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Description of the First *Leptestheria* Species (Branchipoda, Spinicaudata) from Brazil

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Leptestheria (Spinicaudata: Leptestheriidae) was collected for the first time from Brazil. This species was found during a study on temporary pools in the municipality of Palmas de Monte Alto in Bahia state, which is in the Caatinga climatic zone. A morphological description of this new species is presented and compared with other known South American species. Our new species differs from the other described species by the form of the head and the telson. The associated fauna is comparable to what was observed by Gurney in 1931 in Paraguay or by Roessler in 1995 in Colombia, indicating possible connections between the dry regions of South America.

Key words: Bahia, Biogeography, Leptestheriidae, Morphology, Taxonomy.

BACKGROUND

The first clam shrimp observations in Brazil date from the middle of the 19th century and concern the Cyzicidae: *Cyzicus brasiliensis* (Baird 1849) and *Cyzicus dallasi* (Baird, 1852) (Baird 1849 1852; von Ihering 1895; Daday 1915). Both were treated as nomina dubia by Daday (1915) as both taxa were described based on empty carapaces. The absence of precise geographical locality data and the fact that no Cyzicids have been sampled again in Brazil, raises questions about the presence of this family in that region (Daday 1915; Rabet and Thiéry 1998).

In 1889, Lilljborg reported the limnadiid clam shrimp *Eulimnadia antillarum* (Baird, 1852) in Brazil, probably incorrectly (Rogers et al. 2020). Later, Sars (1902) described *E. brasiliensis* from animals previously identified as *E. texana* by Ihering in 1895. Other limnadiid species were reported later in Brazil (Rabet et al. 2014). Of the spinicaudatans, only Leptestheriidae had not yet been reported from Brazil, although it is represented in several neighbouring countries, such as Paraguay (Gurney 1931), Colombia (Roessler 1995), Venezuela (Daday 1923, García and Pereira 2003), Peru (Harding 1940), and Argentina (Halloy 1979). *Leptestheria compleximanus* (Packard, 1877) was the first species to be described from the Americas from a population in the United States. The species *L. vanhoffni* Daday, 1923 and *L. pestai* Daday, 1923 subsequently described from Mexico were recently proposed in synonymy with *L. compleximanus* (Maeda-Martinez et al. 2002; Rogers et al. 2020) or considered as still valid (García and Pereira 2003). *Leptestheria venezuelica* Daday, 1923 was the first species described from South America, reported from Aruba, Venezuela, and Chile (Rogers et al. 2020). Later, *Leptestheria titicacae* Harding, 1940 was described from Peru, as well as from Argentina and Bolivia. *Leptestheria tucumanensis* Halloy, 1979 described from Argentina, is considered as a junior synonym of *L. titicacae* (Rogers et al. 2020). More recently, *Leptestheria brevispina* (García and Pereira, 2003) and *Leptestheria cristata* (García and Pereira 2003) were described from Venezuela. There are also several South American populations in

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Paraguay and Colombia whose status is still uncertain (Gurney 1931; Roessler 1995; see Rogers et al. 2020 for complete review).

The situation within the family has been recently modified by a first large genetic study (Schwentner et al. 2020). It suggests that a revision of the family is necessary at the genus and species levels. Following this study, a population we sampled in Brazil clearly appears to be close too, but sufficiently distinct from *L. venezuelica*, as well as genetically distant from the group of the North American *L. compleximanus*.

We present here the description of this new *Leptestheria* species collected during a study of temporary ponds in Palmas de Monte Alto (Bahia, Brazil).

MATERIALS AND METHODS

Sampling and culture

Specimens were collected in the field using a handheld dip net. Sediment was sampled from the pool edge and subsequently dried. 100 g of sediment was incubated at 28°C, with permanent light, in a 10 l tank filled with fresh rainwater. The culture substrate being particularly loamy, the tank was regularly filtered to allow observation of the development of the organisms. All specimens were preserved in 95% ethyl alcohol.

Morphological study

The specimens were observed and photographed with a stereomicroscope (an Olympus SZX7 coupled to Olympus DP20 camera) and with a microscope (an Olympus BX51 coupled to SC 50 camera). The drawings were made from different images using Adobe Photoshop Elements 15. Length/width ratios of the occipital condyle were performed by measuring the basal width and the length perpendicular from the base to the apex.

Examined specimens were deposited in the following institutions: Museu de Zoologia, Universidade de São Paulo (MZUSP); Muséum national d'Histoire naturelle (MNHN).

Comparative material

Comparisons were made with *Leptestheria* species from the Americas from the literature and by direct examination of the material below.

Leptestheria venezuelica Daday de Deés, 1923: Venezuela, between the Rio Apuri and the Rio Guanaparo; F. Geay collector; (MNHN-IU-2007-805 = MNHN-Bp515) (N = 1); (MNHN-IU-2007-806 = MNHN-Bp516) (N = 1).

Leptestheria compleximanus (Packard, 1877): Mexico, Baja California, "Mares l'Arraya de la Purissima"; L. Diguet collector; 3 September 1905; (MNHN-IU-2007-730 = MNHN-Bp448) (N = 6); (MNHN-IU-2007-731 = MNHN-Bp449) (N = 8); Mexico, Baja California; L. Diguet collector; (MNHN-IU-2007-733 = MNHN-Bp450) (N = 4). With the label *Leptestheria pestai* Daday de Deés, 1923: Mexico, Mexico City; (MNHN-IU-2007-756=MNHN-Bp471) (N = 2).

RESULTS

TAXONOMY

Suborder Spinicaudata Linder, 1945
Family Leptestheriidae Daday, 1923
Genus Leptestheria Daday, 1913

Leptestheria brasiliensis sp. nov.

(Figs. 1–4)

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Type locality: Brazil, Bahia, Palmas de Monte Alto (14°9'55.98"S, 43°3'39.24"W) (Figs. 1A, 2) in a temporary pool at 22 December 2014 by M.L. Oliveira, N. S. Silva, H. Gonçalves, J. G. Neto and S. Lacau.

Type material: Holotype, male (MZUSP 39601). Allotype, female (MZUSP 39602). Paratypes: cultured from soil 9 to 31 July 2015 MA 214 - three males and three females (MZUSP 39603), culture from soil 9 to 23 July 2015 MA 214 - three males and three females (MNHN-IU-2019-2312).

Etymology: Epithet derived from Brazil, the country where this new species was found.

Specific Diagnosis: *Both sexes*: The carapace rectangular. Dorsal margin straight or slightly arched (Figs. 3a, 4a). Head with occipital angle convex and apically acute, interior margin concave. Rostral spine long (length/width ratio > 10) (Figs. 3c, 4c). Trunk with 22 segments. Thoracic segments with small mid-dorsal spines, increasing in size distally, with penultimate segments bearing the longest spines. Last segment with a short spine (Figs. 3k, 4e). Telson with two rows of 35–40 spines each. The spines are uniform in size next to each other but posteriorly progressively becoming longer and more aciculate. Many spines denticulate (Figs. 3k, 4e). Cercopods with two dorsolateral rows of spines each. Each row with about 22 spines. Spines long, acute and denticulate, covering over 80% of

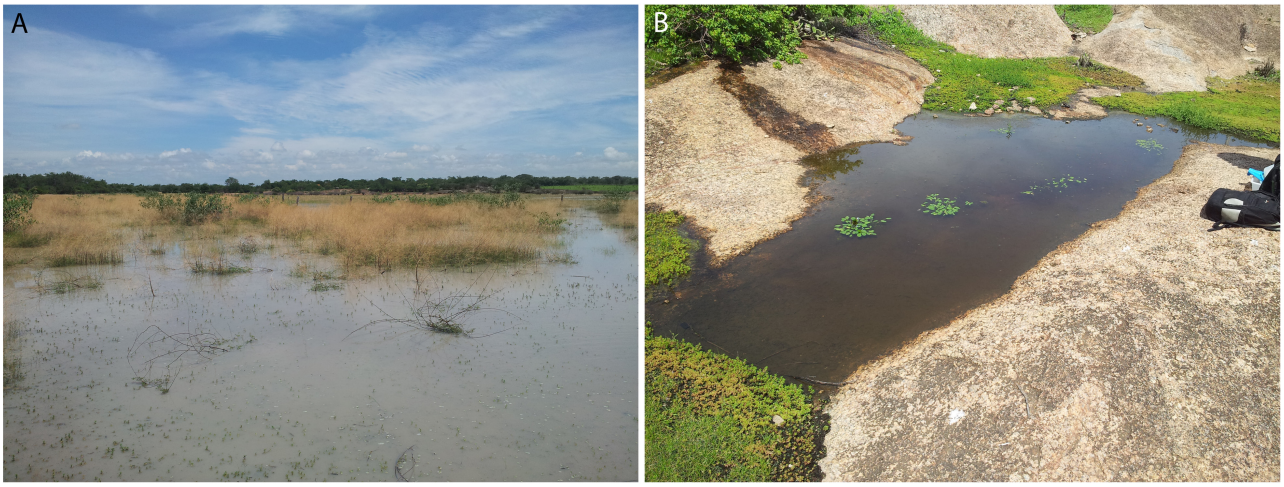

Fig. 1. Representative *Leptestheria brasiliensis* sp. nov. habitats. A: clay pond 22 December 2014 – locus typicus, B: 23 December 2014 rock pool.

Fig. 2. Distribution of *Leptestheria* in South America (Literature used in this paper).

the cercopod proximal base. Distalmost spine longest (Figs. 3m, 4h).

Specific Diagnosis: *Male*: first thoracopod endite V distally with many short setae. The endopod (movable finger) curved, apex acute with many rounded spines. Endite IV (gripping area) with an extension and apically long blunt spines.

Specific Diagnosis: *Female*: ninth and tenth thoracopods with epipods bearing cylindrical extensions for supporting the eggs.

Description: *Male*: Wild adult carapace 7.43 mm length, 2.63 mm width, 4.16 mm height (n = 1). Cultured adult carapace 2.18–4.96 mm length (n = 7), 1–1.32 width (n = 4), 1.25–2.73 mm height (n = 7)

Head with rostrum rounded and large (Fig. 3c). Rostral spine long (length/width ratio of ~12–13), straight, set at 45° angle. Ocellus irregular. Head anterior margin dorsal to the eye in lateral view slightly sinuate with three small concavities. Occipital condyle directed posteriorly, dorsally flattened, and apically

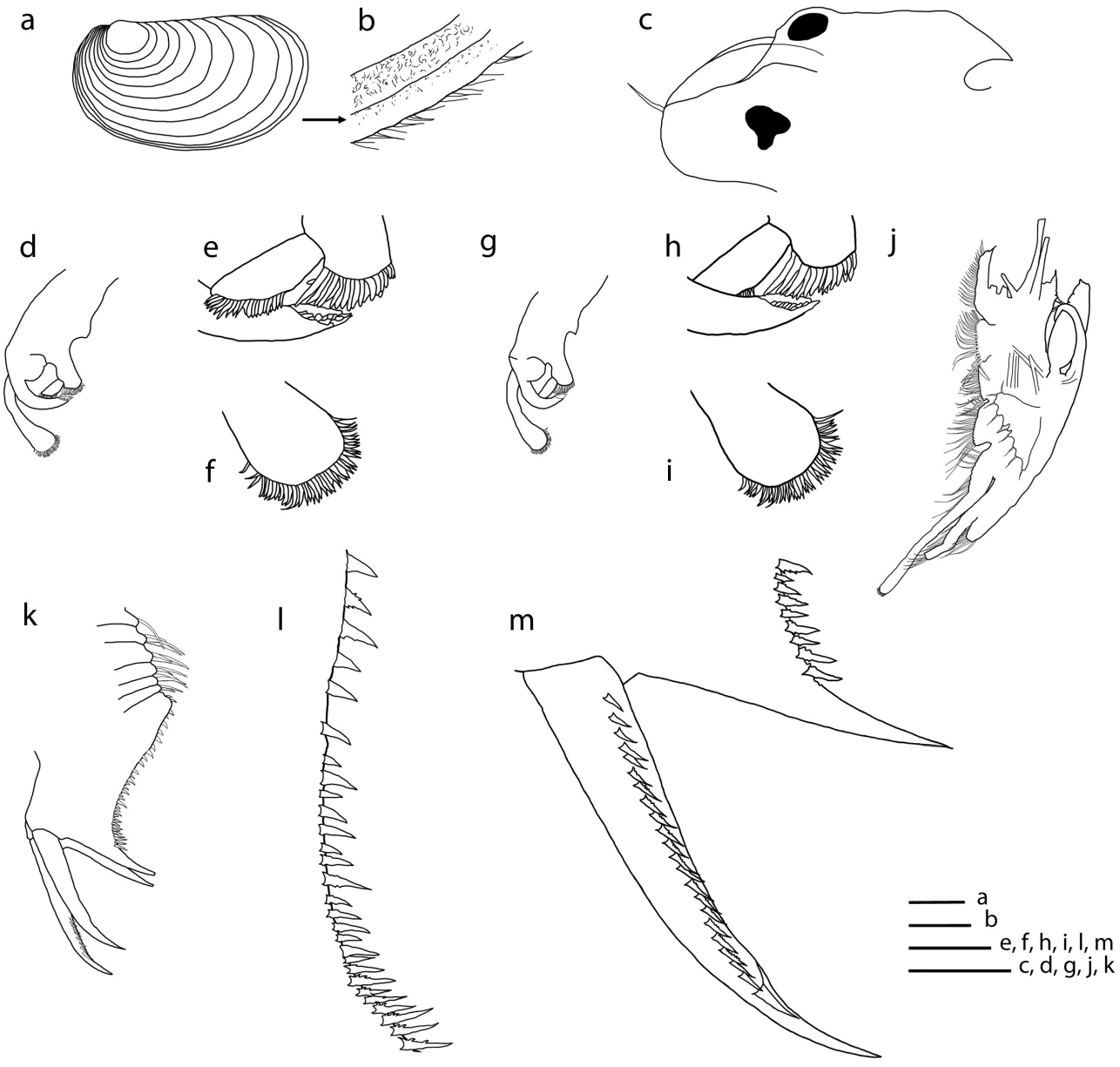

Fig. 3. *Leptestheria brasiliensis* sp. nov. male. a: carapace, b: carapace detail, c: head, d: first thoracopod, e, f: thoracopod detail, g: second thoracopod, h, i: second thoracopod detail, j: third thoracopod, k: telson, l: telson margin detail; m: right cercopod detail (only medial spine row represented). Scale bars: a = 1 mm; b = 0.2 mm; e, f, h, i, l, m = 0.1 mm; c, d, g, j, k = 0.5 mm.

acute (length/width ratio of ~0.75). Posterior margin concave.

First antenna indistinctly articulated, with 12–16 lobes bearing sensory setae. Second antenna anterior (dorsal) branch with 13 to 14 flagellomeres, posterior (ventral) branch with 10 to 14 flagellomeres. Each flagellomere ventrally with two or three long setae and dorsally with three to six acute, thin and fine spines.

Carapace rectangular (Fig. 3a), dorsal margin straight or slightly arched. Anterior, posterior, and ventral margins rounded with marginal setae. Ventral margin setae long, becoming shorter on anteriorly and posteriorly. Carapace intervals and growth lines with short setae. Umbo short and slightly pronounced (Fig. 3b). Growth line numbers variable depending on age; 18 in wild specimens and averaging 12 in cultured specimens.

Trunk with 22 segments. Thoracic segments medially with small dorsal spines (starting about segment nine), increasing in size posteriorly, with penultimate segments bearing the longest spines (Fig. 3k). Last segment with a short spine.

Thoracopod I endite 5 (Fig. 3d, e, f) distally with many short setae. Endopod (movable finger) curved, apex acute with many rounded spines. Endite IV (gripping area) with an extension and apically long blunt spines.

Telson spine rows of 36–40 denticulate spines each (Fig. 3k, l). Spine length relatively regular with some slightly smaller spines interposed irregularly. Spines increasing in size posteriorly, becoming aciculate (length/width ratio approximately 1.7 to 5.5; ratio larger/smaller length 2.6 to 2.7).

Cercopod with two dorsolateral spine rows (Fig 3m only right cercopod medial row represented). Each row about 22 spines long, acute and denticulate (length/width ratio of 2.9–3.7) covering over 80% of the proximal base of the cercopods. Distalmost spine longest (length/width ratio of 3.9; 1.5 to 2.2 longer than the proximal spines).

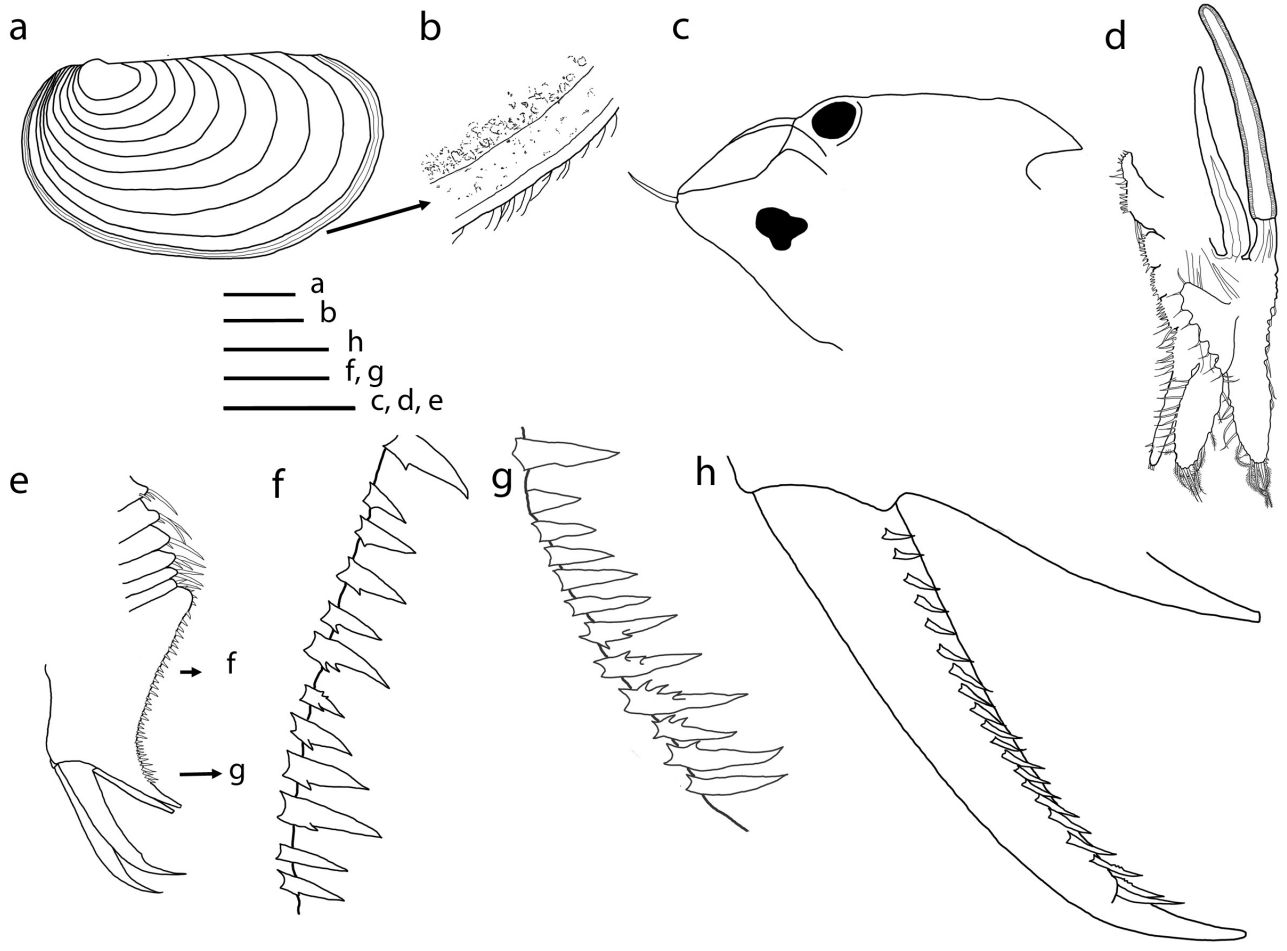

Fig. 4. *Leptestheria brasiliensis* sp. nov. female. a: carapace, b: carapace detail, c: head, d: ovigerous thoracopod, e: telson, f, g: telson margin detail.; h: right cercopod detail (only medial spine row represented). Scale bars: a = 1 mm; b = 0.2 mm; h = 0.1 mm; f, g = 0.05 mm; c, d, e = 0.5 mm.

Description: *Female*: Wild specimen carapace 6.1 mm length, 1.9 mm width, 3.6 mm height (n = 1). Cultured specimen carapace 3.3–4.8 mm length (n = 6), 1.0–1.9 width (n = 4), 1.9–2.8 mm height (n = 6).

Carapace similar to male with various number of growth lines; ~17 in wild specimens and ~11 in cultured specimens.

Head with a rounded and small, angular rostrum (Fig. 4c). Rostral spine long and arcuate (length/width ratio of ~10–11). Ocellus irregular. Anterior margin in lateral view dorsal to eye with a small concavity. Occipital condyle anteriorly rounded, convex, apically acute (length/width ratio of ~0.95), posterior margin concave.

First antenna indistinctly articulated, with 12–16 lobes bearing sensory setae. Second antenna anterior (dorsal) branch with 13 to 16 flagellomeres, posterior (ventral) branch with 10 to 14 flagellomeres. Each flagellomere ventrally with one to three long setae and dorsally with two to seven acute, thin spines

Trunk with 22 segments.

Thorax dorsomedially with small spines, increasing in size posteriorly, with distal most spines very long (Fig. 4e). Distalmost thoracic segments with spines very long and denticulate. Last segment with a short spine. These spines smaller than in the male.

Thoracopods IX and X (Fig. 4d) with epipods bearing cylindrical extensions (egg mass supporting appendages).

Telson (Fig. 4e, f, g) and cercopods (Fig. 4h) as in male.

Ecology and habitat

The habitat of *L. brasiliensis* is temporary pools in the southern part of Bahia State in the municipality of Palmas de Monte Alto in the Caatinga climatic zone. The species was observed in two other loamy pools some kilometres near the locus typicus. The species was also observed in turbid water rock pools bordering small inselbergs (*e.g.*, 14°9'20.64"S, 43°3'28.14"W) (fig. 1B; and Rabet et al. 2018, fig. 7–E).

Two culture series from the locus typicus sediment provided specimens and information on species growth. First mating was observed 10 days after culture inundation, and individual longevity was at least two months. In the field, *L. brasiliensis* was most often observed co-occurring with *Dendrocephalus orientalis* Rabet & Thiéry, 1996 in various pool types, but in the pools with heavy loam it also co-occurred with *Spiralifrons mira* (Gurney 1931), *Eulimnadia colombiensis* Roessler, 1989 and *Eulimnadia* sp. In rock pools *L. brasiliensis* was associated with *Metalimnadia* sp. However, only *Metalimnadia* sp. alone occurred in clear water at the top of the inselbergs.

DISCUSSION

Differential Diagnosis

The diagnostic characters used in South American *Leptestheria* are presented in table 1. *Leptestheria*

Table 1. Main morphological characters used in South American *Leptestheria*

Species	Distribution	Rostral spine length/width ratio and shape	Occipital condyle length/width ratio and shape	Telson spine number, disposition, and relative length (ratio longer/shorter length)
L. brasiliensis	Brazil	10.5–13, dorsally arcuate	0.75–0.95, apically acute, posterior margin concave	35–40 spines, length uniform but posterior ones progressively becoming longer and more aciculate (2.6–2.7)
L. brevispina	Venezuela	5.4–6.2, male dorsally arcuate, and female straight	0.2–0.3, blunt	16–18 spines, small spines interspersed among larger spines in male, female with homogeneous small spines (male: 2.5, female: 1.4)
L. cristata	Venezuela	3.9–4.3, straight	0.8–0.9, more or less ventrally curved, apically acute, posterior margin concave	23 spines, small spines interspersed among larger spines (3.1–3.5)
L. titicacae	Peru, Argentina, Bolivia	2.8–5.6 dorsally arcuate	0.9–1.4, apically acute, posterior margin more or less concave	4–6 robust spines with many minute spines interspersed (> 10)
L. venezuelica	Venezuela, Aruba, Chile	3.5–5.5, ventrally arcuate in male, straighter in female	0.85–1.15, more or less ventrally curved, apically acute, posterior margin concave	29–34 spines, length uniform but posterior ones progressively becoming longer and more aciculate (3.3–5)

venezuelica Daday, 1923 are most similar to *L. brasiliensis*. In this species presents a similar telson with uniform adjacent spine lengths but with the posterior spines progressively becoming longer and more aciculate. The head also is very similar to *L. brasiliensis* sp. nov. However, in *L. venezuelica* the rostral spine is smaller and the occipital angle is more curved than in *L. brasiliensis*. In addition, there are fewer telson spines and they lengthen proportionally more posteriorly in *L. venezuelica* than in *L. brasiliensis*. *L. cristata* García & Pereira, 2003 has several protuberances on the carapace dorsal margin and an irregular telson spination pattern which are not present in *L. brasiliensis*. The egg-supporting appendages are also different; in *L. cristata* the ovigerous limbs are 5–10–11 and not limbs 9–10 as in *L. brasiliensis*.

Leptestheria brevispina differs from *L. brasiliensis* in that the male carapace dorsal margin bears a distal acute extremity that is not present in *L. brasiliensis*. *Leptestheria brevispina* also has a blunt occipital extension, a right angle frontal margin, an irregular telson spination pattern, and three ovigerous legs.

Leptestheria titicacae has a round carapace and a very irregular telson supination pattern, with short and thin spines mixed with broad and robust spines, an arrangement which is not present in any other Neotropical species.

The genetically closest population to *L. brasiliensis* is *L. venezuelica* from Chile (Schwentner et al. 2020). In the future, more populations from the Americas will need to be included to understand relationships in American *Leptestheria*.

Ecological analysis

Roessler (1995) mentions that an undescribed population of *Leptestheria* (his *Leptestheria* sp. 2) in Colombia has very important ecological similarities with *L. brasiliensis*. This form was reported from pools on the bank of the Orinoco River living in muddy-bottomed pools and in rock pools at the base of inselbergs sometimes associated with *Metalimnadia serratura* Mattox, 1952. This situation is similar to what we observed in Palmas de Monte Alto, but unfortunately the Colombian species is not described yet and we are unaware if there are morphological similarities between both species.

Leptestheria compleximanus Packard, 1877 determined *as L. vanhoffeni* Daday, 1923 was reported from Chaco in Paraguay where *Spiralifrons mira* was described (Gurney 1931). This determination is doubtful. Indeed, it is possible that this population from Paraguay is *L. brasiliensis* or another similar undescribed species.

These observations suggest also that there are many places to be explored in Brazil and in South America in general. This research suggests also linkages between different dry Neotropical zones and their ecological associations. A greater understanding of the relationships between the American species can only be achieved through integrative analyses including genetic and morphology. In this way, there is no doubt that new species of *Leptestheria* will be described from the Americas.

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Availability of data and materials: All materials in this paper were deposited in the museums listing in the paper.

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Ethics approval consent to participate: Not applicable.

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