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RESEARCH ARTICLE
TAXONOMIC CATALOG OF THE BRAZILIAN FAUNA

Taxonomic Catalog of the Brazilian Fauna: Superorder Cladocera (Crustacea: Branchiopoda), taxonomic history, diversity and distribution

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ABSTRACT. The Taxonomic Catalog of the Brazilian Fauna (CTFB) is an initiative involving the effort of hundreds of researchers in several institutions, including international partners. Its main objective is to make public and give free access to a checklist of valid species occurring in Brazil. This catalog includes information on Cladocera, a group of microcrustaceans that occupy inland water and marine ecosystems. In this study, we evaluated the Cladocera part of the Brazilian Fauna Catalog. Among the taxa described or reported, we observed 155 valid species (37 endemic) and 61 genera (2 endemic) distributed in 11 families. European researchers represented 50% of all the authors involved in descriptions of species, and European collections keep most primary types, although many species have types that have been lost or not designed. Brazilian researchers were involved with a large number of descriptions, especially in the last 15 years. Our findings indicated that Cladocera taxa were observed in all hydrographic regions (Paraná with 119 species), biomes (Atlantic Forest with 126 species) and states, except state of Rondônia. The catalogue of Brazilian cladoceran fauna should be improved, as there are still large geographic ranges to be sampled in Brazil.

KEY WORDS. Biodiversity, Chydoridae, Europe, Neotropics, Taxonomy, Zooplankton.

INTRODUCTION

Cladocera is an ancient group within Branchiopoda which occupies inland waters since the Palaeozoic (Kotov and Korovchinsky 2006, Van Damme and Kotov 2016), although a small number of extant species dwell in marine ecosystems (Van Damme et al. 2022). Several studies indicate the ecological importance of Cladocera for the functioning of aquatic ecosystems, especially in planktonic zones (Esteves 1998, Bledzki and Rybak 2016). However, most species live in association with some substrate, for instance at the bottom, leaves and stems and roots of macrophytes, swimming between aquatic vegetation, burrowing in organic matter or among fine particles of sediments (Elmoor-Loureiro 1997, Orlova-Bienkowskaja 2001, Kotov and Stifter 2006, Jeong et al. 2017). Some specialized species have abandoned water bodies to live in semi-terrestrial conditions (Frey 1980, Sousa et al. 2017).

In an effort to compile the worldwide distribution of Cladocera, Forró et al. (2008) indicated the presence of species in all zoogeographic regions, totalizing about 620 species. According to those authors, the Neotropical zone has about 186 species and 50 genera. Since then, several species and genera have been added to fauna list, expanding the diversity in the Neotropics (Kotov et al. 2010, Andrade-Sossa et al. 2020). From 2008, at least 30 new taxa were described or reported only in Brazil, reinforcing the idea that a complete inventory of species still has a long way to go.

To reduce gaps in the richness and geographic distribution of cladocerans in Brazil, several researchers have published inventories for different Brazilian regions (e.g., Rocha et al. 2011, Brito et al. 2020, Macêdo et al. 2021, 2022, Santos et al. 2021). This type of study is very relevant in a megadiverse country that has seen few sampling efforts; however, initiatives such as the Taxonomic Catalog of the Brazilian

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Fauna (in Portuguese: Catálogo Taxonômico da Fauna do Brasil – CTFB) is fundamental to compile data and provide reliable information checked by specialists, as supporting evidence for public policies related to biodiversity. Besides that, the catalog is an important data resource that might be used to study biodiversity patterns on large geographic scales.

The CTFB was developed based on the Convention of Biological Diversity and Aichi goals (https://www.cbd.int/). This is an initiative supported by government agencies with proactive efforts from universities and scientific associations, including international partners. More than 500 researchers have been working since 2015 to improve the knowledge of animal biodiversity in Brazil, in order to make available to the public the relevant taxonomic information and the checklist of valid species occurring in the country, with free access (http://fauna.jbrj.gov.br/fauna/listaBrasil/ConsultaPublicaUC/ConsultaPublicaUC.do). Herein, our aim was evaluate the Cladocera part of the Brazilian Fauna Catalog.

MATERIAL AND METHODS

The data used to build the catalogue of Brazilian cladoceran fauna were obtained from the Brazilian Cladocera Database, composed of resources from the literature (Elmoor-Loureiro 2000, Elmoor-Loureiro et al. 2022) and data available in https://cladocera.wordpress.com/. To each species described or reported in Brazil we extracted the authors, their nationality, the publication date and information about primary types and location where deposited.

To avoid biogeographic and taxonomic mistakes, we did a critical analysis of the names available in the Brazilian literature. Then, we removed from the catalogue erroneous reports, species without taxonomic information, and names applied to species from the other continents and with adequate taxonomic information. Using a Geographical Information System and a set of geographical coordinates, we obtained the distribution of each species described or reported in Brazil. After that, we obtained the number of species for federative units, biomes, and hydrographic regions (just inland water fauna). The richness is presented in maps built using shape files provided by the Instituto Brasileiro de Geografia e Estatística (IBGE – http://www.ibge.gov.br) and the Agência Nacional de Águas e Saneamento Básico (ANA – https://www.gov.br/ana).

RESULTS AND DISCUSSION

A brief history of knowledge of Cladoceran taxonomy in Brazil

The first studies about Brazilian cladoceran fauna were revealed between the end of the 19th and the beginning of the 20th centuries, reporting some common European species (the region of world most studied at that time) or describing new taxa, previously unknown (e.g., Ihering 1895, Sars 1901). A few decades later, different researchers included new species among the Brazilian fauna (Brehm and Thomsen 1936, Brehm 1938, Bergamin 1939a, 1939b, 1939c, 1940a, 1940b, 1941).

According to our data, new species were added to Brazilian fauna only from the 1960s onwards, with a description of *Daphnia gessneri* Herbst, 1967. Since then, interest has been increasing, attracting a number of European researchers who dedicated themselves to studying samples collected in Brazilian water bodies or revisiting material deposited in museums. The relevance of these researchers is anchored in the fact that half of all the authors describing species reported for Brazil are of European origin. Lower contributions were observed among researchers originating from Asia, Africa, and Oceania (Table 1). Curiously, these regions of the world were also explored by European researchers in the past (e.g., Dumont 1981, Dumont and Silva-Briano 2000, Smirnov and Timms 1983) and in recent times (e.g., Van Damme et al. 2013, Van Damme and Sinev 2013, Sinev 2016).

Table 1. Nationalities of authors who described species reported in Brazil. Here, Latin American nationality does not include Brazil, which is considered separately.

Nationality	Number of authors	Percentagem
Brazil	20	23.3
Asia	1	1.2
Europe	43	50
Latin America	10	11.6
North America	9	10.5
Africa	2	2.3
Oceania	1	1.2

Researchers from the Latin American countries has made a moderate contribution (Table 1), but the renowned Argentinian cladocerologist Juan César Paggi stands out, having participated in the description of five species reported in Brazil. In particular, the number of Brazilian researchers describing species might be considered significant (despite being lower than the number of European authors), a perception influenced by for studies published in the last 15 years and that proves that there has been clear progress towards the understanding of Brazilian cladoceran biodiversity (Kotov and Elmoor-Loureiro 2008, Sinev and Elmoor-Loureiro 2010, Elmoor-Loureiro et al. 2013, Elmoor-Loureiro 2014, Sousa et al. 2015, 2016, 2017, Sousa

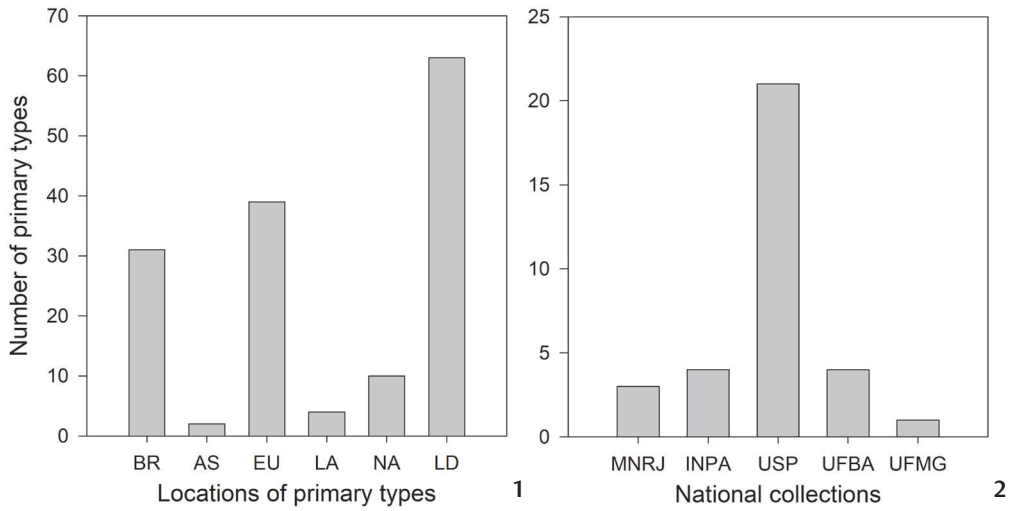
and Elmoor-Loureiro 2018, Sousa et al. 2021). However, two worrying findings emerge from our analysis: first, the number of women describing species reported in Brazil is very low (12 researchers) because, in many cases, they were forbidden to participate in expeditions in the 19th and early 20th century. Second, there are just two Brazilian taxonomists (sensu Wheller 2014) actively dedicated to studying Cladocera (only one is woman), although several authors with a broader interest or who are non-taxonomists have participated in describing some species.

The influence and relevance of European researchers for Brazilian cladoceran fauna might also be observed from where the material types were deposited (Fig. 1). It is significant that there are at least 63 species with holotypes lost or not designated (Fig. 1), corresponding to species described by pioneering European authors, which increases the importance of this researcher group. No material was found deposited in collections from Africa and Oceania. From the total number of species reported in Brazil, 39 have holotypes and lectotypes deposited in museums or European collections (18 were designated using material from Brazil). Regarding public Brazilian collections, there are 31 holotypes, paratypes, neotypes or lectotypes deposited (Fig. 2). The highest number of types can be found in the Zoological Museum of São Paulo University (USP), National Institute for Research in the Amazon (INPA), and Zoological Museum of Bahia Federal University (UFBA). It is fundamental that species lacking types and with natural distribution in Brazil should receive attention in future taxonomic revisions.

The catalog of Cladocera fauna in Brazil

The literature suggests different approaches to evaluating the number of species of cladocerans occurring in Brazil; thus, there are some discrepant data. The most recent paper indicated the occurrence of 169 inland water species compiled from ecological and taxonomic studies; however, the authors highlighted the toned for solid taxonomic evaluation of at least 1/3 of reported species (Elmoor-Loureiro et al. 2022). Thus, we removed from the catalog any inquerenda species and invalid names: *Alona fasciculata* Daday, 1905, *Pleuroxu paraplesius* Frey, 1993, *Pleuroxu scopuliferus* (Ekman, 1900), *Leydigia schubarti* Brehm & Thomsen, 1936; names applied to species from the other continents and with adequate taxonomic information: *Alona intermedia* Sars, 1862, *Sida crystalina* (O.F. M*üller*, 1776), *Macrothrix flabelligera* Smirnov, 1992, *Macrothrix spinosa* King, 1853, *Macrothrix laticornis* (Jurine, 1820); and doubtful reports (*Diaphanosoma dentatum* Herbst, 1968). Supported by our analysis of several populations collected in Brazil, we added to the catalogue *Macrothrix squamosa* Sars, 1901, a Neotropical member of *laticornis-spinosa* group.

From a temporal perspective and applying a critical interpretation of names observed in Brazilian literature, we



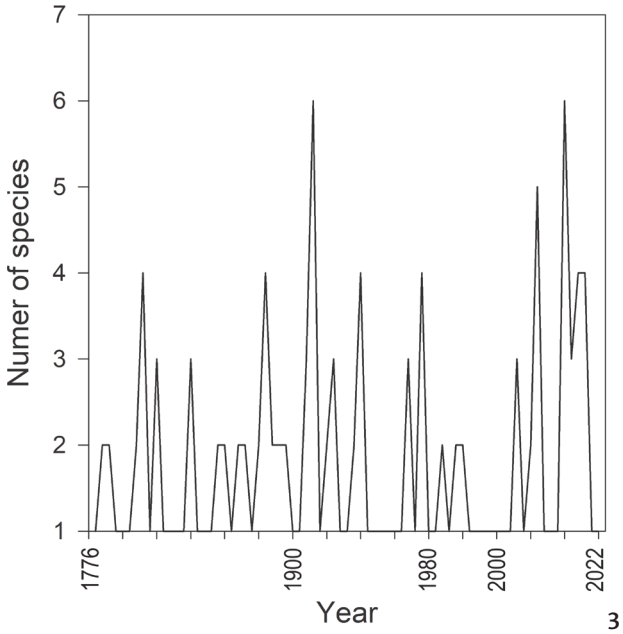
Figures 1–2. Number of primary types: (1) Types deposited in collections from the different world regions; (2) Types deposited only in Brazilian collections. (BR) Brazil, (AS) Asia, (EU) Europe, (LA) Latin America except Brazil, (NA) North America, (LD) Lost or not designated, (MNRJ) Museu Nacional do Rio de Janeiro, (INPA) Instituto Nacional de Pesquisas da Amazônia, (MZUSP) Museu de Zoologia da Universidade de São Paulo, (MZUFBA) Museu de Zoologia da Universidade Federal da Bahia, (UFMG) Instituto de Biologia, Universidade Federal de Minas Gerais.

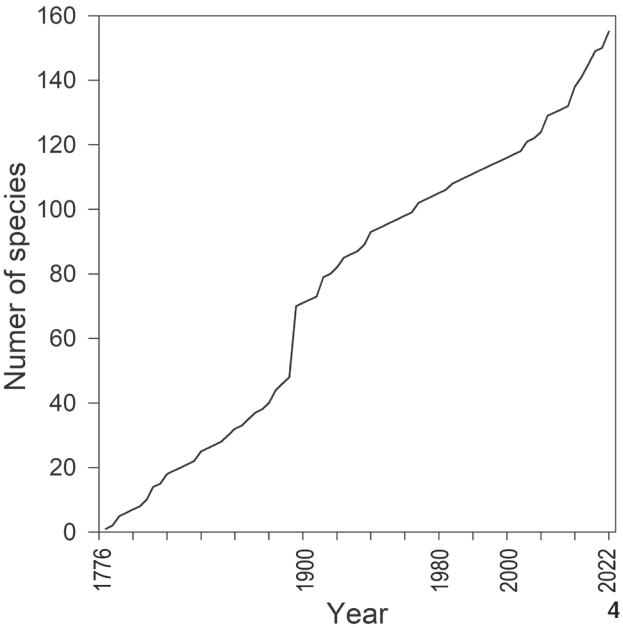
found 155 species described or reported in Brazil (Figs 3, 4) of which 37 might be considered endemic (Table 2). Eleven families cover a total of 61 genera. Chydoridae is the most diverse lineage of Cladocera, with 34 genera and 77 species, of which 21 are endemic. *Kisakiellus* Sousa & Elmoor-Loureiro, 2018 is the only genus occurring exclusively in Brazil. *Chydorus* Leach, 1816 is the genus with most species. On the other hand, Chydoridae has at least 15 genera with just one species each.

Table 2. Number of families, genera and species described or reported in Brazil.

Family	Genus	Species	Endemic species
Acantholeberidae	1	1	1
Bosminidae	2	8	1
Chydoridae	34	77	21
Daphniidae	4	22	0
Eurycercidae	1	3	1
Holopedidae	1	1	1
Ilyocryptidae	1	6	3
Macrothricidae	5	11	5
Moinidae	3	8	2
Podonidae	4	6	0
Sididae	5	12	2

Macrothricidae is represented by five genera, with eleven species, of which five are considered endemic. *Macrothrix* Baird, 1843 is the genus with most species within Macrothricidae. In Moinidae, there are two endemic species and *Micromoina* Dumont, Rietzler & Kalapothakis, 2013 is the only genus occurring exclusively in Brazil. Daphniidae and Podonidae do not have exclusive species in Brazil. Other families, such as Acantholeberidae, Holopedidae and Eurycercidae, cover lesser diversity and include one genus (Tables 2, 3). The Brazilian cladoceran fauna should be considered megadiverse, representing almost 70% of the entire Neotropical diversity, with richness similar to or greater than that in countries such as Argentina, Chile, Colombia, Paraguay, Uruguay and Venezuela (Kotov and Fuentes-Reinés 2015, Caraballo et al. 2022, González-Rivas et al. 2022, Paggi et al. 2022, Duré et al. 2022, de los Ríos-Escalante et al. 2023).





Figures 3–4. Species described or reported in Brazil: (3) Species by year of description; (4) Cumulative number of species.

Diversity in different geographic approaches

As a trend in cladoceran studies, local and regional checklists have formed the basis for evaluating literature data, sampling effort and richness on the different ecological scales, working to reduce the Wallacean shortfalls (Hortal et al. 2015). States such as Bahia, Ceará, Maranhão, Mato Grosso, Mato Grosso do Sul, Minas Gerais, Pernambuco, Rio de Janeiro, Santa Catarina, and São Paulo, and also the Distrito Federal possess checklists available in the literature (Sousa et al. 2009, Rocha et al. 2011, Santos-Wisniewiski et al. 2011, Boos et al. 2012, Sousa and Elmoor-Loureiro 2012,

Table 3. Number of species in each genus descibed or reported in Brazil.

Family	Genus	Number of species
Acantholeberidae	*Acantholeberis* Lilljeborg, 1853	1
Bosminidae	*Bosmina* Baird, 1845	5
	Bosminopsis Richard, 1895	3
Chydoridae	*Acroperus* Baird, 1843	1
	Alona Baird, 1843	3
	Alonella Sars, 1862	2
	Anthalona Van Damme, Sinev & Dumont, 2011	4
	Bergamina Elmoor-Loureiro, Santos-Wisniewski & Rocha, 2013	1
	Biapertura Smirnov, 1971 emend. Sinev, 2022	1
	Bryospilus Frey, 1980	1
	Camptocercus Baird, 1843	2
	Celsinotum Frey, 1991	2
	Chydorus Leach, 1816	8
	Coronatella Dybowski & Grochowski, 1894	5
	Dadaya Sars, 1901	1
	Disparalona Fryer, 1968	4
	Dunhevedia King, 1853	4
	Ephemeroporus Frey, 1982	5
	Euryalona Sars, 1901	1
	Flavalona Sinev & Dumont, 2016	3
	Graptoleberis Sars, 1862	1
	Karualona Dumont & Silva-Briano, 2000	1
	Kisakiellus Sousa & Elmoor-Loureiro, 2018	1
	Kurzia Dybowski & Grochowski, 1894	3
	Leberis Smirnov, 1989	1
	Leydigia Kurz, 1875	2
	Leydigiopsis Sars, 1901	4
	Magnospina Sousa, Elmoor-Loureiro & Santos, 2016	1
	Monospilus Sars, 1862	2
	Nicsmirnovius Chiambeng & Dumont, 1999	2
	Notoalona Rajapaksa & Fernando, 1987	1
	Ovalona Van Damme & Dumont, 2008	2
	Oxyurella Dybowski & Grochowski, 1894	2
	Parvalona Van Damme, Kotov & Dumont, 2005	1
	Picripleuroxus Frey, 1993	2
	Prendalona Sousa, Elmoor-Loureiro & Santos, 2018	2
	Pseudochydorus Fryer, 1968	1
Daphniidae	*Ceriodaphnia* Dana, 1853	8
	Daphnia O. F. Mueller, 1776	5
	Scapholeberis Schoedler, 1858	2
	Simocephalus Schoedler, 1858	7
Eurycercidae	*Eurycercus* Baird, 1843	3
Holpedidae	*Holopedium* Zaddach, 1855	1
Ilyocryptidae	*Ilyocryptus* Sars, 1862	6
Macrothricidae	*Grimaldina* Richard, 1892	1
	Guernella Richard, 1892	1
	Macrothrix Baird, 1843	7
	Onchobunops Fryer & Paggi, 1972	1
	Streblocerus Sars, 1862	1
Moinidae	*Micromoina* Dumont, Rietzler & Kalapothakis, 2013	1
	Moina Baird, 1850	6
	Moinodaphnia Herrick, 1887	1
Podonidae	*Evadne* Loven, 1836	2
	Pleopis Dana, 1853	1
	Podon Lilljeborg, 1853	2
	Pseudevadne Claus, 1877	1
Sididae	*Diaphanosoma* Fischer, 1850	6
	Latonopsis Sars, 1888	1
	Penilia Dana, 1852	1
	Pseudosida Herrick, 1884	2
	Sarsilatona Korovchinsky, 1985	2

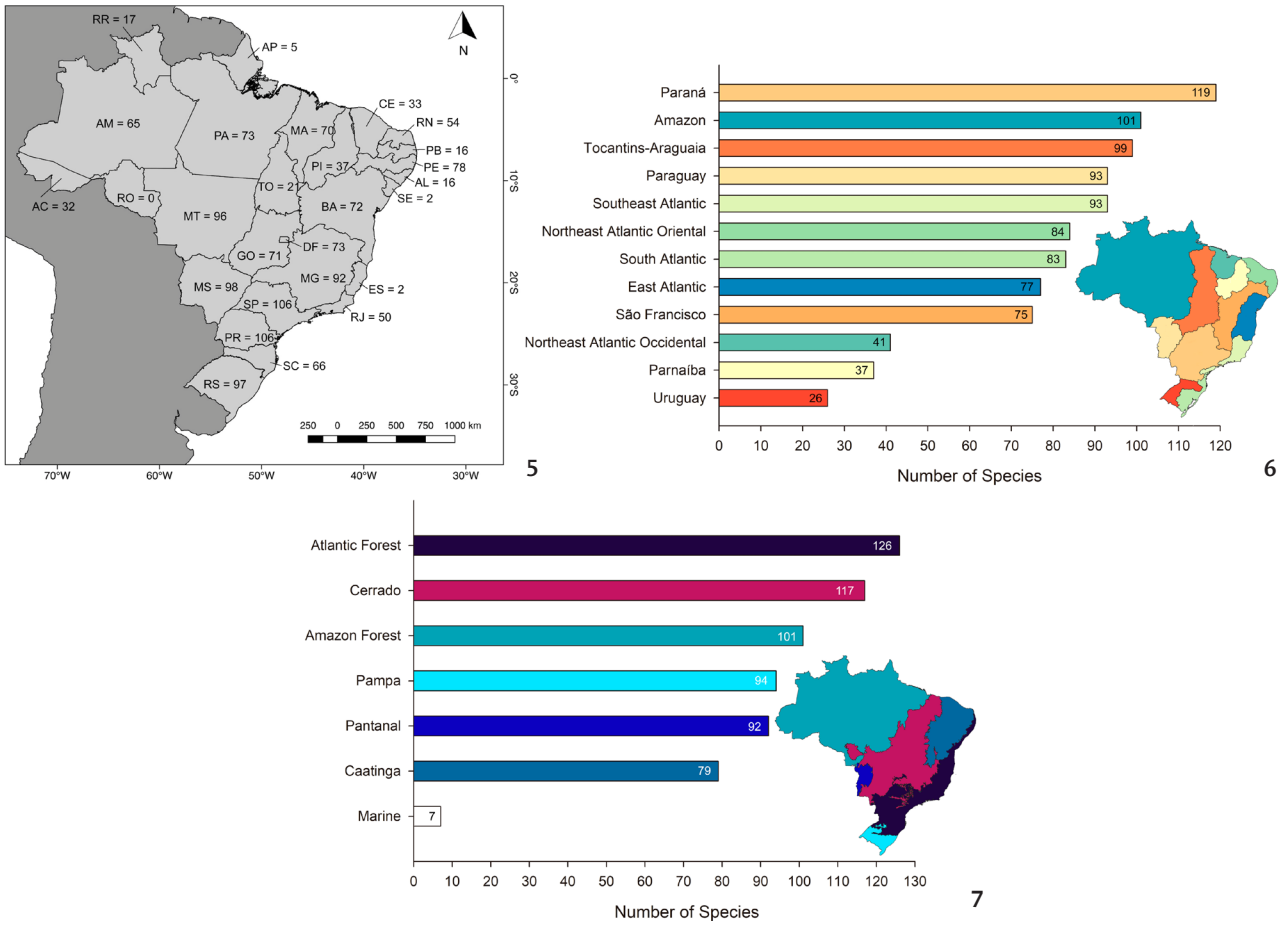
Soares and Elmoor-Loureiro 2011, Zanata et al. 2017, Brito et al. 2020, Macêdo et al. 2021, 2022, Santos et al. 2021). According to our findings, the number of species observed in each state varies greatly, due to the critical evaluation of names available. The state with most species was São Paulo and the least numerous was Ceará (Fig. 5). Regarding states without available checklists, Paraná and Rio Grande do Sul present a high number of species. Alagoas, Amapá, Espírito Santo, Roraima and Sergipe have reports of fewer than 20 species reported. No species has yet been recorded in state of Rondônia (Fig. 5).

The territorial extent of hydrographic regions seems to be related to richness. For instance, Paraná, Amazon and Tocantins-Araguaia are the areas with most species. These results are similar for Paraguay and the Southeast Altantic. Uruguay, Parnaíba and the Western Northeast Atlantic have a lower territorial extent and number of species (Fig. 6). Using a biome framework, the Atlantic Forest, Amazon Forest, Pampa, Pantanal and Cerrado have more than 90 species reported and the Caatinga has 79 (Fig. 7). Naturally, the diversity of marine cladocerans is lower than that of inland water bodies; thus, the presence of five genera and seven species in the marine biome should be considered significant.

Spatial analysis using geographical distribution data of cladocerans showed a large sampling effort focused in a few areas of the country (Elmoor-Loureiro et al. 2022, Martins et al. 2023). This scenario suggests that regional richness differences could be biased by researchers' geography. The same studies indicated an estimated richness that is greater than what has been observed until now and suggest that new species will be discovered. Thus, we should regard the Brazilian catalogue of cladoceran fauna as still incomplete and under construction.

FINAL REMARKS

Cladocera represents an important lineage of Branchiopoda crustaceans. Therefore, these animals have been



Figures 5–7. Number of species described or reported to Brazil: (5) Federative Units; (6) Hydrographic Regions; (7) Biomes. (AC) Acre, (AL) Alagoas, (AP) Amapá, (AM) Amazonas, (BA) Bahia, (CE) Ceará, (DF) Federal District, (ES) Espírito Santo, (GO) Goiás, (MA) Maranhão, (MT) Mato Grosso, (MS) Mato Grosso do Sul, (MG) Minas Gerais, (PA) Pará, (PB) Paraíba, (PR) Paraná, (PI) Piauí, (RJ) Rio de Janeiro, (RN) Rio Grande do Norte, (RS) Rio Grande do Sul, (RO) Rondônia, (RR) Roraima, (SC) Santa Catarina, (SP) São Paulo, (SE) Sergipe, (TO) Tocantins.

investigated in Brazil since the 19th century. The taxonomic history involving species reported in Brazil is linked to the effort made by researchers of different nationalities, especially Europeans. Most primary types of species described or reported in Brazil are deposited in European collections. The contribution of Brazilian researchers has increased in the last 15 years, positively impacting the understanding of Brazilian cladoceran biodiversity. Our findings suggest that the Brazilian catalogue is composed of 155 species (37 endemic), 61 genera and 11 families distributed among the biomes, hydrographic regions and Brazilian states, except Rondônia. The catalogue of Brazilian cladoceran fauna is expected to improve and expand, given that there are still large geographic areas to be sampled in Brazil.

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