Original Article

Braz. J. Vet. Parasitol., Jaboticabal, v. 26, n. 1, p. 74-80, jan.-mar. 2017
ISSN 0103-846X (Print) / ISSN 1984-2961 (Electronic)
Doi: http://dx.doi.org/10.1590/S1984-29612017013

Helminth fauna of *Leptodactylus syphax* (Anura: Leptodactylidae) from Caatinga biome, northeastern Brazil

Helmintofauna de *Leptodactylus syphax* (Anura: Leptodactylidae) do bioma da Caatinga, Nordeste do Brasil

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Received November 30, 2016
Accepted February 21, 2017

Abstract

Leptodactylus syphax is distributed in central, southeastern and northeastern Brazil, eastern Bolivia and southern Paraguay, occupying open areas and rock outcrops, in rock cavities and termite burrows. We collected 21 frogs from the Caatinga region of the state of Ceará, northeastern Brazil, and 7,021 helminths were recovered from 18 of these hosts (overall prevalence = 85.7%). Six helminth taxa were recovered, as follows: *Aplectana membranosa* (n = 3,756); *Schrankiana formosula* (n = 3,176); larvae of *Physaloptera* sp. (n = 43); unidentified nematode larvae (n = 7); digenean metacercariae of *Lophosicyadiplostomum* sp. (n = 2); and cystacanths of Acanthocephala (n = 37). The similarity of helminth composition between *L. syphax* from the Caatinga and other species of the *L. fuscus* group showed that some anurans were clustered according to parasite species and others according to geographic locality. This study presents new helminth records for the Neotropical region, thus helping in understanding the pattern of species distribution, and it increases the knowledge of parasites associated with amphibians.

Keywords: *Leptodactylus fuscus* group, helminths, parasites, *L. syphax*, Caatinga.

Resumo

Leptodactylus syphax está distribuída na região central, Sudeste e Nordeste do Brasil, Leste da Bolívia e Sul do Paraguai, ocupando áreas abertas e afloramentos rochosos, cavidades rochosas ou de cupins. Foram coletadas 21 rãs oriundas da região de Caatinga do Ceará, nordeste brasileiro, e 7.021 helmintos foram recuperados em 18 hospedeiros (prevalência geral = 85,7%). Seis *taxa* de helmintos foram recuperados, como segue: *Aplectana membranosa* (n = 3.756), *Schrankiana formosula* (n = 3.176), larvas de *Physaloptera* sp. (n = 43), larvas de nematódeos não identificado (n = 7), metacercárias de *Lophosicyadiplostomum* sp. (n = 2), e cistacantos de Acantocéfalos (n = 37). A similaridade da composição de helmintos entre *L. syphax* da Caatinga e outras espécies do grupo *L. fuscus* mostrou que alguns anuros foram agrupados de acordo com a espécie do parasita e outros de acordo com a localidade geográfica. Este estudo apresenta novos registros de helmintos para a região Neotropical, ajudando na compreensão do padrão de distribuição das espécies e aumenta o conhecimento sobre os parasitas associados a anfíbios.

Palavras-chave: *Leptodactylus fuscus* grupo, helmintos, parasitas, *L. syphax*, Caatinga.

Introduction

Knowledge about biological diversity and its distribution is of such importance that it should be considered before any further study. Global diversity includes parasites such as helminths, which are associated with several vertebrates and can be modulated by their host and environment. Helminths can also influence host population conditions through co-evolutionary processes (POULIN, 1995, 1999). Compared with what is known about the helminth fauna of some vertebrates, such as fish, birds and mammals, knowledge of helminth richness in amphibians is relatively poor (AHO, 1990). Considering the richness of anuran species in Brazil – around 1026 species (SEGALLA et al., 2014; FROST,

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2015) – the number of helminth species is expected to be higher. In the Caatinga biome, located in northeastern Brazil, there are approximately 53 anuran species, and most of them have an unknown helminth fauna (ALBUQUERQUE et al., 2012; CAMPIÃO et al., 2014). One of these species is *Leptodactylus syphax* (Bokermann, 1969), which is distributed across central, southeastern and northeastern Brazil, eastern Bolivia and southern Paraguay, occupying open areas and rocky outcrops, in rock or termite cavities. This species does not seem to adapt well to anthropogenic disturbance (IUCN, 2015).

According to De Sá et al. (2014), the leptodactylid species *Leptodactylus syphax* was placed in the *Leptodactylus fuscus* group, which is composed of species of similar sizes that occupy similar niches and are phylogenetically close together. On the other hand, the species of this group have wide distribution and occupy different habitats, which can influence component communities of related parasites (GOATER & GOATER, 2001). However, there is only one record of a helminth parasite associated with *L. syphax*: the nematode *Aplectana* sp., which was reported from the state of Mato Grosso do Sul, Brazil (CAMPIÃO et al., 2014).

In the present study, the component community of helminths associated with *L. syphax* in the Caatinga, Brazil, is reported. In addition, the similarity of helminth community composition in other species of the *L. fuscus* group from different South American regions is compared in order to analyze whether clusters were formed according to geographic region or helminth species.

Materials and Methods

This study was conducted in the municipality of Farias Brito, Cariri region, state of Ceará, northeastern Brazil. Twenty-one specimens of *L. syphax* were collected through visual encounter surveys from February 2013 to August 2014, fixed in 10% formalin, preserved in 70% alcohol and then deposited in the Herpetological Collection of the Regional University of Cariri, (URCA-H 4864, 4865, 4866, 4867, 4868, 4876, 4882, 4923, 4924, 4925, 4926, 4929, 4933, 4936, 4938, 7144, 7145, 7149, 7152, 9823, 9949), municipality of Crato, state of Ceará. All organs were removed and examined individually under a stereoscope and the helminths collected were transferred to 70% ethanol. Larvae of Acanthocephala (cystacanths) and metacercariae were stained with alcoholic hydrochloric acid-carmine and cleared in creosote, while nematodes were diaphanized in lactophenol. Helminths were deposited in the Coleção Helmintológica do Instituto de Biociências de Botucatu (CHIBB 7956, 7957, 7958, 7959, 7960, 7961, 7962, 7963, 7964, 7965, 7966, 7967, 7968, 7969, 7970, 7971, 7972, 7973, 7974, 7975, 7976, 7977, 7978). Subsequently, these temporary slides were analyzed using a microscope equipped with the LASV3.8 image system. The collection of specimens of *L. syphax* was authorized by SISBIO (#32758-2).

As described by Bush et al. (1997), we used ecological descriptors such as prevalence, mean abundance and mean intensity of infection. These descriptors were calculated in the SigmaStat 3.1 software (SYSTAT Software, Inc.). The similarity of the helminth fauna of the *L. fuscus* species group in which *L. syphax* is included was analyzed considering the geographic localities occupied by these species, and a cluster analysis was performed using the Bray-Curtis similarity index performed using the Past software (BRAY & CURTIS, 1957), scored as presence (1) or absence (0) of data on helminth species.

Results

Helminths associated with Leptodactylus syphax from the Caatinga

We recovered 7,021 helminths from 18 of the 21 specimens of *L. syphax*, thus resulting in overall prevalence of 85.7%, mean abundance of 334.3 ± 85.0 and an average of 390.0 ± 93.0 helminths in each infected host, with parasitism intensity ranging from at least two up to 1,300 helminths. The mean richness was 1.4 ± 0.2 species and the taxon richness in the component community comprised four nematode species: *Aplectana membranosa* (n = 3756); *Schrankiana formosula* (n = 3176); larvae of *Physaloptera* sp. (n = 43); unidentified larvae (n = 7); digenean metacercariae of *Lophosicyadiplostomum* sp. (n = 2); and cystacanths of Acanthocephala (n = 37) (Table 1).

Table 1. Prevalence (P%), mean intensity of infection (MII), mean abundance (MA) with standard error (SE), range of infection (Ri) and site of infection (SI) of helminths associated with *Leptodactylus syphax* from the Caatinga, Brazil.

Helminthes	P%	MII	Ri	MA	SI*
Nematoda					
Aplectana membranosa	71.4	250.4 ± 63.0	2-771	178.8 ± 51.2	Si, Li
Schrankiana formosula	42.9	353.0 ± 128.1	6-1000	151.2 ± 65.9	Li
Physaloptera sp. (larvae)	9.5	21.5 ± 19.5	2-41	2.0 ± 1.9	Sto
Unidentified larvae	4.8	7.0	-	0.3 ± 0.3	Cav
Digenea					
Lophosicyadiplostomum sp. (metacercariae)	4.8	2.0	2	0.1 ± 0.1	Kid
Acanthocephala					
Cystacanths	4.7	37.0	37	1.7 ± 1.7	Cav
Total	**85.7**	**390.0 ± 93.0**	**2-1300**	**334.3 ± 85.0**	-

*Si (small intestine), Li (large intestine), Sto (stomach), Cav (body cavity), and Kid (kidneys).

Similarity to helminth community composition of other species of the Leptodactylus fuscus group in different South American regions

Only eight species in the *L. fuscus* group have helminth records from South American countries, in Argentina, Brazil, Ecuador, Paraguay and Peru (Table 2). Among these, Argentina and Brazil have provided most of the records. Based on these records, a cluster with a cophenetic correlation coefficient of 0.81 was presented (Figure 1). Some hosts were grouped according to locality and others according to the composition of helminth species. Hosts sampled in the state of Mato Grosso do Sul (MS) shared the same clade of helminth species with similarity (0.6) shown in a cluster for *L. elenae* and *L. syphax* (1.0), with closer similarity than between *L. fuscus* and *L. mystacinus* (0.8). Another pair of hosts that showed a correlation was *L. bufonius* and *L. mystacinus* (0.6): although from different localities, both shared *Oswaldocruzia proencai* with *L. bufonius* from Paraguay (0.4). *Leptodactylus fuscus* and *L. mystaceus* showed similarity (0.6) from Rio de Janeiro. *Leptodactylus fuscus* and *L. mystacinus*; and *L. fuscus* and *L. mystaceus,* from different localities, presented the same similarity measurement (0.5). *Leptodactylus syphax* from Ceará was more similar to *L. mystacinus* from Rio de Janeiro (0.2) Three host species formed an outgroup because they did not share any helminth species (0.0).

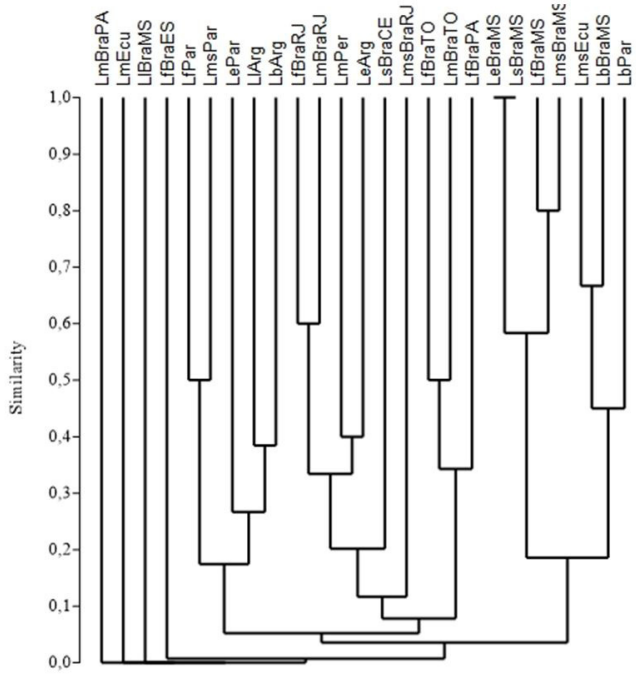

Figure 1. Cluster analysis based on the composition of helminth parasites of the *Leptodactylus fuscus* group from South America. Host species: *Leptodactylus bufonius* (Lb), *Leptodactylus elenae* (Le), *Leptodactylus fuscus* (Lf), *Leptodactylus latinasus* (Ll), *Leptodactylus mystaceus* (Lm), *Leptodactylus mystacinus* (Lms) and *Leptodactylus syphax* (Ls). Original records: Argentina (Arg), Brazil (Bra), Ecuador (Ecu), Paraguay (Par) and Peru (Per). Brazilian States: Ceará (CE), Espírito Santo (ES), Mato Grosso do Sul (MS), Pará (PA), Rio de Janeiro (RJ) and Tocantins (TO).

Discussion

Although members of Leptodactylidae have been included in many studies on helminth fauna in relation to other families, the present study shows the helminth component community of *L. syphax* for the first time. In addition, this is the first study conducted on this host in the Brazilian Caatinga. Also, this is the first record of *Lophosicyadiplostomum* sp. for all anurans of the family Leptodactylidae and the first record of parasitism by all these helminths in hosts in the Caatinga, which extends their geographic distribution, except for *Aplectana* sp., *Physaloptera* larvae and Acanthocephala, which had already been recorded in *Rhinella jimi* and *R. granulosa* in the Caatinga biome (MADELAIRE, 2012).

The parasite community of *L. syphax* showed low richness, compared with the congeneric group. The environment conditions found in the Caatinga, which is characterized by long periods of drought, may have had an influence, through not allowing other forms of infection to become established (e.g. indirect-cycle parasites). Community richness would vary depending on the environmental conditions because of the way in which species respond to biotic factors (POULIN & KRASNOV, 2010).

The component community of helminths in *L. syphax* in this study comprised four species of Nematoda, one of Acanthocephala and one of Digenea, while Vicente et al. (1990) recorded *Aplectana* sp., which is a very common nematode in the intestines of frogs of the Leptodactylidae group (Table 2), and *Schrankiana formosula*, another nematode that is found only in the large intestine, as well as in *L. fuscus* (GOLDBERG et al., 2007). These two nematode species presented the highest prevalence, mean abundance and mean intensity of infection, which can be explained by the greater host body surface, which means they are more exposed to infective stages of parasites (POULIN, 1995). In addition to this, these nematode species of the family Cosmocercidae and Atractidae have direct life cycles and, in the case of *A. membranosa*, the females produce great quantities of eggs, thus resulting in higher reproductive rates and higher abundance of infective larvae in the environment, while *S. formosula,* according Anderson (2000) who claims that family Atractidae presents autoinfective species. There is a passive interaction between these two species, relating to limited resources and to the fact that both of them need to exploit their host in a very short time (DE JONG, 1976; IVES & MAY, 1985; LOMNICKI, 1988), referring to the reproductive mode of Cosmocercidae.

Larvae of *Physaloptera* sp. were recovered from the stomach of *L. syphax*, which can be considered to be an intermediate or paratenic host for this helminth because its diet consists mostly of insects, which harbor the infective larvae (OLSEN, 1986). Species of the *L. fuscus* group show ecological similarities, in that they live temporarily near puddles while at the tadpole stage, but in the adult stage they remain in terrestrial environments and receive further infection by nematodes through oral ingestion or penetration through the skin, in spite of their body length and different localities. Thus, these nematodes are characterized as having low specificity (ANDERSON, 2000).

The presence of cystacanths in cavities suggests that *L. syphax* can be considered to be an intermediate or paratenic host, such

Table 2. Records of helminths associated with leptodactylids of the *Leptodactylus fuscus* group in South American countries, according to Campião et al. (2014). TR (Transchaco), CO (Province of Corrientes), MS (State of Mato Grosso do Sul), AS (Assunción), CH (Chaco), RC (Province of Remanso Castillo), CN (Province of Concepción), SM (Province of Santa Maria), PA (State of Pará), ES (State of Espiríto Santo), RJ (State of Rio de Janeiro), TO (State of Tocantins), SCE (Province of Santa Cecilia) and CU (Cuzco).

Host	Parasite	Country	Locality	Reference
	Acanthocephalus caspanensis	Paraguay	TR	Smales (2007)
	Centrorhynchus sp.	Argentina	CO	González & Hamann (2006)
	Ortleppascaris sp.	Argentina	CO	González & Hamann (2006)
	Aplectana hylambatis	Argentina	CO	González & Hamann (2006)
	Aplectana sp.	Argentina	CO	González & Hamann (2006)
	Cosmocerca ornata	Brazil	not reported	Baker & Vaucher (1984)
	Cosmocerca parva	Argentina	CO	González & Hamann (2006)
	Cosmocerca podicipinus	Argentina	CO	González & Hamann (2006)
	Physaloptera sp.	Argentina	CO	González & Hamann (2006)
Leptodactylus bufonius	*Oswaldocruzia proencai*	Brazil	MS	Vicente et al. (1990)
		Paraguay	AS	Lent et al. (1946)
		Argentina	CH	Lent et al. (1946)
		Paraguay	RC	Lent et al. (1946)
	Oswaldocruzia sp.	Argentina	CO	González & Hamann (2006)
	Rhabdias elegans	Argentina	CO	González & Hamann (2006)
	Schulzia travassosi	Paraguay	CN	Durette-Desset et al. (1986)
		Argentina	not reported	González & Hamann (2015)
	Catadiscus inopinatus	Argentina	CO	Hamann, et al. (2006)
	Glypthelmins repandum	Argentina	CO	González & Hamann (2006)
	Aplectana delirae	Argentina	CO	González & Hamann (2016)
	Aplectana elenae	Paraguay	not reported	Baker (1987)
	Aplectana hylambatis	Paraguay	not reported	Baker & Vaucher (1986)
	Aplectana paraelenae	Paraguay	not reported	Baker (1987)
Leptodactylus elenae	*Aplectana* sp.	Brazil	MS	Baker & Vaucher (1986)
	Cosmocerca podicipinus	Paraguay	not reported	Baker & Vaucher (1986)
	Cosmocerca parva	Argentina	CO	González & Hamann (2016)
	Oxyascaris oxyascaris	Paraguay	not reported	Baker & Vaucher (1986)
	Schrankiana formosula	Paraguay	not reported	Baker & Vaucher (1988)
	Oswaldocruzia proencai		not reported	Vicente et al. (1990)
	Schrankiana formosula	Brazil	PA	Goldberg et al. (2007)
		Brazil	RJ	Freitas, 1959 apud Campião et al. (2014)
	Schrankiana fuscus	Brazil	PA	Goldberg et al. (2007)
	Schrankiana larvata	Brazil	PA	Goldberg et al. (2007)
		Brazil	TO	Freitas, 1959 apud Campião et al. (2014)
		Brazil	MS	Freitas, 1959 apud Campião et al. (2014)
	Aplectana hylambatis	Paraguay	not reported	Baker & Vaucher (1986)
Leptodactylus fuscus	*Aplectana* sp.	Brazil	MS	Freitas, 1959 apud Campião et al. (2014)
	Cosmocerca parva	Brazil	RJ	Vicente et al. (1990)
	Cosmocerca podicipinus	Brazil	TO	Baker & Vaucher (1986)
	Oxyascaris oxyascaris	Brazil	MS	Baker & Vaucher (1986)
	Oxyascaris caudacutus	Brazil	RJ	Vicente et al. (1990)
	Ochoterenella convoluta	Brazil	not reported	Walton (1935)
	Oswaldocruzia mazzai	Brazil	TO	Goldberg et al. (2009)
	Oswaldocruzia vaucheri	Brazil	PA	Goldberg et al. (2007)
	Oswaldocruzia sp.	Brazil	ES	Travassos et al., 1964 apud Campião et al. (2014)
	Mesocoelium monas	Brazil	RJ	Rodrigues et al. (1990)
Leptodactylus gracilis	*Strongyloides carinii*	Brazil	not reported	Pereira, 1935 apud Campião et al. (2014)

Table 2. Continued...

Host	Parasite	Country	Locality	Reference
Leptodactylus latinasus	*Schrankiana schranki*	Argentina	CO	Hamann et al. (2006)
	Aplectana hylambatis	Argentina	CO	Hamann et al. (2006)
	Cosmocerca cruzi	Argentina	CO	Hamann et al. (2006)
	Cosmocerca parva	Argentina	CO	Hamann et al. (2006)
	Cosmocerca podicipinus	Argentina	CO	Hamann et al. (2006)
	Cosmocerca rara	Argentina	CO	Hamann et al. (2006)
	Bursotrema aff.*tetracotyloides*	Argentina	CO	Hamann et al. (2006)
	Catadiscus inopinatus	Argentina	CO	Hamann et al. (2006)
	Petasiger sp.	Argentina	CO	Hamann et al. (2006)
	Styphlodora sp.	Argentina	CO	Hamann et al. (2006)
	Travtrema aff. *stenocotyle*	Argentina	CO	Hamann et al. (2006)
	Glypthelmins repandum	Argentina	CO	Hamann et al. (2006)
	Haematoloechus longiplexus	Argentina	CO	Hamann et al. (2006)
	Opisthogonimus sp.	Argentina	CO	Hamann et al. (2006)
Leptodactylus mystaceus	*Aplectana membranosa*	Brazil	RJ	Rodrigues (1986)
	Aplectana travassosi	Ecuador	SCE	Dyer (1990)
	Cosmocerca parva	Brazil	RJ	Fabio, 1982 apud Campião et al. (2014)
		Peru	CU	Bursey et al. (2001)
	Mesocoelium monas	Brazil	RJ	Fabio, 1982 apud Campião et al. (2014)
	Oxyascaris caudacutus	Brazil	RJ	Fabio, 1982 apud Campião et al. (2014)
	Oxyascaris oxyascaris	Brazil	RJ	Fabio, 1982 apud Campião et al. (2014)
	Oswaldocruzia proencai	Ecuador	SCE	Dyer & Altig (1977)
	Physaloptera sp.	Brazil	RJ	Fabio, 1982 apud Campião et al. (2014)
		Peru	CU	Bursey et al. (2001)
	Physalopteroides venancioi	Peru	CU	Bursey et al. (2001)
	Schrankiana freitasi	Brazil	PA	Goldberg et al. (2007)
	Schrankiana larvata	Brazil	TO	Goldberg et al. (2009)
		Peru	CU	Bursey et al. (2001)
Leptodactylus mystacinus	*Centrorhynchus* sp.	Brazil	RJ	Fabio, 1982 apud Campião et al. (2014)
	Aplectana hylambatis	Paraguay	not reported	Baker & Vaucher (1986)
	Aplectana macintoshii	Paraguay	not reported	Baker & Vaucher (1986)
	Aplectana sp.	Brazil	MS	Travassos, 1925 apud Campião et al. (2014)
	Cosmocerca ornata	Paraguay	not reported	Baker & Vaucher (1986)
	Oxyascaris oxyascaris	Brazil	MS	Travassos, 1925 apud Campião et al. (2014)
	Mesocoelium monas	Brazil	RJ	Freitas, 1967 apud Campião et al. (2014)
Leptodactylus syphax	*Aplectana* sp.	Brazil	MS	Vicente et al. (1990)

that this helminth was acquired through ingestion of arthropods. Some species of Acanthocephala are found in amphibians: in most cases, the cystacanths adhered to the mesentery for transportation by an anuran from an aquatic intermediary host to an aquatic predatory bird, for example (KENNEDY, 2006).

Metacercariae of *Lophosicyadiplostomum* were reported for the first time in a frog of the family Leptodactylidae, in the present study. They were found in the kidneys, thus corroborating previous studies in which this digenean was reported in cyst form at this same infection site. Many digeneans parasitize amphibians: for example, the *L. fuscus* group includes *L. latinasus* (HAMANN et al., 2006), which has been reported to be infected by both aquatic and terrestrial parasites. Metacercariae of *Lophosicyadiplostomum* aff. *nephrocystis* were found in the kidneys of *Scinax nasicus*, (HAMANN & GONZÁLEZ, 2009), *Hyla nana* and *Lysapsus limellum* (HAMANN & KEHR, 1998, 1999). Infection with this trematode may have occurred by penetration of cercariae beyond the host's cloaca, subsequently reaching the kidneys. On the other hand, considering the life cycle of Diplostomidae, gastropods could be ingested by anurans and then the larvae could reach anurans' kidneys as reported by Gonzalez & Hamann (2006).

Most hosts within the *L. fuscus* group have shown similarity regarding the areas sampled, but some species have been grouped according to helminth species that they share (Figure 1). The helminth fauna of *L. syphax* in the Caatinga was most similar to that of *L. mystaceus* and *L. fuscus*, in different regions, because they shared three nematode species. Nematodes generally do not have a specificity pattern, and therefore the ability of parasites to

explore a wider range of hosts results in better use of resources and opportunities for successful biological cycles (POULIN, 2005). The host species in question belong to the same group and do not differ much regarding ecology and physiology, although the sampling points for each host have had very different characteristics, even involving different biomes (*e.g.* Caatinga, Atlantic Forest, high altitude as in Cuzco, or the Chaco region of Argentina).

Diverse mechanisms for host infection, the low level of general environmental requirements for these helminths and low host specificity allow parasite infection even in completely different environments (SOUSA & GROSHOLZ, 1991). Specimens of *L. syphax* collected from the Caatinga presented a fauna mostly composed of nematodes considering the number of parasites, that were in most cases, parasites with a direct life cycle (ANDERSON, 2000) that did not require intermediate host. The requirement for an intermediate host usually occurs in environments with greater abundance of water. The Caatinga has extremely low rainfall, with a very long dry season (DUELLMAN, 1999), and consequently there are few environments available for parasites with an indirect life cycle, as opposed to environments from which congeneric species were collected. In addition, *L. syphax* presents a terrestrial habit and active forager, which favors infection by direct life cycle parasites, once this host remains most of its life in the soil.

Knowledge of the helminth fauna associated with vertebrates improves the data on biodiversity and increases the records of occurrences of species of parasites and their relationships with their hosts. This helps expand knowledge of the distribution patterns of these species and aids future studies on ecological host-parasite relationships.

Acknowledgements

Financial support for this study was provided by the Research Support Foundation of the State of São Paulo (Fundação de Amparo a Pesquisa do Estado de São Paulo, FAPESP) (grant no. 2012/24945-1). Robson Waldemar Ávila thanks the National Council for Scientific and Technological Development (Conselho Nacional de Desenvolvimento Científico e Tecnológico, CNPq) for providing a research fellowship (no. 303622/2015-6) and Drausio H. Morais thanks the Coordination Office for Improvement of Higher Education Personnel (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior, CAPES) for providing a research fellowship (CAPES/PNPD no. 22005013001P4).

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