Gastrointestinal parasites in captive wild animals from two Brazilian Zoological Gardens
Parásitos gastrointestinais em animais silvestres em caçadores de dois Jardins Zoológicos brasileiros
Parásitos gastrointestinales en animales silvestres en cautiverio de dos Jardines Zoológicos Brasileños

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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%; 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.

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; Moretti 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 Pholenz, 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*.

**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: Nematelmimths (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**       |                 |       |            |            |           |          |          |
| Ancylostomatidæ    |                 | -     | 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 (Ancylostomatidæ, Metastrongylidæ, Oxyuridæ, Hymenolepididæ, Ascarididæ, Strongyloididæ, Toxocaridæ, Trichostrongylidæ and Trichuridæ), eleven genera (Ancylostoma sp., Angiostrongyus spp.,
Aspiculuris sp., Hyminolespis 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) |
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 Eucoccidiordia. 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)     | 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)         |     |
| Species | ES | NE | NI |
|---------|----|----|----|
| Carcará (*Caracara plancus*) | 5 | 0 | - |
| Casuar (*Casuarius casuarius*)<sup>ES</sup> | 1 | 1 | Coccidia oocysts (100%; 1/1) |
| Ema (*Rhea americana*) | 1 | 1 | Ascaridia sp. eggs (100%; 1/1) |
| Faisão (*Phasianus Colchicus*)<sup>ES</sup> | 2 | 0 | - |
| Galinha D'angola (*Numida meleagris*)<sup>ES</sup> | 4 | 0 | - |
| Irêrê (*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*)<sup>ES</sup> | 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*)<sup>ES</sup> | 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*)<sup>ES</sup> | 2 | 2 | Coccidia oocysts (100%; 2/2) |
| Rola-turca (*Streptopelia decaocto*)<sup>ES</sup> | 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 (Chelonoidis 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 Cercocyn 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; Wyrobsz 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 coccidian 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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