The diversity of helminths in host groups with a high diversity of species like anurans are still underrepresented, especially in sites with severe environmental conditions such as arid and semi-arid regions. This knowledge is needed to understand the role of parasites at different levels of ecological organization. This study aimed to evaluate the parasite composition a taxocenosis of anuran species, describe the richness and diversity of helminths at the component and infracommunity levels, and evaluate the influence of body size on the abundance and diversity of parasites. The anuran hosts were collected at the Environmental Protection Area (EPA) Bica do Ipu in Brazilian semi-arid. The collected hosts were euthanized, necropsied, and examined for helminth parasites. Helminths were identified and the statistical tests were performed. A total of 15 host species composed this study and 1,216 helminths were collected with mean abundance (MA) of 12.9 ± 3.38 and mean intensity of infection (MII) of 25.84 ± 6.44. The mean richness of helminth was 2.3 ± 0.53 (range = 6) and helminth diversity (H’) was 1.36. Helminths infecting the studied amphibian hosts comprised 13 taxa: two cestode species, one acanthocephalan, one trematode, and nine nematodes. The present study contributes to the knowledge of the helminths infecting amphibians from Brazilian Caatinga, as well as the understanding of the diversity patterns of parasitic infracommunities associated with amphibians.

**Keywords:** Amphibians – Inventory – Endoparasites – Nematodes – Mountain swamp – Semi-arid

doi:10.24039/rnh2020142795
La diversidad de los helmintos en los grupos de huéspedes con gran diversidad de especies como los anfibios anuros siguen estando subrepresentados, especialmente en sitios con condiciones ambientales severas como las regiones áridas y semiáridas. Este conocimiento es necesario para comprender el papel de los parásitos en los diferentes niveles de la organización ecológica. Con el fin de evaluar la composición del parásito una taxocenosis de las especies de anuros, describir la riqueza y diversidad de los helmintos a nivel de componentes y de la infracomunidad; además de evaluar la influencia del tamaño del cuerpo en la abundancia y diversidad de los parásitos, se realizó este estudio. Los anuros huéspedes se recogieron en la Zona de Protección Ambiental (EPA) Bica do Ipu en el semiárido brasileño. Los huéspedes recolectados fueron sometidos a eutanasia y a una necropsia en busca de parásitos. En secuencia, se identificaron los helmintos y se realizaron las pruebas estadísticas. Un total de 15 especies de huéspedes compusieron este estudio y se recogieron 1.216 helmintos con abundancia media (MA) de 12,9 ± 3,38 y intensidad media de la infección (MII) de 25,84 ± 6,44. La riqueza media de helmintos fue de 2,3 ± 0,53 (rango = 6), y la diversidad de helmintos (H) fue de 1,36. La comunidad de componentes de helmintos que infectan a los anfibios huéspedes comprende 13 taxones: dos especies de cestodos, un acantocéfalo, un trematodo y nueve nematodos. El presente estudio contribuye al conocimiento de los helmintos que infectan a los anfibios de la Caatinga brasileña, así como a la comprensión de los patrones de diversidad de las infracomunidades parasitarias asociadas a los anfibios.

Palabras clave: Anfibios – Inventario – Endoparásitos – Nematodos – Pantano de montaña – Semiárido

**INTRODUCTION**

Documenting parasite diversity and host relationships are needed to understand the role of parasites at different levels of ecological organization (Wood & Johnson, 2015). Parasites can affect host immunity and population dynamics, thus having effects on community composition and trophic interactions also acting on population control (Bittencourt & Rocha, 2003; Hudson, 2005). Although play essential roles in ecological processes, parasites remain taxonomically neglected and the actual number of species in different groups cannot yet be determined (Windsor, 1998; Poulin & Morand, 2004).

The interaction host-parasite is an outcome of their coevolutionary history, diet, body size, sex, infection site, geographic distribution, behavior, host species, climatic characteristics, and host phylogeny (Muzzall et al., 2001; Araujo-Filho et al., 2017)—. Anurans can act as definitive, intermediate, and paratenic hosts of a wide variety of helminths (Campião et al., 2009; Santos & Amato, 2010; Campião et al., 2014). Body size is a determining factor for the composition of the anuran parasite community, due to the greater amount of food eaten and added extra and intracorporeal surface, increasing the possibilities of oral and skin infection (Santos & Amato, 2010; Campião et al., 2016b; Hamann et al., 2009).

Amphibian’s biology makes it an excellent model for evaluating patterns in the structure of helminth communities (Aho, 1990). They occupy a variety of habitats, have different patterns of life cycle, different reproductive strategies, and occupy various positions in food webs (Koprivnikar et al., 2012). Studies on amphibian parasites have increased in recent years (e.g. Campião et al., 2016a; Oliveira et al., 2019). However, information about the parasites of some amphibian groups is still scarce, and most of restricted to taxonomic descriptions or records of occurrence (Pinhão et al., 2009).

Brazil has the most diverse anuran fauna, with 1,137 species (Segalla et al., 2019). Nevertheless, there are helminth reports for only 185 (7%) species. About 164 helminth species are currently known for Brazilian amphibians, totaling 57% of the taxa described for South America. However, studies describing the ecological aspects of parasites associated with Brazilian amphibian taxocenosis remain underrepresented in the literature (Toledo et al., 2017; da Graça et al., 2017). Data scarcity is even more pronounced in
semi-arid regions where amphibians are strongly influenced by unpredictable rainfall. Severe environmental conditions in arid and semi-arid regions may limit species diversity by selecting clades tolerant to such conditions while shaping their ecology, natural history, and behavior (Garda et al., 2017).

Therefore, the objectives of this study were: (1) evaluate the parasite composition of 15 anuran species; (2) describe the richness and diversity of helminths at the component and infracommunity levels; (3) to evaluate the influence of body size on the abundance, diversity, and richness in anurans of Caatinga, Brazil.

MATERIAL AND METHODS

Anurans were sampled from the Environmental Protection Area (EPA) Bica do Ipu (4°19'10” S, 40°43'04” W), Ipu municipality, Ceará state, Brazil (Fig. 1). The EPA Bica do Ipu, is located at the slopes of the Ibiapaba plateau with an extension of 3,500 ha approximately. The Ibiapaba plateau is a highland marsh (known as brejo de altitude) composed by a mosaic of phytophysiognomies (Santos & Souza, 2012).

Amphibians (n = 92 specimens), comprising representatives of five families: Bufonidae: Rhinella jimii Stevaux, 2002 (n = 1), Rhinella granulosa Spix, 1824 (n = 11); Hylidae: Corythomantis greeningi Boulenger, 1896 (n = 1), Scinax x-signatus Spix, 1824 (n = 4); Phyllomedusidae: Pithecopus nordestinus Caramaschi, 2006 (n = 4); Leptodactylidae: Leptodactylus fuscus Schneider, 1799 (n = 4), Leptodactylus macrosternum Miranda-Ribeiro, 1926 (n = 4), Leptodactylus mystaceus Spix, 1824 (n = 1), Leptodactylus vastus Lutz, 1930 (n = 6), Physalaemus albifrons Spix, 1824 (n = 21), Physalaemus cicada Bokermann, 1966 (n = 9), Physalaemus cuvieri Fitzinger, 1826 (n = 3), Pleurodema diploclastis Peters, 1870 (n = 10), Pseudopaludicola mystacalis Cope, 1887 (n = 12); Odontophrynidae: Proceratophrys cristiceps Müller, 1883 (n = 1) were captured by hand during visual surveys from 7 to 15 April 2014. Specimens were euthanized with intraperitoneal injection of Propofol (CFMV, 2013), after the snout–vent length (SVL) of each specimen was recorded. During necropsy, hosts were sexed and the organs like gastrointestinal tract, lungs, liver, and kidneys were separated and surveyed for helminths under stereomicroscope. Voucher hosts were fixed with 10% formalin, conserved with 70% ethanol and deposited at the Herpetological Collection of the Universidade Regional do Cariri (URCA 9127-9132, 9134-9143, 9145-9148, 9152-9185, 9187-9202, 9107-9211, 9226-9229, 9232-9239, 9241-9245), municipality of Crato, Ceará state, Brazil.

Helminths were fixed in hot alcohol and preserved in 70% ethyl alcohol. For identification, the nematodes were clarified in lactic acid, and cestodes, trematodes, and acanthocephalans were stained with hydrochloric carmine and cleared with creosote. Thereafter, the helminths were mounted in temporary slides and examined under the light microscope ZEISS Axio Imager M2. Species identification followed Travassos et al. (1969), Vicente et al. (1991), and recent bibliographies. The voucher species were deposited at the Herpetological Collection of Universidade Regional do Cariri.

Parasitological descriptors follow Bush et al. (1997): prevalence, intensity, and abundance of infection were calculated, followed by their respective standard errors. All values are expressed as the mean ± standard error (SE). Parasites’ abundance data were tested for normality by the Kolmogorov-Smirnov test. To calculate the wealth and diversity of the community we use the species richness (= total number of helminth species), Shannon index (H’) (Zar, 2010). The Berger–Parker index of dominance (d) was used to determine the most dominant species (Magurran, 2004). Spearman’s rank test (rs) was used to assess the relationship between the host body size and parasitological descriptors. Statistical analyses were performed using BioEstat 5.0 (Ayres et al., 2007) and software R platform, version 2.15.0 (RC team, 2017).

Ethic aspects
Instituto Chico Mendes de Conservação da Biodiversidade (ICMBIO) for collection permits (ICMBio number 32758-1). To Comité de Ética em Pesquisa da Universidade Regional do Cariri, permits 00026/2015.
RESULTS

Of the 92 analyzed hosts, 44 (47.8%) were parasitized with at least one helminth species. Only three analyzed host species presented no infection with helminth parasites (C. greening, R. jimi, and S. x-signatus). A total of 1,190 helminths from 13 taxa was recovered from 12 hosts of five anuran families (Table 1), with mean abundance of 12.9 ± 3.38 and mean intensity of infection of 25.84 ± 6.44. Helminth diversity (H') was 1.36. The mean helminth richness was 2.3 ± 0.53 (max. = 6) species per infected host.

Schrankiana sp. and Raillietnema spectans Gomes, 1964 were the most abundant taxa (d = 0.39, d = 0.36 respectively). Oswaldocruzia mazzai Travassos, 1935 and R. spectans were the helminth taxa that infected the greatest number of host species (8 and 9, respectively). The nematodes Aplectana membranosa Schneider, 1866, Ochoterenella sp., Parapharyngodon sp., and Physaloptera sp. larvae were found only in anuran species. The digenean Gorgoderina parvicava Travassos, 1922 was found only in L. vastus. Cylindrotaenia americana Jewell, 1916 (Cestoda), and Oligacanthorhynchus sp. (Acanthocephala) were found only in P. diplolister (Table 1).

The highest intensity of parasites was found in the rufous frog L. fuscus (n = 446). Pleurodema diplolister and R. granulosa were the hosts exhibiting the highest helminth richness (n = 6). The diversity of the helminths tended to be greatest in P. cicada (H' = 1.15) followed by L. vastus (H' = 1.03) (Table 2).

The overall host body size correlated positively with richness (rs = 0.542, p < 0.001) and abundance of parasites (rs = 0.578, p < 0.001). Considering the analysis of each anuran host species, it was also observed a significant positive correlation with abundance and parasite richness for P. albifrons (abundance/length: rs = 0.489, p = 0.02; richness/length: rs = 0.475, p = 0.02) and P. diplolister (abundance/length: rs = 0.882, p < 0.001; richness/length: rs = 0.740, p = 0.01). However, for L. vastus, the relation of abundance and length was negatively correlated (rs = -0.941, p = 0.01) (Table 3).

DISCUSSION

The richness found in the present study is similar to other studies dealing with the helminth community associated with anurans (Aguiar et al., 2014; Campião et al., 2014; 2016a; da Graça et al., 2017; Müller et al., 2018). However, it may be underestimated because of unidentified species, since the occurrence of cryptic species has already been recorded for the region, as in Rhabdiasidae (Müller et al., 2018). Also, larger numbers of nematode species seem to be a general pattern for South American amphibians (Campion et al., 2014).

Monoxenous nematodes, such as R. spectans and O. mazzai, infected more host species. According to Anderson (2000), parasites with direct life cycles have low specificity and simple mode of transmission that can occur through egg ingestion or larval penetration through the host skin. Moreover, R. spectans and O. mazzai have been recorded infecting several Brazilian anurans, including P. diplolister, Dermatotytonus muelleri (Boettger, 1885), Leptodactylus latrans (Steffen, 1815), Rhinella crucifer (Wied Neuwiëd, 1821), Rhinella icteric (Spix, 1824), L. fuscus, L. mystaceus, Physalaemus albifrons, P. cicada, and P. cuvieri (Campião et al., 2014; Teles et al., 2015; Alcantara et al., 2018; Oliveira et al., 2019).

Cylindrotaenia americana is also a monoxenous parasite infecting the intestinal mucosa (Stumpf, 1981). Actually, it has been reported in North and South America, Asia, and Europe in hosts of the families Bufonidae, Ranidae, Hylidae, Brachycephalidae, and Dendrobatidae (Goldberg & Bursey, 2008). In Brazil, there are records of this cestode species infecting R. icteric, Rhinella fernandezae (Gallardo, 1957), Ischnocnema guentheri (Steindachner, 1864), Hypsiboes prasimus (Burmeister, 1856) (Campião et al., 2014), Ischnocnema parva (Girard, 1853), Hyloides phylloides Heyer & Cocroft, 1986 (Aguiar et al., 2014), and P. cicada (Oliveira et al., 2019). Pleurodema diplolister is a new host recorded for C. americana.

Acanthocephalans of the genus Oligacanthorhynchus are heteroxenous and usually have mammals as final hosts (Gallas &
Table 1. Helminths recorded in the 12 host species collected in the Environmental Protection Area (EPA) Bica do Ipu, Ceará, Brazil. Dominance (d), prevalence (%), mean abundance (MA) ± standard deviation (SE), range and number of parasites/host species are presented. Lfus = Leptodactylus fuscus; Lmac = L. macrosternum; Lmys = L. mystaceus; Lvas = L. vastus; Phal = Physalaemus albifrons; Phci = P. cicada; Phcu = P. cuvieri; Pinor = Pithecopus nordestinus; Pldi = Pleurodema diplolister; Prca = Proceratophrys caramaschi; Psmy = Pseudopaludicola mystacalis; Rhgr = Rhinella granulosa. The number in parenthesis is the number of studied hosts.

| Parasite taxa                      | d     | %     | MA ± SE | Range | Lfus (4) | Lmac (4) | Lmys (1) | Lvas (6) | Phal (21) | Phci (9) | Phcu (3) | Pinor (4) | Pldi (10) | Prca (1) | Psmy (12) | Rhgr (11) |
|------------------------------------|-------|-------|---------|-------|----------|----------|----------|----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| **Acantocephala**                  |       |       |         |       |          |          |          |          |           |           |           |           |           |           |           |
| Oligacanthorhynchus sp.            | 0.003 | 1.1   | 0.01 ± 0.01 | 4     | 4        |          |          |          |           |           |           |           |           |           |           |
| **Cestoda**                        |       |       |         |       |          |          |          |          |           |           |           |           |           |           |           |
| Cylindrotaenia americana          | 0.003 | 1.1   | 0.01 ± 0.01 | 4     | 4        |          |          |          |           |           |           |           |           |           |           |
| Unidentified                       |       |       |         |       |          |          |          |          |           |           |           |           |           |           |           |
| **Digenea**                        |       |       |         |       |          |          |          |          |           |           |           |           |           |           |           |
| Gorgoderina parvicava              | 0.0008 | 1.1 | 0.01 ± 0.01 | 10    | 10       |          |          |          |           |           |           |           |           |           |           |
| **Nematoda**                       |       |       |         |       |          |          |          |          |           |           |           |           |           |           |           |
| Aplectana membranosa               | 0.0008 | 1.1 | 0.01 ± 0.01 | 1     | 1        |          |          |          |           |           |           |           |           |           |           |
| Falcaustra mascula                 | 0.04  | 4.35  | 0.58 ± 0.36 | 1-31  | 49       |          |          |          |           |           |           |           |           |           |           |
| Ochoterenella sp.                  | 0.0008 | 1.1 | 0.01 ± 0.01 | 1     | 1        |          |          |          |           |           |           |           |           |           |           |
| Oswaldocruzia mazzai               | 0.18  | 18.5  | 2.34 ± 1.19 | 1-104 | 60       | 16       | 20       | 1         | 12        | 1         | 1         |           |           |           |           |
| Parapharyngodon sp.                | 0.0008 | 1.1 | 0.01 ± 0.01 | 1     | 1        |          |          |          |           |           |           |           |           |           |           |
| Physaloptera sp. larvae            | 0.0008 | 1.1 | 0.01 ± 0.01 | 1     | 1        |          |          |          |           |           |           |           |           |           |           |
| Raillietnema spectans              | 0.36  | 19.6  | 4.59 ± 2.16 | 1-180 | 20       | 56       | 4         | 9         | 4         | 3         | 2         | 218       | 109       |           |           |
| Rhabdias sp.                      | 0.007 | 3.3   | 0.09 ± 0.07 | 1-7   | 1        |          |          |          |           |           |           |           |           |           |           |           |
and three Amazonian strains infecting anurans in the northeast region: *Rhabdias breviensis* Nascimento et al. 2013 in *R. granulosa* from Piauí state, *Rhabdias pseudosphaerocephala* Kuzmin, Tkach & Brooks, 2007 in *Rhinella jimii* from Piauí and Ceará states, and *R. cf. stenocephala* in *Leptodactylus vastus* and *L. macrosternum*. *Rhabdias* spp. are pulmonary parasites of anurans and lizards (Baker, 1987; Teles et al., 2015; Campião et al., 2016a; Toledo et al., 2017; Teles et al., 2018). *Rhabdias* spp. are cryptic species, so only with classical taxonomy, without the help of molecular, it was not possible to precisely identify the species.

Variation in host specificity may determine the structure of helminth communities (Toledo et al., 2017). Eventually, some vertebrates can act as paratenic hosts (Yamaguti, 1963; Goldberg & Bursey, 2004), in this case, the parasites can encyst until they reach the proper host (Baker, 2007). In South America, *Oligacanthorhynchus* sp. was recorded infecting *Odontophrynus americanus* (Duméril & Bibron, 1841) in Paraguay (Campião et al., 2014). Thus *P. diplolister* is a new host record for *Oligacanthorhynchus* sp.

Currently, the genus *Rhabdias* is composed of 84 species (Kuzmin & Tkach, 2018), being 18 reported in Neotropical anurans (Kuzmin et al., 2016; Willkens et al., 2020). Müller et al. (2018) assessing the molecular diversity of *Rhabdias* in Brazil, reports the occurrence of cryptic species

| Component community | Lfus (4) | Lmac (4) | Lmys (1) | Lvas (6) | Phal (21) | Phci (9) | Phcu (3) | Pinor (4) | Pldi (10) | Prea (1) | Psmy (12) | Rhgr (11) |
|---------------------|---------|---------|---------|---------|----------|--------|--------|---------|---------|--------|---------|---------|
| Richness            | 4       | 2       | 1       | 4       | 4        | 4      | 2      | 1       | 6       | 1      | 1       | 6       |
| Diversity (H')      | 0.72    | 0.08    | 1.03    | 0.98    | 1.15     | 0.69   | 0      | 0.46    | 0       | 0      | 0.98    |
| Dominance (d)       | 0.70    | 0.90    | -0.60   | 0.60    | 0.50     | -1     | 0.90   | -       | -       | 0.50   |
| Dominant species    | S       | Om      | -       | Fm      | Om       | Rs     | -      | Rs      | -       | S      |

*S = Schrankiana sp.; Om = Oswaldocruzia mazzai; Fm = Falcaustra mascula; Rs = Raillietnema spectans.*

| Hosts | N  | Richness | Abundance |
|-------|----|----------|-----------|
|       |    | rs       | p         |
|       |    | ps       | p         |
| *Physalaemus albifrons* | 21  | 0.47     | 0.029*    | 0.48      | 0.02*   |
| *Physalaemus cicada* | 9   | 0.54     | 0.11      | 0.63      | 0.05    |
| *Pleurodema diplolister* | 10  | 0.74     | 0.010*    | 0.88      | <0.001* |
| *Leptodactylus fuscus* | 4   | 0.25     | 0.75      | 0.20      | 0.91    |
| *Rhinella granulosa* | 11  | -0.06    | 0.83      | -0.51     | 0.11    |
| *Leptodactylus macrosternum* | 4   | -0.25    | 0.75      | -1.00     | 0.08    |
| *Pseudopaludicola mystacalis* | 12  | 0.50     | 0.10      | 0.50      | 0.10    |
| *Leptodactylus vastus* | 6   | -0.75    | 0.10      | -0.94     | 0.01*   |
| Total hosts | 84 | 0.54     | <0.001*   | 0.57      | <0.001* |

*Values statistically significative (p < 0.05).*

Silvera, 2012; Richardson et al., 2014). Eventually, some vertebrates can act as paratenic hosts (Yamaguti, 1963; Goldberg & Bursey, 2004), in this case, the parasites can encyst until they reach the proper host (Baker, 2007). In South America, *Oligocanthorhynchus* sp. was recorded infecting *Odontophrynus americanus* (Duméril & Bibron, 1841) in Paraguay (Campião et al., 2014). Thus *P. diplolister* is a new host record for *Oligocanthorhynchus* sp.

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| *Leptodactylus vastus* | 6   | -0.75    | 0.10      | -0.94     | 0.01*   |
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*S = Schrankiana sp.; Om = Oswaldocruzia mazzai; Fm = Falcaustra mascula; Rs = Raillietnema spectans.*
Helminths associated with anurans from Brazil

...2017). Herein, R. spectans, O. mazzai, Schrankiana sp., and Rhabdias sp. may be considered generalists and infected more than one host species. Thus, sympatric hosts, although phylogenetically distant may share some helminth taxa, as they are exposed to similar environmental conditions (Krasnov et al., 2012; Lima et al., 2012; Brito et al., 2014). Schrankiana sp. has been recorded in amphibians from the Hylidae and Leptodactylidae families (Goldberg et al., 2007; Campião et al., 2014; Müller et al., 2018; Oliveira et al., 2019). This is the first record for Bufonidae g. granulosa).

The high pattern of infection, abundance, and prevalence was evident among individuals of R. granulosa and L. fuscus. In general, members of the Leptodactylidae are associated with terrestrial habitats being frequently found closer to water bodies, which may expose them to both aquatic and terrestrial parasites (Campião et al., 2016a).

Host body size can influence the establishment of parasite communities; usually larger individuals offer larger colonization areas providing adequate resources for parasite development and reproduction (Poulin, 2004; Campião et al., 2016b). Besides, some studies suggest that body size influence on species richness and abundance of parasitic helminths (Yoder & Coggins, 2007; Ibrahim, 2008; Hamann et al., 2012, 2013; Toledo et al., 2015, 2017). In the present study, the overall size and the size of some amphibian individuals were a determining factor in the richness and abundance of parasite species. According to Toledo et al. (2017), this fact may be related to the greater surface area available for colonization by parasites, as well as the greater intake and more diversified diet of larger frogs. However, an interesting case was observed for L. vastus, in which the abundance of parasites were negatively correlated with host size, contrasting to the pattern mentioned above (Poulin, 2004; Yoder & Coggins, 2007; Ibrahim, 2008; Hamann et al., 2012, 2013; Campião et al., 2016b; Toledo et al., 2015, 2017).

The present study contributes to the knowledge of the helminths infecting amphibians from Brazilian Caatinga, as well as the understanding of the diversity patterns of parasitic infracommunities associated with amphibians.

ACKNOWLEDGMENTS

We thank the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) by the grants to A.F.S.N. (#141572/2019-1), E.P.A. (#141322/2018-7), R.W.A. (#303622/2015-6; #305988/2018-2), D.H.M. (#313241/2018-0) and R.J.S. (#309125/2017-0), PROTAX (#440496/2015-2) and the financial support of Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - CAPES (#88887.501922/2020-00) and Fundação de Amparo à Pesquisa do Estado de São Paulo – FAPESP(#2016/50377-1).
BIBLIOGRAPHIC REFERENCES

Aguiar, A, Morais, DH, Cicchi, PJP & Silva, RJ. 2014. Evaluation of helminths associated with 14 amphibian species from a neotropical Island near the southeast coast of Brazil. Herpetology Review, vol. 45, pp. 227–236.

Aho, JM. 1990. Helminth communities of amphibians and reptiles: comparative approaches to understanding patterns and processes. In: Parasite Communities: Patterns and Processes. Springer Netherlands, Dordrecht, pp. 157–195.

Alcantara, EP, Ferreira-Silva, C, Silva, LAF, Lins, AGS, Ávila, RW, Morais, DH & Silva, RJ. 2018. Helminths of Dermatotus muelleri (Anura: Microhylidae) from Northeastern Brazil. Journal of Parasitology, vol. 104, pp. 550–556.

Anderson, RC. 2000. Nematode parasites of vertebrates. Their development and transmission., 2nd ed. Guelph, Ontario, Canada.

Araujo-Filho, JA, Brito, SV, Lima, VF, Pereira, AMA, Mesquita, DO, Albuquerque, RJ & Almeida, WO. 2017. Influence of temporal variation and host condition on helminth abundance in the lizard Tropidurus hispidus from north-eastern Brazil. Journal of Helminthology, vol. 91, pp. 312–319.

Ayres, M, Ayres Jr, M, Ayres, LD & Santos, AA. 2007. Aplicações estatísticas nas áreas das ciências bio-médicas. Instituto Mamirauá, Belém.

Baker, DG. 2007. Flynn's Parasites of Laboratory Animals: 2nd ed. Blackwell Publishing Ltd, Oxford, UK.

Baker, MR. 1987. Rhabdias collaris n. sp. (Nematoda: Rhabdiasidae) from frogs of Tanzania. Systematic Parasitology, vol. 9, pp. 199–201.

Bittencourt, EB & Rocha, CFD. 2003. Host-ectoparasite Specificity in a Small Mammal Community in an Area of Atlantic Rain Forest (Ilha Grande, State of Rio de Janeiro), Southeastern Brazil. Memórias do Instituto Oswaldo Cruz, vol. 98, pp. 793–798.

Brito, SV, Corso, G, Almeida, AM, Ferreira, FS, Almeida, WO, Anjos, LA, Mesquita, DO & Vasconcelos, A. 2014. Phylogeny and micro-habitats utilized by lizards determine the composition of their endoparasites in the semi-arid Caatinga of Northeast Brazil. Parasitology Research, vol. 113, pp. 3963–3972.

Bush, AO, Lafferty, KD, Lotz, JM & Shostak, AW. 1997. Parasitology Meets Ecology on Its Own Terms: Margolis et al. Revisited. Journal of Parasitology, vol. 83, pp. 575.

Campião, KM, Da Silva, RJ & Ferreira, VL. 2009. Helminth parasites of Leptodactylus podicipinus (Anura: Leptodactylidae) from south-eastern Pantanal, State of Mato Grosso do Sul, Brazil. Journal of Helminthology, vol. 83, pp. 345–349.

Campião KM, Morais DH, Dias OT, Aguiar, A, Toledo, GM, Tavares, LER & Silva, RJ. 2014. Checklist of Helminth parasites of Amphibians from South America. Zootaxa, vol. 3843, pp. 1–93.

Campião KM, Silva, ICO, Dalazen, GT, Paiva, F & Tavares, LER. 2016a. Helminth parasites of 11 anuran species from the Pantanal Wetland, Brazil. Comparative Parasitology, vol. 83, pp. 92–100.

Campião, KM, Dias, OT, Silva, RJ, Ferreira, VL & Tavares, LER. 2016b. Living apart and having similar trouble: Are frog helminth parasites determined by the host or by the habitat? Canadian Journal of Zoology, vol. 94, pp. 761–765.

CFMV. Conselho Federal de Medicina Veterinária. 2013. Métodos de eutanasia. In: Guia brasileiro de boas práticas para eutanásia em animais. Comissao de Ética, Bioética e Bem-da.

Graça, RJ, Oda, FH, Lima, FS, Guerra, V, Gambale, PG & Takemoto, RM. 2017. Metazoan endoparasites of 18 anuran species from the mesophytic semideciduous Atlantic Forest in southern Brazil. Journal of Natural History, vol. 51, pp. 705–729.

Gallas, M & Silvera, EF. 2012. Pathologies of Oligacanthorhynchus pardalis (Acanthocephala, Oligacanthorhynchidae) in Leopardus tigrinus (Carnivora, Felidae) in Southern Brazil. Revista Brasileira de Parasitologia Veterinária, vol. 21, pp. 308–312.

Garda, AA, Stein, MG, Machado, RB, Lion, MB, Juncá, FA & Napoli, MF. 2017. Ecology,
Biogeography, and Conservation of Amphibians of the Caatinga. In: JMC, Silva, I, Leal, M, Tabarelli (eds) Caatinga. Springer International Publishing, Cham, pp 133–149.

Goldberg, SR & Bursey, CR. 2004. Coelomic metazoan endoparasites of 15 colubrid and two elapid snake species from Costa Rica. Caribbean Journal of Science, vol. 40, pp. 62–69.

Goldberg, SR & Bursey, CR. 2008. Helminths from fifteen species of frogs (Anura, Hylidae) from Costa Rica. Phyllomedusa, vol. 7, pp. 25–33.

Goldberg, SR, Bursey, CR, Caldwell, JP, Vitt, LJ & Costa, GC. 2007. Gastrointestinal helminths from six species of frogs and three species of lizards, sympatric in Pará State, Brazil. Comparative Parasitology, vol. 74, pp. 327–342.

Hamann, MI, Kehr, AI, González, CE, Duré, MI & Schaefer, EF. 2009. Parasite and reproductive features of Scinax nasicus (Anura: hylidae) from a South American subtropical area. Interciencia, vol. 34, pp. 214–218.

Hamann, MI, Kehr, AI & González, CE. 2012. Community structure of helminth parasites of Leptodactylus bufonius (Anura: Leptodactylidae) from northeastern Argentina. Zoological Studies, vol. 51, pp. 1454–1463.

Hamann, M.I., Kehr, A.I. & González, C.E. 2013. Helminth communities in the burrowing toad, Rhinella fernandezae, from northeastern Argentina. Biologia, vol. 68, pp. 1155–1162.

Hudson, P. 2005. Parasites, diversity, and the ecosystem. In: F, Thomas, TF, Reanud, JF, Guegan (eds) Parasitism and Ecosystems. Oxford University Press, New York, pp 1–12.

Ibrahim, MM. 2008. Helminth infracommunities of the maculated toad Amietophrynus regularis (Anura: Bufonidae) from Ismailia, Egypt. Diseases of aquatic organisms, vol. 82, pp. 19–26.

Koprivnikar, J, Marcogliese, DJ, Rohr, JR, Orlofske, SA, Raffel, TR & Johnson, PTJ. 2012. Macroparasite infections of amphibians: What can they tell us? Ecohealth, vol. 9, pp. 342–360.

Krasnov, BR, Fortuna, MA, Mouillot, D, Khokhlova, IS, Shenbrot, GI & Poulin, R. 2012. Phylogenetic signal in module composition and species connectivity in compartmentalized host-parasite networks. The American Naturalist, vol. 179, pp. 501–511.

Kuzmin, Y & Tkach, VV. 2018. Rhabdias. In: World Wide Web Electron. Publ. http://izan.kiev.ua/ppages/rhabdias/list.htm . Accessed 3 Mar 2019.

Kuzmin, Y, Melo, FTV, Silva-Filho, HF & Santos, JN. 2016. Two new species of Rhabdias Stiles et Hassall, 1905 (Nematoda: Rhabdiasidae) from anuran amphibians in Para, Brazil. Folia Parasitologica, vol. 63, pp. 3-10.

Lima, DP, Giacomini, HC, Takemoto, RM, Agostinho, AA & Bini, LM. 2012. Patterns of interactions of a large fish-parasite network in a tropical floodplain. Journal of Animal Ecology, vol. 81, pp. 905–913.

Magurran, AE. 2004. Measuring Biological Diversity. Blackwell Publishing Company, Oxford.

Müller, MI, Morais, DH, Costa-Silva, GJ, Aguiar, A, Ávila, RW & Silva, RJ. 2018. Diversity in the genus Rhabdias (Nematoda, Rhabdiasidae): Evidence for cryptic speciation. Zoologica Scripta, vol. 47, pp. 595–607.

Muzzall, PM, Gilliland, MG, Summer, CS & Mehne, CJ. 2001. Helminth communities of green frogs Rana clamitans Latreille, from Southwestern Michigan. Journal of Parasitology, vol. 87, pp. 962.

Oliveira, CR, Ávila, RW & Morais, DH. 2019. Helminths associated with three Physalaemus species (Anura: Leptodactylidae) from Caatinga Biome, Brazil. Acta Parasitologica, vol. 64, pp. 205–212.

Pinhão, R, Wunderlich, A, Anjos, LA & da Silva, RJ. 2009. Helminths of toad Rhinella icterica (bufonidae), from the municipality of Botucatu, São Paulo State, Brazil. Neotropical Helminthology, vol. 3, pp. 35–40.

Poulin, R. 2004. Macroecological patterns of species richness in parasite assemblages. Basic and Applied Ecology, vol. 5, pp. 423–434.
Poulin, R & Morand, S. 2004. Parasite Biodiversity. Smithsonian Institution Books, Washington.

R C team. 2017. R: A Language and Environment for Statistical Computing. R Found Stat Comput.

Richardson, DJ, Gardner, SL & Allen, JW. 2014. Redescription of Oligacanthorhynchus microcephalus (Oligacanthorhynchidae). Comparative Parasitology, vol. 81, pp. 53–60.

Santos, FLA & Souza, MJN. 2012. Caracterização geoambiental do Planalto cuestiforme da Ibiapaba – Ceará. Revista Geonorte, vol. 3, pp. 301–309.

Santos, VGT & Amato, SB. 2010. Helminth fauna of Rhinella fernandezae (Anura: Bufonidae) from the Rio Grande do Sul Coastland, Brazil: Analysis of the parasite community. Journal of Parasitologu, vol. 96, pp. 823–826.

Segalla, MV, Caramaschi, U, Cruz, CAG, Garcia, PCA, Grant, T, Haddad, CFB, Santana, DJ, Toledo, LF & Langone, JA. 2019. Brazilian amphibians: List of species. Herpetologia Brasileira, vol. 8, pp. 65–97.

Stumpf, IVK. 1981. Ciclo evolutivo da Cylindrotaenia americana Jewell, 1916 (Cyclophyllidea: Nematotaeniidae) em Bufo ictericus Spix, 1824. Acta Biologica Paraense, vol. 10, pp. 31-39.

Teles, D, Sousa, JGG, Teixeira, AAM, Silva, MC, Oliveira, RH, Silva, MRM & Ávila, RW. 2015. Helminths of the frog Pleurodema diplolister (Anura, Leuuperidae) from the Caatinga in Pernambuco State, Northeast Brazil. Brazilian Journal of Biology, vol. 75, pp. 251–253.

Yamaguti, S. 1963. Systema Helminthum: Acanthocephala. Interscience Publishers, New York.

Yoder, H.R. & Coggins, J.R. 2007. Helminth communities in five species of sympatric amphibians from three adjacent ephemeral ponds in southeastern Wisconsin. Journal of Parasitology, vol. 93, pp. 755–761.

Zar, JH. 2010. Biostatistical Analysis, 5th ed. Prentice-Hall, Upper Saddle River.