Gastrointestinal parasites in wild and exotic animals from a Zoobotanical Park in Northeast of Brazil

Parasitos gastrintestinais em animais silvestres e exóticos de um Parque Zoobotânico no Nordeste do Brasil

Parásitos gastrointestinales en animales salvajes y exóticos de un Parque Zoobotánico en el Noreste de Brasil

Abstract

One of the obstacles for ex situ conservation of wild and exotic animals are the diseases that affect them in captivity and, among them, the endoparasitoses, which are very frequent. The objective of this study is to report the occurrence of endoparasites in the fecal samples of animals from the Arruda Câmara Zoobotanical Park, at João Pessoa, Paraíba State, Brazil, as well as to identify significant statistical differences between the percentages of each parasite species found. To this end, 66 fecal samples were obtained from 50 species of animals including mammals, birds, and reptiles. Statistical differences between the percentages of each parasite species were obtained using the binomial test at 5%
significance level. A total of 54.5% (36/66) of the fecal samples were positive (p=0.539), among which 80.5% (29/36) presented nematodes, followed by cestodes 19.4% (07/36), protozoans 13.9% (05/36), and mites 16.7% (06/36). This study reports for the first time the association of Balantidium sp. with Tapirus terrestris, Bertiella sp. with Alouatta caraya, Hymenolepis spp., and Aspiculuris spp. as spurious parasites in reptiles; and Entamoeba coli and Eimeria spp. with Iguana iguana in the northeastern part of the country. This study provides knowledge about some of the endoparasites that may occur in zoos in the northeastern region of the country, as well as in expanding the ecological data on wild and exotic animals.

**Keywords:** Birds; Helminths; Mammals; Mini-FLOTAC; Protozoans.

**Resumen**

Un estudio de los obstáculos para la conservación ex situ de animales silvestres y exóticos son las enfermedades que los afectan en cautiverio y, entre ellas, la endoparasitosis, que son muy frecuentes. El objetivo de este estudio es reportar la ocurrencia de endoparasitosis en las muestras fecales de animales del Parque Zoológico Arruda Câmara, en João Pessoa, Paraíba, Brasil, así como identificar diferencias estatísticas significativas entre los porcentajes de cada especie de parásito encontrada. Para ello, se obtuvieron 66 muestras fecales de 50 especies de animales, incluidos mamíferos, aves y reptiles. Las diferencias estadísticas entre los porcentajes de cada especie de parásito se obtuvieron mediante la prueba binomial al nivel de significancia del 5%. Un total de 54,5% (36/66) de las muestras fecales resultaron positivas (p = 0,539), de las cuales 80,5% (29/36) presentaron nematodos, seguido de los cestodos 19,4% (07/36), protozoarios 13,9% (05/36), y ácaros 16,7% (06/36). Este estudio reporta por primera vez la asociación de Balantidium sp. con Tapirus terrestris, Bertiella sp. con Alouatta caraya, Hymenolepis spp. y Aspiculuris spp. como parasitas espúrios en reptiles; e Entamoeba coli y Eimeria spp. con Iguana iguana en el noreste del país. Este estudio brinda conocimiento sobre algunos de los endoparasitosis que pueden ocurrir en zoológicos de la región Nordeste del país, así como en la ampliación de los datos ecológicos sobre animales silvestres y exóticos.

**Palabras clave:** Aves; Helminitos; Mamíferos; Mini-FLOTAC; Protozoarios.

**1. Introduction**

Brazil is the fifth largest country in the world with great diversity of animal species. It is estimated that approximately 20% of all animal species live in this region, in different biomes such as the Atlantic Forest, Pampa, Cerrado, Pantanal, Amazon, and the Caatinga. Among the various types of association existing in nature, parasitism is common, and it is well known that at least half of all the animal taxa is parasitic (Instituto Chico Mendes de Conservação da Biodiversidade, 2017; Lima et al., 2017).

One of the obstacles for ex situ conservation of wild and exotic animals are the diseases that affect them in captivity. Among them, gastrointestinal endoparasitoses are very frequent, and the disease may present itself with or without evident clinical signs. The costs to the host may be negligible, substantial, or even unbearable, depending on the number of parasites, the species, the level of severity of the lesions they inflict, as well as on the vigor and nutritional status of the host. Knowing this, the costs of parasitism may include the loss of resources extracted by the parasite directly from the host and the energy spent by the host to maintain its vital actions. The consequences of these associations are usually linked to the decreased
reproductive and survival capacity of the hosts, therefore affecting their mortality and birth rates (Oliveira et al., 2011; Reed et al., 2012; Lima et al., 2017).

Parasitic diseases present a high prevalence in captive wild and exotic animals, since there is a high environmental contamination that result from keeping animals in confined areas. In addition, the stress caused by the captivity may decrease the resistance of these animals to parasitic diseases. In cases in which animals show signs of parasitic disease, these may range from lack of appetite, weight loss, disorders in the gastrointestinal tract, anemia, and hyperthermia, among others (Fagiolini et al., 2010; Oliveira et al., 2011; Reed et al., 2012).

Among the endoparasites that affect zoo animals, there are also many zoonotic species, therefore representing a public health problem, especially for the professionals and keepers who manage these specimens. Many nematodes that can be found in these animals are of medical concern, such as *Ancylostoma* sp., which can cause cutaneous larva migrans; and *Toxocara* sp., responsible for visceral larva migrans, ocular larva migrans, and cerebral toxocariasis in humans; both being endoparasites widely reported in carnivores. Further, it is also important to highlight the presence of cestodes such as *Hymenolepis* spp., *Taenia* spp., and *Bertiella* spp., which can be found both in primates and rodents, or even as spurious parasites in reptiles, for example. All of these parasites present medical interest and may cause diarrhea, abdominal pain, irritability, and weight loss (Fagiolini et al., 2010; Oliveira et al., 2011; Reed et al., 2012; Lima et al., 2017).

Thus, these sites should have efficient diagnostic techniques to carry out coproparasitological research in wild and exotic animals in zoos. Among these techniques, the Mini-FLOTAC allows the simultaneous diagnosis of helminth eggs/larvae and oocysts/cysts of protozoans, offering an advantage over other coproparasitological techniques. In addition, Mini-FLOTAC also allows the diagnosis of yeasts, such as *Macrorhabdus ornithogaster*, in bird feces (Cringoli et al., 2017).

All this knowledge provides new data on the parasites of these host species, contributing to a better understanding of the parasite-host relationships that occur in these environments. In addition, it also helps in the implementation of management, treatment, and control activities for the parasites that occur in these host species, contributing to the reduction in the number of zoonotic diseases in these parks (Fagiolini et al., 2010).

The present work aimed to report the occurrence of endoparasites in the feces of captive animals and in the animals that attended the Arruda Câmara Zoobotanical Park, João Pessoa, Paraíba, Brazil, as well as to identify the statistical differences between the percentages of the parasites found.

2. Methodology and Case Description

**Ethical aspects**

The project was submitted to the Ethics Committee on the Use of Animals in Research of the Universidade Federal Rural do Semi-Arido (UFERSA) (CEUA-UFERSA) and approved (Nº of opinion 11/2020). All the handling procedures of the animals followed the specific guidelines of the Brazilian College of Animal Experimentation.

**Study area**

The research was conducted at the Arruda Câmara Zoobotanical Park (ACZP), (CNPJ: 08.806.721/0001-03). This park is registered at the Brazilian Institute for the Environment and Renewable Natural Resources under the Registration No. 236567. It is popularly known as Bica, being located between the coordinates 292670mE and 293330mE, and between 921307mN and 921410mN, more precisely in the northern part of the municipality of João Pessoa. This park is set in a 26.4-hectare Atlantic Forest fragment, being the home to native and exotic flora and fauna species, distributed among different areas available for visitation (Figure 1).
Sampled animals

We analyzed 66 fecal samples from animals that were kept at the ACZP, João Pessoa-PB, as well as from wild animals that were attended, totaling 50 species. The fecal samples spontaneously eliminated by the animals were collected individually or in pools from the floor of the enclosure to avoid stressing the hosts and endangering the handlers of the animals.

Among the animals, the samples were collected from carnivorous felids such as *Panthera leo* (n=1), *Puma concolor* (n=2), *Puma yagouaroundi* (n=1), and *Leopardus pardalis* (n=3); procionids like *Nasua nasua* (n=6) and *Procyon cancrivorus* (n=5); primates like *Sapajus flavius* (n=5), *Sapajus libidinosus* (n=7), *Sapajus spp.* (n=3), *Saimiri sciureus* (n=1), *Alouatta caraya* (n=2), and *Chlorocebus aethiops* (n=2); artiodactyla such as *Pecari tajacu* (n=5); perissodactyla like *Tapirus terrestris* (n=1); birds like *Anodorhynchus hyacinthinus* (n=1), *Ara ararauna* (n=1), *Ara chloropterus* (n=1), *Amazona aestiva* (n=1), *Turdus sp.* (n=2), *Cacicus cela* (n=1), *Crax fasciolata* (n=2), *Patagioenas picazuro* (n=1), and *Rupornis magnirostris* (n=1); and the reptiles *Pantherophis guttatus* (n=7), *Bothrops erythromelas* (n=1), *Salvator merianae* (n=1), *Iguana iguana* (n=1), *Cheloonoidis sp.* (n=1), *Chelonoidis carbonaria* (n=1), and *Chelonoidis denticulata* (n=1) (Table 1).

| Common host name            | Scientific host name               | NA |
|-----------------------------|------------------------------------|----|
| Class Mammalia              |                                     |    |
| Order Carnivora             |                                     |    |
| Family Felidae              |                                     |    |
| Lion                        | *Panthera leo*                      | 1  |
| Jaguar                      | *Panthera onca*                     | 1  |
| Cougar                      | *Puma concolor*                     | 2  |
| Jaguarundi                  | *Puma yagouaroundi*                 | 1  |
| Oncilla                     | *Leopardus tigrinus*                | 1  |
| Ocelot                      | *Leopardus pardalis*                | 3  |
| Family Procyonidae          |                                     |    |
| South American coati        | *Nasua nasua*                       | 6  |
| Crab-eating racoon          | *Procyon cancrivorus*               | 5  |
| Family Mustelidae           |                                     |    |

Table 1 - Species of animals captive and cared for at the Arruda Câmara Zoobotanical Park (ACZP) used in the present study. NA: number of animals.
| Animal Type                  | Scientific Name                      | Number |
|-----------------------------|--------------------------------------|--------|
| Tayra                       | Eira barbara                         | 1      |
| Neotropical otter           | Lontra longicaudis                   | 2      |
| Crab-eating fox             | Cerdocyon thous                      | 3      |
| Order Primates              |                                      |        |
| Family Canidae              |                                      |        |
| Blond capuchin              | Sapajus flavus                       | 5      |
| Black-striped capuchin      | Sapajus libidinosus                  | 7      |
| Capuchin                    | Sapajus spp.                         | 3      |
| Common marmoset             | Callithrix jacchus                   | 1      |
| Common squirrel monkey      | Saimiri sciureus                     | 1      |
| Order Primates              |                                      |        |
| Family Cebidae              |                                      |        |
| Black howler                | Alouatta caraya                      | 2      |
| Order Artiodactyla          |                                      |        |
| Family Tayassuidae          |                                      |        |
| Collared pecary             | Pecari tajacu                        | 5      |
| Order Cervidae              |                                      |        |
| Family Cercopithecida       |                                      |        |
| Brown brocket               | Mazama gouazoupira                   | 1      |
| Order Perissodactyla        |                                      |        |
| Family Tapiridae            |                                      |        |
| South American tapir        | Tapirus terrestris                   | 1      |
| Order Pilosa                |                                      |        |
| Family Bradypodida          |                                      |        |
| Brown-throated sloth        | Bradypus variegatus                  | 3      |
| Class Aves                  |                                      |        |
| Order Psittaciformes        |                                      |        |
| Family Psittacidae          |                                      |        |
| Hyacinth macaw              | Anodorhynchus hyacinthinus           | 1      |
| Blue-and-yellow macaw       | Ara ararauna                         | 1      |
| Red-and-green macaw         | Ara chloropterus                     | 1      |
| Turquoise-fronted amazon   | Amazona aestiva                      | 1      |
| Red-shouldered macaw        | Diopsittaca nobilis cumanensis       | 4      |
| White-eyed parakeet         | Psittacara leucophthalmus            | 1      |
| Order Passeriformes         |                                      |        |
| Family Turdidae             |                                      |        |
| Thrush                      | Turdus sp.                           | 2      |
| Yellow-rumped cacique       | Cacicus cela                         | 1      |
| Order Galliformes           |                                      |        |
| Family Cracidae             |                                      |        |
| Typical guans               | Penelope sp.                         | 3      |
| Bare-faced curassow         | Crax fasciolata                      | 2      |
| Order Columbiformes         |                                      |        |
| Family Columbidae           |                                      |        |
| Picazuro pigeon             | Patagioenas picazuro                 | 1      |
| Order Accipitriformes       |                                      |        |
| Family Accipitridae         |                                      |        |
| Roadside Hawk               | Rupornis magnirostris                | 1      |
| Order Pelecaniformes        |                                      |        |
| Family Fregatidae           |                                      |        |
| Magnificent frigatebird     | Fregata magnificens                  | 1      |
| Order Anseriformes          |                                      |        |
| Family Anatidae             |                                      |        |
| Domestic goose              | Anser sp.                            | 1      |
| Order Piciformes            |                                      |        |
| Family Ramphastidae         |                                      |        |
White-throated toucan: *Ramphastos tucanus*  
Order Cariamiformes  
Family Cariamidae  
Red-legged seriema: *Cariama cristata*  
Class Lepidosauria  
Order Squamata  
Family Colubridae  
Corn snake: *Pantherophis guttatus*  
Family Boidae  
Rainbow boa: *Epicrates assisi*  
India rock python: *Python molurus*  
Green anaconda: *Eunectes murinus*  
Family Viperidae  
Caatinga lancehead: *Bothrops erythromelas*  
Family Teiidae  
Argentine black and white tegu: *Salvator merianae*  
Family Iguanidae  
Green iguana: *Iguana iguana*  
Class Archelosauria  
Order Testudines  
Family Testudinidae  
Tortoise: *Chelonoidis sp.*  
Red-footed tortoise: *Chelonoidis carbonaria*  
Yellow-footed tortoise: *Chelonoidis denticulata*  

Source: Personal archive.

**Laboratory Analysis**

The fecal samples were preserved in 5% formalin and sent to the Laboratory of Animal Parasitology (LAP) at the Universidade Federal Rural do Semi-Árido (UFERSA) for coproparasitological analysis. The techniques used were the direct method (Hoffmann, 1987), zinc sulfate flotation (Willis, 1921), spontaneous sedimentation (Hoffmann et al., 1934), and Mini-FLOTAC (Cringoli et al., 2012; 2013; 2017). The Mini-FLOTAC technique (Cringoli et al., 2012; 2013; 2017) was used to determine the parasite load since it is a quantitative method for obtaining EPG (eggs per gram of stool), OPG (oocysts per gram of stool), CPG (cysts per gram of stool), LPG (larvae per gram of stool), and TPG (trophozoites per gram of stool) values, with 10 as the conversion factor.

Photographs of the endoparasites found were taken with a digital camera and the classification was made according to specific literature, such as Foreyt (2002).

**Statistical analysis**

The data were collected in a table and then transferred to the statistical program SPSS (Statistical Page for Social Sciences) version 23.0. They were expressed as simple frequency and percentage of parasites and compared among them for significant statistical differences using the binomial test for homogeneous proportions. The significance level was set at 5%.

**3. Results**

Of the total number of analyzed fecal samples (n=66), 54.5% (36/66) were positive (p=0.539), with single parasitism being observed in 52.8% (n=19) of the animals and multiple parasitism in 47.2% (n=17). Of these 36 positive samples, 44.4% were from mammals, in which 37.4% corresponded to the order Carnivora; 50.0% to the order Primates; 6.3% were from the order Artiodactyla; and 6.3% from Perissodactyla. Birds corresponded to 25.0% of the positive samples, with 44.5% Psittaciformes, 22.2% Passeriformes, 11.1% Galliformes, 11.1% Columbiformes, and 11.1% Accipitriformes. Finally, reptiles represented 30.6% of the positive samples, with 75.0% belonging to the order Squamata and 25.0% to the order Testudines (Table 2).
Table 2 - Endoparasites found at the Arruda Câmara Zoobotanical Park (ACZP). EPG: eggs per gram of stool. LPG: larvae per gram of stool. CPG: cysts per gram of stool. OPG: oocysts per gram of stool. TPG: trophozoites per gram of stool.

| Host                        | Origin | Result                                                                 |
|-----------------------------|--------|------------------------------------------------------------------------|
| Panthera leo                | ACZP   | Eggs of Toxascaris leonina                                              |
| Puma concolor               | ACZP   | Eggs of Toxocara sp. (40 EPG)                                          |
| Puma yagourouundi           | ACZP   | Eggs of Toxocara sp. (400 EPG)                                         |
| Leopardus pardalis          | Free-living | Eggs of Strongyloides sp. (10 EPG) and Rhabditida-type larvae (10 LPG). |
| Nasua nasua                 | ACZP   | Cestoda-type eggs (70 EPG), eggs of Strongyloides sp., Ancylostomatidae-type eggs, and Rhabditida-type larvae (30 LPG). |
| Procyon cancrivorus         | ACZP   | Eggs of Strongyloides sp. (200 EPG), Ancylostomatidae-type eggs (30 EPG), and Rhabditida-type larvae (70 LPG). |
| Tapirus terrestris          | ACZP   | Eggs of Strongyloides sp. (240 EPG), Ancylostomatidae-type eggs (50 EPG), and Rhabditida-type larvae (50 LPG). |
| Sapajus flavus              | ACZP   | Eggs of Strongyloides sp. (30 EPG), Ancylostomatidae-type eggs (20 EPG), and Rhabditida-type larvae (20 EPG). |
| Saimiri sciureus            | ACZP   | Nematoda-type eggs                                                                 |
| Alouatta caraya             | ACZP   | Eggs of Bertiella spp. (110 EPG).                                       |
| Chlorocebus aethiops        | ACZP   | Eggs of Strongyloides sp. (140 EPG), eggs of Trichuris sp. and Rhabditida-type larvae. |
| Pecari tajacu               | ACZP   | Eggs of Strongyloides sp. (180 EPG), Strongyloida-type eggs (110 EPG) and Rhabditida-type larvae (190 LPG). |
| Tapirus terrestris          | ACZP   | Trophozoites and cysts of Balantidium sp. (470 CPG) and non-sporulated coccidia (280 OPG). |
| Anodorhynchus hyacintinus   | ACZP   | Eggs of Capillaria spp.                                                 |
| Ara ararauna                | ACZP   | Eggs of Capillaria spp. (180 EPG).                                      |
| Ara chloropterus            | ACZP   | Eggs of Capillaria spp. (140 EPG).                                      |
| Amazona aestiva             | ACZP   | Eggs of Capillaria spp. (960 EPG).                                      |
| Turdus sp.                  | Free-living | Strongyloida-type eggs and non-sporulated coccidia (30 OPG) and Rhabditida-type larvae (10 LPG). |
| Crax fasciolata             | ACZP   | Oocysts and non-sporulated coccidia (30 OPG) and eggs of Capillaria spp. |
| Patagioenas picazuro        | ACZP   | Eggs of Capillaria spp. (240 EPG).                                      |
| Rupornis magnirostris       | ACZP   | Eggs of Trichuris sp. (30 EPG).                                         |
| Pantheropis guttatus        | ACZP   | Eggs of Aspicularis sp. (20 EPG) and mite eggs.                         |
| ACZP                        |        | Eggs of Hymenolepis sp., eggs of Aspicularis sp., and mite eggs.         |
| ACZP                        |        | Eggs of Hymenolepis sp. (70 EPG), eggs of Aspicularis sp. (50 EPG), and mite eggs. |
| ACZP                        |        | Eggs of Hymenolepis sp. (10 EPG) and mite eggs.                         |
| ACZP                        |        | Eggs of Hymenolepis sp. (20 EPG).                                       |
| ACZP                        |        | Eggs of Hymenolepis sp. (20 EPG).                                       |
| ACZP                        |        | Eggs of Hymenolepis sp. (20 EPG).                                       |
| Bothrops erythromelas       | ACZP   | Eggs of Aspicularis sp. (20 EPG), mite eggs, and mites (Myocoptes musculinus). |
| Salvator merianae           | ACZP   | Eggs of strongylids (60 EPG), Rhabditida larvae (100 LPG), Eggs of Strongyloidea (30 EPG), and mite eggs. |
| Iguana iguana               | Free-living | Cysts of Entamoeba coli (170 CPG), non-sporulated coccidia (130 OPG), and Eimeria sp. (120 OPG). |
| Chelonoidis sp.             | ACZP   | Cysts (50 CPG) and trophozoites (40 TPG) of Balantidium spp., cysts and trophozoites (30 TPG) of Nyctotherus spp., Strongyloida-type eggs (30 EPG), and Rhabditida-type larvae (30 LPG). |
| Chelonoidis denticulata     | ACZP   | Cysts (150 CPG) and trophozoites (2000 TPG) of Balantidium spp., cysts and trophozoites (440 TPG) of Nyctotherus spp., Strongyloida-type eggs (30 EPG), and Rhabditida-type larvae (60 LPG). |

Source: Personal archive.
In the positive samples, the highest prevalence (p=0.001) was of Nematoda, with 80.5% (29/36). Among these worms, parasitic forms of the orders Strongylida (27.5%), Trichinellida (27.5%), and Rhabditida (37.9%) were found. Due to the similarity between the eggs of the order Strongylida, and since we used only morphological traits in this study, we decided in some cases to make an approximate identification of specimens from Ancylostomatidae and Strongylida. Trichinellida eggs of the genera Capillaria and Trichuris were observed. Among the Rhabditida, the following parasites were found: rhabditoid larvae; eggs of the superfamily Ascaridoidea, such as eggs of Toxascaris leonina, Toxocara sp. and unidentified eggs obtained from Crax fasciolata (suggested as Heterakis spp. or Ascaridia spp.); eggs of the superfamily Oxyuroidea, such as eggs of Syphacia sp. and Aspiculuris sp.; and eggs of the superfamily Strongyloidea, in Salvator merianae (suggested as Strongyloides sp. or Rhabdias sp.). In addition, eggs of Nematoda were found in Saimiri sciureus (Table 2).

Cestodes were found in 19.4% of the animals analyzed (07/36), all of them belonging to the order Cyclophyllidea. Thus, we recovered eggs from the Hymenolepididae family, such as Hymenolepis spp; from the Anoplocephalidae family, such as Bertiella spp; and eggs of unidentified Cestoda (suggested as Hymenolepis spp. and Paratriotaenia spp.) (Table 2, Figure 2).
Figure 2 - Eggs, oocysts, trophozoites and cysts found at the Arruda Câmara Zoobotanical Park (ACZP), Objective (40x). A - Egg of *Bertiella* spp. in *Alouatta caraya*; B - Eggs of *Capillaria* spp. in *Amazona aestiva*; C – Unsporulated oocyst of coccidia in *Tapirus terrestris*; D - Unsporulated oocyst of coccidia in *Cacicus cela*; E - *Isospora* sp. in *Cacicus cela*; F – Strongyloida-type eggs in *Chelonoidis* sp.; G – Ancylostomatidae-type eggs in *Sapajus libidinosus*; H – Egg of *Trichuris* spp. in *Rupornis magnirostris*; I – Egg of *Strongyloides* spp. on *Pecari tajacu*; J - Egg of *Syphacia* spp. on *Leopardus pardalis*; K - Egg of *Hymenolepis* spp. on *Pantherophis guttatus*; L - Egg of *Aspiculuris* spp. on *Pantherophis guttatus*; M - Eggs of *Toxocara* spp. on *Puma yagouaroundi*; N - Cyst of *Nyctotherus* spp. on *Chelonoidis* sp.; O - Trophozoites of *Nyctotherus* spp. in *Chelonoidis carbonaria*; P – Cestoda-type eggs in *Sapajus flavius*; Q - Cyst of *Balantidium* spp. in *Chelonoidis* sp.; R – Trophozoites of *Balantidium* spp. in *Chelonoidis* sp.; S – Ascaridoidea-type egg in *Crax fasciolata*; T – Entamoeba coli cyst in *Iguana iguana*.

Source: Personal archive.
Protozoans were found in 13.9% of the samples (05/36), with the taxa Coccidia (60%), Gilliothera (60%), and Amoebboza (20%) being recorded. Among the coccidians, non-sporulated oocysts were found, as well as Eimeria spp. and Isospora spp. The ciliates were represented by cysts and trophozoites of Balantidium sp. and Nycotмонтажera sp. In addition, the only Amoebboza recorded were cysts of Entamoeba coli. Finally, the percentage related to mite eggs and adults in the fecal samples was 16.7% (06/36) (Table 2, Figure 2).

Among the carnivorous mammals, the amount of Toxocara sp. eggs found was 4 eggs (40 EPG) in Puma concolor and 40 eggs (400 EPG) in Puma yagouroundi. In addition, 1 egg (10 EPG) of Strongyloides sp. and 1 (10 LPG) Rhabditidatype larvae were recovered from Nasua nasua. All samples from Sapajus primates were positive for Strongyloides sp. eggs, Ancylostomatidae eggs, and Rhabditida-type larvae. In primates, Strongyloides sp. eggs ranging from 20 (200 EPG) to 84 (840 EPG) units were found in the genus Sapajus, and 14 (140 EPG) in the species Chlorocebus aethiops. Regarding the Ancylostomatidae family, there was a range of 3 (30 EPG) to 20 eggs (200 EPG) obtained from primates of the genus Sapajus. The number of Rhabditida-type larvae ranged from 2 (20 EPG) to 7 (70 EPG) in this genus. In addition, 7 eggs (70 EPG) of Cestoda were recovered from Sapajus flavius and 11 eggs (110 EPG) of Bertiella spp. were found in Alouatta caraya (Table 2).

In the bird samples, there was a prevalence of Capillaria sp. eggs, with 14 (140 EPG) being found in Ara chloropterus, 18 (180 EPG) in A. ararauma, 24 (240 EPG) in Patagioenas picazuro, and 96 (96 EPG) in Amazona aestiva. In addition, 3 oocysts (30 OPG) of Isospora sp., 2 oocysts (20 OPG) of unsporulated coccidian, and 1 (10 LPG) Rhabditida-type larva were found in Cacicus cela; 3 Ascaridoidea-type eggs (30 EPG) in Crax fasciolata; and 3 eggs (30 EPG) of Trichuris sp. in Rupornis magnirostris. Among reptiles, we obtained Aspiculuris sp. eggs ranging from 2 (20 EPG) to 5 (50 EPG) units in snakes like Pantherophis guttatus and Bothrops erythromelas. Hymenolepis sp. eggs were also recovered, ranging from 1 (10 EPG) to 7 (70 EPG) units in P. guttatus. Regarding the lacerbitid samples, in Iguana iguana 17 cysts (170 CPG) of Entamoeba coli, 13 oocysts (130 OPG) of non-sporulated coccidia, and 12 oocysts (120 OPG) of Eimeria sp. were found; while in Salvator merianae, 6 eggs (60 EPG) of strongilids, 10 Rhabditida-type larvae (100 LPG), and 3 Strongyloidoidea-type (30 EPG) were recovered. The largest number of parasitic forms recovered in this study was of Balantidium sp., with 15 cysts (150 CPG) and 200 trophozoites (2000 TPG), obtained from Chelonioides denticulata, an occurrence that was not observed for Chelonoidis sp., in which 5 cysts (50 CPG) and 4 trophozoites (40 TPG) were obtained. In addition, in the testudine samples we noticed 38 cysts (380 CPG) and 44 trophozoites (440 TPG) of NycotmanagedTypeera sp. obtained from C. denticulata, as well as only 3 trophozoites (30 TPG) from Chelonoidis sp.; 3 Strongylida-type eggs (30 OPG) from C. denticulata and Chelonoidis sp.; 6 Rhabditida-type larvae (60 LPG) from C. denticulata and only 3 (30 LPG) from Chelonoidis sp. (Table 2).

4. Discussion

Researches carried out in several countries, including Brazil, have been carried out to determine the occurrence of parasitism in wild animals in zoos by means of coproparasitological analysis. In general, Cystoisospora sp., Toxocara cati, Strongyloides stercoralis, Toxascaris leonina, and hookworms are commonly reported for mammalian carnivores. In artiodactyls, protozoans such as Eimeria spp. and Cryptosporidium spp., as well as nematodes such as Trichuris sp., Toxocara vitulorum, Strongyloides sp., and parasites of the Paramphistomidae family have also been observed. Eggs of the Ancylostomatidae family, Trichuris sp., Strongyloides sp., Prosthemorchis elegans, and Bertiella spp. have been found in primates. In Brazil, Capillaria sp., Ascaridia sp., Heterakis sp., Libyostrongylus sp., Raillietina spp., Eimeria spp., and Isospora spp. have already been reported in birds (Fagiolini et al., 2018, Marques et al., 2019).

Among the findings of this study, the first record of gastrointestinal endoparasites from Tapirus terrestris in Northeast Brazil stands out. This study reports the occurrence of non-sporulated oocysts of coccids, and cysts and trophozoites of
Balantidium, both being reported for the first time in Brazil. Generally, infections by endoparasites in free-living tapirids are asymptomatic, but signs of parasitic disease have been observed in captive animals. We also highlight the first record of Bertiella spp. in Alouatta caraya in the Northeast, Brazil. Clinical signs of this parasitic disease have not been demonstrated for this primate species, but the importance of this zoonosis has been reported, which may occur mainly in patients with direct or indirect contact with these animals, resulting in abdominal discomfort, diarrhea, gastroenteritis, and anorexia (Oliveira et al., 2011; Fernandes-Santos et al., 2020).

Further, this is the first occurrence of Hymenolepis spp. and Aspicularis spp. as spurious parasites from reptiles in Brazil, exhibiting pseudoparasitism in these animals from the moment they ingest rodents, which are the definitive hosts. Although these pseudoparasites do not infect them, reptiles can be regarded as dispersers of viable parasitic forms that may cause infection in their respective hosts, such as rodents, non-human primates, and humans. In addition, this study also highlights the parasitism by Entamoeba coli and Eimeria spp. in Iguana iguana. Although infection by the latter is usually asymptomatic, generally when Entamoeba coli affects the gastrointestinal system, it may cause necrotic enteritis, hepatitis and liver abscesses, lethargy, diabetes, regurgitation, convulsions, depression, hematochezia, and death in Squamata (Rinaldi et al., 2012; Lima et al., 2017; 2021).

Despite the great relevance of Zoological Parks and the struggle of these institutions to maintain the health of their animals, implementing prevention, diagnosis, and treatment programs, it is well known that many captive animals are housed close to each other, making parasitic infections inevitable. In addition, captive animals are often under considerable stress, which decreases their immunity and makes them more susceptible to infections. These parasites can pose a serious threat to the captive animals, occasionally causing fatalities. Many of these diseases, besides interfering with the welfare of the host species and affecting considerably their birth and mortality rates, may be zoonotic, posing a risk to animal handlers and animal care workers. In the present case, there was still the aggravating factor of the enclosures being within a forest reserve, which favors a greater contact of the animals with the droppings of other individuals, or even with intermediate hosts (Fagiolini et al., 2010; Oliveira et al., 2011; Snak et al., 2014; Schieber, M.C.; Štrkolcová, 2019; Dashe; Behanu, 2020; Patra et al., 2020).

The parasitological diagnosis of wild and exotic animals kept in captivity is essential to assist decisions related to their treatment, since they provide important information about the health of the herd and the immune resistance of the hosts. In addition, this information collaborates with the scientific community and contributes to provide ecological data for each of the species herein studied, favoring their conservation and preservation (Barros et al., 2017).

Although there are previous works that have carried out parasitological surveys in animals from zoos in Brazil, these studies, besides being very scarce, are much spaced. Typically, these investigations did not evaluate most of the animals kept at those zoobotic parks. The present research was the pioneer, in Brazil, to perform the parasitological diagnosis of most of the vertebrate animals of the same zoobotic park, with species from the Mammalia, Aves, Archelosaurus, and Lepidosauria taxa.

5. Conclusions

A total of 54.5% of the tested animals were parasitized, which represents a risk to the health of both humans and animals, since many of these pathogens are also of medical importance. This research helps to broaden the ecological data and assists in the ex-situ conservation of wild and exotic animals. Based on the knowledge generated by this study, additional work is possible in order to understand the ecology of these endoparasites in the animals herein studied; investigate the potential consequences that these hosts may face in the wild; and the way parasitism might affect the welfare of host species in captivity and in the wild. Finally, this study contributes to the knowledge of endoparasites that may occur in zoos in Brazil and specifically in the Northeast region of this country, as well as for the species studied here.
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