Research, Society and Development, v. 10, n. 13, e486101321255, 2021
(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v10i13.21255

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

Received: 09/30/2021 | Reviewed: 10/09/2021 | Accept: 10/17/2021| Published: 10/20/2021

Aksa Ingrid Vieira Batista
ORCID: https://orcid.org/0000-0003-0696-7194
Universidade Federal Rural do Semi-Árido, Brazil
E-mail: aksaingridmv@gmail.com
Gabriel Vinicius Carvalho de Lucena
ORCID: https://orcid.org/0000-0001-9789-6066
Universidade Federal de Campina Grande, Brazil
E-mail: gabrielviniciuslucenac@gmail.com
Thiago Ferreira Lopes Nery
ORCID: https://orcid.org/0000-0002-4051-428X
Arruda Câmara Zoobotanical Park, Brazil
E-mail: nerylf@gmail.com
Cintia Cleub Neves Batista
ORCID: https://orcid.org/0000-0001-5363-7863
Arruda Câmara Zoobotanical Park, Brazil
E-mail: cintiacleub@hotmail.com
Jael Soares Batista
ORCID: https://orcid.org/0000-0001-9663-7468
Universidade Federal Rural do Semi-Árido, Brazil
E-mail: jael.batista@ufersa.edu.br
Igor Espínola Winkeler
ORCID: https://orcid.org/0000-0003-1861-9509
Universidade Federal da Paraíba, Brazil
E-mail: igor_winkeler@hotmail.com
Caio Michel de Morais Rolim
ORCID: https://orcid.org/0000-0001-9992-506X
Universidade Federal Rural do Semi-Árido, Brazil
E-mail: michelrolim97@gmail.com
Wesley Adson Costa Coelho
ORCID: https://orcid.org/0000-0001-7039-9481
Faculdade Nova Esperança de Mossoró, Brazil
E-mail: wesleyadson@outlook.com
Emanuel Lucas Bezerra Rocha
ORCID: https://orcid.org/0000-0002-1265-0698
Universidade Federal Rural do Semi-Árido, Brazil
E-mail: emanuellucasvet@gmail.com
Victor Fernando Santana Lima
ORCID: https://orcid.org/0000-0002-7255-0664
Universidade Federal de Sergipe, Brazil
E-mail: victor.fslima@gmail.com
Josivania Soares Pereira
ORCID: https://orcid.org/0000-0002-2407-9417
Universidade Federal Rural do Semi-Árido, Brazil
E-mail: josigej@ufersa.edu.br

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, Paraiba 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.

Resumo

Um dos obstáculos da conservação *ex situ* de animais silvestres e exóticos são as doenças que os acometem em cativeiro e, dentre elas, as endoparasitoses são muito frequentes. O objetivo deste trabalho é relatar a ocorrência de endoparasitos em amostras fecais de animais do Parque Zoobotânico Arruda Câmara, em João Pessoa, Paraíba, Brasil, bem como identificar diferenças estatísticas significativas entre os percentuais de cada espécie de parasito encontrada. Para tanto, foram obtidas 66 amostras fecais de 50 espécies de animais, entre mamíferos, aves e répteis. As diferenças estatísticas entre as porcentagens de cada espécie de parasito foram obtidas pelo teste binomial com nível de significância de 5%. Um total de 54,5% (36/66) das amostras fecais foram positivas (p = 0,539), entre as quais 80,5% (29/36) eram de nematoides, seguidos de cestoides 19,4% (07/36), protozoários 13,9% (05/36), e ácaros 16,7% (06/36). Este estudo relata pela primeira vez a associação de *Balantidium* sp. em *Tapirus terrestris*, *Bertiella* sp. em *Alouatta caraya*, *Hymenolepis* spp. e *Aspiculuris* spp. como parasitas espúrios em répteis; e *Entamoeba coli* e *Eimeria* spp. com *Iguana Iguana* no nordeste do país. Este estudo fornece conhecimento sobre alguns dos endoparasitos que podem ocorrer em zoológicos da região Nordeste do país, bem como auxilia na ampliação dos dados ecológicos sobre animais silvestres e exóticos.
Palavras-chave: Aves; Helmintos; Mamíferos; Mini-FLOTAC; Protozoários.

Resumen

Uno de los obstáculos para la conservación *ex situ* de los animales silvestres y exóticos son las enfermedades que los afectan en cautiverio y, entre ellas, las endoparasitosis, que son muy frecuentes. El objetivo de este estudio es reportar la ocurrencia de endoparásitos en las muestras fecales de animales del Parque Zoobotánico Arruda Câmara, en João Pessoa, Estado de Paraíba, Brasil, así como identificar diferencias estadísticas significativas entre los porcentajes de cada especie parasitaria 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%. El 54,5% (36/66) de las muestras fecales resultaron positivas (p = 0,539), de las cuales el 80,5% (29/36) presentaron nematodos, seguido de los cestodos 19,4% (07/36), protozoos 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 parásitos espurios en reptiles; y *Entamoeba coli* y *Eimeria* spp. con *Iguana iguana* en el noreste del país. Este estudio brinda conocimiento sobre algunos de los endoparásitos que pueden ocurrir en los zoológicos de la región noreste del país, así como en la ampliación de los datos ecológicos sobre animales silvestres y exóticos.
Palabras clave: Aves; Helmintos; Mamíferos; Mini-FLOTAC; Protozoos.

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

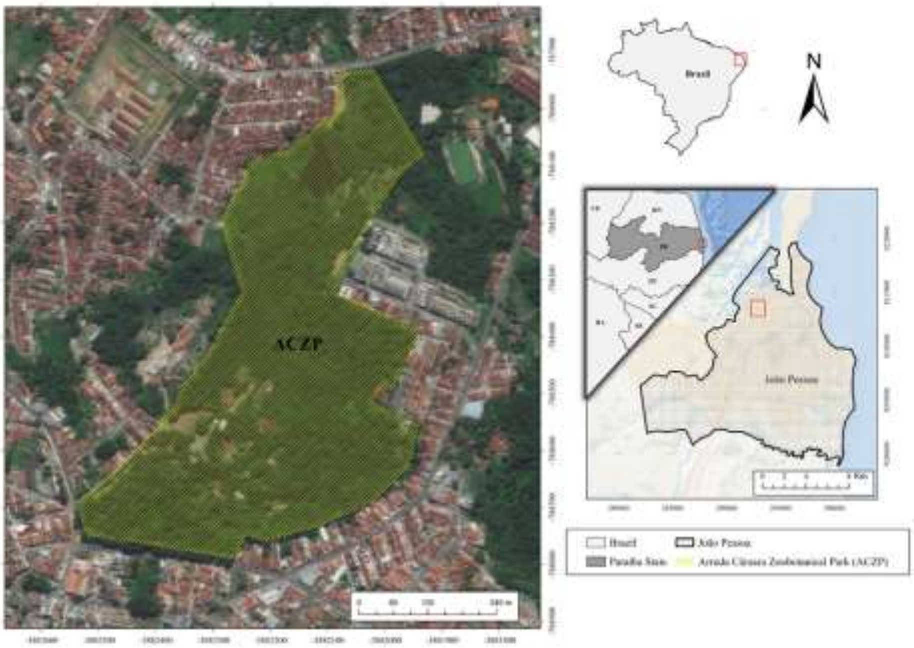
Ethical aspects

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 9213107mN and 9214100mN, 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).

Figure 1 - Map of the Arruda Câmara Zoobotanical Park (ACZP) collection region, Paraíba State, Brazil.



Source: Personal archive.

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 yagouroundi* (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 aeothiops* (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), *Chelonoidis* sp. (n=1), *Chelonoidis carbonaria* (n=1), and *Chelonoidis denticulata* (n=1) (Table 1).

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.

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	

(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v10i13.21255

Tayra	*Eira barbara*	1
Neotropical otter	*Lontra longicaudis*	2
	Family Canidae	
Crab-eating fox	*Cerdocyon thous*	3
	Order Primates	
	Family Cebidae	
Blond capuchin	*Sapajus flavius*	5
Black-striped capuchin	*Sapajus libidinosus*	7
Capuchin	*Sapajus* spp.	3
Common marmoset	*Callithrix jacchus*	1
Common squirrel monkey	*Saimiri sciureus*	1
	Family Atelidae	
Black howler	*Alouatta caraya*	2
	Family Aotidae	
Three-striped night monkey	*Aotus trivirgatus*	1
	Family Cercopithecidae	
Grivet	*Chlorocebus aeothiops*	2
Rhesus macaque	*Macaca mulatta*	1
	Order Artiodactyla	
	Family Tayassuidae	
Collared pecary	*Pecari tajacu*	5
	Family Cervidae	
Brown brocket	*Mazama gouazoupira*	1
	Order Perissodactyla	
	Family Tapiridae	
South American tapir	*Tapirus terrestris*	1
	Order Pilosa	
	Family Bradypodidae	
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
	Family Icteridae	
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*	1
	Order Cariamiformes	
	Family Cariamidae	
Red-legged seriema	*Cariama cristata*	2
	Class Lepidosauria	
	Order Squamata	
	Family Colubridae	
Corn snake	*Pantherophis guttatus*	7
	Family Boidae	
Rainbow boa	*Epicrates assisi*	1
India rock python	*Pithon molurus*	1
Green anaconda	*Eunectes murinus*	1
	Family Viperidae	
Caatinga lancehead	*Bothrops erythromelas*	1
	Family Teiidae	
Argentine black and white tegu	*Salvator merianae*	1
	Family Iguanidae	
Green iguana	*Iguana iguana*	1
	Class Archelosauria	
	Order Testudines	
	Family Testudinidae	
Tortoise	*Chelonoidis* sp.	1
Red-footed tortoise	*Chelonoidis carbonaria*	1
Yellow-footed tortoise	*Chelonoidis denticulata*	1

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 yagouaroundi	ACZP	Eggs of *Toxocara* sp. (400 EPG)
Leopardus pardalis	Free-living	Eggs of *Syphacia* sp.
Nasua nasua	ACZP	Eggs of *Strongyloides* sp. (10 EPG) and Rhabditida-type larvae (10 LPG).
Procyon cancrivorus	ACZP	Egg of Strongylida-type
Sapajus flavius	ACZP	Cestoda-type eggs (70 EPG), eggs of *Strongyloides* sp., Ancylostomatidae-type eggs, and Rhabditida-type larvae (30 LPG).
Sapajus libidinosus	ACZP	Eggs of *Strongyloides* sp. (200 EPG), Ancylostomatidae-type eggs (30 EPG), and Rhabditida-type larvae (70 LPG).
	ACZP	Eggs of *Strongyloides* sp. (240 EPG), Ancylostomatidae-type eggs (50 EPG), and Rhabditida-type larvae (50 LPG).
	ACZP	Eggs of *Strongyloides* sp. (50 EPG), Ancylostomatidae-type eggs (20 EPG), and Rhabditida-type larvae.
Sapajus spp.	ACZP	Eggs of *Strongyloides* sp. (840 EPG), Ancylostomatidae-type eggs (120 EPG), and Rhabditida-type larvae (20 LPG).
Saimiri sciureus	ACZP	Nematoda-type eggs.
Alouatta caraya	ACZP	Eggs of *Bertiella* spp. (110 EPG).
Chlorocebus aeothiops	ACZP	Eggs of *Strongyloides* sp. (140 EPG), eggs of *Trichuris* sp. and Rhabditida-type larvae.
Pecari tajacu	ACZP	Eggs of *Strongyloides* sp. (180 EPG), Strongylida-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 hyancinthinus	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	Strongylida-type eggs.
Cacicus cela	Free-living	Oocysts and non-sporulated coccidia (30 OPG), *Isospora* sp. (20 OPG) and Rhabditida-type larvae (10 LPG).
Crax fasciolata	ACZP	Ascaridoidea-type eggs (30 EPG) and eggs of *Capillaria* spp.
Patagioenas picazuro	ACZP	Eggs of *Capillaria* spp. (240 EPG).
Rupornis magnirostris	ACZP	Eggs of *Trichuris* sp. (30 EPG).
Pantherophis guttatus	ACZP	Eggs of *Aspiculuris* sp. (20 EPG) and mite eggs.
	ACZP	Eggs of *Hymenolepis* sp., eggs of *Aspiculuris* sp., and mite eggs.
	ACZP	Eggs of *Hymenolepis* sp. (70 EPG), eggs of *Aspiculuris* 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.
Bothrops erythromelas	ACZP	Eggs of *Aspiculuris* sp. (20 EPG), mite eggs, and mites (*Myocoptes musculinus*).
Salvator merianae	ACZP	Eggs of strongylids (60 EPG), Rhabditida larvae (100 LPG), Eggs of Strongyloidoidea (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., Strongylida-type eggs (30 EPG), and Rhabditida-type larvae (30 LPG).
Chelonoidis denticulata	ACZP	Cysts (150 CPG) and trophozoites (2000 TPG) of *Balantidium* spp., cysts (380 CPG) and trophozoites (440 TPG) of *Nyctotherus* spp., Strongylida-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 Ascarididoidea, 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 Strongyloidoidea, 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 – Strongylida-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* spp.; 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%), Cilliophora (60%), and Amoebozoa (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 *Nyctotherus* sp. In addition, the only Amoebozoa 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) Rhabditida-type 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, *Strongyloide*s 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 aeothiops*. 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. ararauna*, 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 lacertid 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 *Chelonoidis 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 *Nyctotherus* 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., *Prosthernorchis elegans*, and *Bertiella* spp. have been found in primates. In Brazil, *Capillaria* spp., *Ascaridia* sp., *Heterakis* sp., *Libyostrongylus* spp., *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 *Aspiculuris* 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, diarrhea, 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 zoobotanic parks. The present research was the pioneer, in Brazil, to perform the parasitological diagnosis of most of the vertebrate animals of the same zoobotanic park, with species from the Mammalia, Aves, Archelosauria, 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.

Acknowledgments

We thank the Federal Rural University of the Semi-Arid (UFERSA) for the support in developing this research and the researchers from the Laboratory of Animal Parasitology (LPA-UFERSA) and the entire team of the Zoobotanical Park Arruda Câmara, in João Pessoa-PB, which were essential for this study.

References

Ayres, M. C. C., Peixoto, M. S. R., da Silva, W. B., Gomes, D. M., Nunes, O. C., Borges, K. B., & de Almeida, M. A. O. (2016). Ocorrência de parasitos gastrintestinais em Psitacídeos, mantidos em Parques Ecológicos na região metropolitana de Salvador, Bahia. *Brazilian Journal of Veterinary Medicine*, 38(2), 133-136.

Barros, L. A., Sant, L. X., & Magalhães, B. S. N. (2017). Prevalência de parasitos gastrointestinais em mamíferos selvagens do Jardim Zoológico do Rio de Janeiro. *Revista Brasileira de Ciência Veterinária*, 24(4), 179-183.

Capasso, M., Maurelli, M. P., Ianniello, D., Alves, L. C., Amadesi, A., Laricchiuta, P., & Rinaldi, L. (2019). Use of Mini-FLOTAC and Fill-FLOTAC for rapidly diagnosing parasitic infections in zoo mammals. *Revista Brasileira de Parasitologia Veterinária*, 28, 168-171.

Cringoli, G., Rinaldi, L., Maurelli, M. P., & Utzinger, J. (2010). FLOTAC: new multivalent techniques for qualitative and quantitative copromicroscopic diagnosis of parasites in animals and humans. *Nature protocols*, 5(3), 503-515.

Cringoli, G., Rinaldi, L., Albonico, M., Bergquist, R., & Utzinger, J. (2013). Geospatial (s) tools: integration of advanced epidemiological sampling and novel diagnostics. *Geospatial health*, 7(2), 399-404.

Cringoli, G., Maurelli, M. P., Levecke, B., Bosco, A., Vercruysse, J., Utzinger, J., & Rinaldi, L. (2017). The Mini-FLOTAC technique for the diagnosis of helminth and protozoan infections in humans and animals. *Nature protocols*, 12(9), 1723-1732.

Dashe, D., & Berhanu, A. (2020). Study on Gastrointestinal Parasitism of Wild Animals in Captivity at the Zoological Garden of Haramaya University, Ethiopia. *Open Journal of Veterinary Medicine*, 10(9), 173-184.

Fagiolini, M., Lia, R. P., Laricchiuta, P., Cavicchio, P., Mannella, R., Cafarchia, C., & Perrucci, S. (2010). Gastrointestinal parasites in mammals of two Italian zoological gardens. *Journal of Zoo and Wildlife Medicine*, 41(4), 662-670.

Fernandes-Santos, R. C., Medici, E. P., Testa-José, C., & Micheletti, T. (2020). Health assessment of wild lowland tapirs (Tapirus terrestris) in the highly threatened Cerrado biome, Brazil. *Journal of wildlife diseases*, 56(1), 34-46.

Foreyt, W.J. (2002). *Veterinary parasitology: reference manual.* Blackwell Publishing Professional.

Hoffman, W. A.; Pons, J. A. & Janer, J. L. (1934). The sedimentation-concentration method in schistosomiasis mansoni. *Journal of Tropical Medicine and Public Health*, 9.

Hoffmann, R. P. (1987). *Diagnóstico de parasitismo veterinário*. Sulina.

Kvapil, P., Kastelic, M., Dovč, A., Bártová, E., Čížek, P., Lima, N., & Štrus, Š. (2017). An eight-year survey of the intestinal parasites of carnivores, hoofed mammals, primates, ratites and reptiles in the Ljubljana zoo in Slovenia. *Folia parasitologica*, 64, 01-06.

Lima, V. F. S., Bezerra, T. L., Andrade, A. F. D., Ramos, R. A. N., Faustino, M. A. D. G., Alves, L. C., & Meira-Santos, P. O. (2016). Gastrointestinal parasites of exotic birds living in captivity in the state of Sergipe, Northeastern Brazil. *Revista Brasileira de Parasitologia Veterinária*, 26, 96-99.

Lima, V. F. S., do Nascimento Ramos, R. A., Giannelli, A., Andrade, W. W. A., López, I. Y. T., do Nascimento Ramos, I. C., & Alves, L. C. (2021). Ocorrência de parasitos gastrointestinais zoonóticos de roedores eo risco de infecção humana em diferentes biomas do Brasil. Brazilian Journal of Veterinary Medicine, 43(1), e113820-e113820.

Marques, S. M. T., Menetrier, L. D. C., Natal, A. C. C., Fernandes, L. S., Meyer, J., & Alievi, M. M. (2019). Prevalência de parasitos intestinais em aves domésticas e silvestres do sul do Brasil. *Revista Agrária Acadêmica*. 2(5), 17-24.

Oliveira, S.G.; Prates, H. M., Mentz, M., & Bicca-Marques, J. C. (2011). Prevalência de *Bertiella* sp. em um grupo de bugios-pretos, *Alouatta caraya* (Humbolt, 1812). In: Melo, F. R.; Mourthé, I. **A. *Primatologia no Brasil.***, Sociedade Brasileira de Primatologia.

Patra, G., Lalremruati, P., Ghosh, S., Parida, A., Kumar Borthakur, S., & Behera, P. (2020). Prevalence of gastrointestinal parasites in captive non-human primates of zoological gardens in North-Eastern region of India. *Biological Rhythm Research*, 51(5), 690-698.

Reed, T. E., Daunt, F., Kiploks, A. J., Burthe, S. J., Granroth-Wilding, H. M., Takahashi, E. A., & Cunningham, E. J. (2012). Impacts of parasites in early life: contrasting effects on juvenile growth for different family members. *PLoS One*, 7(2), e32236.

Rinaldi, L., Mihalca, A. D., Cirillo, R., Maurelli, M. P., Montesano, M., Capasso, M., & Cringoli, G. (2012). FLOTAC can detect parasitic and pseudoparasitic elements in reptiles. *Experimental Parasitology*, 130(3), 282-284.

Schieber, M. C., & Strkolcova, G. (2019). Prevalence of Endoparasites in Carnivores in a Zoo and a Wolves park in Germany. *Folia Vet*, 63, 54-59.

Snak, A., Lenzi, P. F., Agostini, K. M., Delgado, L. E., Montanucci, C. R., & Zabott, M. V. (2014). Análises coproparasitológicas de aves silvestres cativas. *Ciência Animal Brasileira*, 15, 502-507.

Willis, H. H. (1921). A simple levitation method for the detection of hookworm ova. *Medical Journal of Australia*, 2(18).