ASSOCIATIONS BETWEEN BIOMASS, BODY CONDITION AND BLOOD PARASITISM IN AVIAN SPECIES FROM BRAZILIAN CERRADO

ABSTRACT

Blood parasites can infect innumerous avian species affecting the fitness and survival of their hosts. There is a wide interspecific variation in the parasites prevalence related to biological, ecological and evolutionary hosts factors. This study aimed to determine the blood parasites prevalence in avian species from Brazilian Cerrado and to investigate the associations between biomass, body condition and blood parasitism. A total of 1,098 blood smears from 549 individuals (56 species) collected in four forest fragments were analyzed. Of these, 109 (19.85%) individuals from 33 species were infected: 13 (2.36%) were positive for *Haemoproteus* and 103 (18.76%) for *Plasmodium*. There was co-infection between both genera of parasites in seven individuals. Among bird species, prevalence ranged from zero to 100%. Positive and significant correlations between prevalence and biomass and body condition index were found. Hemosporids vectors track their hosts by CO_2 detection. Since great organisms emit more CO_2, our results suggest that larger birds may be more susceptible to hemosporids vectors. In addition, species with higher body condition indices can be more tolerant to parasites, possibly because they have more energy reserves. This study showed that species with higher biomass and body condition indices were associated with higher blood parasites prevalence, suggesting that these factors are efficient predictors to explain the interspecific variations. This information could be important for the understanding of parasite-host relationships, and useful for bird conservation programs.

Key-Words: avian malaria, wild birds, *Plasmodium*, *Haemoproteus*, host-parasite relationship.

INTRODUCTION

Parasitism is an ecological relation that affects the dynamics and evolution of animal populations, exerting selective forces such important as predation and competition. Protozoan hemosporids of the genus *Haemoproteus* and *Plasmodium* are considered model organisms for understanding evolutionist and ecological theories, because they have a wide geographic distribution and parasite several types of vertebrate hosts. These parasites are considered threats to species conservation, especially when introduced into populations not adapted to them. In this sense, they are able to promote population declines and extinctions, and may affect the structure of the host communities.

In birds, hemosporids can occur in several species, however, impacts are difficult to estimate in natural populations, and especially in areas where they are common and hosts are adapted. Despite this, many species of *Haemoproteu*s and *Plasmodium* are responsible for acute and/or chronic infections in domestic and wild birds. Such infections can be pathogenic, causing host deaths, or reducing physical and reproductive birds' aptitudes by commitment various factors, including neural development, vocalization, and sexual selection.

These parasites are transmitted by hematophagous insects (Diptera: Culicidae, Ceratopogonidae, Hippoboscidae, Simuliidae) and present a complex development cycle, which includes asexual reproduction in birds tissues and sexual reproduction in dipterans gut. Vectors have great abundance and diversity in tropical environments (Nunn et al. 2005), where great hemosporids diversity can also be verified. However, vectors generally do not occur in arid, high altitude and low temperature environments, which explain the hemosporids absence in avian species from these locations. Therefore, it can be affirmed that vectors play a fundamental role in the hemosporids infection maintenance in birds' populations and communities.

There is a great variation in hemosporids prevalence among avian species in a community. The interspecific differences have been attributed to biological, ecological and evolutionary hosts' factors, as well as aspects related to the vectors ecology. In this sense, hemosporids prevalence variations can be related to different forms that host species deal with infection, controlling or maintaining it. In addition, it can be also related to factors that cause differential birds' exposure to the vectors.

Heavier birds may be more susceptible to vectors since larger organisms can emit greater amount of CO_2, which is the main chemical compound used by the vectors to track their hosts. Birds with higher biomasses are usually related to higher body condition indices.

These indices are measurements of the organisms' fitness, and may indicate capacity to store energy. Parasitic infections are factors that can negatively affect the birds' body condition, due to the high energy cost in controlling them. However, in some host species, the infection does not affect their body condition, suggesting there are species that present greater tolerance to parasites than others.

This study aimed to determine the blood parasites prevalence in avian species from Brazilian Cerrado and to investigate the relationship between biomass, body condition and blood parasitism.

MATERIAL AND METHODS

Study site

The study was carried out in four seasonal semideciduous forest areas in the Triângulo Mineiro region, Minas Gerais State, Brazil. The region is located in the Cerrado biome, but highly impacted, with more than 70% of the area occupied by agriculture and livestock. The climate of the region is Aw type according to Köppen classification, characterized by a marked seasonality, with rainy and dry seasons. The annual rainfall is around 1,500 mm and the average temperature is 22ºC. The forest fragments studied were situated in: 1. Mata da Água Fria Farm: in the Araguari municipality, with 200 hectares. 2. RPPN Galheiro: in Perdizes municipality, with 260 hectares. 3. Glória Experimental Farm (Federal University of Uberlândia) and 4. São José Farm: both in Uberlândia municipality, with 30 and 20 hectares, respectively.

Capture of birds

A total of 549 individual birds belonging to 56 species and 21 families were captured from June/2013 to December/2015. Birds were captured using 20 to 25 mist nets exposed in tracks from 06:00 am to 17:00 pm, which were checked at 30 minutes intervals. Weight and tarsus length measurements were performed for all captured birds, using hand dynamometers and digital caliper, respectively. Individuals were identified according to Sigrist (2009) and marked with metal ring provided by the Research Center for Wild Birds Conservation in Brazil (CEMAVE/ICMBio). Nomenclature and systematic order were realized according to the Brazilian Committee of Ornithological Records.

Preparation and analysis of blood smears

Blood samples (5.0 µl) were collected from the tarsal-metatarsal veins using syringes with sterile and disposable needles. Duplicate blood smears were prepared, air-dried and fixed in absolute methanol. After staining with Giemsa's solution (5%), the slides were examined microscopically. Approximately 200 fields were screened using 100x objective and immersion oil. Hemosporids identifications were performed according to Valkiunas (2005) descriptions.

Statistical analyzes

To estimate the individuals' body condition, the Relative Mass Index (RMI) was calculated by a simple linear regression between logarithmic values of the right tarsus and biomass of birds. Regression residual values were used as RMI. To verify the relationship between hemosporids prevalence with biomass and body condition of avian species, Pearson correlations were used. Premise of normality was met by performing logarithmic transformations of the data. The analyses were made only for species that presented a minimum number of five individuals, conducted at a significance level of 5%, and performed on SYSTAT 10.2 software.

RESULTS

A total of 1,098 blood smears were analyzed in this study. The overall prevalence of hemosporids was 19.85%. For *Haemoproteus* spp. and *Plasmodium* spp., 13 (2.36%) and 103 (18.7%) birds were positive, respectively. Co-infection with both parasites genera was reported in seven individuals. The prevalence among species ranged from zero to 100%. A total of 23 species did not present any infected individuals whereas in five species all the individuals were infected. Of the 56 species analyzed, 33 (59%) showed positivity for *Plasmodium* spp., of them, six (10.7%) were also infected by *Haemoproteus* spp. (Table 1).

Table 1: Avian species examined and infected according to the parasites genera and the variables used in the statistical analyzes.

Taxa	Individuals:		Parasites:		Variables:	
	Examined	Infected (%)	*Haemoproteus*	*Plasmodium*	Biomass (g)	RMI

[1]: Species that were first recorded as hosts of hemosporids.

[2]: Species that presented individuals with co-infection by the two genera of parasites.

For statistical analysis, 485 individuals from 24 species were used (only species with five or more individuals). There was a positive and significant correlation between hemosporids prevalence and the average biomass values of the species ($r = 0.492$, $gl = 22$, $p = 0.014$), indicating that heavier avian species are more susceptible to hemosporids infection (Fig. 1). There was a positive and significant correlation between prevalence and the average RMI values of the species ($r = 0.679$, $gl = 22$, $p = 0.001$), demonstrating that infection probability may be higher in species with higher body condition indices (Fig. 2).

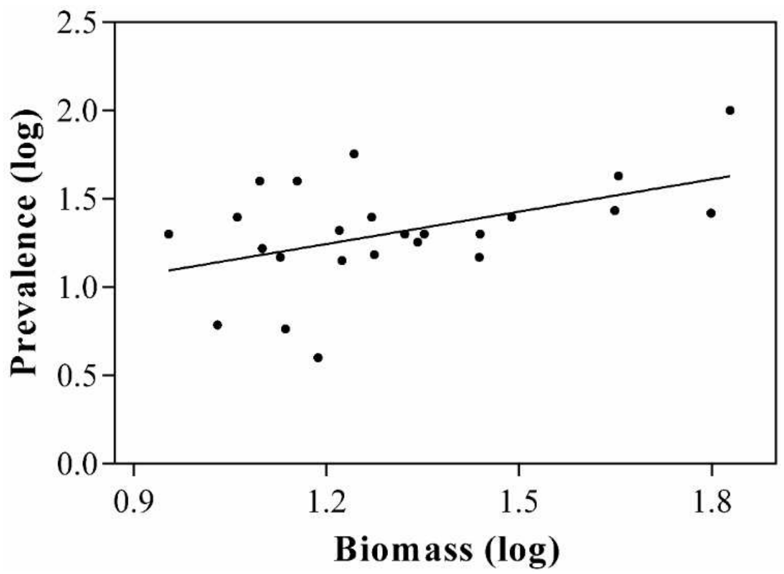

Fig. 1 Scatter plot demonstrating the positive correlation found between hemosporids prevalence and the average biomass of the avian species

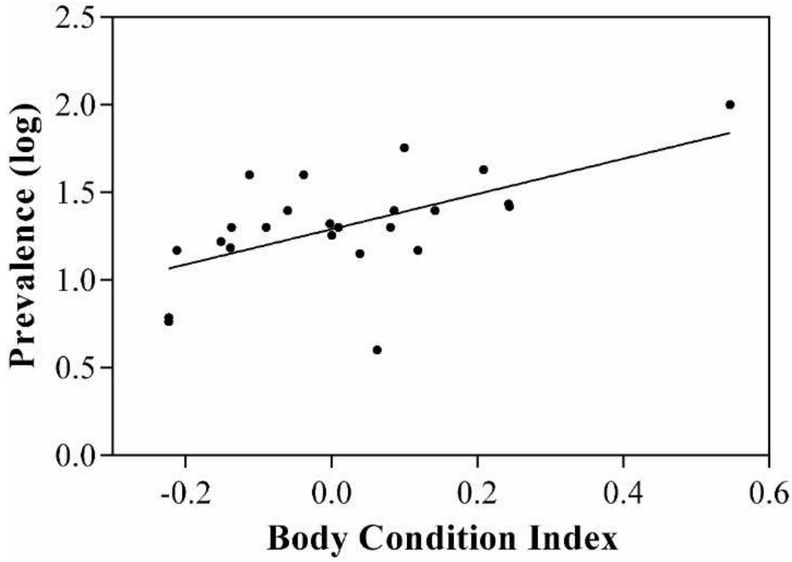

Fig. 2 Scatter plot demonstrating the positive correlation found between hemosporids prevalence and the body condition index of the avian species

DISCUSSION

This study demonstrated the presence of hemosporids in wild birds from Brazilian Cerrado. The prevalence recorded (19.85%) was comparable to prevalence found in earlier studies conducted in birds from the same biome (21%; 24.4%) but higher than the one found in social birds (10.7%). This is the first report of hemosporids in *Taraba major*, *Neopelma pallescens*, *Schiffornis virescens*, *Corythopis delalandi*, *Elaenia parvirostris*, *Arremon flavirostris* and *Myiothlypis leucophrys*. New hosts of hemosporids have been previously found in Brazil, indicating that although the Brazilian avifauna is one of the most diverse worldwide, basic information about several species is still unknown.

The prevalence of hemosporids among species ranged from zero to 100%. Great variation in the prevalence seems to be common in bird communities since this pattern has been earlier reported by several authors. Natural factors can be responsible for this amplitude once parasite prevalence in a community depends on a complex interaction between biotic and abiotic factors, including biological, ecological and behavioral host aspects and characteristics of habitat, vegetation and climate.

The relationship between hemosporids prevalence and average biomass of the species was positive and significant, corroborating the hypothesis that larger species are more susceptible to infection. In communities of birds from Cerrado, this association was previously tested by Fecchio et al. (2011), who found no relation, and by Lobato (2012), who verified that heavier birds were more infected. This relationship can be attributed to biological and behavioral characteristics of vectors and birds. The hematophagous insects locate their hosts visually, recognizing color and body shape; and olfactory, through the detection of carbon dioxide and lactic acid. In this sense, heavier birds may be more susceptible to be located by the vectors, since larger animals release more volatile compounds and can provide a larger surface area for foraging activity of the vectors.

In the present study, all individuals of *Monasa nigrifrons* (Black-fronted Nunbird), the species with the highest biomass recorded, were positive for hemosporids. This species lives in groups, use the "sit-and-wait" foraging behavior and nest in cavities on the ground or in gullies. These characteristics may improve the location of the animals by vectors. According to Fecchio et al. (2011), it is expected that more carbon dioxide is emitted in groups than by solitary individuals, and such compound can accumulate inside cavities, increasing the source of odor for the vectors.

The body condition analysis allows estimating the individual capacity to store energy resources and to survive adverse situations. Indices with negative values indicate worse body condition when compared to positive values. In a bird community from Cerrado, Baesse (2015) verified that heavier species exhibit higher body condition indices. Therefore, as in the current study the heavier species were related to higher parasites prevalence, it was expected that such relationship would also be found for species with higher body condition.

A positive relationship between infection and body condition was found. This relationship has been previously reported by other studies, suggesting that organisms with higher energy reserves are more tolerant to parasites because they provide more resources for parasites reproduction and development. However, there are reports of negative relationships, indicating commitment of host fitness since the energy used in hosts physiological and reproductive processes is redirected to the immune system to control parasite proliferation.

Probably there is a trade-off between host resistance and tolerance to parasites. The trade-off is understood as the costs and benefits of a particular biological strategy. Resistance refers to the ability of hosts to control infection, but at a high cost, while tolerance indicates ability to maintain parasites at the lowest cost. In an experimental study, Cornet et al. (2013) found that birds more resistant to parasitic infections were also less tolerant. According to Sorci (2013), there is a great interspecific variation in bird's propensity to be resistant or tolerant to parasites. It is likely that biological differences between species are one of the predictors in this variation. Heavier species with higher body condition indices may be more tolerant, as evidenced in the current study.

CONCLUSION

It was found a great variation in the hemosporids (*Plasmodium* and *Haemoproteus*) prevalence among avian species examined. The biomass and body condition indices were efficient to explain these variations. Species with higher biomass and body condition indices were related to higher hemosporids prevalence. Therefore, this study can be considered important for the understanding of host-parasite relationship and useful for bird conservation programs.