A new species of nematode, from the family Spiruridae, is described using parasites from the esophageal mucosa of Proechimys roberti (Rodentia: Echimyidae), which were obtained during a fauna survey in the Tapirapé-Aquirí National Forest, Carajás Reserve, Brazil, Eastern Brazilian Amazon. The helminths were collected from the esophagus, fixed and processed for light microscopy. Spirura carajaensis n. sp. differs from other species in the genus because it has a left spicule with a well-developed sheath, which is leaf-shaped and covers the terminal half of the spicule. Males and females have a small appendix on the caudal end. This structure has not been reported before for this genus. The present study reports the first record of parasitism by Spirura in rodents of the genus Proechimys in Brazil and in the Amazon biome.

Keywords: Spirura; Spirura carajaensis; Proechimys; Amazon; Brazil

Introduction

The genus Proechimys (Rodentia: Echimyidae) comprises 16 species of rodents in Brazil, with at least 5 species occurring in the Brazilian Amazon (Bonvicino et al., 2008). In the state of Pará (Eastern Amazon), Bonvicino et al. (2008) reported the occurrence of P. curviro, P. goeldii and P. guianensis species, while Weksler et al. (2001) additionally revealed the presence of P. roberti and P. oris. These rodents are terrestrial and can be found in forested areas of the Amazon, gallery forests and semi-deciduous forests in the Cerrado biome (Bonvicino et al., 2008).

Such species are of public health interest in Brazil because they are reservoirs of Leishmania sp. and Trypanosoma sp. (Barretto et al., 1985). However, there have been few studies examining their helminth fauna.

According to Anderson (2009), the nematodes of the family Spiuridae (Oerley, 1885) are distributed in 3 genera (Paraspirura (Sandground, 1936), Spirura (Blanchard, 1849), and Protspirura (Seurat, 1914)). Currently, approximately 26 mammalian parasite species are known in the genus Spirura, with a cosmopolitan distribution (Peralta-Rodríguez et al., 2012).

In Brazil, only 2 of these genera have been recorded as parasites of mammals: Protspirura and Spirura (Vicente et al., 1977), and the authors list three species of the genus Spirura that are parasites of Brazilian mammals. However, only Spirura delicata (Vicente et al., 1992) was identified as a primate parasite in the Amazon biome, and Spirura guianensis (Ortlepp, 1924) (syn. Spirura tamarini Cosgrove et al., 1963) was identified to infect marsupials in the Atlantic Forest biome (Amato et al., 1976). This study aims to add new data to the nematode fauna of the rodent P. roberti in the Amazon biome and describes a new spirurid species. In addition, this study reports for the first time the parasitism of Spirura in P. roberti, which is a new a host for the genus in Brazil.

Material and Methods

The digestive tract samples from the 9 specimens of Proechimys roberti collected in the Tapirapé-Aquirí National Forest analyzed in this study were kindly donated by Dr. Rogério Rossi and were fixed in 10% formaldehyde. These samples were analyzed in the Cellular Biology and Helminthology Laboratory (Laboratório de Biología Celular e Helmintologia – LBCH) at the Biological Sciences Institute, Federal University of Pará (Universidade Federal do Pará – UFPA) to investigate the presence of helminthes.

The nematodes were removed from the mucosa of the esophagus, where they were attached. After removal, they were processed in increasing grades of ethanol and clarified in Aman lacto-phenol. The morphological analysis and identification of taxonomic characters were performed under an Olympus BX41.
Eight nematode specimens were found in the esophagus of *Proechimys roberti*; however, only three males and one female were used for morphometric analysis under light microscopy. The other four specimens, comprising two males and two females, had been broken posteriorly to the ventral hump during removal from the host esophagus.

The measurements of the male specimens are organized as follows: lowest obtained values, highest obtained values and the means ± standard deviation, with the last 2 presented between parentheses (all the values are in micrometers, except where indicated). For the female specimen, the absolute values are presented.
Results

*Spirura carajaensis* n. sp.
(Figs. 1 – 2)

**General diagnosis.** Based on 3 adult males and 1 adult female. Stout cuticle with transversal striations. Mouth elongated dorsoventrally and ornamented with 6 bifid teeth, with 1 larger central pair and 2 smaller lateral pairs (Figs. 1a and 2b). Deirids anterior to the nerve ring, excretory pore posterior to the nerve ring. Pharynx followed by a long esophagus (Fig. 1b) clearly divided into a muscular anterior region and a glandular posterior region (Fig. 2a). Ventral hump (cuticular boss) at the end of the first third of the glandular esophagus (Figs. 1b and 2a). Conical tail with a small cuticular projection forming a caudal appendix in both sexes (Figs. 1e and 3a). Male tails ornamented with 8 pairs of pedunculated papillae and 2 pairs of sessile papillae at the end of the tail, and a pair of phasmids lateral to the sessile papillae (Fig. 3a).

**Males:** 10 – 15 mm (12.6 ± 2.7) in length; pharynx 56 – 72 (64.9 ± 8.1) long; larger denticles 19.5 – 23.4 (22.1 ± 2.2) and smaller denticles 13 – 14.3 (13.4 ± 0.7). Muscular regions of the esopha-
gus measuring 221.3 – 304 (258.7 ± 41.9), and glandular regions measuring 4.2 – 4.4 mm (4.3 ± 0.1) in length. Deirid, nerve ring and excretory pore at 150 – 250.7 (200.3 ± 71.8), 208 – 193.3 (242.7 ± 44.8) and 344 – 426.7 (372.4 ± 47) from the anterior extremity, respectively. Ventral hump 0.9 – 1.4 mm (1.2 ± 0.2) from the anterior extremity. Conical tail, elongated, strongly ventrally curved, with a well-developed caudal wing ornamented with 8 pairs of pedunculated papillae (4 pre-cloacal pairs and 4 post-cloacal pairs) and 2 pairs of sessile papillae next to the caudal extremity (Figs. 1f, 3a and 3b). Unequal spicules, with the left spicule larger, measuring 301.3 – 344 (319 ± 22.3) in length x 83.1 – 98.7 in width (89.2 ± 8.3), distinctly winged, with a well-developed foliar sheath (Fig. 3d). Right spicule smaller and simpler (Fig. 3c) measuring 211.7 – 285.3 (250.9 ± 37.1) x 20.8 – 32 (25 ± 6.1). Triangular gubernaculum (Fig. 3e) measuring 39 – 61.3 (53.3 ± 12.5) x 13 – 48 (38 ± 18). Cloaca 261 – 280 (271 ± 13) from the posterior end.

Female: 19.5 mm in length; pharynx 101 long; larger denticles measuring 28 and smaller denticles measuring 15 in length. Muscular region of the esophagus measuring 317 and glandular region measuring 6.1 mm. Deirid, nerve ring and excretory pore at 190, 328 and 437 from the anterior extremity, respectively. Ventral hump positioned at 1.98 mm from the anterior extremity. Conical tail with rounded extremity and a small appendix (Figs. 1e and 2c). Vulva post-equatorial (Fig. 1d), 5.4 mm from the posterior region; tail 197 long; oviparous females. Eggs (Fig. 2d) measuring 15.6 – 26 (21.6 ± 4.5) × 11.7 – 18.2 (14.1 ± 2.8).

Fig. 3. Line drawings of the male posterior end of Spirura carajaensis n. sp. a) Lateral view of the copulatory bursa, showing the caudal alae, the papillae distribution and the spicules. Bar: 100 µm. b) Schematic drawing with ventral view of the copulatory bursa. Bar: 100 µm. c) Detail of the right spicule Bar: 50 µm. d) Detail of the left spicule. Bar: 50 µm. e) Detail of the gubernaculum. Bar: 50 µm.
Taxonomic summary

Spiruridae Oertel, 1885

Spirura carajaensis n. sp.

Host: Proechimys roberti Thomas 1901.

Site of infection: esophagus

Locality: Tapirapé – Aquirí National Forest, Carajás Reserve, Pará state, Brazil (5°35' and 6°00' S and 50°24' and 51°06' W).

Prevalence and intensity of infection: 22% (2 rodents infected / 9 rodents collected), 3 – 5 (4.0 ± 2.1 mean intensity).

Specimens deposited: Holotype male (MPEG No. 00033), allotype female (MPEG No. 00034), and 2 paratypes (2 males) (MPEG N: 00035).

Etymology: The name references the original locality of the hosts.

Remarks

The new species described in this study shows morphological characteristics common to the genus Spirura, according to Yamauchi (1961), Vicente et al. (1997) and Anderson et al. (2009), including an esophagus divided in 2 parts, a unique cuticular boss located next to the anterior extremity and the disposition of the caudal papillae.

According to Quetin and Krishnasamy (1975), the genus Spirura is divided into two groups. The first group comprises more primitive species that have 8 – 12 pairs of pre-cloacal papillae, with the exemption of S. mounporti (Diouf et al., 2013), which has five pairs of pre-cloacal papillae. The second group is considered more evolved and has approximately 20 species, which have four pairs of pre-cloacal papillae. Our material corresponds to the second group.

Only four nematode species have been described to parasitize rodents of the Sciuridae family, and all of them were found in North America: Spirura infundibuliformis (McLeod, 1933), infecting Spermophilus tridecemlineatus; Spirura zapi (Erickson, 1938), infecting Zapus hudsonius hudsonius in Minnesota; Spirura leucurusi (Babero, 1973), a parasite of Ammospermophilus leucurus, and Spirura michiganensis (Sandground, 1935), described from Eutamias striatus lysteri (in Michigan (Peralta-Rodríguez et al., 2012). However, S. leucurusi, S. michiganensis and S. zapi are likely synonymous of S. infundibuliformis (Anderson et al., 1993). An important and common characteristic of the species described in North America is the presence of 8 to 12 pairs of pre-cloacal papillae (Sandground, 1935; Quetin and Krishnasamy, 1975; Peralta-Rodríguez et al., 2012).

In South America, there are only 2 species of the genus, which were described from mammalian hosts: Spirura guianensis, (Ortlepp, 1924; Chitwood, 1938) (= Spirura tamarni Cosgrove et al., 1963), a parasite of primates and marsupials, and Spirura delicata (Vicente et al., 1992), a parasite of Leontocebus mystax. Spirura carajaensis n. sp. that shows similarities to the morphological characteristics and biome habitat of Spirura guianensis regarding the shape and disposition of teeth-like projections and the caudal papillae distribution.

Among the 20 species of the genus, only S. dentata (Monnig, 1938), S. aurangabadensis (Ali and Lovekar, 1966) and S. guianensis display teeth-like formations on the apical region (Quetin and Krishnasamy, 1975). The new species has 3 pairs of bifid denticles in the oral opening, with the central pair larger than the lateral pairs, similar to what is found in S. guianensis. However, it is different from S. dentata, which has 3 non-bifid denticles of the same size, and S. aurangabadensis, which has bifid denticles of the same size.

Concerning the number and disposition of the caudal papillae, Spirura carajaensis n. sp. has 10 pairs; 4 pairs are pre-cloacal pedunculated papillae, 4 pairs are post-cloacal pedunculated papillae and 2 sessile pairs are at the end of the tail in addition to a pair of phasmids. This characteristic differs from the description of S. delicata, which has a total of 9 pairs of papillae, of which 4 pairs are pedunculated and pre-cloacal, 2 pairs are pedunculated and post-cloacal and 3 pairs are sessile on the tip of the tail (Vicente et al., 1992). There is no agreement regarding the number of caudal papillae in the description of S. guianensis. Ortlepp (1924) described 9 pairs: 4 pre-cloacal, 4 post-cloacal and 5 papillae on the tail extremity. Cosgrove et al. (1963) described 11 pairs: 4 pre-cloacal and pedunculated, 4 post-cloacal and pedunculated and 3 grouped sessile pairs. Quetin (1973) described 10 pairs with a single pre-cloacal papilla and a pair of phasmids between the last 2 pairs of caudal papillae. Amato et al. (1976) described 11 pairs: 4 pre-cloacal, 4 pedunculated and post-cloacal and 3 grouped sessile pairs. The distribution and the number of papillae of S. carajaensis n. sp. are similar to S. guianensis as described by Quetin (1973). However, the new species do not have the single pre-cloacal papilla.

The size and shape of the spicule distinguishes Spirura carajaensis n. sp. from the other species of the Spirura genus previously described in South America. The left spicule of S. carajaensis n. sp. is approximately 25 % larger than its right spicule, similarly to the difference observed in S. guianensis, according to the description of Quetin (1973). However, according to the descriptions of Cosgrove et al. (1963) and Amato et al. (1976), S. guianensis has a right spicule slightly larger than the left spicule (difference of 17 to 19 %). S. carajaensis also differs from S. delicata, which has a large asymmetry of the spicules (the right spicule is 65 % bigger than the left spicule). In addition, neither S. guianensis nor S. delicata have a leaf-shaped sheath in the terminal half of the left spicule as observed in S. carajaensis n. sp.

The leaf-shaped sheath in the terminal half of the spicule was only mentioned in the description of S. michiganensis and S. malayensis, a parasite of Tupai a in Malaysia (Quetin and Krishnasamy, 1975). However, S. michiganensis and S. malayensis differ from S. carajaensis n. sp. by not having bifid teeth and having only a 10 % difference in length between their spicules. In addition to the characteristics described before, a notably important morphological characteristic that distinguishes S. carajaensis n. sp. from S. guianensis is the shape of the cuticular projections on the posterior extremity of the helminth. Female S. guianensis have 5 digit-shaped projections, while S. carajaensis n. sp. has a single digit-shaped projection both in the female and the male tail.

Discussion

The vertebrates originating from fauna surveys are important for the findings of local biodiversity; however, the parasite infracommunity is often neglected. Studies of parasites found in these vertebrates add data to helminth diversity without the need for performing euthanasia in new hosts. In summary, the data of the...
present study describe a new and first species of the genus Spirura, a parasite of rodents of Proechimys in the Brazilian Amazon. This parasite shows notable morphological characteristics that distinguish it from other species of the genus, such as the unique shape and proportions of the spicules and the presence of a unique digit-shaped caudal appendix in both sexes.

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