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AQUATIC FUNGI OCCURRING IN BRAZIL: A SYSTEMATIC REVIEW

*[1]Veluma Martins Pereira; [1,2]Clarice Maia Carvalho.

[1]Programa de Pós-Graduação em Ciência, Inovação e Tecnologia para a Amazônia, Universidade Federal do Acre, Rio Branco, Acre, Brasil, [2]Centro de Ciências Biológicas e da Natureza da Universidade Federal do Acre, Rio Branco, Acre, Brasil.

* Autor correspondente: veluma_pereira@hotmail.com

ABSTRACT

The description of aquatic fungi is still new in the literature, and in Brazil, even with different climatic and hydrological regimes, it still presents a low description of this group of microorganisms. Thus, the objective of this work was to make a systematic review of the aquatic fungi identified in Brazilian biomes. The Scientific Electronic Library Online (SCIELO), Science Direct and Google Scholar databases were used, using the descriptors: Aquatic Fungi Brazil, Fungi igarapé Brazil, Zoosporic fungi Brazil. Studies in the Portuguese and English languages, published from 1999 to May 2019 entered the study. 41 works were selected, described 1293 aquatic fungi, distributed in 328 genera. The Atlantic Forest biome had the highest number of described fungi (49,8%) the samples most used in studies in Brazil were the union of leaves and soil (16%) and the genus *Penicillium* showed the highest frequency of occurrence in Brazil (3.4%). Thus, this study shows the lack of studies on this group of fungi, mainly in the Pantanal and Pampa biome, where no work has been found, and the need for further studies on the distribution, ecology and identification of aquatic fungi in Brazil.

Keywords: Aquatic microorganism; Fresh water; Brazilian biome.

1. INTRODUCTION

Aquatic systems are inhabited by a diversity of decomposers that use dead plant tissues as energy source, among them, aquatic fungi [1]. These fungi occur most commonly and abundantly in deciduous leaves that decompose in running water [2]. The species diversity of these fungi tends to increase towards Ecuador, but this trend is less in the case of freshwater organisms [3], and the richness of aquatic fungi species reaches its maximum in mid-latitudes [4]. Due to their contrasting climatic and hydrological regimes, the tropics and subtopics encompass diverse environments ranging from dry desert areas and dry forests to wetland wetlands, also spanning a variety of altitudes [5].

Studies with diversity and abundance of aquatic fungi show generally low numbers in tropical and subtropical systems, where some factors may be related to this, such as seasonality, low conidia production, physical conditions, low nutrient content in running water, low quality of substrates and competition from other decomposers in the colonization of organic matter [6].

When submerged, aquatic fungi generally invest ≥ 60% of their production in large, hyaline and thin-walled conidia [7]. The sporulation rate can reach 7×10^6 conidia per gram of dry mass per day, and often peaks before fungal biomass [8].

Colonization begins with the fixation of aquatic fungi spores to organic matter, being mainly affected by surface morphology and structure, and is a precondition for spore germination and substrate invasion by hyphae [5]. No effects of temperature on the fixation of conidia on leaves or other surfaces have yet been observed, however, the species of fungi differ in the chemical composition of their germination rates [9]. In addition, development requires considerable metabolic investment and temperature is likely to affect fixation rates and efficiency and, therefore, fungal colonization [10].

Its dominance over leaves that decompose in aquatic environments is related to the ability to remain active at very low temperatures, and to the release of large amounts of tetrarchic and sigmoid spores that facilitate the fixation of spores on surfaces with turbulent waters [9].

Of the seven phyla proposed for the Fungi kingdom (Microsporidia, Chytridiomycota, Blastocladiomycota, Neocallimastigomycota, Glomeromycota, Ascomycota and Basidiomycota) [11], the majority of aquatic fungi belong to the Phylum Ascomycota and Chytridiomycota, and are reported in a smaller number of Basidiomycota [12].

Temperate countries, due to their sampling effort, have described most of the knowledge that is possessed about fungi present in aquatic environments [13]. Studies on the composition of freshwater fungi have been done over the past 50 years with approximately 3,050 fungal taxa reported for aquatic habitats (freshwater and oceanic) [14].

Despite being considered of ecological importance, freshwater fungi are still poorly researched on diversity, ecology and distribution in Brazil, and studies are needed to understand the function and interaction in black, white and clay waters, as well as the high demand for water new researchers trained in the identification of these organisms [15].

Thus, this work aimed to make a systematic review of the aquatic fungi described in biomes occurring in Brazil.

2. MATERIAL AND METHODS

The present study is a systematic literature review, searching the Scientific Electronic Library Online (SCIELO), Science Direct and Google Scholar databases, using the keywords: Aquatic Fungi Brazil, Fungi igarapé Brazil and Zoosporic fungi Brazil. Studies in the Portuguese and English languages, published between 1999 and May 2019, entered the study. The number of works found in the search is organized in Table 1.

Table 1. Publications on aquatic fungi occurring in Brazil.

Keywords	Scielo	Science Direct	Google Scholar	Total
Aquatic Fungi Brazil	9	5	7	21
Fungi igarapé Brazil	0	0	5	5
Zoosporic fungi Brazil	8	0	7	15
Total	17	5	19	41

As exclusion criteria, duplicate papers (found in more than one search base) were removed, outside the scope of the research and studies done outside Brazil.

The extraction of data after the selection of works, a total of 41 works were selected (Table 2), 5 on the Amazon biome (12.2%), 10 on the Caatinga (24.4%), 8 on the Cerrado (19.5%) , 18 from the Atlantic Forest (43.9%) (Table2), and none found for Pantanal and

Pampa, these being used in the results of the present study. In addition to the selected works, other works were also used to elaborate the introduction and enrich the discussion of this article.

The data synthesis was organized in graphs and described in the text according to the Brazilian biome of occurrence.

Table 2. Biome, city, state, collected material, number of identified fungi and reference to aquatic fungi described in Brazil.

Biome	City (State)	Collected Material	No. Identified Fungi	Reference
Amazon	Barcelos (AM)	water, soil	26	Silva; Oliveira, 2012
	Belém (PA)	submerged trash	2	Monteiro; Gusmão, 2014
	Belém (PA)	leaf, branch	220	Monteiro, 2014
	Manaus, Presidente Figueiredo (AM)	natural foam	17	Fiuza et al., 2015
	Iranduba (AM)	submerged wood	18	Cortez, 2016
Caatinga	Serra da Jibóia (BA)	plant material	18	Barbosa et al., 2007
	Serra da Jibóia (BA)	branch, bark, leaf, petiole	42	Barbosa; Gusmão, 2011
	Jaboatão dos Guararapes (PE)	soil	54	Oliveira et al., 2011
	Pindobaçu (BA)	leaf, branch, bark	17	Almeida et al., 2012
	Chapada do Araripe e Serra de Ibiapaba (CE); Brejo Paraibano (PB)	water foam	4	Fiuza; Gusmão, 2013
	Serra da Fumaça (BA)	leaf	8	Almeida et al., 2014
	Piripiri, Caracol, Teresina, Floriano, Campo Maior e Demerval Lobão (PI)	water, soil	4	Rocha et al., 2016
	Serra da Tromba (BA)	leaf, submerged wood, branch, bark	15	Fiuza et al., 2017
	Teresina, Pedro II, José de Freitas (PI)	water, soil	5	Rocha et al., 2017
	Piatã, Serra da Tromba, Chapada Diamantina (BA)	leaf	75	Fiuza et al., 2019
Cerrado	Itirapina (SP)	water, soil	9	Baptista et al., 2004
	Mogi Guaçu (SP)	soil	29	Nascimento, 2010
	Mogi Guaçu (SP)	soil, leaf	5	Souza et al., 2011
	Distrito Federal (DF)	water	31	Nascimento et al., 2011
	Mogi Guaçu (SP)	soil	29	Nascimento et al., 2012
	Lagoa dos Patos (MG)	water	15	Silveira et al., 2013
	Distrito Federal (DF)	leaf	15	Gomes et al., 2016
	Betim (MG)	water	5	Belgini et al., 2018
Atlantic forest	São Paulo (SP)	water, soil	33	Rocha; Zottarelli, 2002
	Cubatão (SP)	water, branch, leaf	272	Schoenlein-Crusius et al., 2006
	Recife (PE)	water, soil	5	Cavalcanti; Milanez, 2007
	São Paulo (SP)	water	14	Zottarelli; Rocha, 2007
	Santo André (SP)	water, soil	29	Zottarelli; Gomes, 2007
	Santo André (SP)	water, soil	29	Zottarelli; Gomes, 2007
	Santo André (SP)	water, soil	35	Gomes; Zottarelli, 2008
	São Paulo (SP)	water, soil, vegetable substrate	6	Miranda; Zottarelli, 2008

Maringá (PR)	root	10	Marins et al., 2009
São Paulo (SP)	water, soil	18	Nascimento; Zottarelli, 2009
São Paulo (SP)	leaf	24	Schoenlein-Crusius et al., 2009
São Paulo (SP)	water, leaf	38	Jesus et al., 2013
São Paulo (SP)	leaf	27	Schoenlein-Crusius et al., 2014
São Paulo (SP)	leaf	25	Schoenlein-Crusius et al., 2015
São Paulo (SP)	leaf	26	Schoenlein-Crusius et al., 2016
Viçosa (MG)	plant part	11	Soares et al., 2017
São Paulo (SP)	leaf	34	Schoenlein-Crusius et al., 2018
Recife (PE)	leaf	23	Silva et al., 2019

3. RESULTS

41 works referring to aquatic fungi made in Brazil were selected, where 1,322 were identified, 659 (49.8%) in the Atlantic Forest biome, 282 (21.3%) in the Amazon, 242 (18.3%) in the Caatinga and 138 (10.4%) in the Cerrado. The identified fungi were distributed em 328 genera, the most frequent *Penicillium* (3.4%), *Achlya* (3.2%) and *Phythium* (3%) (Figure 1).

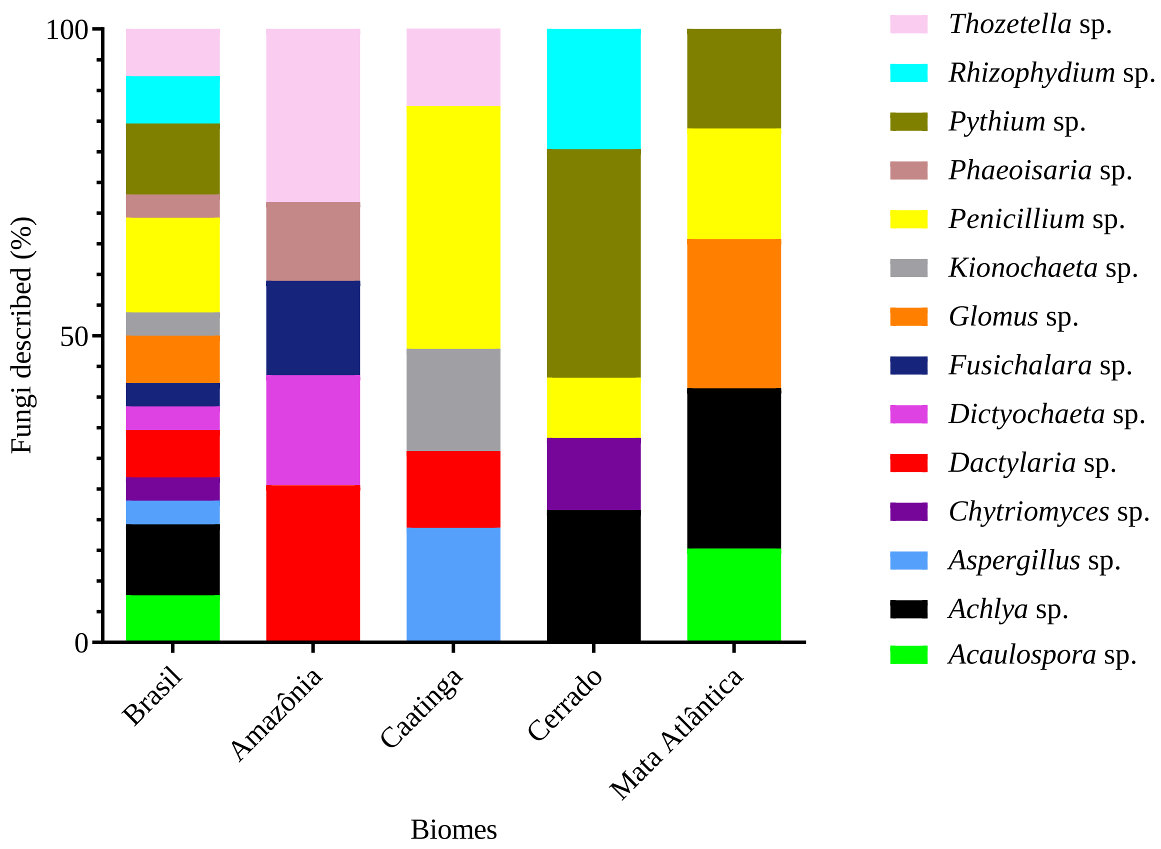

Figure 1. Five aquatic fungi most described in biomes in Brazil from 1999 to 2019.

Samples of leaves and soil were the most used materials in study in Brazil with 16%, followed by water (12%) and the other materials used foam, branches, submerged wood and plant material (Figure 2).

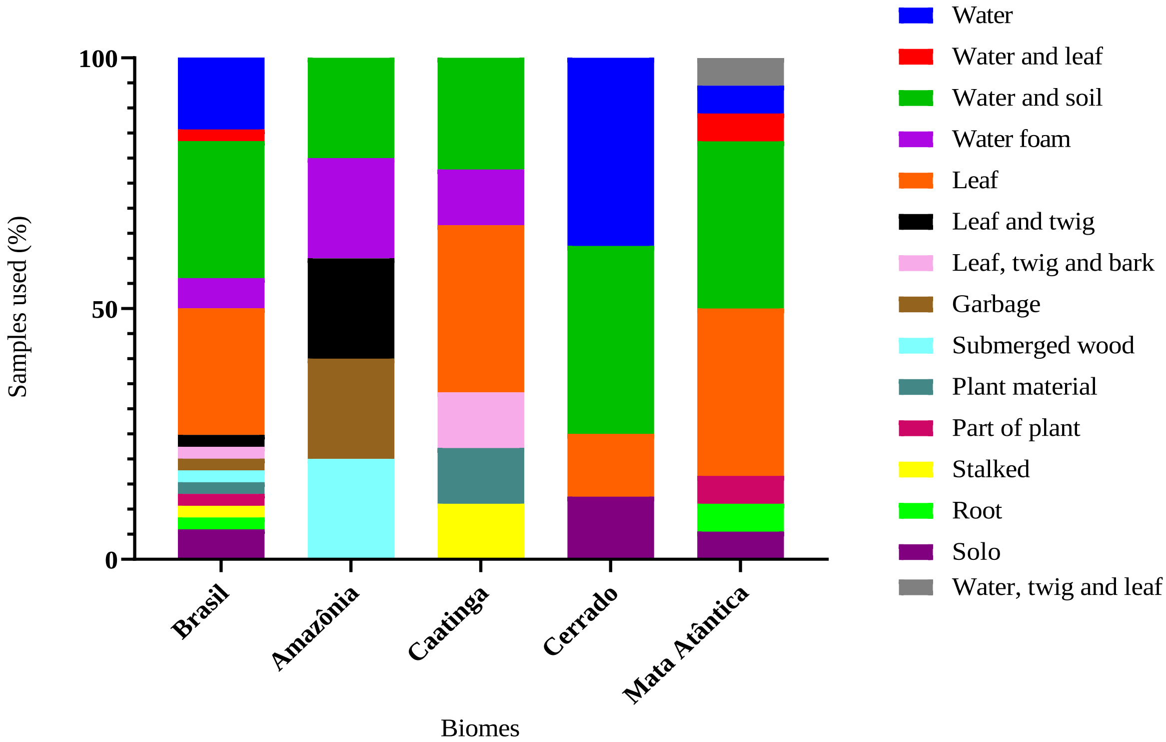

Figure 2. Five samples most used in studies describing aquatic fungi in Brazil from 1999 to 2019.

For the Amazon Biome, 5 studies were found, describing 282 fungi, distributed in 153 genera. The samples used in the studies were water, leaf, branch, submerged garbage, natural foam, submerged wood and soil. The most frequent genera were *Thozetella* (3.8%), *Dactylaria* (3.5%) and *Dictyochaeta* (2.4%), all of the Ascomycota Phylum (Figures 3).

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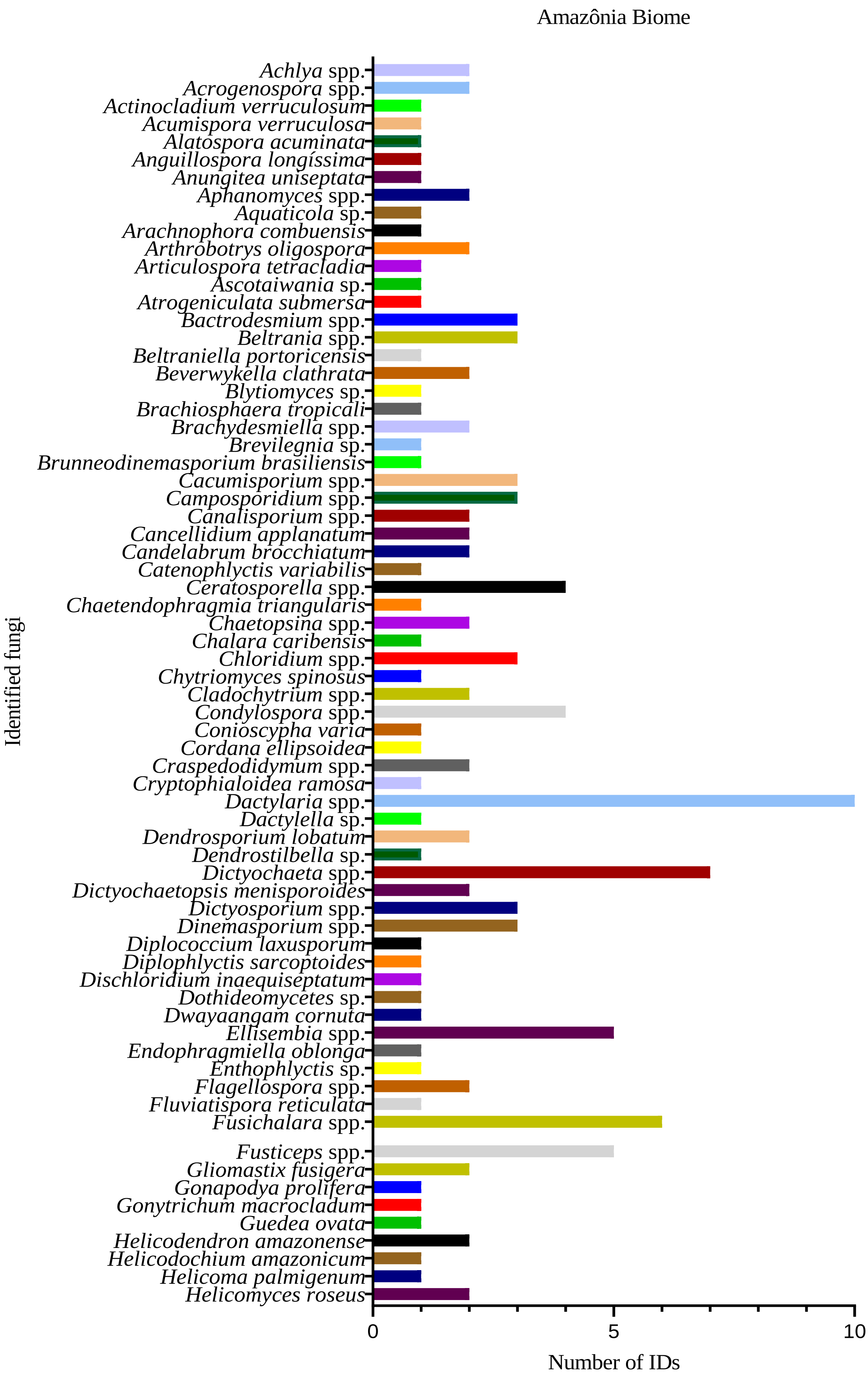

Figure 3. Abundance of aquatic fungi described in the Amazon Biome in Brazil (Part 1).

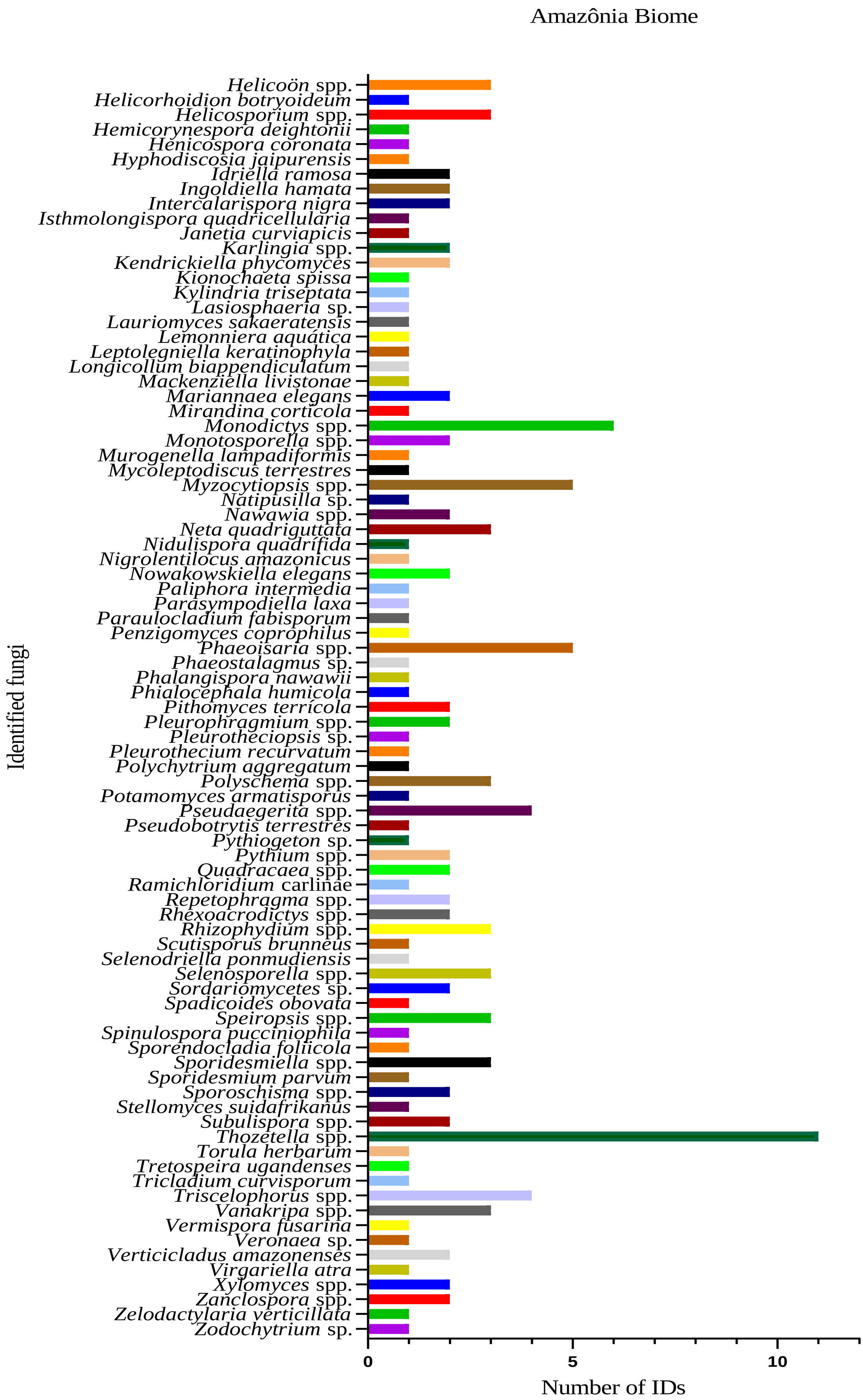
Amazônia Biome
Identified fungi
Number of IDs
0
5
10
Helicoön spp.
Helicorhoidion botryoideum
Helicosporium spp.
Hemicorynespora deightonii
Henicospora coronata
Hyphodiscosia jaipurensis
Idriella ramosa
Ingoldiella hamata
Intercalarispora nigra
Isthmolongispora quadricellularia
Janetia curviapicis
Karlingia spp.
Kendrickiella phycomyces
Kionochaeta spissa
Kylindria triseptata
Lasiosphaeria sp.
Lauriomyces sakaeratensis
Lemonniera aquática
Leptolegniella keratinophyla
Longicollum biappendiculatum
Mackenziella livistonae
Mariannaea elegans
Mirandina corticola
Monodictys spp.
Monotosporella spp.
Murogenella lampadiformis
Mycoleptodiscus terrestres
Myzocytiopsis spp.
Natipusilla sp.
Nawawia spp.
Neta quadriguttata
Nidulispora quadrifida
Nigrolentilocus amazonicus
Nowakowskiella elegans
Paliphora intermedia
Parasympodiella laxa
Paraulocladium fabisporum
Penzigomyces coprophilus
Phaeoisaria spp.
Phaeostalagmus sp.
Phalangispora nawawii
Phialocephala humicola
Pithomyces terrícola
Pleurophragmium spp.
Pleurotheciopsis sp.
Pleurothecium recurvatum
Polychytrium aggregatum
Polyschema spp.
Potamomyces armatisporus
Pseudaegerita spp.
Pseudobotrytis terrestres
Pythiogeton sp.
Pythium spp.
Quadracaea spp.
Ramichloridium carlinae
Repetophragma spp.
Rhexoacrodictys spp.
Rhizophydium spp.
Scutisporus brunneus
Selenodriella ponmudiensis
Selenosporella spp.
Sordariomycetes sp.
Spadicoides obovata
Speiropsis spp.
Spinulospora pucciniophila
Sporendocladia foliicola
Sporidesmiella spp.
Sporidesmium parvum
Sporoschisma spp.
Stellomyces suidafrikanus
Subulispora spp.
Thozetella spp.
Torula herbarum
Tretospeira ugandenses
Tricladium curvisporum
Triscelophorus spp.
Vanakripa spp.
Vermispora fusarina
Veronaea sp.
Verticicladus amazonenses
Virgariella atra
Xylomyces spp.
Zanclospora spp.
Zelodactylaria verticillata
Zodochytrium sp.

Figure 3. Abundance of aquatic fungi described in the Amazon Biome in Brazil (Part 2).

In the Caatinga Biome, 10 studies were observed, with 242 aquatic fungi identified in 120 genera. The materials used in the studies were leaf, branch, bark, plant material, petiole, water foam, submerged wood and soil. The genera that showed the highest frequency were *Penicillium* (7.8%), *Aspergillus* (3.7%) and *Thozetella* (3.3%), all of the Ascomycota Phylum (Figure 4).

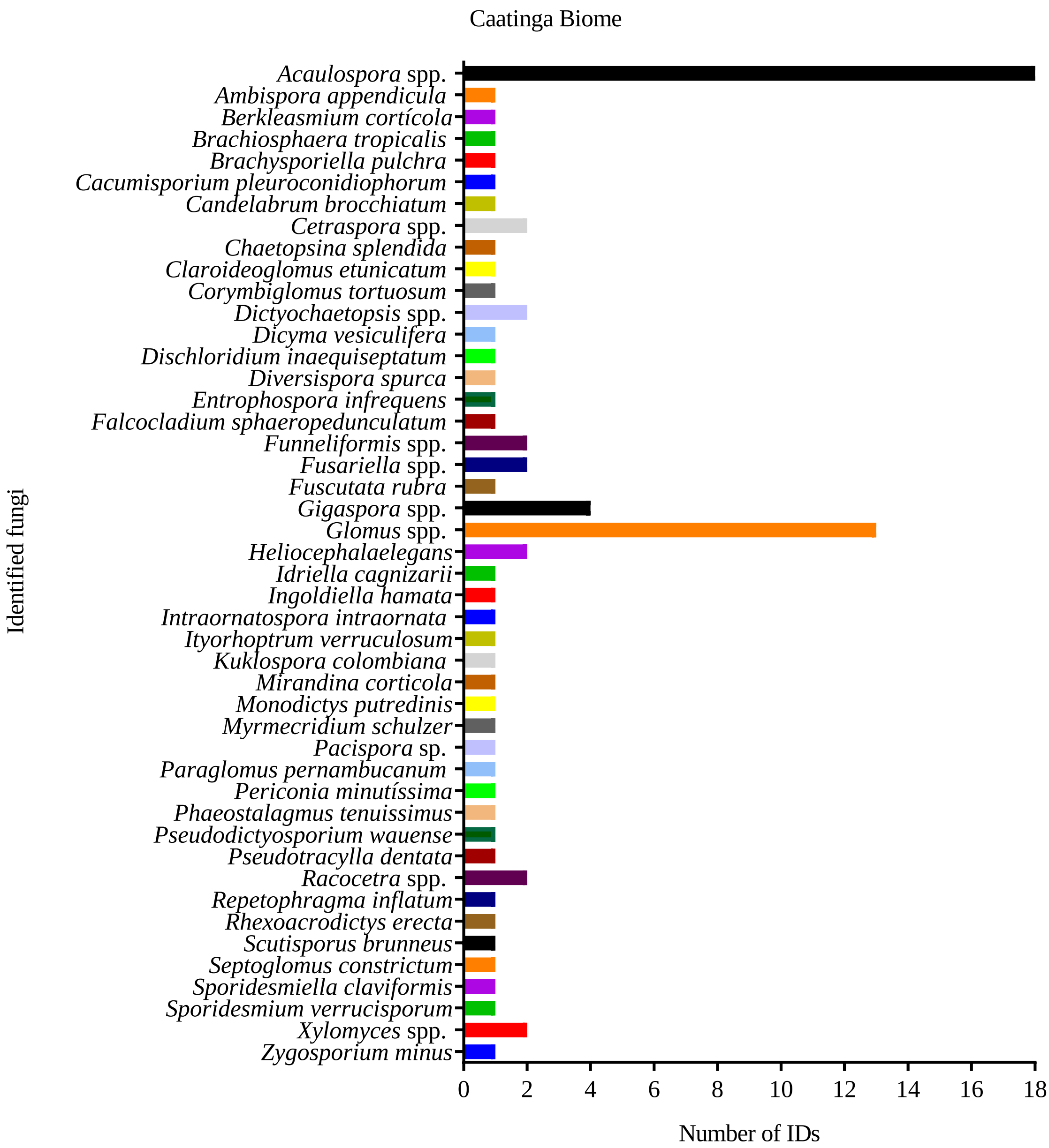

Figure 4. Abundance of aquatic fungi described in the Caatinga Biome in Brazil.

In the Cerrado Biome, 8 studies were reported, with the identification of 138 fungi organized into 60 genera, the genera with the highest incidence *Pythium* (13.7%), *Achlya* (7.9%), of the Phylum Oomycota, previously classified as a fungus, but currently classified as algae in the Chromist kingdom, and *Rhizophydium* (7.2%), of the Phylum Chytridiomycota (Figure 5). The samples used in the studies were leaves, wet and decomposing leaves, water and soil.

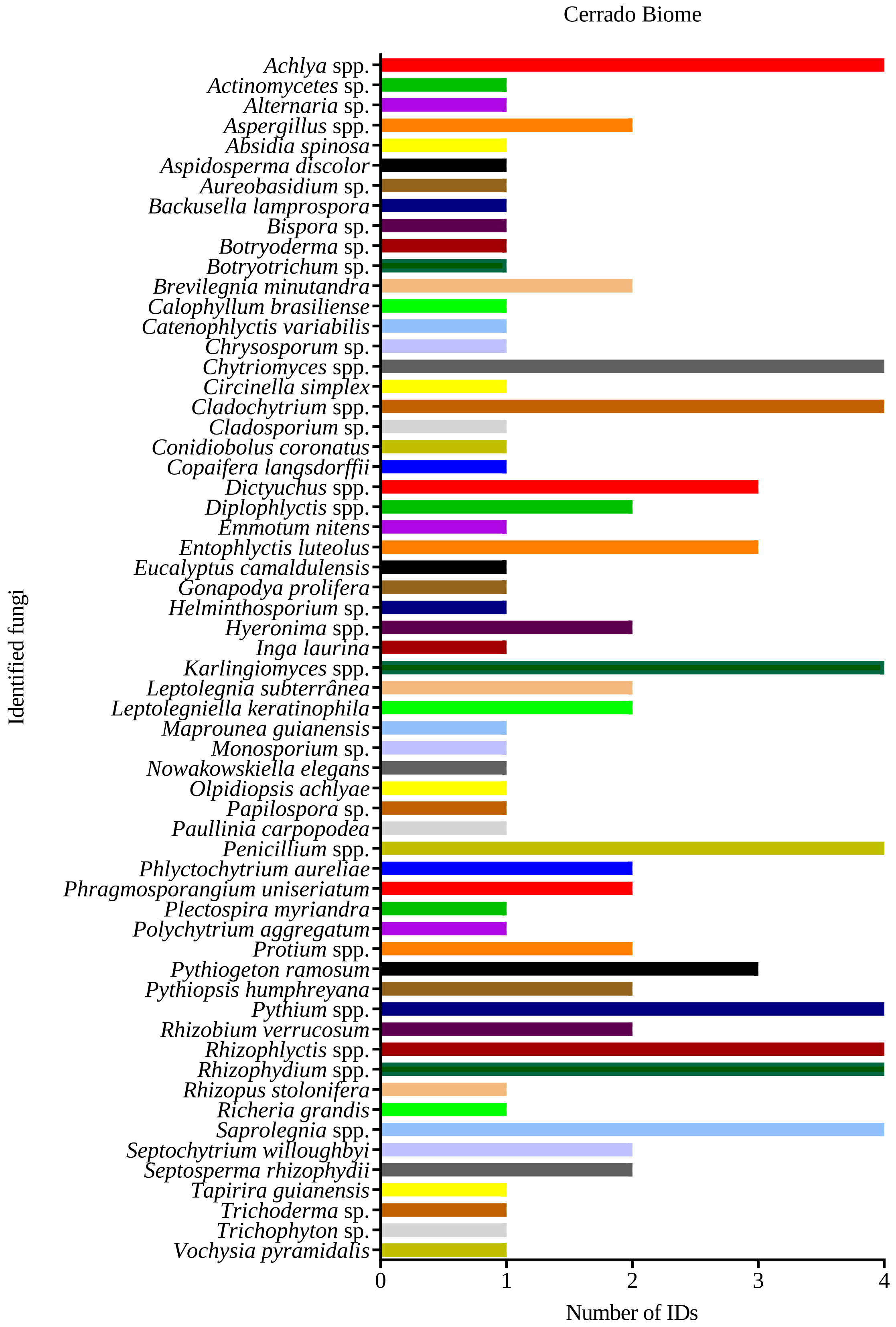

Figure 5. Abundance of aquatic fungi described in the Cerrado Biome in Brazil.

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In the Atlantic Forest Biome, 18 studies were described, with the identification of 652 aquatic fungi and 157 genera, the most identified of which were *Achlya* (4.6%), Phylum Oomycota, Chromist kingdom, *Glomus* (4.3%), Phylum Glomeromycota. and *Penicillium* (3.2%), Phylum Ascomycota (Figure 6). Water, soil, leaves, roots, plant substrate and plant part were used as samples.

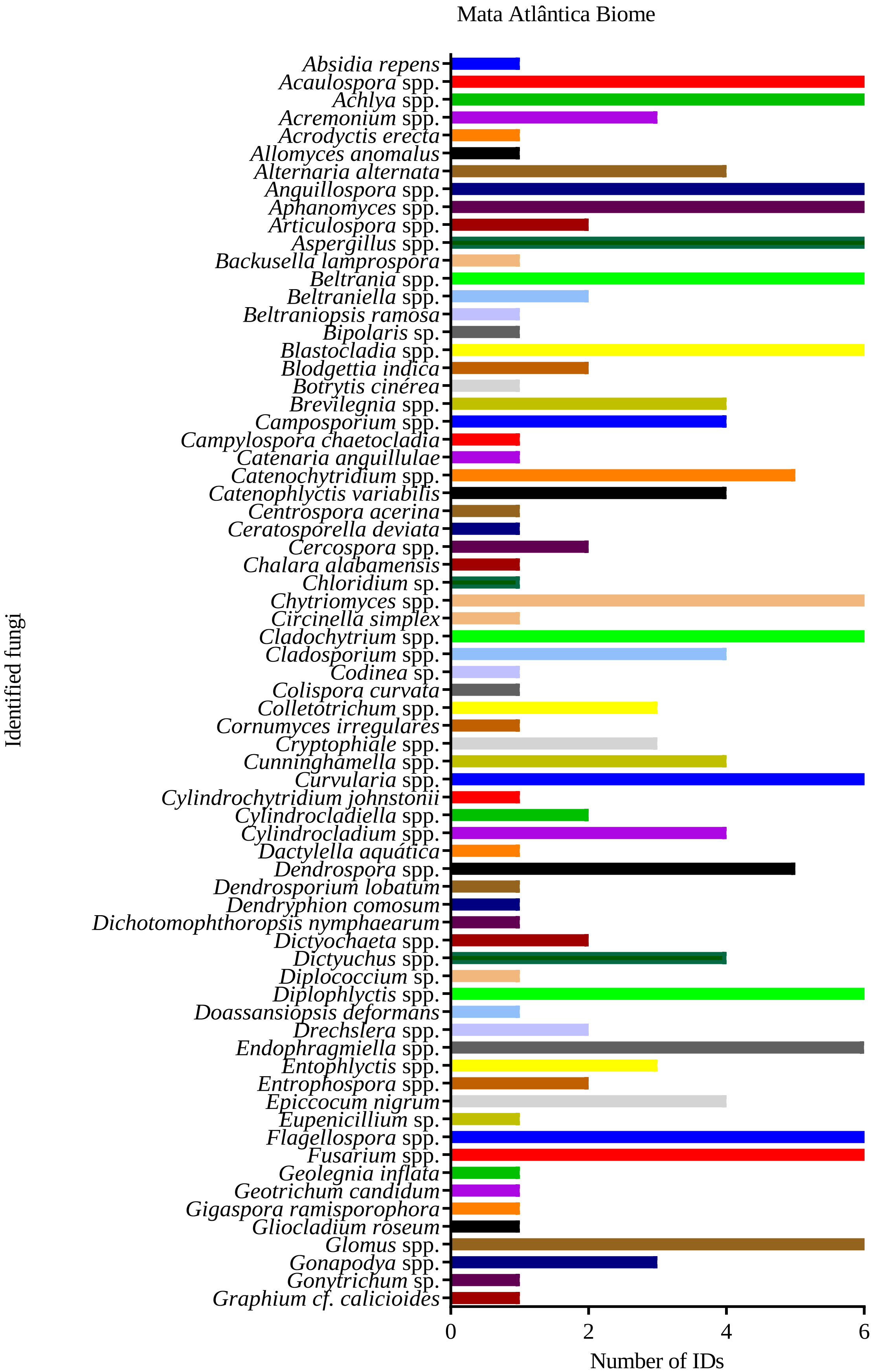
Mata Atlântica Biome
Identified fungi
Absidia repens
Acaulospora spp.
Achlya spp.
Acremonium spp.
Acrodyctis erecta
Allomyces anomalus
Alternaria alternata
Anguillospora spp.
Aphanomyces spp.
Articulospora spp.
Aspergillus spp.
Backusella lamprospora
Beltrania spp.
Beltraniella spp.
Beltraniopsis ramosa
Bipolaris sp.
Blastocladia spp.
Blodgettia indica
Botrytis cinérea
Brevilegnia spp.
Camposporium spp.
Campylospora chaetocladia
Catenaria anguillulae
Catenochytridium spp.
Catenophlyctis variabilis
Centrospora acerina
Ceratosporella deviata
Cercospora spp.
Chalara alabamensis
Chloridium sp.
Chytriomyces spp.
Circinella simplex
Cladochytrium spp.
Cladosporium spp.
Codinea sp.
Colispora curvata
Colletotrichum spp.
Cornumyces irregulares
Cryptophiale spp.
Cunninghamella spp.
Curvularia spp.
Cylindrochytridium johnstonii
Cylindrocladiella spp.
Cylindrocladium spp.
Dactylella aquática
Dendrospora spp.
Dendrosporium lobatum
Dendryphion comosum
Dichotomophthoropsis nymphaearum
Dictyochaeta spp.
Dictyuchus spp.
Diplococcium sp.
Diplophlyctis spp.
Doassansiopsis deformans
Drechslera spp.
Endophragmiella spp.
Entophlyctis spp.
Entrophospora spp.
Epiccocum nigrum
Eupenicillium sp.
Flagellospora spp.
Fusarium spp.
Geolegnia inflata
Geotrichum candidum
Gigaspora ramisporophora
Gliocladium roseum
Glomus spp.
Gonapodya spp.
Gonytrichum sp.
Graphium cf. calicioides
0
2
4
6
Number of IDs

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Figure 6. Abundance of aquatic fungi described in the Atlantic Forest Biome in Brazil (Part 1).

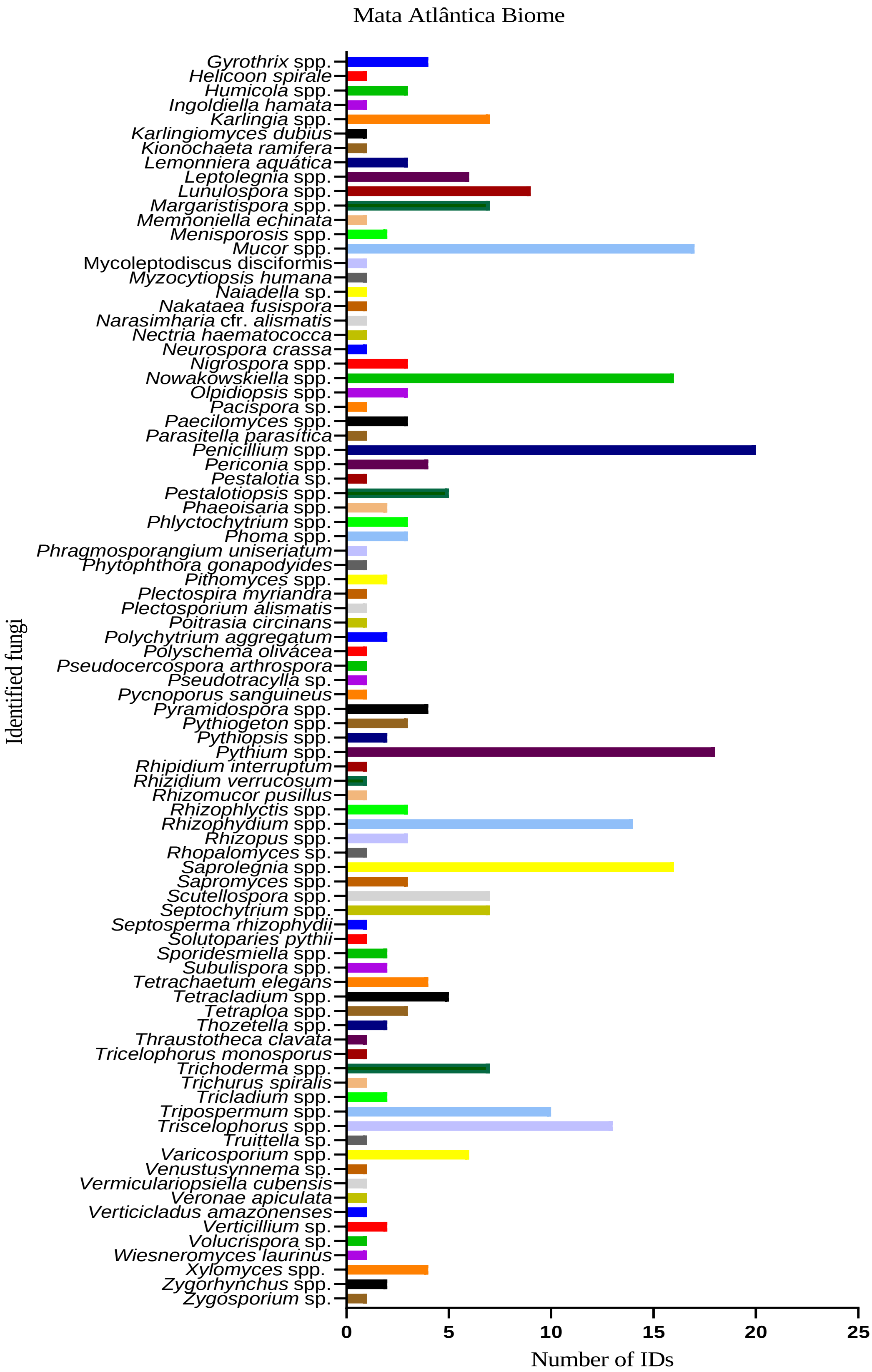

Figure 6. Abundance of aquatic fungi described in the Atlantic Forest Biome in Brazil (Part 2).

4. DISCUSSION

In this study, we analyzed the works related to aquatic fungi in Brazil. The systematic review identified 41 studies, describing 1,322 fungi, distributed in 328 genera with the most frequent *Penicillium* (3.4%), *Achlya* (3.2%), *Phythium* (3%), *Rhizophydium* (2%) and *Glomus* (2%). According to the Brazilian List of Plants and Fungi, the two most frequent groups of fungi are Basidiomycota and Ascomycota, with more than 30 and 60 thousand species already described [47], corroborating the findings of this work, where *Penicillium* was the most frequent genus, from the Phylum Ascomycota. *Achlya* and *Phythium* are algae from the Phylum Oomycota, previously classified in the Fungi Kingdom, but currently located in the Chromist Kingdom. *Glomus* is from the Phylum Glomeromycota and Dactylaria from the Phylum Ascomycota.

The samples used in most studies in Brazil were the combination of water and soil (27.3%). Aquatic studies indicate that the leaves are primarily colonized by fungi [48], but woody materials are usually colonized by aquatic fungi, due to the presence of resistance in periods of dehydration when substrates emerge [49].

In the Amazon Biome, studies were carried out only in the states of Amazonas and Pará, thus showing the scarcity of studies in the other states of this biome. Fungi in the first occurrence were identified, such as the genera *Fusticeps* and *Triscelophorus*. The knowledge of fungi present in aquatic environments of the Amazon biome is very limited [50], demonstrating the need for professional training, and the production of new studies in states without identification of aquatic fungi, necessary to describe the fungi present in this environment, as well as their importance for the region's ecosystem, especially in the black waters that make up the hydrographic organization of the Amazon basin [50; 54; 13].

In the Caatinga Biome, studies were carried out in the states of Bahia, Pernambuco, Piauí and Rio Grande do Norte, using samples of leaves, branches, bark, plant material, petiole, water foam, submerged wood and soil. Fungal diversity in arid and semi-arid ecosystems can be considered equal or superior when compared to humid environments [17; 51; 22]. These communities are affected by biotic and abiotic factors and are constantly changing, with a complex interaction of organisms occurring. [22].

The Cerrado Biome used samples of wet and decomposing leaves, water and soil. The Cerrado Biome is considered the third largest biome in Brazil, suffering intense deforestation with the progress of the urbanization process and agricultural activities, especially in the State of São Paulo [28]. Despite the pollution, in the studies carried out in the Cerrado, the diversity of these organisms in this biome was also relevant [52].

The Atlantic Forest Biome, consisted of works done in São Paulo, Minas Gerais and Pernambuco where the studied areas presented diversity in the fungi community associated with submerged litter decomposition similar to other locations in tropical regions of Brazil [44]. The organisms found are normally abundant in plant material, however, molecular studies have shown the presence and the important contribution of these organisms in the process of fungal succession in leaf substrates in lotic and lentic aquatic ecosystems [33]. The greater amount of work carried out in this biome led to a greater description of aquatic fungi, and this result was probably due to the greater number of specialists in these states and greater sampling effort.

Pampa and Pantanal did not present any work in this analysis, with a survey carried out it was observed that changes in the soil directly affect the fungi community, especially when these changes are due to anthropic action [53]. Although the Pantanal biome is known as a wetland, with periodic flooding and responsible for the balance of the ecological system of the entire region, these are considered to be unknown [53].

In view of the results presented, this study presents the scarcity of information on aquatic fungi, thus showing the need for studies and training of specialized researchers to enable increased knowledge about the distribution, ecology and identification of these fungi in the different biomes of Brazil, mainly in biomes rich in aquatic habitats, such as the Amazon and Pantanal.

CONCLUSIONS

The bibliographic review on the diversity of aquatic fungi in Brazil revealed that the Atlantic Forest biome had a greater number of described fungi confirming the expected diversity in this rich forest biome. Leaves and soil were the most used materials in studies in Brazil and the genus *Penicillium* had a higher frequency of occurrence in Brazil.

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REFERENCES

[1] JIANG, Y. et al. Plants transfer lipids to sustain colonization by mutualistic mycorrhizal and parasitic fungi. **Science**, v. 356, n. 6343, p. 1172-1175, 2017.

[2] INGOLD, C. T. Aquatic hyphomycetes of decaying alder leaves. **Transactions of the British Mycological Society**, v. 25, n. 4, p. 33-339, 1942.

[3] BERNARDE, P. S. Ambientes e temporada de vocalização da anurofauna no Município de Espigão do Oeste, Rondônia, Sudoeste da Amazônia-Brasil (Amphibia: Anura). **Biota Neotropica**, v. 7, n. 2, p. 87-92, 2007.

[4] MANJARRES, G. G. et al. Contribución al conocimiento hidrobiológico de la parte baja de los ríos de la vertiente noroccidental de la Sierra Nevada de Santa Marta, Colombia. **Intropica**, v. 1, n. 1, p. 39-50, 2004.

[5] CANHOTO, C. et al. Stream salinization and fungal-mediated leaf decomposition: a microcosm study. **Science of the Total Environment**, v. 599, n.1, p. 1638-1645, 2017.

[6] SINGH, A. et al. Optimal physical parameters for growth of *Trichoderma* species at varying pH, temperature and agitation. **Virology and Mycology**, v. 3, n. 1, p. 127-134, 2014.

[7] FIUZA, P. O. et al. Ingoldian fungi of Brazil: some new records and a review including a checklist and a key. **Phytotaxa**, v. 306, n. 3, p. 171-200, 2017.

[8] NASCIMENTO, J. M. et al. Estudo da Remoção do Íon Cobre por meio de Biossorção usando Biomassa de Levedura (*Saccharomyces cerevisiae*). **CETEM**, 2016. 50 f.

[9] GESSNER, M. O. et al. 17 Fungal Decomposers of Plant Litter in Aquatic Ecosystems. **Environmental and microbial relationships**, v. 4, n. 1, p. 301-302, 2007.

[10] BÄRLOCHER, F. Aquatic hyphomycetes in a changing environment. **Fungal Ecology**, v. 19, n. 1, p. 14-27, 2016.

[11] GROSSART, H. et al. Discovery of dark matter fungi in aquatic ecosystems demands a reappraisal of the phylogeny and ecology of zoosporic fungi. **Fungal Ecology**, v. 19, n.1, p. 28-38, 2016.

[12] WIJAYAWARDENE, N. N. et al. Notes for genera: Ascomycota. **Fungal Diversity**, v. 86, n. 1, p. 1-594, 2017.

[13] CORTEZ, A. C. et al. **Influência da sazonalidade e do modo de coleta na diversidade de fungos decompositores de madeira submersa de ambientes aquáticos da Região Amazônica**. 2016. 89 f. Tese (Doutorado em Biotecnologia) - Universidade Federal do Amazonas, Manaus, 2016.

[14] KODSUEB, R. et al. Relationships between terrestrial and freshwater lignicolous fungi. **Fungal Ecology**, v. 19, n. 1, p. 155-168, 2016.

[15] SEIFERT, K. A. The genera of Hyphomycetes. **Persoonia: Molecular Phylogeny and Evolution of Fungi**, v. 27, n. 1, p. 119-120, 2011.

[16] BARBOSA, F. R. et al. Conidial fungi from the semi-arid Caatinga biome of Brazil. New species *Deightoniella rugosa* & *Diplocladiella cornitumida* with new records for the neotropics. **Mycotaxon**, v. 102, p. 39-49, 2007.

[17] BARBOSA, F. R. et al. Conidial fungi from semi-arid Caatinga Biome of Brazil. Rare freshwater hyphomycetes and other new records. **Mycosphere**, v. 2, n. 4, p. 475- 485, 2011.

[18] FIUZA, P. O.; GUSMÃO, L. F. P. Ingoldian fungi from semiarid Caatinga biome of Brazil. The genus *Campylospora*. **Mycosphere**, v. 4, p. 559-565, 2013.

[19] FIUZA, P. O. et al. Rare hyphomycetes from freshwater environments from Chapada Diamantina, Bahia, Brazil. **Nova Hedwigia**, v. 104, n. 4, p. 451-466, 2017.

[20] FIUZA, P. O. et al. Diversity of freshwater hyphomycetes associated with leaf litter of *Calophyllum brasiliense* in streams of the semiarid region of Brazil. **Mycological Progress**, v. 18, n. 7, p. 907-920, 2019.

[21] OLIVEIRA, L. G. de et al. Filamentous fungi isolated from Candeias Beach, Pernambuco, Brazil. **Hoehnea**, v. 38, n. 2, p. 215-220, 2011.

[22] ROCHA, J. R. S. et al. The genus Allomyces (Blastocladiomycota) in the State of Piauí, Brazil. **Hoehnea**, v. 43, n. 3, p. 487-495, 2016.

[23] ROCHA, J. R. S.; ROCHA, PONTES, F.; MACHADO, J. L. O gênero Myzocytiopsis (Oomycota) no estado do Piauí: Novos registros para o Brasil. **Gaia Scientia**, v. 11, n. 1, p. 98-115, 2017.

[24] BAPTISTA, F. R. et al. The genus *Pythium pringsheim* from Brazilian cerrado areas, in the state of São Paulo, Brazil**. Revista brasileira de botânica**, 2004.

[25] BELGINI, D. R. et al. Integrated diversity analysis of the microbial community in a reverse osmosis system from a Brazilian oil refinery. **Systematic and applied microbiology**, v. 41, n. 5, p. 473-486, 2018.

[26] GOMES, P. P.; MEDEIROS, A. O.; JÚNIOR, J. G. The replacement of native plants by exotic species may affect the colonization and reproduction of aquatic hyphomycetes. **Limnologica**, v. 59, p. 124-130, 2016.

[27] NASCIMENTO, C. A. **Avaliação da diversidade de organismos zoospóricos da Reserva Biológica e Estação Experimental de Mogi Guaçu, Estado de São Paulo, Brasil.** Tese (Doutorado em Biodiversidade Vegetal e Meio Ambiente) - Instituto de Botânica da Secretaria de Estado do Meio Ambiente, São Paulo, 2010.

[28] NASCIMENTO, C. L. Diversidade de fungos zoospóricos da Reserva Biológica de Mogi Guaçu, estado de São Paulo, Brasil. **Rodriguésia-Instituto de Pesquisas Jardim Botânico do Rio de Janeiro**, v. 63, n. 3, p. 587-611, 2012.

[29] SILVEIRA, E. S.; LOBATO, R. C.; ABREU, P. C. Fungos e leveduras no estuário da Lagoa dos Patos e praia do Cassino, Rio Grande, RS, Brasil. **Atlântica (Rio Grande)**, v. 35, n. 1, p. 45-54, 2013.

[30] SOUZA, J. I. et al. Zygomycetes from “Reserva Biológica de Mogi Guaçu”, São Paulo State, Brazil. **Mycotaxon**, v. 116, p. 303-312, 2011.

[31] CAVALCANTI, M. S.; MILANEZ, A. I. Hyphomycetes isolados da água e do solo da Reserva Florestal de Dois Irmãos, Recife, PE, Brasil. **Acta Botanica Brasilica**, v. 21, n. 4, p. 857-862, 2007.

[32] GOMES, A. L.; PIRES-ZOTTARELLI, C. A. Oomycota (Straminipila) da Reserva Biológica de Paranapiacaba, Santo André, SP, Brasil. **Acta Botanica Brasilica**, v. 22, n. 2, p. 373-392, 2008.

[33] JESUS, A. L. et al. Diversidade de organismos zoospóricos heterotróficos do Parque Estadual das Fontes do Ipiranga, São Paulo, SP, Brasil: novas citações. **Hoehnea**, v. 40, n. 1, p. 167-180, 2013.

[34] MARINS, J. F.; CARRENHO, R.; THOMAZ, S. M. Occurrence and coexistence of arbuscular mycorrhizal fungi and dark septate fungi in aquatic macrophytes in a tropical river–floodplain system. **Aquatic Botany**, v. 91, n. 1, p. 13-19, 2009.

[35] MIRANDA, M. L.; ZOTTARELLI, C. L. O gênero Pythium no Parque Estadual da Serra da Cantareira, Estado de São Paulo, Brasil. **Hoehnea**, v. 35, n. 2, p. 281-288, 2008.

[36] NASCIMENTO, C. A.; PIRES-ZOTTARELLI, C. A. Chytridiales (Chytridiomycota) do Parque Estadual da Serra da Cantareira, SP, Brasil. **Acta Botanica Brasilica**, v. 23, n. 2, p. 459-473, 2009.

[37] ROCHA, M.; ZOTTARELLI, C. A. Chytridiomycota e Oomycota da Represa do Guarapiranga, São Paulo, SP. **Acta Botanica Brasilica**, v. 16, n. 3, p. 287-309, 2002.

[38] SCHOENLEIN-CRUSIUS, I. H. et al. Microscopic fungi in the Atlantic Rainforest in Cubatão, São Paulo, Brazil. **Brazilian Journal of Microbiology**, v. 37, n. 3, p. 267-275, 2006.

[39] SCHOENLEIN-CRUSIUS, I. H.; MOREIRA, C. G.; BICUDO, D. C. Aquatic Hyphomycetes in the Parque Estadual das Fontes do Ipiranga-PEFI, São Paulo, Brazil. **Brazilian Journal of Botany**, v. 32, n. 3, p. 411-426, 2009.

[40] SCHOENLEIN-CRUSIUS, I. H. et al. Riqueza dos fungos ingoldianos e aquáticos facultativos no Parque Municipal do Ibirapuera, São Paulo, SP, Brasil. **Hoehnea**, v. 41, n. 1, p. 61-76, 2014.

[41] SCHOENLEIN-CRUSIUS, I. H.; MOREIRA, C. G.; GOMES, E. C. Riqueza dos fungos ingoldianos e dos fungos aquáticos facultativos do Parque Municipal da Aclimação, São Paulo, SP, Brasil. **Hoehnea**, v. 42, n. 2, p. 239-251, 2015.

[42] SCHOENLEIN-CRUSIUS, I. H. et al. Diversity of conidial fungi and some abiotic variables of the water after the reopening of the Pirarungaua stream in the Jardim Botânico, São Paulo, São Paulo State, Brazil. **Hoehnea**, v. 43, n. 1, p. 57-75, 2016.

[43] SCHOENLEIN-CRUSIUS, I. H.; MOREIRA, C. G.; GOMES, E. P. C. Riqueza de fungos ingoldianos e de fungos aquático-facultativos no Parque Municipal do Carmo, São Paulo, SP, Brasil. **Hoehnea**, v. 45, n. 3, p. 379-393, 2018.

[44] SILVA, G. R.; CASTAÑEDA-RUIZ, R. F.; MALOSSO, E. Comparison of aquatic hyphomycetes communities between lotic and lentic environments in the Atlantic rain forest of Pernambuco, Northeast Brazil. **Fungal biology**, v. 123, n. 9, p. 660-668, 2019.

[45] SOARES, D. J.; BARRETO, R. W.; BRAUN, U. Brazilian mycobiota of the aquatic weed Sagittaria montevidensis. **Mycologia**, v. 101, n. 3, p. 401-416, 2009.

[46] PIRES-ZOTTARELLI, C. A.; ROCHA, M. New records of Chytridiomycota and Oomycota from the "Parque Estadual das Fontes do Ipiranga (PEFI)", SP, Brazil. **Acta Botanica Brasilica**, v. 21, n. 1, p. 125-136, 2007.

[47] PIRES-ZOTTARELLI, C. A.; GOMES, A. L. Contribuição para o conhecimento de Chytridiomycota da " Reserva Biológica de Paranapiacaba", Santo André, SP, Brasil. **Biota Neotropica**, v. 7, n. 3, p. 309-329, 2007.

[48] MAIA, L. C. et al. Diversity of Brazilian fungi. **Rodriguésia**, v. 66, n. 4, p. 1033-1045, 2015.

[49] KRAUSS, G. et al. Fungi in freshwaters: ecology, physiology and biochemical potential. **FEMS Microbiology Reviews**, v. 35, n. 4, p. 620-651, 2011.

SAJEBTT, Rio Branco, UFAC
v.8 n.1 (2021): Edição jan/abr.
ISSN: 2446-4821

[50] SIVICHAI, S. et al. Fungal colonisation of wood in a freshwater stream at Tad Ta Phu, Khao Yai National Park, Thailand. **Fungal Diversity**, v. 10, n. 1, p. 113-129, 2002.

[51] MONTEIRO, J. S. **Fungos conidiais associados a substratos vegetais submersos em fragmentos florestais do bioma Amazônia**. 2014. Tese (Doutorado em Biologia de Fungos) Departamento de Micologia, Centro de Ciências Biológicas, Universidade Federal de Pernambuco, Recife, 2014.

[52] ALMEIDA, D. A. et al. Alguns fungos conidiais aquáticos-facultativos do bioma Caatinga. **Acta Botanica Brasílica**, v. 26, n. 4, p. 924-932, 2012.

[53] WELLBAUM, C. et al. Fungos filamentosos em folhas do ambiente terrestre e aquático da Ilha dos Eucaliptos, Represa do Guarapiranga, São Paulo, SP. **Revista Brasileira de Botânica**, v. 22, n. 1, p. 69-74, 1999.

[54] MERCANTE, M. A. et al. Geomorphology and habitat diversity in the Pantanal. **Brazilian Journal of Biology**, v. 71, n. 1, p. 233-240, 2011.

[55] FIUZA, P. O. et al. First records of Ingoldian fungi from the Brazilian Amazon. **Brazilian Journal of Botany**, v. 38, n. 3, p. 615-621, 2015.