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Helminth parasites of Phyllodactylidae and Gekkonidae lizards in a Caatinga ecological station, northeastern Brazil

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Abstract: We investigated the parasites of five lizard species belonging to Phyllodactylidae (*Phyllopezus pollicaris* and *Gymnodactylus geckoides*) and Gekkonidae (*Hemidactylus agrius*, *Lygodactylus klugei* and *Hemidactylus brasilianus*) families in a semiarid region of Brazil. Six nematode species were identified: *Parapharyngodon alvarengai* and *Spauligodon oxkutzcabiensis* (Pharyngodonidae), *Physaloptera lutzi* (Physalopteridae), *Skrjabinelazia intermedia* (Seuratidae), *Trichospirura* sp. (Rhabdochonidae) and *Piratuba* sp. (Onchocercidae), and a cestode species, *Oochoristica* sp. (Linstowiidae). The most prevalent species were *Spauligodon oxkutzcabiensis*, which infected *P. pollicaris* (75%), and *Parapharyngodon alvarengai*, which infected *G. geckoides* (29%). South American lizards were identified as being new hosts for the *Trichospirura* genus (a usual parasite of mammals), and there were 16 new occurrences of parasite species in the five lizard species studied herein.

Keywords: *Squamata, Nematoda, Cestoda, geckos, semiarid*

Helmintos parasitas de lagartos Phyllodactylidae e Gekkonidae em estação ecológica na Caatinga, nordeste do Brasil

Resumo: Nós investigamos os parasitas de cinco espécies de lagartos pertencentes às famílias Phyllodactylidae (*Phyllopezus pollicaris* e *Gymnodactylus geckoides*) e Gekkonidae (*Hemidactylus agrius*, *Lygodactylus klugei* e *Hemidactylus brasilianus*) em região semiárida do Brasil. Seis espécies de nematoides foram encontrados: *Parapharyngodon alvarengai* e *Spauligodon oxkutzcabiensis* (Pharyngodonidae), *Physaloptera lutzi* (Physalopteridae), *Skrjabinelazia intermedia* (Seuratidae), *Trichospirura* sp. (Rhabdochonidae), *Piratuba* sp. (Onchocercidae) e uma espécie de cestódeo, *Oochoristica* sp. (Linstowiidae). As espécies de maiores prevalências foram *S. oxkutzcabiensis*, a qual infectou *P. pollicaris* (75%) e *P. alvarengai* a qual infectou *G. geckoides* (29.%). Nós documentamos novo registro de hospedeiro para lagartos na América do Sul pertencente ao gênero *Trichospirura*, o qual é comum em mamíferos, e 16 novas ocorrências de espécies parasitas nas cinco espécies de lagartos aqui estudadas.

Palavras chave: *Squamata, Nematoda, Cestoda, geckos, semiárido*

Introduction

Helminths are parasites that infect the internal and external organs of most invertebrate and vertebrate groups (Fergunson 1942; Round 1968; Salgado-Maldonado et al. 2005; Hamann et al. 2006a, b; Ávila et al. 2012). Among this wide diversification of hosts, there is a great diversity of parasites in South American lizards (Ávila & Silva 2010), and several studies have recorded variation in parasite richness and diversity (Bursey & Goldberg 2004; Bursey et al. 2005; Anjos et al. 2013; Araujo-Filho et al. 2014; Brito et al. 2014a, b; Galdino et al. 2014; Sousa et al. 2014).

Knowledge of the lizard-associated helminth fauna has increased through research concerning (i) records of new hosts (Bursey & Goldberg 2004; Bursey et al. 2005; Ávila & Silva 2010; McAllister et al. 2011; Ávila et al. 2012), (ii) descriptions of new parasite species (Bursey et al. 2003; Pereira et al. 2012), and (iii) influence of biotic and abiotic variables on helminth diversity and abundance (Sharpilo et al. 2001; Brito et al. 2014a, b; Galdino et al. 2014).

Phyllodactylidae and Gekkonidae are two lizard families of the Gekkota clade that are phylogenetically closely related taxa (Sites et al. 2011). Both families occur in Brazil with, respectively, 13 and six nominal species (Costa & Bérnils 2015), and only *Gymnodactylus geckoides* Spix, 1825, *Phyllopezus periosus* Rodrigues, 1986, *Phyllopezus pollicaris* (Spix, 1825) (Phyllodactylidae)*, Hemidactylus mabouia* Moreau de Jonnes, 1818, and *Hemidactylus agrius* Vanzolini, 1978 (Gekkonidae) occur within the Caatinga biome. *Hemidactylus brasilianus* (Amaral, 1935) and *Lygodactylus klugei* (Smith, Martin & Swain, 1977) (Gekkonidae) often inhabit the Caatinga biome (Vitt 1995; Rocha et al. 2011; Andrade et al. 2013). These species are sit-and-wait foragers, have nocturnal habits (except for the diurnal *L. klugei*) and an insectivore diet (Vitt 1995; Colli et al. 2003; Rocha & Rodrigues 2005; Mesquita et al. 2006; Sousa 2010; Recorder et al. 2012; Albuquerque et al. 2013; Passos & Rocha 2013; Passos et al. 2015). The studies reporting helminth parasitism in South America for both families have been conducted by Anjos et al. (2005), Ávila & Silva (2010), Ávila et al. (2010), Ávila & Silva (2013), Brito et al. (2014a), Sousa et al. (2014), Cazorla & Morales Moreno (2015) and Bezerra et al. (2016).

Parasites are good indicators of healthy ecosystems, which is essential to studies of conservation and maintenance of host populations (Marcogliese 2004, 2005), which may reflect the anthropic influence in the environment in which they reside (Hamman et al. 2006b). Thus, characterization of the parasite population of a certain area of the Caatinga biome is essential, especially for future studies on species conservation.

The current study characterizes the helminth richness of parasitic species and the parameters of parasitic infection (prevalence, mean intensity of infection and range) in lizards of the Phyllodactylidae and Gekkonidae families collected at the Aiuaba Ecological Station, northeastern Brazil.

Material and Methods

Lizards were collected at the Aiuaba Ecological Station (ESEC Aiuaba), municipality of Aiuaba, state of Ceará, northeastern Brazil (6°36'27"S and 40°08'00.9"W, 466m asl, datum SIRGAS 2000) (Figure 1). The sampled area is within the Caatinga biome, which is characterized by xerophytic plants, shrubs, thorny trees and open areas (Andrade-Lima 1981). The climate in this biome is semiarid, hot tropical, with an average annual rainfall of 562.4 mm, average temperature ranging from 24 ºC to 26 ºC and a rainy season from February to April (IPECE 2015).

We conducted manual collections through active searching over four sampling expeditions, two in 2014 (September and November) and two in 2015 (February and April) with authorization provided by the "Sistema de Autorização e Informação em Biodiversidade" (SISBIO order number 43753-1). The lizards were euthanized with a lidocaine lethal dose. Their snout-vent length (SVL) was measured with a digital caliper (± 0.01mm). Thereafter they were labelled, fixed with 10% formaldehyde and preserved in 70%

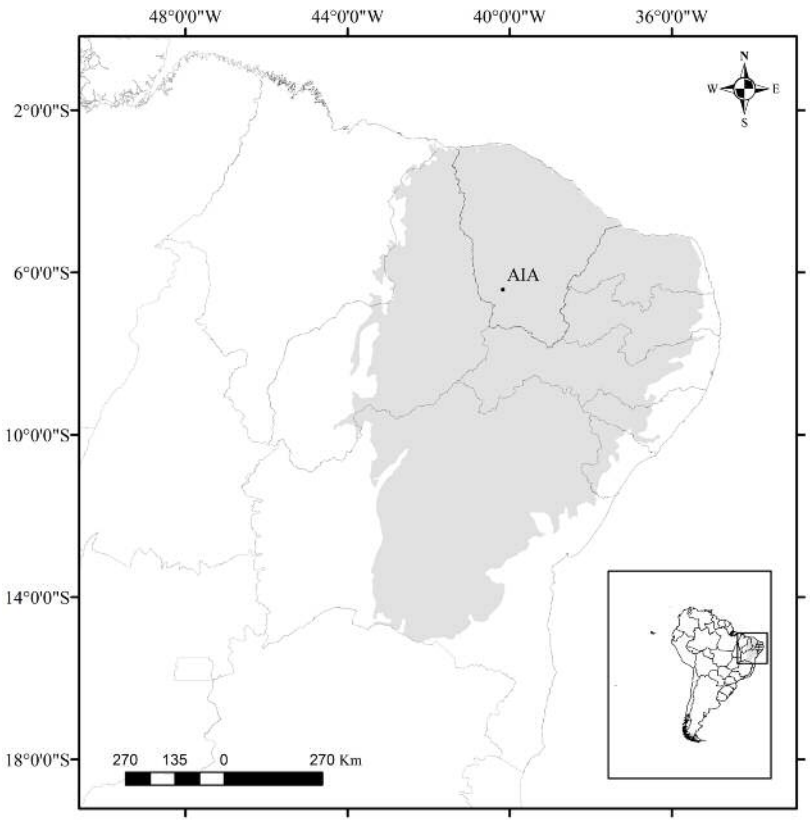

Figure 1. Geographic map featuring the Aiuaba Ecological Station (AIA), state of Ceará, northeastern Brazil. In gray, the Caatinga biome as conceived by IBGE (2004).

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ethyl alcohol. Lizard specimens were deposited in the Herpetological Collection of the Regional University of Cariri, municipality of Crato, state of Ceará, Brazil. The hosts were dissected under a stereomicroscope and their body cavity, lung, stomach, small intestine and large intestine was analyzed in search of helminths. The lizard's gonads were analyzed to determine their gender and sexual maturity. We considered as mature males those with developed testicles and a convoluted epididymis, and as mature females those that had vitellogenic follicles in their oviducts and/or eggs in their ovaries.

The nematodes were cleared in a Hoyer solution and the cestodes were colored in Carmim and cleared in a Hoyer solution as well for identification (Everhart 1957). The parasites were mounted on temporary slides for identification, and their morphology was compared with specimens present in the parasitological collection of the Universidade Regional do Cariri – URCAP, and bibliographic reference on the description of the parasite species found that did not have specimens in the collection. Subsequently, they were deposited in the Parasitological Collection of the Regional University of Cariri (Appendix 1). The prevalence and the mean intensity of infection for each endoparasite species were calculated for each lizard species according to Bush et al. (1997).

Results

We sampled a total of 355 lizards specimens, distributed in the five focused species of this study. Phyllodactylidae: *Phyllopezus pollicaris*, 132 specimens, 57 males (SVL = 64.2 ± 8.4 mm) and 75 females (SVL = 62.5 ± 11.9 mm); *Gymnodactylus geckoides*, 71 specimens, 30 males (SVL = 37.7 ± 3.7 mm) and 41 females (SVL = 37.5 ± 4.1 mm). Gekkonidae: *Hemidactylus agrius*, 63 specimens, 28 males (SVL = 47.1 ± 3.8 mm) and 35 females (SVL = 47.8 ± 3.7 mm); *Lygodactylus klugei*, 65 specimens, 25 males (SVL = 27.5 ± 2.5 mm) and 40 females (SVL = 28.1 ± 2.4 mm); and *Hemidactylus brasilianus*, 24 specimens, 11 males (SVL = 45 ± 5.9 mm) and 13 females (SVL = 43.6 ± 5.7 mm). All lizards were in full sexual maturity.

We found six nematode species [*Parapharyngodon alvarengai* Freitas, 1957, *Spauligodon oxkutzcabiensis* (Chitwood, 1938), *Physaloptera lutzi* Cristofaro, Guimarães & Rodrigues, 1976, *Skrjabinelazia intermedia* Freitas, 1940, *Trichospirura* sp. Smith & Chitwood, 1967 and *Piratuba* sp. Lent & Freitas, 1941] and one cestode of the genus *Oochoristica* Lühe, 1898 that could not be identified at the species level (Table 1).

Helminth parasites found in this study have different life cycles. While *P. lutzi*, *Oochoristica* sp., *Piratuba* sp., *Trichospirura* sp. and *S. intermedia*

Table 1. Helminth parasites collected in lizards belonging to Phyllodactylidae and Gekkonidae families from the Aiuaba Ecological Station, municipality of Aiuaba, state of Ceará, northeastern Brazil. Number of Infected hosts = (NI), Prevalence = P (%), Mean Intensity of Infection = MII and Range (R). (*) New records of hosts.

Parasite	Location in host	Host (NI)	P (%)	MII (R)
NEMATODA				
Pharyngodonidae				
Parapharyngodon alvarengai	large intestine	*Phyllopezus pollicaris* (6)	4.54%	1.33 (1-2)
	large intestine	*Hemidactylus brasilianus**(2)	8.33%	1 (1)
	small intestine; large intestine	*Hemidactylus agrius* (8)	12.69%	1.87 (1-4)
	small intestine; large intestine	*Gymnodactylus geckoides* (21)	29.57%	1.66 (1-5)
Spauligodon oxkcutzcabiensis	small intestine; large intestine	*Phyllopezus pollicaris* (99)	75%	26.02 (270)
	large intestine	*Hemidactylus brasilianus** (2)	8.33%	5.5 (3-8)
	large intestine	*Hemidactylus agrius** (11)	17.46%	1.9 (1-4)
	large intestine	*Gymnodactylus geckoides* (1)	1.40%	18 (18)
	large intestine	*Lygodactylus klugei** (4)	6.15%	3 (1-9)
Physalopteridae				
Physaloptera lutzi	stomach; large intestine	*Phyllopezus pollicaris** (4)	3.03%	1.25 (1-2)
	stomach	*Hemidactylus brasilianus** (1)	4.16%	1 (1)
	stomach	*Hemidactylus agrius* (1)	1.58%	6 (6)
	stomach; large intestine	*Gymnodactylus geckoides* (9)	12.67%	2 (1-4)
	stomach	*Lygodactylus klugei* (1)	1.53%	1 (1)
Seuratidae				
Skrjabinelazia intermedia	small intestine; large intestine	*Phyllopezus pollicaris** (1)	0.75%	2 (2)
	large intestine	*Hemidactylus brasilianus** (4)	16.66%	1.25 (1-2)
	large intestine	*Hemidactylus agrius** (17)	26.98%	1.64 (1-4)
Rhabdochonidae				
Trichospirura sp.	gallbladder	*Phyllopezus pollicaris** (13)	9.84%	3.69 (1-11)
	gallbladder	*Hemidactylus brasilianus** (2)	8.33%	3.5 (2-5)
	gallbladder	*Hemidactylus agrius** (12)	19.04%	2.58 (1-7)
	gallbladder	*Gymnodactylus geckoides** (4)	5.63%	1.5 (1-3)
Onchocercidae				
Piratuba sp.	body cavity	*Gymnodactylus geckoides** (1)	1.40%	1 (1)
CESTODA				
Linstowiidae				
Oochoristica sp.	small intestine	*Phyllopezus pollicaris* (2)	1.51%	1.5 (1-2)
	small intestine	*Hemidactylus brasilianus** (1)	4.16%	2 (2)
	small intestine	*Hemidactylus agrius** (1)	1.58%	1 (1)

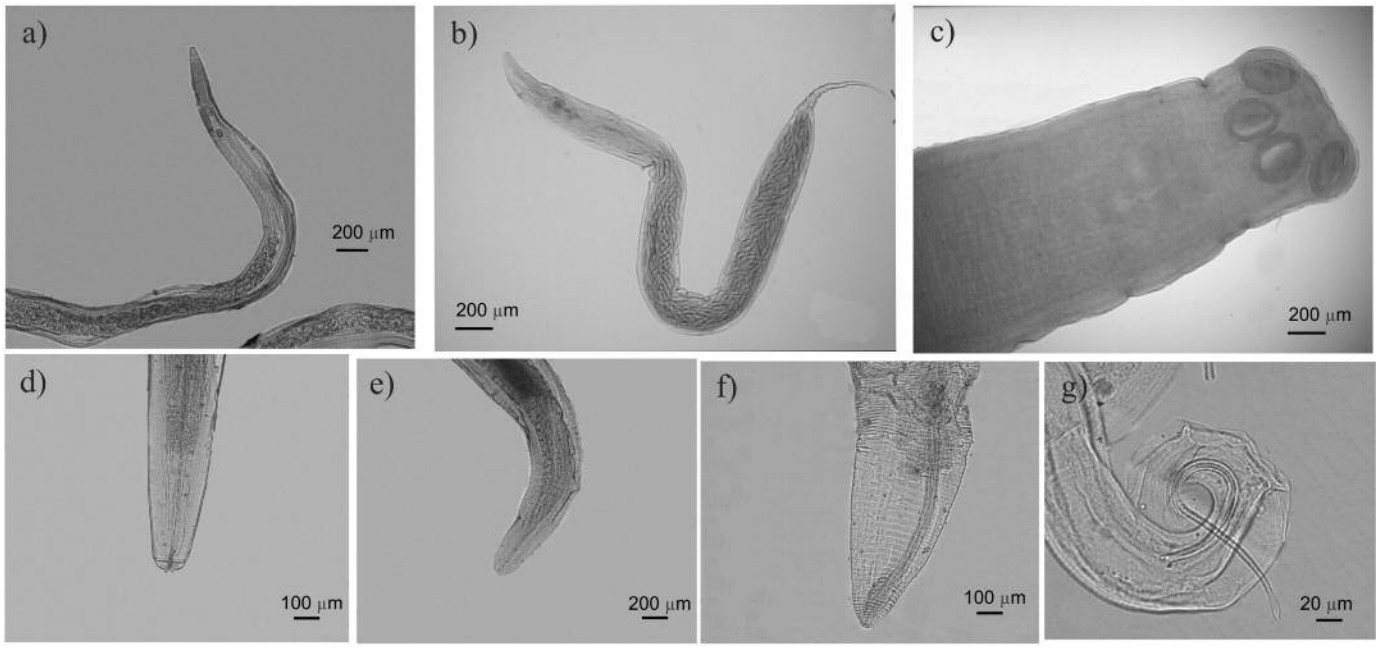

Figure 2. Helminths of the gastrointestinal tract of geckos from the Aiuaba Ecological Station (AIA), state of Ceará, northeastern Brazil: (a) *Skrjabinelazia intermedia* (posterior view); (b) *Spauligodon oxkutzcabiensis* (entire specimen); (c) *Oochoristica* sp. (anterior view); (d) *Physaloptera lutzi* (anterior view); (e) *Piratuba* sp. (anterior view); (f) *Parapharyngodon alvarengai* (anterior view); (g) *Trichospirura* sp. (posterior view).

have heteroxenic life cycles, which requires more than one host to complete its life cycle, *P. alvarengai* and *S. oxkutzcabiensis* have monoxenic life cycles, not requiring more than one host (Illgen–Wilcke et al. 1992, Anderson, 2000, Lhermitte et al. 2007) (Figure 2).

Discussion

Among the parasite species identified, there were 16 new records of hosts distributed among the five lizard species sampled in this study. We found three parasite species in *P. pollicaris*, four in *H. agrius*, two in *G. geckoides*, six in *H. brasilianus* and one in *L. klugei*.

Spauligodon oxkutzcabiensis was first recorded with *Thecadactylus rapicauda* (Houttuyn, 1782) (Phyllodactylidae). In South America, *S. oxkutzcabiensis* was recorded in association with the following lizards (Ávila et al. 2010; Goldberg et al. 2010; Goldberg & Bursey 2010; Sousa et al. 2014): *G. geckoides*, *Hemidactylus mabouia* (Moreau de Jonnès, 1818), *Microlophus occipitalis* (Peters, 1871), *Phyllodactylus reissi* (Peters, 1862), *P. inaequalis* Cope, 1876, *P. johnwrighti* Dixon & Huey, 1970, *P. microphyllus* (Cope, 1876), *Phyllopezus lutzae* (Loveridge, 1941) [= *Bogertia lutzae*] and *Tropidurus guarani* Alvarez, Cei & Scolaro, 1991 [= *T. spinulosus*]. *Spauligodon oxkutzcabiensis* was present in all five lizard species sampled in this research. It is, therefore, considered here as the lizard's generalist endoparasite for Phyllodactylidae and Gekkonidae, adding *H. agrius*, *H. brasilianus* and *L. klugei* to the list of new records of hosts.

Parapharyngodon alvarengai was recorded as being hosted by *Ameivula ocellifera* (Spix, 1825) [= *Cnemidophorus ocellifer*], *Ameiva ameiva* (Linnaeus, 1758), *Amphisbaena ridleyi* Boulenger, 1890, *Brasiliscincus heathi* (Schmidt & Inger, 1951), *G. geckoides*, *Phyllopezus pollicaris*, *P. periosus*, *Trachylepis atlantica* (Schmidt, 1945), *Tropidurus hispidus* (Spix, 1825), *T. semitaeniatus* (Spix, 1825) and *Hemidactylus agrius* Vanzolini, 1978 (Anjos et al. 2011; Ávila et al. 2012; Brito et al. 2014b). We observed *P. alvarengai* infecting *P. pollicaris*, *G. geckoides*, *H. agrius* and *H. brasilianus*.

Physaloptera lutzi infected all lizards sampled in the current study. Although it had been originally described as a parasite of *A. ameiva*, we recorded both *P. pollicaris* and *H. brasilianus* as new hosts for this species. Other records of hosts for *P. lutzi* were also reported in the literature (Anjos et al. 2011; Ávila et al. 2010, 2012; Brito et al. 2014b): *Ameivula abaetensis* (Dias, Rocha & Vrcibradic, 2002) [= *Cnemidophorus abaetensis*], *Ameivula littoralis* (Rocha, Araújo, Vrcibradic & Costa, 2000) [= *Cnemidophorus littoralis*], *A. ocellifera*, *Enyalius bilineatus* Duméril & Bibron, 1837, *Eurolophosaurus nanuzae* (Rodrigues, 1981), *Liolaemus alticolor* Barbour, 1909, *L. ornatus* Koslowsky, 1898, *L. quilmes* Etheridge, 1993, *Tropidurus guarani*, *T. semitaeniatus*, *T. hispidus*, *T. itambere* Rodrigues, 1987, *T. torquatus* (Wied, 1820), *H. agrius*, *L. klugei*, *G. geckoides*, *Micrablepharus maximiliani* (Reinhardt & Lütken, 1862) and *Salvator merianae* (Duméril & Bibron, 1839) [= *Tupinambis merianae*]. Given that *P. lutzi* has a heteroxenic life cycle, its intermediate host is probably a food item that is consumed by all sampled lizards in our study area.

Regarding the *Trichospirura* genus, our data revealed *P. pollicaris*, *G. Geckoides*, *H. agrius* and *H. brasilianus* lizards as new host records for South America. Only primates from the following genera had been previously recorded as hosts for *Trichospirura*: *Callicebus* Thomas, 1903 (Orihel & Seibold 1971; Pacheco et al. 2003), *Callithrix* Erxleben, 1777 (Smith & Chitwood 1967; Resende et al. 1994), *Saimiri* Voigt, 1831 (Orihel & Seibold 1971), *Aotus* Illiger, 1811 (Orihel & Seibold 1971), *Callimico* Miranda Ribeiro, 1922 (Orihel & Seibold, 1971) and *Saguinus* Hoffmannsegg, 1807 (Cosgrove et al. 1968).

The *Skrjabinelazia* genus was found infecting geckos (Lhermitte et al. 2007; Anjos et al. 2011). Nevertheless, records for *S. intermedia* were restricted so far to a teid *Ameivula nativo* (Rocha, Bergallo & Peccinini–Seale, 1997) [= *Cnemidophorus nativo*] (Menezes et al. 2004), twice in Tropiduridae [*Tropidurus torquatus* and *T. guarani*, Vicente et al. 1993] and once for Dactyloidae *Dactyloa punctata* (Daudin, 1802) [= *Anolis punctatus*] (Ávila & Silva 2010). Our data provided three host records for *S. intermedia*: *P. pollicaris*, *H. agrius*, and *H. brasilianus*.

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Little is known about the biology of the genus *Oochoristica*. Most studies on the genus were limited to describe new species and record new hosts (Ávila & Silva 2010; Brito et al. 2014b; Sousa et al. 2014). Our study reports three records of hosts (*P. pollicaris*, *H. agrius* and *H. brasilianus*) with two new infection records for the genus *Oochoristica*.

Piratuba is a genus that belongs to the Onchocercidae family. It has a widespread distribution throughout South America, in which other studies reported that lizards from the genera *Tropidurus*, *Kentropyx* Spix, 1825, *Plica* (Linnaeus, 1758), *Polychrus* Merrem, 1820, *Dactyloa* (Daudin, 1804) [= *Anolis*] and *Ameiva* Meyer, 1795 were infected by parasites of the referred genus (Ávila & Silva 2010). We recorded a specimen *Piratuba* sp. infecting *Gymnodactylus geckoides*, which corresponds to a new record for *Piratuba*.

Currently, there are 23 genera of helminths recognized as parasites of the lizard families Phyllodactylidae and Gekkonidae (Anjos et al. 2005; Ávila & Silva 2010; Ávila et al. 2010; Avila & Silva 2013; Brito et al. 2014a; Sousa et al. 2014; Cazorla & Morales Moreno 2015; Bezerra et al. 2016; this study); for the Caatinga biome, about 10 species of helminths have already been reported with a prevalence above 50% (Anjos et al. 2005; Avila et al. 2012; Brito et al. 2014b; Sousa et al. 2014; this study), and there were four helminth species with prevalences below 60% for deserts and coastal areas in Peru (Goldberg & Bursey 2010); two species had prevalences of 33.3% in the Brazilian Amazon forest (Ávila & Silva 2013); two species had prevalences up to 22.8% in the Atlantic Forest (Ávila et al. 2010; Almeida-Gomes et al. 2012); and three helminth species had prevalences below 15% for the tropical thorny mountain areas of Venezuela (Cazorla & Morales Moreno 2015). Notwithstanding that some genera and species of helminths were previously reported for different biomes as parasites of geckos, as *S. oxkutzcabiensis* and all species of the genera *Oochoristica* and *Parapharyngodon*, almost all prevalences registered for them were below that obtained for the Caatinga biome [e.g., *Oochoristica* sp. and species of the genus *Parapharyngodo*n presented up to 55% prevalence, while *S. oxkutzcabiensis* did not exceed 8% in coastal environments of the tropical thorny mountain areas in Peru and Venezuela (Goldberg & Bursey 2010; Cazorla & Morales Moreno 2015)]. These results suggest that the different environmental conditions of distinct biomes may favor one parasitic species over another, such as *S. oxkutzcabiensis*. The presence of *Trichospirura* in lizards of the genus *Sceloporus* in Mexico and *H. brookii haitianus* Meerwarth, 1901 in Hispaniola (Goldberg et al. 2003; Powell et al. 1990), suggests that the new host records documented here may not be species-specific of the studied biome. Therefore, additional studies are necessary in the different biomes to determine the true helminth diversity of these two families of lizards.

The current study increases to 16 the number of new host records in association with the families Phyllodactylidae and Gekkonidae in the Caatinga biome. However, the development of new research on other areas of the biome is essential to enhance our scientific knowledge of the diversity of helminths associated with lizards.

Supplementary material

The following online material is available for this article:

Appendix 1: Voucher specimens of helminth parasites and respective host lizards collected in the Aiuaba Ecological Station, northeastern Brazil.

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Author Contributions

Adonias Aphoena Martins Teixeira: contribution to data collection; contribution to identification of parasites and lizards; contribution to data analysis and interpretation; contribution to manuscript preparation and critical revision.

Antonio Marcos Alves Pereira: contribution to data collection; contribution to identification of parasites and lizards; contribution to data analysis and interpretation; contribution to manuscript preparation and critical revision.

Diêgo Alves Teles: contribution to data collection; contribution to identification of parasites and lizards; contribution to data analysis and interpretation; contribution to manuscript preparation and critical revision.

João Antonio Araujo Filho: contribution to data collection; contribution to identification of parasites and lizards; contribution to data analysis and interpretation; contribution to manuscript preparation and critical revision.

Samuel Cardozo Ribeiro: contribution to data collection; contribution to identification of parasites and lizards; contribution to data analysis and interpretation; contribution to manuscript preparation and critical revision.

Samuel Vieira Brito: contribution to data collection; contribution to identification of parasites and lizards; contribution to data analysis and interpretation; contribution to manuscript preparation and critical revision.

Vandeberg Ferreira Lima: contribution to data collection; contribution to identification of parasites and lizards; contribution to data analysis and interpretation; contribution to manuscript preparation and critical revision.

Waltécio de Oliveira Almeida: contribution to data collection; contribution to identification of parasites and lizards; contribution to data analysis and interpretation; contribution to manuscript preparation and critical revision.

Conflicts of interest

The authors declares that they have no conflict of interest related to the publication of this manuscript.

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