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Gastrointestinal parasites in captive wild animals from two Brazilian Zoological Gardens

Parasitos gastrintestinais em animais silvestres em cativeiro de dois Jardins Zoológicos brasileiros

Parásitos gastrointestinales en animales silvestres en cautiverio de dos Jardines Zoológicos Brasileños

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Igo Gonçalves dos Santos
ORCID: https://orcid.org/0000-0003-2318-8053
Federal University of Sergipe, Brazil
E-mail: goncalvesigo1267@gmail.com
Aksa Ingrid Vieira Batista
ORCID: https://orcid.org/0000-0003-0696-7194
Universidade Federal Rural do Semi-Árido, Brazil
E-mail: aksaingridmv@gmail.com
Weslania Souza Inacio da Silva
ORCID: https://orcid.org/0000-0003-4393-544X
Federal University of Sergipe, Brazil
E-mail: weslaniainacio@hotmail.com
Manuel Benicio Oliveira Neto
ORCID: https://orcid.org/0000-0002-7499-4971
Federal University of Sergipe, Brazil
E-mail: netooliveiraufs@gmail.com
Sofia Cerqueira Schettino
ORCID: https://orcid.org/0000-0001-9660-0921
Federal University of Sergipe, Brazil
E-mail: kaouro4@hotmail.com
Matheus Resende Oliveira
ORCID: https://orcid.org/0000-0002-6535-1077
Federal University of Sergipe, Brazi
E-mail: matheusrxoliveira@gmail.com
Rafael Antonio Nascimento Ramos
ORCID: https://orcid.org/0000-0002-0347-9358
Federal University of the Agreste of Pernambuco, Brazil
E-mail: rafaelanramos10@yahoo.com.br
Leucio Câmara Alves
ORCID: https://orcid.org/0000-0003-3417-5143
Rural Federal University of Pernambuco, Brazil
E-mail: leucioalves@gmail.com
Márcio Bezerra-Santos
ORCID: https://orcid.org/0000-0001-9962-6537
Federal University of Sergipe, Brazil
E-mail: bio_marcio2006@hotmail.com
Victor Fernando Santana Lima
ORCID: https://orcid.org/0000-0002-7255-0664
Federal University of Sergipe, Brazil
E-mail: victor.fslima@gmail.com

Abstract
Keeping animals in zoos is important for the preservation of endangered species. However, captive animals can also be affected by different species of parasites. Herein, we aimed to evaluate the occurrence of gastrointestinal parasites in wild and exotic animals from two zoos in the state of Sergipe, Northeastern Brazil. Fecal samples were obtained by spontaneous defecation of 287 specimens, grouped into mammals (n = 101), birds (n = 99), and reptiles (n = 87). The samples were assessed using two techniques, Mini-FLOTAC and Ziehl-Neelsen, to identify helminths and protozoa, respectively. In total, 60.2% (173/287) of the animals evaluated were positive for some type of gastrointestinal parasite. Among the classes evaluated, mammals (81.1%; 82/101; *p*-value <0.0001) were mostly affected, followed by birds (56.6%; 56/99) and reptiles (40.2%; 35/87). Furthermore, our findings showed that the parasites Ancylostomatidae and coccidian oocysts were the most abundant among the species. It is important to highlight the first record of some parasites in species in the South America, such as: Ancylostomatidae in Asian Elephant (*Elephas*

maximus) and Brown Bear (*Ursus arctos*); *Toxascaris leonina* in Leo (*Panthera leo*); and Trichostrongyloidea and Ascarididae in *Equus quagga burchellii* and *Lama glama*. Taken together, our data showed a high occurrence of gastrointestinal parasites in captive animals, including zoonotic species, which may pose a risk to animal and human public health.
Keywords: Diagnosis; Endoparasites; Mini-FLOTAC; Zoological gardens.

Resumo
Manter animais em zoológicos é importante para a preservação de espécies ameaçadas de extinção. No entanto, animais em cativeiro também podem ser afetados por diferentes espécies de parasitos. Neste trabalho, objetivamos avaliar a ocorrência de parasitos gastrintestinais em animais silvestres e exóticos de dois zoológicos do estado de Sergipe, Nordeste do Brasil. Amostras fecais foram obtidas por defecação espontânea de 287 espécimes, agrupados em mamíferos (n = 101), aves (n = 99) e répteis (n = 87). As amostras foram avaliadas por meio de duas técnicas, Mini-FLOTAC e Ziehl-Neelsen, para identificar helmintos e protozoários, respectivamente. No total, 60,2% (173/287) dos animais avaliados foram positivos para algum tipo de parasito gastrintestinal. Dentre as classes avaliadas, os mamíferos (81,1%; 82/101; p-valor <0,0001) foram os mais afetados, seguidos por aves (56,6%; 56/99) e répteis (40,2%; 35/87). Além disso, nossos achados mostraram que os parasitos Ancylostomatidae e oocistos de coccídios foram os mais abundantes entre as espécies. É importante destacar o primeiro registro de alguns parasitos em espécies na América do Sul, tais como: Ancylostomatidae em Elefante Asiático (*Elephas maximus*) e Urso Pardo (*Ursus arctos*); *Toxascaris leonina* em Leão (*Panthera leo*); e Trichostrongyloidea e Ascarididae em *Equus quagga burchellii* e *Lama glama*. Em conjunto, nossos dados mostraram uma alta ocorrência de parasitos gastrintestinais em animais de cativeiro, incluindo espécies zoonóticas, o que pode representar um risco para a saúde pública animal e humana.
Palavras-chave: Diagnóstico; Endoparasitos; Jardins zoológicos; Mini-FLOTAC.

Resumen
Tener animales en zoológicos es importante para la preservación de especies en peligro de extinción. Sin embargo, los animales en cautiverio también pueden verse afectados por diferentes especies de parásitos. Aquí, nuestro objetivo fue evaluar la ocurrencia de parásitos gastrointestinales en animales salvajes y exóticos de dos zoológicos en el estado de Sergipe, noreste de Brasil. Se obtuvieron muestras fecales por defecación espontánea de 287 ejemplares, agrupados en mamíferos (n = 101), aves (n = 99) y reptiles (n = 87). Las muestras se evaluaron mediante dos técnicas, Mini-FLOTAC y Ziehl-Neelsen, para identificar helmintos y protozoos, respectivamente. En total, el 60,2% (173/287) de los animales evaluados resultaron positivos para algún tipo de parásito gastrointestinal. Entre las clases evaluadas, los mamíferos (81,1 %; 82/101; p-value <0,0001) fueron los más afectados, seguidos de las aves (56,6 %; 56/99) y los reptiles (40,2 %; 35/87). Además, nuestros hallazgos mostraron que los parásitos Ancylostomatidae y los ooquistes de coccidios fueron los más abundantes entre las especies. Es importante destacar el primer registro de algunos parásitos en especies de Sudamérica, tales como: Ancylostomatidae en Elefante Asiático (*Elephas maximus*) y Oso Pardo (*Ursus arctos*); *Toxascaris leonina* en Leo (*Panthera leo*); y Trichostrongyloidea y Ascarididae en *Equus quagga burchellii* y *Lama glama*. En conjunto, nuestros datos mostraron una alta incidencia de parásitos gastrointestinales en animales en cautiverio, incluidas especies zoonóticas, que pueden representar un riesgo para la salud pública animal y humana.
Palabras clave: Diagnóstico; Endoparásitos; Jardines zoológicos; Mini-FLOTAC.

1. Introduction

Notably, keeping some species of animals in zoos can be useful for their preservation, especially of endangered species, or victims of mistreatment caused by the trafficking of wild animals. In addition, they can be useful for scientific studies, environmental education and understanding the biological behavior of species (Conde, 2013; Morezzi et al, 2021). However, when animals are kept in captivity with inadequate or unhealthy management and environment, they can be affected by different types of pathogens, especially parasites, which can cause injury and even death (Melo et al, 2019).

In Brazil, prior studies have already demonstrated the occurrence of several species of helminths and gastrointestinal protozoa in captive mammals, birds, and reptiles (Barbosa et al, 2019S; Frezza, et al, 2021; Melo et al, 2021). Despite most infections in these animals occur due to inadequate management of habitat or food, factors such as proximity to other domestic or free-living species, and even contact with humans, must also be considered in the transmission chain of gastrointestinal parasites (Thompson et al, 2009; Holsback et al, 2013; Barbosa et al, 2020; Schaper et al, 2021;). In this context, early diagnosis and appropriate management measures must be adopted in order to avoid the emergence of these diseases in captive animals and even evolution with clinical complications (Kvapil et al, 2017).

Previous studies carried out in birds have shown that helminths of the Capillariidae family (*Capillaria dispar*, *C. falconis*, and *C. corvum*) can cause severe lesions in areas of the gastrointestinal tract, such as the esophagus and intestine. Clinically, birds affected by *Capillaria* sp. may present vomiting, bloody diarrhea, anorexia and, if not properly treated, progress to death. (Gomes et al, 1993). Likewise, birds infected by intracellular coccidian protozoa of the Eimeriidae family (*Eimeria* sp. and *Isospora* sp.) may present with anorexia, weight loss, hepatomegaly, and splenomegaly (Abdisa et al, 2019; Barbón et al, 2019).

Additionally, some gastrointestinal parasites of wild animals (such as *Ancylostoma caninum*, *Giardia* sp. and *Cryptosporidium* spp.), due to their zoonotic potential, in addition to causing risks to the animals, is also a challenge for human public health (Ryan et al, 2016; Vizcaychipi et al, 2016; Ryan e Zahedi, 2019; Nath et al, 2021). Also, although many infected species do not show clinical signs (asymptomatic), some animals may have retarded growth, weight loss, diarrhea, reduced food consumption, low fertility, and high mortality rate. In human hosts, those parasites can cause abdominal changes, bloody stools, anemia, microvilli atrophy, and weakness (Oliveira, et al, 2017; Betson et al, 2020).

Importantly, the identification of parasite species in captive animals can help to understand the parasite-host relationships between different species. In addition, early diagnosis and timely treatment of hosts can reduce the occurrence of clinical complications and deaths and mitigate the chances of transmission of the parasites to other animals and even to humans (Cringoli et al, 2017; Capasso, et al, 2019; Lozano et al, 2021). Therefore, we aimed herein to identify of gastrointestinal parasites in wild and exotic captive animals from two zoos in the Northeastern Brazil.

2. Methodology

Study Area

The present study was carried out in two zoos located in the municipalities of Laranjeiras and Aracaju, state of Sergipe (10º 59"29"S 37º02'53 W), Northeast region of Brazil. The state of Sergipe is bordered by the Atlantic Ocean, to the east; the states of Bahia, to the west and south; and Alagoas, to the north, whose interstate division is delimited by the São Francisco River. The state's territory is formed by the Caatinga and Atlantic Forest biomes and with annual rainfall index ranging from 500 to 1000 mm (IBGE, 2021).

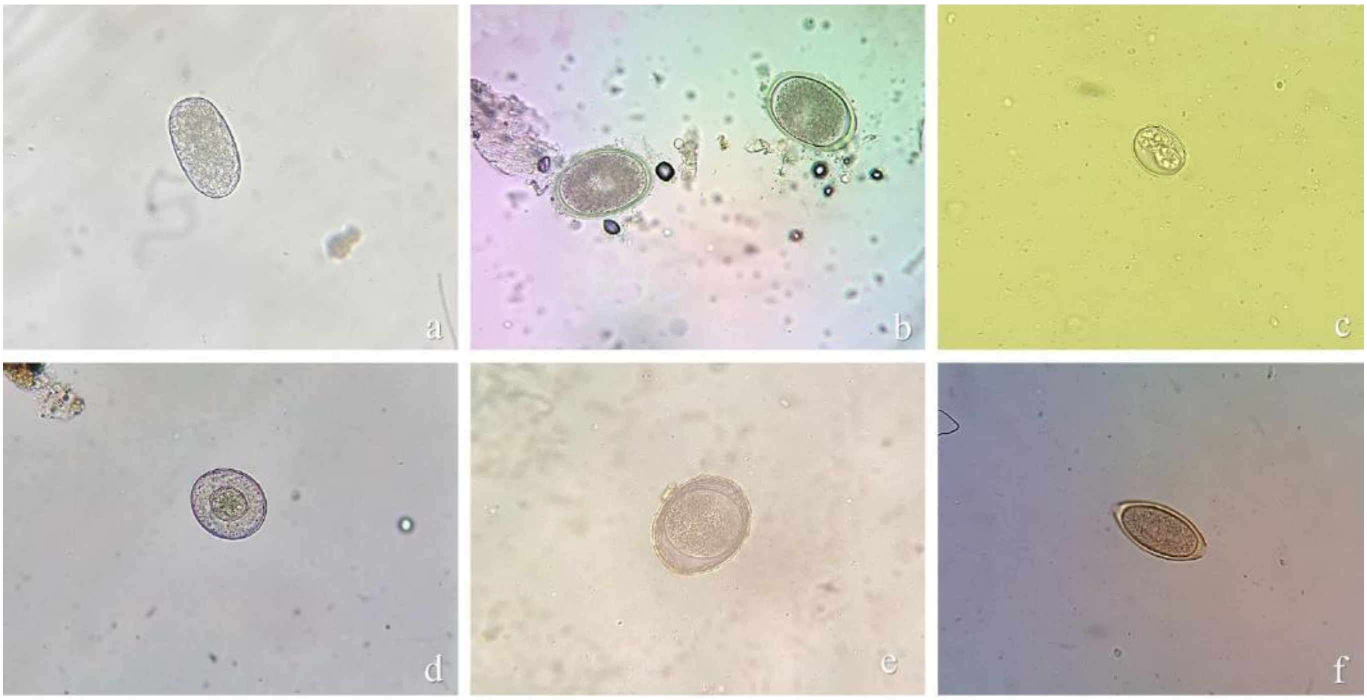
Animals and Sampling

For this study, fecal samples were obtained, all by spontaneous defecation, from 287 specimens of captive, wild and/or exotic animals, of different ages and sex. They were classified into mammals (n=101; wild carnivores n=11; exotic carnivores n=03; exotic herbivores n=23; wild omnivores n=31; exotic omnivores n=4; wild primates n=29); birds (n=99; wild n=63; exotic n=36); and reptiles (n=87; wild n=86; exotic n=1). All samples were deposited in collection tubes containing 10% formaldehyde and kept under refrigeration at 4°C until laboratory processing.

Laboratory Analysis

Subsequently, the samples were processed individually by the Mini-FLOTAC®, technique, using the flotation solutions (sodium chloride, specific gravity, s.g. = 1.200) (Cringoli et al, 2010). The detection of *Cryptosporidium* spp. oocysts was performed using the Centrifugal Sedimentation with formaldehyde-ether followed by smears stained with Ziehl-Neelsen (Henriksen and Pohlenz, 1981) and the Kinyoun method (Brasil, 1996). All methods were performed following the recommendations reported in the original description of each technique. All cysts, oocysts, and eggs were identified based on morphological features previously described (Figure 1) (Smith et al, 1995; Bowman et al, 2010; Taylor et al, 2017).

Figure 1. Gastrointestinal parasites in captive wild animals of two Brazilian Zoological Gardens. **a** - Ancylostomatidae egg in *E. maximus*; **b** - *Ascaridia* sp. eggs in *A. amazonica*; **c** - Coccidian oocyst in *E. murinus*; **d** - *Hymenolepis* sp. egg in *S. apella*; **e** - *Toxascaris leonina* egg in *P. leo*; **f** - *Trichuris* sp. egg in *E. barbara*.



Source: Authors.

Statistical analysis

Data were tabulated in Microsoft Excel spreadsheets version 365® and analyzed by GraphPad Prism software version 9.2.0. Absolute and relative frequencies of gastrointestinal parasites were calculated in each group of animals. We used the chi-square test for equality to compare positivity between groups. The significance level established for the study was 5% and differences between groups were considered statistically when a *p*-value <0.05 was obtained.

3. Results

Our analyzes identified 60.2% (173/287) of the samples positive for some gastrointestinal parasite. When comparing the positivity percentages between animal groups, mammals (81.1%; 82/101) were significantly the most affected, followed by birds (56.6%; 56/99) and reptiles (40.2%; 35/87) (*p*-value <0.0001). In addition, twenty-two different genera and/or species of gastrointestinal helminths (75%) and protozoa (25%) were identified and classified among: Nemathelminths (75%), Cestodeans (5%), Amoebas (10%), Coccidia (10%) and Diplomonads (5%) (Table 1). Interestingly, Ancylostomatidae and Coccidia were the most frequent parasites in wild animals assessed in this study.

Table 1. Number of positive for each animal category of two Brazilian Zoological Gardens.

Parasites	**Animal category**					
	Birds	**Carnivores**	**Herbivores**	**Omnivores**	**Primates**	**Reptiles**
Helmints						
Ancylostomatidae	-	3	1	1	28	30
Ancylostoma sp.	-	2	-	-	-	
Angiostrongylus spp.	-	1	-	-	-	-
Ascaridia sp.	15	-	-	-	-	-
Aspiculuris sp.	-	1	-	-	-	-
Capillaria sp.	15	-	-	-	-	-
Hymenolepis sp	-	-	-	-	1	-
Parascaris equorum	-	-	7	-	-	-
Strongyloides spp.	1	-	3	-	5	-
Syphacia sp.	-	1	-	-	1	-
Toxascaris leonina	-	1	-	-	-	-
Toxocara sp.	-	2	-	-	-	-
Trichostrongyloidea	7	-	4	1	-	-
Trichostrongylus sp.	-	-	5	-	-	-
Trichuris sp.	-	-	-	1	-	-
Protozoa						
Balantidium sp.	-	-	-	-	2	-
Coccidia	31	-	-	28	5	8
Cryptosporidium sp.	1	-	-	-	-	3
Entamoeba spp.	-	6	-	-	3	-
Giardia sp.	4	5	-	-	2	-
Absolute Frequency (n/N)	56/99	11/14	13/23	30/35	28/29	35/87
Relative Frequency (%)	56,5	78,5	56,5	85,7	96,5	40,2

Source: Authors.

Furthermore, when we evaluated the positivity in each group of animals, nine types of eggs from different families were identified among mammals (Ancyostomatidae, Metastrongylidae, Oxyuridae, Hymenolepididae, Ascarididae, Strongyloididae, Toxocaridae, Trichostrongylidae and Trichuridae), eleven genera (*Ancylostoma* sp., *Angiostrongyus* spp., *Aspiculuris* sp., *Hyminolepis* sp., *Parascaris* sp., *Strongyloides* spp., *Syphacia* sp., *Toxascaris* sp., *Toxocara* sp., *Trichostrongylus* sp., and *Trichuris* sp.) and two helminth species (*Parascaris equorum* and *Toxascaris leonina*). Additionally, among the protozoa, we also identified three families (Balantiididae, Entamoebidae, and Hexamitidae), three genera (*Balantidium* sp., *Entamoeba* sp., and *Giardia* sp.), and coccidian oocysts belonging to the order Eucoccidiorida. Importantly, we also observed hookworms in fecal samples of Carnivores (*Leopardus tigrinus* and *Ursus arctos*), Herbivores (*Elephas maximus*), Omnivorous (*Eira barbara*), and Primates (*Sapajus apella*, *S. libidinosus,* and *S. nigritus*). Coccidian oocysts, *Entamoeba* sp., and *Giardia* sp. were the most frequent protozoa, mainly in artiodactyl mammals and primates (Table 2).

Table 2. Frequency of gastrointestinal parasitic infection in captive wild Mammals of two Brazilian Zoological Gardens.

Type of animals (Host)	NE	NI	Gastrointestinal Parasite Found
Carnivores			
Cachorro-do-mato (*Cerdocyon thous*)	3	3	*Angiostrongylus* spp. larvae (33%; 1/3), *Toxocara* sp. eggs (33%; 1/3), *Giardia* sp. cysts (100%; 3/3) and *Entamoeba* sp. cysts (100%; 3/3)
Gato-do-mato (*Leopardus tigrinus*)	1	1	*Ancylostoma* sp. eggs (100%; 1/1), *Toxocara* sp. eggs (100%; 1/1), *Aspiculuris* sp. eggs (100%; 1/1) and *Syphacia* sp. eggs (100%; 1/1)
Jaguatirica (*Leopardus pardalis*)	2	1	*Ancylostoma* spp. eggs (50%; 1/2)
Leão (*Panthera leo*) ES	1	1	*Toxascaris leonina* eggs and larvae (100%; 1/1) and *Entamoeba* sp. cysts (100%; 1/1)
Mão-pelada (*Procyon cancrivorus*)	4	3	Ancylostomatidae eggs (33%; 1/3), *Giardia* sp. cysts (66%; 2/3) and *Entamoeba* sp. cysts (66%; 2/3)
Quati-de-cauda-anelada (*Nasua nasua*)	1	0	-
Urso-pardo (*Ursus arctos*) ES	2	2	Ancylostomatidae eggs (100%; 2/2)
Herbivores			
Búfalo (*Bubalus bubalis*) ES	3	3	Trichostrongyloidea eggs (100%; 3/3)
Cervo-dama (*Dama dama*) ES	4	1	Trichostrongyloidea eggs (100%; 1/1)
Cervo-nobre (*Cervus elaphus*) ES	1	0	-
Elefante-asiático (*Elephas maximus*) ES	1	1	Ancylostomatidae eggs (100%; 1/1)
Hipopótamo-comum (*Hippopotamus amphibius*) ES	3	0	-
Llama (*Lama glama*) ES	2	1	*Parascaris equorum* eggs (50%; 1/2)
Zebra-de-burchell (*Equus quagga burchellii*) ES	9	7	*Parascaris equorum* eggs (85%; 6/7), *Trichostrongylus* sp. eggs (71%; 5/7) and *Strongyloides* spp. eggs (42%; 3/7)

Omnivores			
Caititu (*Dicotyles tajacu*)	28	28	Coccidia oocysts (100%; 28/28)
Cutia (*Dasyprocta aguti*)	1	1	Trichostrongyloidea eggs (100%; 1/1)
Irara (*Eira barbara*)	2	1	Ancylostomatidae eggs (100%; 1/1) and *Trichuris* sp. eggs (100%; 1/1)
Mercol (*Rattus norvegicus*) ES	4	0	-
Primates			
Macaco-prego (*Sapajus apella*)	13	12	Ancylostomatidae eggs (92,3%; 12/13), *Hymenolepis* sp. eggs (8%; 1/12), *Syphacia* sp. eggs (8%; 1/12), *Strongyloides* spp. eggs (41%; 5/12), *Giardia* sp. cysts (8%; 1/12), *Entamoeba* sp. cysts (25%; 3/12), *Balantidium* sp. cysts (16%; 2/12) and Coccidia oocysts (41%; 5/12)
Macaco-prego-amarelo (*Sapajus libidinosus*)	12	12	Ancylostomatidae eggs (100%; 12/12) and *Giardia* sp. cysts (8%; 1/12)
Macaco-prego-preto (*Sapajus nigritus*)	4	4	Ancylostomatidae eggs (100%; 4/4)

ES- Exotic species; NE- Number Examined; NI- Number Infected. Source: Authors.

Among the birds, four families (Ascarididae, Capillariidae, Strongyloididae and Trichostrongylidae) and four genera of helminths (*Ascaridia* sp., *Capillaria* sp., *Strongyloides* sp., and *Trichostrongylus* sp.) were identified. Furthermore, we also identified two families (Cryptosporidiidae and Hexamitidae) and two genera of protozoa (*Cryptosporidium* sp. and *Giardia* sp.) and coccidia oocysts belonging to the order Eucoccidiorida. Importantly, the eggs of the helminths *Ascaridia* sp. (36.8%; 14/38) and *Capillaria* sp. (39.4%; 15/38) and coccidian protozoan oocysts (86.1%; 31/36) were the most frequent in Anseriformes (*Dendrocygna viduata*), Columbiformes (*Streptopelia decaocto*), Galliformes (*Penelope superciliaris*), and Psittaciformes birds (*Ara macao*, *Ara ararauna*, *Amazonas amazônica,* and *Amazona aestiva*) (Table 3).

Table 3. Frequency of gastrointestinal parasitic infection in captive wild Birds of of two Brazilian Zoological Gardens.

Type of animals (Host)	NE	NI	Gastrointestinal Parasite Found (%; n/N)
Birds			
Araracanga (*Ara macao*)	2	2	*Capillaria* sp. eggs (100%; 2/2) and Coccidia oocysts (50%; 1/2)
Arara-canindé (*Ara ararauna*)	7	7	*Capillaria* sp. eggs (57%; 4 /7), *Cryptosporidium* sp. oocysts (14%; 1/7) and Coccidia oocysts (71%; 5/7)
Cacatua (*Cacatua alba*) ES	1	0	-
Calopsita (*Nymphicus hollandicus*) ES	2	1	Coccidia oocysts (50%; 1/2)

Carcará (*Caracara plancus*)	5	0	-
Casuar (*Casuarius casuarius*) ES	1	1	Coccidia oocysts (100%; 1/1)
Ema (*Rhea americana*)	1	1	*Ascaridia* sp. eggs (100%; 1/1)
Faisão (*Phasianus Colchicus*) ES	2	0	-
Galinha D'angola (*Numida meleagris*) ES	4	0	-
Irerê (*Dendrocygna viduata*)	7	7	*Ascaridia* sp. eggs (71%; 5/7) and *Capillaria* sp. eggs (28%; 2/7)
Jacupemba (*Penelope superciliaris*)	2	2	Trichostrongyloidea eggs (100%; 2/2) and Coccidia oocysts (100%; 2/2)
Jandaia (*Eupsittula aurea*)	4	0	-
Jandaia-verdadeira (*Aratinga jandaya*)	2	0	-
Mutum-cavalo (*Mitu tuberosum*)	3	3	Trichostrongyloidea eggs (66%; 2/3), *Strongyloides* spp. eggs (33%; 1/3) and Coccidia oocysts (66%; 2/3)
Mutum-de-penacho (*Crax fasciolata*)	2	1	Coccidia oocysts (50%; 1/2)
Papagaio-do-mangue (*Amazona amazonica*)	5	5	*Ascaridia* spp. eggs (100%; 5/5) and *Capillaria* sp. eggs (100%; 5/5)
Papagaio-eclectus (*Eclectus roratus*) ES	1	0	-
Papagaio-moleiro (*Amazona farinosa*)	1	0	-
Papagaio-verdadeiro (*Amazona aestiva*)	2	2	*Ascaridia* sp. eggs (100%; 2/2) and *Capillaria* sp. eggs (100%; 2/2)
Pato-real (*Anas platyrhynchos*)	3	3	*Giardia* sp. cysts (100%; 3/3)
Pavão-indiano (*Pavo cristatus*) ES	6	3	*Ascaridia* sp. eggs (33%; 1/3) and Coccidia oocysts (100%; 3/3)
Periquitão-maracanã (*Psittacara leucophthalmus*)	4	0	-
Periquito-australiano (*Melopsittacus undulatus*)	5	1	-
Pomba-goura (*Goura cristata*) ES	2	2	Coccidia oocysts (100%; 2/2)
Rola-turca (*Streptopelia decaocto*) ES	17	10	Trichostrongyloidea eggs (20%; 2/10), *Giardia* sp. cysts (10%; 1/10) and Coccidia oocysts (100%; 10/10)
Saracura-três-potes (*Aramides cajaneus*)	1	0	-
Seriema (*Cariama cristata*)	4	4	*Ascaridia* sp. eggs (25%; 1/4) and Coccidia oocysts (75%; 3/4)
Socó-boi (*Tigrisoma lineatum*)	1	0	-
Tucano-de-bico-verde (*Ramphastos dicolorus*)	1	0	-
Urubu-rei (*Sarcoramphus papa*)	1	1	Trichostrongyloidea eggs (100%; 1/1)

ES- Exotic species; NE- Number Examined; NI- Number Infected. Source: Authors.

Finally, among the reptiles, we identified a family of helminths (Ancylostomatidae; 34.4%), a single genus of protozoan (*Cryptosporidium* sp.; 12%), and coccidian oocysts (9.1%; 8/87) in specimens of Squamates (*Boa constrictor*, *Python molurus bivittatus,* and *Eunectes murinus*) and Testudines (C*helonoidis carbonaria* and *C. denticulata*) (Table 4).

Table 4. Frequency of gastrointestinal parasitic infection in captive wild Reptiles of two Brazilian Zoological Gardens.

Type of animals (Host)	**NE**	**NI**	**Gastrointestinal Parasite Found (%; n/N)**
Reptiles			
Cágado-do-nordeste (*Mesoclemmys tuberculata*)	2	0	-
Jabuti-piranga (*Chelonoidis carbonaria*)	72	25	Ancylostomatidae eggs (100%; 25/25) and *Cryptosporidium* sp. oocysts (12%; 3/25)
Jabuti-tinga (*Chelonoidis denticulata*)	2	2	Ancylostomatidae eggs (100%; 2/2)
Jacaré-de-papo-amarelo (*Caiman latirostris*)	2	0	-
Jiboia (*Boa constrictor*)	6	6	Ancylostomatidae eggs (50%; 3/6) and Coccidia oocysts (100%; 6/6)
Jiboia arco-íris (*Epicrates cenchria assisi*)	1	0	-
Píton birmanesa (*Python molurus bivittatus*) [ES]	1	1	Coccidia oocysts (100%; 1/1)
Sucuri-verde (*Eunectes murinus*)	1	1	Coccidia oocysts (100%; 1/1)

ES- Exotic species; NE- Number Examined; NI- Number Infected. Source: Authors.

4. Discussion

In this study, we described the occurrence of helminths and gastrointestinal protozoa in different groups of mammals, birds, and reptiles, both wild and/or exotic, from two zoos in the Northeast region of Brazil. Herein, the percentage of positivity (60.2%) among the evaluated species was higher than that of studies carried out in Malaysia (56.3%) and Serbia (51.96%), and much higher than those observed in England (31%), India (29.5%), and Nigeria (21.9%) (Lim et al, 2008; Otegbade e Morenikeji, 2014; Carrera-Játiva et al, 2018; Ilic et al, 2018; Patra et al, 2019). In addition, other surveys carried out in the Brazilian territory observed percentages of positivity lower than those obtained in our study: 41.76% in Rio Grande do Sul (Mewius et al, 2021), 40.8% in Pernambuco (Santos et al, 2015), and 16.5% in Rio de Janeiro (Barros et al, 2017).

It is important to highlight that these differences may be related to the diversity of animal species between the various regions, with predominance, in the most affected areas, of those that contribute to the maintenance of the biological cycle of the parasites (Betson et al, 2020). Additionally, areas with a higher rate of positivity among the animals may have failures in the sanitary management of the environments and, mainly, considering the transmission routes of gastrointestinal parasites, due to inadequate handling or insufficient hygiene of the food distributed to the animals.

Among mammals, the positivity rate, as well as the diversity of parasites, can be influenced mainly by the type of food that these animals are provided with. For example, among carnivores that consume small rodents, there is a higher risk of infection with the helminth *Angiostrongylus* sp. This was corroborated by our findings. The species *Cerdocyon thous* showed a high positivity rate for *Angiostrongylus* sp. Similarly, felids consuming contaminated meat have a high risk of infection by ascarids. In our study, specimens of *Panthera leo* showed high rates of infection by these worms (Spratt, 2015; Rostami et al, 2020).

Interestingly, the species *Ursus arctos* (brown bear) was diagnosed with parasites of the Ancylostomatidae family. This is probably the first report of this type of infection in South America. Clinically, infection by these worms in other animals can cause anemia, stunted growth, tissue damage, gastrointestinal inflammation and death and can therefore also cause seriousness to the brown bear. Nevertheless, further studies are required to assess the clinical manifestations of these worms in this species of bear. (Seguel e Gottdenker, 2017).

On the other hand, among herbivores, which regularly consume pasture, there is a high risk of ingesting vegetables contaminated by other species of parasites, especially if they come from uncontrolled pasture areas. In this context, there is a high risk of infection by different species of helminths, such as hookworms, which have previously been identified parasitizing *Elephas maximus* in regions of Asia (Abhijith et al, 2018). Likewise, we also identified specimens of *E. maximus* parasitized by hookworms and this is possibly the first report on specimens from South America.

Interestingly, parasites that are normally reported in Equidae and domestic ruminants can also be identified in exotic animals kept in zoos, as observed in *Equus quagga burchellii* and *Lama glama*. (Andersen et al, 2013). Herein, we identified eggs of Trichostrongyloidea and Ascarididae among these equids which, as discussed above, can occur due to feeding with contaminated vegetables and without adequate control in captivity. Nonetheless, it should also be emphasized that the constant practices of prophylactic use of anthelmintics can cause resistance of the worm species to the drugs regularly used (Andersen et al, 2013; Wyrobisz et al, 2016).

Notably, due to the usually varied diet among omnivorous, there is a risk of infection by parasites present in both animal and plant foods. Furthermore, we highlight the high rate of infection by protozoa in this group, whose transmission may be related to food contamination, as well as the ingestion of water containing cysts of the parasites (Tiddi et al, 2019; Li et al, 2020). In our study, it was observed that omnivorous kept in zoos, such as peccaries and primates, were mainly infected by the protozoa *Entamoeba* spp. and Coccidia. Interestingly, primates often throw food at each other and, considering their habit of touching the perianal region, there is a high risk of transmission of cysts from these parasites. Thereby, they can act as accidental mechanical vectors for other primates, and even for peccaries (Foil e Gorham, 2000).

Among the bird species evaluated in this study, those with the highest percentage of parasites were mainly Anseriformes, Galliformes, and Psittaciformes. The most common parasite in this group was the helminth *Capillaria* sp., whose parasitism may be related to foraging habits in soil contaminated by larval eggs. It may also be associated with contact with synanthropic specimens, since the proximity of birds with these animals facilitates the transmission of the worm (Papini et al, 2012; Carrera-Játiva et al, 2018). Likewise, it is important to highlight the high percentage of birds infected with Coccidia. This species of parasite has been frequently reported in several species of captive birds (Papini et al, 2012). In this study, the species *Ara ararauna*, *Pavo cristata*, *Streptopelia decaocto*, and *Cariama cristata* were the most parasitized, possibly due to contact with free-living paratenic hosts or due to contaminated fomites transported by keepers, such as shoes and/or cleaning objects. More importantly, high rates of cooccidian infection significantly increase the risk of transmission in captivity and also mortality among these birds (Cordón et a., 2009; Knight et al, 2018).

In reptiles, the high frequency of infected specimens is probably due to the habit of this group of crawling in the environment in which they live and also to the sharing of herds with other animals. Moreover, it may be associated with the consumption of hosts contaminated with hookworms and protozoa (Coccidia and *Cryptosporidium* sp.) and that are not submitted to methods of elimination of the infectious stages, such as freezing. This form of transmission among reptiles was previously reported in a study carried out in Italy (Papini et al, 2011).

Importantly, gastrointestinal parasites of zoonotic species have been identified and which may therefore also pose a risk to human health. In our study, the main species with zoonotic potential were the helminths *Ancylostoma* sp. and *Toxocara* sp., and the protozoa *Giardia* sp. and *Cryptosporidium* sp. The presence of these parasites among animals represents an additional risk for captive caretakers. Considering this, it is important to emphasize that control and prophylaxis measures for zoonoses are fundamental to avoid problems that may affect individuals who interact daily with these animals. Besides, it is important to monitor animal health by trained professionals who always seek to work with preventive medicine. In addition, it is recommended that routine examinations be carried out for the diagnosis of these parasites among captive species and also among the team that works in zoological units.

5. Conclusion

Taken together, our findings demonstrate that wild and exotic animals kept in zoos are also at risk of infection with several species of gastrointestinal parasites. Our data showed that among the classes of animals, mammals were the most affected, followed by birds and reptiles. Additionally, this was the first study to report the occurrence of gastrointestinal parasites in *U. arctos* and *E. maximus* in South America. These data therefore reinforce the urgent need for improvements in sanitary measures and routine parasitological examinations. These measures are required to avoid compromising human and animal health, as well as understanding the parasite-host relationship in animals parasitized by helminths not yet reported in these animal species.

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