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of Gastrotricha (Macrodasysida,
Planodasyidae) from São Paulo, Brazil*

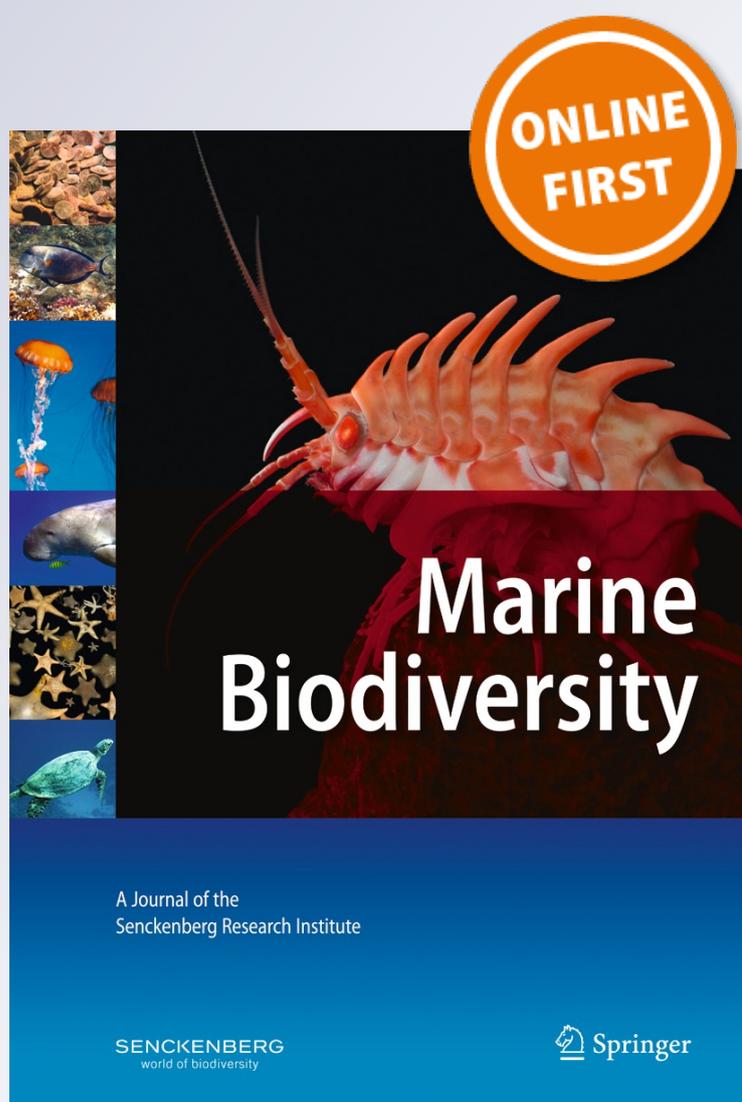
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Crasiella fonseci, a new species of Gastrotricha (Macrodasysida, Planodasyidae) from São Paulo, Brazil

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Abstract A new gastrotrich species of the genus *Crasiella* (Macrodasysida: Planodasyidae) is described from sublittoral sands of Ilha do Tamanduá (Caraguatatuba, São Paulo), Brazil. *Crasiella fonseci* n. sp. is up to 560 µm long and differs from its congeners in its unique trilobed head shape, distinct indentation at the pharyngeal pores, and the presence of reinforcing rods in the caudal pedicles. Adhesive tubes are only present in ventrolateral and posterior series. The ventrolateral adhesive tubes are of multiple sizes and form two slightly-staggered columns down the length of the body. Tubes of the pharyngeal region are short, stout, and protrude laterally, while most tubes of the trunk region are distinctly thinner, more flaccid, and project posteriorly. Caudally, the tubes are again stouter and project laterally. Seven posterior adhesive tubes are borne on a pair of small caudal pedicles that are reinforced internally with rods. Animals are simultaneous hermaphrodites with a small frontal organ and large, apparently non-muscular caudal organ. This is the first report of the genus from South American waters.

Keywords Meiofauna · Brasil · Gastrotrich · Biodiversity

Introduction

The Brazilian coastline encompasses 7,491 km of sandy beaches, mangrove forests, rocky shores, estuaries, coral reefs, and mudflats, among other habitats (Couta et al. 2003). Despite this vast heterogeneity, relatively little is known about the benthic invertebrate fauna of many marine environments, particularly sandy shores (Couta et al. 2003), which are known as dynamic habitats because of wave scour and shifting sediments. Animals that

occupy these environments are typically well suited for handling such physical forces, but they are generally not restricted to these habitats. For example, meiofaunal taxa that occupy the interstitial spaces among sand grains are often present in both sandy shores and sublittoral sediments, despite the differences in current regime, granulometry and a host of other physical and biotic factors that change once wave exposure changes (Giere 2009). As data accumulates on Brazilian meiofauna from both ecological perspectives (e.g., Souza-Santos et al. 2003; Di Domenico et al. 2008; Maria et al. 2013) and taxonomic perspectives (e.g., Todaro and Rocha 2004; da Fonsêca-Genevois et al. 2009; Grohmann 2013), meiobenthologists will be in a better position to understand how the diversity of Brazilian coastal habitats affects the community composition of meiofauna, and ultimately how habitat diversity and meiofaunal biodiversity are interrelated.

Among the more dominant groups of marine meiofauna are species of Gastrotricha, which can be highly abundant in both littoral and shallow sublittoral sandy environments and generally rank third in total abundance behind species of Copepoda and Nematoda (Hochberg 1999). Gastrotrichs differ from these latter two taxa with respect to several important characteristics: gastrotrichs rely on ventral cilia for locomotion, they are often heavily adorned with adhesive tubes that limit unintentional (e.g., current-borne) movement (see Todaro 2013), and they are restricted to interstitial spaces, generally being unable to move sand grains and therefore burrow while moving. For these reasons, gastrotrichs are generally most abundant in well-sorted, porous sediments (Hummon 2007) and are often present alongside a wide variety of other meiofauna including flatworms, gnathostomulids, rotifers and temporary meiofauna (larval and subadult macrofauna) such as species of Holothuroidea (Echinodermata) and Polychaeta (Annelida).

Despite our growing knowledge of gastrotrich biodiversity in poorly studied regions such as the coastlines of Central America (Hochberg 2008) and the islands of the Tropical Northwestern Atlantic (Hummon 2010; Hochberg 2010;

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Hochberg and Atherton 2010, 2011), studies of marine species in South America are relatively rare (Remane 1953; Dioni 1960; Hummon 1974; Todaro and Rocha 2004, 2005; Todaro 2012, 2013). Interestingly, the first report of a marine gastrotrich in South America comes from the southern coast of Brazil (du Bois-Raymond Marcus 1952), though it was not until the investigations of Forneris (1985, 1989) that additional marine taxa were reported. In fact, the first detailed survey of marine gastrotrichs in the southern hemisphere took place in São Paulo, Brazil, when Todaro and Rocha (2004) sampled 23 littoral/sublittoral sites revealing 43 species, with later research revealing additional taxa (Todaro and Rocha 2005). To date, three taxa have been described as new to science (Todaro and Rocha 2004; Todaro 2012, 2013). In an effort to gain further data on the marine gastrotrichs from this region, I made collections from a series of littoral and sublittoral sites around São Paulo, which was part of a larger survey of marine meiofauna sponsored by the São Paulo Research Foundation (FAPESP). Here, I provide the description of a new species of *Crasiella*, which constitutes the first report of a member of the Planodasyidae from South America.

Materials and methods

Sediments were collected by SCUBA from 15 m depth off the coast of Ilha do Tamanduá in Caraguatuba, São Paulo, Brazil, on 5 November 2012. Sediments were placed in plastic buckets and extracted the same day while at the Centro de Biologia Marinha da USP, São Sebastião, Brazil. Approximately 100 mls of sediment was placed into a 1-l Erlenmeyer flask containing 900 ml of isotonic $MgCl_2$ and allowed to rest for 10 min. The flask was subsequently shaken and gently poured over a 43- μm mesh, which collected the fauna that were then washed into a Petri dish with seawater. Fauna was examined with a stereomicroscope and individual animals were isolated onto a glass microscope slide, covered with isotonic $MgCl_2$, and covered with a coverslip. Specimens were examined with a Zeiss Axioskop with digital camera. Zeiss software was used to capture a series of images and take measurements. Lengths and positions of external structures and internal organs are described in terms of percentage body units, with total body length from anterior (U00) to posterior (U100) as 100 units.

Several specimens were removed after examination and placed in 5 % formalin in seawater for 1 week. The animals were then rinsed in phosphate-buffered saline (pH 7.4), placed in phosphate-buffered saline with 1 % Triton X (PBT) for 1 h, and stained overnight in Alexa Fluor 488 phalloidin (Invitrogen) in PBT. Specimens were mounted in Fluoromount G (Southern Biotech, AL, USA) on glass slides and examined on an Olympus FV 300 confocal laser scanning microscope equipped with a multi-argon laser. A series of optical z-projections

(0.5 μm per slice \times 75 slices) were used to generate a single stacked image in Olympus Fluoview software (v.5.0).

One stained specimen was removed from the mounting medium and prepared for museum archival at the Museu de Zoologia, Universidade Estadual de Campinas, Brasil. Preparation for archival involved: rinsing the animal in 0.1 M PBS for 1 h; placing the animal in 1 % OsO_4 in 0.1 M PBS for 30 min (to increase contrast); rinsing again in 0.1 M PBS for 15 min followed by dehydration through an ethanol series (10 min per step); transferal to propylene oxide for 30 min; embedding in epon on a glass microscope slide with a coverslip; and placing in an oven at 60 °C for 24 h.

Sediments from the samples were dried and separated by size fraction through a series of sieves including 4, 2, 1, 0.5, 0.25, 0.125, and 0.063 mm. Sieve fractions were weighed and granulometric data calculated using GRANPLOTS with line segment (Balsillie et al. 2002).

Results

Phylum Gastrotricha Metschnikoff, 1865

Order Macrodasyida Remane, 1925 [Rao & Clausen, 1970]

Family Planodasyidae Rao & Clausen, 1970

Genus *Crasiella* Clausen 1968

Crasiella fonsecai n. sp.

Diagnosis Body length to 560 μm long and strap-shaped; three-lobed head without piston pits; distinct indentation at region of pharyngeal pores around U32; pharyngeointestinal junction (PhIJ) at U36; intestine narrow and with obvious food items; no distinct set of anterior adhesive tubes (TbA); up to 20 short (4–10 μm long), stout, ventrolateral adhesive tubes (TbVL) in pharyngeal region, somewhat staggered in position, from the U04 to PhIJ; approximately 43 adhesive tubes in trunk region, staggered in position; the first ~30 TbVL are long (10–21 μm) and flaccid in appearance and extend posteriorly; the remaining 11–13 TbVL are shorter (7–10 μm), more robust in appearance, and extend laterally; seven posterior adhesive tubes (TbP) extend off the caudal pedicles; distinct, reinforcing, epidermal rods present within the caudal pedicles; epidermal glands numerous in pharyngeal region and along lateral body margins of trunk; paired testes at PhIJ extend as vasa deferentia to ca. U50; glandular caudal organ to 86 μm long at the posterior end; non-muscular frontal organ to 39 μm long at U64; single large egg at U60.

Etymology The species is named in honor of Dr. Gustavo Fonseca, who organized the FAPESP meiofauna workshop.

Material Examined Seven specimens were examined with a compound microscope for photography and measurements. Five specimens were fixed in 5 % formalin and processed for

muscle staining; only two specimens were sufficiently relaxed for confocal microscopy and museum archival.

Type Locality Ilha do Tamanduá in Caraguatuba, São Paulo, Brazil; 15 m depth; granulometry: Mean 0.5034 ϕ , SD 0.4733 ϕ , Skewness 4.3804, kurtosis 27.9455, median 0.2643 ϕ , *Holotype* Subadult deposited at Museu de Zoologia, Universidade Estadual de Campinas, Brasil.

Description

Body strap-shaped with distinct three-lobed head and slightly tapering posterior that ends in a pair of small caudal pedicles (Fig. 1). Body length 250 (subadult) – 560 μm (adult). Most measurements are based on the largest reproductive adult (560 μm long). Head and pharyngeal region distinct from trunk; head has three lobes (Figs. 1, 2a), though the anterior lobe can be somewhat multilobed. Piston pits are absent. Widths of head at widest point of first and second lobes are 56 and 74 μm , respectively, in a 560- μm -long adult. The pharyngeal region is somewhat wavy in outline (average width behind second lobes is ~69 μm) and tapers toward the pharyngeal pores at U32, where distinct indentations are present (body width of 64 μm). Widths of trunk in the region of the PhIJ, U50, and base of caudal lobes are 76, 86, and 17 μm , respectively.

Tactile cilia present along lateral and dorsolateral surfaces in somewhat staggered positions. Approximately 60 tactile hairs (7–16 μm long) per side in a 500- μm -long adult. Anterior cilia are shorter (5–10 μm) than cilia along pharyngeal and trunk regions (to 16 μm). The posterior trunk (~U75–U95) appears to have only few, sporadic cilia along the lateral margins. Locomotor cilia are distributed as two ventral columns from approximately U06–U95.

Adhesive tubes present in ventrolateral (TbVL) and posterior (TbP) locations only (Fig. 2a–c). There is no distinct set of anterior adhesive tubes (TbA) that can be differentiated from the TbVL (Fig. 2c). TbVL in the pharyngeal region are generally short (4.5–10 μm long), robust in structure, and extend laterally. There are approximately 18–20 TbVL in the pharyngeal region, with ~10 tubes (4.5–7 μm long) clustered from U04 to U16; the remaining tubes are mostly evenly spaced to the PhIJ (U36). In the trunk region, the TbVL are noticeably more flaccid in structure and directed posteriorly. There are approximately 25–35 TbVL from U36 to U83; these tubes are of different sizes (10–21 μm long), staggered in position, and often overlapping. From ~U83 on, the TbVL have a slightly different appearance, taking on a more lateral orientation and appearing stiff (Fig. 2a, b); there are 11–13 tubes/side (6–10 μm long). Posterior adhesive tubes (TbP) are arranged on a pair of small caudal pedicles (Fig. 2b, d). Caudal pedicles extend to 18 μm long (base to tip of longest tube) in a 560- μm -long adult specimen. In most specimens, there are seven TbP per side. Tubes are arranged as two short medial tubes (inner: 3 μm ; outer: 4 μm long), two long tubes (inner:

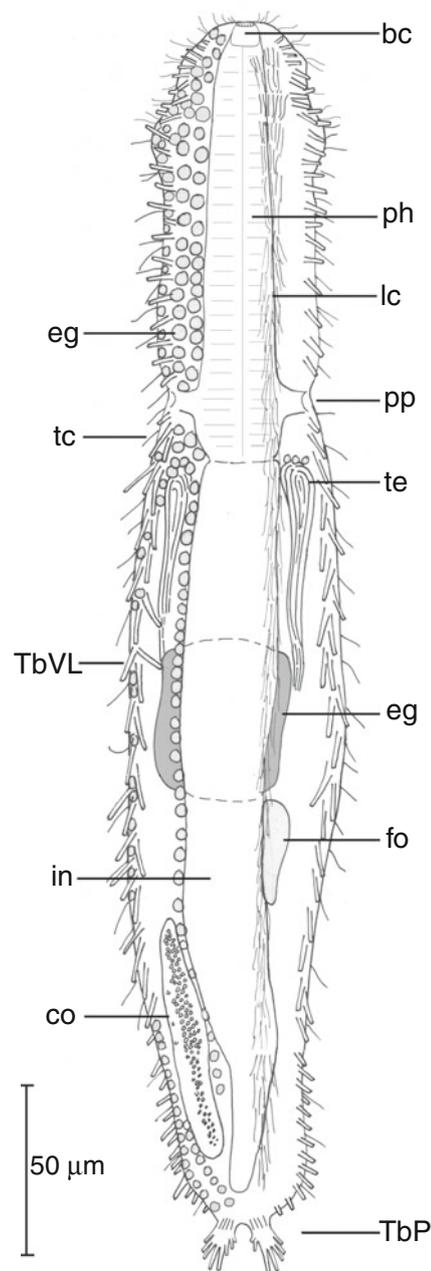
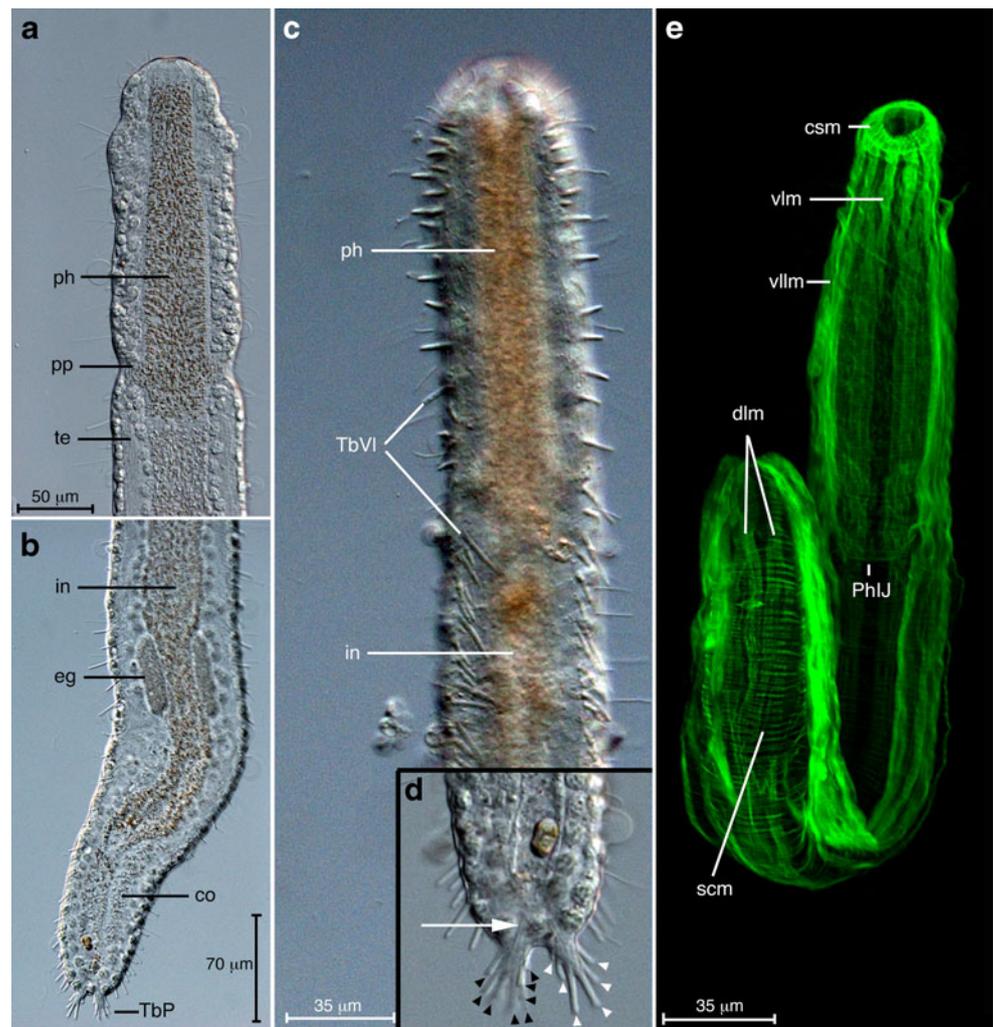


Fig. 1 *Crasiella fonseci* n. sp., composite schematic of adult specimen showing dorsal (*left*) and ventral (*right*) views; buccal capsule (*buc*), caudal organ (*co*), egg (*eg*), epidermal glands (*ep*), frontal organ (*fo*), intestine (*in*), ventral locomotory cilia (*lc*) pharynx (*ph*), pharyngeal pores (*pp*), posterior adhesive tubes (*TbP*), tactile cilia (*tc*), testes (*te*), ventrolateral adhesive tubes (*TbVL*)

10–11 μm ; outer: 9 μm long) and three shorter tubes with progressively decreasing length (inner: 6 μm ; middle: 4–5 μm ; lateral: 4 μm). Several specimens appeared to have an asymmetrical number of tubes (Fig. 2d). It is undetermined if the 7 TbP per side is a low estimate and therefore an observational error due to the insertion of smaller tubes in more ventral positions. The caudal pedicles of all specimens contained elongate epidermal rods (arrow, Fig. 2d).

Fig. 2 *Crasiella fonsecai* n. sp. **a, b** Dorsal view of live adult specimen. **c** Ventral view of the anterior end of live adult specimen. **d** Posterior end of live adult specimen showing the TbP; *black (left) and white (right) arrowheads* denote individual tubes; *white arrow* denotes internal fibers. **e** Musculature of specimen viewed with CLSM; caudal organ (*co*), circular sphincter muscles of the mouth (*csm*), dorsal longitudinal muscles (*dlim*), egg (*eg*), intestine (*in*), pharygeointestinal junction (*PhIJ*), pharynx (*ph*), pharyngeal pores (*pp*), posterior adhesive tubes (*TbP*), somatic circular muscles (*scm*), testes (*te*), ventral longitudinal muscles (*vlim*), ventrolateral longitudinal muscles (*vllm*), ventrolateral adhesive tubes (*TbVI*)



Epidermal glands Refractile epidermal glands present along dorsolateral and lateral body walls (Fig. 2a). All glands approximately 4–5 µm in diameter. In the pharyngeal region, the glands form two columns between the pharynx and lateral border of the body; approximately 25 glands are packed tightly together on either side of pharynx. In the trunk, the two columns are distinctly separate. One column of more than 50 glands borders either side of the intestine for its entire length; the second column follows the lateral margin of the body to the caudal end (Figs. 1, 2a, b). The number of glands in the lateral body regions were not counted.

Digestive tract A small terminal mouth to 7 µm diameter lined with small, inner projections. The mouth leads into an expansive buccal capsule to 16 µm long. The myoepithelial pharynx gradually expands in width from just behind the buccal capsule (23 µm) to a maximum of 35 µm for most of the pharynx length. Pharyngeal pores at U32; the indentation at the region of the pores appear to be a combination of outgrowth of the pharyngeal wall and ingrowth of the overlying epidermis. The intestine is more-or-less straight and narrow, tapering from a

maximum width of 35 µm behind the PhIJ to ca. 15 µm at the terminal end around U93. Diatoms and other organic matter were present in the intestines of most specimens.

Reproductive system Paired testes begin at the PhIJ and extend posteriorly as vasa deferentia to at least U50. A male pore(s) was not detected. Large ovum to 47 µm diameter present in single specimen at U60 (Fig. 1b). Smaller oocytes were not observed. Frontal organ extends from ~U64 to U71, is elongate and ca. 39 µm long × 11 µm wide. Caudal organ on opposite side of intestine from frontal organ; caudal organ is glandular, does not appear to be muscular, and is 86 µm long × 15 µm wide (adult of 560 µm length). A thin internal duct was observed extending along the anterior-posterior axis of the caudal organ of only a single specimen (not shown). No opening of the caudal organ was observed.

Muscular system Only a brief description of the muscular system is provided here. Circular, helicoidal and longitudinal muscles are present (Fig. 2e). Splanchnic circular muscles ensheath the entire length of the pharynx and form a dense

sphincter around the mouth opening (csm; Fig. 2e). The circular muscles lie beneath the longitudinal and helicoidal bands of the pharynx. In the trunk region, somatic circular muscles (scm) enclose both the helicoidal bands of the intestine and the overlying longitudinal muscles (Fig. 2e). Longitudinal muscles are present radially around the digestive tract, forming pairs of dorsal, dorsolateral, lateral, ventrolateral and ventral bands. Thick ventrolateral longitudinal muscles (vlm, Fig. 2e) are the largest muscles in the body and extend from approximately U10 (posterior of the mouth margin) to the caudal end. There was no evidence of muscles associated with any portion of the reproductive system in two specimens (total body lengths: 250 (subadult) and 400 μm (adult)).

Discussion

The genus *Crasiella* was erected by Clausen (1968) to distinguish a group of macrodasyidan gastrotrichs with small caudal lobes (pedicles) and an asymmetrical digestive tract. To date, the monophyly of *Crasiella* has not been verified using either morphological or molecular data. Since Clausen's description of the type species *Crasiella diplura* in Bergen, Norway, six additional species have been added to the taxon from around the globe including: *C. oceanica* d'Hondt, 1974 from Roscoff, France; *C. pacifica* Schmidt 1974 from Santa Cruz, Galapagos Islands; *C. indica* Rao 1981 from Orissa, India; *C. azorensis* Hummon 2008 from the Azore Islands, Portugal; *C. skaia* Hummon 2010 from the Bahamas; and *C. clauseni* Lee and Chang 2012 from Jeju Island, South Korea. Additional geographic records may be found in Hummon (2009).

In general, the body shape of species of *Crasiella* is unremarkable, and so the key diagnostic feature for taxonomic identification is centered on the distribution of the adhesive tubes and the structure of the caudal pedicles. According to Todaro and Hummon (2008), the adhesive tubes of the anterior end (TbA) are often arranged in a longitudinal series as opposed to forming a single row or cluster below the ventral mouth margin or being borne on fleshy lobes. While there is some variation in this pattern (see Clausen 1968; d'Hondt 1974; Schmidt 1974; Rao 1981; Hummon 2008; Lee and Chang 2012), all species are nonetheless easily distinguished by it, and this holds true for *C. fonsecai* n. sp. Moreover, the anterior adhesive tubes of the Brazilian specimens are not distinct from the adhesive tubes of the pharyngeal region, i.e., the tubes form a continuous series from the pharyngeointestinal junction to the anterior end without a distinct space in between (e.g., compare with *C. azorensis* and *C. oceanica*) or a change in their orientation (e.g., compare with *C. oceanica* and *C. indica*). In this respect, the new species is most similar to *C. clauseni* recorded from South

Korea (Lee and Chang 2012), but with far fewer adhesive tubes.

Like other species of *Crasiella*, the Brazilian specimens have a more abundant and dense distribution of adhesive tubes in the trunk region compared to the pharyngeal region. In some species, such as *C. clauseni*, the tubes form dense clusters. Some species also possess tubes of varying size along their trunk (e.g., *C. oceanica*, see Hummon 2008), but not in such a regular pattern (short tubes – long tubes – short tubes) as in *C. fonsecai* n. sp. There is also a noticeable change in the structure and orientation of the adhesive tubes along the trunk compared to the pharynx. In the pharyngeal region, the tubes are stout and directed laterally, while most tubes of the trunk region are noticeably more flaccid and many (but not all) are directed posteriorly. Caudally, the adhesive tubes are more laterally oriented and stout in structure.

The adhesive tubes of the caudal pedicles are also a distinguishing feature of the new species. The pedicles themselves are relatively small and bear seven tubes per side, though some variation in tube number was noted. Characteristic of the new species is the presence of internal rods within the pedicles (long white arrow; Fig. 2d). Similar rods, termed striated fibers, were noted for species of *Turbanella* by Tyler and Rieger (1980) and may function in cytoskeletal support during times of adhesion. Such structures have yet to be noted for other species of *Crasiella*.

The reproductive system of the Brazilian species fits the profile of other species in the genus with one notable exception: the caudal organ of *C. fonsecai* n. sp. does not appear to be muscular. Several macrodasyidan gastrotrichs (reviewed in Ruppert 1991; Kieneke et al. 2012), including two species of *Crasiella* (Guidi et al. 2011), are known to possess a well-developed circular muscle layer around the caudal organ, which is assumed to facilitate sperm transfer. While the Brazilian specimens were not examined with transmission electron microscopy, CLSM and phalloidin staining provided a clear view of the specimens' splanchnic and somatic musculature (see Fig. 2e), and no caudal organ was discernable; it is important to note that a glandular caudal organ was visible in live specimens, fixed whole mounts, and stained specimens. An alternative explanation for the absence of muscles might be that they are only formed after complete development of the organ, i.e., the Brazilian specimens were still in the process of caudal organ development.

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