ACTA
AMAZONICA

http://dx.doi.org/10.1590/1809-4392202101730

ORIGINAL ARTICLE

Checklist of Amazonian gasteroid fungi (Agaricomycetidae, Phallomycetidae, Basidiomycota)

Nathalia Mendonça de ASSIS[1*], Jefferson dos Santos GÓIS[1*], Julimar Freire de FREITAS-NETO[1], Flávia Rodrigues BARBOSA[2], Iuri Goulart BASEIA[1,3]

[1] Universidade Federal do Rio Grande do Norte, Centro de Biociências, Programa de Pós-Graduação em Sistemática e Evolução. Av. Senador Salgado Filho, 3000, Campus Universitário, Natal, 59072-970, RN, Brazil

[2] Universidade Federal de Mato Grosso, Instituto de Ciências Naturais, Humanas e Sociais, Sinop, Mato Grosso, 78557-267, Brazil

[3] Universidade Federal do Rio Grande do Norte, Departamento de Botânica e Zoologia, Av. Senador Salgado Filho, 3000, Campus Universitário, Natal, 59072-970, RN, Brazil

* Corresponding author: nathalia.assis@outlook.com; jeff.gois@outlook.com; https://orcid.org/0000-0002-1946-3975

ABSTRACT

The Amazon rainforest is the largest tropical rainforest in the world, with high biodiversity of organisms. Despite the increasing knowledge about fungal diversity in the last few years, many fungal taxa, including gasteroid clades, are still poorly known. Gasteroid fungi are recognized by the maturation of basidiospores inside the basidiomata and by the passive release of spores. We conducted a detailed survey of published data on the species that occur in Amazon forests. We confirmed the occurrence of 83 species distributed in 22 genera, eight families and four orders. The most representative genera was *Geastrum,* followed by *Cyathus*, *Lycoperdon* and *Phallus*. We present an identification key for Amazonian gasteroid genera and a map of record distribution. This review is expected to contribute to identify distribution gaps for further research on gasteroid fungi and to subsidize policies for the conservation of fungi in the Amazon region.

KEYWORDS: Neotropics, biodiversity, taxonomy, Gasteromycetes, rainforest

Checklist de fungos gasteroides da Amazônia (Agaricomycetidae, Phallomycetidae, Basidiomycota)

RESUMO

A floresta amazônica é a maior floresta tropical do mundo, com alta biodiversidade de organismos. Apesar do crescente aumento sobre o conhecimento da diversidade fúngica nos últimos anos, muitos táxons de fungos, especialmente clados gasteróides, ainda são pouco conhecidos. Os fungos gasteróides são reconhecidos pela maturação dos basidiósporos no interior do basidioma e pela liberação passiva de esporos. Baseado em dados publicados, realizamos um levantamento detalhado das espécies que ocorrem na floresta amazônica. Nós confirmamos a ocorrência de 83 espécies distribuídas em 22 gêneros, 8 famílias e 4 ordens. Os gêneros mais representativos foram *Geastrum,* seguido por *Cyathus*, *Lycoperdon* e *Phallus*. Apresentamos uma chave de identificação para gêneros de gasteróides amazônicos e um mapa de distribuição de registros. Espera-se que esta revisão contribua para identificar lacunas de distribuição para futuras pesquisas sobre fungos gasteroides e para subsidiar políticas de conservação de fungos na região amazônica.

PALAVRAS-CHAVE: Neotrópicos, biodiversidade, taxonomia, Gasteromycetes, floresta tropical

INTRODUCTION

The Amazon rainforest is a mosaic of different phytophysiognomies that form one of the largest and most diverse rainforests in the world (Coutinho 2006; MMA 2007). The region faces important conservation challenges, with increasingly high rates of deforestation and biodiversity loss (Oliveira-Filho and Metzger 2006; Giam 2017). In this context, the knowledge about the fungal community is essential for the conservation and restoration of these areas (Fink *et al.* 2021) since fungi act directly in nutrient cycling in the soil (Kirk *et al.* 2008).

Estimates indicate that 90% of the species of fungi are unknown to science (Antonelli *et al.* 2020). The Neotropical region, especially in extensive forests such as Amazonia, probably harbors many undiscovered species, mainly due to the high rate of endemic species per area (Hawswork and Lücking 2017). Recent studies reported the occurrence of about 1000 species of macrofungi for the Brazilian Amazon

CITE AS: Assis, N.M.; Góis, J.S.; Freitas-Neto, J.F.; Barbosa, F.R.; Baseia, I.G. 2022. Checklist of Amazonian gasteroid fungi (Agaricomycetidae, Phallomycetidae, Basidiomycota). *Acta Amazonica* 52: 131-141.

forest (Maia *et al.* 2015). Despite being relatively better known than other groups, publications on gasteroid fungi, a group characterized by passive spore dispersion, are also scarce and widely dispersed throughout the Amazon domain, concentrating mainly around few research poles in the region (Maia *et al*. 2015).

Gasteroid fungi have various morphotypes and grow on different types of substrates, such as soil, wood, manure, and leaves, acting directly in nutrient cycling, as well as decomposition of organic matter and mycorrhizal symbiosis (Miller and Miller 1988; Alexopoulos *et al.* 1996). Some groups have medical and pharmacological importance. For example, *Cyathus* Haller species have compounds capable of reducing neurodegenerative effects (Yin *et al.* 2019). *Geastrum* Pers. has species with bactericidal efficacy and biotechnological potential for waste degradation through enzymatic activities (Kuhar *et al.* 2016; Sevindik *et al.* 2017).

The first records of gasteroid fungi cited for the Amazon were made by Montagne (1839), who recorded *Geastrum ambiguum* Mont. and *Phallus indusiatus* Vent.: Pers. in the Bolivian Amazon forest. Since then, most records of new Amazonian genera and species were from Brazil, especially in recent years (e.g., Trierveiler-Pereira *et al*. 2009; Henkel *et al*. 2010; Alfredo *et al*. 2012a; Alfredo *et al*. 2012b; Silva *et al*. 2013; Cabral *et al*. 2014a; Smith *et al*. 2015; Baseia *et al*. 2016; Crous *et al*. 2016; Cabral *et al*. 2017; Crous *et al*. 2017; Accioly *et al*. 2018; Crous *et al*. 2018; Accioly *et al*. 2019; Assis *et al*. 2019; Cabral *et al*. 2019).

In this study, we carried out a compilation of published records of gasteroid fungi in Amazonian forests and provide an identification key for Amazonian genera.

MATERIAL AND METHODS

In this study, the geographical delimitation for the Amazon domain presented by Tejada *et al.* (2020), which comprises the Amazon Basin, was used. Data for this checklist were obtained through an extensive search in literature records published for the Amazon domain in Bolivia, Brazil, Colombia, Ecuador, French Guiana, Guyana, Peru, Surinam, and Venezuela until March 2021. Electronic databases such as Google Scholar, Biodiversity Heritage Library, and Web of Science were used in the research. Regarding habitat, the search terms were rainforest, moist forest, flooded forest, tropical lowland rainforest, forest of pre-Andean slopes, floodplain forest (*várzea*), forested stream swamps (*igapó*), and upland or non-flooded forest (*terra firme*). The search concerned mostly indexed journals, however, for older publications, we also used thesis, books and short communications that contained records of gasteroid fungi for Amazonia. Records with doubtful identification or that did not indicate any specific data about locality were not considered.

The author names and basionym of each species were obtained from Mycobank (http://www.mycobank.org/) and Index Fungorum (http://www.indexfungorum.org/), and taxonomical treatment followed Kirk *et al.* (2008). Records without identification at the species level were not considered. When the original manuscript did not provide geographical coordinates, points from nearby localities were used as proxies. In cases where only the country was reported, no geographic coordinates were informed, and the record was not included in the distribution map. QGISsoftware was used to produce a map of record distribution. Species were listed in alphabetical order.

RESULTS

The survey returned 54 publications resulting in 83 species of gasteroid fungi recorded for the Amazonian domain (Table 1), of which 26 have been originally described for this region, comprising 22 genera. Figure 1 shows the records of gasteroid fungi species that were observed in the Amazon domain. The most representative are *Geastrum* (30 species), *Cyathus* (10), *Lycoperdon* Pers. (8) and *Phallus* Junius ex L. (7), which represented about 65% of all records published until March 2021. All genera recorded are distributed in eight families (Agaricaceae Chevall., Boletaceae Chevall., Diplocystaceae Kreisel, Geastraceae Corda, Nidulariaceae Dumort., Phallaceae Corda, Physalacriaceae Corner, Sclerodermataceae Corda) and four orders (Agaricales Underw., Phallales E. Fisch., Geastrales K. Hosaka & Castellano and Boletales E.-J. Gilbert).

Most records were from the Brazilian Amazon (64 species), followed by Bolivia and French Guiana (10 species each),

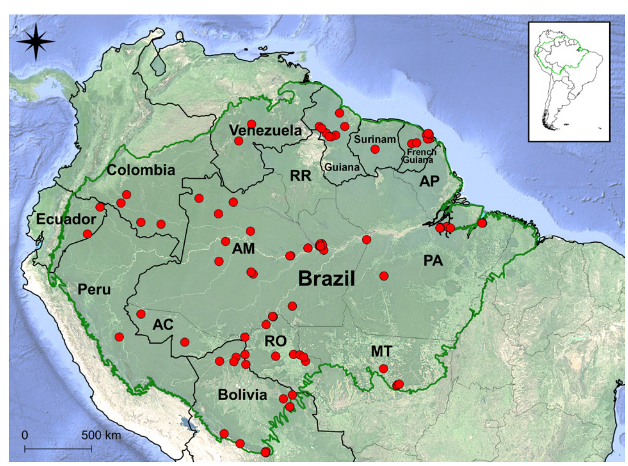

Figure 1. Records of gasteroid fungi species (red circles) in the Amazon domain. Each dot represents a species record, and there may be more than one dot for the same species. Records for which it was not possible to estimate the geographic coordinates are not shown on the map. The green line represents the limits of the Amazon biome. AC = Acre state; AM = Amazonas state; AP = Amapá state; PA = Pará state; RO = Rondônia state; RR = Roraima state; MT = Mato Grosso state. This figure is in color in the electronic version.

Table 1. Species of gasteroid fungi recorded for the Amazon rainforest. Asterisks (*) represent species originally described based on types from the Amazon. (–) indicates that the location indicated by the authors was too vague to approximate geographical coordinates.

Family/Species	Country (state/province)	Coordinates	Reference
***Agaricomycetidae* Parmastto.**			
Arachnion album Schwein.	Bolivia (Concepción)	16°07'41.4"S, 62°02'23.1"W	Calonge *et al.* (2000)
Castellanea pakaraimophila T.W. Henkel & M.E. Smith*	Guiana (Cuyuni-Mazaruni)	5°26'21.3"N, 60°04'43.1"W	Smith *et al.* (2015)
Calvatia oblongispora V.L. Suárez, J.E. Wright & Calonge	Brazil (Amazonas)	3°04'45.4"S, 60°05'18.1"W	Suárez *et al.* (2009)
Calvatia cyathiformis (Bose) Morgan	Brazil (Pará)	1°47'37.0"S, 51°26'03.8"W	Sotão *et al.* (2009)
Costatisporus cyanescens T.W. Henkel & M.E. Smith*	Guiana (Potaro-Siparuni)	5°18'04.8"N, 59°54'40.4"W	Smith *et al.* (2015)
Cyathus amazonicus Trierv.-Per. & Baseia*	Brazil (Rondônia)	8°07'39.1"S, 63°21'52.9"W	Trierveiller-Pereira *et al.* (2009)
	Brazil (Amazonas)	3°14'09.0"S, 60°53'10.0"W	Accioly *et al.* (2018)
	Brazil (Mato Grosso)	13°05'60.0"S, 54°25'55.3"W	Assis *et al.* (2021)
Cyathus albinus Accioly, R. Cruz & Baseia*	Brazil (Amazonas)	3°14'09.0"S, 60°53'10.0"W	Accioly *et al.* (2018)
Cyathus berkeleyanus (Tul. & C. Tul.) Lloyd	Brazil (Pará)	1°47'37.0"S, 51°26'03.8"W	Sotão *et al.* (2009)
Cyathus earlei Lloyd	Brazil (Amazonas)	3°14'09.0"S, 60°53'10.0"W	Accioly *et al.* (2018)
	Brazil (Amazonas)	3°05'31.0"S, 59°59'39.0"W	
Cyathus helenae H.J. Brodie	Brazil (Pará)	1°47'37.0"S, 51°26'03.8"W	Sotão *et al.* (2009)
Cyathus limbatus Tul. & C. Tul. = *Cyathodes limbatum*	Brazil (Amazonas)	0°18'43.1"N, 68°39'09.3"W	Berkeley and Cooke (1876)
	Brazil (Amazonas)	2°57'47.5"S, 59°55'23.2"W	Accioly *et al.* (2018)
	Brazil (Rondônia)	10°48'45.0"S, 61°54'51.7"W	Capelari and Maziero (1988) Trierveiler-Pereira *et al.* (2011b)
	Guiana	–	Brodie and Dennis (1954)
Cyathus morelensis C.L. Gómez & Pérez-Silva	Brazil (Amazonas)	2°57'47.5"S, 59°55'23.2"W	Cruz *et al.* (2012)
Cyathus stercoreus (Schwein.) De Toni ≡ *Nidularia stercorea* Schwein.	Brazil (Pará)	1°47'37.0"S, 51°26'03.8"W	Sotão *et al.* (2009)
Cyathus striatus (Huds.) Wild	Brazil (Pará)	1°47'37.0"S, 51°26'03.8"W	Sotão *et al.* (2009)
	Colombia (Amazonas)	1°32'00.1"S, 71°21'56.6"W	Vasco-Palacios *et al.* (2005)
Cyathus triplex Lloyd	Brazil (Amazonas)	3°14'09.0"S, 60°53'10.0"W	Accioly *et al.* (2018)
	Brazil (Pará)	1°47'37.0"S, 51°26'03.8"W	Sotão *et al.* (2009)
	Guiana (Potaro-Siparuni)	4°58'07.2"N, 59°35'00.9"W	Brodie and Dennis (1954)
Disciseda verrucosa G. Cunn.	Bolívia (Concepción)	16°07'41.4"S, 62°02'23.1"W	Calonge *et al.* 2000
Guyanagaster necrorhiza, M.E. Sm & Aime*	Guiana (Potaro-Siparuni)	5°18'04.8"N, 59°54'40.4"W	Henkel *et al.* (2010)
Jimtrappea guyanensis T.W. Henkel, M.E. Sm. & Aime*	Guiana (Potaro-Siparuni)	5°18'04.8"N, 59°54'40.4"W	Smith *et al.* (2015)
Lycogalopsis solmsii E. Fisch. as *Morganella rimosa* Baseia & Alfredo in (Alfredo et al 2012)	Brazil (Amazonas)	2°45'27.4"S, 66°45'35.7"W	Dennis (1953)
	Brazil (Amazonas)	2°57'47.5"S, 59°55'23.2"W	Alfredo *et al.* (2012a)
	Brazil (Pará)	1°47'37.0"S, 51°26'03.8"W	Sotão *et al.* (2009)
Lycoperdon albostipitatum (Baseia & Alfredo) Baseia, Alfredo & M.P. Martín* ≡*Morganella albostipitata* Baseia & Alfredo	Brazil (Amazonas)	2°57'47.5"S, 59°55'23.2"W	Alfredo *et al.* (2012a)
Lycoperdon arenicola (Alfredo & Baseia) Baseia, Alfredo & M.P. Martín* ≡*Morganella arenicola* Alfredo & Baseia	Brazil (Amazonas)	3°05'51.4"S, 60°01'02.8"W	Alfredo *et al.* (2014)
Lycoperdon costaricense (M.I. Morales) Baseia, Alfredo & M.P. Martín ≡*Morganella costaricensis* M.I. Morales	Bolivia (Vaca Diez)	11°00'46.2"S, 66°00'42.0"W	Suarez and Wright (1996)
Lycoperdon juruense Henn.	Brazil (Amazonas)	5°05'04.4"S, 64°47'25.8"W	Hennings (1904)
Lycoperdon fuligineum Berk. & M.A. Curtis ≡Morganella fuliginea (Berk. & M.A. Curtis) Kreisel & Dring	Brazil (Amazonas)	2°58'45.3"S, 59°57'09.9"W	Cabral *et al.* (2014a)
	Brazil (Pará)	1°47'37.0"S, 51°26'03.8"W	Sotão *et al.* (2009)

Table 1. Continued

Family/Species	Country (state/province)	Coordinates	Reference
***Agaricomycetidae* Parmastto.**			
Lycoperdon fuligineum Berk. & M.A. Curtis ≡Morganella fuliginea (Berk. & M.A. Curtis) Kreisel & Dring	Brazil (Rondônia)	10°56'25.3"S, 63°11'08.5"W	Capelari and Maziero (1988)
	Brazil (Mato Grosso)	13°06'44.3"S, 54°28'35.5"W	Rodrigues *et al.* (2021)
	Bolivia (Manuripi)	11°17'52.6"S, 67°11'09.4"W	Suarez and Wright (1996)
	Venezuela (Aragua)	4°24'25.8"N, 65°49'25.3"W	Dennis (1953)
Lycoperdon oblongatum Accioly, Baseia & M.P. Martín*	Brazil (Amazonas)	2°58'45.3"S, 59°57'09.9"W	Alfredo *et al.* (2017)
Lycoperdon pyriforme (Schaeff.) Kreisel & D. Krüger ≡*Morganella pyriformis* (Schaeff.) Kreisel & D. Krüger	Bolivia (Santa Cruz de la Sierra)	11°31'41.5"S, 65°18'38.4"W	Rocabado *et al.* (2007)
Lycoperdon epixylon Berk. & M.A. Curtis	Brazil (Amazonas)	4°56'32.3"S, 64°56'29.5"W	Hennings (1904)
Sclerangium braziliense Henn	Brazil (Amazonas)	0°47'35.5"S, 67°15'48.3"W	Hennings (1904)
Scleroderma anomalosporum Baseia, B.D.B. Silva & M.P. Martín*	Brazil (Pará)	5°13'24.2"S, 55°28'01.3"W	Baseia *et al.* (2016)
Scleroderma camassuense M.P. Martín, Baseia & B.D.B. Silva*	Brazil (Pará)	5°13'24.2"S, 55°28'01.3"W	Baseia *et al.* (2016)
Scleroderma duckei B.D.B. Silva, M.P. Martín & Baseia*	Brazil (Amazonas)	2°58'45.3"S, 59°57'09.9"W	Baseia *et al.* (2016)
Scleroderma minutisporum Baseia, Alfredo & Cortez*	Brazil (Amazonas)	2°55'12.9"S, 59°54'15.0"W	Alfredo *et al.* (2012b)
Scleroderma sinnamariense Mont.	Brazil (Amazonas)	4°10'44.1"S, 67°13'45.0"W	Singer and Araújo (1979)
	Guiana (Potaro-Siparuni)	4°41'53.1"N, 59°13'01.3"W	Henkel *et al.* (2012)
Scleroderma stellatum Berk.	Brazil (Amazonas)	4°56'32.3"S, 64°56'29.5"W	Berkeley and Cooke (1876)
	Brazil (Pará)	1°48'13.5"S, 51°26'29.9"W	Sotão *et al.* (2009)
Tremellogaster surinamensis E. Fisch. *	Surinam	–	Linder (1930)
	Guiana (Bartica)	6°23'25.0"N, 58°37'55.9"W	Linder (1930)
	Guiana (Potaro-Siparuni)	4°42'23.0"N, 59°22'12.2"W	Henkel *et al.* (2012)
	Colombia (Amazonas)	1°23'42.6"S, 72°47'45.0"W	Vasco-Palacios *et al.* (2005)
Tulostoma exasperatum Mont. = *Schizostoma exasperatum*	Brazil (Rondônia)	11°18'09.4"S, 61°03'11.0"W	Trierveiler-Pereira *et al.* (2011b)
Vascellum pampeanum (Speg.) Homrich as *Lycoperdon pampeanum* Speg.	Bolivia (Entre Rios)	17°42'57.5"S, 63°52'41.8"W	Rocabado *et al.* (2007)
***Phallomycetidae* K. Hosaka, Castellano & Spatafora**			
Clathrus crispus Turpin ≡ *Clathrella crispa* (Turpin) E. Fischer	French Guiana (Roura)	4°36'25.2"N, 52°17'07.1"W	Cheype (2010)
Geastrum albonigrum Calonge & M. Mata	Brazil (Mato Grosso)	10°49'31.8"S, 61°27'31.7"W	Trierveiler-Pereira *et al.* (2011b)
	Brazil (Mato Grosso)	13°06'19.4"S, 54°27'33.3"W	Rodrigues *et al.* (2021)
Geastrum ambiguum Mont.	Bolivia (Santa Cruz)	18°00'48.3"S, 59°37'39.1"W	Montagne (1839)
Geastrum baculicrystallum J.O. Sousa, Accioly, Baseia & M.P. Martín*	French Guiana (Saint-Laurent-du-Maroni)	4°12'25.8"N, 53°29'15.6"W	Accioly *et al.* (2019)
Geastrum echinulatum B.D.B. Silva & Baseia*	Brazil (Amazonas)	2°56'34.2"S, 60°01'08.3"W	Silva *et al.* (2013)
Geastrum englerianum Henn	Brazil (Amazonas)	3°07'09.7"S, 60°01'19.1"W	Hennings (1904)
Geastrum entomophilum Fazolino, Calonge & Baseia	Brazil (Pará)	1°56'53.3"S, 51°40'09.6"W	Leite *et al.* (2011)
	Brazil (Mato Grosso)	12°51'11.0"S, 54°28'47.3"W	Rodrigues *et al.* (2021)
Geastrum fimbriatum Fr.	Brazil (Pará)	1°56'53.3"S, 51°40'09.6"W	Leite *et al.* (2011)
	Brazil (Rondônia)	8°05'57.6"S, 63°23'08.4"W	Trierveiler-Pereira *et al.* (2009)
	Brazil (Pará)	1°27'39.1"S, 48°26'24.2"W	Trierveiler-Pereira *et al.* (2011a)
	Bolivia (Concepción)	16°07'52.1"S, 62°02'29.6"W	Calonge *et al.* (2000)
	Brazil (Mato Grosso)	13°06'44.3"S, 54°28'35.5"W	Rodrigues *et al.* (2021)
Geastrum hariotii Lloyd	Brazil (Pará)	1°47'52.9"S, 51°26'24.6"W	Sotão *et al.* (2009)
	Surinam (?) as *Geaster hariotii*	–	Coker and Couch (1928)

Table 1. Continued

Family/Species	Country (state/province)	Coordinates	Reference
***Phallomycetidae* K. Hosaka, Castellano & Spatafora**			
Geastrum hyalinum Freitas-Neto, N.M. Assis, J.O. Sousa & Baseia*	Brazil (Mato Grosso)	13°02'28.6"S, 54°33'31.6"W	Assis *et al.* (2019)
Geastrum hirsutum Baseia & Calonge	Brazil (Pará)	1°47'32.2"S, 51°29'39.8"W	Sotão *et al.* (2009)
Geastrum inpaense T.S. Cabral, B.D.B. Silva & I.G. Baseia*	Brazil (Amazonas)	3°05'46.6"S, 59°58'44.0"W	Cabral *et al.* (2014a)
Geastrum ishikawae Accioly, J.O. Sousa, Baseia & M.P. Martín*	Brazil (Amazonas)	3°05'46.6"S, 59°58'44.0"W	Crous *et al.* (2016)
Geastrum javanicum Lév.	Brazil (Pará)	1°42'09.6"S, 50°59'39.9"W	Sotão *et al.* (2009)
	Brazil (Mato Grosso)	13°06'44.3"S, 54°28'35.5"W	Rodrigues *et al.* (2021)
Geastrum juruense Henn. (as *Geaster juruensis*)	Brazil (Amazonas)	2°42'52.9"S, 60°09'09.3"W	Hennings (1904)
Geastrum lageniforme Vittad.	Brazil (Amazonas)	3°05'31.0"S, 59°59'39.0"W	Cabral *et al.* (2014a)
	Brazil (Pará)	1°56'53.3"S, 51°40'09.6"W	Leite *et al.* (2011)
	Brazil (Mato Grosso)	10°50'31.3"S, 61°27'37.0"W	Trierveiler-Pereira *et al.* (2011b)
	Bolivia (Concepción)	16°07'52.3"S, 62°02'29.9"W	Calonge *et al.* (2000)
Geastrum lilloi L.S. Domínguez	Brazil (Pará)	1°56'53.3"S, 51°40'09.6"W	Leite *et al.* (2011)
Geastrum lloydianum Rick	Brazil (Amazonas)	3°05'46.6"S, 59°58'44.0"W	Cabral *et al.* (2014a)
Geastrum mirabile Mont.	Guiana (Upper Demerara-Berbice)	5°26'12.8"N, 58°15'39.1"W	Dennis (1953)
Geastrum neoamericanum J.O. Sousa, Accioly, M.P. Martín & Baseia	Brazil (Rondônia)	9°34'53.4"S, 65°23'06.3"W	Accioly *et al.* (2019)
	French Guiana	4°56'13.92"N, 52°19'33.60"W	Accioly *et al.* (2019)
Geastrum ovalisporum Calonge & Mor.-Arr.	Bolivia (Concepción)	16°07'52.1"S, 62°02'29.6"W	Calonge *et al.* (2000)
Geastrum pusillipilosum J.O. Sousa, Alfredo, R.J. Ferreira, M.P. Martín & Baseia	Brazil (Mato Grosso)	12°59'52.8"S, 54°38'28.6"W	Rodrigues *et al.* (2021)
Geastrum rubellum P.-A. Moreau & C. Lécuru*	Brazil (Acre)	9°56'39.1"S, 69°40'04.1"W	Accioly *et al.* (2019)
Geastrum rusticum Baseia, B.D.B. Silva & T.S. Cabral	Brazil (Mato Grosso)	12°57'29.2"S, 54°35'38.7"W	Rodrigues *et al.* (2021)
Geastrum saccatum Fr.	Brazil (Amazonas)	3°05'46.6"S, 59°58'44.0"W	Cabral *et al.* (2014a)
	Brazil (Amazonas)	3°07'09.7"S, 60°01'19.1"W	Hennings (1904)
	Brazil (Pará)	1°56'53.3"S, 51°40'09.6"W	Leite *et al.* (2011)
	Bolivia (Concepción)	16°07'52.1"S, 62°02'29.6"W	Calonge *et al.* (2000)
	Colombia (Caquetá)	0°34'15.7"N, 73°49'07.1"W	Vasco-Palacios *et al.* (2005)
Geastrum schweinitzii (Berk. & M.A. Curtis) Zeller	Brazil (Amazonas)	3°05'46.6"S, 59°58'44.0"W	Cabral *et al.* (2014a)
	Brazil (Pará)	1°42'09.6"S, 50°59'39.9"W	Sotão *et al.* (2009)
	Brazil (Mato Grosso)	13°04'38.9"S, 54°32'35.7"W	Rodrigues *et al.* (2021)
	Surinam (Paramaribo)	5°50'00.0"N, 55°10'00.0"W	Zeller (1948)
Geastrum scleroderma Mont.	Brazil (Amazonas)	3°07'09.7"S, 60°01'19.1"W	Hennings (1904)
Geastrum triplex Jungh.	Brazil (Amazonas)	3°05'46.6"S, 59°58'44.0"W	Cabral et al. (2014a)
	Brazil (Mato Grosso)	13°21'24.6"S, 54°35'01.2"W	Rodrigues *et al.* (2021)
	Venezuela	10°28'23.0"N, 66°59'44.0"W	Coker and Couch (1928)
Geastrum trichifer Rick	Guiana (Cuyuni-Mazaruni)	7°04'00.0"N, 59°51'00.0"W	Dennis (1953)
Geastrum velutinum Morgan	Brazil (Pará)	1°42'09.6"S, 50°59'39.9"W	Sotão *et al.* (2009)
Geastrum verrucoramulosum T.S. Cabral, J. O Sousa & Baseia*	Brazil (Amazonas)	3°07'09.9"S, 60°01'40.4"W	Cabral *et al.* (2017)
	Brazil (Acre)	7°56'14.6"S, 72°47'23.2"W	Cabral *et al.* (2017)
Lysurus arachnoideus (E. Fisch.) Trierv.-Per. & Hosaka ≡ *Aseroe arachnoidea* E. Fisch.	Brazil (Amazonas)	3°23'00.8"S, 59°45'23.2"W	Cabral *et al.* (2015)
Mutinus bambusinus (Zoll.) E. Fisch.	Bolivia (Vaca Diez)	10°49'26.7"S, 65°22'19.2"W	Wright (1960)

Table 1. Continued

Family/Species	Country (state/province)	Coordinates	Reference
Phallomycetidae **K. Hosaka, Castellano & Spatafora**			
Mutinus fleischeri Penz.	Brazil (Amazonas)	3°05'31.0"S, 59°59'39.0"W	Cabral *et al.* (2014a)
Mutinus verrucosus T.S. Cabral, B.D.B. Silva, K. Hosaka, M.P. Martín & Baseia *	Brazil (Pará)	3°55'43.8"S, 54°37'22.8"W	Crous *et al.* (2017)
Mutinus caninus (Huds.) Fr.	Brazil (Rondônia)	11°00'13.4"S, 61°11'15.7"W	Trierveiler-Pereira *et al.* (2011b)
Phallus aff. multicolor (Berk. & Broome) Cooke ≡ *Dictyophora multicolor* Berk. & Broome	French Guiana (Cayenne)	4°53'57.4"N, 52°19'12.2"W	Cheype (2010)
Phallus atrovolvatus Kreisel & Calonge	Brazil (Amazonas)	2°58'19.6"S, 60°03'35.0"W	Cabral *et al.* (2014a)
	French Guiana (Cayenne)	4°52'17.0"N, 52°14'51.6"W	Cheype (2010)
Phallus cinnabarinus (W.S. Lee) Kreisel ≡ *Dictyophora cinnabarina* W.S. Lee	Brazil (Pará)	1°25'50.8"S, 48°27'26.8"W	Cabral *et al.* (2015)
	Brazil (Pará)	1°27'07.8"S, 48°28'37.7"W	
	French Guiana (Cayenne)	4°56'41.7"N, 52°19'00.9"W	Cabral *et al.* (2015)
Phallus denigricans T.S. Cabral, B.D.B. Silva & Baseia*	Brazil (Amazonas)	2°01'39.8"S, 64°58'53.0"W	Cabral *et al.* (2019)
	Brazil (Amazonas)	0°02'18.9"N, 66°12'25.8"W	
Phallus indusiatus Vent.: Pers. ≡ *Dictyophora indusiata* (Vent.) Desv.	Brazil (Amazonas)	3°46'54.9"S, 62°06'56.7"W	Cabral *et al.* (2019)
	Brazil (Pará)	1°47'54.5"S, 51°29'13.7"W	Sotão *et al.* (2009)
	Brazil (Pará)	2°48'60.0"S, 55°01'48.7"W	Cabral et al. (2019)
	Brazil (Rondônia)	8°06'27.5"S, 63°24'56.4"W	Trierveiler-Pereira *et al.* (2009)
	Brazil (Rondônia)	8°41'09.0"S, 63°52'04.7"W	
	Brazil (Mato Grosso)	13°14'41.1"S, 54°30'29.7"W	Rodrigues *et al.* (2021)
	Colombia (Amazonas)	'0°01'20.8"S, 74°12'55.9"W	Vasco-Palacios *et al.* (2005)
	Colombia (Caquetá)	'0°20'57.9"S, 72°17'18.8"W	
	French Guiana (Cayenne)	4°33'48.2"N, 52°12'23.5"W	Cheype (2010)
	French Guiana (Cayenne)	4°37'54.0"N, 52°20'14.4"W	
	Bolivia (Vaca Diez)	10°49'26.7"S, 65°22'19.2"W	Wright (1960)
	Bolivia	–	Montagne (1839)
Phallus merulinus (Berk.) Cooke ≡ *Dictyophora merulina* Berk.	Brazil (Amazonas)	3°05'31.6"S, 59°59'42.2"W	Cabral *et al.* (2014a)
	Brazil (Amazonas)	3°05'31.0"S, 59°59'39.0"W	
	Brazil (Amazonas)	3°01'52.4"S, 59°50'35.7"W	
	Brazil (Amazonas)	3°01'52.4"S, 59°50'35.7"W	
	French Guiana (Cayenne)	4°52'28.6"N, 52°15'37.8"W	Cheype (2010)
	French Guiana (Cayenne)	4°56'46.1"N, 52°18'28.5"W	
	French Guiana (Tonnégrande)	4°49'50.4"N, 52°26'42.4"W	Cheype (2010)
Phallus purpurascens T.S. Cabral, B.D.B. Silva & Baseia*	Brazil (Amazonas)	3°05'31.0"S, 59°59'39.0"W	Cabral *et al.* (2019)
	Brazil (Mato Grosso)	11°50'02.7"S, 55°30'02.3"W	
Staheliomyces cinctus E. Fisch., Mitt.	Brazil (Amazonas)	3°47'29.5"S, 62°10'28.9"W	Cabral *et al.* (2014a)
	French Guiana (Cayenne)	4°33'04.6"N, 52°21'49.2"W	Cheype (2010)
	Bolivia (Madre de Dios)	11°19'56.8"S, 66°10'22.6"W	Wright (1960)
	Ecuador (Rio Napo)	2°14'07.4"S, 76°36'05.0"W	Burr *et al.* (1996)
	Surinam	–	Dennis (1970)
Xylophallus xylogenus (Mont.) E. Fisch	French Guiana (Cayenne)	4°52'17.0"N, 52°14'51.6"W	Cheype (2010)
	French Guiana (Cayenne)	4°56'39.0"N, 52°19'25.6"W	
	Peru (Madre de Dios)	12°21'50.6"S, 70°24'60.0"W	Gómez and Gazis (2006)

Table 1. Continued

Family/Species	Country (state/province)	Coordinates	Reference
***Phallomycetidae* K. Hosaka, Castellano & Spatafora**			
Xylophallus xylogenus (Mont.) E. Fisch	Ecuador (Sucumbíos/ Orellana)	0°18'53.3"S, 75°42'22.7"W	
	Brazil (Mato Grosso)	13°06'44.3"S, 54°28'35.5"W	Rodrigues *et al.* (2021)
Xylophallus clavatus T.S. Cabral, M.P. Martín, C.R. Clement, K. Hosaka & Baseia*	Brazil (Amazonas)	0°02'18.9"N, 66°12'25.8"W	Crous et al. (2018)
	Brazil (Amazonas)	2°38'04.2"S, 56°42'29.6"W	
	Brazil (Pará)	2°57'11.0"S, 54°58'27.7"W	

Guiana (7 species), Surinam (4 species), Colombia (3 species), Venezuela and Ecuador (2 species each) and Peru (1 species). All species are listed in Table 1.

Among the 83 species present in the Amazon, 26 have been originally described for this region in recent years, showing a huge potential occurrence of new taxa (Table 1). Among the 22 genera, *Staheliomyces* E. Fisch. had the highest number of records in all Amazonian countries, being absent only from Colombia, Peru, and Venezuela. In Brazil, most genera and species were recorded in the states of Amazonas and Pará, followed by Rondônia and Mato Grosso, while no records were found for the states of Amapá, Tocantins and Maranhão. An identification key for the genera reported from the Amazon domain is presented below.

Identification key to Amazon genera of gasteroid fungi

1 – Presence of stipe or pseudostipe....................................2

1'– Absence of stipe...3

2 – Pulverulent gleba..4

2'– Mucilaginous gleba...5

3 – Gleba stored in peridioles....................................*Cyathus*

3' – Mucilaginous, pulverulent or spongy gleba, not stored in peridioles..10

4 – Dehiscence of the peridium through the formation of an apical pore..*Tulostoma*

4' – Irregular dehiscence of the peridium.................................21

5 – Pseudostipe with arms or gleba......................................6

5'– Pseudostipe without arms..7

6 – Basidiomata vertical; Arms triangular-shaped without any connections..*Lysurus*

6'– Basidiomata in a form of a cage, with connected arms..*Clathrus*

7 – Receptacle conical and campanulate, located in the apical portion of the pseudostipe; Pseudostipe reticulate...................8

7'– Void pseudoestipe; Gleba located at the apex of the basidiomata on the pseudostipe or forming a constriction above the center and below the apex on the pseudostipe..................9

8 – Gleba on a receptacle fixed on the apical portion of the pseudostipe; Pseudostipe cylindrical and reticulate.......*Phallus*

8'– Small basidiomata (up to 15 mm); Receptacle smooth with umbilicated apex and attached to the pseudostipe... *Xylophallus*

9 – Gleba located at the apex of the basidiomata, directly on the pseudostipe...*Mutinus*

9'– Gleba forming a constriction above the center and below the apex on the pseudostipe.................................*Staheliomyces*

10 – Pulverulent gleba..11

10'– Mucilaginous or spongy gleba...................................12

11 – Dehiscence through the formation of a pore...................16

11'– Dehiscence through irregular peridium disruption..........19

12 – Epigeous habit; Subglobose basidiomata....................13

12'– Hypogeous or semi-hypogeous habitat; Subglobose to ovoid basidiomata...14

13 – Exoperidium black and verrucous; Gleba reddish orange; Spores ornamented...*Guyanagaster*

13'– Exoperidium white and with a little ornamentation; Spores smooth..*Lycogalopsis*

14 – Peridium glabrous to subtomentose; Columella absent..*Costatisporus*

14'– Peridium glabrous to subglabrous; Columella present....15

15 – Gleba brown in color; Basidiospores subfusiform, yellowish brown, often dextrinoid; Basidia subclavate and cystidia absent.. *Castellanea*

15'– Gleba pink in color; Basidiospores subfusiform, pink to reddish brown and inamyloid; Basidia clavate and cystida present...*Jimtrappea*

16 – Dehiscence through the exoperidium, shattering into rays, star-shaped basidiomata; Subgleba absent..........*Geastrum*

16'– Dehiscence does not result in a star-shaped basidiomata; Subgleba present or absent………....……......................... 17

17 – Subgleba absent...*Disciseda*

17'– Subgleba present...18

18 – Presence of a membrane separating the gleba from the subgleba (diaphragm)..*Vascelum*

18'– Absence of diaphragm....................................*Lycoperdon*
19 – Capillitium absent..20
19'– Capillitium present..*Calvatia*
20 – Peridium three-layered................................*Tremellogaster*
20'– Peridium one-layered......................................*Arachnion*
21–Basidiospores with reticulate or spiny ornamentation .... *Scleroderma*
21'– Basidiospores with subreticulate ornamentation .... *Sclerangium*

DISCUSSION

Throughout the twentieth century, publications on gasteroid fungi in the Amazon were scarce and scattered among the domain countries. However, in the 21st century, publications have undergone a significant increase, and most are concentrated in the Brazilian Amazon. Despite the significant increase in data on the gasteroid mycota, knowledge about these organisms in the Amazon domain is still scarce relative to the extent and large biodiversity in this region. Although Amazonian centers of endemism are widely known for animals and plants (Silva et al. 2005), for fungi there are no studies with quantitative data on endemism rates, even with some species being found in the same regions, e.g Scleroderma species (Baseia *et al*. 2016).

Studies carried out in the Neotropical region involving integrative taxonomy have revealed a great diversity of species hidden within cosmopolitan taxa and contributed to the description of new species and new genera (Alfredo *et al*. 2017; Sousa, *et al*. 2017; Accioly *et al*. 2018; Accioly *et al*. 2019; Cabral *et al*. 2019; Sousa, *et al*. 2019). These works, besides solving taxonomic conflicts, show the great diversity of species that remain undetected, especially in poorly sampled areas. Some species found in the Amazon have morphological features that suggest possible adaptations to the region, such as *Geastrum verrucoramulosum* T.S. Cabral, J.O. Sousa & Baseia and *Cyathus albinus* Accioly, R. Cruz & Baseia (Cabral *et al.* 2017; Accioly *et al.* 2018).

Genera such as *Arachnion* Schwein., *Castellanea* T.W. Henkel & M.E. Smith, *Costatisporus* T.W. Henkel & M.E. Smith, *Clathrus* P. Micheli ex L., *Disciseda* Czern., *Guyanagaster* T.W. Henkel, M.E. Smith & Aime, *Jimtrappea* T.W. Henkel, M.E. Smith & Aime, *Lysurus* Fr., *Sclerangium* Lév., *Tulostoma* Pers., and *Vascellum* F. Šmarda have been recorded only once, which reflects sampling effort rather than restricted distribution. Some records, especially the older ones, lack detailed information on the collection site and other aspects, such as habitat. *Geastrum hariotii* Lloyd was recorded for South Guiana (currently Guiana, French Guiana, and Surinam), but the authors did not mention the specific collection locality of the species (Coker and Couch 1928). Likewise, *Geastrum schweinitzii* (Berk. & M.A. Curtis) Zeller is only mentioned for Surinam (Zeller 1948), and *Geastrum triplex* Jungh. only for Venezuela (Coker and Couch 1928).

The analysis of species distributions is frequently complicated by taxonomic problems, mainly in groups where interspecific differences are inconspicuous, as in species complexes and cryptic species (Vizzini *et al.* 2013). This is a recurrent problem for gasteroid fungi, and recent studies merging classical taxonomy with molecular techniques (e.g., barcoding) have shown that there is a high diversity of hidden species for groups that were considered as well known (Accioly *et al.* 2019). This is the case for *Geastrum hirsutum* Baseia & Calonge, *G. schweinitzii* and *G. triplex*, which have already been proven to be species complexes (Kasuya *et al*. 2012; Accioly *et al*. 2019). Likewise, the genus *Myriostoma* Desv. was thought to be monospecific, but more recent revisions revealed a diversity of five species for the genus (Sousa *et al.* 2017; Sousa *et al.* 2019). *Lycoperdon* is another genus that had recent changes in its classification. Due to the high morphological similarity between *Lycoperdon* and closely related genera, such as *Morganella* Zeller and *Vascellum*, many species were incorrectly identified, showing the need for molecular data to delimit species with higher reliability (Larsson and Jeppson 2008; Phosri *et al.* 2014; Rusevska *et al.* 2014; Alfredo *et al.* 2017). Using molecular and morphological data, Alfredo *et al*. (2017) also demonstrated the existence of new species and new combinations of previously identified materials, evidencing that there was a hidden diversity of *Lycoperdon* species under the name *Morganella*. Most records for these groups occur in the Amazon, highlighting that low geographical coverage of fungal surveys and taxonomic uncertainity allow the assumption that the diversity and distribution of gasteroid fungi in Amazonian forests is still widely underestimated.

The need for more studies to increase the knowledge of gasteroid diversity is made more urgent by the accelerating anthropic impacts on the region. For example, Baseia *et al.* (2016) identified three new species of *Scleroderma* Pers. and classified them as endangered. Two of these species were found in areas that are now flooded by hydroelectric dams. Greater knowledge on the Amazonian funga is necessary to better evaluate its diversity, ecosystemic roles and conservation strategies.

CONCLUSIONS

This checklist contributes to the expansion and summarization of the current knowledge of gasteroid fungi in the Amazon region. The data presented here highlight the necessity to expand collection efforts, especially in little or unexplored areas, to improve the representativeness of gasteroid fungi in herbaria and reduce the unknown component of Amazonian fungi. However, an increase in publications on Amazonian gasteroid fungi over the past two decades provided data on unexplored areas and revealed taxonomic novelties. In this context, continuing biodiversity surveys are the foundation for an increase of the knowledge on these fungi and the design of more effective conservation strategies for the promotion of forest preservation.

ACKNOWLEDGMENTS

The authors would like to express their thanks to the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES – Brazil) for the scholarships awarded to Nathalia M. Assis, Jefferson S. Góis and Julimar F. Freitas-Neto.

REFERENCES

Accioly, T; Cruz, R.H.S.F.; Assis, N.M; Ishikawa, N.K.; Hosaka, K.; Martín, M.P.; Baseia, I.G. 2018. Amazonian bird's nest fungi (Basidiomycota): current knowledge and novelties on *Cyathus* species. *Mycoscience,* 59: 331–342.

Accioly, T.; Sousa, J.O.; Moreau, P-A.; Lécuru, C.; Silva, B.D.B.; Roy, M.; *et al*. 2019. Hidden fungal diversity from the Neotropics: *Geastrum hirsutum*, *G. schweinitzii* (Basidiomycota, Geastrales) and their allies. *PLoS ONE,* 14: e0211388.

Alexopoulos, C.J.; Mims, C.W.; Blackwell, M. 1996. *Introductory Mycology*. 4th ed. Wiley, New York, 800p.

Alfredo, D.S.; Accioly, T.; Baseia, I.G. 2014. *Morganella arenicola*, a new species record from North and Northeast, Brazil. *Turkish Journal of Botany,* 38: 595–599.

Alfredo, D.S.; Baseia, I. G.; Accioly, T.; Silva, B.D.B.; Moura, M.P.; Marinho, P.; Martín, M.P. 2017. Revision of species previously reported from Brazil under *Morganella*. *Mycological Progress,* 16: 965–985.

Alfredo, D.S.; Leite, A.G.; Braga-Neto, R.; Baseia, I.G. 2012a. Two new *Morganella* species from the Brazilian Amazon rainforest. *Mycosphere,* 3: 66–71.

Alfredo, D.S.; Leite, A.G.; Braga-Neto, R.; Cortez, V.G.; Baseia, I.G. 2012b. *Scleroderma minutisporum*, a new earthball from the Amazon rainforest. *Mycosphere,* 3: 294–298.

Antonelli, A.; Fry, C.; Smith, R.J.; Simmonds, M.S.J.; Kersey, P.J.; Pritchard, H.W.; *et al.* 2020. *State of the World's Plants and Fungi 2020*. Royal Botanic Gardens, Kew, 100p.

Assis, N.M.; Freitas-Neto, J.F.; Gurgel, R.A.F.; Cruz, R.H.S.F.; Barbosa, F.R.; Baseia, I.G. 2021. Fungos Gasteroides. In: Rodrigues, D.J.; Barbosa, F.R.; Noronha, J.C; Carpanedo, R.S.; Tourinho, A.N.; Battirola, L.D.(Org.). *Biodiversidade da Estação Ecológica do Rio Ronuro*. Fundação UNISELVA (Série Livros – MT Ciência.), Cuiabá, p.91-105.

Assis, N.M.; Freitas-Neto, J.F.; Sousa, J.O.; Barbosa, F.R.; Baseia, I.G. 2019. *Geastrum hyalinum* (Basidiomycota, Geastraceae), a new species from Brazilian Southern Amazon. *Studies in Fungi,* 4: 83-89.

Baseia, I.G.; Silva, B.D.B.; Ishikawa, N.K.; Soares, J.V.C.; França, I.F.; Ushijima, S.; *et al*. 2016. Discovery or extinction of new *Scleroderma* species in Amazonia? *PLoS ONE,* 11: e0167879.

Berkeley, M.J.; Cooke, M.C. 1876. The Fungi of Brazil, including those collected by JWH Trail, Esq., MA, in 1874. *Journal of the Linnean Society of London, Botany,* 15: 363–398.

Brodie, H.J.; Dennis, R.W.G. 1954. The Nidulariaceae of the West Indies. *Transactions of the British Mycological Society,* 37: 151–160.

Burr, B.; Barthlott, W.; Westerkamp, C. 1996. *Staheliomyces* (Phallales) visited by *Trigona* (Apidae): melittophily in spore dispersal of an Amazonian stinkhorn? *Journal of Tropical Ecology,* 12: 441–445.

Cabral, T.S.; Silva, B.D.B.; Ishikawa, N.K.; Alfredo, D.S.; Braga-Neto, R.; Clement, C.R.; Baseia, I.G. 2014a. A new species and new records of gasteroid fungi (Basidiomycota) from Central Amazonia, Brazil. *Phytotaxa,* 183: 239–253.

Cabral, T.S.; Silva, B.D.B.; Marinho, P.; Baseia, I.G. 2014b. *Geastrum rusticum* (Geastraceae, Basidiomycota), a new earthstar fungus in the Brazilian Atlantic rainforest–a molecular analysis. *Nova Hedwigia,* 98: 265–272.

Cabral, T.S.; Clement, C.R.; Baseia, I.G. 2015. Amazonian phalloids: new records for Brazil and South America. *Mycotaxon,* 130: 315–320.

Cabral, T.S.; Sousa, J.O.; Silva, B.D.B.; Martin, M.P.; Clement, C.L.; Baseia, I.G. 2017. A remarkable new species of *Geastrum* with an elongated branched stipe. *Mycoscience,* 58: 344–350.

Cabral, T.S.; Silva, B.D.B.; Martín, M.P.; Clement, C.R.; Hosaka, K; Baseia, I.G. 2019. Behind the veil – exploring the diversity in *Phallus indusiatus* s.l. (Phallomycetidae, Basidiomycota). *MycoKeys,* 58: 103–127.

Calonge, F.D.; Moreno-Arroyo, B.; Gómez, J. 2000. Aportación al conocimiento de los Gasteromycetes, Basidiomycotina de Bolivia (América del Sur). *Geastrum ovalisporum* sp. nov. *Boletin de la Sociedad Micologica de Madrid,* 25: 271–276.

Capelari, M.; Maziero, R. 1988. Fungos macroscópicos do estado de Rondônia região dos rios Jaru e Ji-Paraná. *Hoehnea,* 15: 28–36.

Cheype, J.L. 2010. Phallaceae et *Clathrus* récoltés en Guyane Française. *Bulletin Mycologique et Botanique Dauphinpe-Savoie,* 66: 51–66.

Coker, W.C.; Couch J.N. 1928. Family Lycoperdaceae. In: Coker, W.C.; Couchm, J.N. (Ed.). *The Gasteromycetes of the Eastern United States and Canada*: The University of North Carolina Press, Baltimore, p.58–143.

Coutinho, L.M. 2006. O conceito de bioma. *Acta Botanica Brasilica,* 20: 13–23.

Crous, P.W.; Wingfield, M.J.; Burgess, T.I.; Hardy, G.J.; Crane, C.; Barrett, S.; *et al.* 2016. Fungal Planet description sheets: 469–557. *Persoonia,* 37: 218–403.

Crous, P.W.; Wingfield, M.J.; Burgess, T.I.; Hardy, G.E.S.J.; Barber, P.A.; Alvarado, P.; *et al*. 2017. Fungal Planet description sheets: 558-624. *Persoonia,* 38: 240–384.

Crous, P.W.; Wingfield, M.J.; Burgess, T.I..; Hardy, G.E.S.J.; Gené, J.; Guarro; Baseia, I.G. 2018. Fungal Planet description sheets: 716–784. *Persoonia*, 40: 240–393.

Cruz, R.H.S.F.; Lima, R.A.A.; Braga-Neto, R.; Baseia, I.G. 2012. *Cyathus morelensis*, a rare bird's nest fungus in the Brazilian Amazon rainforest. *Mycosphere,* 3: 880–882.

Dennis, R.W.G. 1953. Some West Indian Gasteromycetes. *Kew Bulletin,* 8: 307–328.

Dennis, R.W.G. 1970. Fungus flora of Venezuela and adjacentes countries. *Kew Bulletin Additional Series*, 3: 1–531.

Fazolino, E.P.; Calonge, F.D.; Baseia, I.G. 2008. *Geastrum entomophilum*, a new earthstar with an unusual spore dispersal strategy. *Mycotaxon*, 104: 449–453.

Fink, S.; Gross, A.; Senn-Irlet, B.; Scheidegger, C. 2021. Citizen Science data predict high potential for macrofungal refugia outside protected riparian áreas. *Fungal Ecology,* 49: 100981.

Fischer, E.; Claussen, P.; Harms, H.; Prantl, K.; Engler, A. 1933. *Die natürlichen Pflanzenfamilien*. 7th ed. Wilhelm Engelmann, Leipzig, 533p.

Giam, X. 2017. Global biodiversity loss from tropical deforestation. *Proceedings of the National Academy of Sciences of the United States of America,* 114: 5775–5777.

Gómez, L.D.; Gazis, R. 2006. Dos Gasteromycetes (Basidiomycotina, Fungi) del Perú. *Brenesia,* 65: 71–71.

Hawksworth, D.L.; Lücking, R. 2017. Fungal diversity revisited: 2.2 to 3.8 million species. *Microbiol Spectrum,* 5: FUNK–0052–2016.

Henkel, T.W.; Aime, M.C.; Chin, M.M.; Miller, S.L.; Vilgalys, R.; Smith, M.E. 2012. Ectomycorrhizal fungal sporocarp diversity and discovery of new taxa in *Dicymbe* monodominant forests of the Guiana Shield. *Biodiversity and Conservation,* 21: 2195–2220.

Henkel, T.W.; Smith, M.E.; Aime, M.C. 2010. *Guyanagaster*, a new wood-decaying sequestrate fungal genus related to *Armillaria* (Physalacriaceae, Agaricales, Basidiomycota). *American Journal of Botany,* 97: 1474–1484.

Hennings, P. 1904. Fungi amazonici a. cl. Ernesto Ule collecti: 1. *Hedwigia,* 43: 154–186.

Kasuya, T.; Hosaka, K.; Uno, K.; Kakishima, M. 2012. Phylogenetic placement of *Geastrum melanocephalum* and polyphyly of *Geastrum triplex*. *Mycoscience,* 53: 411–426.

Kirk, P.M.; Cannon, P.F.; Minter, D.W.; Stalpers, J.A. 2008. *Dictionary of the Fungi*. 10th ed. CABI Publisher, Wallingford, 771p.

Kuhar, F.; Castiglia, V.C.; Zamora J.C. 2016. Detection of manganese peroxidase and other exoenzymes in four isolates of *Geastrum* (Geastrales) in pure culture. *Revista Argentina de Microbiologia,* 48: 274–278.

Larsson, E.; Jeppson, M. 2008. Phylogenetic relationships among species and genera of Lycoperdaceae based on ITS and LSU sequence data from north European taxa. *Mycological Research,* 112: 4–22.

Leite, A.G; Assis, H.K.; Silva, B.D.B.; Sotão, H.M.P.; Baseia, I.G. 2011. *Geastrum* species from the Amazon Forest, Brazil. *Mycotaxon,* 118: 383–392.

Linder D.H. 1930. Notes on *Tremellogaster surinamensis*. *Mycologia,* 22: 265–270.

López-Quintero, C.A; Straatsma, G; Franco-Molano, A.E; Boekhout, T. 2012. Macrofungal diversity in Colombian Amazon forests varies with regions and regimes of disturbance. *Biodiversity and Conservation,* 21: 2221–2243.

Maia, L.C.; Carvalho Júnior, A.A.D.; Cavalcanti, L.D.H.; Gugliotta, A.D.M.; Drechsler-Santos, E.R.; Santiago, A.L.D.A. 2015. Diversity of Brazilian fungi. *Rodriguésia,* 66: 1033–1045.

Miller, K.O.; Miller, H.H. 1988. Gasteromycetes: Morphological and Development Features. *Mad Rivers Press*, Eureka, 156p.

MMA. 2007. Ministério do Meio Ambiente, Secretaria de Biodiversidade e Florestas. Portaria nº 9, de 23 de janeiro de 2007, define *Áreas Prioritárias para Conservação, Uso Sustentável e Repartição dos Benefícios da Biodiversidade Brasileira* (https://www.sema.rs.gov.br/legislacao-ambiental). Accessed on 04 Feb 2022.

Montagne, C. 1839. Florulae Boliviensis, ou cryptogammes de la Bolivie, recuéillis par Alcide d´Orbigny. In: d'Orbigny, A. (Ed.). *Voyage dans l´Amerique Méridionale*, Tome VII, Chez Pitois-Levrault, Paris, p.46–49.

Oliveira-Filho, F.J.B.; Metzger, J.P. 2006. Thresholds in landscape structure for three common deforestation patterns in the Brazilian Amazon. *Landscape Ecology,* 21: 1061–1073.

Phosri, C.; Watling, R.; Suwannasai, N.; Wilson, A.; Martín, M.P. 2014. A new representative of star-shaped fungi: *Astraeus sirindhorniae* sp. nov. from Thailand. *PLoS ONE,* 9: e71160.

Rocabado, D.; Wright, J.E.; Maillard, O.; Muchenik, N. 2007. Catalogo de los Gasteromycetes (Fungi: Basidiomycotina) de Bolivia. *Kempffiana,* 3: 3–13.

Rusevska, K.; Karadelev, M.; Phosri, C.; Dueñas, M.; Watling, R.; Martín, M.P. 2014. Rechecking of the genus *Scleroderma* (Gasteromycetes) from Macedonia using barcoding approach. *Turkish Journal of Botany,* 38: 375–385.

Sevindik, M.; Akgul, H.; Akata, I.; Selamoglu, Z. 2017. *Geastrum pectinatum* as an alternative antioxidant source with some biochemical analysis. *Medical Mycology,* 3: 1–5. doi: 10.4172/2167-7972.100026

Silva, B.D.B.; CabraL, T.S.; Marinho, P.; Ishikawa, N.K.; Baseia, I.G. 2013. Two new species of *Geastrum* (Geastraceae: Basidiomycota) found in Brazil. *Nova Hedwigia,* 96: 445–456.

Silva, J.M.C.; Rylands, A.B.; Fonseca, G.A.B. 2005. The fate of the Amazonian areas of endemism. *Conservation Biology,* 19: 689–694.

Singer, R.; Araujo, I.J.S. 1979. Litter decomposition and ectomycorrhiza in Amazonian forests, 1: A comparison of litter decomposing and ectomycorrhizal Basidiomycetes in latosol-terra-firme rain forest and white podzol campinarana. *Acta Amazonica,* 9: 25–41.

Smith, M.E.; Amses, K.R.; Elliot, T.F.; Obase, K.; Aime, M.A.; Henkel, T.W. 2015. New sequestrate fungi from Guyana: *Jimtrappea guyanensis* gen. sp. nov., *Castellanea pakaraimophila* gen. sp. nov., and *Costatisporus cyanescens* gen. sp. nov. (Boletaceae, Boletales). *IMA Fungus,* 6: 297–317.

Sótão, H.M.P.; Gilbertoni, T.; Maziero, R.; Baseia, I.G.; Medeiros, P.S.; Junior, A.L.M.; Capelari, M. 2009. Fungos macroscópicos da Floresta Nacional de Caxiuanã: Basiodimycota (Agaricomycetes). In: Lisboa, P.L.B. (Org.). *Caxiuanã: Desafios para a conservação de uma Floresta Nacional na Amazônia*. Museu Paraense Emílio Goeldi, Belém, p.383–396.

Sousa, J.O.; Baseia I.G.; Martín M.P. 2019. Strengthening *Myriostoma* (Geastraceae, Basidiomycota) diversity: *Myriostoma australianum* sp. nov. *Mycoscience,* 60: 25–30.

Sousa, J.O.; Suz, L.M.; García, M.A.; Alfredo, D.S.; Conrado, L.M.; Marinho, P.; Ainswoth, A.M.; Baseia, I.G; Martín, M.P. 2017. More than one fungus in the pepper pot: Integrative taxonomy unmasks hidden species within *Myriostoma coliforme* (Geastraceae, Basidiomycota). *PloS ONE,* 12: e0177873.

Suárez, V.L.; Wright, J.E. 1996. South American Gasteromycetes V. The genus *Morganella*. *Mycologia,* 88: 655–661.

Suárez, V.L.; Wright, J.E.; Calonge, F.D. 2009. *Calvatia oblongispora* sp. nov. from Brazil, with close affinities to *Calvatia sporocristata* from Costa Rica. *Mycotaxon,* 108: 7–323.

Tejada, G.; Görgens, E.B.; Ovando, A.; Ometto, J.P. 2020. Mapping data gaps to estimate biomass across Brazilian Amazon forests. *Forest Ecosystems,* 7: 25. doi: 10.1186/s40663-020-00228-1

Trierveiler-Pereira, L.; Gomes-Silva, A.C.; Baseia, I.G. 2009. Notes on gasteroid fungi of the Brazilian Amazon rainforest. *Mycotaxon,* 110: 73–80.

Trierveiler-Pereira, L.; Calonge, F.D.; Baseia, I.G. 2011a. New distributional data on *Geastrum* (Geastraceae, Basidiomycota) from Brazil. *Acta Botanica Brasilica,* 25: 577–585.

Trierveiler-Pereira, L.; Gomes-Silva, A.C.; Baseia, I.G. 2011b. Observations on gasteroid Agaricomycetes from the Brazilian Amazon rainforest. *Mycotaxon,* 118: 273–282.

Vasco-Palacios, A.M.; Franco-Molano, A.E.; López-Quintero, C.A.; Boekhout, T. 2005. Macromicetes (Ascomycota, Basidiomycota) de la región del médio Caquetá, departamentos de Caquetá y Amazonas (Colombia). *Biota Colombiana,* 6: 127–140.

Vizzini A.; Magiora D.M.; Tolaini F., Ercole E. 2013. A new cryptic species in the genus *Tubariomyces* (Inocybaceae, Agaricales). *Mycological Progress,* 12: 375–381.

Wright, J.E. 1960. Notas sobre Faloídeas sud y centroamericanas. *Lilloa,* 30: 339–359.

Yin, X.; Wei, K.; Wang, WW.; Gao, Y.G.; Stadler, M.; Kou, R.W.; Gao, J.M. 2019. New cyathane diterpenoids with neurotrophic and anti-neuroinflammatory activity from the bird's nest fungus *Cyathus africanus*. *Fitoterapia,* 134: 201–209.

Zeller, S.M. 1948. Notes on certain Gasteromycetes, including two new orders. *Mycologia,* 40: 639–668.

RECEIVED: 02/10/2021
ACCEPTED: 19/01/2022
ASSOCIATE EDITOR: Nelson Menolli Junior