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Filling the gaps on parasites of *Osteocephalus*: Helminth community structure of *Osteocephalus cabrerai* (Anura: Hylidae) from the Brazilian Amazon

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ABSTRACT

Osteocephalus cabrerai is an arboreal anuran widely distributed in South America. However, there are no parasitological studies conducted on the species, resulting in a parasite fauna completely unknown. Thus, this study aims to characterize the parasitic community structure of *O. cabrerai* in the municipality of Pedra Branca do Amapari, Amapá state, Amazon region, Brazil. We collected and necropsied 84 specimens of *O. cabrerai* to search for helminths. Parasite community structure was analyzed using helminth parasite richness, diversity, and abundance. The helminth component community of *O. cabrerai* comprises six nematode species: *Cosmocerca parva*, *Cosmocerca podicipinus*, *Oxyascaris oxyascaris*, *Oswaldocruzia chabaudi*, and *Physaloptera* sp. (larvae). Most helminth species represent the first record for the genus *Osteocephalus*, except *Physaloptera* sp. The helminth infections in the host showed a typical aggregated distribution pattern for parasites. We only found a positive correlation between the host weight and total intensity. Our bibliography revision reinforces the need for further studies on the helminth fauna of *Osteocephalus* spp.

1. Introduction

The hylids are one of South America's most studied anuran. However, most records are for species of the genera *Boana* Gray, 1825, *Dendropsophus* Fitzinger, 1843; and *Phyllomedusa* Wagler, 1830; Campião et al., (2014, 2015). Currently, the genus *Osteocephalus* Steindachner, 1862 is composed of approximately 28 species, and the parasitic fauna is known only for *Osteocephalus taurinus* Steindachner, 1892, and *Osteocephalus leprieurii* (Duméril and Bibron, 1841) (Campião et al., 2014; Frost, 2024). The helminth fauna of those species is composed of 13 helminth taxa recorded in the states of Amapá, Amazonas, Pará, and Mato Grosso in Brazil, the city of Cusco, Peru, and Ecuador (Vaucher, 1981, 1987; Bursey et al., 2001; Smales, 2007; Campião et al., 2014; Feitosa et al., 2015; Tavares-Costa et al., 2018; Pedroso-Santos et al., 2019; Santos et al., 2019, 2022; Anjos et al., 2021).

Several studies on parasites of *Osteocephalus* spp. focused on descriptions of new species and isolated records of new hosts and localities (e.g. Feitosa et al., 2015; Tavares-Costa et al., 2018; Pedroso-Santos et al., 2019; Anjos et al., 2021; Santos et al., 2022). In this context, characterizing the parasite community of *Osteocephalus* spp. in the Amazon region is essential for understanding factors that affect parasite distribution and supporting future ecological studies.

To date, no parasitological studies have been conducted on the species *Osteocephalus cabrerai* (Cochran and Goin, 1970), resulting in a parasite fauna completely unknown. Thus, this study aims to characterize the parasite community of *O. cabrerai* as well as understand factors that influence in parasite distribution on this host in the Brazilian Amazon Region.

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2. Materials and methods

2.1. Host sampling and collection of parasites

During helminthological surveys, 84 specimens of *O. cabrerai* (Fig. 1) were collected between May 2019 and March 2022 in the "Beija-Flor Brilho de Fogo" Extractive Reserve (0°47 ‘30.6′ N, 51°58 ‘42.1′ W), located in the municipality of Pedra Branca do Amapari, Amapá state, Brazil. The amphibian hosts were identified according to Pedroso-Santos et al. (2019) and Frost (2024).

The hosts were anesthetized, measured, weighed, and necropsied for helminthological examination. All internal organs were placed in Petri dishes with saline solution (NaCl 0.9%), dissected, and examined under a LEICA EZ4 stereomicroscope. The helminths found were cleaned in saline solution, killed with heated 70% alcohol, and preserved in the same solution at room temperature.

For morphological analysis, the nematodes were hydrated in distilled water, cleared in Amann's lactophenol 20%, mounted on temporary slides, and examined under an Olympus BX41 microscope (Olympus, Tokyo, Japan) coupled with a drawing tube (without zoom adjustment), and Olympus BX53 microscope (Olympus America, Center Valley, Pennsylvania) equipped with differential interference contrast optics and a digital imaging system.

We also conducted a bibliographic reference search to compile the records of helminth parasitics in *Osteocephalus* spp., using seven electronic databases (Google, Google Scholar, PubMed, Scielo, Science Direct, Scopus and Web of Science). We used such search strings: Topic: [(“*Osteocephalus*") and (“helminth" or "parasites" or "nematodes" or "platyhelminthes" or "acanthocephalan")]. We prepared a table with all this compilation, including published records, available data, and information from the present study.

2.2. Data analysis

The infection prevalence, mean intensity, and mean abundance were calculated according to Bush et al. (1997). We calculate confidence intervals in 95% for prevalence with Sterne's method and mean abundance with Bootstrap BCa using Quantitative Parasitology 3.0 software.

We classified the helminth communities at the infracommunity (all helminth populations of a single specimen of *O. cabrerai*) and component community levels (all helminth infracommunities within the *O. cabrerai* population). The total number of helminth species (= richness), Shannon index (H′), and Pielou evenness index (J′) as H′/H’ maximum represents the community richness and diversity (Zar, 2010). The Brillouin diversity index (HB) and Pielou evenness index (E) were used to describe the diversity and uniformity of helminth infracommunities. The Berger–Parker index of dominance (d) was used to determine the most abundant species in the component community (Magurran, 2004). The frequency of dominance (FD) was used to determine the percentage of infra communities in which a parasite species is numerically dominant. All these parameters were calculated using the PAST 4.11 software (Hammer et al., 2001; Magurran, 2004).

The variance-to-mean ratio (ID) and the index of discrepancy of Poulin (D) were calculated for species with prevalence >10% using the Quantitative Parasitology 3.0 software to determine the distribution pattern of parasite infra communities (Rózsa et al., 2000). The significance of ID for each parasite species was tested using d-statistics, where $d < 1.96$ represents a random distribution and $d > 1.96$, an aggregate distribution (Ludwig and Reynolds, 1988).

We used the method proposed by Thul et al. (1985) to calculate the importance of each parasite in the community. Thus, the helminth species were classified into four groups (dominant, codominant, subordinate, and unsuccessful) based on their prevalence, intensity, and maturity factor (equal to 1.0 if at least one mature specimen of species is found and equal to 0 if otherwise), which is related to the degree of host specificity.

The Kendall Correlation (τ) was used to test the correlation between morphological characters of the host (Snout-vent length [SVL] and body weight), and helminth mean species richness, intensity, and abundance at the infra community level and abundance of helminth species at the component community level. These analyses were performed using the R 4.4.0 software. We did not test the association between host sex and parasite community characteristics due to our samples' low number of females (males = 60; females n = 24).

Richness was estimated using the species accumulation curve, which analyzes the number of observed species as a function of the sampling effort. We used the non-parametric richness estimator Chao 2 to check if the observed richness approached the estimated richness. These statistical analyses were performed using the Vegan (Oksanen, 2010) package in R software.

Fig. 1. Dorsolateral view of an adult specimen of *Osteocephalus cabrerai* from Amapá state, Brazil.

3. Results

The overall parasite prevalence was 64.28% (55 specimens infected out of 84 collected). We obtained 292 specimens of nematodes (mean abundance, 3.47; mean intensity, 5.4) assigned to six different taxa, *Aplectana pella* Borges, Willkens, Santos, Costa-Campos and Melo, 2023, *Cosmocerca parva* Travassos, 1925, *Cosmocerca podicipinus* Baker and Vaucher, 1984, *Oswaldocruzia chabaudi* Ben Slimane and Durette-Desset, 1996, *Oxyascaris oxyascaris* Travassos, 1920, and *Physaloptera* sp. (larvae) (Table 1, Fig. 2). The curve of the accumulated species observed did reach an asymptote (Fig. 3), indicating that the observed helminth species richness (6 species) was equal to the expected (Chao 2 richness estimator = 6) (Fig. 4).

The component helminth community of *Osteocephlus cabrerai* presented low diversity, the predominance of certain parasite species, and high uniformity (Table 2). The large intestine was the most infected organ (=4 spp.), followed by the small intestine (=1 spp.) and stomach (=1 spp.) (Table 1). The most common helminth in *O. cabrerai* is *C. parva* (41.67%). Less frequently, frogs are parasitized by *A. pella* (27.38%) and *O. chabaudi* (14.29%). All of them showed aggregated distribution (Table 3). Other taxa of helminths presented a prevalence below 10%: *C. podicipinus* (3.57%), *O. oxyascaris* (5.95%) and *Physaloptera* sp. (1.19%). Hosts were predominantly infected by one species of helminths (Fig. 5).

Table 1

Helminth parasites record of *O. cabrerai* from Amapá state, Brazil. N: number of helminths, prevalence (%) with 95% confidence interval, mean intensity with ranges, mean abundance with 95% confidence interval, site of infection of helminth parasites of *O. cabrerai,* importance value (I), and frequency of dominance. Classification of helminths: I ≥ 1.0, dominant species; I = 0, unsuccessful species; 0.01≤ I < 1.0, codominant species. Abbreviations: P, prevalence; CI, confidence interval; MI, mean intensity; MA, mean abundance; FD, frequency of dominance; Small intestine, SI; Large intestine, LI; Stomach, S.

Helminth	N	P (%) ± CI	MI	MA ± CI	Site of Infection	I	Classification	FD (%)
Aplectana pella	99	27.38 ± 0.188–0.380	4.3; range 1–15	1.18 ± 0,69–1,9	LI	14.441	Dominant	33.90
Cosmocerca parva	161	41.67 ± 0.315–0.524	4.6; range 1–27	1.92 ± 1.27–3.17	LI	35.737	Dominant	55.13
Cosmocerca podicipinus	9	3.57 ± 0.010–0.100	3; range 2–4	0.107 ± 0.023–0.303	LI	0.171	Codominant	3.08
Oswaldocruzia chabaudi	16	14.29 ± 0.082–0.237	1.33; range 1–3	0.19 ± 0.095–0.321	SI	1.218	Dominant	5.47
Oxyascaris oxyascaris	6	5.95 ± 0.024–0.135	1.2; range 1–2	0.071 ± 0.011–0.143	LI	0.190	Codominant	2.05
Physaloptera sp. (larvae)	1	1.19 ± 0.001–0.064	1; range 1–1	0.011 ± 0.001–0.064	S	0	Unsuccessful	0.34

We found three dominant species of nematodes (widespread species in the host population), two codominant species (contributed to a lesser degree in the helminth community), and one unsuccessful species (accidental infection), which was able to enter the host but did not reach maturity therein (Table 1).

The mean SVL of the anurans was 53.2 ± 7.5 mm (29–80.3), and the body weight was 7.07 ± 3.3 g (2–18.9). We observed a positive correlation between the host body weight and the total intensity of infection (total intensity vs. SVL: $\tau = 0.16$; $p = 0.10$; total intensity vs. weight: $\tau = 0.31$; $p = 0.00$). In contrast, the total abundance was not correlated with characters of the host (total abundance vs. SVL: $\tau = 0.02$; $p = 0.73$; total abundance vs. weight: $\tau = 0.04$; $p = 0.62$). There was no correlation between host variables and mean helminth richness (mean helminth richness vs. SVL: $\tau = - 10$; $p = 0.35$; mean helminth richness vs. weight: $\tau = - 2$; $p = 0.84$). Also, there were no significant correlations between helminth abundance species and the host body size or weight (*A. pella* vs. SVL: $\tau = 0.02$; $p = 0.75$, *A. pella* vs. weight: $\tau = 0.02$; $p = 0.78$; *C. parva* vs. SVL: $\tau = 0.10$, $p = 0.22$, *C. parva* vs. weight: $\tau = 0.11$, $p = 0.15$; *O. chabaudi* vs. SVL: $\tau = - 0.6$, $p = 0.49$, *O. chabaudi* vs. weight: $\tau = - 0.13$, $p = 0.13$).

In our bibliography analysis, we found 13 helminth taxa parasitizing two species of *Osteocephalus*. Additionally, if we include the records of the present work, at least 18 helminths taxa are associated with the *Osteocephalus* spp. in South America. The highest helminth richness was found in *O. taurinus* (n = 13 spp.), followed by *O. cabrerai* (n = 6 spp.) and *O. leprieurii* (n = 1 spp.). Brazil harbors the richest helminth fauna registered for *Osteocephalus* spp., with 11 species, followed by Peru (n = 6 spp.) and Ecuador (n = 3 spp.). Cosmocercidae was the most common parasite (n = 6 spp.), followed by Physalopteridae (n = 3 spp.), Polystomatidae (n = 3 spp.), Pharyngodonidae (n = 3 spp.), Molineidae (n = 2 spp.), Onchocercidae (n = 1 spp.), Rhabdiasidae (n = 1 spp.) and Oligacanthorhynchidae (n = 1 spp.) (see Table 4).

4. Discussion

The component helminth community of *O. cabrerai* comprised six nematode species. The diversity indices, the helminth population's dominance, and the parasite community's evenness indicate that the sampling effort was sufficient to characterize the helminth species in the studied area and the host. The Chao estimate and the observed data in the species accumulation curve also indicate that. The parasites found in the present study are also the most common among all anuran families from South America, including *Osteocephalus* spp. (Campião et al., 2014; see Table 4).

In our analysis, nematodes of the Cosmocercidae family showed the highest prevalence, mean intensity, and mean abundance in the helminth community. The most prevalent, abundant, and dominant species was *C. parva*, while *C. podicipinus* was codominant in the helminth community. Species of the *Cosmocerca* Diesing, 1816 are distributed worldwide (Ni et al., 2020), and both species found in the present study are considered generalists. Additionally, at least one of them was registered parasitizing anurans from the families Aromobatidae, Bufonidae, Craugastoridae, Dendrobatidae, Eleutherodactylidae, Hylidae, Hylodidae, Leptodactylidae, Microhylidae, Odontophrynidae, Ranidae and Strabomantidae (Goldberg and Bursey, 2008; Santos and Amato, 2013; Campião et al., 2014).

In the present study, *Aplectana pella* was the second most dominant species among the cosmocercids. Recently, Santos et al. (2023) described *A. pella* as parasitizing *Boana boans* (Linnaeus, 1758) collected from the same locality as *O. cabrerai* in this study. Both host species exhibit arboreal habits and occupy equivalent ecological niches. Our findings also support the hypothesis that hosts exposed to similar environmental conditions share helminth taxa (Aho, 1990; Krasnov et al., 2011; Poulin et al., 2011; Toledo et al., 2018; Draghi et al., 2020).

We also found that *Oxyascaris oxyascaris* was codominant and had low prevalence in the component community. The type-host for these nematode species is *Mastigodryas bifossatus* Raddi, 1820(= *Drymobius bifossatus*) (snake); however, they are commonly found infecting Leptodactylidae species (Campião et al., 2014; Lins et al., 2017; Silva et al., 2018). Some previous studies registered the species in other tree frogs: *Boana raniceps* (Cope, 1862), *Boana faber* (Wied-Neuwied, 1821) and *Trachycephalus typhonius* (Linnaeus, 1758) (Campião et al., 2016, 2017; Euclydes et al., 2022; Euclydes and Campião, 2024).

Oswaldocruzia chabaudi was one of the dominant nematodes found in the community of *O. cabrerai*. This species also infects other arboreal hylids, such as *B. boans*, *Boana fasciata* (Günther, 1858), *Boana geographica* (Spix, 1824), and *Boana wavrini* (Parker, 1936; Campião et al., 2014; Willkens et al., 2021). These results reinforce that *O. chabaudi* is mainly associated with arboreal amphibians, which occupy similar ecological niches and have overlapping geographical distributions, as proposed by Willkens et al. (2021).

Our study indicates that *O. cabrerai* represents the definitive host for most helminth species. Also, we conclude that this frog had a minor role as a paratenic host, as the only nematode larvae found were *Physaloptera* sp. (larvae) in the gastric mucosa. In the Neotropical region, nematodes of the genus *Physaloptera* are commonly found as non-encysted larvae in anurans (González and Hamann, 2012; Madelaire et al., 2012; Campião et al., 2014). These nematodes also showed the lowest values of importance (unsuccessful pioneer), prevalence, intensity, and abundance, indicating that this might represent an unsuccessful host or an accidental host species. The heteroxenic life cycle of these species involves arthropods as intermediate hosts and vertebrates as definitive or paratenic hosts (Hamann et al., 2015; Martins-Sobrinho et al., 2017; Alcantara et al., 2018; Coimbra et al., 2023).

We found predominantly generalist nematodes with monoxenous life cycles. In this context, the contact of *O. cabrerai* with terrestrial environments, mainly during the reproductive period (Menin et al., 2011) may promote the transmission and infection of direct life cycle helminths. Additionally, the absence of digenean's and cystacanths indicates that *O. cabrerai* interacts less with helminths of complex life cycles and encounters fewer species of potential intermediate hosts. Thus, we reinforce the importance of understanding the host's diet for new insights into its interactions with intermediate hosts and their parasites.

The distribution of helminths in *O. cabrerai* showed a typical aggregated pattern for parasites, which could be influenced by specific

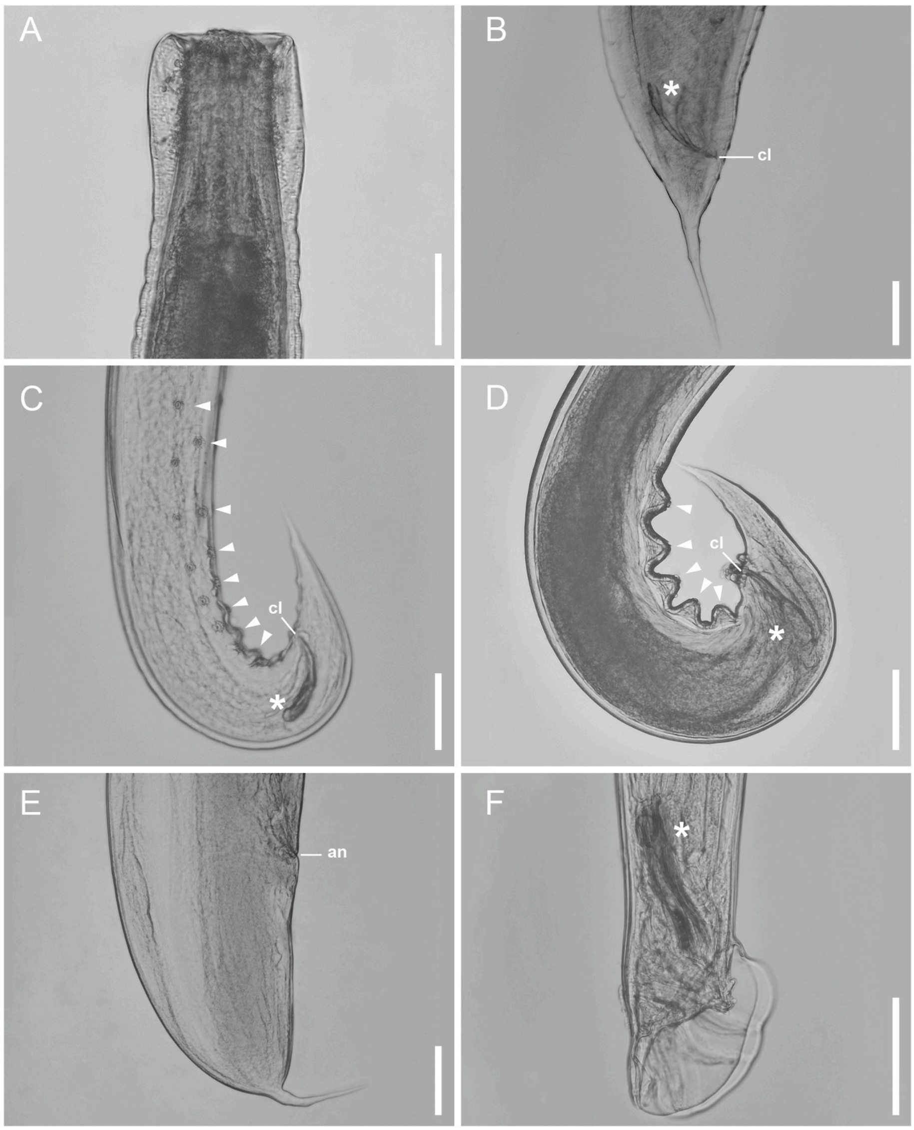

Fig. 2. Photomicrographs of the helminth species associated with *Osteocephalus cabrerai* from Amapá state, Brazil. A, *Physaloptera* sp. (larvae) anterior region. B, *Aplectana pella* male caudal region, spicules (asterisk). C, *Cosmocerca parva* male caudal region, precloacal papillae (arrowheads) and spicules (asterisk). D, *Cosmocerca podicipinus* male caudal region, preclocal papillae (arrowheads) and spicules (asterisk). E, *Oxyascaris oxyascaris* female caudal region. F, *Oswaldocruzia chabaudi* male caudal region, spicules (asterisk). Abbreviations: Cloaca, cl; Anus, an. *Scale–bars:* A 50 μm; B, C, D, E, F 100 μm.

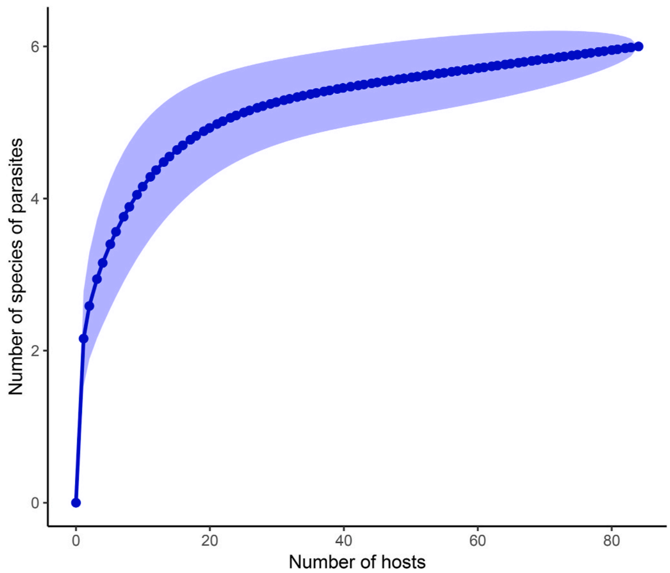

Fig. 3. Parasite species richness distributed in *Osteocephalus cabrerai* specimens from Amapá state, Brazil.

Table 2
Parasite community characteristics of the helminth infracommunities and component communities of *O. cabrerai* from Amapá state, Brazil. Abbreviation: SD, standard deviation.

Community characteristics	Values
Infracommunities	
Mean Brillouin diversity index (HB) (±SD)	0.16 ± 0.20
Mean evenness (E) (±SD)	0.14 ± 0.17
Component community	
Species richness	6
Shannon-Wiener diversity index (H)	1.06
Evenness (J)	0.59
Berger-Parker (d)	0.55

Table 3
Dispersion index (DI) and d-statistic (*d*), discrepancy index (D) and distribution for the parasite infracommunities (prevalence >10%) of *O. cabrerai* from the Brazilian Amazon. Distribution classification: d < 1.96, random distribution; d > 1.96, aggregate distribution.

Helminth	DI	*d*	D	Distribution
Aplectana pella	6.81	20.699	0.842	Aggregate
Cosmocerca parva	8.2	23.972	0.778	Aggregate
Oswaldocruzia chabaudi	1.45	2.592	0.875	Aggregate

aspects of the parasite (life cycle and transmission methods), host susceptibility to the parasite, infection, and immune response (Anderson and Gordon, 1982; Cardoso et al., 2021; Rubenina et al., 2021). In the aggregated pattern, most infected hosts have a small number of parasites, while a few hosts have many parasites (Anderson and Gordon, 1982; Draghi et al., 2020).

In general, parasite community characteristics of *O. cabrerai* were not correlated to host size (SVL and weight), except for a positive correlation between total intensity and host weight. The positive correlation observed in the present study is also observed in previous studies like Hamann et al. (2012, 2013) and Toledo et al. (2018). This data supports the hypothesis that larger hosts are capable of providing more habitats and a greater diversity of resources, such as different niches, compared to smaller hosts as proposed by other authors (Poulin, 1997; Duré and Kehr, 1999; Bolek and Coggins, 2003; Hamann et al., 2006, 2012, 2013; Hamann and González 2015; Kamiya et al., 2014; Morand, 2015; Čeirāns et al., 2021). Additionally, hosts with larger body sizes have a greater surface area, increasing the likelihood of contact with direct life-cycle nematodes in the soil (Aho, 1990; Morand, 2015).

However, the uncorrelated factors (total abundance vs. SVL, total abundance vs. weight, mean helminth richness vs. SVL, mean helminth richness vs. weight, helminth abundance species vs. SVL) indicate that other aspects of the host like physiology, behavior, and seasonality can also explain variations in the mean helminth richness, intensity, and species abundance (Poulin, 1997; Oliveira et al., 2019).

Although *Osteocephalus* genus is widely distributed in South America with 28 species, most do not have any information about their helminth fauna. In our bibliographic revision, we found parasitological studies for only two *Osteocephalus* species, in which *O. taurinus* was the most widely parasitized species (n = 13 spp.). In contrast, we found just one helminth record for *O. leprieurii*. Our study reinforces the need to add new data on the helminth fauna of this host group.

We provide the first study of the helminth community structure of *O. cabrerai*. The component community was composed predominantly of nematodes with a monoxenous life cycle, high prevalence, and abundant infection. Most parasite species here represent the first record for the genus *Osteocephalus*, except for *Physaloptera* sp. The helminth infections

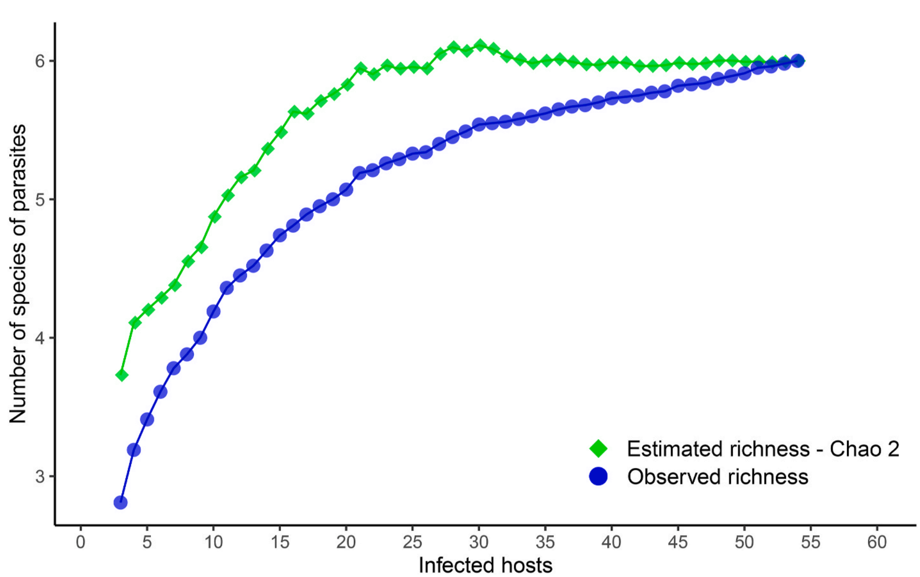

Fig. 4. Species accumulation curve with the 95% error bars showing the accumulation of helminth taxa found in *Osteocephalus cabrerai* from Amapá state, Brazil.

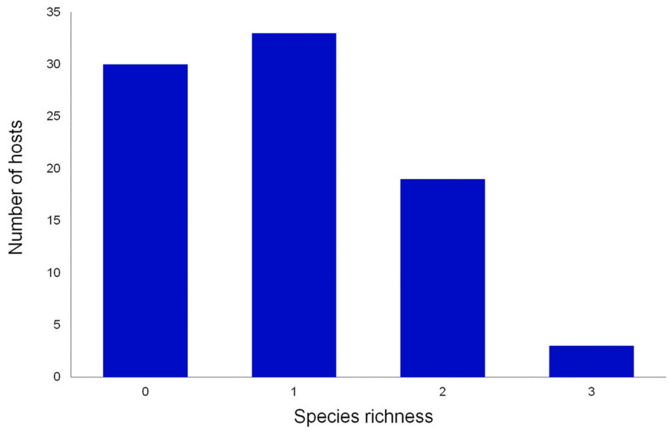

Fig. 5. Comparison between the observed and the estimated richness for helminth parasites of *Osteocephalus cabrerai* using Chao 2 richness estimator.

in the host showed a typical aggregated distribution pattern for parasites.

Our findings contribute to anurans helminth fauna and provide new insights into helminth communities' distribution patterns. *Osteocephalus cabrerai* body weight positively influences the total intensity of parasite infection. The bibliography revision reinforces that we still have little information on the helminth fauna of *Osteocephalus* spp. and that additional and future studies will be necessary to bring new data on amphibian parasites and their ecological relationships.

Ethics approval

All procedures contributing to this work comply with all applicable institutional, national, and international guidelines for animal care and use Animal Research Ethics Committee, Federal University of Pará, under license N8341260821CEUA/UFPa. The present study was approved by Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio), Brazil, and host specimens were collected under license number SISBIO: 48,102–2.

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CRediT authorship contribution statement

Jorge Kevin Silva Neves: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Evelyn Lebrego Cardoso:** Writing – review & editing, Methodology, Formal analysis, Data curation. **Gabriel Lima Rebêlo:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis. **Adriano José Silva Félix:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation. **Soraya Almeida Machado:** Writing – review & editing, Methodology, Investigation, Formal analysis, Data curation. **Carlos Eduardo Costa-Campos:** Writing – review & editing, Resources, Project administration, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Jeannie Nascimento Santos:** Writing – review & editing, Resources, Project administration, Funding acquisition, Formal analysis. **Francisco Tiago Vasconcelos Melo:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Table 4
Records of parasitic helminth in *Osteocephalus* spp., including new reports for *O. cabrerai* from the present study.

Helminth	Helminth Family	Country	Reference
Host: *Osteocephalus cabrerai*			
Nematoda			
Aplectana pella Santos, Borges and Melo, 2023	Cosmocercidae	Brazil	**Present study**
Cosmocerca parva Travassos, 1925		Brazil	**Present study**
Cosmocerca podicipinus Baker and Vaucher, 1984		Brazil	**Present study**
Oxyascaris oxyascaris Travassos, 1920		Brazil	**Present study**
Oswaldocruzia chabaudi Ben Slimane and Durette-Desset, 1996	Molineidae	Brazil	**Present study**
Physaloptera sp. (larvae)	Physalopteridae	Brazil	**Present study**
Host: *Osteocephalus taurinus* Steindachner, 1862			
Monogenoidea			
Polystoma naponensis Vaucher, 1987	Polystomatidae	Ecuador	Vaucher (1987)
Mesopolystoma samiriensis Vaucher, 1981		Peru	Vaucher (1981)
Nematoda			
Cosmocerca brasiliense Travassos, 1925	Cosmocercidae	Peru	Bursey et al. (2001)
Cosmocercoides meridionalis Anjos et al.,2021		Brazil	Anjos et al. (2021)
Kentropyxia hylae Feitosa et al.,2015	Molineidae	Brazil	Feitosa et al. (2015)
Ochoterenella vellardi (Travassos, 1929; Esslinger, 1986	Onchocercidae	Peru	Bursey et al. (2001)
Physaloptera sp. (larvae)	Physalopteridae	Peru	Bursey et al. (2001)
Physalopteroides venancioi (Lent, Freitas and Proença, 1946; Sobolev, 1949		Peru	Bursey et al. (2001)
Batracholandros spectatus (Freitas and Ibañez, 1962; Freitas and Ibañez, 1965	Pharyngodonidae	Peru	Bursey et al. (2001)
Parapharyngodon politoedi Santos, Argôlo, Santos, Rodrigues, Gonzaléz, Santos and Melo, 2019		Brazil	Santos et al. (2019)
Parapharyngodon curupira Santos et al.,2022		Brazil	Santos et al. (2022)
Rhabdias sp.	Rhabdiasidae	Brazil	Tavares-Costa et al. (2018)
Acanthocephala			
Oligacanthorhynchus sp. (cystacanth)	Oligacanthorhynchidae	Ecuador	Smales (2007)
Host: *Osteocephalus leprieurii* (Duméril and Bibron, 1841)			
Monogenoidea			
Polystoma naponensis	Polystomatidae	Ecuador	Vaucher (1987)

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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