



RESEARCH ARTICLE
TAXONOMIC CATALOG OF THE BRAZILIAN FAUNA

Taxonomic Catalog of the Brazilian Fauna: the intriguing copepod order Monstrilloida (Crustacea: Copepoda), taxonomy and diversity

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ABSTRACT. Monstrilloid copepods are endoparasites of marine benthic invertebrates (i.e., polychaetes, molluscs) during their juvenile stages. A final copepodite stage V preadult leaves the host and moults into a non-feeding, reproductive planktonic adult. The taxonomy of Monstrilloid copepods has been historically complex. The current list of species of Brazilian Monstrilloida is available from the “Catálogo Taxonômico da Fauna do Brasil” website (CTFB), an on-line database with taxonomic information on the species known to occur in Brazil. Based on current taxonomical contributions, a total of 14 valid nominal species of Monstrilloida have been recorded from Brazil, including six endemic species (43%). Species of *Cymbasoma* (five species: 36%) and *Monstrilla* (six species: 43%) total up to 78% of the Brazilian monstrilloid species diversity. *Monstrillopsis* and *Caromiobenella* are both represented by three species. Records of Monstrilloida are concentrated in the East, Southeast, and Northeast regions of the country, with an absence of records for the Rio Grande region. The records of Monstrilloid copepods should be revised in the light of evidence suggesting that widespread nominal species like *Cymbasoma longispinosum* Bourne, 1890, *Cymbasoma rigidum* Thompson I.C., 1888, *Monstrillopsis dubia* (Scott T., 1904), and *Monstrilla grandis* Giesbrecht, 1891 probably represent species complexes. A better knowledge of the taxonomy, distribution, and biology of the Brazilian Monstrilloida taxa is important to support their conservation. The revision of previous records, the occurrence of species complexes among the Brazilian monstrilloid fauna, the discovery of hosts, and reliably matching males and females of monstrilloids are pending assignments to significantly improve our knowledge of the group.

KEY WORDS. Biodiversity, biomas, Brazilian monstrilloids, distribution, parasitic copepods, species complex.

INTRODUCTION

The order Monstrilloida Sars, 1901 represents one of the most puzzling taxa among the widespread and highly diverse crustacean Class Copepoda (Suárez-Morales 2011, 2018). Monstrilloids are endoparasites of marine benthic invertebrates during their juvenile stages, which include an infective lecithotrophic naupliar stage and four endoparasitic nauplioid stages feeding on the fluids of the host (Suárez-Morales 2018). During their endoparasitic immature stages, monstrilloids can be detected as external nodules on the mantle of molluscs or growing swellings of the body

surface of polychaetes. A final copepodite stage V preadult copepodite stage exits through the body wall of the host and soon moults into a non-feeding, reproductive planktonic adult that lacks mouthparts (Suárez-Morales et al. 2014).

Monstrilloids are rarely found; a small number of individuals can be obtained occasionally in plankton samples from shallow coastal and estuarine environments, particularly at night. They have been collected in deep-water samplings of epibenthic fauna (Suárez-Morales and Mercado-Salas 2023). There are reports of relatively high local concentrations of monstrilloids from reef-related areas (Suárez-Morales 2001a). As parasites, they can affect

the populations of commercially valuable molluscs (Carneiro-Schaefer et al. 2017), causing detectable histopathological damages (Suárez-Morales et al. 2010) or the death of their polychaete hosts (Suárez-Morales et al. 2014).

Monstrilloid copepods have been noticed since the earliest marine planktological surveys, during the 19th century. Most of the first species descriptions were from the Northeast Atlantic and the Mediterranean (Grygier 1995, Suárez-Morales and Grygier 2021). The first record of a monstrilloid copepod was published by Krøyer (1842), who illustrated a single specimen from a Norwegian fjord; he named it *Thaumatoessa typica* Krøyer, with no descriptive text accompanying the figure. A description was provided by him later but with a different name: *Thaumaleus typicus* Krøyer, 1849 and a brief diagnosis of this new nominal genus. The original specimen was re-examined by Grygier (1993), who determined that this first described monstrilloid is in fact a preadult (i.e., CV copepodite) specimen, likely a species of *Monstrilla*. *Thaumaleus* is thus now a junior subjective synonym of *Monstrilla*, but *Monstrilla* in turn became a subjective junior synonym of *Thaumatoessa* (Grygier 1993). To conserve the widely used *Monstrilla*, *Thaumatoessa* was suppressed by the International Commission on Zoological Nomenclature. Krøyer's studies began a long and complex history of nomenclatural and taxonomic problems that are still being treated (Grygier 1995, Grygier and Suárez-Morales 2018, Suárez-Morales and Grygier 2021).

With the recent exclusion of *Strilloma* Isaac, 1974 as a valid genus (Suárez-Morales and Gasca 2004), and the description of two monotypic genera from Canada and Australia, the order Monstrilloida currently includes nearly 180 nominal species worldwide; they are all contained in Monstrillidae Dana, 1849, which is currently known to comprise seven valid genera: *Monstrilla* Dana, 1849, *Cymbasoma* Thompson, 1888, *Monstrillopsis* G.O. Sars, 1921, *Maemonstrilla* Grygier & Ohtsuka, 2008, *Australomonstrillopsis* Suárez-Morales & McKinnon, 2014, *Caromiobenella* Jeon, Lee & Soh, 2018, and *Spinomonstrilla* Suárez-Morales, 2019 (Grygier and Ohtsuka 2008, Suárez-Morales 2011, 2018, 2019, Jeon et al. 2018). Until 2016–2017, when Suárez-Morales and McKinnon (2016) added 25 species to *Cymbasoma* and Jeon et al. (2018) reassigned 10 species of *Monstrilla* to *Caromiobenella*, *Monstrilla* was clearly the most speciose genus within the order (see Suárez-Morales 2011), but it is currently the second (53 species) after *Cymbasoma* (79) and followed by *Monstrillopsis* (20), *Caromiobenella* (10), *Australomonstrillopsis* (1), and *Spinomonstrilla* (1). Currently, some of the main taxonomically relevant morphological characters among the Monstrilloida, include: 1) the male and

female urosome segmentation, 2) segmentation and setal armature of male and female antennules (see Grygier and Ohtsuka 1995), 3) cephalosome and urosome shape and proportions, 4) integumental ornamentation of the cephalosome, 5) structure and armature of female and male fifth legs, 6) number of caudal setae, 7) position of the oral cone, and 7) structure of the male genital complex (Suárez-Morales and Dias 2000, 2001a, 2001b, Suárez-Morales and McKinnon 2014, 2016, Lee et al. 2016).

Data about the Brazilian fauna are being compiled in the “Catálogo Taxonômico da Fauna do Brasil – CTFB” (Taxonomic Catalogue of the Brazilian Fauna), an online catalogue that started in 2015, focusing exclusively on the Brazilian fauna. The CTFB website (<http://fauna.jbrj.gov.br>) is regularly updated by experts in different animal taxa. Currently, there are about 120,000 valid extant animal species represented in the CTFB. The section related to Monstrilloida is built and administrated by the authors of this study and provides a revised checklist of the Brazilian species, as well as information related to these records, for instance year of publication, authorities, list of synonymies, hosts, geographic distribution for the Brazilian states, and ecological biomes. The type locality and museum repository for all associated type specimens is being updated to the Monstrilloida section of the CTFB (Dias and Suárez-Morales 2023). This study was inspired by the CTFB work of Santos et al. (2020) on the Brazilian Trichoptera (Insecta) and Machado and Martins (2022) on the Brazilian Neuroptera (Insecta).

In this contribution we provide an overview of the current knowledge of the monstrilloid copepods in Brazil, with an emphasis on its diversity and current collections, but also including basic aspects of the morphology of the Brazilian species.

MATERIAL AND METHODS

All data analyzed were extracted from the CTFB website, specifically, the section focused on the Monstrilloida (Dias and Suárez-Morales 2023), which was updated in March, 2023. The classification of Monstrilloida adopted in the CTFB follows WoRMS (2024). The taxonomic information in the CTFB has been regularly updated based on published taxonomic accounts, original descriptions, regional crustacean catalogs (Johnsson 1998), taxonomic revisions, and faunistic inventories (Razouls et al. 2023), when species level identifications were provided.

In the CTFB, detailed information for each species of Monstrilloida described or reported for Brazil was

provided: author's name, year of description, synonyms, location of primary type specimens, literature, year it was first reported from Brazil, origin (native or cryptogenic), whether it is endemic to Brazil or not, distribution by marine biogeographic domains and geographic regions in Brazilian states, and occurrence in other countries. The location of the primary type specimens was also registered, and institution records were individualized. Our dataset was organized first by family and genus containing a list of species for each of these taxa. The available taxonomic papers were analyzed to obtain the complete geographic distribution for each species and data were then organized in a dataset of the political division in the 26 Brazilian states plus the Federal District. The occurrence of monstrillids reported from Brazil but not identified to species level was also included in the species list, and assigned to state referred by the literature. All data available were then incorporated to the CTFB website. The number of endemic species is provided for the whole country.

RESULTS AND DISCUSSION

Historical data on South America and Brazilian Monstrilloida

Overall, the knowledge on the South American monstrilloids has been sporadic and is still fragmentary. The first species recorded from South America was *Monstrilla grandis* Giesbrecht, 1891 from the cold waters of the southern Argentinean coast (Giesbrecht 1891). Additional South American records of monstrillid copepods are also from Argentina, including the discovery of new localities for two species of *Monstrilla* along the Argentinean shelf system (Ramírez 1971). Also, Biancalana et al. (2007) reported *Monstrilla helgolandica* Claus, 1863 from Ushuaia Bay, adjacent to the Subarctic Beagle Channel. Subsequently, Suárez-Morales et al. (2008) reported, for the first time, two members of *Monstrillopsis* from the high latitudes of South America, one of which was undescribed: *M. igniterra* Suárez-Morales, Ramírez & Derisio, 2008. They also described a new species of *Monstrilla* (*M. patagonica*) from the same area. From plankton samples obtained from the Chilean fjords, Marin and Antezana (1985) recorded *M. grandis*, a nominal species that is suspected to represent a widespread species group (see Suárez-Morales et al. 2013, 2017, Chang 2014). Also from South America's coastal areas, Suárez-Morales et al. (2006) described *Monstrillopsis chilensis* Suárez-Morales, Bello-Smith & Palma, 2006 from the plankton of the Chilean Pacific coast. According to Chang (2014), Marin and Antezana's (1985)

work from Chilean fjords includes unspecified records from Brazil as well.

In reference to the Brazilian monstrilloid fauna, a total of 14 valid nominal species of Monstrillidae are recorded, with six species (43%; Figs 1, 2) endemic to the country (Table 1). *Monstrilla careli* Suarez-Morales & Dias, 2000 was described from the coastal areas of the Brazilian states of Rio de Janeiro, Bahia, and Pernambuco, but was later reported from a reef system of the Mexican Caribbean (Suárez-Morales 2001b). In view of the latest record, it is no longer considered endemic to Brazil. In reference to this group, two genera, *Cymbasoma* and *Monstrilla* constitute 78% of the Brazilian monstrilloid species diversity. *Monstrilla* is the most diverse genus, represented by six species (43%), followed by *Cymbasoma* (five species: 36%). The genera *Monstrillopsis* and *Caromiobenella* are known to occur in Brazilian waters, where they are represented by two and one species, respectively (Table 1).

Table 1. Family, genus, number of total and endemic species of Monstrilloida occurring in Brazil.

Family	Genus	Species	Endemic species
Monstrillidae	<i>Caromiobenella</i> Jeon, W. Lee & Soh, 2018	1	1
	<i>Cymbasoma</i> Thompson I.C., 1888	5	1
	<i>Monstrilla</i> Dana, 1849	6	3
	<i>Monstrillopsis</i> Sars G.O., 1921	2	1

The first mention to the Brazilian Monstrilloida was published by Oliveira (1945), who proposed a new genus and species, *Guanabaraenia jurujubae* Oliveira, 1945 based on specimens collected during a plankton survey of the Guanabara Bay, state of Rio de Janeiro. The designation of this material as a monstrilloid copepod was explicitly tentative in that publication, pending further confirmation. Both the drawings and the description of that material allow us to conclude that the specimens reported are clearly not members of the Monstrilloida.

After Oliveira's (1945) research at the Guanabara Bay, no there were no records of Monstrilloida in Brazil until Dias (1996) reported seven nominal species from different coastal areas; hence, her report of *Cymbasoma* cf. *longispinosum*, *Cymbasoma* cf. *rigidum*, *Cymbasoma quadridens* Davis, 1947, *Monstrilla reticulata* Davis, 1949 (currently known as *Caromiobenella brasiliensis* Dias & Suárez-Morales, 2000), *M. grandis*, *M. rugosa*, and *Monstrillopsis dubia* (Scott T., 1904) species complex represented the first species of the Monstrilloida to be recorded from Brazil. Subsequent collaborations (i.e.,

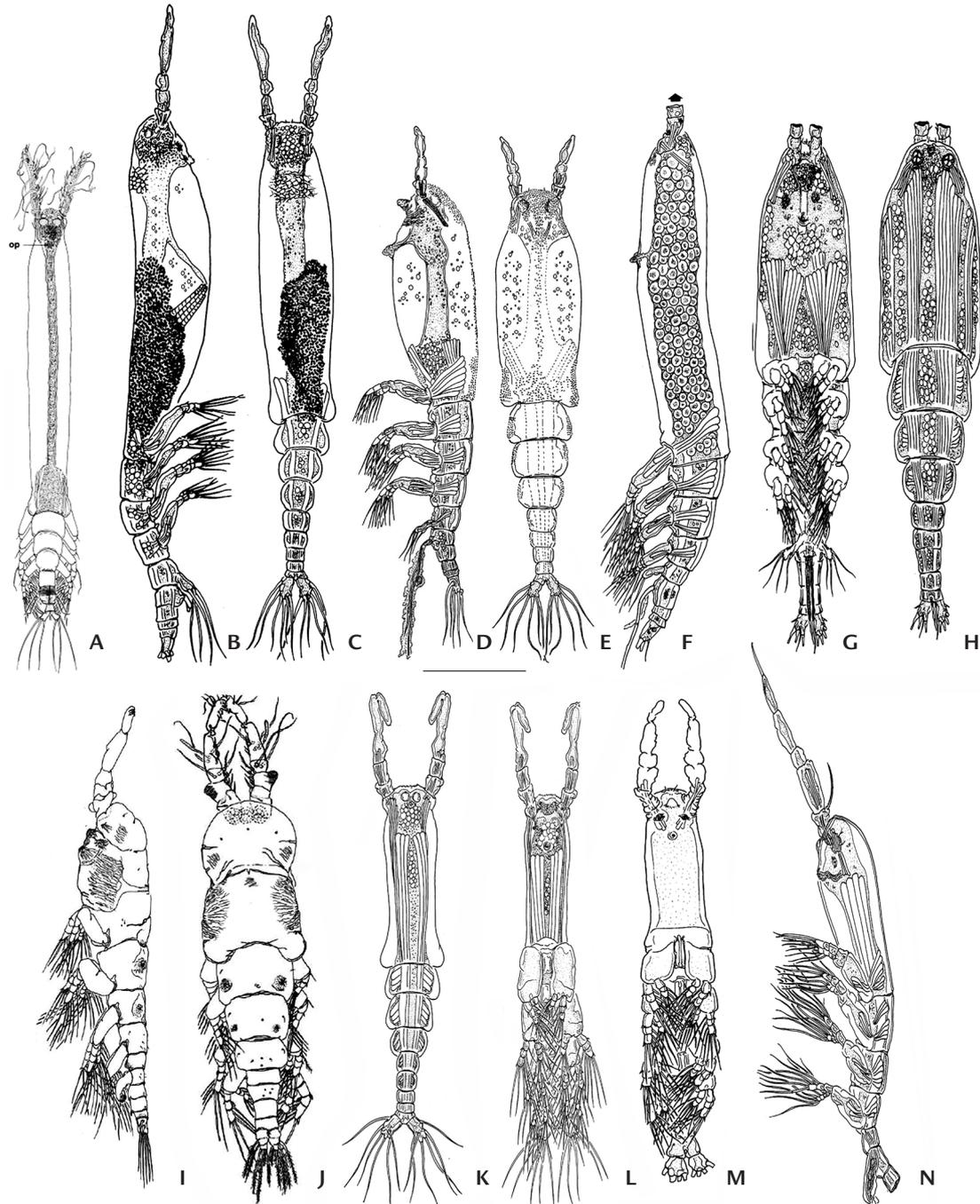


Figure 1. Monstrilloid copepod species described from Brazil: (A) *Cymbasoma rochai* adult female, dorsal view; (B) *Monstrilla careli* adult female, lateral view; (C) same, dorsal view; (D) *M. pustulata* adult female, lateral view; (E) same, dorsal view; (F) *M. satchmoi* adult female, lateral view; (G) *Caromiobenella brasiliensis* adult female, ventral view; (H) same, dorsal view; (I) *C. brasiliensis* adult male, lateral view; (J) same, dorsal view; (K) *Monstrilla bahiana* adult male, dorsal view; (L) same, ventral view; (M) *Cymbasoma rochai* adult male, ventral view; (N) *Monstrillopsis fosshageni* adult male, lateral view. Illustrations modified from Suárez-Morales and Dias (2000, 2001), Dias and Suárez-Morales (2023), Suárez-Morales et al. (2020). Scale bar: 0.5 mm.

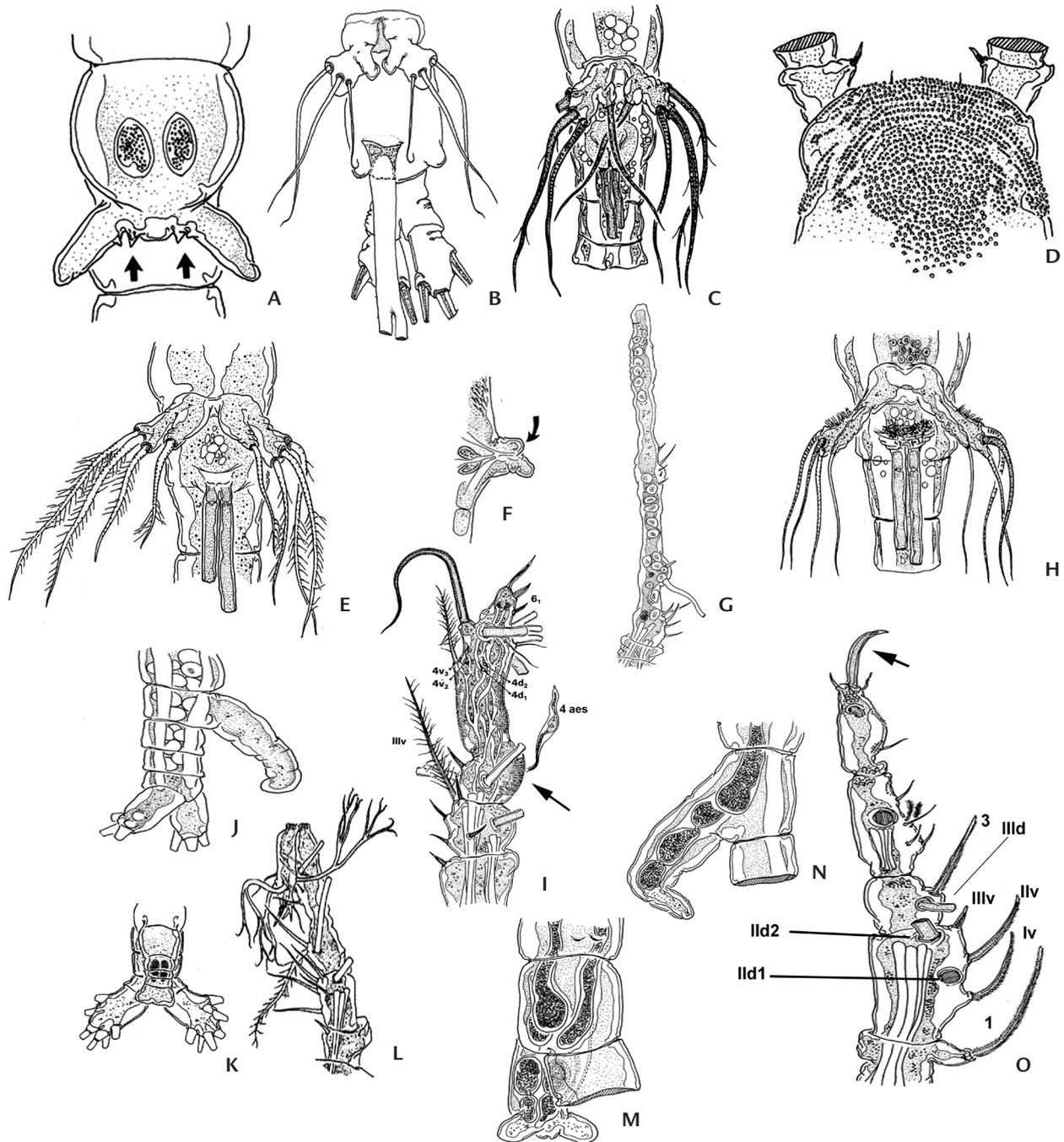


Figure 2. Distinctive morphological characters of the Monstrilloid copepods described from Brazil: (A) *Cymbasoma rochai* male genital complex showing spiniform processes; (B) *C. rochai* female fifth leg and ovigerous spines; (C) *Monstrilla careli* female fifth leg, ventral view; (D) *M. pustulata* female forehead with integumental field of pustules; (E) same, fifth leg, ventral view; (F) *M. satchmoi*, bilobed female oral papilla, lateral view; (G) same, left antennule, dorsal view; (H) *C. brasiliensis* female fifth legs, ventral view; (I) same, right antennule, dorsal view; (J) *M. bahiana* male genital complex, lateral view; (K) same, ventral view showing lappets; (L) same male right geniculate antennule, dorsal view; (M) *M. fosshageni* male genital complex, semi-lateral view; (N) same, lateral view; (O) *M. fosshageni* male left geniculate antennule, dorsal view.

Suárez-Morales and Dias 2000, 2001a, 2001b, Suárez-Morales et al. 2020, Da Rosa et al. 2021) allowed the discovery of several new species of *Monstrilla*, *Monstrillopsis* and *Cymbasoma* including *Monstrilla careli* and *C. brasiliensis* (Suárez-Morales and Dias 2000), the first two species described from Brazilian specimens. *Monstrilla pustulata* Suárez-Morales & Dias, 2001 (Suárez-Morales and Dias 2001a), *Monstrilla satchmoi* Suárez-Morales & Dias, 2001, *Monstrilla bahiana* Suárez-Morales & Dias, 2001, *Cymbasoma rochai* Suárez-Morales & Dias, 2001, *Monstrillopsis fosshageni* Suárez-Morales & Dias, 2001 (Suárez-Morales and Dias 2001b) were described only one year after the first species of Monstrilloida were described. During a series of zooplankton surveys in Brazilian waters, Dias and Bonecker (2007a, 2007b) and Dias et al. (2008) expanded the geographical range of two monstrilloid species, *C. quadridens* and *C. brasiliensis* in the Brazilian northeast coast. Also, Dias and Bonecker (2007a, 2007b) reported the occurrence of 14 monstrilloid species based on zooplankton surveys in neritic and oceanic areas off the coast of Brazil, including *Cymbasoma* cf. *gracile*. This nominal species was originally described from the Suez Canal, its status is uncertain, and the Brazilian specimens probably represent an undescribed species. Most recently, *M. brasiliensis*, described from a female, was transferred to *Caromiobenella*, previously known from males only (Jeon et al. 2018). The designation of *M. brasiliensis* as a species of *Caromiobenella* by Da Rosa et al. (2021) represented the third documented discovery of females assignable to *Caromiobenella*, the first record of the genus in the Southwestern Atlantic, and the first documented record of monstrilloids from coastal tidepools.

Brazilian authors of Monstrilloida

Records of Monstrilloida species originally described originated from Brazil are contained in three articles published between 2000 and 2001, by the two authors of the present study, one from Brazil (C. Dias) and one from Mexico (E. Suárez-Morales). In addition, the recent designation of *M. brasiliensis* as a species of *Caromiobenella* was carried out by the same researchers who described the first Brazilian species of Monstrilloida (CD, ES-M), and coauthored by J. Rosa.

In a few routine zooplankton surveys Monstrilloida has been usually registered at the Order level, possibly because of the rarity of these organisms (Dias and Bonecker 2007a, Leite et al. 2010) and their taxonomic complexity (Suárez-Morales 2011). Due to the extensive gap in the occurrence of species off the Brazilian coast that needs to be addressed in future research, greater sampling and identification efforts are needed. It is important to collect

these organisms using methods that aim to catch them (i.e., night time collections, light traps), also including the parasitological examination of benthic polychaetes or molluscs (Suárez-Morales et al. 2010, 2014).

Type Specimens

All the primary type specimens of Brazilian monstrilloids are deposited in Brazilian institutions (National Museum, Federal University of Rio de Janeiro – MN/UFRJ). With the exception of *Monstrilla bahiana*, *M. satchmoi*, and *Monstrillopsis fosshageni* which don't have secondary types, all secondary types are also deposited in the MN/UFRJ collection (25 total types = 78%). Specimens of *M. pustulata*, *M. careli*, *C. brasiliensis*, *Cymbasoma rochai*, and *M. bahiana* (7 types = 22%) are deposited in the collection of El Colegio de la Frontera Sur – ECOSUR, Collection of Zooplankton, ECO-CHZ in Mexico.

Monstrilloida distribution in Brazil

The locations of institutions where major monstrilloid researchers work in Brazil have influenced the distribution of species records in the country. The states of Espírito Santo, with 10 species, Bahia with nine, and Rio de Janeiro with eight are the three states with the greatest numbers of records (Fig. 3A). The records of Monstrilloida are concentrated in the East, Southeast, and Northeast marine ecoregions (Spalding et al. 2007). Among the Brazilian ecoregions, only the Rio Grande ecoregion has no official records of Monstrilloida (Fig. 3B). This disparity is likely the result no zooplankton studies targeting the local biodiversity. In Brazil, Amazonia is the least explored area in the country. Among the three Amazonian states, only the state of Pará has one record of a single species.

Bahia (Ba) and Espírito Santo (ES) have the greatest number of endemic species (Ba and ES – *Caromiobenella brasiliensis*, *Cymbasoma rochai*, *Monstrilla bahiana*; Ba – *Monstrilla satchmoi*; ES – *Monstrillopsis fosshageni*; 4 species each state), followed by Rio de Janeiro (3 species – *Caromiobenella brasiliensis*, *Cymbasoma rochai*, and *M. pustulata*). *Cymbasoma* cf. *gracile* and *Cymbasoma rigidum* Thompson I.C., 1888 are the most widespread species in the country, with records from Rio Grande do Norte, Bahia, Rio de Janeiro, Espírito Santo, and Paraná. *Monstrilla pustulata*, *M. satchmoi*, and *Monstrillopsis fosshageni* have the most restricted distribution within Brazil, with records in only one state, concentrated in the East and Southeast Brazilian ecoregions (Fig. 3B).

Some records should be revised in the light of evidence suggesting that *Cymbasoma longispinosum* Bourne,

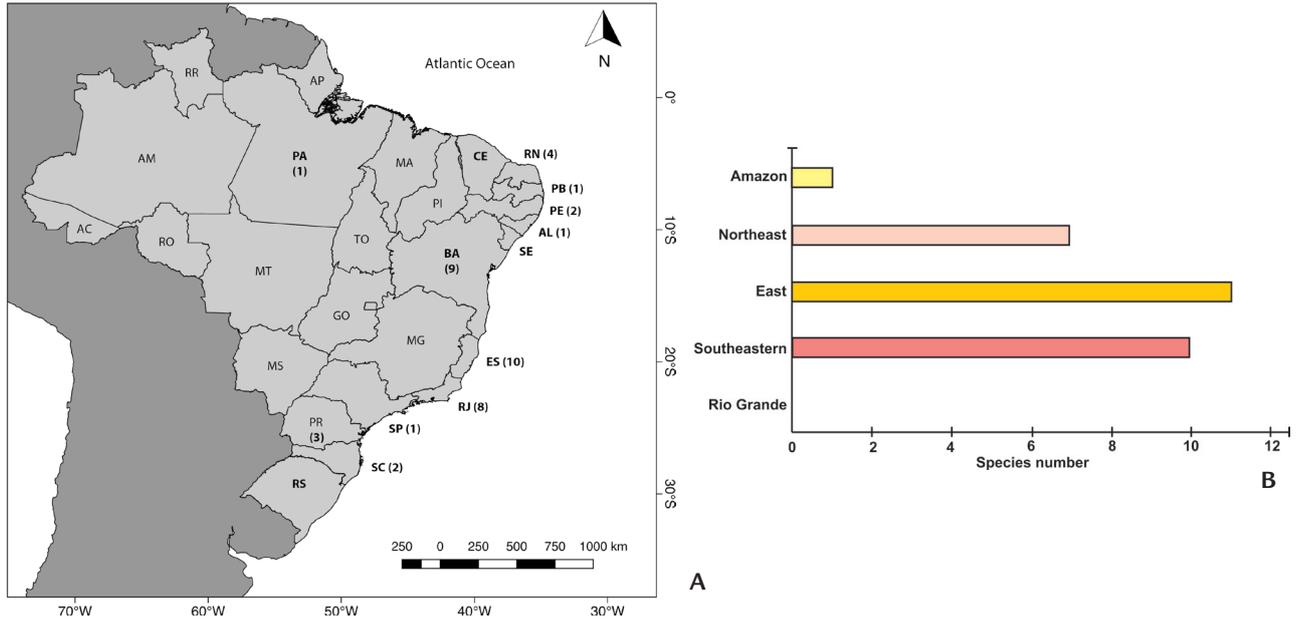


Figure 3. Distribution of species of the copepod order Monstrilloida: (A) Brazilian map showing the number of Monstrilloida species recorded from each state; (B) Monstrilloida species number by Brazilian marine ecoregions. State abbreviations: (AC) Acre, (AL) Alagoas, (AM) Amazonas, (AP) Amapá, (BA) Bahia, (CE) Ceará, (DF) Federal District, (ES) Espírito Santo, (GO) Goiás, (MA) Maranhão, (MG) Minas Gerais, (MS) Mato Grosso do Sul, (MT) Mato Grosso, (PA) Pará, (PB) Paraíba, (PE) Pernambuco, (PI) Piauí, (PR) Paraná, (RJ) Rio de Janeiro, (RN) Rio Grande do Norte, (RO) Rondônia, (RR) Roraima, (RS) Rio Grande do Sul, (SC) Santa Catarina, (SE) Sergipe, (SP) São Paulo, (TO) Tocantins.

1890, *Cymbasoma rigidum*, and *M. grandis* probably represent species complexes containing different undescribed species with limited geographic distributions (Üstün et al. 2014, Suárez-Morales et al. 2017, 2020, Suárez-Morales 2018, Suárez-Morales and Grygier 2021).

The *Cymbasoma longispinosum* species complex is clearly the most studied among the Monstrilloida (Suárez-Morales et al. 2020). It is currently known to contain 11 nominal species showing subtle differences in the body proportions, ovigerous spines, fifth legs, and urosome ornamentation (Üstün et al. 2014, Suárez-Morales et al. 2020) and are distributed in distinct geographical areas, including Europe (*C. longispinosum* s.str.), the southern sector of the Gulf of Mexico (*C. chelemense* Suárez-Morales & Escamilla-Sánchez, 1997), the Gulf of California (*C. californiense* Suárez-Morales & Palomares-García, 1999), Japan, Korea, Vietnam, India (*C. morii* Sekiguchi, 1982) (Grygier 1993, Chang 2014), the Red Sea, Egypt (*C. janetae* Mageed, 2010), Turkey (*C. sinopense* Üstün, Suárez-Morales & Terbiyik, 2014), and western Australia (*C. jinigudira* Suárez-Morales & McKinnon, 2014).

The Brazilian *Cymbasoma rochai* is the first Brazilian species that has been assigned to the widespread *C. longispi-*

nosum species complex (Suárez-Morales and Dias 2001a). Suárez-Morales et al. (2020) described the female of *C. rochai*, based on specimens collected in the estuary of the Perequê-Açu River (Rio de Janeiro, Brazil, 23° 13'01"S–44° 42'40"W) and reviewed specimens described as *C. longispinosum*. Earlier records of these species from different parts of the Brazilian coastal and estuarine systems (occurrences on Pará and Rio Grande do Norte states; Leite et al. 2010) should be revised to determine if they correspond to undescribed species.

Cymbasoma rigidum has also been proposed as a complex comprising different morphotypes. According to Suárez-Morales (2011) and Suárez-Morales and Grygier (2021), this nominal species is known to contain at least four distinct taxa and most records should be revised. The length of the A1 and length and development of the inner lobe, and the relative length of the inner seta of the outer lobe of the P5 show strong variation along its apparent cosmopolitan geographic distribution. It seems unlikely that all these mixed patterns can be reliably associated with a single species.

Another possible species complex is that of the nominal species *M. dubia*. This species has a supposedly cosmo-

opolitan distribution (Suárez-Morales 2011: 6, 12) and is now known to contain at least three different species. The species would be restricted to Scotland (60°N), and the records of *M. dubia* for the Southern Hemisphere may refer to *M. chilensis*, *M. igniterra*, or an undescribed taxa.

Future studies

The overall knowledge on the Brazilian Monstrilloida still contains gaps that should be addressed in future studies. Learning more about the distribution of these taxa is extremely important for the conservation of our biodiversity. One major concern that must be addressed is the insufficient sampling in many Brazilian states and ecoregions. The unbalanced collecting effort skews the known Monstrilloid distributions to the Northeast, East and Southeast. In addition to reviewing the individual records of species complexes found on the Brazilian coast, it would be interesting to carry out parasitological studies focused on the detection of monstrilloids, the identification of their hosts, and try to obtain individuals of both sexes to rear them in the laboratory.

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