SPIXIANA	42	1	7–14	München, September 2019	ISSN 0341–8391

A new species of *Argulus*, a fish parasite from the Brazilian Amazon

(Crustacea, Branchiura)

Amanda K. S. Souza, Daniel B. Porto & José C. O. Malta

Souza, A. K. S., Porto, D. B. & Malta, J. C. O. 2019. A new species of *Argulus*, a fish parasite from the Brazilian Amazon (Crustacea, Branchiura). Spixiana 41 (1): 7–14.

Argulus angelae sp. nov. was described from eleven fish species from the Solimões River, Catalão floodplain lake complex, Iranduba township, Amazonas, Brazil. The new species is characterized by five triangular and two oval flag-like protrusions on the male's second and third pair of legs, respectively, and pigmentation on the carapace and cephalothorax's dorsal part.

Amanda Karen Silva de Souza (corresponding author), Daniel Brito Porto & José Celso de Oliveira Malta, Fish Parasite Laboratory, Campus II, National Institute of Amazonian Research – INPA, Av. André Araújo, 2.936, Petrópolis, CEP 69067-375, Manaus, Amazonas, Brazil; e-mail: atjsouza15@gmail.com

Introduction

Branchiura are ectoparasites able to attach to the slippery bodies of fish and swim freely to find another host. Nearly 210 species are known, and they belong to four genera: *Argulus* Müller, 1785; *Dolops* Audouin, 1837; *Chonopeltis* Thiele, 1900 and *Dipteropeltis* Calman, 1912 (Martin & Davis 2001). These ectoparasites occur mainly on freshwater fish and yet some species of *Argulus* have been described on marine fishes. There are scattered reports of Branchiura being found on tadpoles, salamanders and even alligators (Ringuelet 1943, Piasecki & Avenant-Oldewage 2008).

Thirteen *Argulus* species occur in Brazil (Malta 1998, Luque et al. 2013). Five of them, namely: *A. multicolor* Schuurmans Stekhoven, 1937; *A. pestifer* Ringuelet, 1948; *A. juparanaensis* Lemos de Castro, 1950; *A. amazonicus* Malta & Silva, 1986; *A. chicomendesi* Malta & Varella, 2000 (Malta 1982, 1983,1984, 1998, Malta & Silva 1986, Malta & Varella 2000), have been reported in the Amazon. The present study includes a description of a new species from the Amazon, Brazil.

Material and methods

Thirty-eight *Argulus angelae* sp. nov. specimens were collected at the Catalão floodplain lakes complex, located between the Negro and Solimões rivers (03°10' 04"S 59°54'45"W). Samples were collected in February, May, June and July 2016, license SISBIO-6531958 and CEUA-036/2016. Fishes were harvested with gill nets. Argulids were removed, fixed in 70 % ethanol and studied by light and stereo microscopy.

The specimens were clarified on slides in glycerin. All measurements are in millimeters and shown as follows: range, minimum-maximum and arithmetic mean (within brackets). The description is based on the measurements of 10 adult females and 10 males.

Drawings were made with a light microscope Olympus BH-2 with camera lucida attachment. Types, fixed in 70 % ethanol, were deposited, in the non-insect Invertebrate Collection of the National Research Institute of Amazonia (INPA), Manaus, Amazonas, Brazil.

Results

Argulus angelae sp. nov.

Material examined. – Holotype: adult female (INPA-CR 2209) from the body surface of *Triportheus albus* Cope, 1872, in liquid medium, from Catalão floodplain lakes complex 03°10'04"S 59°54'45"W, between the Negro and Solimões rivers, State of Amazonas, Brazil. – Paratypes: *Schizodon fasciatus* Spix & Agassiz, 1829 (4 ♀♀ and 2 ♂♂) (INPA-CR 2214, 2222); *Potamorhina latior* (Spix & Agassiz, 1829) (2 ♀♀ and 2 ♂♂) (INPA-CR 2223); *Rhytiodus microlepis* Kner, 1858 (6 ♀♀ and 10 ♂♂) (INPA-CR 2211); *Psectrogaster rutiloides* (Kner, 1858) (1 ♀) (INPA-CR 2213); *Potamorhina altamazonica* (Cope, 1878) (1 ♀) (INPA-CR 2215); *Leporinus friderici* (Bloch, 1794) (1 ♀) (INPA-CR 2216); *Semaprochilodus insignis* (Jardine, 1841) (1 ♀ and 2 ♂♂) (INPA-CR 2210); *Rhaphiodon vulpinus* Spix & Agassiz, 1829 (1 ♀) (INPA-CR 2212); *Steindachnerina elegans* (Steindachner, 1875) (3 ♀♀) (INPA-CR 2220), *Hemiodus* sp. (1 ♀) (INPA-CR 2219), in liquid medium.

Female (Figs 2–12, 18–20)

Total length (tl) 1.6–3.4 (2.9) mm (Figs 2–3). Body elongated. Milk-white coloured dorsal surface with light yellow markings. Carapace longer than wide. Carapace length (cl) 1.1–2.2 (1.8) mm, total length/carapace length (tl/cl) ratio 1.5–1.7 (1.6). Carapace lateral lobes cover sympods and a third of endopods and exopods on the first pair of legs and the anterior half of the sympods on the second pair. Antero-lateral depressions pronounced and deep, forming a distinct frontal region (Figs 2–3) delimited by the rectangular side grooves. Edge of suction cups visible in dorsal view. Well-defined interocular ribs. Large paired compound eyes in anterior third of the body (Fig. 2). Nauplius eye located on dorsal surface near the centre of carapace. Ventral surface of anterior frontal region armed with numerous similar-sized, sharply pointed, regularly arranged spines beyond anterior margin of larger posterior respiratory area (Fig. 3). Lateral lobes broadly rounded, extending posteriorly to cover base of 2nd pair of legs (Figs 2–3), separated by large sinus with more than ⅓ the length of the carapace. Carapace length/width (cl/w) ratio 0.9–1.2 (1.1). Respiratory areas consist of smaller ovoid, anterior "area" to larger, posterior ovoid "area" (Figs 3, 11). These are vaguely defined to visible on the ventral surface of the lobes, somewhat obscured in dorsal view.

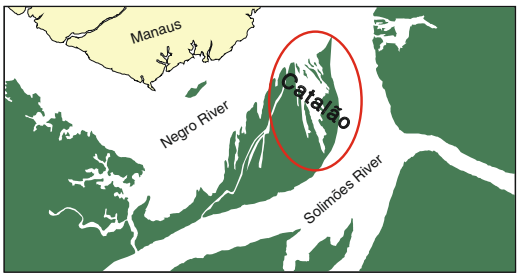


Fig. 1. Map of the collection area, Catalão floodplain lakes complex highlighted in the circle.

Thorax (pereon) (Figs 2–3) distended with eggs and indistinctly 4-segmented ventral surface. Dorsal surface displaying three longitudinal pigmented bands, the two lateral ones formed by small circular melanophores and the central one without pigments. On the first somite, a row of dark brown pigments occurs perpendicularly to the body axis, extending across the carapace's lobes, shown as Y-shaped patterns.

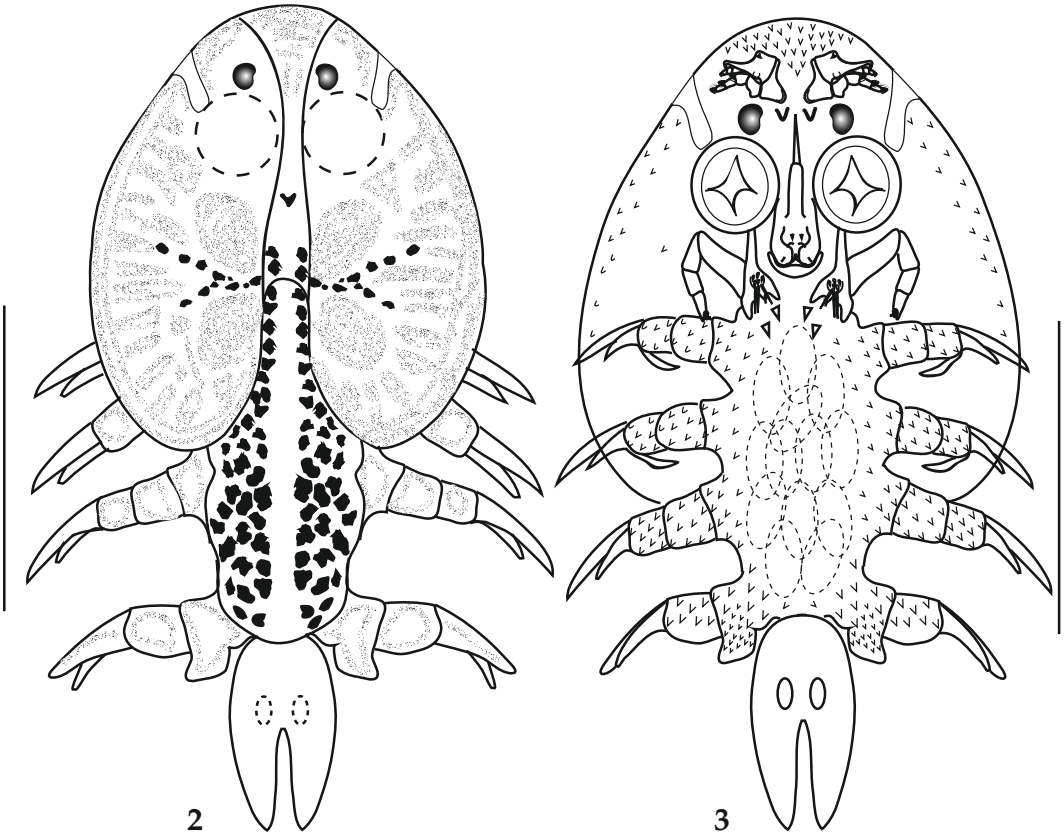
Abdomen (pleon) length (Figs 2–3) (al) 0.4–0.9 (0.7), posterior lobes taper to straight sharp points, separated by a sinus, encompassing nearly 55 % of total abdomen length, longer than wide, bearing small homogeneously distributed spines on the ventral and dorsal surface all-over. Total length/abdomen length (tl/al) ratio 3.5–4.2 (3.9). Abdomen (pleon) width (aw) 0.2–0.7 (0.4). Total length/abdomen width (tl/aw) ratio 1.3–2.3 (1.8). Abdomen longer than wide, posterior lobes tapering to a point from behind anal sinus. Paired spermathecae rounded, situated in fused part of abdomen.

First antenna (antennule) (Fig. 8) very small, hooks short, approaching each other at midline. First antenna (Fig. 8) comprising 2 sections: stout proximal section; slender distal section; both 2-segmented. First segment with large, pointed posterior spine; 2nd segment with a small hook-like anterior spine, a small hook-like terminal spine and a small hook-like medial spine. 3rd segment bearing single seta, terminal segment displaying group of apical spines.

Second antenna (Fig. 8) 4-segmented: 1st segment bearing pectinate scales, slight projection on posterior margin; 2nd and 3rd with number of pectinate setae; 4th terminating in group of small apical spines. Pair of small post-antennal spines occur on ventral surface of cephalothorax (Fig. 3).

First maxilla (maxillula) transformed to large suction cups, supporting rods with 4–7 sclerites (Fig. 9). Rod elements similar in form; rim of suction cups with a fringe of simple setae in the anterolateral part. Second maxilla (Fig. 12) consist of 5 segments: basal plate ornamented with 3 posteriorly directed sharp teeth and long antero-lateral process; 2nd segment with a spine distally; 3rd and 4th segment very short; 5th with 3 small terminal claws.

Retractile pre-oral spine, without scales, located midway between maxillary suckers. Mouth tube of moderate length, usually not reaching thoracic ac-



Figs 2–3. Female of *Argulus angelae* sp. nov. **2.** Dorsal view. **3.** Ventral view. Scale bars = 1 mm.

cessory spines, bearing a pair of simple spines on its anterior margin. Denticulate mandibles visible within mouth tube denticles single row (Fig. 10).

Pair of accessory spines located between maxillae and pair of thoracic spines posterior the maxillae (Fig. 3). First to fourth pair of thoracopods biramous and of near equal size; sympods 2-segmented (precoxa, coxa, basis, exopod and endopod), exopods and endopods with plumose setae. First and second pair of legs (Figs 4, 7) with a dorsal flagellum on the second segment and ornamented with plumose setae.

Third (Fig. 6) and fourth pair (Fig. 7) of thoracopods with the first, second and third segment covered with spines; first segment with pronounced natatory lobe (coxopodite expansion), with rounded margins and posterior tip (tapered end) having seven feathery setae; second segment displaying five plumose setae on the posterior margin.

Male (Figs 13–17, 21–22)

Total length (tl) 2.2–3.1 (2.7) mm, about 8 % less than the female (Fig. 14). Dorsal surface of milk-white colour with light yellow markings, but with a rather lighter and dense coloration than in females. Carapace heart-shaped, slightly wider than long. Carapace length (cl) 0.7–1.6 (1.4) mm. Carapace total length/length ratio (tl/lc) 1.8–3.1 (2.0).

Frontal region (Fig. 13) better defined than female's and well defined by antero-lateral depressions and a posterior cephalic sulcus. Lateral lobes broadly rounded (Fig. 13), separated by large X-shaped sinus nearly half as long as the carapace, and similar to that in females. Dorsal carapace markings similar to that of female, but less dense. Respiratory areas (Fig. 11) are moderately defined and partly visible from dorsal aspect of the lobes.

Thorax (pereon) (Fig. 13) smaller, narrower and less prominent than the female's and displays four well-defined somites. Dorsal surface with three longitudinal pigment bands: the two lateral ones

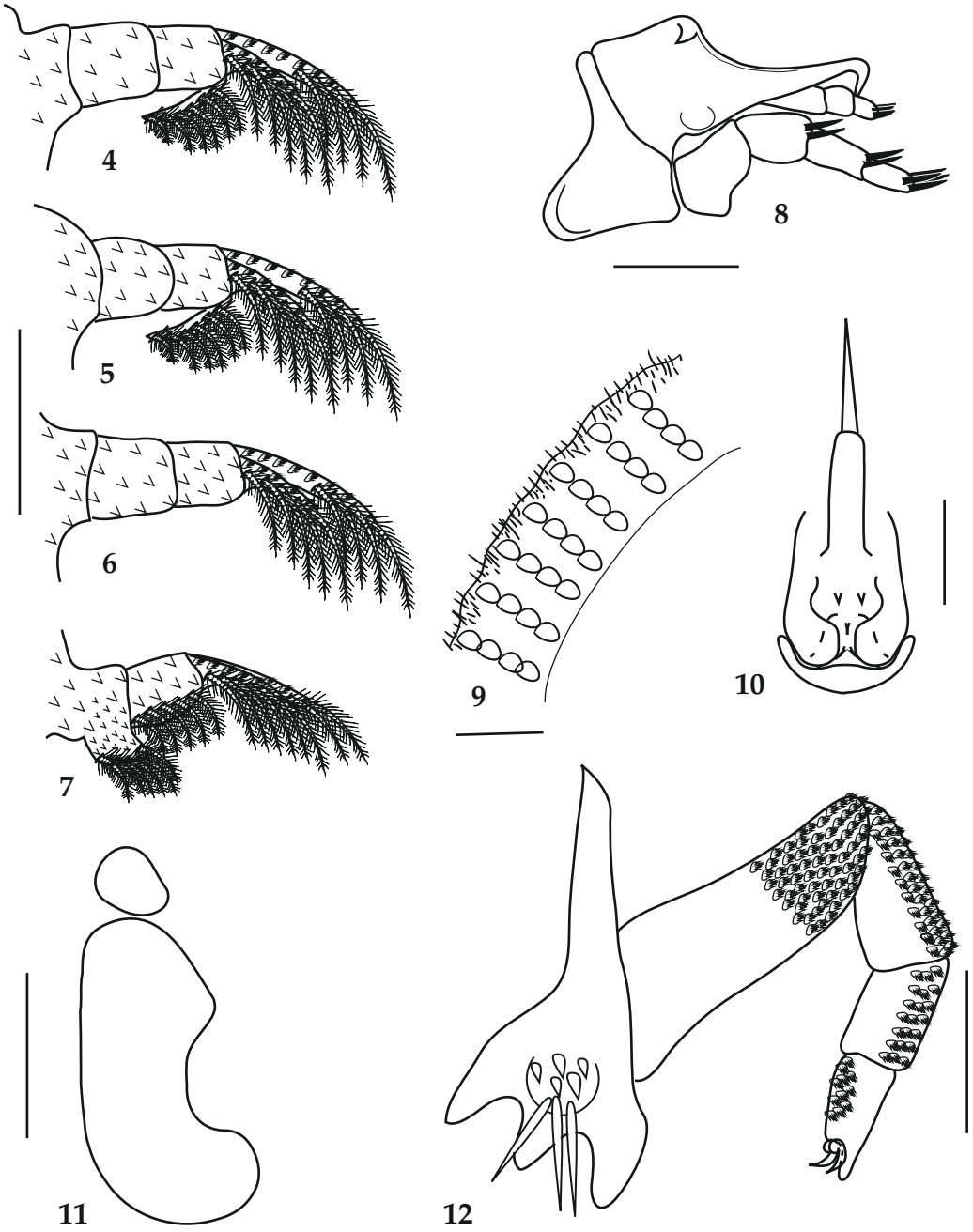


Fig. 4–12. Female of *Argulus angelae* sp. nov. **4–7.** Legs; scale bar = 0.1 mm. **8.** Antenna 1, 2 and antennule. **9.** First maxilla; scale bar = 0.1 mm. **10.** Retractile pre-oral spine and mouth tube; scale bar = 0.1 mm. **11.** Respiratory area; scale bar = 1.0 mm. **12**. Second maxilla; scale bar = 0.2 mm.

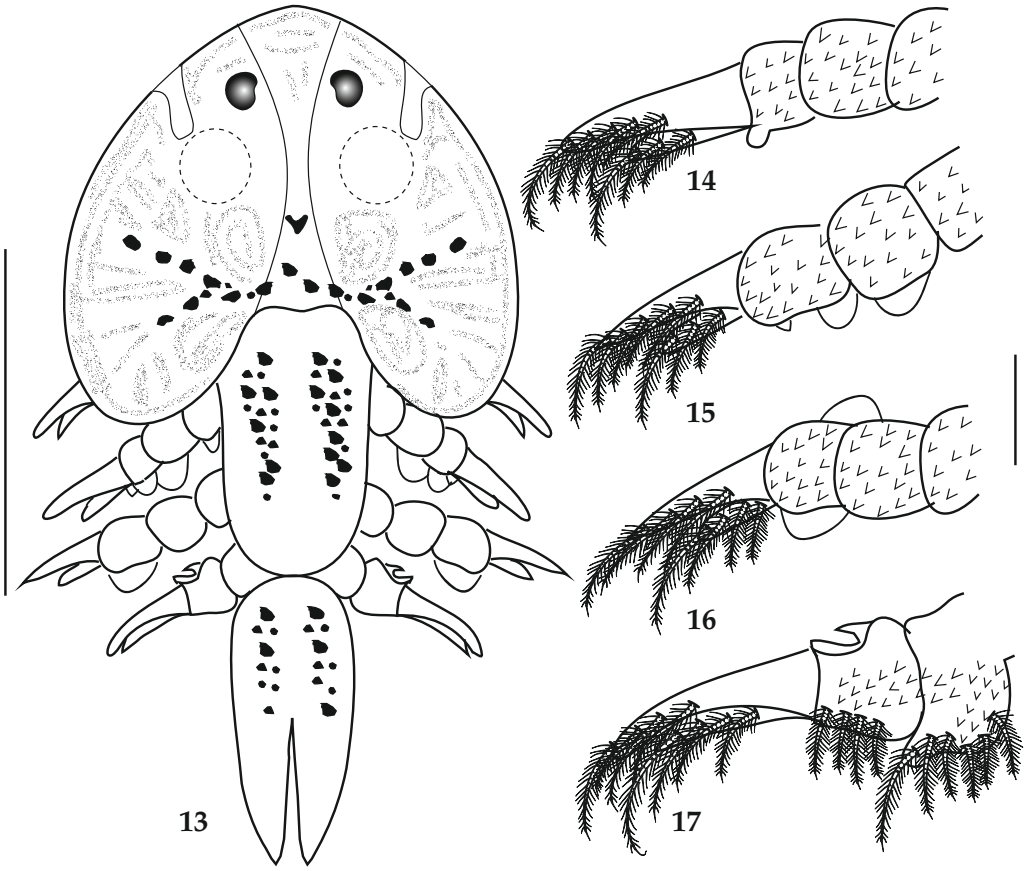


Fig. 13–17. Male of *Argulus angelae* sp. nov. **13.** Dorsal view; scale bar = 1.0 mm. **14–17.** Legs; scale bar = 0.1 mm.

being formed by melanophores and the central one without patches, but less evident than the female's.

Abdomen (pleon) (Fig. 13) oval and slightly longer than wide, total length/abdomen length ratio (tl/al) 2.4–3.3 (3.0). Abdomen width (aw) 0.2–0.4 (0.3). Abdomen length/width (al/aw) ratio 2.3–4.0 (2.9). Pair of well-defined testis in similar shape than the abdomen, occupying nearly 90 % of the abdominal area. Abdominal lobes extending towards anal sinus, lanceolate at the extremities. Well-defined posterior abdomen sinus, 42 % of the total length of the abdomen. On both sides of the midline of the abdomen there are melanophores forming small dark spots.

First to 4th pair of biramous limbs (swimming legs, thoracic legs, thoracopods, pereopods) of nearly equal size; sympods 2-segmented (precoxa, coxa, basis, exopod and endopod), exopods and endopods with plumose setae (Figs 14–17). First and 2nd thoracic legs provided with flagella, arising from dorso-proximal region of exopod (Figs 14–15).

Sexually dimorphic characters present in 2nd, 3rd and 4th legs. Sexual modifications of the 2nd leg consists of five flag-like protrusions (Fig. 15), adorned with scales. Third leg with two rounded flag-like protrusions (Fig. 16). Fourth leg with peg process on anterior side modified at the tip opposite to the cup-shaped elevation (accessory structure of couplings). Modifications of the fourth pair of male legs include an anterior projection with a median aperture covering the gonopore. Natatory lobes are triangular in shape with four sections of plumose arrows. Area of attachment: body surface, base of the fins, gills and buccal cavities.

Etymology. The specific name is a tribute to Dra. Angela Maria Bezerra Varella, for all the years dedicated to the studies in fish parasitology in the Amazon, a great researcher and advisor of the postgraduate course in freshwater biology and inner fishing of the National Research Institute of Amazonia. The name of the species derives from the researcher's first name: Angela – *angelae*.

Figs 18–20. Female of *Argulus angelae* sp. nov. **18.** ventral view; **19.** dorsal view; **20.** antennas; a, b, section 1 of first antenna; c, section 2 of first antenna; d, second antenna.

Fig. 21–22. Male of *Argulus angelae* sp. nov. **21.** Dorsal view; **22.** Legs.

Discussion

Argulus angelae sp. nov. is the fifth species of the genus *Argulus* described from the Amazon. *Argulus angelae* is similar to *A. chicomendesi*, it differs from it by being smaller, and the carapace ventral region having spines between the first and second maxillae as well as in the shape of respiratory areas and in the structure of the second, third and fourth legs of the male, along with a pair of spines in the anterior portion near the mouth.

Branchiura species, when in confined environments (tanks and aquaria) do not have a parasitic specificity, whereas in nature, each species has a restricted group of hosts (Ringuelet 1943). Similar results were found in Branchiura species in North America (Wilson 1902), in Africa (Fryer 1968) and in the Brazilian Amazon (Malta 1984).

The *Argulus* species with the largest number of host fishes from North America are: *A. appendiculosus* Wilson, 1907 with 45 species; *A. alosae* Gould, 1841 with 22; *A. megalops* Smith, 1873, *A. laticauda* Smith, 1873 and *A. maculosus* Wilson, 1902 with 21 host fish species. From Europe: *Argulus foliaceus* (Linnaeus, 1758) with 32 species; *A. coregoni* Thorell, 1864 with 6 and *A. arcassonensis* Cuénot, 1912 with 4. From Asia: *A. foliaceus* and *A. indicus* Weber, 1892 with 13 species; *A. coregoni* with 12; *A. siamensis* Wilson, 1926 with 9 and *A. japonicus* Thiele, 1900 with 8. From Africa: *Argulus africanus* Thiele, 1900 with 35 species; *A. rhipidiophorus* Monod, 1931 with 16; *A. cunningtoni*, Fryer, 1965 and *A. kosus* Avenant-Oldewage, 1994 with 8 host fish species (Neethling & Avenant-Oldewage 2016).

From South America: *Argulus chicomendesi* Malta & Varella, 2000 with 10 species (Malta & Varella 2000); *A. multicolor* Schuurmans Stekhoven, 1937 with 9; *A. juparanaensis* Lemos de Castro, 1950 and *A. violaceus* Thomsen, 1925 with 8 host fish species (Neethling & Avenant-Oldewage 2016). *Argulus*

angelae sp. nov. is the South American species with the highest number of hosts, with 11 fish species registered, all of the order Characiformes.

Sexually dimorphic characters occur in 2nd, 3rd and 4th legs. Males of *Argulus* present dimorphic changes in the legs. *Argulus angelae* sp. nov. has sexual structures on 2nd and 3rd legs. Flag-like protrusions structures were found in *A. ernsti* Weibezahn & Cobo, 1964 from Venezuela, two on the second leg and two on the third pair of legs, yet with different shapes (Weibezahn & Cobo 1964).

In *A. smalei* Avenant-Oldewage & Oldewage, 1995 from South Africa, on posterior face of 2nd leg flat disc covered by pectinate scales. Two bulbous and flag-like protrusions covered by scales on anterior face of 3rd leg (Avenant-Oldewage & Oldewage 1995).

In *A. angelae* sp. nov. the sexual modifications displayed by male in the 2nd leg are the five flag-like protrusions adorned with scales and third leg two rounded and these features being unique to this particular species.

The mouth tube of *A. fryeri* Rushton-Mellor, 1994 from Lake Turkana, Kenya, Africa, bears a pair of accessory spines located posterior to mouth tube. *Argulus gracilis* Rushton-Mellor, 1994 from Tanganyika lake exhibits a pair of accessory spines located on either side of labium (Rushton-Mellor 1994). *Argulus angelae* sp. nov. also displays a pair of simple spines on its anterior margin of mouth tube.

Argulus angelae sp. nov. has a carapace which is slightly longer than broad, partly covering the second pair of legs. They are similar to *A. chicomendesi* (Malta & Varella, 2000); *A. violaceus* Thomsen, 1925; *A. multicolor* Schuurmans Stekhoven, 1937; *A. canadensis* Wilson, 1914; *A. lepidostei* Kellicott, 1877 (Yamaguti, 1963).

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