

## Research Paper

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# Endoparasite community of anurans from an altitudinal rainforest enclave in a Brazilian semiarid area

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## Abstract

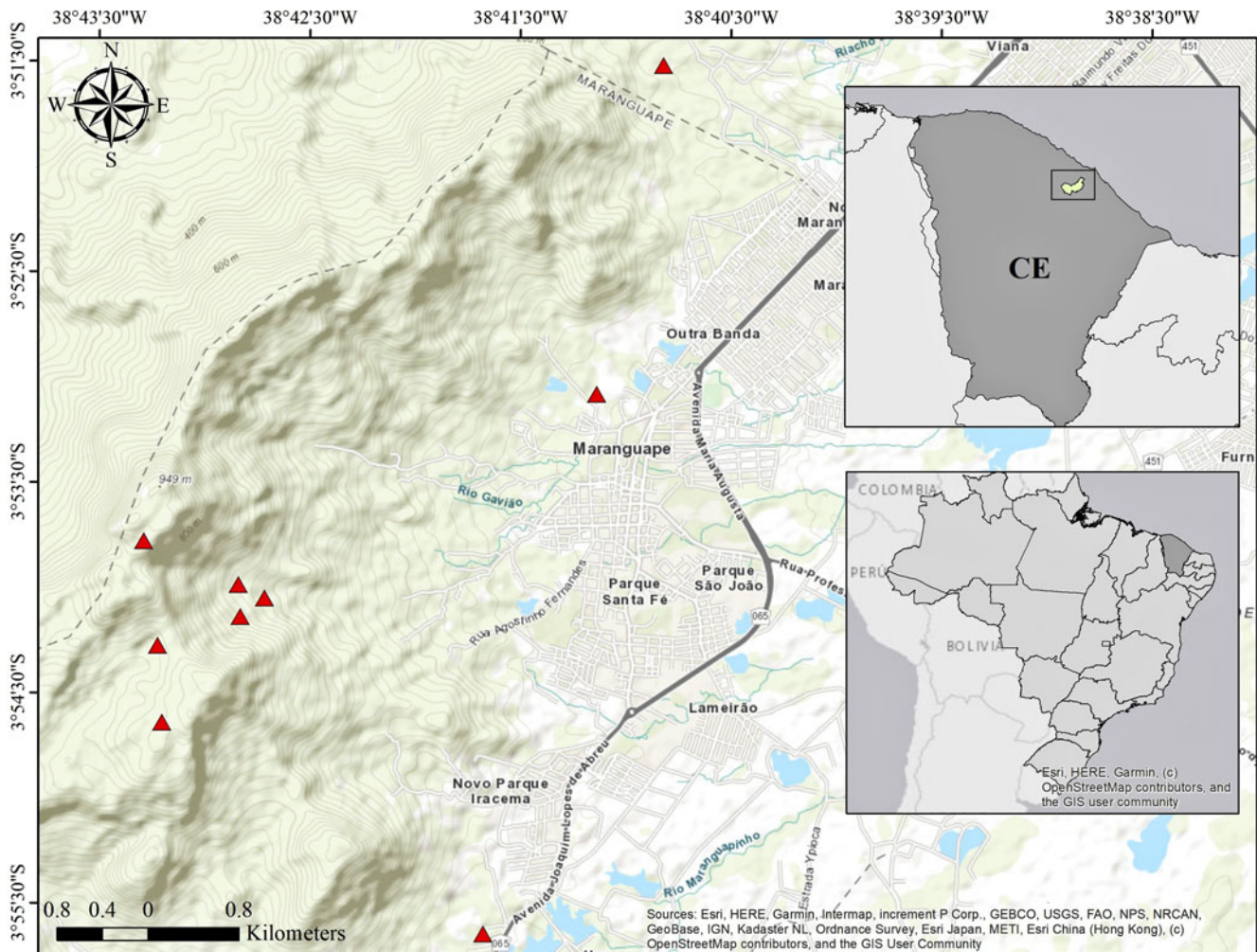
In the present study, we aimed to describe the composition of endoparasites associated with anurans from an altitudinal rainforest enclave in northeastern Brazil. Additionally, we tested if microhabitat use influences endoparasite abundance and richness, as well as the hypothesis that larger frogs tend to be more parasitized. We sampled 306 individuals from 25 anuran species that were necropsied and analysed using a stereomicroscope. The total endoparasite prevalence was 79.08%, with a parasitic community consisting of 46 taxa. Overall, we found the common pattern described for Neotropical amphibians, which is the predominance of generalist and direct-cycle parasites. Twenty new host records and two possible new parasite species were found, highlighting the importance of this type of inventory. We also observed that microhabitat use was associated with a significant difference in parasite richness between groups, in which arboreal and terrestrial species, and aquatic and arboreal species contributed to these differences. Moreover, larger frogs tended to be more parasitized regarding only an interspecific view. Our results suggest that parasite richness is directly related to infection cycle and how the host exploits its habitat.

## Introduction

Parasites are diverse organisms that are an integral part of nature, representing most of the global biodiversity and one of the most common life strategies on the planet (Windsor, 1998; Poulin & Morand, 2004; Kuris, 2008). Parasitic organisms are also ecologically important (Marcogliese, 2004; Poulin & Morand, 2004) because they are closely related to environmental conditions, and thus, might be considered potential indicators of environmental quality (Catalano *et al.*, 2013). Despite the increase of parasitological studies, the science as a whole is still far from having complete knowledge about the parasite biodiversity and ecology on Earth (Poulin & Morand, 2004). Therefore, inventories are the basis for studies, and determining which and how many species is part of an ecosystem is essential for understanding the diversity and functioning of organisms (Segalla *et al.*, 2021). In addition, these organisms are involved in various processes of nature regulation and might influence host population conditions because they interfere in crucial processes such as competition, migration, dispersal and speciation (Vitt & Caldwell, 2009; Matias *et al.*, 2018). Thus, knowledge about parasite diversity and distribution is important to understand the role of parasite-host ecological relationships on ecosystem dynamics (Poulin & Krasnov, 2010; Campião *et al.*, 2015b).

The altitudinal enclaves of humid montane forests known as 'brejos-de-altitude' [highland swamps] are isolated areas in the morphoclimatic domain of the Caatingas, which are marked by a high degree of endemism of their herpetofauna (Borges-Nojosa & Caramaschi, 2003; Albuquerque *et al.*, 2012; Borges-Nojosa *et al.*, 2016). As they are considered exceptional environments, due to local climatic conditions, they form isolated systems considered as unique elements (Vanzolini, 1981; Borges-Nojosa & Caramaschi, 2003). Such areas are classified as of extreme biological importance (MMA, 2000; Sousa *et al.*, 2004), and responsible for the greatest richness of anurans in Ceará state, northeastern Brazil (Roberto & Loebmann, 2016). Despite the recent increase of parasitological studies dealing with anurans from these mountains (Silva-Neta *et al.*, 2020; Mascarenhas *et al.*, 2021; Machado *et al.*, 2022), their parasite diversity is still underestimated.

According to Aho (1990), anurans show low parasite richness that is variable and isolationist when compared to other vertebrate groups. However, some amphibian species may present



**Fig. 1.** Schematic map of the sampling points in Maranguape mountain, Ceará state, northeastern Brazil. Red triangles represent sampling points.

a higher richness of helminths (Hamann *et al.*, 2006), being currently accepted that amphibians harbour rich and diverse helminth fauna (Camião *et al.*, 2014; Oliveira *et al.*, 2019; Mascarenhas *et al.*, 2021; Machado *et al.*, 2022). Recently published studies (e.g. Camião *et al.*, 2015b; Lins *et al.*, 2017; Oliveira *et al.*, 2019; Silva-Neta *et al.*, 2020; Mascarenhas *et al.*, 2021) report processes that influence the structure of helminth communities in amphibians, including host size, genus, diet, site of infection, species and behaviour. In addition, features of host habitats are key factors in parasite colonization (Goater *et al.*, 2005), drawing attention to the composition of parasite communities, which vary widely among host populations of the same species (Poulin *et al.*, 2011; Bezerra *et al.*, 2016).

In the present study: (i) we aimed to describe the composition of endoparasites associated with anurans from an altitudinal rainforest enclave in northeastern Brazil; (ii) to test if microhabitat use influences endoparasite abundance and richness; and (iii) to test the hypothesis that larger frogs tend to be more parasitized.

## Material and methods

### Study area

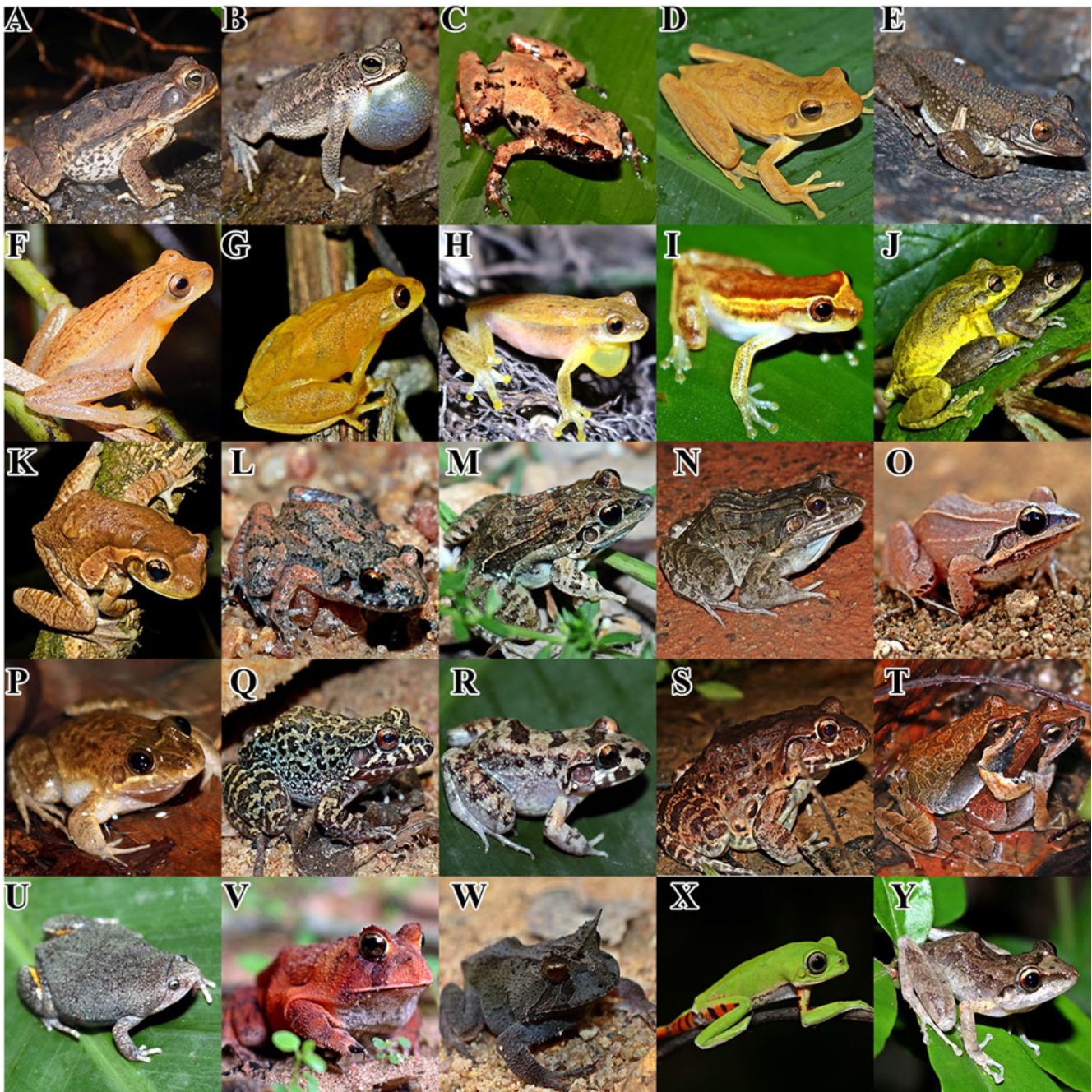
Sampling took place in the Maranguape mountain, Ceará state, northeastern Brazil (fig. 1), a crystalline residual massif with a

maximum altitude of 920 m, vegetation composed of humid forest covering the highest points, dry forest in the intermediate points gradually replacing the humid forest, and Caatinga in the lowlands (Borges-Nojosa & Caramaschi, 2003). The climatic regime is defined by two distinct seasons: dry season from June to December, and rainy season from January to May, with average annual precipitation of 1300 mm, and temperatures ranging from 26°C to 28°C (Ceará, 2002; IPECE, 2017).

### Sampling

Anuran sampling occurred during the rainy season, from April to May 2019 (15 days of sampling) and from February to May 2020 (17 days of sampling), through visual and auditory searches (Bernarde, 2012). The sampling period started at dusk and extended until midnight (17:00–00:00 h), which is the time period when the majority of anuran species are most active in foraging and reproduction. For each individual, we determined the microhabitat use considering the site of capture (arboreal, aquatic or terrestrial).

The collected specimens were euthanized with a lethal injection of sodium thiopental (Thiopentax®), following the ethical procedures of the Federal Council of Veterinary Medicine - CFMV (2013). Afterwards, we measured the mass with a Pesola scale (precision 0.1 g) and the snout–vent length (SVL) using a Mitutoyo®



**Fig. 2.** Anurans found in Maranguape mountain, Ceará state, northeastern Brazil: (A) *Rhinella diptycha*; (B) *Rhinella granulosa*; (C) *Adelophryne maranguapensis*; (D) *Boana raniceps*; (E) *Corythomantis greeningi*; (F) *Dendropsophus minusculus*; (G) *Dendropsophus minutus*; (H) *Dendropsophus nanus*; (I) *Dendropsophus tapacurensis*; (J) *Scinax x-signatus*; (K) *Trachycephalus typhonius*; (L) *Adenomera juikitam*; (M) *Leptodactylus fuscus*; (N) *Leptodactylus macrosternum*; (O) *Leptodactylus mystaceus*; (P) *Leptodactylus pustulatus*; (Q) *Leptodactylus syphax*; (R) *Leptodactylus troglodytes*; (S) *Leptodactylus vastus*; (T) *Physalaemus cuvieri*; (U) *Elachistocleis piauiensis*; (V) *Proceratophrys cristiceps*; (W) *Proceratophrys renalis*; (X) *Pithecopus gonzagai*; and (Y) *Pristimantis relictus*.

digital caliper (precision 0.01 mm). Voucher specimens were fixed in 10% formalin according to Calleffo (2002) and deposited in the Herpetological Collection of the Federal University of Ceará (CHUFC – A 9762 to A 9953), Fortaleza, Brazil.

#### Parasitological procedures

We necropsied the anurans after performing a ventral incision and examined for the presence of endoparasites in the organs

(gastrointestinal tract, lungs, liver and kidneys) and internal cavity using a stereomicroscope according to Amato *et al.* (1991). For species identification, we collected and prepared the endoparasites following specialized methodologies according to each taxonomic group (Yamaguti, 1971; Schmidt, 1986; Vicente *et al.*, 1991; Andrade, 2000). Temporary slides were analysed using a light microscope. Voucher specimens were deposited in the Parasitological Collection of the Universidade Federal do Ceará (CPUFC – 196 to 441), Fortaleza, Brazil.

**Table 1.** The endoparasite community found in the anuran species from Maranguape mountain, Ceará state, northeastern Brazil.

Parasites	<i>n</i>	N.H	P (%)	M.I. + R	Ab. ± S.E.	S.I.
<b>Acanthocephala</b>						
<i>Centrorhynchus</i> sp.	168	14	16.67	0.69 (1–15)	0.55 ± 0.50	S. C. SI. LV.
<i>Oligacanthorhynchus</i> sp.	16	3	1.96	0.07 (1–10)	0.05 ± 1.47	C.
<b>Annelida</b>						
<i>Dero (Allodero) lutzi</i>	4	3	0.98	0.02 (1–2)	0.01 ± 0.33	UD.
<b>Nematoda</b>						
<i>Aplectana crucifer</i>	7	1	0.33	0.03 (7)	0.02	LI.
<i>Aplectana membranosa</i>	43	6	4.58	0.18 (1–9)	0.14 ± 0.69	SI. LI.
<i>Aplectana meridionalis</i>	45	1	1.96	0.19 (3–21)	0.15 ± 2.81	SI. LI.
<i>Capillaria</i> sp.	1	1	0.33	0.004 (1)	0.003	UD.
<i>Cosmocerca brasiliense</i>	10	1	0.33	0.04 (10)	0.03	SI. LI.
<i>Cosmocerca parva</i>	265	12	13.07	1.10 (1–74)	0.87 ± 2.08	S. SI. LI. LG.
<i>Cosmocerca podicipinus</i>	46	1	1.63	0.19 (2–26)	0.15 ± 4.28	S. SI. LI. LG.
<i>Cosmocerca rara</i>	85	4	1.96	0.35 (2–48)	0.28 ± 7.76	SI. LI.
<i>Cosmocerca</i> sp.	282	10	15.36	1.17 (1–41)	0.92 ± 1.32	S. SI. LI.
<i>Cosmocercoides</i> sp.	4	1	0.52	0.02 (4)	0.01	LI.
<i>Falcaustra mascula</i>	23	4	1.31	0.10 (1–11)	0.08 ± 2.49	SI. LI.
<i>Ochoterenella convoluta</i>	4	1	0.33	0.02 (4)	0.01	C.
<i>Ochoterenella</i> cf. <i>vellardi</i>	12	1	0.65	0.05 (2–10)	0.04 ± 4	C.
<i>Ochoterenella</i> sp.	4	3	0.65	0.02 (1–3)	0.01 ± 1	C. S.
<i>Oswaldocruzia mazzai</i>	980	15	27.12	4.05 (1–87)	3.20 ± 1.90	C. S. SI. LI.
<i>Oxyascaris caatingae</i>	21	3	0.98	0.09 (1–18)	0.07 ± 5.50	SI. LI.
<i>Parapharyngodon</i> cf. <i>duniae</i>	15	1	0.65	0.06 (6–9)	0.05 ± 1.50	SI. LI.
<i>Physaloptera</i> sp.	247	19	19.61	1.02 (1–37)	0.81 ± 0.78	C. S. LV. LG.
<i>Physalopteroides venancioi</i>	8	2	0.65	0.03 (2–6)	0.03 ± 2.0	C. S. SI.
<i>Porrocaecum</i> sp.	13	4	1.31	0.05 (1–8)	0.04 ± 1.60	C. S. LV.
<i>Raillietnema spectans</i>	1026	13	13.73	4.24 (1–253)	3.35 ± 7.79	SI. LI.
<i>Rhabdias breviensis</i>	276	11	11.44	1.14 (1–80)	0.90 ± 2.68	LG. LV.
<i>Rhabdias</i> cf. <i>stenocephala</i>	10	2	1.63	0.04 (1–4)	0.03 ± 0.54	LG.
<i>Rhabdias pseudosphaerocephala</i>	27	2	0.98	0.11 (9)	0.09	LG.
<i>Rhabdias</i> sp.	447	13	14.38	1.85 (1–105)	1.46 ± 2.90	LG.
<i>Schrankiana schranki</i>	905	4	1.96	3.74 (1–700)	2.96 ± 111.62	SI. LI.
<i>Strongyloides</i> sp.	14	6	2.61	0.06 (1–4)	0.05 ± 0.41	S. SI. LI.
Nematoda gen. sp.	7	2	0.65	0.03 (1–6)	0.02 ± 2.50	S. LI.
unidentified Ascarididae larvae	2	2	0.52	0.008 (1)	0.007	C.
unidentified Cosmocercidae larvae	1740	18	18.30	7.19 (1–247)	5.69 ± 7.36	S. SI. LI. LV.
<b>Platyhelminthes</b>						
<b>Cestoda</b>						
<i>Cylindrotaenia americana</i>	6	2	0.98	0.02 (2)	0.02	SI.
<b>Monogenea</b>						
<i>Polystoma</i> cf. <i>lopezromani</i>	14	2	0.98	0.06 (1–8)	0.05 ± 2.02	UB.
<b>Trematoda</b>						
<i>Catadiscus marinholutzi</i>	1	1	0.33	0.004 (1)	0.003	LI.

(Continued)

Table 1. (Continued.)

Parasites	n	N.H	P (%)	M.I. + R	Ab. ± S.E.	S.I.
<i>Catadiscus propinquus</i>	76	3	2.61	0.31 (2–22)	0.25 ± 2.67	SI, LI.
<i>Choledocystus simulans</i>	37	1	0.98	0.15 (1–35)	0.12 ± 11.33	SI.
<i>Choledocystus vitellinophilum</i>	1	1	0.33	0.004 (1)	0.003	SI.
<i>Gorgoderina parvicava</i>	3	1	0.33	0.01 (3)	0.01	UB.
<i>Lophosicyadiplostomum</i> sp.	17	3	0.98	0.07 (3–7)	0.06 ± 1.33	K.
<i>Mesocoelium monas</i>	3	1	0.65	0.01 (1–2)	0.01 ± 0.50	SI.
<i>Neohaematolechus neivai</i>	56	1	1.31	0.23 (3–21)	0.18 ± 4.18	G, SI.
<i>Rauschiella linguatula</i>	13	2	1.96	0.05 (1–4)	0.04 ± 0.60	S, SI.
<i>Rudolphitrema</i> sp.	5	1	0.33	0.02 (5)	0.02	SI.
unidentified Metacercaria larvae	53	4	1.96	0.22 (5–18)	0.17 ± 2.05	K.
Total	7042	242	79.08	29.09 (1–700)	23.01 ± 1.58	

n, number of parasites; N.H, number of infected hosts; P%, prevalence; M.I., mean intensity; R, range; Ab., abundance; S.E., standard error; S.I., site of infection; C, cavity; S, stomach; SI, small intestine; LI, large intestine; LV, liver; LG, lung; G, gallbladder; PA, pancreas; K, kidney; UB, urinary bladder; and UD, urinary duct.

We measured the following parasitological parameters according to Bush *et al.* (1997): prevalence (percentage of parasitized amphibians in each host species); mean intensity of infection (mean number of parasites in parasitized amphibians); and mean parasite abundance.

### Statistical analyses

We used the non-parametric Kruskal–Wallis test (Shapiro–Wilk  $< 0.05$ ) to investigate whether parasite richness and abundance vary in response to microhabitat used by anuran species (aquatic, arboreal and terrestrial), followed by Dunn's *post-hoc* test to investigate which groups contributed most to the differences ( $P$ -values adjusted with the Benjamini–Hochberg method). Regarding both interspecific and intraspecific views, we tested the influence of anuran body size (SVL and mass) on the abundance and richness of parasites with a linear mixed model, using host sex as a random effect. For this test, we used only anuran species with more than five individuals parasitized. Analyses and graphs were performed using the packages ggplot2 (Wickham, 2016), nlme (Pinheiro & Bates, 2000), vegan (Oksanen *et al.*, 2016) and FSA (Ogle *et al.*, 2022) from R software (R core team, 2021).

### Results

We sampled 306 individuals from 25 anuran species (fig. 2), of which 242 individuals (75 females, 161 males and six juveniles) were parasitized with at least one parasite taxon. We found 7042 helminth specimens, with an overall prevalence of 79.08%, mean infection intensity of 29.09 and total abundance of  $23.01 \pm 1.58$ . The endoparasite community consisted of 46 taxa. The most abundant taxa were *Raillietnema spectans*, *Oswaldocruzia mazzai* and *Schrankiana schranki*. The highest prevalence values were observed for *Oswaldocruzia mazzai*, *Physaloptera* sp. and *Centrorhynchus* sp. Endoparasite richness ranged from two to 17 parasites taxa per host, *Oswaldocruzia mazzai* and *Physaloptera* sp. being the most prevalent parasites (table 1).

The most parasitized anurans were *Trachycephalus typhonius* ( $n = 17$ ), *Pristimantis relictus* ( $n = 17$ ) and *Physalaemus cuvieri* ( $n = 15$ ). *Adelophryne maranguapensis* was not parasitized, while

*Leptodactylus troglodytes* ( $n = 2$ ), *Rhinella granulosa* ( $n = 3$ ) and *Adenomera juikitam* ( $n = 3$ ) had few associated parasite taxa. In addition, we found 20 new host records and two possible new parasite species (table 2).

We observed that microhabitat use was associated with a significant difference in parasite richness between groups ( $H = 13.35$ ,  $P = 0.0012$ ), in which Dunn's *post-hoc* test evidenced that arboreal and terrestrial species ( $P = 0.001$ ) and aquatic and arboreal species ( $P = 0.023$ ) contributed significantly to these differences (fig. 3). By contrast, parasite abundance did not vary significantly between groups ( $H = 5.2821$ ,  $P > 0.05$ ).

We also observed that larger frogs (SVL) tend to be more parasitized considering the parasite abundance ( $T = 2.148$ ,  $P = 0.0328$ ) and richness ( $T = 4.576$ ,  $P = 0.0001$ ), regardless of sex (intercept = 0.0041 and 0.1291, respectively) (fig. 4). Mass had no significant influence on both abovementioned parasitological descriptors ( $P > 0.05$ ). In an intraspecific view, parasite load (richness and abundance) seemed not to be influenced by the size of each anuran species (table 3).

### Discussion

Communities of endoparasites associated with anurans generally show high richness and diversity (Campião *et al.*, 2014); in the present study, we found 46 parasite taxa, corroborating this pattern. Following the same infection pattern found in other Neotropical anurans (Lins *et al.*, 2017; Oliveira *et al.*, 2019; Silva-Neta *et al.*, 2020; Mascarenhas *et al.*, 2021), as well as in other vertebrate groups, such as reptiles (Brito *et al.*, 2014; Carvalho *et al.*, 2018), mammals (Santos *et al.*, 2015; Biolchi *et al.*, 2021) and birds (Santos *et al.*, 2015), nematodes was the helminth group with the highest representation (65.2%) of the collected specimens. Nematodes are abundant in the number of species, generalists, and well distributed in the environment. Species with direct life cycle reach their hosts by oral ingestion or active penetration of infectious larvae through the skin, not requiring an intermediate host for their development (Anderson, 2000), which facilitates the dispersion and high incidence of infection of this parasite group. Although parasitological studies dealing with anuran communities in northeastern Brazil have recently increased, there are still important gaps in our

**Table 2.** List of endoparasites found in the anuran species from Maranguape mountain, Ceará state, northeastern Brazil and literature review for previous records.

Hosts (n = 306)	Parasite species	P (%)	A.M.	Reference
<b>Bufoidea</b>				
<i>Rhinella diptycha</i>	unidentified Cosmocercidae larvae	13.3	16.7	–
(n = 15; P% = 86.7)	<i>Cosmocerca</i> sp.	26.7	3.5	new record
	<i>Ochoteranella</i> sp.	6.7	0.2	Aguiar et al., 2021
	<i>Oswaldocruzia mazzai</i>	53.3	8.9	Aguiar et al., 2021
	<i>Physaloptera</i> sp.	13.3	0.4	Amorim et al., 2019
	<i>Raillietnema spectans</i>	6.7	0.9	Amorim et al., 2019
	<i>Rhabdias pseudosphaerocephala</i>	20	1.8	Aguiar et al., 2021
	<i>Rhabdias</i> sp.	60	4.8	Amorim et al., 2019; Aguiar et al., 2021
	<i>Schrankiana schranki</i>	6.7	0.1	new record
	<i>Centrorhynchus</i> sp.	13.3	0.6	new record
	<i>Oligacanthorhynchus</i> sp.	6.7	0.1	new record
	<i>Mesocoelium monas</i>	13.3	0.2	new record
<i>Rhinella granulosa</i>	<i>Oswaldocruzia mazzai</i>	66.7	3.2	Silva-Neta et al., 2020
(n = 6; P% = 83.3)	<i>Physaloptera</i> sp.	66.7	5.7	Campião et al., 2014; Teles et al., 2018
	<i>Raillietnema spectans</i>	83.3	14.8	Teles et al., 2018; Silva-Neta et al., 2020
<b>Strabomantidae</b>				
<i>Pristimantis relictus</i>	unidentified Cosmocercidae larvae	15.6	7.2	–
(n = 45; P% = 88.9)	<i>Aplectana membranosa</i>	13.3	0.5	new record
	<i>Aplectana meridionalis</i>	13.3	1	new record
	<i>Capillaria</i> sp.	2.2	0.02	new record
	<i>Cosmocerca parva</i>	8.9	0.1	new record
	<i>Cosmocerca rara</i>	2.2	1.1	new record
	<i>Cosmocerca</i> sp.	33.3	1.4	new record
	<i>Ochoteranella</i> cf. <i>vellardi</i>	4.4	0.3	new record
	<i>Oswaldocruzia mazzai</i>	2.2	0.02	new record
	<i>Physaloptera</i> sp.	13.3	0.2	new record
	<i>Raillietnema spectans</i>	20	6.1	new record
	<i>Rhabdias brevisensis</i>	15.6	0.2	new record
	<i>Rhabdias</i> sp.	13.3	0.7	new record
	<i>Strongyloides</i> sp.	2.2	0.02	new record
	Nematoda gen. sp. (females)	2.2	0.02	<sup>a</sup>
	<i>Choledocystis simulans</i>	6.7	0.8	new record
	<i>Gorgoderina parvicava</i>	2.2	0.1	new record
<b>Eleutherodactylidae</b>				
<i>Adelophryne maranguapensis</i>	–	–	–	not parasitized
<b>Hylidae</b>				
<i>Boana raniceps</i>	unidentified Cosmocercidae larvae	60	30.67	–
(n = 15; P% = 93.3)	<i>Aplectana membranosa</i>	6.7	0.53	Aguiar et al., 2021; Sani et al., 2021
	<i>Cosmocerca parva</i>	13.3	5.67	González & Hamann, 2011, 2015; Machado et al., 2022

(Continued)

Table 2. (Continued.)

Hosts (n = 306)	Parasite species	P (%)	A.M.	Reference
	<i>Cosmocerca rara</i>	6.67	1.73	new record
	<i>Oswaldocruzia mazzai</i>	46.67	17.2	Campião et al., 2015a; Machado et al., 2022
	<i>Oxyascaris caatingae</i>	6.67	0.07	new record
	<i>Physaloptera</i> sp.	13.33	1.27	Campião et al., 2016a; Graça et al., 2017; Sani et al., 2021
	<i>Physalopteroides venancioi</i>	6.67	0.4	Campião et al., 2016b
	<i>Rhabdias breviensis</i>	33.33	9.67	new record
	<i>Rhabdias</i> sp.	40	8.73	Graça et al., 2017; Sani et al., 2021; Machado et al., 2022
	<i>Strongyloides</i> sp.	6.67	0.27	new record
	<i>Centrorhynchus</i> sp.	20	0.8	new record
	<i>Choledocystus vitellinophilum</i>	6.67	0.07	Travassos et al., 1969; Aguiar et al., 2021
<i>Corythomantis greeningi</i>	unidentified Cosmocercidae larvae	20	11	–
(n = 5; P% = 100)	<i>Cosmocerca</i> sp.	20	2.2	new record
	<i>Oswaldocruzia mazzai</i>	60	1.2	new record
	<i>Rhabdias</i> sp.	20	2.6	new record
	<i>Dero (Allodero) lutzii</i>	20	0.2	Morais et al., 2017
	<i>Polystoma</i> cf. <i>lopezromani</i>	20	0.2	new record
<i>Dendropsophus minusculus</i>	unidentified Cosmocercidae larvae	13.3	0.8	–
(n = 15; P% = 40)	<i>Cosmocerca parva</i>	6.7	0.8	new record
	<i>Physaloptera</i> sp.	6.7	3.4	new record
	<i>Rhabdias breviensis</i>	13.3	0.8	new record
	<i>Centrorhynchus</i> sp.	6.7	0.4	new record
	<i>Cylindrotaenia americana</i>	6.7	0.4	new record
	unidentified Metacercaria larvae	6.7	2.2	–
<i>Dendropsophus minutus</i>	unidentified Cosmocercidae larvae	6.3	2.5	–
(n = 16; P% = 75)	<i>Cosmocerca parva</i>	31.3	2.9	new record
	<i>Cosmocerca</i> sp.	12.5	0.1	Martins-Sobrinho et al., 2017
	<i>Ochoterella</i> sp.	6.3	0.06	new record
	<i>Oswaldocruzia mazzai</i>	6.3	0.06	new record
	<i>Physaloptera</i> sp.	6.3	0.06	new record
	<i>Raillietnema spectans</i>	6.3	0.06	new record
	<i>Rhabdias breviensis</i>	6.3	0.4	new record
	<i>Rhabdias pseudosphaerocephala</i>	6.3	0.1	new record
	<i>Rhabdias</i> sp.	6.3	0.06	new record
	<i>Centrorhynchus</i> sp.	6.3	0.9	new record
	<i>Lophosicyadiplostomum</i> sp.	6.3	0.4	Aguiar et al., 2021
	unidentified Metacercaria larvae	6.3	0.3	–
<i>Dendropsophus nanus</i>	unidentified Cosmocercidae larvae	7.7	0.06	–
(n = 13; P% = 38.5)	<i>Centrorhynchus</i> sp.	23.1	0.8	Campião et al., 2014

(Continued)

Table 2. (Continued.)

Hosts (n = 306)	Parasite species	P (%)	A.M.	Reference
	<i>Cylindrotaenia americana</i>	15.4	0.3	Hamann & Kehr, 1998
	<i>Lophosicyadiplostomum</i> sp.	7.7	0.4	Queiroz et al., 2020
<i>Dendropsophus tapacurensis</i>	unidentified Cosmocercidae larvae	5.9	0.06	–
(n = 17; P% = 23.5)	<i>Physaloptera</i> sp.	17.6	0.4	new record
	<i>Rhabdias breviensis</i>	5.9	0.06	new record
<i>Scinax x-signatus</i>	unidentified Cosmocercidae larvae	17.4	2	–
(n = 23; P% = 69.6)	<i>Aplectana membranosa</i>	4.3	0.04	new record
	<i>Cosmocerca parva</i>	8.7	0.5	new record
	<i>Cosmocerca rara</i>	4.3	0.2	new record
	<i>Cosmocercoides</i> sp.	4.3	0.2	<sup>a</sup>
	<i>Physaloptera</i> sp.	21.7	1.9	new record
	<i>Rhabdias breviensis</i>	26.1	2.9	new record
	<i>Rhabdias</i> sp.	13	3.2	new record
	<i>Strongyloides</i> sp.	4.3	0.04	new record
	<i>Centrorhynchus</i> sp.	8.7	1.2	Martins-Sobrinho et al., 2017
	<i>Oligacanthorhynchus</i> sp.	4.3	0.04	new record
	<i>Dero (Allodero) lutzi</i>	4.3	0.04	Morais et al., 2017
	<i>Lophosicyadiplostomum</i> sp.	4.3	0.1	new record
	unidentified Metacercaria larvae	4.3	0.3	–
<i>Trachycephalus typhonius</i>	unidentified Ascarididae larvae	5.6	0.1	–
(n = 18; P% = 100)	unidentified Cosmocercidae larvae	50	13.5	–
	<i>Aplectana crucifer</i>	5.6	0.4	new record
	<i>Cosmocerca parva</i>	5.6	0.2	new record
	<i>Cosmocerca</i> sp.	27.8	3.3	Campião et al., 2014
	<i>Oswaldocruzia mazzai</i>	55.6	10.4	new record
	<i>Parapharyngodon</i> cf. <i>duniae</i>	11.1	0.8	Bursey & Brooks, 2004
	<i>Physaloptera</i> sp.	5.6	0.1	Campião et al., 2016a; Graça et al., 2017
	<i>Raillietnema spectans</i>	22.2	1.1	new record
	<i>Rhabdias breviensis</i>	5.6	0.1	new record
	<i>Rhabdias</i> sp.	5.6	0.1	Graça et al., 2017
	<i>Schrankiana schranki</i>	5.6	0.1	new record
	<i>Strongyloides</i> sp.	11.1	0.3	new record
	Nematoda gen. sp. (female)	5.6	0.3	<sup>a</sup>
	<i>Centrorhynchus</i> sp.	38.9	0.7	Aguiar et al., 2021
	<i>Dero (Allodero) lutzi</i>	5.6	0.1	Graça et al., 2017
	<i>Polystoma</i> cf. <i>lopezromani</i>	11.1	0.7	Campião et al., 2014; Graça et al., 2017
<b>Leptodactylidae</b>				
<i>Adenomera juikitam</i>	<i>Cosmocerca</i> sp.	25	0.5	new record
(n = 8; P% = 25)	<i>Oswaldocruzia mazzai</i>	12.5	0.13	new record
	<i>Rhabdias</i> sp.	12.5	0.13	new record

(Continued)



Table 2. (Continued.)

Hosts (n = 306)	Parasite species	P (%)	A.M.	Reference
<i>Leptodactylus fuscus</i> (n = 4; P% = 100)	<i>Cosmocerca parva</i>	25	0.3	Morais, 2013; Campião et al., 2014
	<i>Physaloptera</i> sp.	50	2	Morais, 2013
	<i>Raillietnema spectans</i>	50	29.5	Silva-Neta et al., 2020
	<i>Rhabdias</i> sp.	50	1.3	Cañizales, 2021
	<i>Schrankiana schranki</i>	75	50.5	Morais, 2013
	<i>Centrorhynchus</i> sp.	50	1.3	Sani et al., 2021
	<i>Catadiscus propinquus</i>	25	0.5	Aguiar et al., 2021
<i>Leptodactylus macrosternum</i> (n = 14; P% = 100)	unidentified Cosmocercidae larvae	14.3	0.2	–
	<i>Cosmocerca parva</i>	7.1	2.6	González & Hamann, 2011; Campião et al., 2014
	<i>Cosmocerca</i> sp.	14.3	0.7	new record
	<i>Falcaustra mascula</i>	7.1	0.07	Morais, 2013; Graça et al., 2017
	<i>Oswaldocruzia mazzai</i>	35.7	5.1	Silva-Neta et al., 2020
	<i>Physaloptera</i> sp.	42.9	2.2	Campião et al., 2016a; Queiroz et al., 2020; Vieira et al., 2021
	<i>Physalopteroides venancioi</i>	7.1	0.1	Morais, 2013; Campião et al., 2016a
	<i>Rhabdias breviensis</i>	21.4	0.5	new record
	<i>Rhabdias</i> sp.	35.7	0.9	González & Hamann, 2011; Graça et al., 2017; Queiroz et al., 2020; Vieira et al., 2021
	<i>Centrorhynchus</i> sp.	21.4	0.3	Campião et al., 2014
	<i>Porrocaecum</i> sp.	7.1	0.6	González & Hamann, 2015
	<i>Catadiscus propinquus</i>	7.1	0.1	Queiroz et al., 2020
	<i>Rauschiella linguatula</i>	14.3	0.4	Graça et al., 2017; Aguiar et al., 2021
	<i>Leptodactylus mystaceus</i> (n = 3; P% = 100)	<i>Cosmocerca</i> sp.	66.7	0.7
<i>Oswaldocruzia mazzai</i>		66.7	1.7	Campião et al., 2015a
<i>Physaloptera</i> sp.		33.3	0.07	Queiroz et al., 2020
<i>Raillietnema spectans</i>		33.3	2.7	Silva-Neta et al., 2020
<i>Leptodactylus pustulatus</i> (n = 11; P% = 90.9)	unidentified Cosmocercidae larvae	9.1	0.3	–
	<i>Cosmocerca</i> sp.	9.1	0.4	new record
	<i>Oxyascaris caatingae</i>	9.1	0.2	new record
	<i>Physaloptera</i> sp.	9.1	0.5	Morais, 2013
	<i>Rhabdias</i> cf. <i>stenocephala</i>	36.4	0.5	new record
	<i>Rhabdias</i> sp.	9.1	0.2	new record
	<i>Centrorhynchus</i> sp.	18.2	0.5	new record
	<i>Catadiscus propinquus</i>	54.5	6.5	new record
	<i>Rauschiella linguatula</i>	36.4	0.7	new record
<i>Leptodactylus syphax</i> (n = 2; P% = 100)	<i>Falcaustra mascula</i>	50	4.5	Morais, 2013
	<i>Ochoterenella convoluta</i>	50	2	new record
	<i>Oswaldocruzia mazzai</i>	100	3.5	new record
	<i>Raillietnema spectans</i>	100	96	new record
	<i>Rhabdias</i> cf. <i>stenocephala</i>	50	2	new record
	<i>Porrocaecum</i> sp.	50	1	new record
<i>Leptodactylus troglodytes</i>	unidentified Cosmocercidae larvae	100	1	–

(Continued)

Table 2. (Continued.)

Hosts (n = 306)	Parasite species	P (%)	A.M.	Reference
	<i>Raillietnema spectans</i>	100	17	new record
<i>Leptodactylus vastus</i>	unidentified Cosmocercidae larvae	22.2	0.4	–
(n = 9; P% = 100)	<i>Falcaustra mascula</i>	11.1	1.2	new record
	<i>Ochoterenella</i> sp.	11.1	0.1	new record
	<i>Oswaldocruzia mazzai</i>	55.6	1.6	Silva-Neta et al., 2020
	<i>Oxyascaris caatingae</i>	11.1	2	new record
	<i>Physaloptera</i> sp.	55.6	3.3	new record
	<i>Raillietnema spectans</i>	11.1	28.1	Silva-Neta et al., 2020
	<i>Rhabdias brevisensis</i>	44.4	1.9	new record
	<i>Rhabdias</i> sp.	33.3	4	new record
	<i>Schrankiana schranki</i>	11.1	77.8	Campião et al., 2014
	<i>Centrorhynchus</i> sp.	33.3	2.9	new record
	<i>Oligacanthorhynchus</i> sp.	44.4	1.6	new record
	<i>Neohaematoloechus neivai</i>	44.4	6.2	new record
	<i>Porrocaecum</i> sp.	11.1	0.2	new record
<i>Physalaemus cuvieri</i>	unidentified Cosmocercidae larvae	17.2	6.7	–
(n = 29; P% = 96.6)	<i>Aplectana membranosa</i>	3.4	0.1	new record
	<i>Cosmocerca parva</i>	27.6	1	Santos & Amato, 2013
	<i>Cosmocerca podicipinus</i>	10.3	0.2	new record
	<i>Cosmocerca rara</i>	24.1	2.5	new record
	<i>Cosmocerca</i> sp.	20.7	0.5	Aguiar et al., 2015
	<i>Oswaldocruzia mazzai</i>	27.6	0.4	Oliveira et al., 2019
	<i>Physaloptera</i> sp.	17.2	0.6	Toledo et al., 2017; Sani et al., 2021;
	<i>Raillietnema spectans</i>	17.2	2.3	Oliveira et al., 2019; Silva-Neta et al., 2020
	<i>Rhabdias brevisensis</i>	3.4	0.03	new record
	<i>Rhabdias</i> sp.	17.2	1.6	Graça et al., 2017; Toledo et al., 2017; Aguiar et al., 2021
	<i>Strongyloides</i> sp.	10.3	0.2	new record
	<i>Centrorhynchus</i> sp.	3.4	0.03	new record
	<i>Porrocaecum</i> sp.	3.4	0.2	new record
	<i>Rudolphitrema</i> sp.	20.7	0.3	new record
Microhylidae				
<i>Elachistocleis piuiensis</i>	<i>Cosmocerca parva</i>	50	9.5	new record
(n = 4; P% = 75)	<i>Physaloptera</i> sp.	25	0.3	new record
	<i>Raillietnema spectans</i>	25	1	new record
Odontophrinidae				
<i>Proceratophrys cristiceps</i>	unidentified Cosmocercidae larvae	50	0.04	–
(n = 2; P% = 100)	<i>Aplectana membranosa</i>	50	0.04	Teles et al., 2017; Silva et al., 2019
	<i>Falcaustra mascula</i>	50	0.04	Silva et al., 2019
	<i>Physaloptera</i> sp.	50	1	Teles et al., 2017; Silva et al., 2019
<i>Proceratophrys renalis</i>	unidentified Ascarididae larvae	7.1	0.1	–
(n = 14; P% = 92.9)		21.4	3.1	–

(Continued)

**Table 2.** (Continued.)

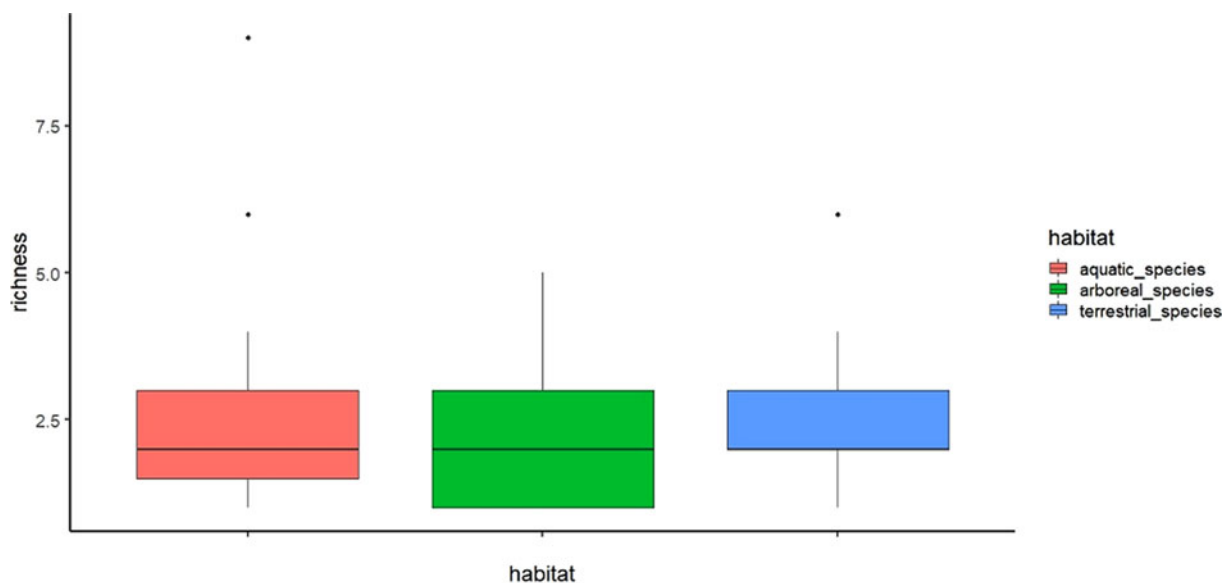
Hosts (n = 306)	Parasite species	P (%)	A.M.	Reference
	unidentified Cosmocercidae larvae			
	<i>Aplectana membranosa</i>	14.3	0.4	new record
	<i>Cosmocerca parva</i>	42.9	1.4	new record
	<i>Oswaldocruzia mazzai</i>	85.7	13.8	new record
	<i>Physaloptera</i> sp.	21.4	0.7	new record
	<i>Raillietnema spectans</i>	28.6	1.5	new record
	<i>Centrorhynchus</i> sp.	21.4	0.6	new record
Phyllomedusidae				
<i>Pithecopus gonzagai</i>	unidentified Cosmocercidae larvae	21.4	1.5	–
(n = 14; P% = 92.9)	<i>Cosmocerca parva</i>	7.1	0.07	Martins-Sobrinho <i>et al.</i> , 2017
	<i>Cosmocerca brasiliense</i>	7.1	0.7	new record
	<i>Oswaldocruzia mazzai</i>	7.1	0.5	new record
	<i>Physaloptera</i> sp.	14.3	0.3	new record
	<i>Rhabdias breviensis</i>	14.3	0.7	new record
	<i>Strongyloides</i> sp.	14.3	0.1	new record
	<i>Centrorhynchus</i> sp.	42.9	1.1	Martins-Sobrinho <i>et al.</i> , 2017
	<i>Catadiscus marinholti</i>	7.1	0.07	new record
	unidentified Metacercaria larvae	21.4	2.1	–

n, number of hosts; P%, prevalence; and A.M., abundance.  
<sup>a</sup>possible new species.

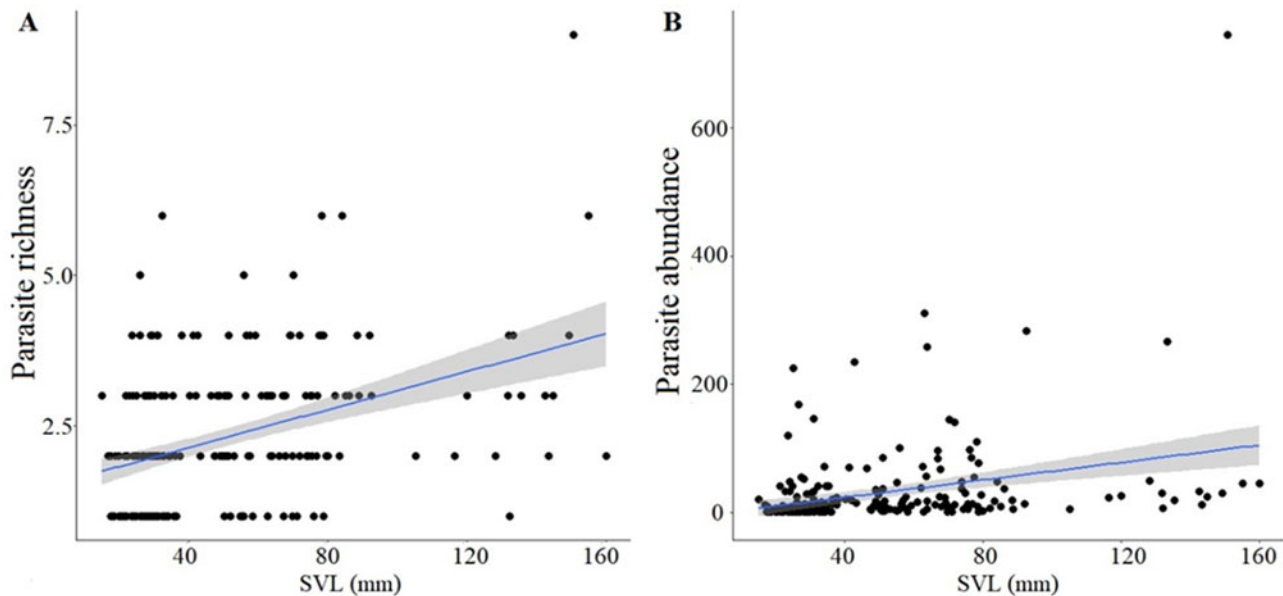
knowledge about them. For example, of the 25 host species sampled herein, six have not been surveyed for parasites yet. In addition, we present 20 new host records (see table 2), reinforcing the importance of parasite checklists.

Due to the increase in parasitological studies (Mascarenhas *et al.*, 2021), it is quite common to find records of parasites not

previously reported for host species (Aguiar *et al.*, 2014; Silva *et al.*, 2019). In the last decade, several studies on parasitism in Neotropical amphibians have been conducted (Madelaire *et al.*, 2012; Aguiar *et al.*, 2015; Chero *et al.*, 2016; Amorim *et al.*, 2019; Silva-Neta *et al.*, 2020; Sani *et al.*, 2021; Machado *et al.*, 2022), with the nematode parasites *Falcaustra mascula*,



**Fig. 3.** Boxplot representing the parasite richness between the groups of microhabitats used by the anurans.



**Fig. 4.** Relationship of parasite richness (A) and abundance (B) with the host's body size (anuran interspecific view) from Maranguape mountain, Ceará state, north-eastern Brazil.

*Ochoterenella* sp., *Oswaldocruzia mazzai*, *Oxyascaris oxyascaris*, *Physaloptera* sp., *Raillietnema spectans* and *Rhabdias* sp. being the most commonly reported species. In our study, we found the same scenario, despite the low prevalence for some of the aforementioned species. This result is possibly due to the wide distribution of these parasites and their generalist habitats regarding host selection (Campião et al., 2014, 2015b; Oliveira et al., 2019). In addition, the lack of taxonomic studies can be a limiting factor for an accurate identification of some parasite species distributed in the studied region. However, the description of new species has been increasing as parasitological studies progress (Felix-Nascimento et al., 2020).

*Oswaldocruzia mazzai* showed the highest prevalence (27.12%) and was present in 60% of the parasitized host species in the anuran community in our study. This result may be related to the direct life cycle of this parasite and the simple mode of transmission (Anderson, 2000). The genus *Physaloptera* had the second highest prevalence (19.61%). Parasites of this group are commonly found in all anuran parasite studies and have also been observed in several classes of terrestrial vertebrates (Ogassawara et al., 1986; Tung et al., 2009; Cabral et al., 2018). In amphibians, they are usually found in the larval stage, suggesting that these vertebrates are used as paratenic hosts. We also collected four individuals of *Cosmocercoides* sp. (one male and three females) in the large intestine of one specimen of *Scinax x-signatus*. The species was assigned to the genus *Cosmocercoides* due to the presence of a large number of rosette-like caudal papillae surrounded by punctuations. This is the first record of *Cosmocercoides* sp. for altitudinal rainforest enclave areas within the large Caatinga phytophysognomy, nevertheless, further studies are necessary to define the species. Additionally, we also provide the first record of infection in Brazil of the species *Parapharyngodon* cf. *duniae*.

We also found nematode larvae parasitizing the small intestine and/or large intestine of several host species. Larvae of this type are commonly found in amphibian and reptile species (Ávila & Silva, 2010; Campião et al., 2014), and this larval stage may be

associated with the monoxenous cycle of the parasite (Anderson, 2000), besides representing a recent infection and/or reproduction of the adult parasites in the host.

Platyhelminthes was the second most diverse phylum found in the present study, with 13 different taxa belonging to three classes (Cestoda, Monogenea and Trematoda). The most diverse class of Platyhelminthes was Trematoda with 11 taxa recorded. The aquatic habitat facilitates trematodes' infection, which usually have snails as intermediate hosts (Madelaire et al., 2012). These parasites also use amphibians as intermediate hosts (Guillén-Hernández et al., 2000), found more often in aquatic and semi-aquatic frogs such as leptodactylids (Campião et al., 2014; Oliveira et al., 2019). *Catadiscus propinquus* was the most abundant trematode and represents a new host record for *Leptodactylus pustulatus*. Indeed, some species are new host records; however, all trematodes had low prevalence considering the species pool (see table 2). Cestodes were represented by *Cylindrotaenia americana*, a cestode commonly found in Brazil, including in altitudinal rainforests' enclaves (Oliveira et al., 2019; Silva-Neta et al., 2020). Herein, we provide the first record of this cestode in the treefrogs *Dendropsophus minusculus* and *Dendropsophus nanus*. Regarding monogenean parasites, we found 14 individuals of *Polystoma* cf. *lopezromani* parasitizing *Corythomantis greeningi* and *Trachycephalus typhonius*. *Polystoma* is the most diverse genus known in Polystomatidae (Sinnappah et al., 2001), having a direct life cycle, which can be completed in the gills of tadpoles or urinary duct of adult anurans (Bentz et al., 2006).

Acanthocephalans are extensively reported for reptiles (Matias et al., 2018; Araújo et al., 2020) and amphibians (Oliveira et al., 2019; Silva-Neta et al., 2020) as cystacanths. They are parasites with indirect life cycle, in which arthropods act as intermediate hosts, and fish, mammals or waterfowl as final hosts (Baker, 2007). The presence of these cystacanths in amphibian hosts indicates that these species are used as paratenic hosts, possibly infected through the diet. In the present study, we found two genera represented by *Centrorhynchus* and *Oligacanthorhynchus*. *Centrorhynchus* sp. is the most common

**Table 3.** Relationship between parasite richness and abundance with anuran body size (snout-vent length (SVL) and mass), regarding an interspecific view, obtained through linear mixed models.

Taxa	Parasite richness			Parasite abundance			
	St. D. ± S.E.	<i>T</i>	<i>P</i>	RE	<i>T</i>	<i>P</i>	RE
<b>Bufo</b>							
<i>Rhinella diptycha</i>				0.000131			0.00604
mass	141.86 ± 39.34	-0.566	0.586		-0.584	0.575	
SVL	31.09 ± 8.62	0.183	0.859		0.322	0.755	
<b>Hylidae</b>							
<i>Boana raniceps</i>				1.721969			43.6378
mass	6.62 ± 1.76	0.0891	0.930		-0.262	0.798	
SVL	7.80 ± 2.08	0.880	0.399		-0.067	0.947	
<i>Dendropsophus minutus</i>				2.577e-05			0.00364
mass	0.17 ± 0.05	-0.116	0.910		0.099	0.923	
SVL	3.13 ± 0.94	1.562	0.162		-0.294	0.776	
<i>Scinax x-signatus</i>				7.145e-05			0.00087
mass	0.49 ± 0.12	0.453	0.658		-1.731	0.108	
SVL	2.60 ± 0.65	-0.537	0.600		1.964	0.073	
<i>Trachycephalus typhonius</i>				2.401e-05			0.00168
mass	6.69 ± 1.57	-0.734	0.474		-1.429	0.174	
SVL	10.02 ± 2.36	0.498	0.625		1.305	0.212	
<b>Leptodactylidae</b>							
<i>Leptodactylus macrosternum</i>				2.686e-05			0.000906
mass	25.08 ± 6.70	0.727	0.485		0.971	0.356	
SVL	15.34 ± 4.10	0.966	0.359		-1.110	0.295	
<i>Leptodactylus pustulatus</i>				0.4825533			13.08361
mass	5.19 ± 1.64	-0.664	0.530		-0.743	0.485	
SVL	9.22 ± 2.91	0.754	0.479		1.190	0.278	
<i>Leptodactylus vastus</i>				6.832e-05			0.028361
mass	104.23 ± 34.74	1.473	0.200		1.257	0.264	
SVL	37.15 ± 12.38	-0.352	0.738		-0.777	0.472	
<i>Physalaemus cuvieri</i>				2.987e-05			13.82402
mass	0.42 ± 0.07	0.634	0.531		-0.263	0.794	
SVL	1.87 ± 0.35	-0.242	0.810		-0.427	0.672	
<b>Odontophrynidae</b>							
<i>Proceratophrys renalis</i>				3.469e-05			9.79580
mass	3.47 ± 0.96	1.138	0.284		1.184	0.266	
SVL	3.33 ± 0.92	-0.475	0.645		-2.072	0.068	
<b>Phyllomedusidae</b>							
<i>Pithecopus gonzagai</i>				3.101e-05			0.000532
mass	0.33 ± 0.09	1.249	0.243		0.790	0.449	
SVL	2.29 ± 0.63	-0.118	0.908		-0.093	0.927	
<b>Strabomantidae</b>							
<i>Pristimantis relictus</i>				4.676e-05			0.002645

(Continued)

Table 3. (Continued.)

Taxa	Parasite richness			Parasite abundance			
	St. D. ± S.E.	T	P	RE	T	P	RE
mass	0.48 ± 0.07	0.919	0.363		-0.196	0.864	
SVL	3.81 ± 0.60	-0.012	0.990		0.171	0.845	

St. D. ± S.E., standard deviation and standard error.

Significant values and percentage of variation in response that is explained by the fixed effects (mass and SVL) are represented by *P* and *T* values. Random effects were obtained through the intercept values (RE).

genus reported in Brazil for anuran hosts (Fabio, 1982; Smales, 2007). *Oligacanthorhynchus* sp. are heteroxenous parasites and usually have mammals as final hosts (Richardson et al., 2014). In South America, they are reported infecting *Odontophrynus americanus* (Silva et al., 2018) and *Pleurodema diplolister* (Silva-Neta et al., 2020). This study is the first record of *Oligacanthorhynchus* sp. for the anurans *Leptodactylus vastus*, *Rhinella diptycha* and *Scinax x-signatus*.

Regarding the phylum Annelida, we found four individuals of *Dero* (*Allodero*) *lutzi* in the urinary duct of *Corythomantis greeningi*, *Scinax x-signatus* and *Trachycephalus typhonius*. The genus *Dero* is known to use frogs for transport and as hosts (Oda et al., 2015). This behaviour is stimulated by chemicals released by the amphibians, which are used by the parasite for dispersal (Lopez et al., 2005). *Dero* (*Allodero*) *lutzi* has been found parasitizing different amphibians, mainly arboreal species (Oda et al., 2015), likely because these parasites are free-living inhabitants of bromeliad ponds and tree holes (Lopez et al., 1999).

The characteristics and the way the host explores its habitat can influence the composition and structure of the helminth fauna, and explain the richness and diversity of the parasites associated with it (Poulin & Morand, 2004; Chandra & Gupta, 2007; Euclides et al., 2021). Thus, anuran amphibians have a diverse parasite fauna due to their natural history (Prudhoe & Bray, 1982), which are generally associated with two types of environments, aquatic and terrestrial (Chandra & Gupta, 2007). Species of arboreal amphibians tend to have low parasite richness, due to a possible reduction in the encounter with infective parasitic larvae. On the other hand, host anurans with terrestrial or semi-aquatic habitats tend to have greater contact with the terrestrial environment when searching for water bodies, increasing the odds of contact with a greater number of parasites (Pizzatto et al., 2013; Euclides et al., 2021).

However, we observed that the arboreal habitat had great parasite richness. The higher number of individuals classified as arboreal ( $n = 163$ ) in the present study may be an explanation for the significant relationship of arboreal habitat with parasite richness. Most species classified as arboreal were found during the reproductive period, in which anurans seek out puddles and mate for reproduction, passing through terrestrial and aquatic environments. This provides a greater likelihood of direct contact with infectious larvae, which allows a greater variety of parasites to become established in these animals (Chandra & Gupta, 2007).

According to Todd (2007), endoparasitic helminths of amphibians require an aquatic environment for the development and transmission of their infective stages, as this promotes increased parasite transmission. However, we observed that the use of terrestrial and arboreal microhabitat contributed significantly to the abundance of parasites, showing that most helminth parasites of amphibians do not require an aquatic environment in the process of transmission and infection. Our data also indicated no

relationship between host sex and parasite richness, but this result may have been influenced by the difference in the number of individuals of each sex analysed (Madeira & Sogayar, 1993). Moreover, most anuran hosts do not present differentiation in habitat use according to sex, being both subject to the same chances of infection by infective larvae available in the environment. It is also noteworthy that biotic factors such as the immune system and host age also affect parasitism, as they influence the life of both parasite and host (Pietroock & Marcogliese, 2004).

Overall, at an interspecific view, we observed that larger frogs tend to be more parasitized. Indeed, larger hosts can support a higher parasite load and even higher species richness because they offer greater microhabitat diversity favouring the development and reproduction of parasites (George-Nascimento et al., 2004; Campião et al., 2015b). However, this hypothesis was not supported in the present study at intraspecific views. This pattern was also found in other parasitological studies dealing with amphibians (e.g. Oliveira et al., 2019; Mascarenhas et al., 2021; Machado et al., 2022). It seems that this hypothesis might be more evidenced concerning a species pool with anuran species of different sizes (e.g. Silva-Neta et al., 2020). Therefore, for congeneric species, we believe that other aspects such as microhabitat use, physiology, behaviour and seasonality, might have a greater influence on parasite load than the anuran size.

We conclude that the endoparasite composition of anurans from Maranguape mountain follow the common pattern described for Neotropical amphibians, showing high species richness and prevalence. We also recorded the first parasitological data for six anuran species and 20 new host records, which corroborates the hypothesis that amphibians are good models for parasite studies due to their way of life, behaviour and feeding. Furthermore, we stress the importance of parasite inventories for host species in understudied regions. We also emphasize that endoparasite composition has a significant relationship with the type of habitat used by the host due to the life cycle and mode of transmission of the parasites. As for the relationship between richness and host size, we indicate here that the size factor is predictive only if it has a large variation from the average host size.

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**Conflicts of interest.** None.

**Ethical standards.** The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional guides on the care and use of laboratory animals. Collection permit Instituto Chico Mendes de Conservação da Biodiversidade - ICMBio (#72384-1 and #73215-1) and Ethic Committee on Animal Use of the Federal University of Ceará (CEUA-UFC) (#CEUA 6314010321).

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