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# Parasitological assessment of wild ring-tailed coatis (*Nasua nasua*) from the Brazilian Atlantic rainforest

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## 1. Introduction

The Brazilian Atlantic Rainforest, once one of the largest rainforests in the Americas, currently exists as isolated small fragments scattered over the original area. The Iguaçu National Park (PARNA Iguaçu) is one of the largest remnants of the Brazilian Atlantic Rainforest, representing one of the most-preserved areas of this Biome (Ribeiro et al., 2009). There are 71 species of mammals registered in the park, among which the ring-tailed coatis, *Nasua nasua* (Carnivora: Procyonidae), is one of the most abundant carnivores in the Park (Vega, 2003; Kasper, 2007). These procyonids are important for the forest dynamics, as they use large foraging areas in which they move constantly, acting as good seed dispersers and predating the population of small and medium-sized mammals, birds, and reptiles, as well as invertebrates (Costa and Mauro, 2008).

Parasites may regulate, directly or indirectly, the density and dynamics of their host population (Renaud et al., 1996). Thus, a better understanding of wildlife parasites is important for a better understanding of the natural history of the host species and its health status (Rubel et al., 2003). However, even though the importance of parasites is unquestionable, the knowledge on the helminth fauna of ring-tailed coatis is limited to descriptions of parasites obtained by chance or checklists (Vieira et al., 2008).

Previous results of parasitological studies on ring-tailed coatis from Iguaçu National Park indicated a large diversity of filarial nematodes, all of which were identified for the first time (Moraes et al., 2017). Therefore, the parasite richness of these procyonids may be underestimated because of the lack of studies.

According to Boomker (2014), the composition of species and the parasite burden of helminths in a host are the result of the geographic distribution and habitat preference of these hosts, and therefore, studies should be conducted in representative areas of every biome. Thus, this study aimed to describe the parasites of ring-tailed coatis from one of the most important remnants of the Brazilian Atlantic rainforest, the PARNA Iguaçu, and describe their respective propagula.

## 2. Materials and methods

### 2.1. Study area

This study was performed in the Iguaçu National Park, Foz do Iguaçu, Brazil. The park is located in the southwestern portion of the Paraná State, between S25°05′ and S25°40′ and W54°30′ and W54°40' (Fig. 1). The Iguaçu National Park is considered one of the largest conservation areas in the Brazilian Atlantic Forest, comprising an area of 185,262 ha, with a total perimeter of 420 km, of which 300 km are watercourses (IBAMA, 1981).

### 2.2. Animals

Over 15 months, 13 recently roadkilled ring-tailed coatis were collected from the BR-469 road, inside the PARNA Iguaçu area, and frozen in plastic bags at −20 °C.

Additionally, 75 ring-tailed coatis were captured using baited Tomahawk traps and pole nets. These animals were chemically restrained with tiletamine and zolazepam (5 mg/kg, IM) for biometric and clinical examinations. Each animal was individually identified with a numbered ear tag, and fecal samples were collected directly from the rectum and kept under refrigeration.

### 2.3. Parasitological methods

*Necropsy:* After thawing the body at room temperature, all the organs were removed, and the body cavities and subcutaneous tissues were carefully examined. The organs of the cardiopulmonary system and associated vessels, kidneys, urinary bladder, liver, and gall bladder were cut open following anatomical structures such as blood vessels, airways, and bile ducts and thoroughly washed in a metallic sieve. The digestive tract, after separation in its anatomical portions, also was slit and thoroughly washed in a metallic sieve. The resultant contents were fixed and stored in labeled vials containing Railliet & Henry solution until the collection of the helminths was performed under a

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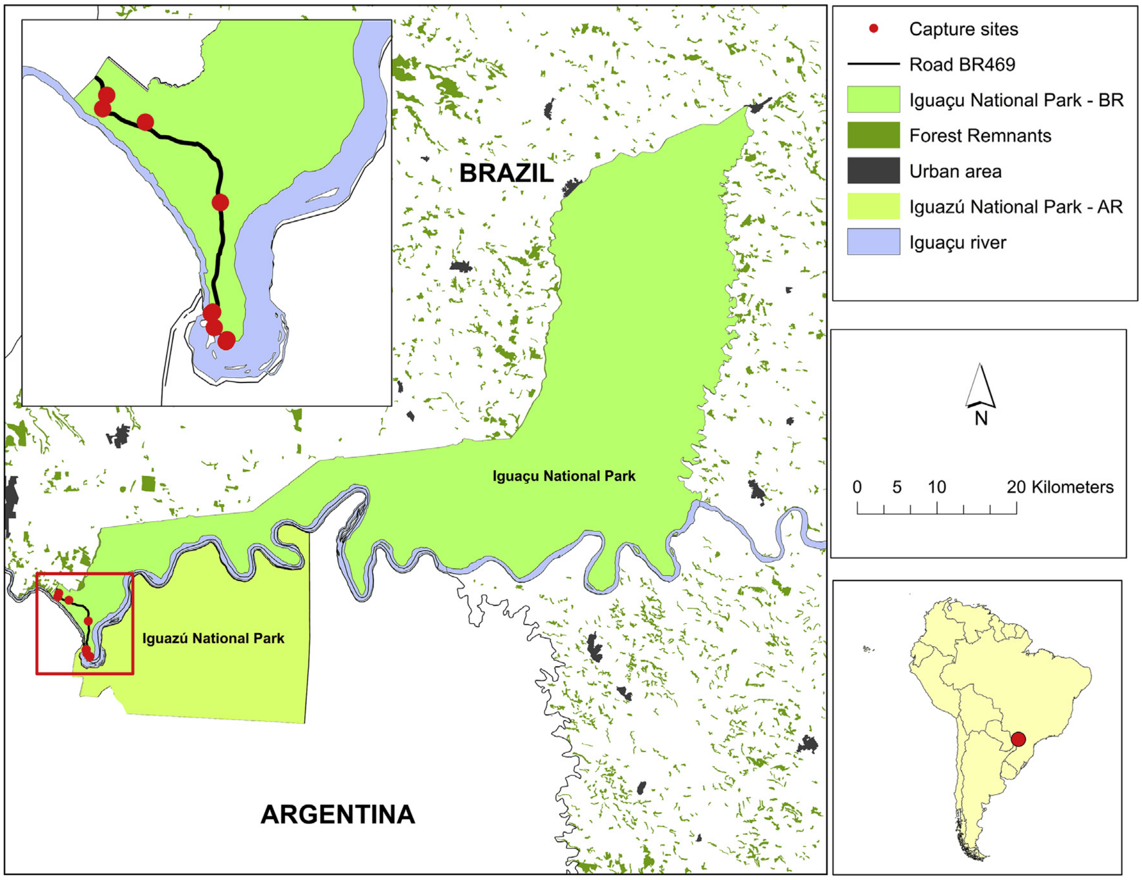


**Fig. 1.** Geographical location of Iguazu National Park, Southern Brazil.

stereomicroscope.

*Taxonomic identification:* After diaphanization in 80% acetic acid solution and, if necessary, beechwood creosote, the specimens were prepared in temporary mounts for morphological and morphometrical examinations. Mature eggs were removed from females or mature specimens in order to evaluate their morphology for comparison with those found in coprodiagnostic methods.

The taxonomic identification of the parasites was performed according to Machado-Filho (1950), Vicente et al. (1997), and Anderson et al. (2009), with additional literature. Vouchers were deposited in the Coleção Helmintológica do Instituto Oswaldo Cruz (CHIOC/Fiocruz), and additional types were kept in the collection of the Laboratory of Parasitic Diseases of Animals, FCAV/Unesp.

*Fecal tests:* The fecal samples (n = 75), weighing at least 10 g, were analyzed within 24 h after collection. The counting of nematode eggs and protozoa oocysts was performed following the Gordon and Whitlock (1939) and Wisconsin (Cox and Todd, 1962 modified by Ito, 1980) techniques. Lungworm larvae, cestodes, and digenean eggs were evaluated qualitatively using the Hoffman sedimentation test (1934). The samples positive for coccidia were kept in 2.5% potassium dichromate for 10 days with constant aeration until sporulation for specific identification (Levine and Ivens, 1986). Eggs and oocysts were identified to the species level when feasible, in accord with the identified adult parasites. In some cases, as for the strongylid-type eggs, the identification remained at the morphogroup level because of the absence of diagnostic characters for each identified species. The morphometric data of the eggs and oocysts, based on at least 50 specimens, are expressed in millimeters as the arithmetic mean ± standard deviation, followed by the range in parentheses. The images were obtained with an Olympus BX-51 microscope equipped with a digital QColor 3 camera (Olympus, Tokyo, Japan), and they were then processed using ImagePro Plus v. 4.0 software (Mediacy.com).

### 2.4. Ethical aspects

All procedures adopted in this study were approved by the Ethics Committee on Animal Use of the FCAV/Unesp (protocol 07553/14) and are in accord with international standards. The captures were authorized by the Sistema de Autorização e Informação em Biodiversidade (SISBIO protocol 38006–2).

## 3. Results

This study examined the helminth fauna of ring-tailed coatis from an important remnant of the Brazilian Atlantic rainforest.

The majority of the roadkilled animals were females and subadult animals, representing 69.2% (9/13) and 61.5% (8/13) of the ring-tailed coatis, respectively. In necropsy, nematodes were clearly the most numerous group, with 11 species, followed by digenetics, cestodes, and acanthocephalans, with one representant each. The most frequent species of these procyonids was *Neoncicola potosi*, followed by *Uncinaria bidens*, *Molineus nasuae*, and *Atriotaenia sandgroundi*, all of which are parasites of the small intestine. The digenetic *Athesmia heterolecithodes* was the least frequent parasite, with only one specimen found in one of the examined ring-tailed coatis, representing a prevalence of 7.69% and a low mean abundance of 0.14. The trichostrongylid family Molineidae was the taxonomic group with most represented species, with four in total. *M. nasuae* and *M. barbaris* were the most abundant species, with mean abundances of 138.07 and 114.38, respectively. The parasitic infracommunity of ring-tailed coatis was composed mainly of core (n = 9) and secondary (n = 4) species, but *A. heterolecithodes* remained as a satellite species, with a prevalence lower than 10%. The descriptors

**Table 1**
Descriptors of infection for the diagnosed helminths of *Nasua nasua* from PARNA Iguaçu, Brazilian Atlantic Rainforest.

| | Site of infection | Prevalence | Mean abundance | MI[a] | Range of intensity | Original host | Referências |
|---|---|---|---|---|---|---|---|
| **NEMATODA** | | | | | | | |
| **Ancylostomatoidea** | | | | | | | |
| **Ancylostomatidae** | | | | | | | |
| *Ancylostoma braziliense* | SI | 15.38% (2/13) | 1.7 | 7 | 2–12 | *Canis familiaris* | Faria (1910) |
| *Uncinaria bidens* | SI | 79.92% (10/13) | 27.0 | 35 | 1–100 | *Nasua nasua* | Freitas and Rodrigues (1964) |
| **Trichostrongyloidea** | | | | | | | |
| **Molineidae** | | | | | | | |
| *Molineus nasuae* | SI | 79.92% (10/13) | 138.07 | 180 | 1–1.177 | *Nasua nasua* | Lent and Freitas (1938) |
| *Molineus barbaris* | SI | 61.53% (8/13) | 114.38 | 186 | 3–861 | *Eira Barbara* | Travassos (1913) |
| *Molineus felineus* | SI | 46.15% (6/13) | 11.69 | 25 | 2–88 | *Herpailurus yagouaroundi* | Travassos (1937) |
| *Molineus* sp. | SI | ? | 33.0 | 62 | 2–154 | *Nasua nasua* | Present study |
| **Trichinelloidea** | | | | | | | |
| **Capillaridae** | | | | | | | |
| *Baruscapillaria procyonys.* | SI | 46.15% (6/13) | 10.46 | 22 | 1–42 | *Procyon lotor* | Pence (1975) |
| **Metastrongyloidea** | | | | | | | |
| **Filaroididae** | | | | | | | |
| *Filaroides milksi* | Lg | 23.07% (3/13) | 8.92 | 38 | 1–113 | *Canis familiaris* | Whitlock (1956) |
| **Physalopteroidea** | | | | | | | |
| **Physalopteridae** | | | | | | | |
| *Physaloptera semilanceolata* | S | 53.83% (7/13) | 2.92 | 5 | 1–15 | *Nasua nasua* | Ortlepp (1922) |
| **Rhabditoidea** | | | | | | | |
| **Strongyloididae** | | | | | | | |
| *Strongyloides stercoralis* | SI | 23.07%(3/13) | 25.23 | 109 | 2–317 | *Canis familiaris* | Costa and Freitas (1970) |
| **Ascaridoidea** | | | | | | | |
| **Ascarididae** | | | | | | | |
| *Toxocara alienata* | SI | 15.38% (2/13) | 0.23 | 1 | 1–2 | *Nasua nasua* | Sprent (1982) |
| **DIGENEA** | | | | | | | |
| **Dicrocoelidae** | | | | | | | |
| *Athesmia heterolecithodes* | L | 53.84% (7/13) | 0.14 | 1 | 1 | *Cerdocyon thous* | Braun (1899) |
| **CESTODA** | | | | | | | |
| **Anoplocephalidae** | | | | | | | |
| *Atriotaenia sandgroundi* | SI | 76.92% (10/13) | 24.53 | 35 | 1–87 | *Nasua nasua* | Baer (1927) |
| **ACANTHOCEPHALA** | | | | | | | |
| **Oligocanthorhynchidae** | | | | | | | |
| *Neoncicola potosi* | LI | 92.30% (12/13) | 15.69 | 17 | 1–46 | *Potus flavus* | Machado Filho (1950); |

[a] Parasitic Intensity Mean; *SI: Small intestine – L: Liver– S: Stomach – Lg: Lung – LI: Large intestine.

of infection for each identified species are listed in Table 1.

The fecal examinations revealed a prevalence of 95.4% for gastrointestinal nematodes, with multiparasitism being observed in all hosts. Eight parasites species or morphogroups were identified, and their eggs/oocysts are presented in Fig. 2. The most frequent species/morphogroups were the strongylids (58.6%), followed by *Eimeria nasuae* (49,5%), *Strongyloides stercoralis* (38.6%), *Capillaria procyonis* (29.6%), *Toxocara alienata* (14.6%), and *Spirometra* sp. (2.60%). *Neoncicola*

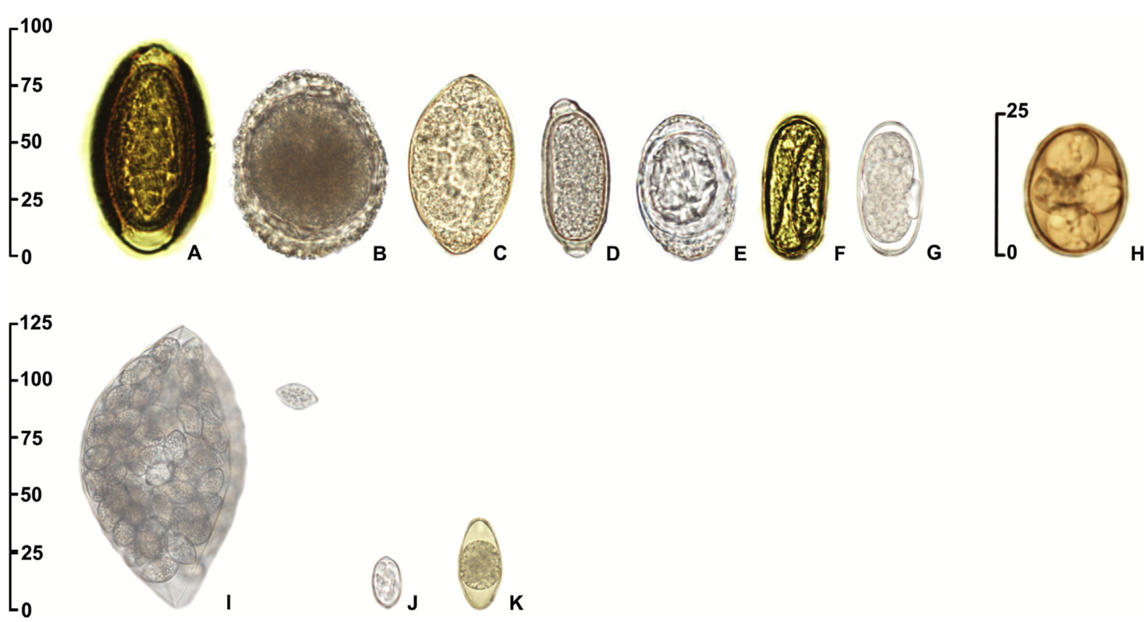


**Fig. 2.** Helminth eggs and protozoa oocysts in wild ring-tailed coatis feces (A–H) and Pseudoparasites (I to K). A. *Neoncicola potosi*; B. Toxocara alienata; C. *Spirometra* sp.; D. *Baruscapillaria procyonis*; E. *Atriotaenia sandgroundi*; F. Spirurida; G. Strongylid; H. *Eimeria nasuae*; I. Gametocyte of *Monocystis*sp. with spores; J. Sporocyst of *Monocystis sp.* after sporulation in potassium dichromate solution 2.5% for 10 days; K. Oxyuridae egg.

**Table 2**
Morphometric data of helminth eggs and protozoan oocysts found in wild ring-tailed coatis fecal samples captured in the Iguaçu National Park, Brazil.

| Taxonomic group | Length (μm) | Width(μm) |
|---|---|---|
| *Neoncicola potosi* | 72.4954 ± 2.4718 | 46.6913 ± 2.9688 |
| *Toxocara alienata* | 70.2233 ± 6.8923 | 61.3870 ± 2.2815 |
| *Baruscapillaria procyonis* | 63.9638 ± 3.4208 | 28.8588 ± 2.6241 |
| *Atriotaenia sandgroundi* | 49.2010 ± 6.2664 | 37.6480 ± 0.4270 |
| *Eimeria nasuae* | 19.6077 ± 1.7507 | 17.9444 ± 1.2316 |
| *Monocystis* sp. | 21.0064 ± 1.2060 | 11.7047 ± 0.4725 |
| Strongylid* | 65.4138 ± 7.6628 | 43.1010 ± 5.8556 |
| *Strongyloides stercoralis* | 55.0927 | 25.7601 |

*potosi*, *Atriotaenia sandgroundi*, and Spirurids were identified in 1.33% of the studied animals. The morphometric data of these eggs/oocysts are presented in Table 2.

Notably, pseudoparasitism by *Monocystis*, a common gregarine endoparasite of earthworms, and Oxyuridae eggs, often found in rodents but never recorded in carnivores, accounted for 6.6% and 9.3% of the positive results.

Adults coatis had a lower richness of helminth eggs/oocysts than subadults and puppies. However, the adult animals had a higher prevalence of infection for some parasite groups, as in the case of infection by *Eimeria nasuae*, while infection by ascaridid helminths was more prevalent in puppies and *C. procyonis* infection was higher in subadult animals.

## 4. Discussion

The observed parasitic richness, unprecedented for the study area and, in parts, for the biome, revealed a predominance of monoxenous parasites in ring-tailed coatis, with nine species in total. Albeit two of the four most prevalent species, namely *A. sandgroundi* and *N. potosi*, are heteroxenic, the alimentary habits of the mammal host, which include invertebrates, do not favor infection by parasites that exploit these organisms as intermediary or paratenic hosts.

The ring-tailed coatis have complex social behavior, as the adult males have solitary habits, while the females and younglings form numerous groups of up to 30 individuals (Gompper and Decker, 1998). The observed parasite richness may be related to this characteristic of the host, as there is evidence that animals with gregarious habits have more parasites (Morand and Poulin, 1998). The lack of studies on the parasite fauna of ring-tailed coatis from other biomes or areas with distinct ecology hinders further insights into this subject, but comparisons between ring-tailed coatis from areas with higher and lower populational densities could help to determine if the social behavior is a determinant factor for parasite richness or if environmental characteristics are more important for this feature.

The finding of *Strongyloides stercoralis* infection in roadkilled ring-tailed coatis is remarkable, as this species also infects domestic dogs and humans, in which it can cause a severe disease (Camillo-Coura et al., 2013). Although the fecal tests of the captured ring-tailed coatis revealed the presence typical *Strongyloides* eggs, rhabditoit larvae were not found in the sedimentation tests. Therefore, even though the observed species is in fact *S. stercoralis*, the observed parasites probably belong to the junior synonym *Strongyloides nasua*, which are morphologically indistinguishable from the former but with oviparous parthenogenetic females (Darling, 1911).

The host range and geographical distribution of some of the parasite species identified in the studied host were greatly expanded compared to those described originally in the Brazilian Northern region, in Pará (Lent and Freitas, 1938; Vicente et al., 1997), Paraíba (Lima et al., 2013), and Mato Grosso do Sul States (Vicente et al., 1997). Other areas, such as Peru (Tantaléan and Gonzalo, 1992; Gomez-Puerta, 2014) and Trinidad (Cameron, 1936), have also been reported as occurrence areas for some of the species identified in this study. The results obtained by our team represent the southernmost point of the range of distribution for these parasites.

Some of the identified species, namely the acanthocephalan *N. potosi*, the trichostrongylids *M. barbaris* and *M. felineus*, and the digenean *A. heterolecithodes*, were originally described to affect different hosts in other biomes. Nonetheless, one of the *Molineus* species is probably a new taxon, as it is morphologically distinguishable from other species of this genus. These findings demonstrate the relevance of faunal inventories for better understanding the parasite biodiversity composition and distribution.

Considering the parasites of domestic carnivores, the occurrence of *Ancylostoma braziliensis* parasitizing the ring-tailed coatis may indicate parasite exchange between domestic and wild animals in the region studied. Wild carnivores may have contact with domestic dogs when they move to human areas or even when dogs venture into natural areas. This fact is a consequence of an anthropogenic effect on natural populations in protected areas (Woodroffe, 2004; Ritchie et al., 2014). Thus, the presence of exotic animals in the interior of protected areas is a concern because it increases the frequency of contact between these animals and the local wildlife.

## 5. Conclusion

All the identified species represent new locality records, as there are no previous studies on parasites of *N. nasua* in the area in the literature. This study also represents a new host record for seven of the species found in ring-tailed coatis. In relation to the parasitic exchange of two the identified helminth species, they are known parasites of domestic dogs, suggesting parasitic spillover to wild carnivores.

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