A. A., Karesh, W. B., Kilbourn, A., Spielman, A., & Lal, A. A. (1998). Wild primate populations in emerging infectious disease research: The missing link? *Emerging Infectious Diseases, 4*, 149–158.

Yingst, S. L., Huzella, L. M., Chuvala, L., & Wolcott, M. (2010). A rhesus macaque (*Macaca mulatta*) model of aerosol-exposure brucellosis (*Brucella suis*): Pathology and diagnostic implications. *Journal of Medical Microbiology, 59*, 724–730.

Zanette, M. F., Lima, V. M. F., Laurenti, M. D., Rossi, C. N., Vides, J. P., et al (2014). Serological cross-reactivity of *Trypanosoma cruzi*, *Ehrlichia canis*, *Toxoplasma gondii*, *Neospora caninum* and *Babesia canis* to *Leishmania infantum chagasi* tests in dogs. *Revista da Sociedade Brasileira de Medicina Tropical, 47*(1), 105–107.