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Synopsis of the knowledge, zoogeography and an on-line interactive map of Brazilian marine gastrotrichs

Ariane Campos Equal first author, [1] , **André Rinaldo Senna Garraffoni** Corresp. Equal first author, [1]

[1] Departamento de Biologia Animal, Universidade Estadual de Campinas, Campinas, São Paulo, Brazil

Corresponding Author: André Rinaldo Senna Garraffoni
Email address: arsg@unicamp.br

Information regarding the records of Brazilian marine gastrotrichs is presented. We systematize and organize the existing information associated with approximately 23 species (8 endemic species from the Brazilian coast) and their 1,581 records from 36 marine ecoregions of the world. A link is provided to an on-line interactive map where all occurrences for each species are shown, accompanied by geographic co-ordinates, oceans, country, cities, granulometric characteristics and ecoregions. Furthermore, a critical analysis of the geographical distributions of Brazilian marine gastrotrichs, an estimate of the number of undescribed species, a summary of the existence and status of taxonomical collections, and a list of the current specialists for this taxon are also presented

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Ariane Campos and André Rinaldo Senna Garraffoni

Laboratório de Evolução de Organismos Meiofaunais, Departamento de Biologia Animal, Instituto de Biologia, Universidade Estadual de Campinas, 13083-862, Campinas, SP, Brazil

Corresponding Author
André R. S. Garraffoni, arsg@unicamp.br

Abstract

Information regarding the records of Brazilian marine gastrotrichs is presented. We systematize and organize the existing information associated with approximately 23 species (3 endemic species from the Brazilian coast) and their 1,581 records from 36 marine ecoregions of the world. A link is provided to an on-line interactive map where all occurrences for each species are shown, accompanied by geographic co-ordinates, oceans, country, cities, granulometric characteristics and ecoregions. Furthermore, a critical analysis of the geographical distributions of Brazilian marine gastrotrichs, an estimate of the number of undescribed species, a summary of the existence and status of taxonomical collections, and a list of the current specialists for this taxon are also presented.

Subjects: Marine Biology, Biodiversity, Taxonomy, Zoology
Keywords: Gastrotricha, Chaetonotida, Macrodasyida, biodiversity, species distribution.

Introduction

Organism diversity is a result of historical processes, and all extant species are phylogenetically connected through time. Therefore, it is only possible to understand the structural changes that we observe in the light of evolution (*Nunes & Christoffersen, 2009*). Knowledge regarding biodiversity, history and interconnections is essential in understanding and

anticipating the effects of disturbances, such as habitat destruction or the exchange of organisms between different localities, in this system (*Andreas Schmidt-Rhaesa, 2002*).

In the last decade, more than 20,000 marine species (9% of those currently known) have been described (*Appeltans et al., 2012*). The number of marine species described per year reached an all-time high in the past decade, with over 2,000 species described in each of four different years. The statistical model predicted a total of 540,000 marine species, with a 95% probability interval of 320,000 to 760,000. When stratified by the different taxonomic groups, the estimates were comparable to or less than the estimates. For taxonomic groups where the majority of species remain to be described, the rate of discovery is still rising; therefore, the model could not make a meaningful estimate of total species numbers, which was the case for Gastrotricha. (*Appeltans et al., 2012*).

Gastrotricha are microinvertebrates (from 80 µm to 3,500 µm) commonly found in marine and freshwater habitats that are recognized for their complex anatomy and life cycle, with a predominance of hermaphroditism (*Weiss 2001; Todaro & Hummon 2008; Balsamo et al. 2014; Kånneby & Hochberg 2014*). Although gastrotrichs can be considered a cosmopolitan taxon found on all major continents (*Kånneby & Hockberg 2014*), at least marine gastrotrichs show some level of endemism, mainly in the Northern Hemisphere (*Garraffoni & Balsamo, 2017*)

The taxon comprises approximately 820 species (*Todaro, 2019a,b*), traditionally divided into the two orders: Macrodasyida and Chaetonotida (see *Kieneke et al. 2008*). The first order comprises 9 families, 34 genera and more than 300 species (*Todaro, 2019a*), with strap-shaped bodies, the presence of pharyngeal pores and, usually, numerous adhesive tubes present in the anterior, lateral and posterior regions (*Todaro & Hummon 2008; Kånneby & Hockberg 2014*). The majority of macrodasyids are marine species; only four species have been reported in freshwater from the Swiss Alps, Brazilian streams and a reservoir and aquifer from the USA (*Ruttner-Kolisko 1955, Kisielewski 1987, Garraffoni et al. 2010, 2019; Todaro et al. 2012, Araújo et al. 2013, Kånneby & Wicksten 2014, Kånneby & Kirk, 2017*). Within Chaetonotida, 7 families, 30 genera and nearly 520 species (*Todaro, 2019b*) are interstitial or epibenthic in marine and brackish water, and 2/3 live in freshwater habitats (*Balsamo et al. 2008; 2014*). They are tenpin-shaped and have been reported to have one pair (rarely two) of adhesive tubules, limited to the posterior end (*Balsamo et al. 2008, Kånneby & Hochberg 2014*). The taxon

Chaetonotida is divided into two suborders: Multitubulatina (only one genus, *Neodasys*) and Paucitubulatina. Within this order, the family Chaetonotidae is the most specious taxon among the Gastrotricha, comprising approximately 1/3 of the species described for the whole group (*Kisielewski, 1991, 1997*).

Knowledge about marine gastrotrich biodiversity began to be discovered a few decades ago in South America (*Hochberg, 2014*). The first two mentions of the taxon in Brazil occurred when du Bois-Raymond Marcus (1952) reported an undescribed species of the genus *Thaumastoderma* collected at a 3-5 m depth off the coast of Ilhabela Island (northern coast of São Paulo state) and Forneris (1985) cited an undescribed species of the genus *Macrodasys* sampled in the intertidal zone of Porchat Island (Santos region of São Paulo state). However, we can consider that the gastrotrich fauna were not discovered until the pioneer taxonomical study was carried out by Todaro & Rocha (2004) along the northern coasts of the state of São Paulo (Ubatuba, Caragutatuba, Ilhabela and São Sebastião). In this first study, the authors described one new species, *Macrodasys fornerisae,* and reported 42 other species (most of these species were undescribed species belonging to Macrodasyida and Chaetonotida). One year later, Todaro and Rocha (2005) reported results of a second study, mostly conducted on the northern coasts of the state of São Paulo and, for the first time, in the southern part of the State of Rio de Janeiro (Paraty). In this second study, the authors found 30 species, most of which were also found in the first study, but they also reported some species not formally described and species recorded from the first time in Brazil. After, Todaro (2012, 2013) described the new species *Pseudostomella dolichopoda* and *Ptychostomella lamelliphora,* but they appeared as *Pseudostomella* sp. and *Ptychostomella* sp., respectively, in Todaro & Rocha (2004, 2005). All four of these studies performed by Antonio Todaro were part of a larger research programme studying the diversity of marine invertebrates of the northern coasts of the state of São Paulo (*Migotto & Tiago 1999*).

During the workshop "Taxonomy and Diversity of Marine Meiofauna" held in São Sebastião, state of São Paulo, (*Fonseca et al. 2014*), Hochberg (2014) described the new species *Crasiella fonseci*. Additionally, Araújo et al. (2014) described another species belonging to the genus *Pseudostomella* (*P. squamalongispinosa*). Araújo et al. (2014), for the first time, found and described a new species of Gastrotricha from Brazil outside of the state of São Paulo; the new species was found on the south coast of the state of Bahia (Nova Viçosa).

Araújo et al. (2016) reported a new record of *Pseudostomella dolichopoda* Todaro, 2012, originally described from the northern coast of São Paulo, and now collected from the state of Espírito Santo. Garraffoni et al. (2016) analysed the patterns of diversity in marine Gastrotricha among benthic habitats and localities along with the southeastern Brazilian coast. The authors concluded that the diversity patterns of Brazilian marine gastrotrichs could be explained by differences in sediment textures, tidal zones, and localities. Garraffoni et al. (2017) reported new records of marine gastrotrichs from sublittoral sediments around São Sebastião Island (where the municipality of Ilhabela is housed). Among the findings, species belonging to the genus *Acanthodasys* (Macrodasyida) were reported for the first time in the Southern Hemisphere, and *Dactylopodola todaroi* was described as a new species. Recently, Todaro et al. (2019) described a new Macrodasyida genus (*Kryptodasys*) with 3 distinct species from Italy, Sweden and Brazil. The Brazilian species (*Kryptodasys carlosrochai*) appeared as "*nov. gen. nov. spec.*" in Todaro and Rocha (2004).

The aim of the present study was to systematize and organize the knowledge about Gastrotricha diversity on the Brazilian coast, with a species inventory, critical analysis of geographical distribution patterns of these species and some future perspectives about the study of these taxa in Brazil.

Materials and Methods

MARINE ECOREGIONS OF THE WORLD

We avoided using geopolitical boundaries to analyse gastrotrich distributions because the delimitation of such areas does not reflect natural units (*Nihei, 2006*). Thus, we used the biogeographic regionalization for coastal and shelf areas proposed by Spalding et al. (2007) to establish the distribution patterns of species. The hierarchical system proposed by these authors has three levels of inclusiveness: ecoregion (smallest-scale unit), province (nested within the realm) and realm (largest spatial unit). In the present study, we used the spatial unit ecoregion, as it is defined as "Areas of relatively homogeneous species composition, clearly distinct from adjacent systems. The species composition is likely to be determined by the predominance of a small number of ecosystems and/or a distinct suite of oceanographic or topographic features" (*Spalding et al., 2007*).

The system proposed by Spalding et al. (2007) is composed of 232 ecoregions covering all coastal and shelf waters of the world. Among them, 5 ecoregions occur in Brazil: Amazonia, northeastern Brazil, eastern Brazil, southeastern Brazil and Rio Grande (Fig. 1).

LITERATURE DATABASE

Distribution data on marine gastrotrichs up to 2010 were obtained from the "Global distribution of marine Gastrotricha" compilation by Dr. William D. Hummon (*Todaro 2017b*), and from 2011 to 2017, we gathered data directly from the literature (see complete list in *Garraffoni & Balsamo, 2017*) (Fig. 1, Supplemental data 1). Furthermore, we also listed all species collected but not yet described by Todaro and Rocha (2004; 2005) and Garraffoni et al. (2017) and data obtained by ARSG and collaborators that is not yet published (Supplemental data 2).

BRAZILIAN SPECIES RECORDS

The species lists of Brazilian gastrotrichs followed the classification proposed by Todaro (2019a,b).

Below the name of each species there is mention about the type locality, a summary of records per country, and the total number of records in Brazil and the world. When possible, a brief remark about the current species distribution and taxonomy status is noted. The list of the geographic coordinates of the locality sites where each species was found are arranged following the world bioregionalization framework of ecoregions (the ecoregions number are the same as those reported by Spalding et al. [2007, 578]), countries and beaches.

INTERACTIVE MAP

All species listed in this paper were entered into a spreadsheet, and an interactive map was produced using My Maps in Google Drive. The map can be accessed at https://drive.google.com/open?id=1OHFZF9r5PAR_WiNDLuR5209Z5o9_cfFk&usp=sharing. Screenshots from the My Maps of Marine Gastrotrichs of Brazil are shown in Figure 2 for instructional purposes. Three views are available: Cosmopolitan species in a first layer, with a species distribution around the world (Fig. 2a), Endemic Brazilian species (Fig. 2b) and map view with information of species (Fig. 2c). Names of species can be displayed using the filter

function, where species occurrences can be filtered (Figs. a,b). Each occurrence in the map is clickable, resulting in a window showing an image of the species and information about the record (Fig. 2c).

Schematic drawings of those species formally described in Brazil were redrawn from original descriptions or redescriptions. Micrographs of specimen habitus were used to exemplify the species collected by researchers from the Laboratory of the Meiofaunal Organisms Evolution and yet not formally described. In this case, samples of the upper sediment layer were collected with a manual corer, and in the laboratory, the specimens were sorted with a Zeiss DM2000, mounted on glass slides, observed in vivo under a Zeiss Axioskop 2 plus equipped with differential interference contrast (DIC) and AxioCam MRC5 digital video camera.

Results

To date, specimens of 23 species were collected from the Brazilian coast, and all of these named taxa (at the species level) are considered valid according to modern standards. The order Chaetonotida is the most speciose with 14 species (Chaetonotidae: *Aspidiophorus mediterraneus*; *Aspidiophorus paramediterraneus*; *Aspidiophorus tentaculatus*; *Chaetonotus apechochaetus*; *Chaetonotus atrox*; *Chaetonotus dispar; Chaetonotus neptuni*; *Halichaetonotus decipiens*; *Halichaetonotus marivagus*; *Halichaetonotus spinosus*; Xenotrichulidae: *Draculiciteria tesselata*; *Heteroxenotrichula pygmaea*; *Heteroxenotrichula squamosa*; *Xenotrichula intermedia.* In contrast, 10 species are listed within the order Macrodasyida (Thaumastodermatidae: *Pseudostomella dolichopoda*, *Pseudostomella squamalongispinosa, Ptychostomella lamelliphora*; Planodasyidae: *Crasiella fonseci*; Macrodasyidae: *Macrodasys fornerise, Urodasys viparus*, *Kryptodasys carlosrochai*; Dactylopodolidae: *Dactylopodola baltica*, *Dactylopodola todaroi*).

Only 8 species (30%), all belonging to the order Macrodasyida (*Pseudostomella dolichopoda*, *Pseudostomella squamalongispinosa, Ptychostomella lamelliphora*, *Crasiella fonseci*, *Macrodasys fornerise, Dactylopodola todaroi, Kryptodasys carlosrochai*), were originally described from samples collected in Brazil. Since the first marine gastrotrichs originally described in Brazil were published in 2004 and the last one in 2019, the historical rates of species description are 0.43/per year, much lower when compared, in the same period, with the world historical rates of marine gastrotrich descriptions (8.93/per year).

The number of species registered from the Brazilian coast was only 25% of the total marine gastrotrichs richness estimate, as 66 species were collected but not yet formally (Supplemental data 2). Among these unpublished species, some of them, *e.g.*, *Xenodasys* sp. (Fig. 3) (Xenodasyidae), *Acanthodasys* sp1 and sp2 (Thaumastodermatidae), *Mesodasys* sp., *Dolichodasys* sp. (Cephalodasyidae), *Dendrodasys* sp., *Dendrodasys* aff. *rubomarinus* (Dactylopodolidae) are mentioned for the first time in the Southern Hemisphere.

Gastrotrichs samplings conducted on the Brazilian coastline were performed on at least 38 distinct beaches: 26 in the state of São Paulo (69%), 5 in the state of Rio de Janeiro (13%), 3 in the states of Bahia (7%) and Paraná (7%) and 1 in the state of Espírito Santo (4%).

Nominal species records of Brazilian marine gastrotrichs were present in 37 ecoregions, covering 6.2% of the marine ecoregions of the world (total of 232 ecoregions). Among the 9 ecoregions found in the bioregionalization of the Brazilian coast, only 2 (22%) of them registered the occurrence of species. Among these 2 ecoregions, another strong bias was observed; one of them, Southeastern Brazil (which encompass the northern coast of São Paulo State and southern coast of Rio de Janeiro), contained 97% of the sampling sites in Brazil. Furthermore, the registered gastrotrich species appear to have a very heterogeneous geographic distribution, with few restricted/endemic species (27%) or species with a relatively wide distribution, such as *Heteroxenotrichula pygmaea* and *Aspidiophorus parameditерraneus* present in 21 ecoregions, *Heteroxenotrichula intermedia* in 19 ecoregions, *Aspidiophorus mediterraneus* and *Chaetonotus larrox* in 17 ecoregions and *Halichaetonotus euromarinus, Draculiciteria tesselata* and *Urodasys viviparus* in 13 ecoregions.

Discussion

HISTORICAL STUDY OF BRAZILIAN GASTROTRICHA

This is the first historical review on the gastrotrichs occurring along the Brazilian coast and the first synthesis of the available literature shown as an annotate species checklist. Although the obtained data showed scattered references from Brazilian literature, this panorama has started to change slowly. Historically, in Brazil (and in many other countries Southern Hemisphere, *e.g., Hummon, 1974*; *Hochberg, 2003, 2009; Todaro et al. 2015a,b, 2017*), only sporadic collections were carried out by foreign researchers, and the involvement of Brazilian researchers could thus be considered incipient (*Balsamo et al., 2014; Garraffoni & Balsamo, 2017*). Furthermore, any

research team dedicated to the study this group of animals was active, so the information about diversity was poor and fragmented. However, this panorama started to change slowly when, a few years ago, the senior author of the present study became the first active Brazilian researcher in Brazil and started to coordinate a research group interested in uncovering the systematics, evolution and biogeography of Brazilian gastrotrichs. Thus, tendency to organize and coordinate the researchers who study gastrotrichs as their main or preferred working group seems positive. As an exemplar of this new era in the gastrotricology in Brazil, at least 3 research projects are currently being conducted on marine fauna (1 postdoctoral, 1 PhD and 2 MsC theses).

Garraffoni (2017) noted three major gaps in the current knowledge about Brazilian freshwater Gastrotricha: a) large extensions of the Brazilian inland waters have never been sampled before (records show a strong bias because most of the sampling sites were conducted in the state of São Paulo, and only few samples were conducted in other states); b) identification keys for a great number of genera are absent and there is difficulty in obtaining classic and old literature from the end of century XIV and early century XX; and c) reference collections about the taxon in Brazilian Museums are absent.

Unfortunately, most of these gaps are also observed for marine animals. Most of the surveys are concentrated on the northern coast of São Paulo state and the southern coast of Rio de Janeiro state (*Todaro & Rocha 2004, 2005, Todaro 2012, 2013, Hochberg, 2014, Garraffoni et al. 2017, Todaro et al. 2019*), and only two studies were performed outside this area (Araújo et al. 2014: Bahia State; Araújo et al. 2016: Espírito Santo state) (see below section Brazilian Gastrotricha distribution patterns). This panorama does not change even if we considered those species that were not formally described (supplementary material).

The unique Brazilian collection, with adequate and permanent curatorial attention in Brazil, which contains type material regarding marine Gastrotricha is located in the Zoological Museum "Adão José Cardoso" (ZUEC) of the State University of Campinas. This museum houses the type series for *Pseudostomella squamalongispinosa* Araújo, Balsamo & Garraffoni 2014 (GCH 02-04), *Dactylopodola todaroi* Garraffoni, Di Domenico & Hochberg, 2016 (GCH 26-28) and *Crasiella fonseci* Hochberg, 2014. Regarding this last species, due to problems sending back the type material to Brazil (*pers. comm. R. Hochberg*), in the original description, it was only mentioned that the holotype was deposited at the ZUEC, but without an accession number. However, we had the possibility to obtain the original type material and deposit it at the

ZUEC as GCH-51. Furthermore, additional material was deposited for *Pseudostomella dolichopoda* Todaro, 2012 (GCH 29). The Zoological museum is housed in the same university where the senior author of the present study conducts his research and supervision activities, and it is possible that the number of deposited species will increase in a short period of time. However, the representation of the Gastrotricha specimens in collections in Brazil (and also in the world) is extremely poor.

The only significant difference between Brazilian marine and freshwater gastrotrichs is related to the number of available identification keys; the availability of identification keys is much higher for the former than for the latter. In the last year, taxonomic keys for 6 genera belonging to Gastrotricha were published, and many species of these taxa were recorded in Brazil, *e.g., Aspidiophorus* (*Todaro et al. 2009)*; *Tetranchyroderma* (*Todaro 2002)*; *Pseudostomella* (*Clausen, 2004; Todaro 2012; Araújo et al. 2016*); *Paraturbanella* (*Todaro et al. 2017)*; *Dactylopodola* (*Von Und Zu Gilsa et al. 2014*); *Cephalodasys* (*Kieneke et al. 2015*).

If the taxonomic knowledge of Brazilian gastrotrichs is far from appropriate, then studies on other biological aspects, such as gastrotrich ecology or natural history, are totally absent.

BRAZILIAN GASTROTRICHA DISTRIBUTION PATTERNS

In general, in recent years, researchers interested in better understanding the gastrotrich distribution have given more attention to geographic locations known for poor sampling (*e.g., Todaro & Rocha, 2004, 2005; Todaro, 2012, 2013; Hochberg, 2003, 2009, 2014; Hochberg et al. 2013; Todaro et al. 2014; 2015a,b, 2017, 2019; Kieneke et al. 2015; Garraffoni et al. 2016, 2017; Von Und Zu Gilsa et al. 2014; Araújo et al. 2014, 2016; Araújo & Hochberg, 2017; Chatterjeeet al. 2019*).

In this scenario, when compared to the other countries in South America (Colombia: *Hummon, 1974;* Ecuador, Galapagos Island*: Schmidt 1974;* and Uruguay*: Dioni 1960*), the information of the Gastrotricha fauna in Brazil can be considered to be more complete. However, when only Brazil, with a coastline encompassing almost 7,500 km and varying between ~5° and ~25° of longitude, was analysed, it was found that more than 95% of the country was never sampled. Furthermore, only the coast of São Paulo state (southeast Brazil) can be considered relatively more complete (*Todaro & Rocha 2004, 2005; Todaro 2012, 2013; Hochberg, 2014; Garraffoni et al. 2016, 2017; Todaro et al. 2019; supplementary material*). It is important to

highlight that these results in the state of São Paulo did not happen by accident because many initiatives for funding studies that aimed to reveal the biodiversity of fauna and flora in the state were supported the Virtual Institute of Biodiversity, BIOTA-FAPESP, organized by FAPESP, the State of São Paulo Research Foundation (*Migotto & Tiago 1999; Joly et al. 2010*).

However, if we compared the number of sampled beaches along the São Paulo coastline (26) with the total number beaches in continental and islands in the state (342), the sampling effort is very low, with a very limited number of sample sites (7% of the total beaches in the state). With we considered the states of São Paulo and Rio de Janeiro, which together support 85% of the sampled sites located in Brazil, the sampling effort is even worse (4% of the total beaches in both states). For comparison purposes, the Italian coastline encompasses almost 7,800 km and has the best data information about marine Gastrotricha fauna in the Mediterranean and Black Sea countries *(Todaro et al. 2003*), if not one of the best in the world in this country, gastrotrichs were sampled in 246 localities and comprise 177 different species.

As noted above, this difference regarding the knowledge of gastrotrich biodiversity between the Northern and Southern hemispheres occurs because historically, studies dedicated to this group of animals were conducted by European or American Institutions (*Balsamo et al. 2014; Garraffoni & Balsamo, 2017*). Thus, this discrepancy in information between the two hemispheres has some consequences; a) the first record and description of a marine gastrotrichs in the Mediterranean was done by Claparède (1867). In contrast, the first mention of a Brazilian gastrotrich was noted by Eveline du Bois-Raymond Marcus 85 years after the René-Édouard Claparède publication (*Bois-Raymond Marcus, 1952*), and it was approximately 140 before for Antonio Todaro and Carlos Rocha named the first new species from Brazil (*Todaro & Rocha, 2004*). b) 70% of the marine gastrotrich sampling sites around the world are located in the Northern Hemisphere (mainly in Atlantic coast of United States, Mediterranean and Great Britain coasts) (*Garraffoni & Balsamo, 2017*). c) In recent years, the number of studies dealing with the reconstruction of phylogenetic relationships within Gastrotricha based on molecular data has increased (*Todaro et al., 2011, 2012, 2014, 2015b*). However, the majority of DNA used in these studies was extracted from species collected in the Northern Hemisphere.

Despite the bias in sampling efforts, the geographic ranges of the Brazilian marine gastrotrichs range from relatively restricted distributions, i.e., 1 or 2 ecoregions (6 species) to widespread distributions, i.e., at least 4 ecoregions (22 species). These numbers have a totally

opposite tendency compared to marine gastrotrichs worldwide, as 80% of the species are distributed in only 2 ecoregions (*Garraffoni et al. unpublished data*). A possible explanation for this large number of widely distributed species may be related to the need for generalist taxonomy studies, which are very important to begin the immense challenge of discovering a very diverse and practically unknown (until less than 15 years ago) fauna (*Todaro & Rocha, 2004, 2005; Garraffoni et al., 2017*). As a consequence, the absence of wide-scale reviews in the country can produce uncontextualized taxonomic revisions and spurious data on biodiversity. Finally, in recent years, the ubiquitous distribution of marine gastrotrichs has been challenged (*Kieneke et al. 2012; Curini-Galletti et al., 2012; Garraffoni et al. 2016; Garraffoni & Balsamo, 2017*), and it seems that the number of widespread species is not as high as previously thought.

BRAZILIAN GASTROTRICHA RICHNESS

As reported above, due to the low number of taxonomic studies and sample bias along the Brazilian coast, we can provide the estimated richness of gastrotrichs only for the coasts of the states of São Paulo and Rio de Janeiro. Garraffoni et al. (2016) through a rarefaction function, we estimated 155 Gastrotricha species from the southeast Brazilian coast. Despite the fact that this last number is higher than the observed number species found in the present study, an interesting clarification must be made. We counted at least 87 species registered in this area, but 65 of them were not formally described. Thus, we have good support to say that at least 130 species of marine gastrotrichs from only 5% of the Brazilian coast are waiting to be described. Furthermore, many of these undescribed species belong to very rare taxa, *e.g.*, *Diplodasys* sp., *Dolichodasys* sp., *Mesodasys* sp., *Paradasys* sp., (*Todaro & Rocha, 2004*), sometimes never reported before from the Southern Hemisphere, *e.g.*, *Acanthodasys* sp. 1 and sp. 2 (*Garraffoni et al. 2017*) or *Xenodasys* sp. collected in 2018 at Fome Beach, Ilhabela Island, northern coast of São Paulo state (Fig. 3). The last species belongs to a genus with only three species, each with regional (limited) distributions (*Schuster et al. 2018*).

The large number of unknown species found on the southeastern Brazilian coast is not a surprise. To date, 507 marine gastrotrichs (*Garraffoni & Balsamo, 2017; Todaro, 2019a*) have been described from all the world's oceans, but at least 2,244 to 3,244 species are still unknown and undiscovered (*Appeltans et al. 2012*). Using species richness as a metric for assessment of

the worldwide marine gastrotrich biodiversity, only less than 20% are known (*Appeltans et al. 2012*).

Conclusions

Although the biogeographical knowledge about Brazilian gastrotrich fauna is greatly hampered by regional discrepancies in taxonomic knowledge, there is no doubt about the high diversity of the group and that many new species will be described. It is very important that to carry out studies that aim to sample new areas in different regions along the Brazilian coastline, increase the availability of Brazilian species deposited in museums and increase the amount of nuclear research groups interested in contributing to the increase in the systematic, evolutionary and ecological knowledge of the meiofauna organisms. The on-line map can be interpreted as a starting point to increase the understanding of the diversity and biogeographic patterns of gastrotrichs in Brazil and their affinities with other geographic regions.

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Additional Information and Declarations

FUNDING

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COMPETING INTERESTS

The authors declare that they have no competing interests.

DATA AVAILABILITY

The following information was supplied regarding data availability: Raw data are available in the Supplemental Materials.

FIGURE CAPTIONS

Figure 1. World map with the bioregionalization hierarchical system of ecoregions according to Spalding et al. (2007). Ecoregions observed on the Brazilian coast are coloured light blue. Dots are the sampling sites of the marine gastrotrich species found in Brazil (endemic or not).

Figure 2. Screenshots of the interactive map of Marine Gastrotrichs of Brazil. (A) Row view. (B) Card view. (C) Map view indicating the points where Gastrotricha species were collected. The dataset can be used with the filter function and the card that appears in the point.

Figure 3. *Xenodasys* sp., DIC images from Brazil. (A) Habitus. (B). Dorsal view of the head region with tentacles. (C) Ventral view of the head region with tentacles. (D) Ventral view of the middle body with ventrolateral adhesive tubes. (E) Ventral view of the posterior end. Abbreviations: co, chordoidorgan; cp, cephalic plates; lsp, lateral spines; TbA, anterior adhesive tubes; TbP, posterior adhesive tubes; TbVL, ventrolateral adhesive tubes; ten, head tentacles. Scales: A. 45 µm; B-E. 20 µm.

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Table 1(on next page)

Table 1

Table 1. List of marine species in different ecoregions reported by Spalding et al. (2007). Ecorregion: Eco; Number: N; Aspidiophorus: Asp; Chaetonotus: Cht; Halichaetonotus: Hal; Heteroxenotrichula: Het; Draculiciteria: Dra; Crasiella: Cra; Dactylopodola: Dact; Dendrodasys: Den; Macrodasys: Mac; Urodasys: Uro; Pseudostomella: Pse; Ptychostomella: Pty.

Table 1. List of marine species in different ecoregions reported by Spalding et al. (2007). Ecorregion: Eco; Number: N; *Aspidiophorus*: Asp; *Chaetonotus:* Cht; *Halichaetonotus: Hal*; *Heteroxenotrichula*: *Het*; *Draculiciteria*: *Dra*; *Crasiella*: *Cra*; *Dactylopodola*: *Dact*; *Dendrodasys*: *Den*; *Macrodasys*: *Mac*; *Urodasys*: *Uro*; *Pseudostomella*: *Pse*; *Ptychostomella*: *Pty.*

Eco name	**Eco no**	**List of species**	**No of taxa**	**No of genera**
Northern Norway and Finnmark	23	*Het. intermedia*	1	1
Baltic Sea	24	*Het. intermedia, Dact. baltica*	2	2
North Sea	25	*Asp. mediterraneus, Asp. parameditерraneus, Cht. atrox, Cht. neptuni, Hal. decipiens, Hal. euromarinus, Het. pygmaea, Het. squamosa, Het. intermedia, Dra. tesselata, Dact. baltica*	11	6
Celtic Seas	26	*Asp. mediterraneus, Asp. parameditерraneus, Cht. atrox, Cht. dispar, Cht. neptuni, Hal. decipiens, Hal. euromarinus, Het. pygmaea, Het. squamosa, Het. intermedia, Dra. tesselata, Dact. baltica*	12	6
South European Atlantic Shelf	27	*Asp. mediterraneus, Asp. parameditерraneus, Hal. decipiens, Hal. euromarinus, Het. squamosa, Het. intermedia, Dra. tesselata*	7	4
Azores Canaries Madeira	29	*Cht. atrox, Het. pygmaea, Dra. tesselata*	3	3
Adriatic Sea	30	*Asp. mediterraneus, Asp. parameditерraneus, Cht. apechochaetus, Cht. atrox, Cht. dispar, Cht. neptuni, Hal. decipiens, Hal. euromarinus, Het. pygmaea, Het. squamosa, Het. intermedia, Dra. tesselata, Uro. viviparus*	13	6
Aegean Sea	31	*Asp. mediterraneus, Asp. parameditерraneus; Asp. tentaculatus, Cht. apechochaetus, Cht. atrox, Cht. neptuni, Hal. decipiens, Hal. euromarinus, Hal marivagus, Het. pygmaea, Het. squamosa, Het. intermedia, Dact. baltica, Uro. viviparus*	14	6
Levantine Sea	32	*Asp. parameditерraneus, Cht. apechochaetus,*	11	6

		Cht. atrox, Cht. neptuni, Hal. decipiens, Hal. euromarinus, Het. pygmaea, Het. squamosa, Het. intermedia, Dact. baltica, Uro. viviparus		
Ionian Sea	34	*Asp. mediterraneus, Asp. parameditерraneus, Cht. apechochaetus, Cht. atrox, Cht. dispar, Cht. neptuni, Het. squamosa, Het. intermedia, Dra. tesselata, Uro. viviparus*	10	5
Western Mediterranean	35	*Asp. mediterraneus, Asp. parameditерraneus, Asp. tentaculatus, Cht. apechochaetus, Cht. atrox, Cht. dispar, Cht. neptuni, Hal. decipiens, Hal. euromarinus, Hal marivagus, Het. pygmaea, Het. squamosa, Het. intermedia, Dra. tesselata, Uro. viviparus*	15	6
Gulf of Maine/Bay of Fundy	40	*Asp. mediterraneus, Asp. parameditерraneus, Hal. decipiens, Hal. euromarinus, Het. pygmaea, Het. squamosa, Het. intermedia, Dra. tesselata, Dact. baltica*	9	5
Virginian	41	*Asp. mediterraneus, Asp. parameditерraneus, Cht. atrox, Cht. dispar, Hal. euromarinus, Het. pygmaea, Het. squamosa, Het. intermedia, Dact. baltica*	9	5
Carolinian	42	*Asp. mediterraneus, Asp. parameditерraneus, Cht. neptuni, Hal. euromarinus, Het. pygmaea, Het. squamosa, Het. intermedia, Dra. tesselata, Dact. baltica*	9	6
Northern Gulf of Mexico	43	*Asp. mediterraneus, Asp. parameditерraneus, Cht. atrox, Cht. dispar, Hal. decipiens, Hal. euromarinus, Het. pygmaea, Het. squamosa, Het. intermedia, Dra. tesselata*	10	5
Black Sea	44	*Asp. mediterraneus, Hal. decipiens, Het. pygmaea, Het. intermedia*	4	3
Oregon, Washington, Vancouver Coast and Shelf	57	*Het. pygmaea*	1	1
Southern California Bight	59	*Het. intermedia*	1	1
Bermuda	62	*Uro. viviparus*	1	1

Bahamian	63	*Asp. mediterraneus, Asp. parameditерraneus, Het. pygmaea*	3	2
Eastern Caribbean	64	*Asp. parameditерraneus, Cht. dispar, Het. pygmaea, Dra. tesselata*	4	4
Southwestern Caribbean	67	*Uro. viviparus*	1	1
Greater Antilles	65	*Asp. tentaculatus*	1	1
Western Caribbean	68	*Asp. parameditерraneus*	1	1
Floridian	70	*Asp. mediterraneus, Asp. parameditерraneus, Asp. tentaculatus, Cht. atrox, Cht. dispar, Cht. neptuni, Hal. euromarinus, Het. pygmaea, Het. squamosa, Dra. tesselata, Dact. baltica, Uro. viviparus*	12	7
Eastern Brazil	76	*Pse. dolichopoda, Pse. squamalongispinosa*	2	1
Northern and Central Red Sea	87	*Asp. mediterraneus, Asp. parameditерraneus, Asp. tentaculatus, Cht. apechochaetus, Cht. atrox, Cht. neptuni, Hal. decipiens, Het. pygmaea, Het. squamosa, Uro. viviparus*	10	5
Central Somali Coast	93	*Asp. mediterraneus, Asp. parameditерraneus*	2	1
Maldives	105	*Cht. atrox, Uro. viviparus*	2	2
Eastern India	107	*Cht. atrox, Het. intermedia, Uro. viviparus*	3	2
Andaman and Nicobar Islands	109	*Cht. atrox, Uro. viviparus*	2	2
South Kuroshio	121	*Cht. atrox, Het. pygmaea*	2	2
Hawaii	153	*Asp. parameditерraneus, Het. pygmaea*	2	2
Guayaquil	171	*Asp. parameditерraneus, Het. intermedia*	2	2
Eastern Galapagos Islands	173	*Het. pygmaea*	1	1
Southeastern Brazil	180	*Asp. mediterraneus, Asp. parameditерraneus, Asp. tentaculatus, Cht. apechochaetus, Cht. atrox, Cht. dispar, Cht. neptuni, Hal. decipiens, Hal. euromarinus, Hal marivagus, Het. pygmaea, Het. squamosa, Het. intermedia, Dra. tesselata, Cra. fonseci, Dact. baltica, Dact todaroi, Den.* aff. *rubomarinus, Mac. fornerise, Uro. viviparus, Pse. dolichopoda, Pse. squamalongispinosa, Pty. lamelliphora*	23	12

Figure 1

Figure 1

World map with the bioregionalization hierarchical system of ecoregions according to Spalding et al. (2007). Ecoregions observed on the Brazilian coast are coloured light blue. Dots are the sampling sites of the marine gastrotrich species found in Brazil (endemic or not).

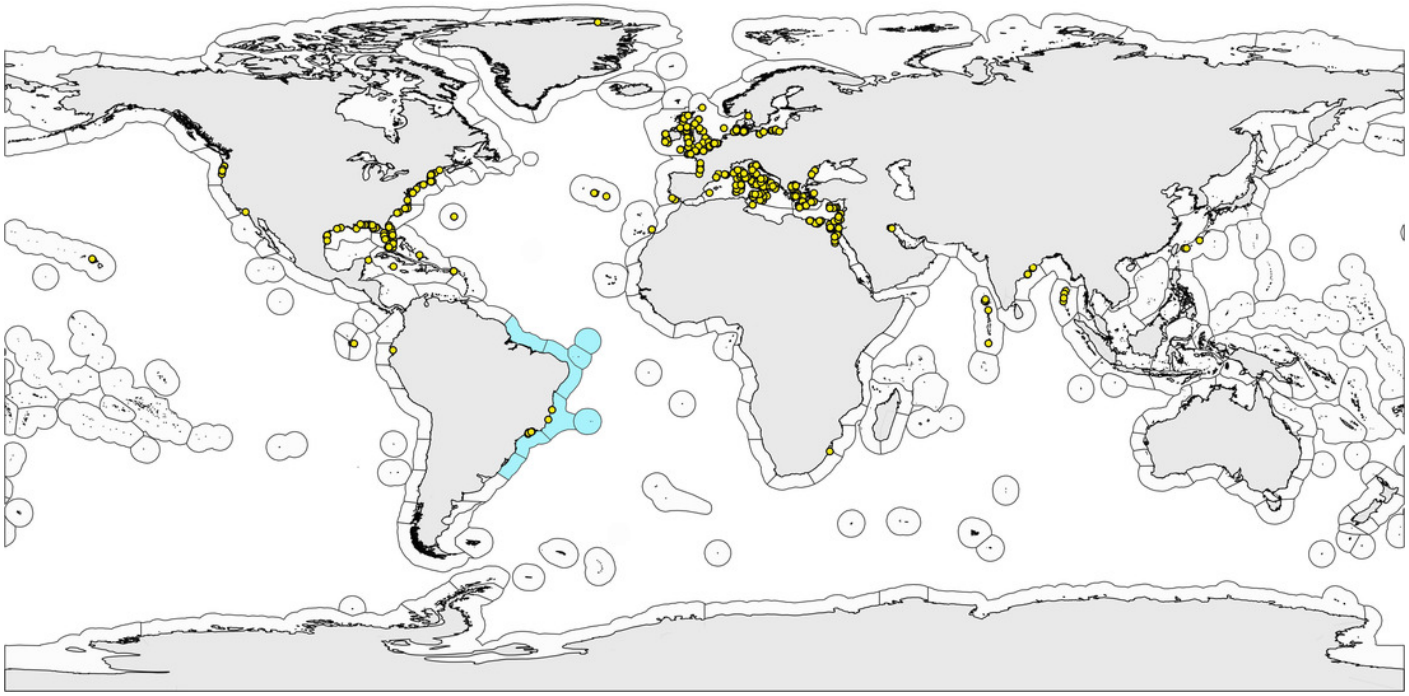


Figure 2

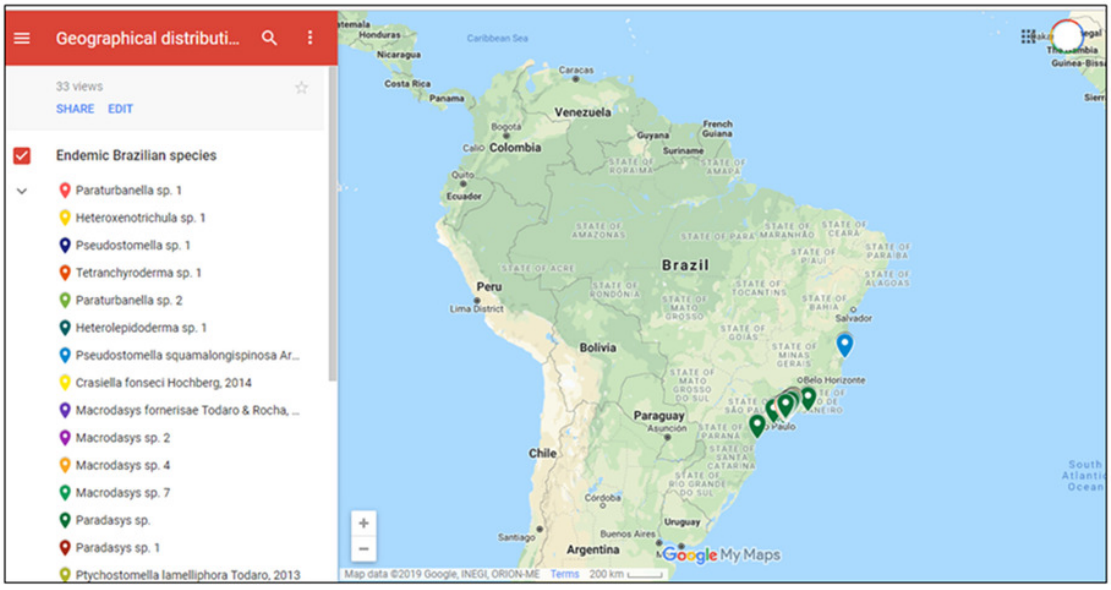
Figure 2

Screenshots of the interactive map of Marine Gastrotrichs of Brazil. (A-C) Map views indicating the points where Gastrotricha species were collected.

A


Geographical distributi...
Cosmopolitan species
Halichaetonotus euromarinus Hummon ...
Aspidiophorus parameditерraneus Hum...
Heteroxenotrichula squamosa Wilke, 1954
Draculiciteria tesselata (Renaud Mornan...
Chaetonotus (S.) atrox Wilke, 1954
Aspidiophorus mediterraneus Remane, 1...
Xenotrichula intermedia Remane, 1934
Heteroxenotrichula pygmaea (Remane, 1...
Chaetonotus (S.) dispar Wilke, 1954
Chaetonotus apechochaetus Hummon, ...
Chaetonotus (S.) neptuni Wilke, 1954
Halichaetonotus decipiens (Remane, 19...
Dactylopodola baltica (Remane, 1926)
Urodasys viviparus Wilke, 1954
Aspidiophorus tentaculatus Wilke, 1954
Halichaetonotus marivagus Balsamo, To...
Pseudostomella dolichopoda Todaro, 20...
Google My Maps

B


Geographical distributi...
33 views
SHARE EDIT
Endemic Brazilian species
Paraturbanella sp. 1
Heteroxenotrichula sp. 1
Pseudostomella sp. 1
Tetranchyroderma sp. 1
Paraturbanella sp. 2
Heterolepidoderma sp. 1
Pseudostomella squamalongispinosa Ar...
Crasiella fonseci Hochberg, 2014
Macrodasys fornerisae Todaro & Rocha, ...
Macrodasys sp. 2
Macrodasys sp. 4
Macrodasys sp. 7
Paradasys sp.
Paradasys sp. 1
Ptychostomella lamelliphora Todaro, 2013
Venezuela
Colombia
Brazil
Peru
Bolivia
Paraguay
Chile
Argentina
Google My Maps

C

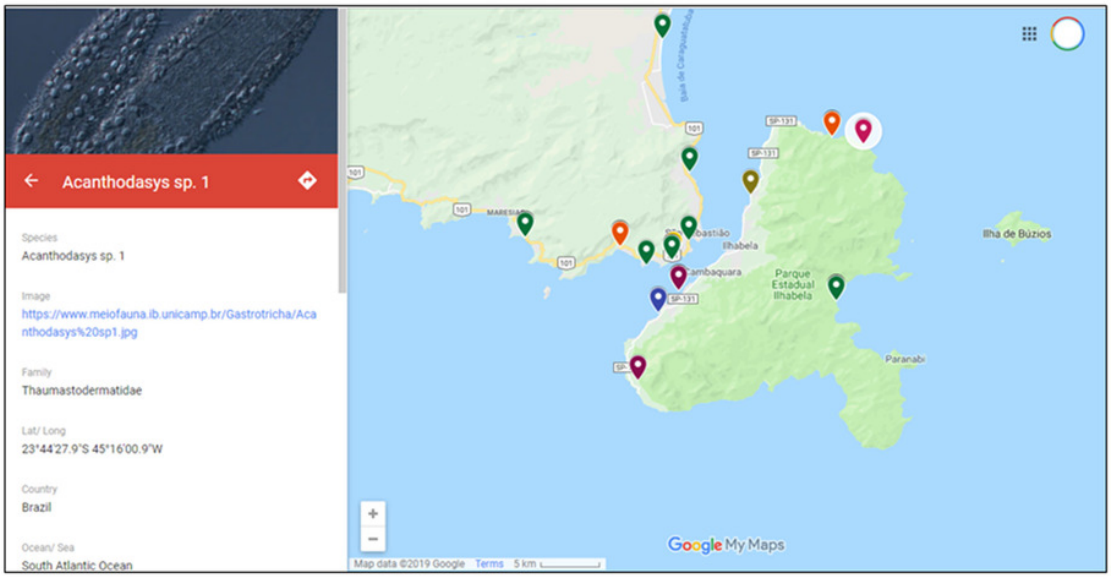

Acanthodasys sp. 1
Species
Acanthodasys sp. 1
Image
https://www.meiofauna.ib.unicamp.br/Gastrotricha/Acanthodasys%20sp1.jpg
Family
Thaumastodermatidae
Lat/ Long
23°44'27.9"S 45°16'00.9"W
Country
Brazil
Ocean/ Sea
South Atlantic Ocean
Ilha de Búzios
Google My Maps

Figure 3

Figure 3

Xenodasys sp., DIC images from Brazil. (A) Habitus. (B). Dorsal view of the head region with tentacles. (C) Ventral view of the head region with tentacles. (D) Ventral view of the middle body with ventrolateral adhesive tubes. (E) Ventral view of the posterior end. Abbreviations: co, chordoidorgan; cp, cephalic plates; lsp, lateral spines; TbA, anterior adhesive tubes; TbP, posterior adhesive tubes; TbVL, ventrolateral adhesive tubes; ten, head tentacles. Scales: A. 45 µm; B-E. 20 µm.