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UNIVERSIDADE FEDERAL RURAL DA AMAZÔNIA (UFRA)
MUSEU PARAENSE EMÍLIO GOELDI (MPEG)
PROGRAMA DE PÓS-GRADUAÇÃO EM CIÊNCIAS BIOLÓGICAS
BOTÂNICA TROPICAL (PPGBot)

RICHARD BRUNO MENDES FREIRE

TAXONOMIA E FILOGENIA DE HYMENOCHAETACEAE (HYMENOCHAETALES, AGARICOMYCETES) NA AMAZÔNIA BRASILEIRA

BELÉM
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Dissertação apresentada à Universidade Federal Rural da Amazônia e ao Museu Paraense Emílio Goeldi, como parte das exigências do Programa de Pós-Graduação em Ciências Biológicas – Botânica Tropical (PPGBot), para obtenção do título de mestre.

Orientador (a): Dra. Adriene Mayra da Silva Soares

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então, por que estremecer?!
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RESUMO

Hymenochaetaceae (Hymenochaetales, Agaricomycetes) é uma família de macrofungos e apresenta uma diversidade com cerca de 830 espécies. Os representantes atuam como saprófitos, patógenos e ectomicorrízicos, e são fundamentais aos ecossistemas naturais. Por muitos anos, a identificação de táxons da família foi marcada pelo agrupamento com base em características morfológicas. Contudo, visto que muitas espécies apresentam pouca heterogeneidade nos caracteres fenotípicos, a utilização de dados moleculares é um método importante para delimitação dos táxons. O objetivo deste trabalho foi realizar um estudo taxonômico por meio de análises morfológicas e moleculares de espécies de Hymenochaetaceae de áreas da Amazônia brasileira. Inicialmente, foi realizado um levantamento das espécies de Hymenochaetaceae na Amazônia brasileira baseado na literatura científica e bancos de dados. Ao todo, 80 táxons foram registrados, 46 desses foram considerados registros válidos, e 34 foram consideradas duvidosos, pela ausência de dados filogenéticos e ecológicos e, desse modo, foram excluídos desta região (Capítulo I). Análises morfológicas e filogenéticas foram realizadas com 97 amostras coletadas no estado do Pará e Amapá, e quatro novas espécies foram descritas. Uma nova espécie de *Fulvifomes*, bem como *F. kawakami*, foram registradas em áreas de várzeas do baixo Tocantins (Pará). A filogenia com os marcadores ITS e LSU, bem como dados morfológicos e ecológicos confirmaram a nova espécie. Adicionalmente, ilustrações e uma chave do gênero são apresentadas (Capítulo II). Três novas espécies do gênero *Fuscoporia* foram descritas baseadas em estudo integrativo de morfologia e análises multilocus dos genes ITS, LSU, RPB2 e TEF1-α. As novas espécies exibem características morfológicas e elevado apoio estatístico que as distinguem de outras espécies de *Fuscoporia*. Descrições morfológicas, ilustrações e comparações de espécies da Amazônia brasileira são fornecidas (Capítulo III). Este estudo ampliou a distribuição das espécies de Hymenochaetaceae na Amazônia brasileira. A abordagem integrativa de caracteres fenotípicos e moleculares forneceram evidências para a delimitação de novas espécies, demonstrando o potencial da biodiversidade Amazônica. Além disso, os dados podem fornecer subsídios para estratégias de conservação e para futuros estudos que auxiliem a compreensão das relações filogenéticas de Hymenochaetaceae.

Palavras-chave: Análises filogenéticas, Basidiomycota, diversidade, macrofungos, região Amazônica.

ABSTRACT

Hymenochaetaceae (Hymenochaetales, Agaricomycetes) is a family of macrofungi comprising a diversity of approximately 830 species. Species of this family function as saprotrophs, pathogens, and ectomycorrhizal organisms, playing a fundamental role in natural ecosystems. For several years, the identification of taxa within this family was based primarily on morphological characteristics. However, given that many species exhibit limited heterogeneity in phenotypic traits, the use of molecular phylogeny data has become an important method for taxa delimitation. This study aimed to conduct a taxonomic investigation through morphological and molecular analyses of Hymenochaetaceae species from areas of the Brazilian Amazon. Initially, a survey of Hymenochaetaceae species in the Brazilian Amazon was conducted based on scientific literature and database records. A total of 80 taxa were recorded, of which 46 were considered valid, while 34 were deemed doubtful due to the absence of phylogenetic and ecological data; these doubtful records were excluded from the region (Chapter I). Morphological and phylogenetic analyses were performed on 97 samples collected in the states of Pará and Amapá, leading to the description of four new species. A new species of *Fulvifomes,* along with *F. kawakamii,* was recorded in floodplain areas of the lower Tocantins region (Pará). Phylogenetic analyses using ITS and LSU markers, combined with morphological and ecological data, confirmed the new species. Additionally, illustrations and a key to the genus are presented (Chapter II). Three new species of the genus *Fuscoporia* were described based on an integrative study combining morphology and multilocus analyses of the ITS, LSU, RPB2, and TEF1-α genes. The new species exhibit distinctive morphological characteristics and strong statistical support, differentiating them from other *Fuscoporia* species. Morphological descriptions, illustrations, and comparisons with species from the Brazilian Amazon are provided (Chapter III). This study expanded the distribution of Hymenochaetaceae species in the Brazilian Amazon. The integrative approach combining phenotypic and molecular traits provided evidence for the delimitation of new species, highlighting the potential of Amazonian biodiversity. Furthermore, the data may contribute to conservation strategies and future studies aimed at understanding the phylogenetic relationships within Hymenochaetaceae.

Keywords: Phylogenetic analysis, Basidiomycota, diversity, macrofungi, Amazon region.

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CONTEXTUALIZAÇÃO

A família Hymenochaetaceae Donk

Hymenochaetaceae, umas das maiores famílias da classe Agaricomycetes Doweld, foi estabelecida por Donk (1948) e tipificada pelo gênero *Hymenochaete* Lév. Apresenta com uma diversidade mundial de 833 espécies, distribuídas em 45 gêneros, sendo os maiores *Hymenochaete*, *Phellinus* Quél., e *Inonotus* P. Karst., com 175, 150 e 125 espécies, respectivamente (WANG *et al.*, 2023; HYDE *et al.*, 2024). Nos últimos anos, o aumento no número de taxóns se deve, em grande parte, à implementação de ferramentas moleculares que complementam os dados morfológicos e ecológicos na correta compreensão da família Hymenochaetaceae (WU *et al.,* 2022; HE *et al.,* 2024).

As espécies apresentam hábitos ectomicorrízicos, atuando na simbiose com plantas, parasitas de árvores vivas, em inúmeras espécies de angiospermas e gimnospermas e saprófitas, que causam a podridão branca na quebra da lignina, celulose e hemicelulose e desempenham um papel fundamental na decomposição da matéria orgânica em ecossistemas florestais e contribui para ciclagem de nutrientes (RYVARDEN, 1991, 2004; CANNON; KIRK, 2007; TEDERSOO *et al.*, 2007, 2010; MORERA *et al.*, 2017; VASCO-PALACIOS *et al.*, 2018). Algumas espécies também são conhecidas por terem propriedades medicinais (LI *et al.*, 2004; BAE *et al.*, 2005a, 2005b; DAI *et al.,* 2007; DONG *et al.*, 2009; ZAPORA *et al.*, 2016). Devido à sua importância ecológica e econômica, espécies de Hymenochaetaceae têm sido extensivamente estudadas.

Principais características de Hymenochaetaceae

Espécies de Hymenochaetaceae *sensu* Donk são caracterizadas por apresentarem basidiomas sazonais ou perenes, na maioria das vezes de coloração marrom ferruginosa (raramente outras cores), devido à presença de esterpilenos nas hifas desses fungos (GILL; STEGLICH, 1987; RYVARDEN, 2004). Os espécimes possuem variação morfológica quanto à disposição no substrato: pileados, ressupinados, efuso-reflexos e estipitados (Figura 1). A superfície abhmenial dos espécimes pode ser pilosa, glabra (sem pelos), geralmente fosca, zonada (com zonas concêntricas) ou azonadas, e a superfície himenial (himenófero) pode apresentar-se poroide, hidnoide, irpicoide a lisa, onde estão presentes as microestruturas férteis, basídios e basidiósporos (GILBERTSON; RYVARDEN, 1986; RYVARDEN, 2004; WANG *et al.*, 2023). O contexto das espécies da família é caracterizado como duplo e/ou heterogêneo, com a presença de uma ou mais linhas pretas delimitando o contexto, ou homogêneo, quando não há presença destas linhas. O basidioma é denominado anual quando apresenta somente uma camada de tubos acima do contexto, e perene, na presença de duas ou mais camadas de tubos, que podem perdurar por um longo período e até por anos (FIDALGO; FIDALGO, 1967; RYVARDEN, 2004; DAI, 2010).

Figura 1. Variação morfológica dos basidiomas de Hymenochaetaceae. A: Pileado. B. Ressupinado. C: Efuso-reflexo. D: Estipitado. Fonte: O autor (2025).

As microestruturas presentes em Hymenochaetaceae são importantes no reconhecimento deste grupo. O sistema hifal é monomítico, dimítico ou trimítico; as hifas são generativas com septos simples e paredes celulares finas, com ausência dos grampos de conexão nos septos, além da presença de hifas esqueléteas, as quais apresentam paredes grossas e apenas um septo simples na base (RYVARDEN, 2004). A maioria dos representantes apresenta microestruturas estéreis, chamadas de setas, que podem ter origem himenial e/ou tramal, e morfologicamente variada (acuminada, bifurcada, pontiaguda e estrelada). Outro destaque no reconhecimento desta família é a reação xantocroica positiva, que resulta no enegrecimento permanente das hifas na presença de hidróxido de potássio (KOH) (RYVARDEN, 1991; 2004; WAGNER; FISCHER, 2002a, 2002b; LARSSON *et al.*, 2006; DAI, 2010; CAMPOS-SANTANA *et al.*, 2015; WANG *et al.*, 2023).

Os basídios são clavados ou em forma de barril, com presença de quatro esterigmas, raramente com dois. Os basidiósporos são lisos, raramente ornamentados, globosos, subglobosos, elipsoides, oblongo-elipsoides a cilíndricos, com paredes finas a espessas, hialinos, cianófilos, amarronzados ou dextrinoides (em com contato com reagebte de Melzer), auxiliando na identificação de espécies (RYVARDEN, 2004; DAI, 2010).

Sistemática e filogenia de Hymenochaetaceae

A família Hymenochaetaceae foi pioneiramente estudada por Patouillard (1900), o qual alocou espécies que apresentavam um tipo de cistídio distinto (atualmente conhecidas como setas). Décadas seguintes, por meio dos trabalhos de Donk (1931; 1933), foi estabelecida a subfamília Hymenochaetoidae e, posteriormente, a família Hymenochaetaceae (Donk, 1948), abrigando todas as espécies com presença de setas himeniais. As principais características de Hymenochaetaceae foram descritas com base nos trabalhos de Donk (1964) e, somente em 1977, foi criada a ordem Hymenochaetales por Oberwinkler (1977), para classificar Hymenochaetaceae e confirmar a presença de setas himeniais como principal característica sinapomórfica da família.

Por muito anos, a identificação de gêneros e espécies de Hymenochaetaceae foram marcados pela taxonomia tradicional, principalmente, pelo agrupamento com base em características morfológicas (Fiasson; Niemelä, 1984; Wagner; Fischer, 2001). A ausência de dados filogenéticos e ecológicos demonstraram limitação da taxonomia tradicional na delimitação de gêneros e espécies, pois a família constitui um grupo bastante heterogêneo (Fiasson, 1982; Fiasson; Niemelä, 1984; Fischer, 1996; Dai, 1999).

Espécies da família Hymenochaetaceae, assim como outras da ordem Hymenochaetales (como Rigidoporaceae Jülich), apresentam baixa heterogeneidade em suas características morfológicas, o que é oriundo de processos de especiação sem diferenças morfológicas significativas (LARSSON *et al.*, 2006; ALVES-SILVA *et al.*, 2020). Para muitas espécies de Hymenochaetaceae, é também designado o termo "espécies crípticas", a qual as espécies são morfologicamente similares a ponto de não serem distinguidas umas das outras, dificultando a correta identificação, impactando diretamente a diversidade de espécies de Hymenochaetaceae e, consequentemente, sua conservação (BICKFORD *et al.*, 2007; DUSSEX *et al.*, 2018). Como por exemplo, o gênero *Fomitiporia* Murrill, que devido seus caracteres morfológicos imperceptíveis, foi durante muitos anos considerado como pertencente ao complexo de *Phellinus robustus-punctatus* (P. Karst.) Bourdot & Galzin (DAVID *et al.*, 1982; RYVARDEN; GILBERTSON, 1994). Sendo assim, foi de extrema importância a implementação de ferramentas moleculares e filogenéticas para delimitação precisa dos táxons, com a finalidade de compreender os complexos de espécies morfologicamente semelhantes, uma vez que as espécies apresentam diferenças genéticas, que as separam em espécies distinas (HIBBETT, 2006).

O primeiro estudo utilizando abordagem filogenética para Hymenochaetaceae foi realizado por Wagner e Fischer (2001) que confirmaram a polifilia de vários gêneros do grupo e propuseram a divisão com suporte monofilético dos gêneros *Phellinus* Quél. [*Porodaedalea* Murrill, *Fomitiporia* Murrill, *Fuscoporia* Murrill, *Phellinidium* (Kotl.) Fiasson & Niemelä, *Phylloporia* Murrill] e *Inonotus* P. Karst. (*Inocutis* Fiasson & Niemelä, *Mensularia* Lázaro Ibiza, *Pseudoinonotus* T. Wagner & M. Fisch. e *Inonotopsis* Parmasto). *Phellinus* é um exemplo notório da polifiletismo em Hymenochaetaceae, tratando-se de um gênero com vários agrupamentos menores, os quais foram posteriormente validados como monofiléticos baseado em filogenias moleculares (FIASSON; NIEMELÃ, 1984; FISCHER, 1996; HANSEN; KNUDSEN, 1997; WAGNER; FISCHER, 2001, 2002a; 2002b). No ano seguinte, Wagner e Ryvarden (2002), em um estudo filogenético da região genômica RNA ribossômico da subunidade grande (LSU) com *Phylloporia*, demonstraram a monofilia do gênero e a sua inclusão em Hymenochaetaceae. Larsson *et al.* (2006) em suas análises, corroboraram o estudo de Wagner e Fischer (2002b) ao apoiarem que esta família não é monofiletica, quando excluídos os gêneros *Coltricia* Gray e *Coltriciella* Murrill. Além de apoiarem a subdivisão de *Phellinus* e *Inonotus* em gêneros menores e a segregação de *Pseudochaete* de *Hymenochaete* Lév. Recentemente, Wang *et al.* (2023), por meio de análises filogenéticas, realizaram uma atualização na taxonomia de Hymenochaetales, e para Hymenochaetaceae, os autores ampliaram o conceito da família, e acomodaram membros originalmente das famílias Neoantrodiellaceae Y.C. Dai, B.K. Cui, Jia J. Chen & H.S. Yuan, e Nigrofomitaceae Jülich, além dos gêneros *Basidioradulum* Nobles e *Trichaptum* Murrill para a família.

Ainda assim, diversos estudos demostraram que muitos gêneros de Hymenochaetaceae são polifiléticos e novos gêneros foram propostos para incluir as diferentes espécies (WAGNER; FISCHER 2001, 2002a; 2002b; NIEMELÄ *et al.*, 2001; DAI *et al.*, 2008; HE; DAI 2012; VLASÁK *et al.*, 2013; RAJCHENBERG *et al.*, 2015; ZHOU, 2015; ZHOU *et al.*, 2015, 2016, 2018; DRECHSLER-SANTOS *et al.*, 2016; WU *et al.*, 2016; YANG *et al.*, 2016; SALVADOR-MONTOYA *et al.*, 2020; LIMA *et al.*, 2022). Portanto, a diversidade de Hymenochaetaceae ainda é provavelmente subestimada (WU *et al.*, 2022).

Para os Neotrópicos, estudos recentes sobre a diversidade de Hymenochaetaceae revelaram muitos novos taxa e informações importantes para identificação de espécies, como hospedeiros, tipos de vegetação, área de distribuição e novas características morfológicas (RAYMUNDO *et al.*, 2013; PIRES *et al.*, 2015; DRECHSLER-SANTOS *et al.*, 2016; ALVES-SILVA *et al.*, 2020; OLIVEIRA *et al.*, 2022; SALVADOR-MONTOYA *et al.*, 2022).

Ainda são poucos os estudos com abordagem filogenética de espécimes de Hymenochaetaceae coletados no Brasil (GÓES-NETO *et al.*, 2002; BALTAZAR *et al.*, 2014; CAMPOS-SANTANA *et al.*, 2014; PIRES *et al.*, 2015; ALVES-SILVA *et al.*, 2020; SALVADOR-MONTOYA *et al.*, 2020, 2022; LIMA *et al.*, 2022; OLIVEIRA *et al.*, 2022; WU et al., 2022; OLIVEIRA; GIBERTONI, 2023; BITTENCOURT *et al.*, 2024a, 2024b; COMIN *et al.*, 2024). Tratando-se da região Amazônica brasileira, apenas cinco trabalhos são conhecidos com espécimes coletados nesta região (ALVES-SILVA *et al.*, 2020; YUAN *et al.*, 2020; LIMA *et al.*, 2022; OLIVEIRA *et al.*, 2022; *WU et al.*, 2022).

Estudos de Hymenochaetaceae na Amazônia brasileira

Os primeiros trabalhos com Hymenochaetaceae para a Amazônia brasileira foram realizados por Hennings (1904, 1905) e Theissen (1911), relatando espécies de *Phellinus*, *Coltricia* e *Hymenochaete*. Na década de 1960, Batista *et al.* (1966), reavaliando materiais coletados por Hennings, relataram espécies de *Phellinus* e *Phylloporia*. Fidalgo (1968) registrou, pioneiramente, espécies de *Coltricia*, *Hymenochaete* e *Fuscoporia* no estado do Mato Grosso. Posteriormente, Sousa (1980) estudou o gênero *Phellinus* para a Amazônia brasileira e apresentou novos registros. Nos anos 1990, Capelari e Maziero (1988) e Bononi (1992) ampliaram os registros de Hymenochaetaceae paras os estados do Acre e Rondônia.

Estudos realizados por Sotão *et al.* (1991, 1997) foram pioneiros com registros de Hymenochaetaceae no estado do Pará. Foi apresentado um levantamento preliminar de fungos na Estação Científica Ferreira Penna (ECFPn) da Floresta Nacional (FLONA) de Caxiuanã, com 33 taxa registrados, dos quais dois para Hymenochaetaceae [*Inonotus* sp. e *Phellinus gilvus* (Schw.) Pat.] (SOTÃO *et al.*, 1997). Posteriormente, Campos e Cavalcanti (2000) registraram a primeira ocorrência de *Phellinus mangrovicus* (Imazeki) Imazeki para o Brasil e Sotão *et al.* (2002a) a ocorrência de espécie em áreas de manguezais no litoral paraense. Sotão *et al.* (2002b), ainda com levantamentos de fungos na ECFPn, listaram mais duas espécies de *Phellinus* (*P. pseudosenex* (Murrill) Bondartseva & S. Herrera e *P. robustus* (P. Karst.) Bourdot & Galzin). Campos *et al.* (2005) publicaram um novo trabalho em manguezais no Pará e listaram mais duas espécies de *Phellinus* (*P. fastuosus* (Lév.) S. Ahmad e *P. gilvus*). Sotão *et al.* (2009), realizaram uma nova lista com coleções procedentes do ECFPn, ao todo apresentaram 130 espécies de Agaricomycetes, dos quais 10 foram de Hymenochaetaceae.

Estudos com Hymenochaetaceae na Amazônia ganharam relevância nas últimas duas décadas. Gomes-Silva *et al.* (2008) descrevem a espécie *Coltricia fragilissima* (Mont.) Ryvarden como um novo registro para o estado de Rondônia e o primeiro para o Brasil. Gomes-Silva e Gibertoni (2009a, 2009b) realizaram uma revisão taxonômica da ocorrência de espécies de Agaricomycetes na Amazônia legal, registraram ao todo 32 espécies de Hymenochaetaceae, distribuídas em alguns gêneros como, *Phellinus*, *Inonotus*, *Hymenochaete* e *Coltricia*. Além da descrição de uma nova espécie do gênero *Coltricia* (*C. globispora* Gomes-Silva, Ryvarden & Gibertoni) (Gomes-Silva *et al.*, 2009).

No início dos anos de 2010, novos trabalhos foram realizados e duas novas espécies de *Phellinus* foram descritas (*Phellinus fibrosus* Ryvarden, Gomes-Silva & Gibertoni e *P. sousae* Ryvarden, Gomes-Silva & Gibertoni) com base em coleções provenientes do estado do Amazonas e Mato Grosso e depositadas no herbário INPA

(GOMES-SILVA *et al.*, 2012). Posteriormente, Gomes-Silva *et al.* (2013) descreveram uma nova espécie de *Inonotus* (*I. amazonicus* Gomes-Silva, Ryvarden & Gibertoni) e reportaram espécies de *Phylloporia* Murrill para os estados de Roraima, Rondônia e Amazonas.

As unidades de conservações tornaram-se um centro de registros de macrofungos Agaricomycetes, incluindo Hymenochaetaceae. Para a FLONA de Caxiuanã, Martins-Júnior *et al.* (2011) analisaram 159 espécimes provenientes de coletas realizadas entre os anos de 1995 e 2008, na ECFPn, e registraram sete espécies do gênero *Phellinus*. Medeiros *et al.* (2013), por meio de um levantamento de fungos poroides no sítio do PPBio, registraram 15 espécies de Hymenochaetaceae. Gibertoni *et al.* (2013) identificaram 14 espécies de fungos poroides de Hymenochaetaceae.

Soares *et al.* (2014) realizaram um estudo pioneiro na FLONA do Amapá com fungos poroides, identificando 97 espécies, das quais 16 são pertencentes a Hymenochaetaceae, distribuídas em sete gêneros. Ainda com os estudos na FLONA do Amapá, Soares *et al.* (2018) descreveram uma nova espécie de *Phellinus* (*Phellinus labyrinthicus* Soares, Gomes-Silva & Ryvarden). Ainda no estado do Amapá, Xavier *et al.* (2018) trabalharam com espécies de Agaricomycetes poroides coletadas entre os anos 2014 e 2017 em áreas florestais da Serra do Navio. Para Hymenochaetaceae, foram identificadas 17 espécies, distribuídas em 11 gêneros.

Na presente década, novos estudos com abordagem filogenética publicaram novos taxóns e registros para a Amazônia. Alves-Silva *et al.* (2020) descreveram uma nova espécie de *Fomitiporia* (*F. conyana* Alves-Silva & Drechsler-Santos) coletada no estado do Mato Grosso. Duas novas combinações em *Fuscoporia* [*F. licnoides* (Mont.) Oliveira-Filho & Gibertoni *F. scruposa* (Fr.) Gibertoni & Oliveira-Filho] foram propostas a partir de espécimes analisados do Maranhão, Pará e Rondônia (YUAN *et al.*, 2020).

Silva *et al.* (2021), realizaram estudos com o gênero *Fomitiporia*, nos estados de Amazonas e Roraima, e reportaram oito espécies. A maioria das espécies representou novos registros para Amazônia [*Fomitiporia apiahyna* (Speg.) Robledo, Decock & Rajchenb., *F. calkinsii* (Murrill) Vlasák & Kout, *F. impercepta* Morera, Robledo & Urcelay, *F. maxonii* Murrill, *F. murrillii* Alves-Silva, R.M. Silveira & Drechsler-Santos, e *F. neotropica* Camp.-Sant., Amalfi, R.M. Silveira, Robledo & Decock].

Lima *et al.* (2022) estudaram *Inonotus sensu lato* por meio de análises morfológicas e moleculares de espécimes, descrevendo um novo gênero para Hymenochaetaceae, *Sclerotus* Xavier de Lima, além de três novas espécies, uma nova combinação e registros de outras espécies, com base em espécimes coletados, entre outros estados, no Amapá e Pará. Oliveira *et al.* (2022) descreveram duas novas espécies de *Fulvifomes* coletadas na Amazônia (*F. waimiriatroariensis* V.R. Targino de Oliveira & Gibertoni e *F. karitianaensis* V.R. Targino de Oliveira, V. Xavier de Lima & Gibertoni) registradas, respectivamente, nos estados do Amazonas e Rondônia e, registraram *Fulvifomes kawakamii* (M.J. Larsen, Lombard & Hodges) T. Wagner & M. Fisch para o Pará e Rondônia.

Couceiro *et al.* (2022) apresentaram um inventário de macrofungos poroides no Oeste paraense, pelo qual foram coletadas 91 espécies. Destas, 16 foram pertencentes à Hymenochaetaceae, com quatro novos registros para o estado do Pará.

Freire e Soares (2024) realizaram um estudo taxonômico com espécies de Hymenochaetaceae em dois municípios do estado do Pará. Um total de 15 espécimes foram identificados (sete gêneros e 12 espécies). Com dois novos registros para Amazônia brasileira.

A maioria dos nomes de espécies citados acima (principalmente os epítetos específicos) sofreram mudanças nomenclaturais e, portanto, muitos não são mais válidos. Para a correta nomenclatura das espécies, por favor verifique a banco de dados da plataforma MycoBank (http://www.mycobank.org).

Com as estimativas da Flora do Brasil (2025), o número atual de espécies de Hymenochaetaceae é de aproximadamente 40 para a Amazônia brasileira. Estes dados estão aquém do potencial que se espera da maior floresta tropical do mundo. Além disso, como apresentado, estudos nas últimas décadas envolvendo uma abordagem integrativa revelaram diversas novidades científicas e mudanças taxonômicas para o grupo. Observa-se então, a necessidade de novos estudos com levantamentos, análises morfológicas e filogenéticas para conhecer a real diversidade da família nesta região.

Diante do exposto, o presente trabalho tem como objetivo realizar estudo taxonômico por meio de análises morfológicas e filogenias moleculares de espécies da família Hymenochaetaceae em áreas da Amazônia brasileira, a fim de elucidar as delimitações filogenéticas das espécies.

Organização da dissertação

A presente dissertação está estruturada em três capítulos. O primeiro capítulo intitulado "Survey of the diversity of Hymenochaetaceae (Hymenochaetales, Basidiomycota) in the Brazilian Amazon", foi aceito para publicação no periódico Acta Amazonica, está redigido em inglês, e formatado nas normas do periódico. O segundo capítulo intitulado "*Fulvifomes paraensis* sp. nov. (Hymenochaetaceae, Basidiomycota), a new species from Floodplain Forests in the Brazilian Amazon", foi submetido ao periódico Mycoscience, redigido em inglês, e formatado nas normas do periódico. O terceiro capítulo intitulado "Three new species of *Fuscoporia* Murrill (Hymenochaetaceae, Basidiomycota) based on morphological and molecular evidence from the Eastern Brazilian Amazon", foi submetido ao periódico Mycological Progress, redigido em inglês, e formatado nas normas do periódico.

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CAPÍTULO I

Título: Survey of the diversity of Hymenochaetaceae (Hymenochaetales, Basidiomycota) in the Brazilian Amazon

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Survey of the diversity of Hymenochaetaceae (Hymenochaetales, Basidiomycota) in the Brazilian Amazon

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ABSTRACT

Brazilian Amazon occupies an area of around 50% of the Brazilian territory and covers nine states. This region is home to a high diversity of plants and fungi. However, the knowledge of these groups is still limited, which could affect the assessment of their geographic distribution and diversity of species and, consequently, conservation strategies aimed at them. Hymenochaetaceae is a family of fungi in the phylum Basidiomycota and has 893 known species worldwide. The goal of this study was to provide an update review of the literature and collection databases on the diversity of Hymenochaetaceae species occurring in the Brazilian Amazon. A total of 46 species were confirmed to occur in the region, with valid records, while 34 species were considered doubtful in view of the type locality, lack of ecological and phylogenetic data and were excluded from the occurrence list until they undergo a more in-depth review. The most representative genera were *Coltricia*, *Fuscoporia*, *Hymenochaete* and *Fomitiporia*. The states of Pará and Rondônia had the highest number of species. The 46 valid species of Hymenochaetaceae registered in this study provide baseline to strategies and polices of conservation and highlighted the importance to cover the extensive sampling gaps in the region and to carry out new taxonomic studies to better understand the diversity of fungi in the Amazon.

KEYWORDS: conservation, distribution, Neotropics, rainforest, wood decaying fungi

Levantamento da diversidade de Hymenochaetaceae (Hymenochaetales, Basidiomycota) na Amazônia brasileira

RESUMO

Amazônia brasileira ocupa uma área com cerca de 50% do território brasileiro e abrange nove estados. Esta região abriga uma alta diversidade de plantas e fungos. No entanto, o conhecimento sobre esses grupos ainda é limitado, o que pode restringir estudos sobre a distribuição geográfica e diversidade de espécies, e, consequentemente, estratégias para conservação. Hymenochaetaceae é uma família de fungos do filo Basidiomycota e possui 893 espécies conhecidas em todo o mundo. O objetivo deste estudo foi fornecer uma revisão atualizada da literatura e dos bancos de dados de coleções sobre a diversidade de espécies de Hymenochaetaceae ocorrentes na Amazônia brasileira. Um total de 46 espécies foram confirmadas como ocorrendo na região, com registros válidos, enquanto 34 espécies foram consideradas duvidosas em vista da localidade-tipo, ausência de dados ecológicos e filogenéticos e foram excluídas da lista de ocorrência até que passem por uma revisão mais aprofundada. Os gêneros mais representativos foram *Coltricia*, *Fuscoporia*, *Hymenochaete* e *Fomitiporia*. Os estados do Pará e Rondônia apresentaram o maior número de espécies. As 46 espécies válidas de Hymenochaetaceae registradas neste estudo fornecem uma base para estratégias e políticas de conservação e destacam a importância de cobrir as grandes lacunas de amostragem na região e de realizar novos estudos taxonômicos para melhor compreender a diversidade de fungos na Amazônia.

PALAVRAS-CHAVE: conservação, distribuição, Neotrópicos, floresta tropical, fungos decompositores

INTRODUCTION

The family Hymenochaetaceae *sensu* Donk includes 893 species described worldwide, distributed in 42 genera (Wijayawardene *et al.* 2022), but the true diversity is likely underestimated (Wu *et al.* 2022). *Phellinus* Quél. (202 species), *Hymenochaete* Lév. (149) and *Inonotus* P. Karst. (120) are the most representative genera (Wijayawardene *et al.* 2022). The main characteristics of Hymenochaetaceae *sensu* Donk are the rusty colored basidiomata, with varying arrangement on the substrate (pileate, resupinate, effused-reflexed and stipitate), simple-septate generative hyphae with permanent darkening when in contact with potassium hydroxide (KOH), dark brown and pointed setae (in most species), often simple, rarely starry, bifurcate, covered or of hyphal and tramal origin (Parmasto and Parmasto 1979; Gill and Steglich 1987; Ryvarden 1991; 2004; Leger 1998; Baltazar *et al.* 2009; Wang *et al.* 2023).

Species of this family cause white rot in wood, breaking down lignin, cellulose and hemicellulose, and act as saprophytes, parasites of living trees, and ectomycorrhizal symbionts (Ryvarden, 1991, 2004; Larsson *et al.* 2006; Cannon and Kirk 2007; Dai *et al.* 2007; Tedersoo *et al.* 2007; 2010; Morera *et al.* 2017; Vasco-Palacios *et al.* 2018). Some species have been intensively studied for their use in traditional medicine and pharmacology (Jang *et al.* 2004; Li *et al.* 2004; Bae *et al.* 2005a; 2005b; Dong *et al.* 2009; Dai *et al.* 2010; Zapora *et al.* 2016; Yan et *al.* 2017; He *et al.* 2021).

The occurrence of Hymenochaetaceae species in the Brazilian Amazon has been reported in taxonomic reviews (Sotão *et al.* 1991; 1997; 2002a; 2002b; 2003; 2009; Jesus 1996; Campos *et al.* 2005; Gomes-Silva and Gibertoni 2009a; 2009b; 2012a; Gibertoni *et al.* 2013; Medeiros *et al.* 2013; Soares *et al.* 2014; Xavier *et al.* 2018; Couceiro *et al.* 2022). New records and new taxa are frequently published (Campos and Cavalcanti 2000; Gomes-Silva *et al.* 2009; 2012b; 2013; Martins-Júnior *et al.* 2011; Soares *et al.* 2018; Alves-Silva *et al.* 2020; Yuan *et al.* 2020; Silva *et al.* 2021; Lima *et al.* 2022; Oliveira *et al.* 2022; Freire and Soares 2024). However, most records from the Brazilian Amazon are based only on morphological data and, therefore, may be imprecise or doubtful, especially considering that type locality and species complex issues within the family have not yet been resolved.

Estimates indicate that around 90% of fungi species are unknown to science (Antonelli *et al.* 2020). The typically high rate of endemism in the Amazon indicates that this biome likely houses many undiscovered fungal species (Hawksworth and Lücking 2017), which is relevant as they play a fundamental role in natural ecosystems (Finlay and Thorn 2019). Thus, we aimed to carry out an updated survey of the diversity and distribution of Hymenochaetaceae species in the Brazilian Amazon based on scientific literature and database records.

MATERIAL AND METHODS

Survey

This survey was based on a comprehensive review of the literature published until March 2024 citing occurrences of Hymenochaetaceae in the Brazilian Amazon (see

Figure 1 for the geographical boundaries of the biome adopted in here). Records of species with Neotropical, Pantropical, or other regional distribution that had phylogenetic support, as well as ecological data (substrate or host), were considered valid. Records lacking substantial information were classified as dubious and, therefore, excluded. Information about type locality and distribution of the species was also checked on the following databases: Flora e Funga do Brasil (http://floradobrasil.jbrj.gov.br); SpeciesLink (http://www.splink.org.br); and Index Fungorum (http://www.indexfungorum.org/). The classification and nomenclature of the species followed the Mycobank database (http://www.mycobank.org).

The following information on species considered valid are provided here: (1) species name, author(s), and publication record; (2) basionym and synonyms (including species with nomenclatural changes); (3) description [author(s) and year]; (4) type locality; (5) host/substrate; (6) distribution in the states that compose the Brazilian Amazon and corresponding references. For excluded taxa, we provide the species name/author(s) and type locality.

Distribution map

The distribution map of the Hymenochaetaceae in the Brazilian Amazon was created according to shapefiles available in the Instituto Brasileiro de Geografia e Estatística (https://www.ibge.gov.br/). We used the coordinates of collection sites available in publications. If the coordinates were not available, we used reference coordinates for the municipality or other toponymal associated with the collection site in the publication. The map was created using software QGIS v. 3.28, datum SIRGAS 2000.

RESULTS

A total of 80 species of Hymenochaetaceae were registered for the Brazilian Amazon, yet only records of 46 species (distributed in 12 genera) were considered valid. Based on 24 publications, there were 36 confirmed occurrence sites of Hymenochaetaceae species with geographic coordinates (Figure 1; Supplementary Material, Table S1). The remaining 34 species recorded in the literature for were excluded from our updated list for the Brazilian Amazon (Supplementary Material, Appendix S1) due to inconsistencies with the type locality of the species and because the studies reporting them only present morphological data and lack further key information that could support the veracity of the record.

The most representative genera were *Coltricia* Gray and *Fuscoporia* Murrill, with eight species each, followed by *Hymenochaete* (6) and *Fomitiporia* Murrill (5) (Figure 2). *Hymenochaete iodina* (Mont.) Baltazar and Gibertoni was recorded in seven states, followed by *H. damicornis* (Link) Lév. and *Coltricia hamata* (Romell) Ryvarden, recorded in six states each. The highest number of species were recorded in the states of Pará (23 species) and Rondônia (21), while the states of Maranhão and Tocantins had records of only two species each (Figure 3).

List of Hymenochaetaceae of the Brazilian Amazon

Coltricia Gray, A natural arrangement of British plants 1: 644 (1821)

Coltricia barbata Ryvarden & de Meijer, Synopsis Fungorum 15: 46 (2002)

Description: Ryvarden (2004).

Type locality: Paraná (Brazil).

Host/substrate: On the ground, in dense ombrophilous forest.

Distribution: Amapá, Pará and Rondônia (Gomes-Silva *et al.* 2012a; Soares et al. 2014; Gibertoni *et al.* 2015; Xavier *et al.* 2018; Couceiro *et al.* 2022).

Coltricia duportii (Pat.) Ryvarden, Occasional Papers of the Farlow Herbarium of Cryptogamic Botany 18: 140 (1983)

Basionym: *Xanthochrous duportii* Pat., Bulletin de la Société Mycologique de France 28: 34 (1912).

Description: Ryvarden (2004).

Type locality: French Guiana.

Host/substrate: On trunk of Arecaceae.

Distribution: Rondônia (Gomes-Silva *et al.* 2012a; Gibertoni *et al.* 2015).

Coltricia fragilissima (Mont.) Ryvarden, Nordic Journal of Botany 2 (1): 78 (1982)

Basionym: *Polyporus fragilissimus* Mont., Annales des Sciences Naturelles Botanique 1: 130 (1854).

Description: Ryvarden (2004) and Gomes-Silva et al. (2008).

Type locality: French Guiana.

Host/substrate: On burnt wood.

Distribution: Rondônia (Gomes-Silva *et al.* 2008).

Coltricia focicola (Berk. & M.A. Curtis) Murrill, North American Flora 9(2): 92 (1908)

Basionym: *Polyporus focicola* Berk. & M.A. Curtis, Journal of the Linnean Society. Botany 10: 305 (1869).

Description: Ryvarden (2004).

Type locality: USA.

Host/substrate: On soil, associated with burnt stumps of Coniferae.

Distribution: Amapá and Pará (Gomes-Silva *et al.* 2012a; Gibertoni *et al.* 2015; Couceiro *et al.* 2022).

Coltricia globispora Gomes-Silva, Ryvarden & Gibertoni, Mycological Progress 8(4): 274 (2009)

Description: Gomes-Silva *et al.* (2009).

Type locality: Rondônia (Brazil).

Host/substrate: On soil.

Distribution: Rondônia and Pará (Gomes-Silva *et al.* 2009; Gibertoni *et al.* 2015; Couceiro *et al.* 2022).

Coltricia hamata (Romell) Ryvarden, Svensk Botanisk Tidskrift 68: 276 (1974)

Basionym: *Pelloporus hamatus* Romell, Bihang til Kongliga Svenska Vetenskaps-Akademiens Handlingar 26 (16): 26 (1901).

Description: Ryvarden (2004).

Type locality: Mato Grosso (Brazil).

Host/substrate: On trunks.

Distribution: Amapá, Amazonas, Mato Grosso, Pará, Rondônia and Roraima (Torrend 1926; Fidalgo 1968; Gomes-Silva *et al.* 2009; 2012a; Gibertoni *et al.* 2013; Medeiros et al. 2013; Soares et al. 2014; Gibertoni *et al.* 2015; Freire and Soares 2024).

Coltricia navispora (T.W. Henkel, Aime & Ryvarden) Y.C. Dai & F. Wu, Fungal Diversity 113: 11 (2022)

Basionym: *Coltriciella navispora* T.W. Henkel, Aime & Ryvarden, Mycologia 95(4): 617 (2003).

Description: Aime *et al.* (2003).

Type locality: Guyana.

Host/substrate: On trunks.

Distribution: Amazonas (Gibertoni *et al.* 2015).

Coltricia velutina Baltazar & Gibertoni, Mycologia 102(6): 1258 (2010)

Description: Baltazar *et al.* (2010).

Type locality: Pernambuco (Brazil).

Host/substrate: On soil.

Distribution: Rondônia (Gomes-Silva *et al.* 2012a; Gibertoni *et al.* 2015).

Coltriciella Murrill, Bulletin of the Torrey Botanical Club 31 (6): 348 (1904)

Coltriciella oblectabilis (Lloyd) Kotl., Pouzar & Ryvarden, Ceská Mykologie 38(3): 140 (1984)

Basionym: *Polystictus oblectabilis* Lloyd, Synopsis of the stipitate polyporoids (7): 164 (1912).

Description: Ryvarden (2004).

Type locality: Brazil.

Host/substrate: In soil.

Distribution: Amazonas and Rondônia (Gibertoni *et al.* 2015).

Fomitiporella Murrill, North American Flora 9 (1): 12 (1907)

Fomitiporella membranacea (Wright & Blumenf.) Y.C. Dai & F. Wu, Fungal Diversity 113: 25 (2022)

Basionym: *Phellinus membranaceus* J.E. Wright & Blumenf., Mycotaxon 21: 422 (1984)

≡ *Fulvifomes membranaceus* (J.E. Wright & Blumenf.) Baltazar & Gibertoni, Mycotaxon 111: 206 (2010)

Description: Wright and Blumenfeld (1984) and Ryvarden (2004).

Type locality: Argentina.

Host/substrate: On Angiospermae.

Distribution: Pará (Gomes-Silva *et al.* 2009; Gibertoni *et al.* 2013; Medeiros et al. 2013; Gibertoni *et al.* 2015).

Fomitiporella umbrinella (Bres.) Murrill, North American Flora 9 (1): 13 (1907)

Basionym: *Poria umbrinella* Bres., Hedwigia 35: 282 (1896).

≡ *Phellinus umbrinellus* (Bres.) S. Herrera & Bondartseva, Mikologiya i Fitopatologiya 14 (1): 8 (1980)

Description: Salvador-Montoya *et al.* (2020).

Type locality: Santa Catarina (Brazil).

Host/substrate: On dead wood.

Distribution: Amapá, Mato Grosso and Pará (Gomes-Silva *et al.* 2009; Gibertoni *et al.* 2013; Medeiros et al. 2013; Soares et al. 2014; Gibertoni *et al.* 2015).

Fomitiporia Murrill, North American Flora 9 (1): 7 (1907)

Fomitiporia conyana Alves-Silva & Drechsler-Santos, Mycological Progress 19(8): 781 (2020)

Description: Alves-Silva *et al.* (2020).

Type locality: Mato Grosso (Brazil).

Host/substrate: On dead standing trunk.

Distribution: Amazonas, Mato Grosso and Roraima (Alves-Silva et al. 2020; Silva et al. 2021).

Fomitiporia impercepta Morera, Robledo & Urcelay, Phytotaxa 321(3): 281 (2017)

Description: Morera *et al.* (2017).

Type locality: Argentina.

Host/substrate: On living trunk of *Lithraea molleoides.*

Distribution: Amazonas and Roraima (Silva et al. 2021).

Fomitiporia maxonii Murrill, North American Flora 9 (1): 11 (1907)

≡ *Phellinus maxonii* (Murrill) D.A. Reid, Kew Bulletin 35 (4): 867 (1981)

Description: Ryvarden (2004).

Type locality: Costa Rica.

Host/substrate: On decayed wood.

Distribution: Roraima (Silva *et al.* 2021).

Fomitiporia murrillii Alves-Silva, R.M. Silveira & Drechsler-Santos, Mycological Progress 19(8): 783 (2020)

Description: Alves-Silva *et al.* (2020).

Type locality: Rio Grande do Sul (Brazil).

Host/substrate: Growing on living *Eucalyptus* sp. tree.

Distribution: Roraima (Silva *et al.* 2021).

Fomitiporia neotropica Campos-Santana, Amalfi, R.M. Silveira, Robledo & Decock, Mycological Progress 13(3): 610 (2014)

Description: Campos-Santana *et al.* (2013).

Type locality: Argentina.

Host/substrate: On dead standing trunk of Angiospermae.

Distribution: Amazonas and Roraima (Silva et al. 2021).

Fulvifomes Murrill, Northern Polypores (5): 49 (1914)

Fulvifomes karitianaensis V.R. Targino de Oliveira, V. Xavier de Lima & Gibertoni, Sydowia 75: 5 (2022)

Description: Oliveira *et al.* (2022).

Type locality: Rondônia (Brazil).

Host/substrate: On decayed wood.

Distribution: Rondônia (Oliveira *et al.* 2022).

Fulvifomes kawakamii (M.J. Larsen, Lombard & Hodges) T. Wagner & M. Fisch., Mycologia 94 (6): 1009 (2002)

Basionym: *Phellinus kawakamii* M.J. Larsen, Lombard & Hodges, Mycologia 77: 346 (1985).

Description: Larsen et al. (1985).

Type locality: Hawaiian Islands (USA).

Host/substrate: On wood of *Casuarina equisetifolia*.

Distribution: Pará and Rondônia (Oliveira et al. 2022).

Fulvifomes luteoumbrinus (Romell) Y.C. Dai & Vlasák, Fungal Diversity 113: 58 (2022)

Basionym: *Phaeoporus luteoumbrinus* Romell, Bihang til Kongliga Svenska Vetenskaps-Akademiens Handlingar 26 (16): 27 (1901).

≡ *Aurificaria luteoumbrina* (Romell) D.A. Reid, Kew Bull. 17(2): 279 (1963)

≡ *Inonotus luteoumbrinus* (Romell) Ryvarden, Synopsis Fungorum (Oslo) 21: 79 (2005)

= *Phellinus sublinteus* (Murrill) Ryvarden, Norwegian Journal of Botany 19: 235 (1972)

Description: Ryvarden (2005).

Type locality: Brazil.

Host/substrate: Not located.

Distribution: Acre, Mato Grosso, Rondônia and Tocantins (Bononi 1992; Gibertoni *et al.* 2015).

Fulvifomes waimiriatroariensis V.R. Targino de Oliveira & Gibertoni, Sydowia 75: 8 (2022)

Description: Oliveira *et al.* (2022).

Type locality: Amazonas (Brazil).

Host/substrate: On unidentified living tree.

Distribution: Amazonas (Oliveira *et al.* 2022).

Fuscoporia Murrill, North American Flora 9 (1): 3 (1907)

Fuscoporia chrysea (Lév.) Baltazar & Gibertoni, Mycotaxon 111: 206 (2010)

Basionym: *Polyporus chryseus* Lév., Annales des Sciences Naturelles Botanique sér. 3, 5: 301 (1846).

≡ *Phellinus chryseus* (Lév.) Ryvarden, A preliminary polypore flora of East Africa: 151 (1980)

Description: Ryvarden and Johansen (1980) and Ryvarden (2004).

Type locality: Colombia.

Host/substrate: Not located.

Distribution: Pará (Couceiro *et al.* 2022).

Fuscoporia griseopora (Reid) Y.C. Dai & F. Wu, Fungal Diversity 113: 72 (2022)

Basionym: *Phellinus griseoporus* D.A. Reid, Memoirs of the New York Botanical Garden 28: 192 (1976).

Description: Ryvarden (2004).

Type locality: Costa Rica.

Host/substrate: On roots of *Danaea cuspidata.*

Distribution: Amapá, Pará and Rondônia (Gomes-Silva *et al.* 2009; Soares et al. 2014; Gibertoni *et al.* 2015; Freire and Soares 2024).

Fuscoporia labyrinthica (Soares, Gomes-Silva & Ryvarden) Y.C. Dai & F. Wu, Fungal Diversity 113: 72 (2022)

Basionym: *Phellinus labyrinthicus* Soares, Gomes-Silva & Ryvarden, Synopsis Fungorum 38: 57 (2018).

Description: Soares *et al.* (2018).

Type locality: Amapá (Brazil).

Host/substrate: On dead wood of Angiospermae.

Distribution: Acre and Amapá (Soares *et al.* 2018).

Fuscoporia licnoides (Mont.) Oliveira-Filho & Gibertoni, Fungal Diversity 104: 129 (2020)

Basionym: *Polyporus licnoides* Mont., Annales des Sciences Naturelles Botanique 13: 204 (1840).

Description: Yuan *et al.* (2020).

Type locality: French Guiana.

Host/substrate: On dead branches.

Distribution: Pará and Rondônia (Yuan *et al.* 2020).

Fuscoporia rhabarbarina (Berk.) Groposo, Log.-Leite & Góes-Neto, Mycotaxon 101: 61 (2007)

Basionym: *Polyporus rhabarbarinus* Berk., Annals and Magazine of Natural History 3: 388 (1839).

Description: Groposo *et al.* (2007).

Type locality: Brazil.

Host/substrate: Not located.

Distribution: Pará (Couceiro *et al.* 2022).

Fuscoporia scruposa (Fr.) Gibertoni & Oliveira-Filho, Fungal Diversity 104: 130 (2020)

Basionym: *Polyporus scruposus* Fr., Epicrisis Systematis Mycologici: 473 (1838)

= *Phellinus gilvus* var. *scruposus* (Fr.) S. Ahmad, Basidiomycetes of West Pakistan: 59 (1972).

Description: Ryvarden (2004).

Type locality: Not located.

Host/substrate: Not located.

Distribution: Maranhão (Yuan *et al.* 2020).

Fuscoporia senex (Nees &Mont.) Ghobad-Nejhad, Mycotaxon 101: 208 (2007)

Basionym: *Polyporus senex* Nees & Mont., Annales des Sciences Naturelles Botanique 5: 70 (1836).

≡ *Phellinus senex* (Nees & Mont.) Imazeki, Bulletin of the Government Forest Experimental Station Meguro 57: 115 (1952)

Description: Ryvarden (2004).

Type locality: Chile.

Host/substrate: On rotten trunks.

Distribution: Amazonas, Maranhão and Pará (Sousa 1980; Sotão *et al.* 2003; Gibertoni *et al.* 2015; Freire and Soares 2024).

Fuscoporia undulata (Murrill) Bondartseva & S. Herrera, Mikologiya i Fitopatologiya 26(1): 13 (1992)

Basionym: *Fomitiporia undulata* Murrill, North American Flora 9 (1): 10 (1907).

≡ *Phellinus undulatus* (Murrill) Ryvarden, Norwegian Journal of Botany 19: 235 (1972)

Description: Ryvarden (2004).

Type locality: Belize.

Host/substrate: On decayed log.

Distribution: Amapá and Pará (Sotão *et al.* 2009; Martins-Júnior *et al.* 2011; Gibertoni *et al.* 2013; Medeiros et al. 2013; Soares et al. 2014; Gibertoni *et al.* 2015; Xavier *et al.* 2018; Couceiro *et al.* 2022).

Hymenochaete Lév., Annales des Sciences Naturelles Botanique 5: 150 (1846)

Hymenochaete damicornis (Link) Lév., Annales des Sciences Naturelles Botanique, 3 5: 151 (1846)

Basionym: *Stereum damicorne* Link, Magazin der Gesellschaft Naturforschenden Freunde Berlin 3 (1): 40 (1809).

Description: Parmasto (2001).

Type locality: Brazil.

Host/substrate: Not located.

Distribution: Acre, Amazonas, Mato Grosso, Pará, Rondônia and Roraima (Hennings 1904; Gibertoni *et al.* 2003; Gomes-Silva *et al.* 2012a; Gibertoni *et al.* 2015; Couceiro *et al.* 2022; Freire and Soares 2024).

Hymenochaete iodina (Mont.) Baltazar & Gibertoni, Journal of the Torrey Botanical Society 139: 432 (2012)

Basionym: *Polyporus iodinus* Mont., Annales des Sciences Naturelles Botanique 16: 108 (1841)

≡ *Cyclomyces iodinus* (Mont.) Pat., Essai taxonomique sur les familles et les genres des Hyménomycètes: 98 (1900)

Description: Ryvarden (2004).

Type locality: French Guiana.

Host/substrate: On rotten wood.

Distribution: Acre, Amapá, Amazonas, Mato Grosso, Pará, Rondônia and Roraima (Gomes-Silva *et al.* 2009; 2012a; Gibertoni *et al.* 2013; Medeiros et al. 2013; Soares et al. 2014; Gibertoni *et al.* 2015; Xavier *et al.* 2018).

Hymenochaete leonina Berk. & M.A. Curtis, Journal of the Linnean Society. Botany 10: 334 (1868)

Description: Parmasto (2001).

Type locality: Cuba.

Host/substrate: On dead wood.

Distribution: Amazonas, Mato Grosso, Pará, Rondônia and Roraima (Léger 1998; Gibertoni *et al.* 2003; Gomes-Silva *et al.* 2012a; Gibertoni *et al.* 2015).

Hymenochaete luteobadia (Fr.) Höhn. & Litsch., Sitzungsberichte der Kaiserlichen Akademie der Wissenschaften Math.-naturw. Klasse Abt. 1 116:750 (1907)

Basionym: *Thelephora luteobadia* Fr., Linnaea 5: 526 (1830).

Description: Parmasto (2001).

Type locality: Suriname.

Host/substrate: On tree trunks.

Distribution: Amazonas, Mato Grosso, Pará, Rondônia, Roraima and Tocantins (Fidalgo 1968; Léger 1998; Gibertoni *et al.* 2003; Gomes-Silva *et al.* 2012a; Gibertoni *et al.* 2015; Couceiro *et al.* 2022).

Hymenochaete reniformis (Fr.) Lév., Annales des Sciences Naturelles Botanique 3 5: 151 (1846)

Basionym: *Stereum reniforme* Fr., Epicrisis Systematis Mycologici: 546 (1838)

≡ *Stipitochaete reniformis* (Fr.) Ryvarden, Transactions of the British Mycological Society 85 (3): 538 (1985).

Description: Ryvarden (1985).

Neotype locality: Brazil.

Host/substrate: Not located.

Distribution: Acre and Mato Grosso (Gibertoni *et al.* 2003; Gibertoni *et al.* 2015).

***Hymenochaete* unicolor** Berk. & M.A. Curtis, Journal of the Linnean Society. Botany 10: 335 (1868)

Description: Parmasto (2001).

Type locality: Cuba.

Host/substrate: On dead trees.

Distribution: Rondônia (Gomes-Silva *et al.* 2012a; Gibertoni *et al.* 2015).

Inonotus P. Karst., Meddelanden af Societas pro Fauna et Flora Fennica 5: 39 (1879)

Inonotus amazonicus Gibertoni & Ryvarden, Mycoscience 54(2): 117 (2013)

Description: Gomes-Silva *et al.* (2013).

Type locality: Mato Grosso (Brazil).

Host/substrate: On hardwood tree.

Distribution: Mato Grosso (Gomes-Silva *et al.* 2013; Gibertoni *et al.* 2015).

Inonotus calcitratus (Berk. & M.A. Curtis) Gomes-Silva & Gibertoni, Mycoscience 54: 117 (2013)

Basionym: *Polyporus calcitratus* Berk. & M.A. Curtis, Journal of the Linnean Society. Botany 10: 314 (1869)

≡ *Phellinus calcitratus* (Berk. & M.A. Curtis) Ryvarden, Norwegian Journal of Botany 19: 234 (1972).

Description: Ryvarden (2004).

Type locality: Cuba.

Host/substrate: Not located.

Distribution: Amapá, Amazonas, Pará and Rondônia (Sousa 1980; Gomes-Silva *et al.* 2009; Sotão *et al.* 2009; Martins-Júnior *et al.* 2011; Gibertoni *et al.* 2013; Medeiros et al. 2013; Soares et al. 2014; Gibertoni *et al.* 2015; Xavier *et al.* 2018).

Inonotus fibrosus (Ryvarden, Gomes-Silva & Gibertoni) Oliveira-Filho & Gibertoni, Synopsis Fungorum 38: 58 (2018)

Basionym: *Phellinus fibrosus* Ryvarden, Gomes-Silva & Gibertoni, Phytotaxa 67: 56 (2012).

Description: Gomes-Silva *et al.* (2012b).

Type locality: Amazonas (Brazil).

Host/substrate: On angiosperm tree.

Distribution: Amazonas (Gomes-Silva *et al.* 2012b; Gibertoni *et al.* 2015).

Inonotus sousae (Ryvarden, Gomes-Silva & Gibertoni) Oliveira-Filho & Gibertoni, Synopsis Fungorum 38: 59 (2018)

Basionym: *Phellinus sousae* Ryvarden, Gomes-Silva & Gibertoni, Phytotaxa 67: 57 (2012).

Description: Gomes-Silva *et al.* (2012b).

Type locality: Brazil.

Host/substrate: On angiosperm tree.

Distribution: Mato Grosso and Rondônia (Gomes-Silva *et al.* 2012b; Gibertoni *et al.* 2015).

Phellinus Quél., Enchiridion Fungorum in Europa media et praesertim in Gallia Vigentium: 172 (1886)

Phellinus ferrugineovelutinus (Henn.) Ryvarden, Norwegian Journal of Botany 19:234 (1972)

Basionym: *Poria ferrugineovelutina* Henn., Hedwigia 44: 59 (1905).

Description: Ryvarden and Johansen (1980).

Type locality: Amazonas (Brazil).

Host/substrate: On bark tree.

Distribution: Acre and Amazonas (Hennings 1905; Batista et al. 1966; Gibertoni *et al.* 2015).

Phylloporia Murrill, Torreya 4: 141 (1904)

Phylloporia chrysites (Berk.) Ryvarden, Norwegian Journal of Botany 19: 235 (1972)

Basionym: *Polyporus chrysites* Berk., Hooker's Journal of Botany and Kew Garden Miscellany 8: 233 (1856).

Description: Núñez and Ryvarden (2000).

Type locality: Venezuela.

Host/substrate: Not located.

Distribution: Acre, Amazonas, Pará and Rondônia (Bononi 1992; Sotão *et al.* 2009; Gomes-Silva *et al.* 2013; Medeiros et al. 2013; Gibertoni *et al.* 2015; Couceiro *et al.* 2022).

Phylloporia sancti-georgii (Pat.) Y.C. Dai & F. Wu, Fungal Diversity 113: 129 (2022)

Basionym: *Polyporus sancti-georgii* Pat., in Patouillard & Lagerheim, Bull. Soc. mycol. Fr. 11(4): 207 (1895)

≡ *Phellinus sancti-georgii* (Pat.) Ryvarden, Norwegian Journal of Botany 19: 235 (1972).

Description: Ryvarden (2004).

Type locality: Venezuela.

Host/substrate: On deciduous wood.

Distribution: Pará (Freire and Soares 2024).

Phylloporia spathulata (Hook.) Ryvarden, Synopsis Fungorum 5: 196 (1991)

Basionym: *Boletus spathulatus* Hook., Synopsis Plantarum 1: 9 (1822).

Description: Ryvarden (2004).

Type locality: Ecuador.

Host/substrate: Not located.

Distribution: Amapá, Amazonas, Pará, Rondônia and Roraima (Theissen 1911; Batista et al. 1966; Capelari and Maziero 1988; Silva and Minter 1995; Gomes-Silva *et al.* 2009; 2013; Gibertoni *et al.* 2013; Medeiros et al. 2013; Soares et al. 2014; Gibertoni *et al.* 2015; Xavier *et al.* 2018; Couceiro *et al.* 2022).

Sclerotus Xavier de Lima, Cryptogamie, Mycologie 43 (1): 10 (2022)

Sclerotus extensus (Lév.) Xavier de Lima, Cryptogamie, Mycologie 43(1): 10 (2022)

Basionym: *Polyporus extensus* Lév., Annales des Sciences Naturelles Botanique 5: 129 (1846).

Description: Lima et al. (2022).

Type locality: Guadeloupe.

Host/substrate: On wood.

Distribution: Amapá and Pará (Lima et al. 2022; Freire and Soares 2024).

Tropicoporus L.W. Zhou, Y.C. Dai & Sheng H. Wu, Fungal Diversity 77: 341 (2015)

Tropicoporus anchietanus (Decock & Ryvarden) Y.C. Dai & F. Wu, Fungal Diversity 113: 170 (2022)

Basionym: *Phellinus anchietanus* Decock & Ryvarden, Cryptogamie Mycologie 18: 222 (1997).

Description: Ryvarden (2004).

Type locality: Acre (Brazil).

Host/substrate: On bark of a tree.

Distribution: Amapá (Xavier et al. 2018).

Tropicoporus dependens (Murril) L. W. Zhou, Y.C. Dai & Vlasák, Fungal Diversity 77: 344 (2015)

Basionym: *Pyropolyporus dependens* Murrill, North American Flora 9 (2): 106 (1908)

≡ *Phellinus dependens* (Murrill) Imazeki, Bulletin of the Government Forest Experimental Station Meguro 57: 114 (1952).

Description: Ryvarden (2004).

Type locality: Cuba.

Host/substrate: On decaying trunks.

Distribution: Amapá, Amazonas and Pará (Sousa 1980; Medeiros et al. 2013; Soares et al. 2014; Gibertoni *et al.* 2015; Xavier *et al.* 2018).

Tropicoporus detonsus (Fr.) Y.C. Dai & F. Wu, Fungal Diversity 113: 172 (2022)

Basionym: *Polyporus detonsus* Fr., Linnaea 5: 519 (1830)

≡ *Phellinus detonsus* (Fr.) Ryvarden, Synopsis Fungorum 19: 173 (2004)

= *Tropicoporus tropicalis* (M.J. Larsen & Lombard) L.W. Zhou & Y.C. Dai, Fungal Diversity 77: 345 (2015).

Description: Larsen and Cobb-Poulle (1990) and Ryvarden (2004).

Type locality: Costa Rica.

Host/substrate: On decaying trunks.

Distribution: Amapá (Lima *et al.* 2022).

DISCUSSION

This survey provides an updated overview of the diversity and distribution of species of Hymenochaetaceae in the Brazilian Amazon, with 46 valid species confirmed for the region. This figure is higher than the 32 species of Hymenochaetaceae listed by Gomes-Silva and Gibertoni (2009b) for the Brazilian Amazon, but lower than the 64 species listed for the geographically more restricted and semi-arid northeastern region of Brazil (Lira *et al*. 2015). The lower numbers of species recorded in the Brazilian Amazon compared to northeastern region of Brazil may represent a subsampling of surveys that is still underestimated, the data showed here are still below of the expected potential for this region.

In this study, most species considered to be valid occurrences have a Neotropical or Pantropical distribution. The type specimen of *Fulvifomes kawakamii* is from the Nearctic region (Hawaii, USA), but the species has a valid record in the state of Pará, Brazil, which is supported by phylogenetic evidence (Larsen *et al.* 1985; Oliveira *et al*. 2022). The 34 excluded species require an in-depth review in order to confirm or refute their occurrence in the Amazon. For example, *Fulvifomes mangrovicus* (Imazeki) T. Hatt. has for many years been reported to occur in the state of Pará (Campos and Cavalcanti 2000; Sotão *et al*. 2003; Campos *et al.* 2005; Gibertoni *et al.* 2015), but the type specimen of this species is from Japan. *Fuscoporia callimorpha* (Lév.) Groposo, Log.-Leite & Góes-Neto (type locality: Madagascar) was recorded in the states of Amapá and Pará (Xavier *et al.* 2018; Couceiro *et al.* 2022; Freire and Soares 2024), and this species shares morphological characters with other species of *Fuscoporia* (Chen *et al.* 2020), such as *Fuscoporia rhabarbarina* (Groposo *et al.* 2007).

Other excluded taxa represent species complexes. *Fulvifomes robiniae* (Murrill) Murrill has distribution in the temperate zones of the USA, where it primarily grows on living *Robinia pseudoacacia* L. trees (Salvador-Montoya *et al.* 2018). Initially, this species was described as being morphologically variable and widely distributed in North and Central America (Kotlaba and Pouzar 1978; Gilbertson and Ryvarden 1987). However, morphological, ecological and molecular studies have shown that specimens resembling *F. robiniae* from different regions of the Americas correspond to distinct species (Salvador-Montoya *et al.* 2018; 2022; Martínez *et al.* 2023). *Fuscoporia gilva* (Schwein.) T. Wagner & M. Fisch. is considered a cosmopolitan and morphologically variable species (Fidalgo and Fidalgo 1968). Brazilian specimens previously identified as *F. gilva sensu lato* were grouped into four clades [*F. semiarida* (Lima-Júnior, C.R.S. de Lira & Gibertoni), *F. licnoides*, *F. scruposa*, and *F. formosana* (T.T. Chang & W.N. Chou) T. Wagner & M. Fisch], but the type specimen of *F. gilva* (PH74281) was not analyzed and, therefore, *F. gilva sensu stricto* is not recognized in Brazil (Yuan *et al.* 2020). The type specimen of *Hymenochaete cacao* (Berk.) Berk. & M.A. Curtis is from India (Berkeley and Curtis 1869) and the species has a Pantropical distribution (Job 1990). In Brazil, it is recorded in the southeastern state of São Paulo, and in the northern states of Pará and Roraima (Gomes-Silva *et al.* 2012a; Gibertoni *et al.* 2015). However, *H. cacao* is morphologically similar to other *Hymenochaete* species, such as *H. villosa* (Lév.) Bres. (Job 1990), making its record in Brazil still uncertain and in need of a molecular evaluation, especially in the Amazon. *Fulvifomes rimosus* (Berk.) Fiasson & Niemelä has the type locality in Australia, and lectotype is from Mauritius (Larsen 1990). Based on phylogenetic analysis, the distribution of *F. rimosus* was restrict to the Mediterranean and Black Sea areas, Africa, Asia and Australia (Wu *et al.* 2022), and many specimens previously described as *F. rimosus* occurring in tropical to temperate areas do not correspond to lectotype (Hattori *et al.* 2014), thus records for Brazil need to be reassessed.

Even species from South America require a more detailed analysis before having their occurrence confirmed for the Amazon. For example, *Fomitiporia apiahyna* (Speg.) Robledo, Decock & Rajchenb. is restricted to *Araucaria* forests in the south and southeastern regions of Brazil (Alves-Silva *et al.* 2020). *Fomitiporia baccharidis* (Pat.) Decock, Robledo & Amalfi is otherwise restricted to high-altitude Andean montane forests in Ecuador and northwestern Argentina (Amalfi *et al.* 2014). *Fuscoporia neocallimorpha* (Gibertoni & Ryvarden) Y.C. Dai & F. Wu was previously recorded in Amazon (as *Phellinus neocallimorphus* Gibertoni & Ryvarden) by Freire and Soares (2024). However, Soares *et al.* (2018) after analyzing the type material of *F. neocallimorpha* (URM 77584) concluded that it was a specimen of *Abundisporus subflexibilis* (Berk. & M.A. Curtis) Parmasto, and synonymized this species. Therefore, the record of *F. neocallimorpha* for the Amazon needs to be reassessed.

The order Hymenochaetales has many species with low variability in morphological characters which form species complexes, making species identification difficult (Alves-Silva *et al.* 2020). As a result, the delimitation and confirmation of the occurrence of many species in the Brazilian Amazon requires a detailed analysis that includes ecological and molecular data. To date, only five studies are known to have used a molecular and phylogenetic approach with specimens of Hymenochaetaceae collected in the Brazilian Amazon (Alves-Silva *et al.* 2020; Yuan *et al.* 2020; Lima *et al.* 2022; Oliveira *et al.* 2022; Wu *et al.* 2022). Greater knowledge about Amazonia fungi is essential to better assess their diversity, ecosystem roles and also to determine conservation strategies (Assis *et al.* 2022). Thus, it is necessary to expand collection efforts, especially in regions that are still little explored in the Amazon, as in the states of Maranhão, Tocantins, and parts of southern Pará and western Amazonas.

CONCLUSIONS

Our findings expand the understanding of the diversity and distribution of Hymenochaetaceae species in the Brazilian Amazon. The 46 valid species still represent an underestimated number of records, particularly in underexplored areas where more intensive surveys are necessary. Future studies integrating morphological, molecular, and ecological approaches will be essential to confirm records of doubtful species, especially parasitic species with specific hosts. This survey establishes a baseline for future research and highlights the importance of deepening knowledge about fungal diversity. Such efforts are crucial to support conservation strategies in response to ongoing global changes, such as habitat loss and deforestation, in the world’s largest tropical forest.

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DATA AVAILABILITY

The data that support the findings of this study are available, upon reasonable request, from the corresponding author (Richard Bruno Mendes Freire).

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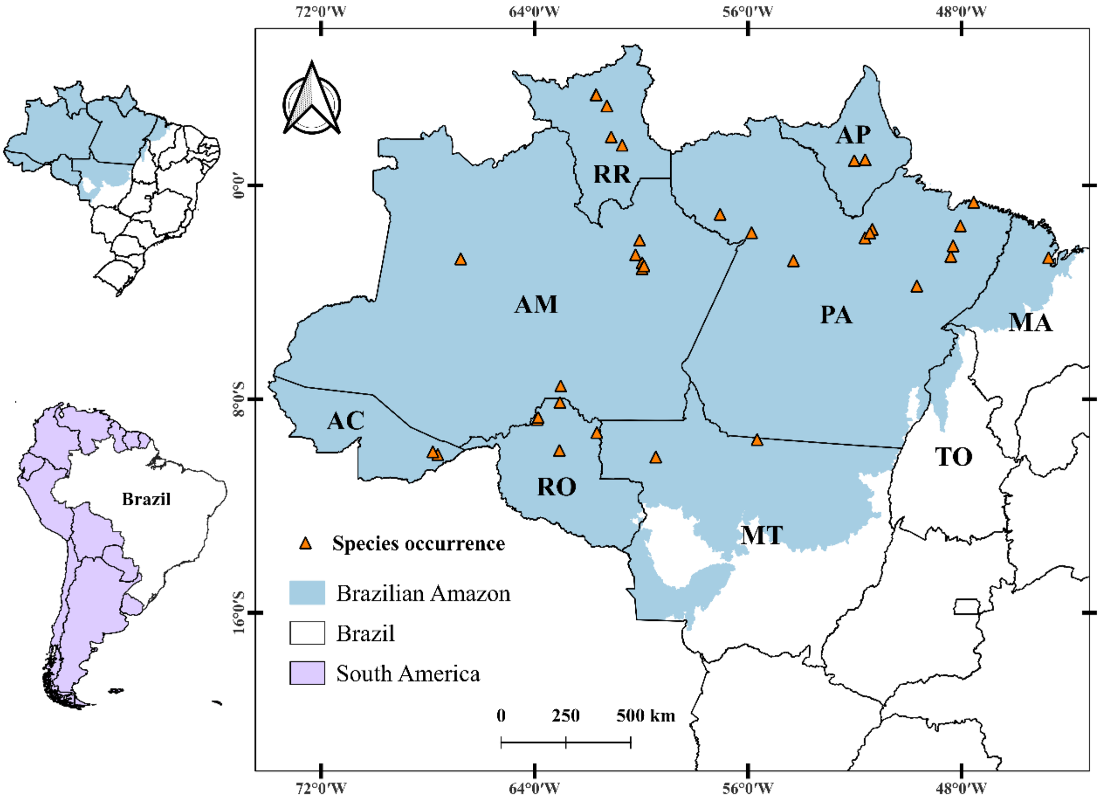

Figure 1. Occurrence records of Hymenochaetaceae in the Brazilian Amazon. Brazilian states: AC = Acre; AP = Amapá; AM = Amazonas; MA = Maranhão; MT = Mato Grosso; PA = Pará; RO = Rondônia; RR = Roraima; TO = Tocantins.

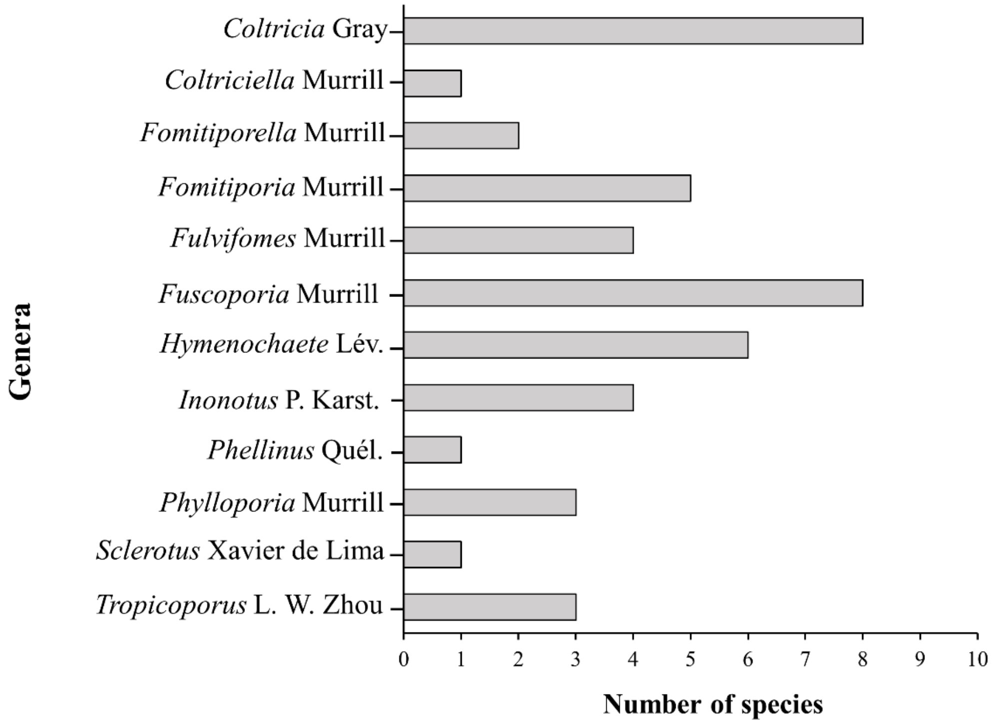

Figure 2. Number of species per Hymenochaetaceae genera with valid records in the Brazilian Amazon.

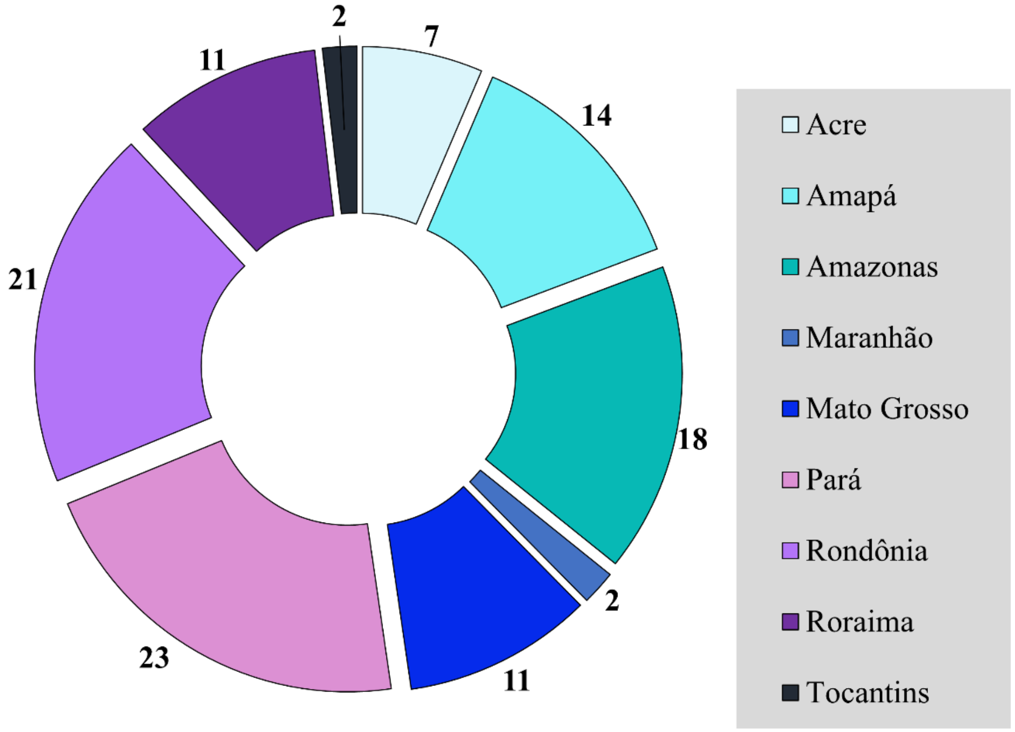

Figure 3. Number of valid records of Hymenochaetaceae species per state of the Brazilian Amazon.

Supplementary material

Table S1. Occurrence sites of Hymenochaetaceae fungi in the area of the Brazilian Amazon biome in eight federal states as registered in the surveyed literature.

State	Coordinates	Source
Acre	10°04′21.14″S, 67°37′39.64″W	Bononi (1992)
Acre	9°58′16″S, 67°48′40″W	Soares *et al.* (2018)
Acre	Undetermined location	Gomes-Silva *et al.* (2013)
Amapá	00°57’49.8”N, 51°36’31.3”W	Soares *et al.* (2014)
Amapá	00°57’49.8”N, 51°36’31.3”W	Soares *et al.* (2018)
Amapá	00°57’49.8”N, 51°36’31.3”W	Lima *et al.* (2022)
Amapá	00°53’44”N, 52°00’08”W	Xavier *et al.* (2018)
Amazonas	2°53’37.0″S, 59°58’22.95″W	Sousa (1980)
Amazonas	03°00′27.0″S, 059°53′59″W	Sousa (1980)
Amazonas	Undetermined location	Gomes-Silva *et al.* (2012b)
Amazonas	3°4′25″S, 60°0′20″W	Gomes-Silva *et al.* (2012b)
Amazonas	3°4′25″S, 60°0′20″W	Gomes-Silva *et al.* (2013)
Amazonas	7°30′22″S, 63°1′15″W	Gomes-Silva *et al.* (2013)
Amazonas	2°44′49″S, 66°46′1″W	Gomes-Silva *et al.* (2013)
Amazonas	02°35′29.0″S, 060°12′54.4″W	Silva *et al.* (2021)
Amazonas	03°00′27.0″S, 059°53′59″W	Silva *et al.* (2021)
Amazonas	2°02’52.7”S, 60°03’45.2”W	Oliveira *et al.* (2022)
Maranhão	2°42′21″S, 44°44′16″W	Yuan *et al.* (2020)
Mato Grosso	10°10′1″S, 59°27′32″W	Fidalgo (1968)
Mato Grosso	10°10′1″S, 59°27′32″W	Gomes-Silva *et al.* (2012b)
Mato Grosso	10°10′1″S, 59°27′32″W	Gomes-Silva *et al.* (2013)
Mato Grosso	9°30′49.04″S, 55°39′25.75″W	Alves-Silva *et al.* (2020)
Pará	00°38′29″S, 47°34′57″W	Sotão *et al.* (2003)
Pará	1°38’48″S, 51°20’36″W	Gomes-Silva *et al.* (2009)
Pará	1°38’48″S, 51°20’36″W	Sotão *et al.* (2009)

Table S1 (continued)

Pará	1°57′36″S, 51°36′55″W	Sotão *et al.* (2009)
Pará	1°38’48″S, 51°20’36″W	Martins-Júnior *et al.* (2011)
Pará	1°38’48″S, 51°20’36″W	Gomes-Silva *et al.* (2012a)
Pará	1°04′43.97″S, 57°02′44.49″W	Gibertoni *et al.* (2013)
Pará	1°45′57″S, 55°51′57″W	Gibertoni *et al.* (2013)
Pará	3°46′4″S, 49°40′22″W	Gibertoni *et al.* (2013)
Pará	1°57′36″S, 51°36′55″W	Medeiros *et al.* (2013)
Pará	1°38’48″S, 51°20’36″W	Yuan *et al.* (2020)
Pará	2°49'11.49"S, 54°17'56.64"W	Couceiro *et al.* (2022)
Pará	1°42′24.09″S, 51°27′34.3″W	Oliveira *et al.* (2022)
Pará	2°15’41.50”S, 48°18’53.27”W	Freire and Soares (2024)
Pará	2°39’16.00”S, 48°23’59.00”W	Freire and Soares (2024)
Pará	1°30’51.204”S, 48°2’29.160”W	Freire and Soares (2024)
Rondônia	9°15′S, 61°40′W	Capelari and Maziero (1988)
Rondônia	8°41'10.7"S, 63°52'05.5"W	Gomes-Silva *et al.* (2008)
Rondônia	8°41'10.7"S, 63°52'05.5"W	Gomes-Silva *et al.* (2009)
Rondônia	8°7′31″S, 63°3′3″W	Gomes-Silva *et al.* (2009)
Rondônia	8°41'10.7"S, 63°52'05.5"W	Gomes-Silva *et al.* (2012a)
Rondônia	8°7′31″S, 63°3′3″W	Gomes-Silva *et al.* (2012a)
Rondônia	8°45′43″S, 63°54′14″W	Gomes-Silva *et al.* (2013)
Rondônia	8°41'10.7"S, 63°52'05.5"W	Gomes-Silva *et al.* (2013)
Rondônia	8°7′31″S, 63°3′3″W	Gomes-Silva *et al.* (2013)
Rondônia	10°26′20″S, 62°27′59″W	Gomes-Silva *et al.* (2013)
Rondônia	8°7′31″S, 63°3′3″W	Yuan *et al.* (2020)
Rondônia	8°41’06.62”S, 63°52’01.16”W	Oliveira *et al.* (2022)
Roraima	2°58′48″N, 61°17′31″W	Gomes-Silva *et al.* (2013)
Roraima	1°48′57″N, 61°7′40″W	Gomes-Silva *et al.* (2013)
Roraima	3°24′0″N, 61°42′0″W	Gomes-Silva *et al.* (2013)
Roraima	Undetermined location	Gomes-Silva *et al.* (2013)

Table S1 (continued)

Roraima	01°30′36″N, 060°42′59″W	Silva *et al.* (2021)
Roraima	03°23′12.6″N, 061°41′24.3″W	Silva *et al.* (2021)

Appendix S1. List of 34 Hymenochaetaceae species recorded for the Brazilian Amazon in the surveyed literature, but not considered valid due to dubious or unconfirmed occurrences (see exclusion criteria in Material and Methods) and excluded from the updated list presented in here.

Species	**Type locality**
Coltricia cinnamomea (Jacq.) Murrill	Austria
Coltricia montagnei (Fr.) Murrill	France
Fomitiporella cavicola (Kotl. & Pouzar) T. Wagner & M. Fisch	Czechoslovakia
Fomitiporia apiahyna (Speg.) Robledo, Decock & Rajchenb.	São Paulo (Brazil)
Fomitiporia baccharidis (Pat.) Decock, Robledo &Amalfi	Ecuador
Fomitiporia calkinsii (Murrill) Vlasák & Kout	USA
Fomitiporia punctata (P. Karst.) Murrill	Norway
Fomitiporia robusta (P. Karst.) Fiasson & Niemelä	Finland
Fulvifomes fastuosus (Lév.) Bondartseva & S. Herrera	Singapore
Fulvifomes imbricatus L.W. Zhou	Thailand
Fulvifomes grenadensis (Murrill) Murrill	Grenada
Fulvifomes mangrovicus (Imazeki) T. Hatt.	Japan
Fulvifomes merrillii (Murrill) Baltazar & Gibertoni	The Philippines
Fulvifomes rimosus (Berk.) Fiasson & Niemelä	Australia
Fulvifomes robiniae (Murrill) Murrill	USA
Fuscoporia callimorpha (Lév.) Groposo, Log.-Leite & Góes-Neto	Madagascar
Fuscoporia contigua (Pers.) G. Cunn.	probably in France

Appendix S1 (continued)	
Fuscoporia gilva (Schwein.) T. Wagner & M. Fisch.	USA
Fuscoporia neocallimorpha (Gibertoni & Ryvarden) Y.C. Dai & F. Wu	Alagoas (Brazil)
Fuscoporia punctatiformis (Murrill) Zmitr., Malysheva & Spirin.	USA
Fuscoporia wahlbergii (Fr.) T. Wagner & M. Fisch	South Africa
Hydnoporia tabacina (Sowerby) Spirin, Miettinen & K.H. Larss.	Great Britain
Hymenochaete cacao (Berk.) Berk. & M.A. Curtis	India
Hymenochaete cinnamomea (Pers.) Bres.	Not located
Hymenochaete microcycla (Zipp. ex Lév.) Spirin & Miettinen	Java (Indonesia)
Hymenochaete pinnatifida Burt	USA
Hymenochaete rheicolor (Mont.) Lév.	India
Hymenochaete rubiginosa (Dicks.) Lév.	Great Britain
Phellinus nilgheriensis (Mont.) G. Cunn.	India
Phylloporia pectinata (Klotzsch) Ryvarden	India
Pyrrhoderma lamaoense (Murrill) L.W. Zhou & Y.C. Dai	The Philippines
Pyrrhoderma noxium (Corner) L.W. Zhou & Y.C. Dai	Malaysia
Tropicoporus melleoporus (Murrill) Salvador-Montoya & Drechsler-Santos	USA
Tropicoporus shaferi (Murrill) Y.C. Dai & F. Wu	Montserrat

CAPÍTULO II

Título: *Fulvifomes paraensis* sp. nov. (Hymenochaetaceae, Basidiomycota), a new species from Floodplain Forests in the Brazilian Amazonian

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Fulvifomes paraensis sp. nov. (Hymenochaetaceae, Basidiomycota), a new species from the floodplain forests of the Brazilian Amazon

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ABSTRACT

Fulvifomes is a monophyletic genus of Hymenochaetaceae (Basidiomycota), with a cosmopolitan distribution and ecological importance. Specimens of *Fulvifomes* were collected from floodplain forest islands in the Brazilian Amazon. Morphological and molecular phylogenetic analyses revealed a new species, *Fulvifomes* paraensis sp. nov., mainly characterized by its pileate basidioma, broadly attached to a dimidiate, hyphal system monomitic in context to subdimitic in trama, and basidiospores broadly ellipsoid to subglobose. This species was found on dead trunks of *Mora paraensis*, a tree species that is endemic to floodplain areas of the eastern Amazon. Additionally, *Fulvifomes kawakamii* is reported for the first time in floodplain forests. Notes and illustrations for these two species, and an identification key for the species of *Fulvifomes* with molecular data from Brazil are provided.

Keywords: Amazonian wetlands, Hymenochaetales, Neotropics, phylogenetic analysis, taxonomy.

1. Introduction

The genus *Fulvifomes* was proposed by Murrill (1914) and initially typified by *Pyropolyporus robiniae* Murrill [now *F. robiniae* (Murrill) Murrill]. It includes species with perennial, sessile basidiomata, a rough to rimose pileal surface, a woody context and the absence of setae (Murrill, 1914). *Fulvifomes* was treated as a synonym of *Phellinus* Quél for several decades (Gilbertson & Ryvarden, 1986, 1987; Larsen & Cobb-Poulle, 1990; Núñez & Ryvarden, 2000; Ryvarden & Johansen, 1980). Only in the early 2000s was *Fulvifomes* confirmed as a monophyletic genus within the family Hymenochaetaceae Donk by Wagner and Fischer (2002), based on phylogenetic analysis of large subunit rRNA (nLSU) gene sequences from *Phellinus sensu lato* and *Inonotus* s.l.

Subsequently, Larsson et al. (2006) confirmed the data of Wagner and Fischer (2002) that supported the segregation of *Fulvifomes*. Dai (2010), based on morphological analyses, included species with hymenial setae in *Fulvifomes.* Nevertheless, Zhou (2014a, b), based on phylogenetic evidence from analyses of nLSU and internal transcribed spacer (ITS) sequences, did not accept species with hymenial setae into *Fulvifomes*, and recircumscribed the genus via the combination of annual to perennial, and sessile, effused reflexed to pileate basidiomata with solitary to imbricate pilei, and a duplex or homogeneous context, hyphal system monomitic to dimitic, absence of both hyphal and hymenial setae, and subglobose to ellipsoid, slightly thick-walled to thick-walled basidiospores. In recent years, new species have been described for the genus according to molecular analyses (Hattori et al., 2022; Ji et al., 2017; Martinez et al., 2023; Oliveira et al., 2022; Salvador-Montoya et al., 2018; Wu et al., 2022; Zhou, 2015; Zhou et al., 2023).

Approximately 20 species of *Fulvifomes* are recorded in Brazil (Flora e Funga do Brasil, 2024; GBIF, 2024), but only eight species are confirmed based on molecular phylogenetic analysis (Jayawardena et al., 2019; Ji et al., 2017; Oliveira et al., 2022; Salvador-Montoya et al., 2018; Wu et al., 2022), of which three are found in the Brazilian Amazon (Oliveira et al., 2022).

In the Amazon, wetland areas namely igapós and várzeas represent approximately 11% of the Amazon basin (Wittmann et al., 2022). A significant portion of these wetlands consists of seasonally flooded forests, the second-largest vegetation formation in the Amazon. These forests play a vital role in maintaining Amazonian biodiversity through carbon storage, regulation of biogeochemical cycles, sediment retention and the provision of timber and non-timber products. They also hold cultural importance, serving as habitats for traditional communities (Junk et al., 2011; Malhi et al., 2006; Maués et al., 2011; Millennium Ecosystem Assessment, 2005; Schöngart et al., 2010; Wittmann et al., 2006, 2013). Additionally, floodplain forests influence tree species diversity and invertebrate populations in several ways, allowing species to survive in changing climatic conditions (Sedell et al., 1990). Despite their ecological importance, information on fungal species in floodplain forests remains scarce, with very few studies currently available (Singer, 1988; Castro et al., 2012).

The present study aimed to analyze specimens of *Fulvifomes* collected in floodplain forest islands in the Brazilian Amazon. A new species of *Fulvifomes* is described based on morphological and molecular phylogenetic analyses.

2. Material and methods

2.1 Study area

The specimens of this study were collected in three islands of floodplain forests in the municipality of Mocajuba: Conceição Island (2°32′31.32″ S, 49°31′29.05″ W), Santaninha Island (2°31′13″ S, 49°31′52″ W), and Tauaré Island (2°35′56.3″ S, 49°30′46.7″ W).

The collections were carried out from November 2022 to November 2023. Collection, preservation, and herbarium procedures followed the methodology of Fidalgo and Bononi (1989) and Neves et al. (2013). The specimens were dehydrated at 40 °C in a food dehydrator.

The distribution map of the collected specimens was created according to the geographical coordinates of the islands of Mocajuba and shapefiles available from the Instituto Brasileiro de Geografia e Estatística (https://www.ibge.gov.br/). The map was created using the software QGIS v. 3.28, Datum SIRGAS 2000.

2.2 Morphological studies

Macromorphological analyses were used to acknowledge the characteristics of the pileal surface, context, tubes, margin and dimensions. Special color terms followed Kornerup and Wanscher (1978). Micromorphological analyses were performed with 3% potassium hydroxide (KOH) plus 1% phloxine solution, and an optical microscope was used to help in the identification of the microstructures, which were also analyzed in terms of shape, dimensions and color (Ryvarden, 2004; Teixeira, 1995). In addition, slides with samples were mounted in Melzer's reagent and cotton blue. The following abbreviations were used: IKI = Melzer's reagent, IKI– = neither amyloid nor dextrinoid, CB = cotton blue, CB– = acyanophilous, L = mean spore length, W = mean spore width, Q = variation in the ratios of L/W among specimens of this study, n = number of spores measured from given number of specimens. Microscopic images were obtained using a microscope (Leica DM6 B, Leica Microsystems CMS GmbH Ernst-Leitz-Str. 17-37 35578 Wetzlar, Germany). Additionally, slides were prepared and observed under a scanning electron microscope (MIRA 3, Tescan) equipped with a high brightness Schottky field emission gun (FEG) at the Laboratório Institucional de Microscopia Eletrônica de Varredura of Museu Paraense Emílio Goeldi (MPEG). After identification, all the specimens were deposited in the João Murça Pires Herbarium (MG) at MPEG.

2.3 DNA extraction, PCR amplification and sequencing

Fragments of dehydrated basidiomata were taken (30–50 mg), placed inside a 1.5 mL microtube with silica gel, and then stored in a freezer at -20 °C until the DNA extraction process in the laboratory. For the DNA extraction, the fragments were manually macerated using liquid nitrogen. The extraction was performed using the DNeasy® Plant Pro Kit, according to the manufacturer's instructions.

Polymerase chain reaction (PCR) was performed to amplify the following regions of interest: ITS and LSU. For ITS, the primers ITS4 (TCCTCCGCTTATTGATATGC) and ITS5 (GGAAGTAAAAGTCGTAACAAGG) were used, while the primers LR0R (ACCCGCTGAACTTAAGC) and LR07 (TACTACCACCAAGATCT) were utilized for LSU (Moncalvo et al., 2000; White et al., 1990). The thermal cycle parameters for both regions were as follows: initial denaturation at 94 °C for 3 min, followed by 35 cycles of denaturation at 95 °C for 30 s, primer annealing at 50 °C for 30 s, and extension at 72 °C for 1 min, and a final extension at 72 °C for 10 min (Lima-Júnior et al., 2014). PCR was performed with a final volume of 12.5 µL containing 1 µL of DNA, 4.25 µL of nuclease-free water, 0.5 µL of each primer and 6.25 µL of PCR Master Mix (Promega corporation, USA). Two microliters of the final PCR product were stained with two microliters of GelRed™ (0.5 µg/mL) (Biotium, USA), assessed via electrophoresis on a 1% agarose gel, and purified using ExoSAP-IT™ PCR Product Cleanup Reagent (Thermo Fisher Scientific, USA). Sanger sequencing was performed with the BigDye Terminator v.3.1 Cycle Sequencing Kit (Applied Biosystems, USA) following the manufacturer's instructions and using the primer pair ITS4/ITS5 for ITS and primer pair LR0R/LR7 for the LSU region. The sequencing was performed in an automated DNA sequencer (SeqStudio Genetic Analyzer, Applied Biosystems, USA) at Laboratório de Biologia Molecular (LBM) of the MPEG (Brazil). All the generated sequences were submitted to the GenBank database (http://www.ncbi.nlm.nih.gov/genbank).

2.4 Phylogenetic analyses

The electropherograms of the ITS and LSU sequences were analyzed and then manually edited using BioEdit v. 7.7 (Hall, 1999). Two datasets were constructed from the sequences generated in this study and combined with the LSU and ITS sequences available in GenBank (Table 1): LSU (73 specimens), and ITS (73 specimens). Both datasets were aligned using the MAFFT v. 7 online program (Katoh & Standley, 2013) using the "Auto" strategy. When necessary, alignments were manually edited in the MEGA 11 program (Tamura et al., 2021). Segments that were potentially ambiguously aligned were detected with the software Gblocks v. online (Lemoine et al., 2019) for the ITS and LSU regions. The program Mesquite v. 3.81 was used to concatenate the sequences of both datasets. As outgroups for phylogenetic inferences (combined ITS-LSU dataset), *Phellinotus neoaridus* Drechsler-Santos & Robledo, and *Phellinotus piptadeniae* (Teixeira) Drechsler-Santos & Robledo were used (Salvador-Montoya et al., 2018).

ModelFinder (Kalyaanamoorthy et al., 2017) was implemented in the IQ-TREE software online (Nguyen et al., 2015; Trifinopoulos et al., 2016) and was used to estimate the optimal partitioning strategy and the best-fit model of nucleotide evolution for the dataset. Phylogenetic trees were constructed using maximum likelihood (ML) and Bayesian inference (BI) methods online via the CIPRES Science Gateway (Miller et al., 2011). For the ML analyses, RAxML-HPC2 on ACCESS (Stamatakis, 2014) was used to conduct studies that began with 1,000 bootstrap (BS) replicates, each one starting from one parsimony tree with randomized stepwise addition. The GTR+G model was used for each partition. For the BI analyses, MrBayes on XSEDE (3.2.7a) was used (Ronquist et al., 2012). The BI analysis was run with four chains of Metropolis-coupled Markov chain

Monte Carlo iterations for 10,000,000 generations, with trees sampled every 1,000 generations. After the run, 25% of the trees were discarded as burn-in and the remaining trees were kept and combined into one 50% majority-rule consensus tree. Bayesian posterior probabilities (BPP) were obtained from the 50% majority consensus of the remaining trees. The sequence alignments and resulting trees were deposited in TreeBASE under the accession number 31804.

3. Results

3.1 Molecular phylogenetic analyses

In total, 12 new sequences of *Fulvifomes* were generated in this study (5 from ITS and 7 from LSU). The combined dataset of both regions included 76 sequences for 33 species (Table 1). The best partitions and evolutionary models were TNe+I+G4 (ITS) and TN+F+I+G4 (LSU). The combined ITS and LSU dataset had 1,413 characters (566 for ITS and 847 for LSU), of which 918 were constant, 155 variable and 340 parsimony informative. The ML and BI analyses produced similar topologies for the clades with solid support, and the BI tree was chosen to represent the phylogenetic placement of the specimens, with BPP and BS values indicated on the branches (Fig. 1). The new sequences of this study were positioned in two clades, specimens AS3499, VF174 and VF181 formed a lineage with statistically strong support (BPP = 1/BS = 100%) and were separated from the other sampled species. The specimens VF51, VF130, VF148 and VF208 formed a clade of *Fulvifomes kawakamii* (BPP = 1/BS = 100%). A new species was confirmed: *Fulvifomes paraensis* sp. nov.

3.2 Taxonomy

Fulvifomes paraensis R.B.M. Freire & A.M.S. Soares **sp. nov.**

Figs. 3, 5E–H.

Mycobank: MB856243

Type: BRAZIL. State of Pará, Mocajuba, floodplain forests, Conceição Island. Coordinates: 2°32′31.32″ S, 49°31′29.05″ W, on decaying tree of *Mora paraensis* (Ducke) Ducke, Nov 2023, leg. A.M.S. Soares AS3499 (Type MG249953).

DNA sequences from the type: PQ602659 (ITS), PQ602667 (LSU).

Etymology: Referring to the state of Pará (Brazil), where the new species was found.

Basidiomata perennial, pileate, imbricate, without distinctive odor or taste and woody hard when dry. Pilei broadly attached to dimidate, semicircular, projecting up to 13.9 cm long and 9.6 wide and 0.8–5.5 cm thick at base. Pileal surface yellow (3B8) to light brown (6D7) in juvenile specimens to brownish grey (4F2) to grey (6F1) in old specimens; azoned to concentrically zoned; crusted, concentrically sulcate; pileal margin brown to dark gray, wavy. Pore surface yellowish brown (5E8), pores circular, 7–9 per mm, almost invisible and obstruct in old specimens, dissepiments thin and entire. Context light yellow (4A5), fibrous-corky and woody hard in old specimens, 0.4–3 cm thick, with a black line under the tomentum. Tubes yellowish brown (5D8), woody hard, up to 6 mm thick, tube layers indistinctly stratified. In KOH, the context and tubes become dark brown.

Hyphal system monomitic in the context and dimitic to subdimitic in the trama of the tubes. Contextual generative hyphae thin- to thick-walled with simple septate, without clamps-connections, occasionally branched, (2.8–) 4–5.5 (–6) µm diam; light yellow in water, yellow to light brown in KOH. Tramal generative hyphae light yellow in KOH, thin- to thick-walled with simple septate, without clamps-connections, 3–4 µm diam; tramal skeletal hyphae dominant, brown in KOH, thick-walled 5.5–6 µm diam, with a narrow lumen, unbranched, aseptate to occasionally septate, not well-differentiated from generative hyphae, setae absent, cystidia and cystidioles absent. Basidia barrel-shaped, 9–10 × 6–8 µm, with four sterigmata up to 3 µm in length. Basidiospores broadly ellipsoid to subglobose, thick-walled, golden yellow to light brown in KOH and hyaline in water, (4.1–) 5–7 × 3–5 (–5.3) µm, IKI–, CB– (L = 4.63 µm, W = 5.77 µm) Q = 1.24 (n = 30).

Additional specimens examined (paratypes): BRAZIL. Municipality of Mocajuba, state of Pará, Conceição Island (2°32′31.32″ S, 49°31′29.05″ W), on trunk of decaying tree of *Mora paraensis*, Jun 2023, leg. V.P. Farias VF174 (MG249954) and VF181 (MG249955).

Habitat and distribution: *Fulvifomes paraensis* is found on decaying trees of *Mora paraensis* (Fabaceae). The species is only known to occur on floodplain forest islands in the Brazilian Amazon (Fig. 2).

Notes: *Fulvifomes paraensis* is characterized by basidiomata perennial; pilei broadly attached to dimidiate, pileal surface azonate to zonate; hyphal system monomitic in the context, and dimitic to subdimitic in the trama; basidiospores broadly ellipsoid to subglobose, golden yellow to light brown in KOH and hyaline in water, averaging 4.63 L × 5.77 W µm. Morphologically, *Fulvifomes paraensis* is similar to *F. grenadensis* (Murrill) Murrill, as both species share perennial basidiomata, yellowish context and broadly ellipsoid to subglobose basidiospores (Ryvarden, 2004). However, *F. paraensis* can be distinguished from *F. grenadensis* by several features: the basidiomata of *F. grenadensis* are solitary, while in *F. paraensis* they are imbricate, pores are 7–9 per mm compared to 4–7 pores per mm in *F. grenadensis*. Additionally, *F. paraensis* has monomitic context hyphae, whereas *F. grenadensis* is dimitic. Both *F. paraensis* and *F. squamosus* Salvador-Mont. & Drechsler-Santos share attached basidiomata and a yellow context. However, *F. squamosus* has a pubescent pilear surface that becomes glabrous, and mature specimens display a squamose texture. Although the shape and size of the basidiospores in both species are similar, *F. squamosus* has flattened basidiospores on the ventral side. This species is predominantly parasitic on *Acacia macracantha* Humb. & Bonpl. ex Willd. in the seasonally dry tropical forests of northern Peru (Salvador-Montoya et al., 2018). *Fulvifomes paraensis* is also similar to *F. waimiriatroariensis* V.R.T. de Oliveira & Gibertoni, as they both have perennial and attached basidiomata, as well as broadly ellipsoid to subglobose basidiospores. However, *F. waimiriatroariensis* can be distinguished by its solitary basidiomata, velutinate pileal surface and smaller basidiospores compared to *F. paraensis* (Oliveira et al., 2022). Furthermore, *F. waimiriatroariensis* is found in the upland forests of the Brazilian Amazon, where it grows on living trees (Oliveira et al., 2022).

Fulvifomes kawakamii (M.J. Larsen, Lombard & Hodges) T. Wagner & M. Fisch., Mycologia 94 (6): 1009 (2002)

Figs. 4, 5A–D, I.

Basionym: *Phellinus kawakamii* M.J. Larsen, Lombard & Hodges, Mycologia 77: 346 (1985)

Holotype: USA, Hawaii (Kauai) on decaying of *Casuarina equisetifolia* L., FP 134854, 13 Oct 1982 (CFMR).

Description: Larsen et al. (1985).

The analyzed specimens have perennial, pileate and imbricate basidiomata. Pilei broadly attached to dimidate, projecting up to 14.5 cm long, 7.8 wide and 3.1 cm thick at base. Pileal surface light brown (6D5) though olive grey (3F2) in old specimens, concentrically zoned in juvenile specimens to azoned in old specimens. Pore surface yellowish brown (5E5), pores round 6–8 (–10) per mm, dissepiments thin and entire. Context greyish yellow (4C5), woody hard, 1–7 mm thick. Tubes yellowish brown (5F8) woody hard, 0.1–1.2 cm thick.

Hyphal system dimitic. Contextual generative hyphae ferruginous brown, thin- to thick-walled with simple septate, without clamps-connections, up to 3 µm diam; contextual skeletal hyphae golden yellow, up to 5 µm diam. Tramal generative hyphae light yellow, thin- to thick-walled with simple septate, without clamps-connections, up to 4 µm diam; tramal skeletal hyphae dominant, brown to reddish brown, thick-walled, up to 4.8 µm diam. Cystidioles infrequent, 2.5–4 × 15 µm. Paraphyses and crystals were observed in the hymenia. Basidia: globose. Basidiospores ellipsoid to subglobose, thick-walled, ferruginous brown in KOH and hyaline in water, (5–) 5.5–7.5 × (4–) 5–6 µm, IKI–, CB– (L = 5.37 µm, W = 5.65 µm) Q = 1.05 (n = 20).

Specimens examined: BRAZIL. Municipality of Mocajuba, state of Pará, floodplain forests, Santaninha Island, 2°31′13″ S, 49°31′52″ W, on trunk of an undetermined decaying tree, 26 Nov 2022, leg. V.P. Farias VF51 (MG249956); the same place, on trunk of an undetermined decaying tree, 21 Jun 2023, leg. V.P. Farias VF130 (MG249957) and VF148 (MG249958); Tauaré Island, 2°35′56.3″ S, 49°30′46.7″ W, on decayed wood, 22 Jun 2023, leg. V.P. Farias VF208 (MG249959).

Habitat and distribution: Brazil and USA (Jayawardena et al., 2019; Larsen et al., 1985; Oliveira et al., 2022). This is the first report of *Fulvifomes kawakamii* in floodplain forests (Fig. 2).

Notes: *Fulvifomes kawakamii* is mainly characterized by having perennial, pileate and imbricate basidiomata, pore surface yellowish brown, hyphal system dimitic, cystidioles infrequent, basidiospores ellipsoid, thick-walled, ferruginous brown (Larsen et al., 1985). This species is similar to *F. nilgheriensis* (Mont.) Bondartseva & S. Herrera, sharing perennial and imbricate basidiomata, hyphal system dimitic and brown basidiospores. However, the basidiomata of *F. nilgheriensis* are solitary and the basidiospores are globose, while in *F. kawakamii* the basidiospores are ellipsoid. The type locality of *F. nilgheriensis* is the Nilgiri Hills (Tamil Nadu) on the Southeastern coast of the Indian Peninsula, showing a distribution of tropical Asia and DNA sequences are known for Americas (Larsen et al., 1985; Wu et al., 2022). Furthermore, *Fulvifomes kawakamii* and *F. rhytiphloeus* (Mont.) Camp.-Sant. & Robledo share pileate basidiomata and pores with similar size (up to 10 per mm); though, in *F. rhytiphloeus*, the basidiomata is applanate and the pore surface dark brown and *F. rhytiphloeus* is found in northeastern and southern Brazil (Campos-Santana et al., 2015; Ryvarden, 2004).

4 Discussion

After analyzing the specimens of *Fulvifomes* collected in the study area, *F. paraensis* is described here as a new Neotropical species, and *F. kawakamii* is reported for the first time in floodplain forests. The phylogenetic reconstruction showed that *F. paraensis* is sister to *F. kawakamii* and is closely related to *F. fastuosus* (Lév.) Bondartseva & S. Herrera, *F. merrillii* (Murrill) Baltazar & Giberton, *F. costaricensis* Y.C. Dai & Vlasák and *F. imbricatus* L.W. Zhou (Fig. 1). Both species, *F. paraensis* and *F. fastuosus*, share a perennial, pileate and broadly attached basidiomata and basidiospores with similar shape and size. However, *F. fastuosus* has solitary and flat to convex basidiomata, dimitic hyphal system and rusty brown basidiospores (Ryvarden, 2004), and the type locality of *F. fastuosus* is Singapore. Additionally, *F. merrillii* shares a perennial basidiomata and circular pores with *F. paraensis*, but *F. merrillii* can be differentiated by its subungulate basidiomata, pores up to 5 per mm, dimitic hyphal system in the trama and subdimitic in the context, and ellipsoid basidiospores (Hattori et al., 2014). The distribution of *F. fastuosus* and *F. merrillii* were previously reported as being the Neotropics (Ryvarden, 2004), but they most likely have a distribution limited to tropical Asia (Wu et al., 2022). *Fuscoporia costaricensis* is distinguished from *F. paraensis* by its smaller pores (9–11 per mm), dimitic hyphal system and occurrence on living angiosperm trees. *F. imbricatus* differs from *F. paraensis* by its collapsed and smaller basidiospores [(4.4–)4.6–5.1(–5.3) × (3.5–)3.7–4.3(–4.5) µm], CB+ reaction and occurrence on living trees of *Shorea* Roxb., with a known distribution in Thailand (Zhou et al., 2015; Wu et al., 2022).

Five species of *Fulvifomes* have their type locality as Brazil [*F. karitianaensis* V.R. Targino de Oliveira, V. Xavier de Lima & Gibertoni, *F. fabaceicola* V.R. Targino de Oliveira, J.R.C. Oliveira-Filho & Gibertoni, *F. luteoumbrinus* (Romell) Y.C. Dai & Vlasák, *F. rhytiphloeus, F. waimiriatroariensis* (Montagne, 1856; Oliveira et al., 2022; Romell, 1901; Wu et al., 2022)], with two of them (*F. karitianaensis* and *F. waimiriatroariensis*) being from the Brazilian Amazon. Phylogenetically, *F. paraensis* formed a clade that was distinct from all these species (Fig. 1). The type of *F. luteoumbrinus* described by Rommell (1901) (as *Phaeoporus luteoumbrinus* Romell) has no available DNA sequences; the sequence used in this study is from a specimen from the USA (CBS 296.56). Based on the known description of this species, *Fulvifomes luteoumbrinus* is easily distinguishable from *F. paraensis* by its annual basidiomata, conchate to applanate pilei, monomitic hyphal system and globose basidiospores, 4–5 × 3.5–4.5 µm (Ryvarden, 2004; Wu et al., 2022).

Fulvifomes paraensis is found on decaying trees of *Mora paraensis*. This tree species, belonging to the Fabaceae family, has timber value and is an important endemic species of the floodplain areas in the eastern Amazon (Wittmann et al., 2013). *Mora paraensis* is recorded in the states of Amazonas, Amapá, Pará and Roraima, occurring in igapó, várzea, and ombrophilous (pluvial) forests, with a wide distribution in the Amazon basin and high density in floodplain forests (Almeida et al., 2004; Carim et al., 2017;

Cattanio et al., 2002; Jordão & Sampaio, 2020; Santos et al., 2004, 2012). The endemism of the substrate of *Fulvifomes paraensis* may indicate the geographic restriction of this new species, as specimens were found growing only on trunks of *M. paraensis*. Several *Fulvifomes* species may have highly specific host preferences, at least at the local population level, and host range could be an important characteristic of the genus (Hattori et al., 2022). Examples include *Fulvifomes acaciae* Meng Zhou, Yuan Yuan & Vlasák, a species only found growing on living trees and fallen trunks of *Acacia* Mill., *F. fabaceicola*, a species found exclusively on living trees of Fabaceae, and *Fulvifomes boninensis* T. Hatt., Y. Ota & Sotome is known only on *Morus boninensis* Koidz. (Hattori et al., 2022; Oliveira et al., 2022; Zhou et al., 2023).

Fulvifomes kawakamii was originally collected in Hawaii on decaying wood of *Casuarina equisetifolia* and, for many years, it was considered to be restricted to the Nearctic region (Larsen et al., 1985). However, based on phylogenetic evidence, specimens of *F. kawakamii* have been found on different hosts in the Neotropics, demonstrating a wide distribution of the species in the Americas (Jayawardena et al., 2019; Oliveira et al., 2022). Sequences generated from the specimens in this study (VF51, VF130, VF148 and VF208) were positioned in the *F. kawakamii* clade (Fig. 1). A possible polytomy within the clade was observed; however, the BPP and BS analysis provided strong support (1/100). This highlights the need for the use of additional genes for more accurate phylogenetic inferences and precise species delimitation.

The knowledge of macrofungi in floodplain forests is virtually nonexistent. Thus, taxonomic studies are needed in order to discover the diversity of fungi and possible new taxa in this environment. This highlights the importance of preserving floodplain forests, given their critical role in maintaining ecological balance. Their small-scale habitat heterogeneity has significant implications for the origin and maintenance of biodiversity, particularly in the Amazon (Wittmann et al., 2013).

4.1 Key to species of Fulvifomes *with molecular data analysis for Brazil*

1a. Hyphae monomitic in context.. 2
1b. Hyphae subdimitic to dimitic in context... 5
2a. Pilear surface cracked becoming squamous with age............................. ***F. squamosus***
2b. Pilear surface uncracked without squama.. 3
3a. Basidiomata annual to perennial, pileal surface velutinous, on living tree.. ***F. waimiriatroariensis***
3b. Basidiomata perennial, pilear surface glabrous, on dead wood................................. 4
4a. Basidiospores ellipsoid, 4–5 × 3.1–4 µm... ***F. karitianaensis***
4b. Basidiospores broadly ellipsoid to subglobose, 5–7 × 3–5........................ ***F. paraensis***
5a. Pores up to 4 per mm, basidiospores ellipsoid with a flattened side........ ***F. fabaceicola***
5b. Pores 5–9 per mm, basidiospores without a flattened side 6
6a. Cystidioles infrequent, chlamydospores present.................................... ***F. kawakamii***
6b. Cystidioles and chlamydospores absent.. 7
7a. Basidiospore globose, dark line between context and pileal surface... ***F. rhytiphloeus***
7b. Basidiospore subglobose, without dark line between context and pileal surface …….8

8a. Pileal surface encrusted, pore surface pale yellow, shining......... ***F. centroamericanus***
8b. Pileal surface, not encrusted, pore surface dark yellow brown to umber.. ***F. nilgheriensis***

Disclosure

The authors declare that there are no conflicts of interest. All the experiments undertaken in this study comply with the current laws of Brazil where they were performed.

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Table 1. Taxa, vouchers, country and GenBank accession numbers of ITS and LSU sequences. Sequences of species studied in this work are in bold. (^{T} = Type materials).

Species	**Voucher**	**Country**	**GenBank accession number**		**References**
			ITS	**LSU**	
Fulvifomes acaciae	JV 0312/23.4-J	Costa Rica	OP828594	OP828596	Zhou et al. (2023)
F. acaciae^{T}	JV 2203/71	USA	OP828595	OP828597	Zhou et al. (2023)
F. boninensis^{T}	FFPRI421009	Japan	LC315786	LC315777	Hattori et al. (2022)
F. boninensis	FFPRI421008	Japan	LC315785	LC315776	Hattori et al. (2022)
F. centroamericanus^{T}	JV0611/III	Guatemala	KX960763	KX960764	Ji et al. (2017)
F. centroamericanus	JV1408/4	Costa Rica	–	KX960768	Ji et al. (2017)
F. costaricensis^{T}	JV1607/103	Costa Rica	MH390414	MH390386	Wu et al. (2022)
F. costaricensis	JV 1407/87	Costa Rica	MH390412	MH390387	Wu et al. (2022)
F. costaricensis	JV 1408/14	Costa Rica	MH390413	MH390385	Wu et al. (2022)
F. dracaenicola^{T}	Dai 22097	China	MW559800	MW559805	Du et al. (2021)
F. dracaenicola	Dai 22093	China	MW559799	MW559804	Du et al. (2021)
F. elaeodendri^{T}	CMW47909	South Africa	MH599096	MH599132	Tchoumi et al. (2020)
F. elaeodendri	CMW48610	South Africa	MH599095	MH599133	Tchoumi et al. (2020)
F. fabaceicola^{T}	VRTO440	Brazil	MT908356	MT906623	Oliveira et al. (2022)
F. fabaceicola	VRTO977	Brazil	OK093361	OK093374	Oliveira et al. (2022)
F. fabaceicola	VRTO(REI)	Brazil	MT908368	MT906636	Jayawardena et al. (2019)
F. fabaceicola	JRF74	Brazil	MH048097	MH048087	GenBank
F. fabaceicola	JV1212/2J	USA	KX960756	–	Ji et al. (2017)
F. fabaceicola	1607/66	Costa Rica	KX960758	–	Ji et al. (2017)
F. fastuosus	CBS 213.36	Philippines	AY558615	AY059057	Zhou (2015)
F. fastuosus	LWZ 20140801-1	Thailand	KR905675	KR905669	Zhou (2014a)
F. floridanus^{T}	JV 0904/76	USA	MH390424	MH390388	Wu et al. (2022)
F. hainanensis^{T}	Dai 11573	China	KC879263	JX866779	Zhou (2014a)

Table 1 (continued)

F. halophilus^{T}	BBH30357	Thailand	JX104687	JX104734	Hattori et al. (2014)
F. halophilus	MU23	Thailand	JX104693	JX104740	GenBank
F. imazekii^{T}	FFPRI421007	Japan	LC315788	LC315779	Hattori et al. (2022)
F. imazekii	FFPRI421006	Japan	LC315787	LC315778	Hattori et al. (2022)
F. imbricatus^{T}	LWZ 20140728-16	Thailand	KR905677	KR905670	Zhou (2015)
F. imbricatus	LWZ 20140729-26	Thailand	KR905679	KR905671	Zhou (2015)
F. indicus	Yuan 5932	China	KC879261	JX866777	Zhou (2014a)
F. indicus	O 25034	Zimbabwe	KC879262	KC879259	Zhou (2014a)
F. jouzaii	JV 1504/16	Costa Rica	MH390425	MH390400	Wu et al. (2022)
F. jouzaii^{T}	JV 1504/39	Costa Rica	MH390426	–	Wu et al. (2022)
F. karitianaensis^{T}	AMO763	Brazil	MH048091	MH048081	Oliveira et al. (2022)
F. kawakamii	PPT152	Brazil	MH048095	MH048085	Jayawardena et al. (2019)
F. kawakamii	AS2486	Brazil	MH048094	MH048084	Jayawardena et al. (2019)
F. kawakamii	VRTO(R674)	Brazil	MT908358	MT906625	Oliveira et al. (2022)
F. kawakamii	CBS 209.36	USA	AY558633	AY059023	GenBank
F. kawakamii	**VF51**	**Brazil**	**–**	**PQ602663**	**This study**
F. kawakamii	**VF130**	**Brazil**	**PQ602660**	**PQ602664**	**This study**
F. kawakamii	**VF148**	**Brazil**	**PQ602661**	**PQ602665**	**This study**
F. kawakamii	**VF208**	**Brazil**	**PQ602662**	**PQ602666**	**This study**
F. krugiodendri^{T}	JV0904/1	USA	KX960762	KX960765	Ji et al. (2017)
F. krugiodendri	JV0312/24.10J	USA	KX960760	KX960766	Ji et al. (2017)
F. labyrinthus^{T}	SFC20160126-30	FS Micronesia	OR168711	OR168721	Suh et al. (2024)
F. labyrinthus	SFC20160126-34	FS Micronesia	OR168712	OR168722	Suh et al. (2024)
F. luteoumbrinus	CBS 296.56	USA	AY558603	AY059051	Wagner and Fischer (2002)
F. merrillii	–	Taiwan	JX484013	JX484002	GenBank
F. nakasoneae^{T}	JV 1109/77	USA	MH390409	MH390374	Wu et al. (2022)
F. nakasoneae	JV 1109/62	USA	MH390407	MH390376	Wu et al. (2022)

Table 1 (continued)

F. nakasoneae	JV 0904/68	USA	MH390408	MH390373	Wu et al. (2022)
***F. paraensis* sp. nov.** ^{T}	**AS3499**	**Brazil**	**PQ602659**	**PQ602667**	**This study**
***F. paraensis* sp. nov.**	**VF181**	**Brazil**	**–**	**PQ602669**	**This study**
***F. paraensis* sp. nov.**	**VF174**	**Brazil**	**PQ602658**	**PQ602668**	**This study**
F. rhizophorus^{T}	SFC20170118-26	FS Micronesia	OR168715	OR168723	Suh et al. (2024)
F. rhizophorus	SFC20170120-06	FS Micronesia	OR168713	OR168724	Suh et al. (2024)
F. rhytiphloeus	VRTO(V384)	Brazil	MT908364	MT906632	Oliveira et al. (2022)
F. rhytiphloeus	VRTOB04	Brazil	MT908362	MT906630	Oliveira et al. (2022)
F. rimosus	M 2392655	Australia	MH628255	MH628017	Wu et al. (2022)
F. robiniae	CBS 211.36	USA	AY558646	AF411825	GenBank
F. robiniae	CFMR 2693	USA	KX065961	KX065995	GenBank
F. siamensis^{T}	BBH32078	Thailand	JX104706	JX104753	Hattori et al. (2014)
F. siamensis	STRXG2	Thailand	JX104708	JX104755	GenBank
F. siamensis	XG2	Thailand	JX104709	JX104756	GenBank
Fulvifomes sp.	–	Taiwan	JX484016	JX484003	GenBank
F. squamosus^{T}	USM 258361	Peru	MF479267	MF479266	Salvador-Montoya et al. (2018)
F. squamosus	USM 258349	Peru	MF479269	MF479264	Salvador-Montoya et al. (2018)
F. squamosus	USM 250536	Peru	MF479268	MF479265	Salvador-Montoya et al. (2018)
F. thailandicus^{T}	LWZ 20140731-1	Thailand	KR905672	KR905665	Zhou (2015)
F. waimiriatroariensis^{T}	VRTO_AMZ01	Brazil	OK086370	OK086356	Oliveira et al. (2022)
F. wrightii^{T}	HCFC 3237	Paraguay	OQ807188	OQ924554	Martínez et al.(2023)
F. wrightii	CTES 568247	Argentina	OQ807190	OQ924562	Martínez et al.(2023)
F. xylocarpicola	KBXG5	Thailand	JX104669	JX104716	GenBank
F. xylocarpicola	MU1	Thailand	JX104671	JX104718	GenBank
Outgroup					
Phellinotus neoaridus	URM 80362	Brazil	KM211294	KM211286	Salvador-Montoya et al. (2018)
P. piptadeniae	URM 80322	Brazil	KM211290	KM211282	Salvador-Montoya et al. (2018)

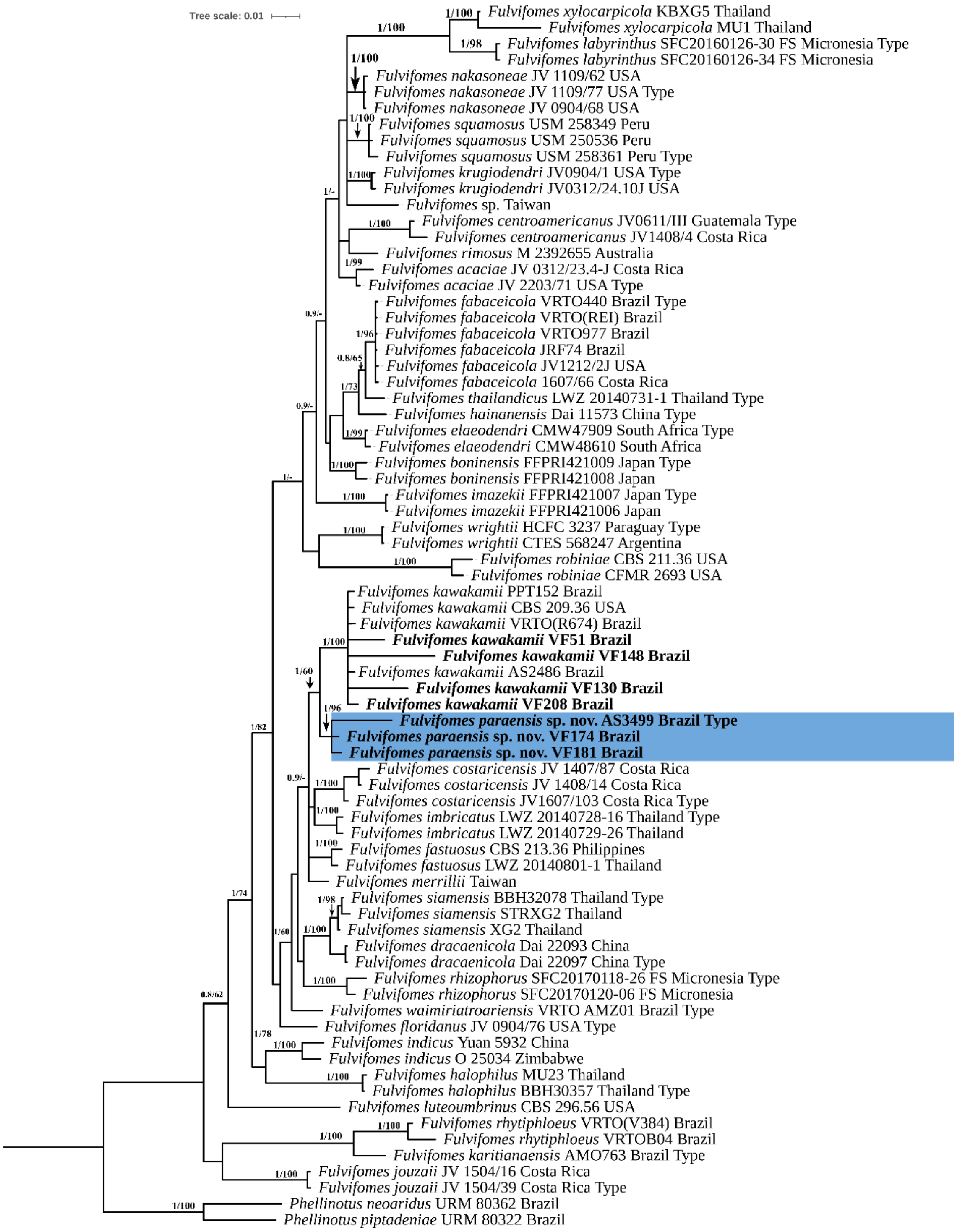

Fig. 1 – Bayesian inference tree of *Fulvifomes* species based on dataset of combined ITS and LSU sequences. BPP (>0.7) and BS values (>50%) are shown above the branches. Sequences of the species in this study are in bold.

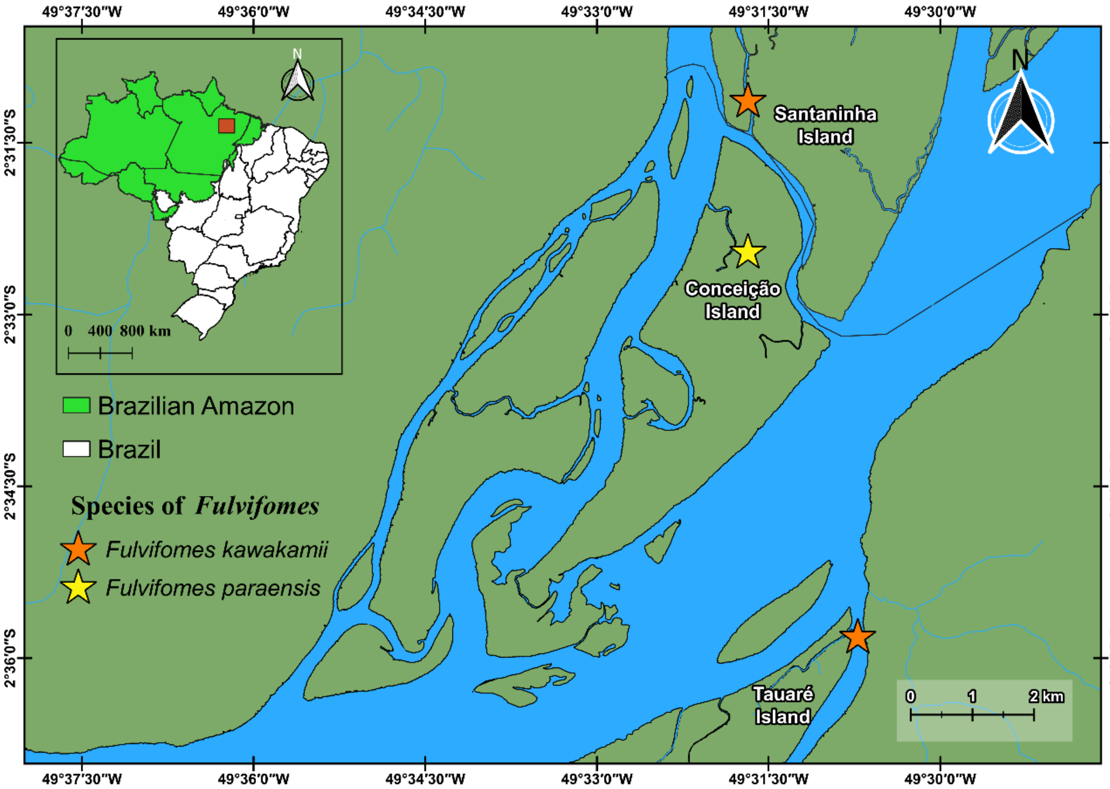

Fig. 2 – Map of the geographic distribution of species studied in this work in islands of Floodplain Forests from the Brazilian Amazon.

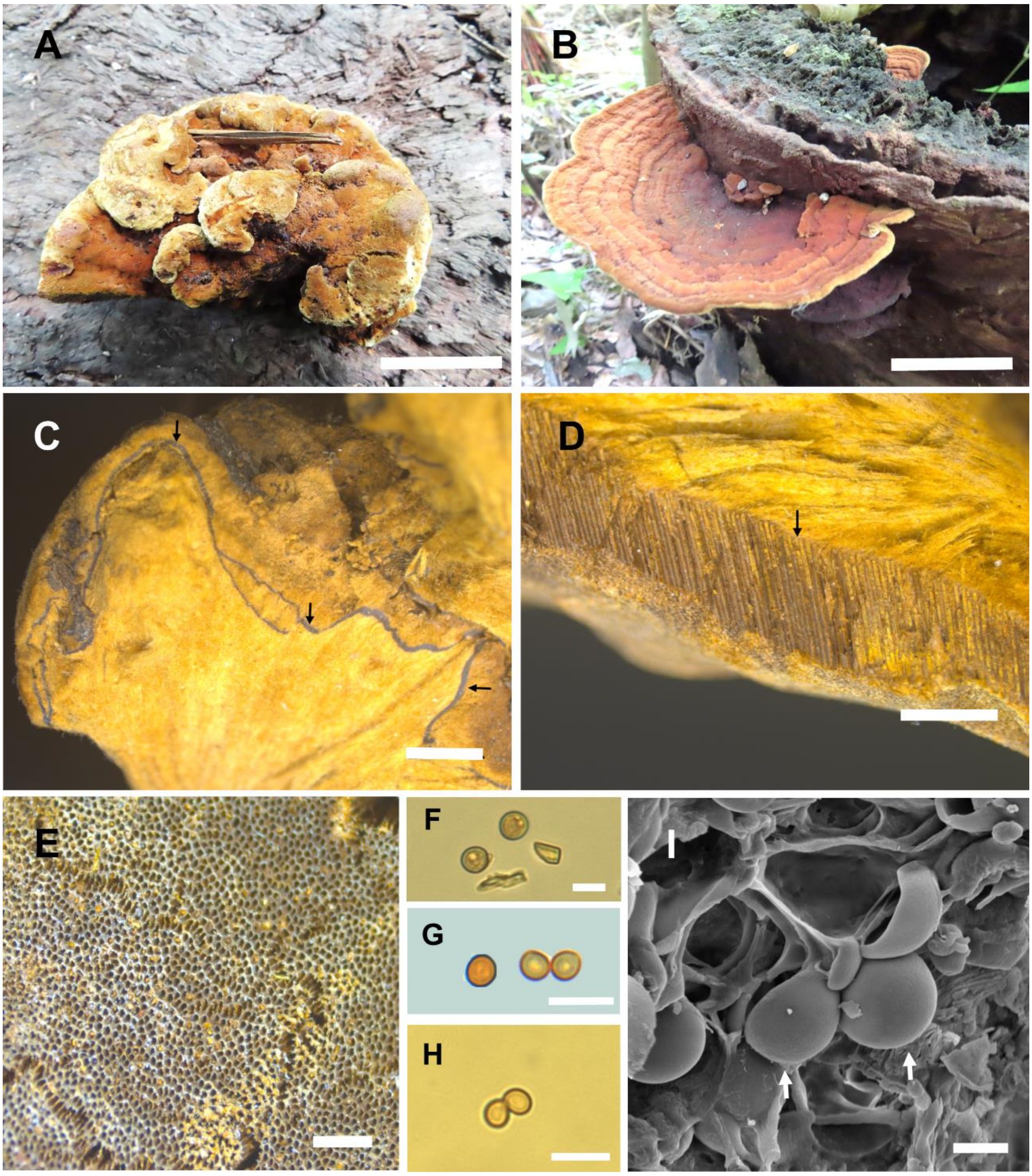

Fig. 3 – Macro- and microscopic features of *Fulvifomes paraensis* sp. nov. A, B: Pilear surface of type AS3499 (MG249953) (A) and paratype VF181 (MG249955) (B). C: Details of the context and black line (type) (black arrow). D: Details of tubes (type) (black arrow). E: Pore surface of type. F–H: Basidiospores (type) in water (F), in KOH (G), in Melzer's reagent (H). I: Basidiospores (white arrow) under SEM. *Bars*: A, B: 2 cm; C, D: 2 mm; E: 1 mm; F: 5 µm; H, G: 10 µm; I: 2 µm.

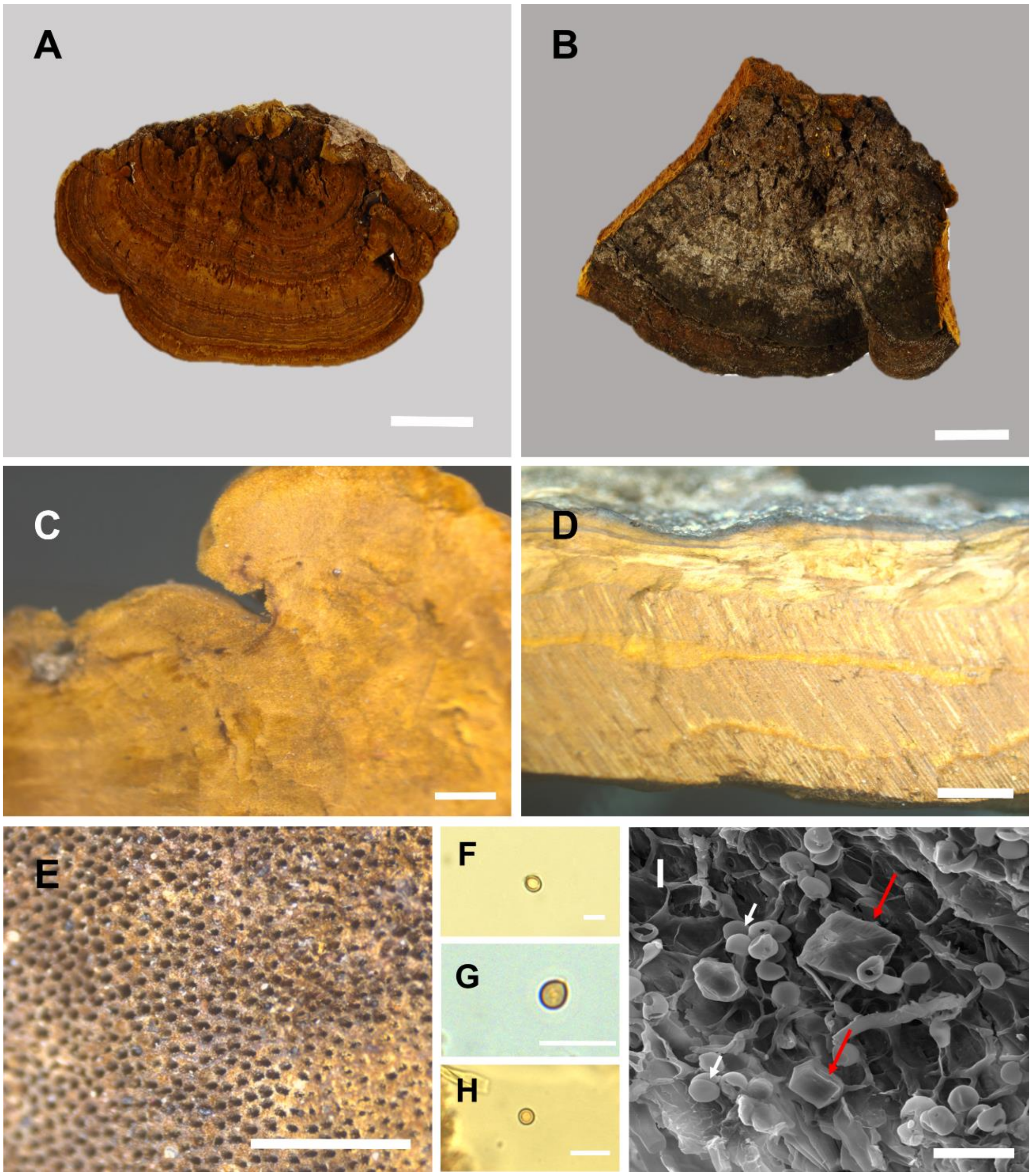

Fig. 4 – Macro- and microscopic features of *Fulvifomes kawakamii*. A, B: Pilear surface of VF148 (A) and VF208 (B). C: Details of the context (VF208). D: Details of tubes (VF208). E: Pore surface (VF148). F–H: Basidiospores in water (F) (VF208), in KOH (G) (VF51) and Melzer's reagent (H) (VF208). I: Basidiospores (white arrow) and crystals (red arrow) under SEM. *Bars*: A, B: 2 cm; C: 1 mm; D: 2 mm; E: 1 mm; F: 5 µm; G–I: 10 µm.

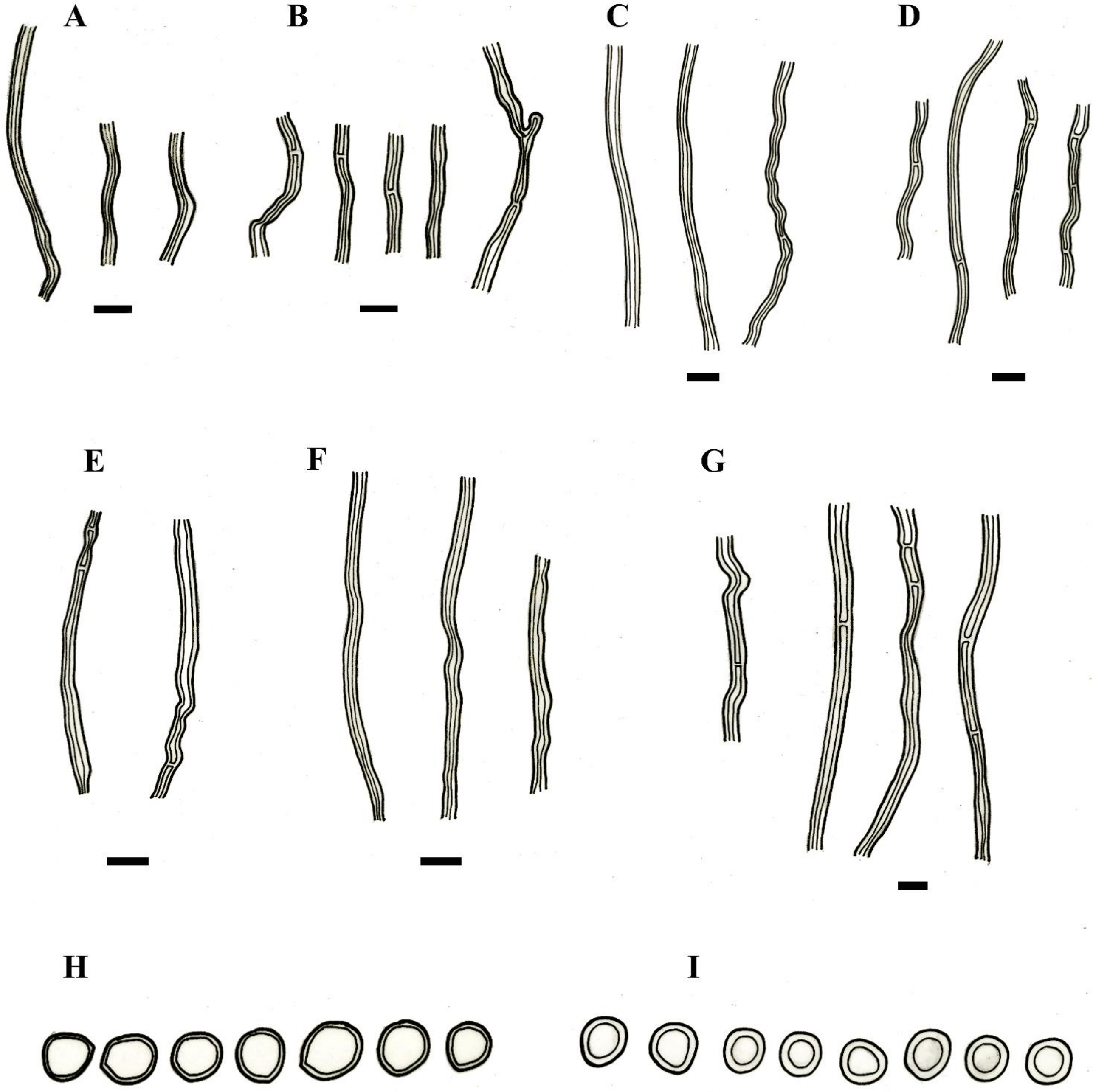

Fig. 5 – Illustration of microscopic features. A–D, I: *Fulvifomes kawakamii*, skeletal (A) and generative hyphae (B) of trama of the tubes, skeletal (C) and generative hyphae (D) of the context, basidiospores (I). E–H: *Fulvifomes paraensis* sp. nov., skeletal (E) and generative hyphae (F) of trama of the tubes, generative hyphae (G) of the context, basidiospores (H). *Bars*: A–G: 10 µm; H, I: 5 µm. Illustrations: Carlos Alvarez (MPEG).

CAPÍTULO III

Título: Three new species of *Fuscoporia* Murrill (Hymenochaetaceae, Basidiomycota) based on morphological and molecular evidence from the Eastern Brazilian Amazon

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Three new species of *Fuscoporia* Murrill (Hymenochaetaceae, Basidiomycota) based on morphological and molecular evidence from the Eastern Brazilian Amazon

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Abstract

Fuscoporia (Hymenochaetaceae, Basidiomycota) is a monophyletic genus of poroid macrofungi with a cosmopolitan distribution, mainly characterized by resupinate to pileate basidiomata, poroid hymenophore, generative hyphae with simple and encrusted septa, and dark brown hymenial setae. The similarity of the morphological characters among the species is taxonomically complex and delimitation of the species still presents uncertainties. The integration of morphological and molecular data has been essential in resolving these complexes. In this study, *Fuscoporia* specimens collected in the Eastern Brazilian Amazon were analyzed using morphological analyses integrated with molecular data based on the markers ITS+LSU+*RPB2*+*TEF1-α*. The analyses revealed three new species: *F. aureofulva (Fuscoporia gilva* group), *F. gibertoniae* and *F. saracaensis (Fuscoporia torulosa* group). In addition, specimens of *F. licnoides* were analyzed on a morphological basis and are presented in this study. These new species expand the knowledge of the distribution of *Fuscoporia* in the Brazilian Amazon. Morphological descriptions and comparisons with *Fuscoporia* species that have previously been recorded in the Brazilian Amazon are provided.

Keywords: Diversity, *Hymenochaetales*, Multigenic phylogeny, Rainforest, Three new taxa, Wood decaying fungi

Introduction

Fuscoporia Murrill is a cosmopolitan genus that belongs to the family Hymenochaetaceae and comprises approximately 100 species (Wu et al. 2022; Chen et al. 2023, 2024). The type species of the genus, *Fuscoporia ferruginosa* (Schrader) Murrill, was described by Murrill (1907) based on a specimen collected in Germany. The genus includes decomposer and/or parasitic species that cause white rot in angiosperms and gymnosperms (Dai et al. 2007; Dai 2010).

Species of *Fuscoporia* are annual to perennial and are morphologically recognized by the combination of pileate to resupinate basidiomata, poroid hymenophore, hyaline thin-walled and smooth basidiospores, dimitic hyphal system, generative hyphae with simple septa, incrustations at the apex, and the presence or absence of hymenial and/or tramal setae (Fiasson and Niemelä 1984; Wagner and Fischer 2001; Dai 2010; Chen and Yuan 2017).

Phylogenetic studies on Hymenochaetaceae have confirmed that the genus *Fuscoporia* constitutes a monophyletic clade (Wagner and Fischer 2002; Larsson et al. 2006). Currently, *Fuscoporia* is divided into six main groups: *F. contigua* (Pers.) G. Cunn., *F. ferrea* (Pers.) G. Cunn., *F. ferruginosa*, *F. gilva* (Schwein.) T. Wagner & M. Fisch., *F. torulosa* (Pers.) T. Wagner & M. Fisch., and *F. viticola* (Schwein.) Murrill (Chen et al. 2020). Recent studies employing molecular approaches have described new species, thereby contributing to advances in understanding the diversity of the genus (Pires et al. 2015; Chen et al. 2019; Du et al. 2020; Vlasák et al. 2020; Yuan et al. 2020; Chen et al. 2023; Bittencourt et al. 2024; Comin et al. 2024; Kim et al. 2024).

In Brazil, 30 species of *Fuscoporia* are currently recognized (Flora e Funga do Brasil 2024; GBIF 2024), with eight (one endemic) recorded for the Brazilian Amazon (Sousa 1980; Sotão et al. 2003; Gomes-Silva et al. 2009; Martins-Júnior et al. 2011; Gibertoni et al. 2013, 2015; Medeiros et al. 2013; Soares et al. 2014, 2018; Xavier et al. 2018; Yuan et al. 2020; Couceiro et al. 2022; Freire and Soares 2024). However, most of Brazil's records still require confirmation, particularly those of species considered cosmopolitan and complex (e.g., *F. ferrea*, *F. ferruginosa*, *F. contigua* and *F. gilva*).

The Amazon is the world's largest tropical rainforest and it hosts a significant number of endemic fungal species. Despite this, it faces critical conservation challenges due to escalating deforestation rates and the consequent loss of biodiversity (Coutinho 2006; Giam 2017). Greater knowledge about Amazonian fungi is essential to better assess their diversity and ecological roles, as well as conservation strategies (Assis et al. 2022). Nevertheless, the low number of records and sampling gaps highlight the need for additional collections and taxonomic studies. Thus, the present study aims to investigate *Fuscoporia* specimens collected in forests of the Eastern Brazilian Amazon through integrative analyses that combine morphological data with molecular phylogeny.

Materials and Methods

Study area

The study areas are characterized as either terra-firme and floodplain forests. These areas include primary vegetation, reforested areas and agroforestry systems. The specimens were collected in the northern region of Brazil, Eastern Amazon: Floresta Nacional de Saracá-Taquera (1°39'24.61" S, 56°24'49.25" W), Mocajuba (2°31'13" S, 49°31'52" W), Serra do Navio (00º53'44" N, 52º00'08" W). The collection, preservation and herbarium procedures followed the methodology of Neves et al. (2013). The specimens were dehydrated in an electric oven at 70 °C or at 40 °C in a food dehydrator.

The distribution map of the new species was created according to geographical coordinates of the areas of the collections, provided by Global Positioning System (GPS), and shapefiles available from the Instituto Brasileiro de Geografia e Estatística (https://www.ibge.gov.br/). The map was created using software QGIS v. 3.28, Datum SIRGAS 2000 (Fig. 1).

Morphological analyses

The specimens were deposited in the João Murça Pires (MG) herbarium of the Museu Paraense Emílio Goeldi (MPEG). Macromorphological descriptions were based on the pileal surface, context, tubes, margin and dimensions. Special color terms followed Kornerup and Wanscher (1978). The micromorphological analyses were performed with 3% potassium hydroxide (KOH) solution with 1% phloxine. Additionally, slides with samples were mounted in Melzer's reagent and cotton blue. The samples were observed under an optical microscope to identify microstructures, which were examined based on shape, dimensions, ornamentation type, and color (Teixeira 1995; Ryvarden 2004). The following abbreviations were used: IKI = Melzer's reagent, IKI– = neither amyloid nor dextrinoid, CB = cotton blue, CB– = acyanophilous, L = mean of all spore, basidia and setae length, W = mean of all spore, basidia and setae width, Q = variation in the ratios of L/W among specimens of this study, n = number of spore, and basidia measured from a given number of specimens. Microscopic images were taken at the Microscopy Laboratory at MPEG, using a microscope Leica DM6 B (Leica Microsystems CMS GmbH, Germany).

DNA extraction, PCR amplification and sequencing

Fragments (30–50 mg) of the basidiomata were placed in 1.5 mL microtubes. The fragments were then manually ground together with liquid nitrogen, and the DNA was extracted using the DNeasy® Plant Pro Kit, according to the manufacturer's instructions.

Polymerase chain reaction (PCR) was performed to amplify the regions of interest: internal transcribed spacer (ITS), large subunit rRNA gene (LSU), and the protein-coding: RNA polymerase II second largest subunit (*RPB2*) and translation elongation factor 1-α (*TEF1-α*). The primers pairs used to amplify the regions were ITS4/ITS5 for ITS, LR0R/LR07 for LSU, fRPB2-7cF/fRPB2-5R for *RPB2,* and 983F/1567R for *TEF1-α* (White et al. 1990; Moncalvo et al. 2000; Matheny et al. 2002; Renher and Buckley 2005). The protocols of the primers and thermal cycle parameters used are available in Table 1. PCR was performed with a final volume of 12.5 µL containing 1µL of DNA, 4.25 µL of nuclease-free water, 0.5 µL of each primer, and 6.25 µL of PCR Master Mix (Promega corporation, USA). Two microliters of the final PCR product were stained with two microliters of Gel-Red (0.5 µg/mL), which were evaluated using electrophoresis on a 1% agarose gel and purified using ExoSAP-IT™ PCR Product Cleanup reagent (Thermo Fisher Scientific, USA). Sanger sequencing was performed with a BigDye Terminator v.3.1 Cycle Sequencing Kit (Applied Biosystems, USA) following manufacturer's instructions. Forward and reverse sequence strands for each gene fragment were obtained. All the procedures were performed at the Laboratório de Biologia Molecular (LBM) at MPEG. The sequencing was performed in an automated DNA sequencer ABI 3130 Genetic Analyzer (Applied Biosystems, USA) at the Laboratório de Citogenômica e

Mutagênese Ambiental (SEAMB) at the Instituto Evandro Chagas (IEC). All the generated sequences were submitted to the GenBank database (http://www.ncbi.nlm.nih.gov/genbank).

Phylogenetic analyses

The electropherograms of the ITS, LSU, *RPB2* and *TEF1-α* sequences were analyzed and manually edited using BioEdit v. 7.7 (Hall 1999). Four datasets were constructed from the sequences generated in this study and combined with the LSU+ITS+*RPB2*+*TEF1-α* sequences available in GenBank (Table 2): ITS (82 sequences), LSU (78 sequences), *RPB2* (27 sequences) and *TEF1-α* (46 sequences). Datasets were aligned using the MAFFT v. 7 online program (Katoh and Standley 2013) using the "Auto" strategy and, when necessary, alignments were manually edited in the MEGA 11 program (Tamura et al. 2021). Potential ambiguously aligned segments were detected with the software Gblocks v. online (Lemoine et al. 2019). The program Mesquite v. 3.81 was used to concatenate the sequences of datasets. *Coniferiporia sulphurascens* (Pilát) L.W. Zhou & Y.C. Dai and *Phellinidium fragrans* (M.J. Larsen & Lombard) Nuss were selected as outgroups for phylogenetic inferences (Zhou et al. 2016).

Phylogenetic trees were constructed using maximum likelihood (ML) and Bayesian inference (BI) methods online via the CIPRES Science Gateway (Miller et al. 2010). The ML analysis was conducted using RAxML-HPC2 on ACCESS (Stamatakis 2014), with a partition scheme applied and the GTR+G model was used for each partition. A total of 100 ML searches were performed, each starting from a parsimony tree generated by randomized stepwise addition under the GTRGAMMA model. For the BI, MrBayes on XSEDE (3.2.7a) was used for the analyses (Ronquist et al. 2012). ModelFinder (Kalyaanamoorthy et al. 2017), implemented in the IQ-TREE online software (Nguyen et al. 2015; Trifinopoulos et al. 2016), was utilized to estimate the optimal partitioning strategy and the best-fitting model of nucleotide evolution for the dataset. The BI analysis was run with four chains of Metropolis-coupled Markov chain Monte Carlo iterations for 10,000,000 generations, with trees sampled every 1,000 generations.

Results

Phylogenetic analyses

In total, 16 new sequences for five *Fuscoporia* specimens were generated in this study (Table 2). The best partitions and evolutionary models were TVM+F+G4 (ITS), TIM3e+I+G4 (LSU), TN+F+G4 (*RPB2*) and TIM2e+G4 (*TEF1-α*). The combined dataset of ITS+LSU+*RPB2*+*TEF1-α* dataset comprised 83 sequences, with 2,622 characters (ITS = 541, LSU = 925, *RPB2* = 642, *TEF1-α* = 514) of which 1,415 were constant and variable sites, and 897 parsimony-informative sites.

The analyses that combined the datasets for ML and BI resulted in phylogenetic topologies that were largely congruent. The BI tree was selected to represent the results of this study, with bootstrap (BS) values for ML and Bayesian posterior probabilities (BPP) indicated on the branches (Fig. 2). Phylogenetic reconstructions of the analyzed specimens revealed three distinct and well-supported monophyletic clades, and formed a lineage with strong statistical support, unassociated with any previously described taxa, indicating the presence of new species. The first clade corresponded to "*Fuscoporia gibertoniae* sp. nov."

(BS = 100/BPP = 1). The second clade was designated as "*Fuscoporia saracaensis* sp. nov." (BS = 88/BPP = 0.93). The third clade was designated as "*Fuscoporia aureofulva* sp. nov." (BS = 83).

Taxonomy

Fuscoporia aureofulva R.B.M. Freire, W. Xavier & A.M.S. Soares sp. nov. (Figs. 3, 4).

Mycobank: MB857185

Type: BRAZIL. Amapá, Serra do Navio, 0°55′54.115″ N, 52°0′23.973″ W, found on an unidentified decaying trunk, 28 February 2015, leg. W. Xavier WX2015-328 (Type MG255055). GenBank numbers: PQ819431 (LSU), PV185904 (*TEF1-α*), PV067188 (*RPB2*).

Etmylogy: The name "*aureofulva*" refers to the color of the context and the margin of hymenophore, where "aureo" means golden, and "fulva" means yellowish.

Description: Basidiomata annual to biannual, effused-reflexed to pileate, without distinctive odor or taste; hard and corky when dry. Pilei dimidiate, projecting up to 3.8 cm in length, 5.2 cm wide, and up to 3 mm thick at the base. Pileal surface brownish orange (5C5) to light brown (6D6), azonate, rough; pileal margin obtuse. Context yellowish brown (5D8), homogeneous, woody and hard, 2–5 mm thick, without a black line under the tomentum. Hymenophore poroid, pore surface greyish yellow (4C8) to dark brown (6F7), and dark yellow (4C7) at the margins; pores circular, 10–12 per mm, almost invisible to the naked eye; dissepiments thin and entire. Tubes yellowish brown (5D8), matching the context in color, woody and hard, tiny, up to 1 mm thick, with indistinctly stratified tube layers. In KOH, the context and tubes become, respectively, reddish brown and light brown.

Hyphal system subdimitic in the context and dimitic in the trama of the tubes. Contextual generative hyphae hyaline, 2.7–5.6 µm diam., infrequent, thin-walled, with simple septa, short ramifications and a narrow lumen. Contextual skeletal hyphae light to dark brown, 5.8–9.1 µm diam., dominant, thick-walled, aseptate to frequently septate, with a narrow lumen. Tramal generative hyphae ferruginous-brown in KOH and light yellow in water, 3.6–4.1 µm diam., rare, thin-walled, with simple and well-defined septa, a narrow lumen, twisted and slightly encrusted. Tramal skeletal hyphae brown in KOH and light yellow in water, 5.2–8.1 µm diam., thick-walled, aseptate, with a narrow lumen. Lageniform cystidioles, 12.9–25.9 × 2–2.7 µm, occasional; crystals observed.

Hyphal setae: Absent.

Hymenial setae: (13.8–)15.7–24.5(–29) × (5.6–)6–9(–11.1) µm [W = 20.76 µm, L = 6.73 µm, setal index = 3.1 µm (n=10)], subulate to straight, light to dark brown, thick-walled, occasional, rarely septate at the base.

Basidia: 4.6 × 2.4 µm, clavate, rare, with four sterigmata, without a septum at the base.

Spores: Basidiospores (2.1–)3–3.6(–3.9) × (2–)3–3.7 µm [W = 3.2 µm, L = 3.1 µm, Q = 1.05 µm (n=10)], globose, hyaline, thin- to thick-walled, light to occasionally dark-colored wall, smooth, IKI–, CB–

Ecology and distribution: *Fuscoporia aureofulva* sp. nov. was found on an unidentified decaying trunk. This species is only known from the type locality in the Eastern Brazilian Amazon (Amapá, Brazil) (Fig. 1).

Notes: This taxon is morphologically characterized by basidiomata that are annual to biannual, effused-reflexed to pileate, context yellowish brown, pore surface greyish yellow to dark brown with dark yellow at the margin, hyphal system subdimitic in the context, and dimitic in the trama of the tubes, generative hyphae twisted, and slightly encrusted, and basidiospores globose, thin- to thick-walled, light to occasionally dark-colored wall. *Fuscoporia aureofulva* is similar to *F. semiarida*, and this species shares annual to biannual, pileate to effused-reflexed basidiomata, and context is homogeneous. However, *F. semiarida* has a hyphal system dimitic in context, lack of cystidioles, and ellipsoid basidiospores (Yuan et al. 2020), while *F. aureofulva* has a hyphal system subdimitic in context, lageniform cystidioles and globose basidiospores.

Fuscoporia gibertoniae R.B.M. Freire & A.M.S. Soares sp. nov. (Figs. 5, 6).

Mycobank: MB857186

Type: BRAZIL. Amapá, Serra do Navio, 0°55′53.987″ N, 52°0′23.807″ W, found on an unidentified decaying trunk, 18 October 2014, leg. W. Xavier WX2014-153 (Type MG255054). GenBank numbers: PQ819481 (ITS).

Etmylogy: In honor of Dr. Tatiana Gibertoni, a notable Brazilian mycologist.

Description: Basidiomata annual, pileate to effused-reflexed, sessile, without distinctive odor or taste, woody when dry. Pilei dimidate, projecting up to 3.6 cm in length, 1.8 cm wide, and 0.25–1 cm thick at the base. Pileal surface olive brown (4D7) to brown (6E7) in juvenile specimens, turning grey (2E1) in old specimens, zoned; pileal margin obtuse. Context yellowish brown (5E8), homogeneous, woody and hard, 0.5–2 mm thick, without a black line under the tomentum. Hymenophore poroid, pore surface light brown (5D5) to brown (5F8), small pores, round, 8–13 per mm, almost invisible to the naked eye; dissepiments thin and entire. Tubes brown (5F8), matching the context in color, woody and hard, tiny, up to 1 mm thick, with tube layers indistinctly stratified. In KOH, the context and tubes become dark brown.

Hyphal system subdimitic in the context and dimitic in the trama of the tubes. Contextual generative hyphae yellow to golden yellow, 2.5–3 µm diam., thin-walled, frequently septate, with a narrow lumen. Contextual skeletal hyphae reddish-brown, 3–4.5 µm diam., thick-walled, aseptate to frequently septate, with a narrow lumen. Tramal generative hyphae light yellow, 3–4 µm diam., thin-walled, simple-septate, with a narrow lumen, heavily encrusted. Tramal skeletal hyphae reddish-yellow, 3.5–4 µm diam., thick-walled, aseptate, with a narrow lumen. Fusoid cystidioles, 10 × 2 µm; crystals were observed.

Hyphal setae: Absent.

Hymenial setae: (12–)15–23(–26) × (3–)4–5(–6) µm, [W = 18.68 µm, L = 4.68 µm, setal index = 3.99 µm (n=20)], subulate, straight, acute at the apex, light brown to brown, thick-walled, often with a septum at the base.

Basidia: 8–12 × 4–5 µm, clavate, with four sterigmata, without a septum at the base.

Spores: Basidiospores (2.5–)2.8–3.7(–4.1) × (2–)3–3.7 µm [W = 3.3 µm, L = 3.2 µm, Q = 1.04 µm (n=10)], globose to ellipsoid, hyaline, thin- to thick-walled, IKI–, CB–.

Ecology and distribution: *Fuscoporia gibertoniae* sp. nov. was found on an unidentified decaying trunk. This species is known from the terra-firme forest and floodplain forest islands in the Eastern Brazilian Amazon (Amapá and Pará, Brazil) (Fig. 1).

Specimens examined (*paratypes*): BRAZIL. Pará, Municipality of Mocajuba, Santaninha island, 2°31′13″ S, 49°31′52″ W, found on a decaying trunk, 21 June 2023, leg. V.P. Farias VF135 (MG255053). GenBank numbers: PQ819480 (ITS), PQ819430 (LSU), PV185903 (*TEF1-α*), PV067187 (*RPB2*).

Notes: This taxon is morphologically characterized by pileate to effused-reflexed basidiomata, small pores (8–13 per mm), hyphal system subdimitic in the context, and dimitic in trama of the tubes, hymenial setae with a septum at the base, and basidiospores globose to ellipsoid, thin- to thick-walled, averaging 3.3 W µm × 3.2 L µm. *Fuscoporia gibertoniae* is similar to *F. atlantica* since both species share pileate to effuse-reflexed basidiomata, homogeneous context and subulate hymenial setae (Pires et al. 2015). However, *F. gibertoniae* can be differentiated from *F. atlantica* by dimidate pilei, the number of pores per mm of *F. gibertoniae* is 8–13, while *F. atlantica* has 7–9, hyphal system is subdmitic in *F. gibertoniae,* while dimitic in *F. atlantica,* and this species presents bigger setae (20–45 × 7–10 µm) (Pires et al. 2015).

Fuscoporia saracaensis R.B.M. Freire & A.M.S. Soares sp. nov. (Figs. 7, 8).

Mycobank: MB857187

Type: BRAZIL. Pará, Porto Trombetas, Floresta Nacional Saracá-Taquera, 1°39’24.61” S, 56°24’49.25” W, found on a decaying trunk, 18 August 2023, leg. A.M.S. Soares AS3239 (Type MG255052). GenBank numbers: PQ878605 (ITS), PQ819429 (LSU), PV185902 (*TEF1-α*), PV067186 (*RPB2*).

Etmylogy: The name “*saracaensis*” refers to the forest plot area “Saracá” where the specimen was found and also to the stream from the Trombetas River basin (“Saracá”) in the Floresta Nacional Saracá-Taquera.

Description: Basidiomata annual to biannual, pileate to effused-reflexed, sessile, without distinctive odor or taste, and woody when dry. Pilei broadly attached to dimidiate, projecting up to 3.2 cm in length, 1.5 cm wide, and up to 3 mm thick at the base. Pileal surface yellowish brown (5E8) to brownish yellow (5C8), zonate; pileal margin obtuse, rarely sharp. Context yellowish brown (5E8) to brown (5E5), homogeneous, soft when young and woody and hard in older specimens, 1–5 mm thick, without a black line beneath the tomentum. Hymenophore poroid, pore surface brownish yellow (5C8) in juvenile specimens to brown (6E8) in older specimens, with small, round to angular pores, 8–10 per mm, almost invisible to the naked eye; dissepiments thin and entire. Tubes brown (6E8), woody and hard, up to 2 mm thick, with tube layers indistinctly stratified. In KOH, the context and tubes become, respectively, dark and dark brown.

Hyphal system dimitic. Contextual generative hyphae light brown, 3.5–4 µm diam., thin- to slightly thick-walled, with short branches, simple septa, with a narrow lumen. Contextual skeletal hyphae brown, 3.8–7 µm diam., dominant, thick-walled, with few or no branches, aseptate. Tramal generative hyphae hyaline to ferruginous-brown, up to 3 µm diam., thin-walled, encrusted at dissepiment edges, simple septa, with a narrow lumen. Tramal skeletal hyphae ferruginous-brown, 4–5 µm diam., dominant, thin- to thick-walled, with a narrow lumen. Cystidioles frequent, hyaline, of two types: fusoid, 12–20 × 3–4 µm; lageniform, 30 × 4 µm.

Hyphal setae: Absent.

Hymenial setae: 18–30(–40) × 4–5 (–6) µm [W = 23.95 µm, L = 5 µm, setal index = 4.79 µm (n=20)], subulate to ventricose at the base, acute at the apex, ferruginous-brown, thick-walled.

Basidia: 6–7 × 4–6 µm [W = 6.6 µm, L = 5.1 µm, Q = 1.29 µm (n=10)], globose, hyaline, four sterigmata, 3–4 µm length, without a septum at the base.

Spores: Basidiospores 3–5 × (1.8–) 2.5–3 (–4) µm, [W = 4.05 µm, L = 2.82 µm, Q = 1.44 µm (n=20)], subcylindrical to oblong-ellipsoid, hyaline, thin-walled, IKI–, CB–.

Ecology and distribution: *Fuscoporia saracaensis* sp. nov. was found on a decaying trunk. This species is only known from the type locality in the Eastern Brazilian Amazon (Pará, Brazil) (Fig. 1).

Specimens examined (*paratypes*): BRAZIL. Pará, Porto Trombetas, Floresta Nacional Saracá-Taquera, 1°39’24.61” S, 56°24’ 49.25” W, found on branches of a decaying unidentified tree, 18 August 2023, leg. A.M.S. Soares AS3229 (MG255051). GenBank numbers: PQ819479 (ITS), PQ819428 (LSU), PV185901 (*TEF1-α*), PV067185 (*RPB2*).

Notes: This taxon is morphologically characterized by basidiomata annual to biannual, pilei broadly attached to dimidiate, fusoid and lageniform cystidioles, hymenial setae subulate to ventricose at the base, and acute at the apex, basidiospores subcylindrical to oblong-ellipsoid, averaging 4.05 µm W × 2.82 µm L. *Fuscoporia saracaensis* shares pileate basidiomata and hyphal system dimitic with *F. griseopora* (D.A. Reid) Y.C. Dai & F. Wu. However, the basidiomata of *F. griseopora* is perennial, and there is a lack of hymenial setae and cystidioles (Table 3) (Ryvarden 2004).

Fuscoporia licnoides (Mont.) Oliveira-Filho & Gibertoni, Fungal Diversity 104: 129 (2020)

Mycobank: MB825474

Basionym: *Polyporus licnoides* Mont.

Description: Yuan et al. (2020).

Type locality: French Guiana.

Ecology and distribution: *Fuscoporia licnoides* is found on decaying dead wood. This species is known in Brazil, French Guiana and USA (Montagne 1840; Yuan et al. 2020; Wu et al. 2022; Oliveira and Gibertoni 2023).

Specimens examined: BRAZIL. Pará, Porto Trombetas, Floresta Nacional Saracá-Taquera, Almeidas OG plot, 1°43’55.36” S, 56°23’55.34” W, on decaying wood, 24 August 2023, leg. A.M.S. Soares AS3331, AS3334; Periquito plot, 1°38’32.86” S, 56°26’15.46” W, on decaying wood, 19 August 2023, leg. A.M.S. Soares AS3287; Bélem, Parque Estadual do Utinga Camillo Vianna, ETA plot, 1°25'27.118" S, 48°26'44.612" W, on a decaying trunk, June 2022, leg. D.S. Brás PU36.

Notes: *Fuscoporia licnoides* is morphologically characterized by basidiomata annual, pileate; hard and corky to slightly flexible pileus; context homogeneous; pores 7–9 per mm; hymenial setae lanceolate to ventricose, 20.6 × 4.6 µm; basidiospores oblong-ellipsoid, hyaline, thin-walled, 4 × 2.27 µm (Yuan et al. 2020). *Fuscoporia licnoides* is morphologically similar to *F. semiarida* and *F. atlantica* or may havebeen previously identified as *Phellinus gilvus* (Oliveira and Gibertoni 2023).

Discussion

The specimens of *Fuscoporia* analyzed in the present study point to three new species: *F. gibertoniae* sp. nov., *F. auerofulva* sp. nov., and *F. saracaensis* sp. nov. The three described species exhibit morphological characteristics that distinguish them from other species within the genus, as well as phylogenetic support (Fig. 2).

The phylogenetic reconstruction demonstrated that *Fuscoporia auerofulva* is closely related to *F. minutissima* Q. Chen, Jing Si & Vlasák, and clustered in a separated branch with moderate value support in the ML analysis (88/-) (Fig. 2). Both species share similarities, such as pileate basidiomata, circular pores (10–13 per mm), and subulate hymenial setae. Nevertheless, *F. minutissima* has perennial basidiomata, larger hymenial setae (up to 40 µm in length), and broadly ellipsoid to subglobose basidiospores with a guttule (Chen et al. 2023), whereas, *F. aureofulva* has annual to biannual basidiomata, hymenial setae up to 29 µm in length, and globose basidiospores. Geographically, *F. minutissima* is known only from the Neoarctic region (Hawaii, USA) on dead *Acacia koa* trees (Chen et al. 2023), while *F. aureofulva* sp. nov. wass found on an unidentified decaying trunk in the Eastern Brazilian Amazon (Fig. 1). Furthermore, the observed genetic variations in the allele frequencies, indicate divergence in the genetic composition of both species. Thus, morphological differences, geographical distribution and the genetic variations separate both species.

Other similar species are *F. formosana* (T.T. Chang & W.N. Chou) T. Wagner & M. Fisch. and *F. scruposa* (Fr.) Gibertoni & Oliveira-Filho (Fig. 2). These species share pileate basidiomata and basidiospores of similar sizes, but are markedly distinct from *F. auerofulva*. For instance, *F. formosana* is distinguished by its imbricate pilei, a black line separating the tomentum from the context, basidia septate at the base, and basidiospores broadly ellipsoid (Chang and Chou 1999; Oliveira and Gibertoni 2023), with these characteristics being absent in *F. auerofulva*. *Fuscoporia formosana* occurs in eastern China, with its type locality in Taiwan, though it was recently reported in northeastern Brazil (Chang and Chou 1999; Yuan et al. 2020; Wu et al. 2022; Oliveira and Gibertoni 2023). Meanwhile, *F. scruposa* can be distinguished by the nodules on the pileus surface, a dimitic hyphal system and ellipsoid basidiospores (Table 3) (Oliveira and Gibertoni 2023). Among the species that are phylogenetically close to *F. auerofulva*, only *F. scruposa* has been recorded in the Brazilian Amazon, specifically in Maranhão state (Yuan et al. 2020), although the type locality of this species remains unknown.

Phylogenetically, *Fuscoporia gibertoniae* forms a sister clade to *F. rhabarbarina* (Berk.) Groposo, Log.-Leite & Góes-Neto and *F. senex* (Nees & Mont.) Ghobad-Nejhad (Fig. 2). The new species share with *F. rhabarbarina* pileate to effused-reflexed basidiomata, yellow context, presence of cystidioles, and ellipsoid basidiospores [(2.5–)2.8–3.7(–4.1) × (2–)3–3.7 µm (*F. gibertoniae*) *vs.* (3.2–)3.3–4.1(–4.2) × (2–)2.1–2.4(–2.5) µm (*F. rhabarbarina*)] (Groposo et al. 2007; Dai 2010). However, *Fuscoporia gibertoniae* differs by its annual basidiomata, leathery consistency, smaller pores (up to 13 per mm), dimitic to subdimitic hyphal system, hymenial setae frequently septate at the base and globose basidiospores, while *F. rhabarbarina* has woody and hard, perennial basidiomata, pores up to 9 per mm, and a dimitic hyphal system. Similarly, *F. gibertoniae* and *F. senex* share characteristics such as dimidiate pileus, brown pore surface, fusoid cystidioles and clavate basidia (Dai 2010). However, *F. senex* is distinguished by its flattened pileus, basidia septate at the base, larger basidiospores [(3.9)4–4.9(5) × (3)3.2–4(4.5) µm] and

CB+ reaction (Dai 2010). Although *Fuscoporia senex* and *F. rhabarbarina* have been already reported in the Brazilian Amazon, these records lack molecular support (Sousa 1980; Sotão et al. 2003; Gibertoni et al. 2015; Couceiro et al. 2022; Freire and Soares 2024).

Fuscoporia saracaensis is phylogenetically close to *F. semiarida* (Lima-Júnior, C.R.S. de Lira & Gibertoni) (Fig. 2) and both share similar morphological features, such as pileate to effused-reflexed basidiomata, pores (7–10 per mm for both), ventricose hymenial setae and small basidiospores [3–5 × 2.5–3 µm (*F. saracaensis*) *vs.* 4–5 × 2–3 µm (*F. semiarida*)]. However, *F. saracaensis* is easily distinguishable from *F. semiarida* due to the presence of fusoid and lageniform cystidioles, larger hymenial setae [up to 40 µm L (*F. saracaensis*) *vs.* up to 26 µm L (*F. semiarida*)] and subcylindrical to oblong-ellipsoid basidiospores. Additionally, while *F. semiarida* is recorded in northeastern Brazil (Yuan et al. 2020), *F. saracaensis* is known only in the Eastern Brazilian Amazon (West Pará) (Fig. 1).

In this study, specimens of *Fuscoporia licnoides* were identified based on morphological characters (AS3331, AS3334, AS3287 and PU36). This species was recently recorded by Yuan et al. (2020) in the Brazilian Amazon in the Pará state (URM87971) [GenBank accession numbers: MH392558 (ITS), MH407357 (LSU)]. Although molecular analyses were performed, the sequences generated failed, so it did not contribute to phylogenetic reconstruction. Nonetheless, the morphological characteristics, combined with the geographic distribution of *F. licnoides*, confirm the identification of the specimens in this study. *Fuscoporia licnoides* is shown to be phylogenetically close to *F. gibertoniae* and *F. saracaensis*. This species differs morphologically from *F. gibertoniae* by its dimitic hyphal system in the context (subdimitic in *F. gibertoniae*), lanceolate to ventricose hymenial setae (subulate to straight in *F. gibertoniae*), and oblong-ellipsoid to broadly ellipsoid basidiospores (globose to ellipsoid in *F. gibertoniae*) (Table 3). Similarly, *F. licnoides* is distinguished from *F. saracaensis* by its glabrous pileus and absence of cystidioles, whereas *F. saracaensis* exhibits a tomentose pileus and two types of cystidioles (fusoid and lageniform cystidioles) (Table 3).

Fuscoporia still presents uncertainties in species delimitation (Chen et al. 2023). Integrating morphological and molecular data has proven essential for resolving species complexes within *Fuscoporia* (Chen et al. 2019, 2020; Comin et al. 2024; Kim et al. 2024). One example is the *F. gilva* complex in Brazil, for which specimens were long identified as *F. gilva sensu lato*. However, through molecular inference, Yuan et al. (2020) identified four distinct clades within this group: *F. formosana, F. semiarida, F. licnoides* and *F. scruposa*. Consequently, *F. gilva sensu stricto* is no longer recognized in Brazil (Yuan et al. 2020). More recently, Chen et al. (2024) demonstrated that *F. semiarida* and *F. licnoides* are phylogenetically grouped within the "*Fuscoporia torulosa*" complex, which also includes other species such as *F. senex*, *F. chrysea*, and the newly described species, *F. gibertoniae* and *F. saracaensis*. Conversely, the "*Fuscoporia gilva*" complex comprises well-known species, including *F. minutissima*, along with the newly described species *F. auerofulva* (Chen et al. 2024).

The occurrence of some *Fuscoporia* species in the Brazilian Amazon still requires revision with support of phylogenetic analyses, as many have been previously classified within species complexes. This study is the first in the region to use multiple genetic markers (ITS, LSU, *RPB2, TEF1-α*). The three new species described in the Brazilian Amazon provide further evidence that this region has a significant and underexplored fungal diversity; however, there is still a need for more investigations using an integrative taxonomy approach (morphology and molecular) to determine the distribution of *Fuscoporia* in this region.

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Statements and Declarations

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Conflict of interest

The authors declare that there are no competing interests.

Author contributions

Material preparation, data collection, identification, phylogenetic analysis, writing of the original draft, and editing were performed by Richard Bruno Mendes-Freire. Data collection, identification, and review: Adriene Mayra da Silva Soares, Maria do Perpétuo Socorro Progene Vilhena, William Kalhy Silva Xavier and Helen Maria Pontes Sotão. Adriene Mayra da Silva Soares was responsible for the funds and supervision in this research. All the authors read and approved the final version of the manuscript.

Data Availability

All data generated or analyzed during this study are included in this published article. Sequence data generated for the present study have been deposited in GenBank with the accession numbers ITS: PQ819480, PQ819481, PQ819479, PQ878605; LSU: PQ819431, PQ819430, PQ819428, PQ819429; *RPB2*: PV067185, PV067186, PV067187, PV067188; *TEF1-α*: PV185901, PV185902, PV185903, PV185904. The alignment file for conducting phylogenetic analyses is available in TreeBASE under number 31919.

Ethical approval

Not applicable.

Consent to participate

Not applicable.

Consent for publication

Not applicable.

Table 1 – Primer sequences and protocols applied during PCR experiments.

Gene/loci	**Primer sequence (forward/reverse)**	**Protocol (C°/time)**
ITS	ITS4—TCCTCCGCTTATTGATATGC ITS5—GGAAGTAAAAGTCGTAACAAGG White et al. (1990)	Initial denaturation: 94º – 03:00 Denaturation: 94º – 00:30 Anneal: 52º – 00:50 Extension: 72º – 01:00 Final extension: 72° - 10:00 Cycles: 35
LSU	LR0R—ACCCGCTGAACTTAAGC LR7—TACTACCACCAAGATCT Moncalvo et al. (2000)	Initial denaturation: 94º – 03:00 Denaturation: 95º – 00:30 Anneal: 50º – 00:30 Extension: 72º – 01:00 Final extension: 72° - 10:00 Cycles: 35
RPB2	7cF—CCCATRGCTTGYTTRCCCAT 5R—GAYGAYMGWGATCAYTTYGG Matheny et al. (2002)	Initial denaturation: 94º – 03:00 Denaturation: 95º – 01:00 Anneal: 52º – 02:00 Extension: 72º – 01:30 Final extension: 72° - 10:00 Cycles: 35
TEF1-α	983F—GCYCCYGGHCAYCGTGAYTTYAT 1567R—ACHGTRCCRATACCACCRATCTT Renher and Buckley (2005)	Initial denaturation: 94º – 03:00 Denaturation: 95º – 00:30 Anneal: 50º – 00:30 Extension: 72º – 01:00 Final extension: 72° - 10:00 Cycles: 35

Table 2 – Taxa, vouchers specimens, locality and GenBank accession numbers of sequences. Sequences of the species studied in this work are in bold.

Species	**Voucher specimens**	**Locality**	**GenBank accession numbers**				**Reference**
			ITS	**LSU**	***TEF1-α***	***RPB2***	
Fuscoporia ambigua	Cui 9244	China	MN816706	MN809995	MN848804	–	Du et al. (2020)
F. ambigua	JV 0509/151 (Holotype)	USA	MN816707	MN809996	–	MN848792	Du et al. (2020)
F. americana	JV 1209/100	USA	KJ940022	MG008467	MH636384	–	Chen et al. (2020)
F. atlantica	SP 465829	Brazil	KP058514	KP058516	–	–	Pires et al. (2015)
F. atlantica	SP 445618 (Holotype)	Brazil	KP058515	KP058517	–	–	Pires et al. (2015)
F. aureofulva	**WX2015-328 (Holoype)**	**Brazil**	**–**	**PQ819431**	**PV185904**	**PV067188**	**This work**
F. australasica	Dai 15625	China	MN816726	MN810018	MN848829	MN848775	Chen et al. (2020)
F. australasica	Dai 15636 (Holotype)	China	MG008397	MG008450	MH636408	MH079402	Chen and Dai (2019)
F. australiana	Dai 18672	Australia	MN816703	MN810014	MN848848	MN848766	Chen et al. (2020)
F. bambusae	Dai 16599 (Holotype)	Thailand	MN816711	MN809999	MN848808	–	Chen et al. (2020)
F. caymanensis	JV 1908/74 (Holotype)	French Guiana	MT676832	MT676833	–	–	Vlasak et al. (2020)
F. caymanensis	JV 1408/5	Costa Rica	MW009110	MW009109	–	–	Vlasak et al. (2020)
F. centroamericana	JV 1607/93 (Holotype)	Costa Rica	MG008444	MG008460	MH636389	–	Chen and Dai (2019)
F. centroamericana	O 908267	Costa Rica	MG008443	–	–	–	Chen et al. (2019)
F. chrysea	JV 1607/106-J	Costa Rica	MN816736	MN810027	MN848818	MN848773	Chen et al. (2019)
F. contigua	Dai 13567A	China	MG008402	MG008455	MN848817	MN159386	Chen and Dai (2019)
F. contigua	Dai 16025	China	MG008401	MG008454	MH636386	MH079406	Chen et al. (2019)
F. costaricana	JV 1407/92 (Holotype)	Costa Rica	MG008446	MG008461	MH636400	–	Chen et al. (2019)
F. costaricana	JV 1504/85	Costa Rica	MG008413	MG478454	MH636401	–	Chen et al. (2019)
F. dollingeri	Dollinger 623 (Holotype)	USA	MW908540	MW898444	–	–	Bittencourt et al. (2024)
F. dollingeri	Dollinger 652	USA	MW908541	MW898445	–	–	Bittencourt et al. (2024)
F. eucalypti	Dai 18783	Australia	MN816730	MN810021	MN848832	MN848776	Chen and Dai (2019)
F. eucalypti	Dai 18792 (Holotype)	Australia	MN816731	MN810022	MN848831	–	Chen and Dai (2019)
F. ferrea	MUCL 45984 (Holotype)	France	KX961112	KY189112	MH636403	–	Chen and Yuan (2017)

Table 2 (continued)

Species	**Voucher specimens**	**Locality**	**GenBank accession numbers**				**Reference**
			ITS	**LSU**	***TEF1-α***	***RPB2***	
F. ferrea	Cui 11801	China	KX961101	KY189101	MN848823	–	Chen and Yuan (2017)
F. ferruginosa	Dai 13200	France	MN816702	MN809993	MN848802	MN848793	Chen et al. (2020)
F. ferruginosa	JV 0408/28	Czech Republic	KX961103	KY189103	MH636397	–	Chen and Yuan (2017)
F. ferruginosa	JV 1507/11-CN	Slovakia	MG008400	MG008453	MH636399	MH079404	Chen et al. (2019)
F. formosana	URM 91197	Brazil	MH392551	MH407350	–	–	Yuan et al. (2020)
F. formosana	URM 91243	Brazil	MH392552	MH407351	–	–	Yuan et al. (2020)
F. gibertaniae	**VF135**	**Brazil**	**PQ819480**	**PQ819430**	**PV185903**	**PV067187**	**This work**
F. gibertaniae	**WX2014-153(Holotype)**	**Brazil**	**PQ819481**	**–**	**–**	**–**	**This work**
F. gilva	JV 0709/75 (Holotype)	USA	MN816720	MN810007	MN848852	–	Chen et al. (2020)
F. gilvoides	MUGBt	Pakistan	ON427781	ON427810	ON479814	ON479791	Cho et al. (2023)
F. gilvoides	SFC2018042612 (Holotype)	Republic of Korea	ON427763	ON427793	ON479802	ON464729	Cho et al. (2023)
F. hawaiiana	JV 2208/H22-J (Holotype)	USA	OQ817709	OQ817855	OQ849746	–	Chen et al. (2023)
F. hawaiiana	JV 2208/H30-J	USA	OQ817710	OQ817856	OQ849747	–	Chen et al. (2023)
F. koreana	SFC2016072693 (Holotype)	Republic of Korea	ON427762	ON427792	ON479801	ON464728	Cho et al. (2023)
F. koreana	SFC20150625-07	Republic of Korea	ON427777	ON427806	ON479811	ON479788	Cho et al. (2023)
F. latispora	JV 0610/VII-Kout (Holotype)	Mexico	MG008436	MG008469	MH636396	–	Chen et al. (2019)
F. latispora	JV 1109/48	USA	MG008439	MG008468	MH636395	MN848799	Chen et al. (2019)
F. licnoides	URM 91236	Brazil	MH392554	MH407353	–	–	Yuan et al. (2020)
F. licnoides	URM 85067	Brazil	MH392557	MH407356	–	–	Yuan et al. (2020)
F. marquesiana	URM 83094 (Holotype)	Brazil	MH392544	MH407343	–	–	Yuan et al. (2020)
F. minutissima	JV 2208/H12-J	USA	OQ817711	OQ817857	OQ849748	–	Chen et al. (2023)
F. minutissima	JV 2208/H16-J (Holotype)	USA	OQ817712	OQ817858	OQ849749	–	Chen et al. (2023)

Table 2 (continued)

Species	Voucher specimens	Locality	GenBank accession numbers				Reference
			ITS	LSU	*TEF1-α*	*RPB2*	
F. nebularis	FLOR75502	Brazil	OR771951	OR827319	–	–	Comin et al. (2024)
F. nebularis	FLOR75497 (Holotype)	Brazil	OR771947	OR827316	–	–	Comin et al. (2024)
F. nebularis	FLOR 52882	Brazil	MN809978	MN809983	–	–	Bittencourt et al. (2024)
F. palomari	JV 1004/5-J (Holotype)	USA	MN816737	–	–	–	Chen et al. (2020)
F. palomari	JV 1305/3-J	USA	MN816738	MN810028	MN848801	–	Chen et al. (2020)
F. punctatiformis	Dollinger 872	unknown	MH050753	–	–	–	Chen and Dai (2019)
F. punctatiformis	Dai 17443	Brazil	MH050755	MH050764	–	–	Chen and Dai (2019)
F. rhabarbarinus	Dai16550	China	MN816744.1	MN810036.1	MN848836		Chen et al. (2020)
F. rhabarbarina	Dai 16226	China	MN816743	MN810035	MN848838	MN848784	Chen et al. (2020)
F. roseocinerea	JV 1407/84	Costa Rica	MN816740	MN810030	MN848819	MN848774	Chen et al. (2020)
F. roseocinerea	JV 1109/78-J	USA	MN816742	MN810032	MN848820	–	Chen et al. (2020)
F. rufitincta	JV 1008/25	USA	KJ940029	KX058575	–	–	Chen and Dai (2019)
F. rufitincta	JV 0904/142	USA	KJ940030	KX058574	–	–	Chen and Dai (2019)
F. saracaensis	**AS3229**	**Brazil**	**PQ819479**	**PQ819428**	**PV185901**	**PV067185**	**This work**
F. saracaensis	**AS3239 (Holotype)**	**Brazil**	**PQ878605**	**PQ819429**	**PV185902**	**PV067186**	**This work**
F. sarcites	FLOR 67948	Brazil	MN809973	MN809981	–	–	Bittencourt et al. (2024)
F. sarcites	FLOR 67297	Brazil	MN809974	MN809982	–	–	Bittencourt et al. (2024)
F. sarcites	JV 0402/20-Kout	Venezuela	MZ169039	–	–	–	Bittencourt et al. (2024)
F. semiarida	URM 83800 (Holotype)	Brazil	MH392562	MH407361	–	–	Yuan et al. (2020)
F. semiarida	URM 83926	Brazil	MH392565	MH407364	–	–	Yuan et al. (2020)
F. senex	Dai 17043	–	MN816747	MN810039	MN848835	MN848786	
F. septiseta	Dai 12820 (Holotype)	China	MG008405	MN810033	MH636394	–	Chen et al. (2019)
F. scruposa	URM91223	Brazil	MH392550.1	MH407349.1	–	–	Yuan et al. (2020)
F. scruposa	URM 83957	Brazil	MH392545	MH407344	–	–	Yuan et al. (2020)
F. sinica	Dai 15489	China	MG008407	MG008458	MH636393	MN848798	Chen et al. (2019)
F. sinica	Dai 15468 (Holotype)	China	MG008412	MG008459	MH636392	–	Chen et al. (2019)

Table 2 (continued)

Species	**Voucher specimens**	**Locality**	**GenBank accession numbers**				**Reference**
			ITS	**LSU**	***TEF1-α***	***RPB2***	
F. subchrysea	Dai 16201 (Holotype)	China	MN816708	MN809997	MN848811	MN848796	Chen et al. (2020)
F. subchrysea	Dai 17656	China	MN816709	MN809998	MN848812	–	Chen et al. (2020)
F. torulosa	JV 1405/2	Czech Republic	KX961106	KY189106	MH636405	MN848779	Chen and Yuan (2017)
F. torulosa	Dai 15518	China	MN816732	MN810023	MN848827	MN848781	Chen et al. (2020)
F. viticola	He 2081	USA	MN121829	MN121770	–	–	Chen and Dai (2019)
F. viticola	He 2123	USA	MN816725	MN810017	–	–	Chen and Dai (2019)
F. wahlbergii	JV 1312/20-Kout	Spain	MN816727	MG008462	–	–	Chen and Dai (2019)
F. yunnanensis	Cui 8182	China	MH050756	MN810029	–	MN848789	Chen and Dai (2019)
F. yunnanensis	Dai 15637	China	MH050757	MH050768	–	–	Chen and Dai (2019)
Outgrup							
Coniferiporia sulphurascens	Cui 10429	China	KR350565	KR350555	–	–	Zhou et al. (2016)
Phellinidium fragrans	CBS 202.90	USA	AY558619	AY059027	–	–	Zhou et al. (2016)

Table 3 – Morphological comparison of *Fuscoporia* species from the Brazilian Amazon.

Species	Basidiomata	Pores per mm	Hyphal system	Setae hymenial morphology	Setae size (µm)	Cystidioles	Basidiospores size (µm)	Basidiospores shape	Reference
F. aureofulva	Annual to biannual, effused-reflexed to pileate	10−12	Subdimitic and dimitic	Subulate to straight	(13.8–)15.7–24.5(–29) × (5.6–)6–9(–11.1)	Lageniform	(2.1–)3–3.6(–3.9) × (2–)3–3.7	Globose	This work
F. chrysea	Annual, resupinate to effused-reflexed	6	Dimitic	Straight	(20) 25–40 × 5–8	Absent	3.5-4.5 × 2.5-3	Broadly ellipsoid to drop-shaped	Ryvarden (2004)
F. gibertoniae	Annual, pileate to effused-reflexed	8−13	Subdimitic and dimitic	Subulate to straight	(12–)15–23(–26) × (3–)4–5(–6)	Fusoid	(2.5–)2.8–3.7(–4.1) × (2–)3–3.7	Globose to ellipsoid	This work
F. griseopora	Perennial, pileate	6−7	Dimitic	Absent	−	Absent	4–5.5	Globose	Ryvarden (2004)
F. labyrinthica	Perennial, resupinate to pileate	2−3	Dimitic	Subulate	40−60 × 7−9	Absent	5−6 × 4.5-5	Subglobose to elliptic	Soares et al. (2018)
F. licnoides	Annual, pileate	7–9	Dimitic	Lanceolate to ventricose	20.6 × 4.6	Absent	4–5 × 2.5–3.5	Oblong-ellipsoid to broadly ellipsoid	Yuan et al. (2020)
F. rhabarbarina	Perennial, effused-reflexed	6−9	Dimitic	Straight	20–30 × 4–5	Present	(3.2–)3.3–4.1(–4.2) × (2–)2.1–2.4(–2.5)	Broadly ellpsoid to ellipsoid	Groposo et al. (2007); Dai (2010)
F. saracaensis	Annual to biannual, pileate to effused-reflexed	8–10	Dimitic	Subulate to ventricose	18–30(–40) × 4–5 (–6)	fusoid and lageniform	3–5 × (1.8–) 2.5–3 (–4)	Subcylindrical to oblong-ellipsoid	This work
F. senex	Perennial, pileate	7–9(11)	Dimitic	Straight	15–30 (40) × 5–9	Present	4.5–6 × 3.5–5	Broadly ellipsoid	Dai (2010)

Table 3 (continued)

F. scruposa	Annual, effused-reflexed to pileate	8–10	Dimitic	Straight	−	Absent	3.5–5 × 2.5–3	Ellipsoid	Oliveira and Gibertoni (2023)
F. undulata	Annual to biennial, resupinate to effused-reflexed	4–6	Dimitic	Sub-ventricose to acuminate, rather scattered, straight	18–25 × 6–8.5	Absent	3.5–4.5 × 2.5–3.5	Broadly ellipsoid	Ryvarden (2004)

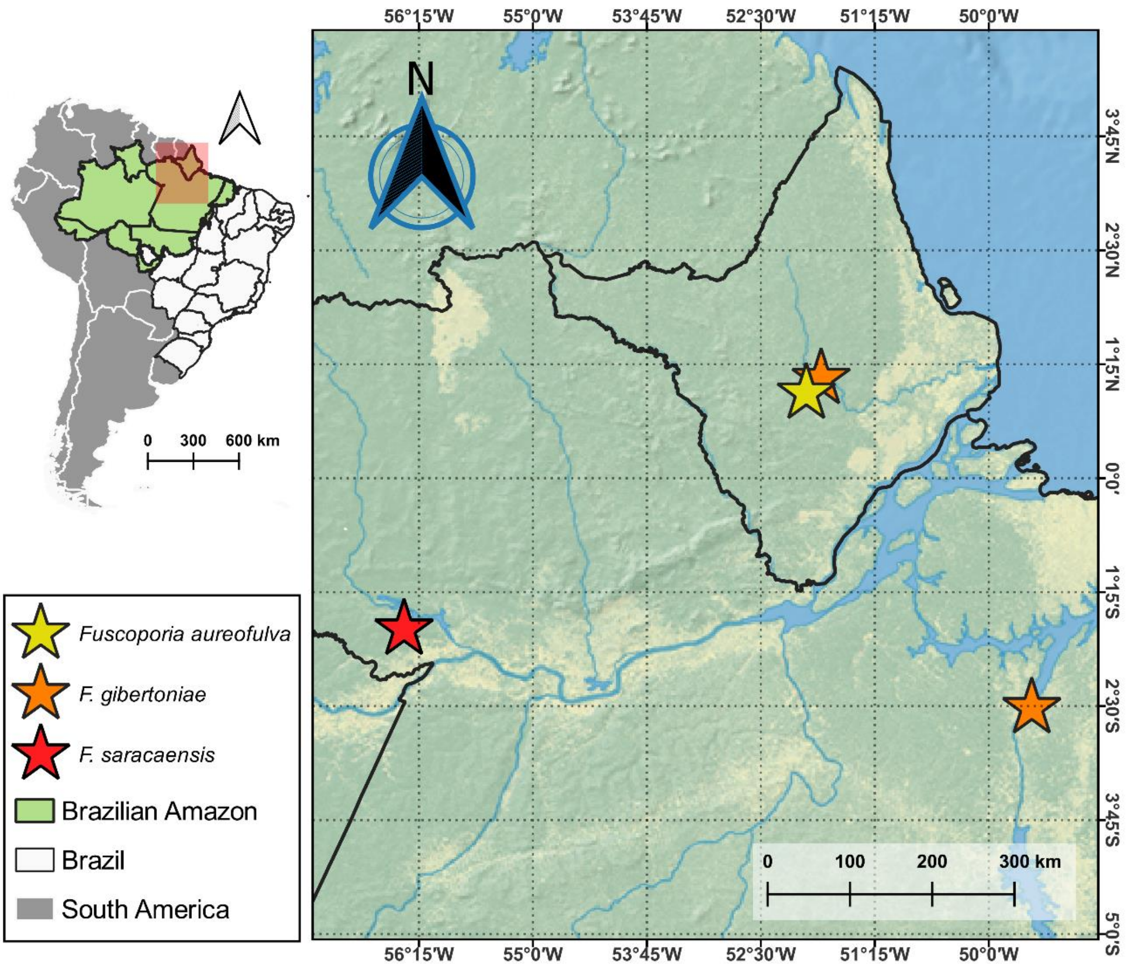

Fig. 1 – Map of the distribution of new *Fuscoporia* species from the Eastern Brazilian Amazon studied in this work

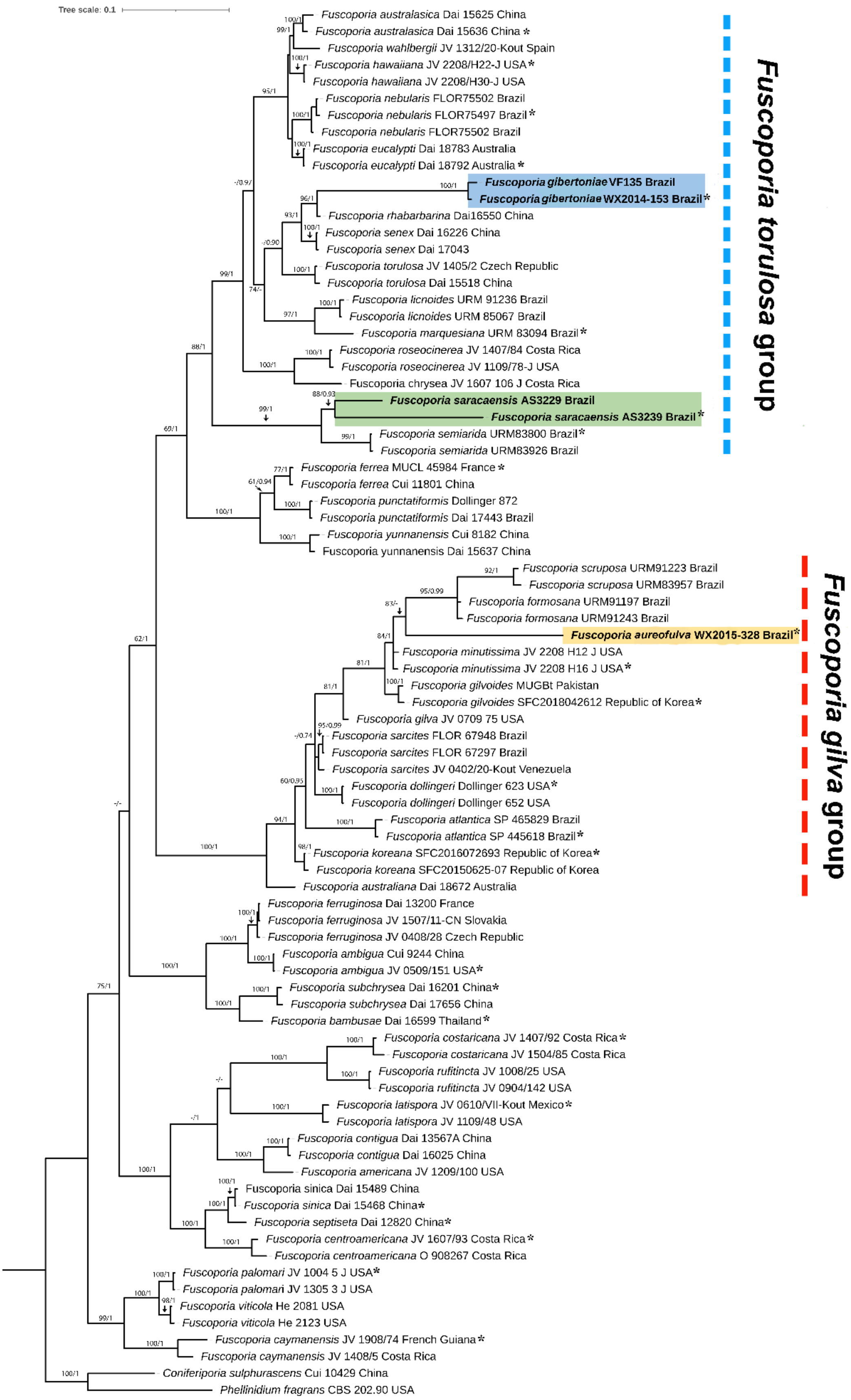

Fig. 2 – Phylogenetic reconstruction of *Fuscoporia* species based on a Bayesian inference (BI) tree of the dataset of the combined ITS, LSU, *RPB2* and *TEF1-α* sequences. ML values of BS (≥60%) and BPP (≥0.7) are shown above the branches. Sequences of the species studied in this work are in bold (* = Type material)

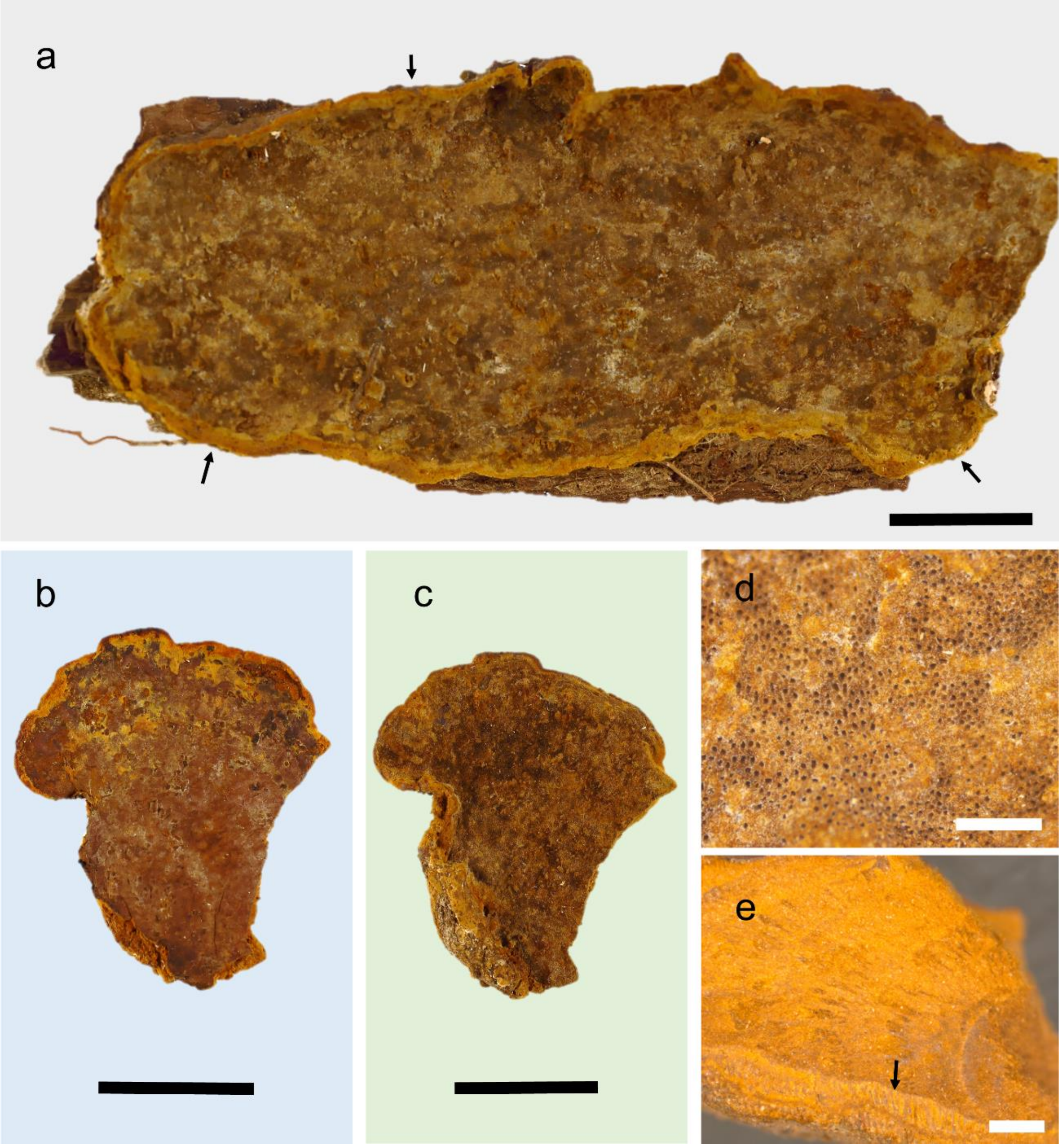

Fig. 3 – Macroscopic features of *Fuscoporia aureofulva* sp. nov. **a** Effused-reflexed basidiomata (details of margin shown by black arrow). **b** Pileate basidiomata. **c** Hymenophore. **d** Pore surface. **e** Details of the context and of the tubes (black arrow). Bars: **a-b** = 2 cm; **d-e** = 1 mm

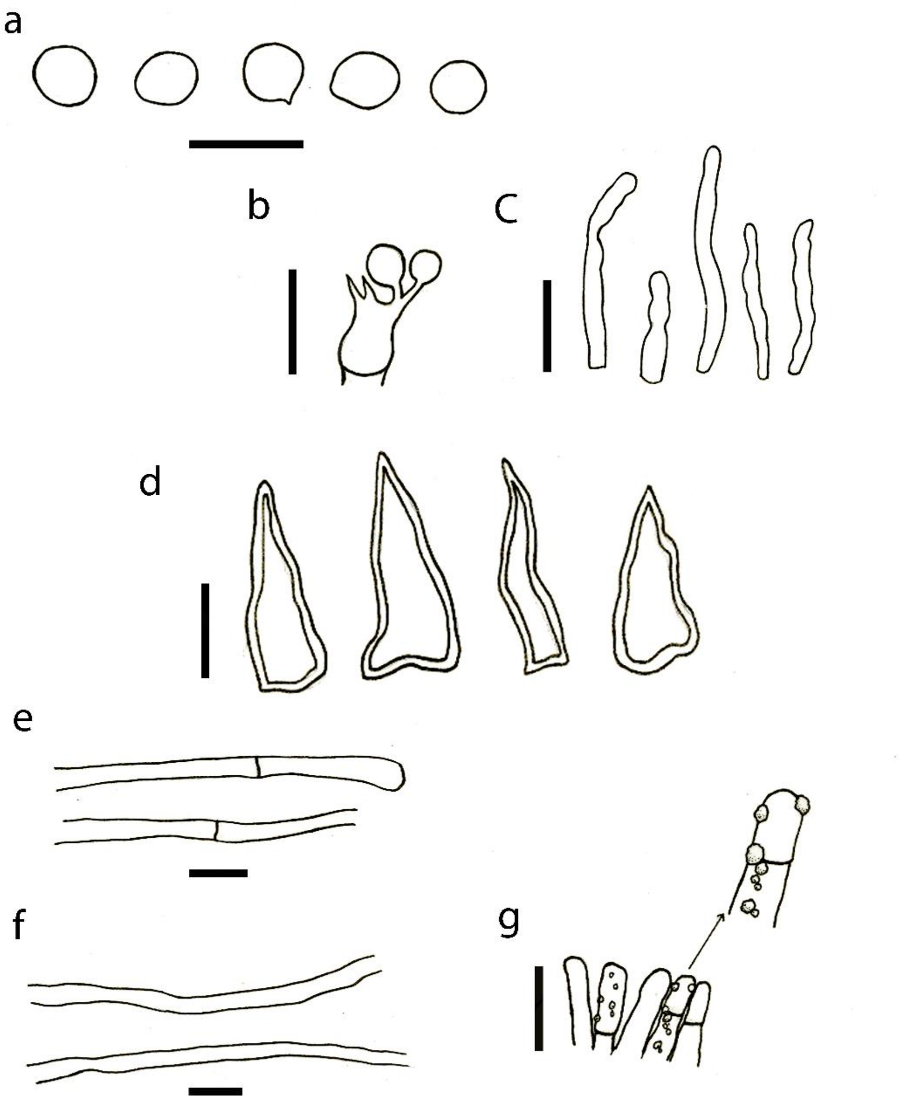

Fig. 4 – Microscopic features of *Fuscoporia aureofulva* sp. nov. **a** Basidiospores. **b** Basidia. **c** Cystidioles. **d** Hymenial setae. **e** Generative hyphae. **f** Skeletal hyphae. **g** Encrusted hyphae. Bars: **a-b** = 5 µm; **c-d** = 10 µm. Drawing by Carlos Alvarez (MPEG)

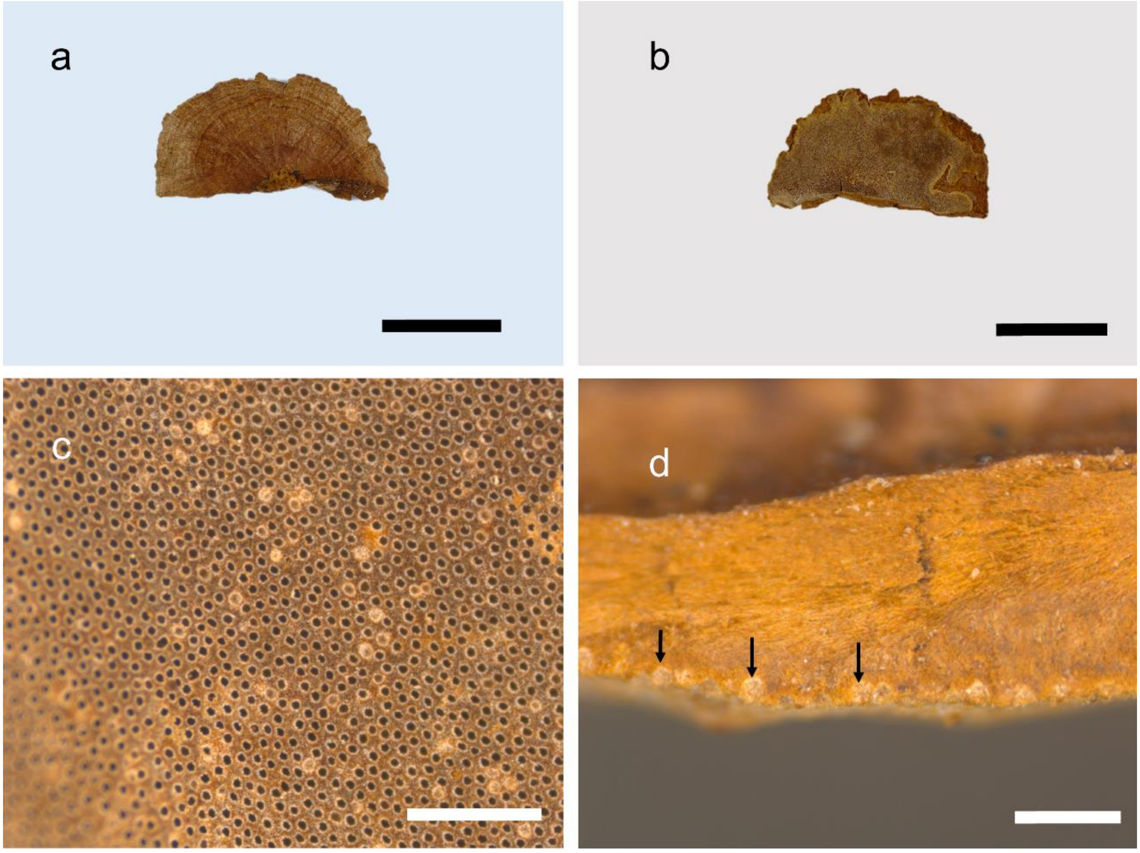

Fig. 5 – Macroscopic features of *Fuscoporia gibertoniae* sp. nov. **a** Basidiomata. **b-c** Hymenophore. **d** Details of the context and of the tubes (black arrow). Bars: **a-b** = 2 cm; **c** = 1 mm; **d** = 0.5 mm

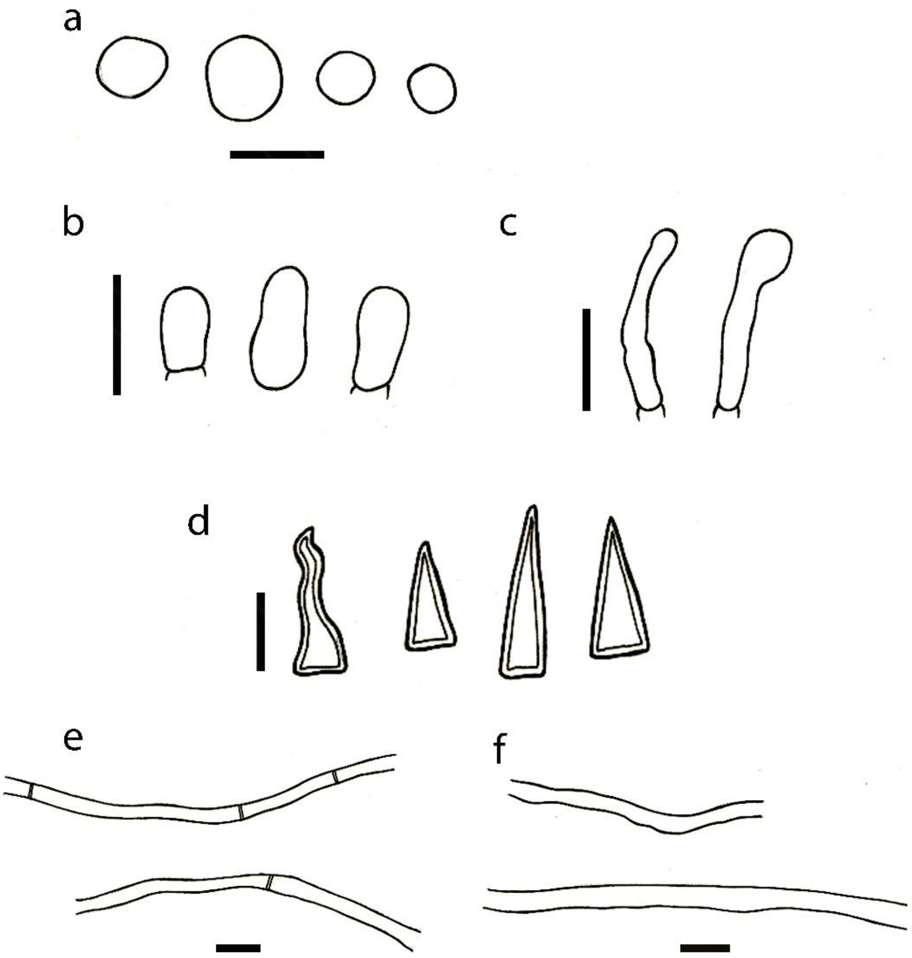

Fig. 6 – Microscopic features of *Fuscoporia gibertoniae* sp. nov. **a** Basidiospores. **b** Basidioles. **c** Cystidioles. **d** Hymenial setae. **e** Generative hyphae. **f** Skeletal hyphae. Bars: **a** = 5 μm; **b-g** = 10 μm. Drawing by Carlos Alvarez (MPEG)

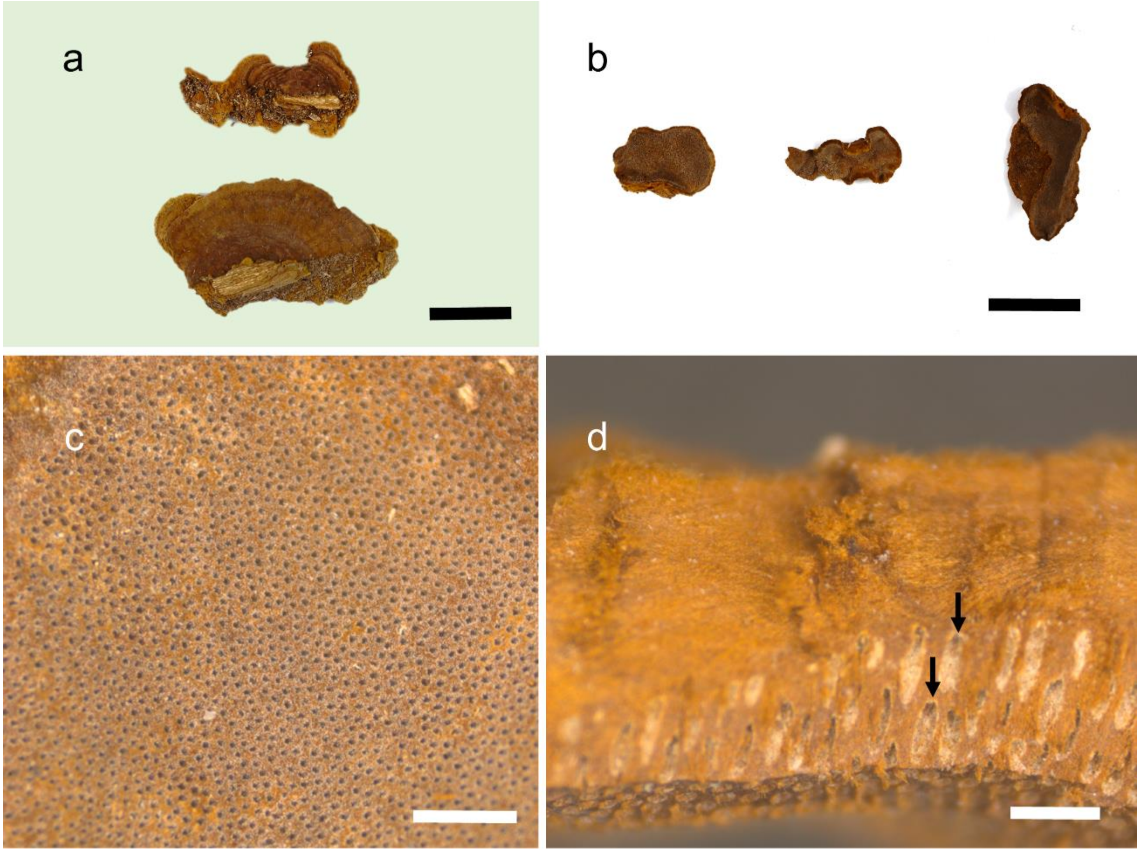

Fig. 7 – Macroscopic features of *Fuscoporia saracaensis* sp. nov. **a** Basidiomata. **b-c** Hymenophore. **d** Details of the context and of the tubes (black arrow). Bars: **a** = 1 cm; **b** = 2 cm; **c** = 1 mm; **d** = 0.5 mm

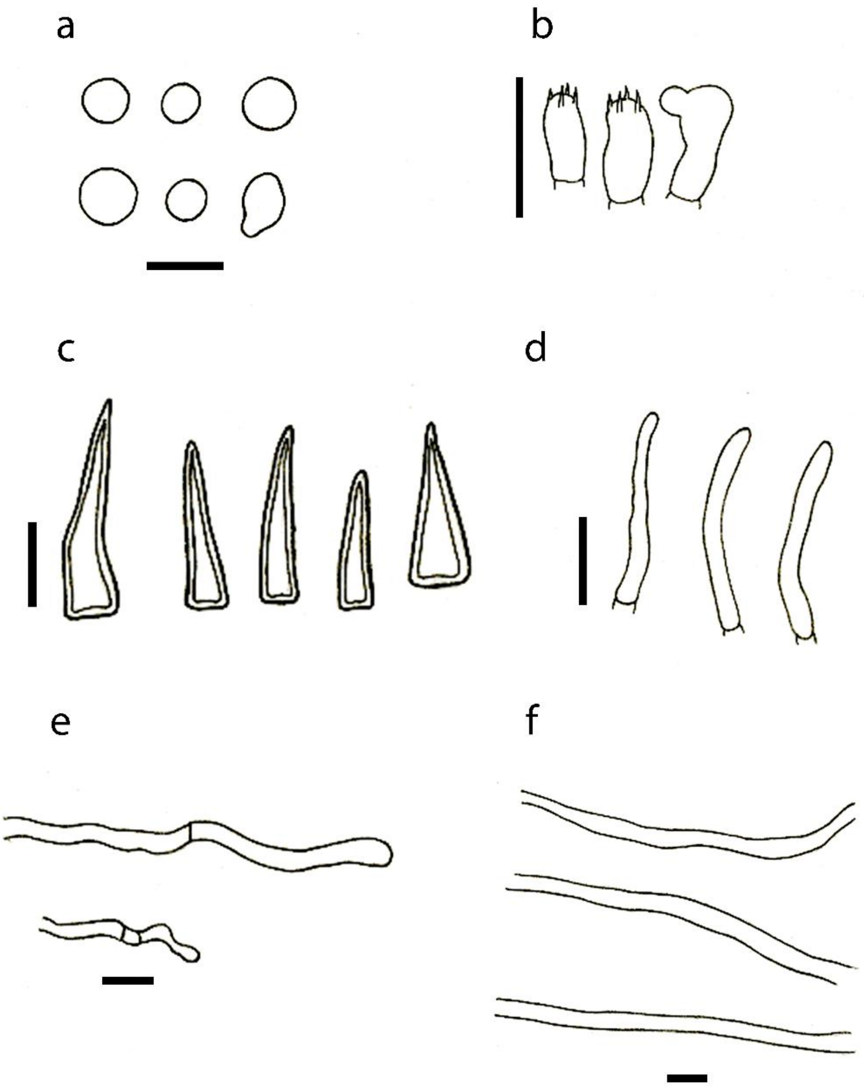

Fig. 8 – Microscopic features of *Fuscoporia saracaensis* sp. nov. **a** Basidiospores. **b** Basidia. **c** Hymenial setae. **d** Cystidioles. **e** Generative hyphae. **f** Skeletal hyphae. Bars: **a** = 5 µm; **b-f** = 10 µm. Drawing by Carlos Alvarez (MPEG)

CONSIDERAÇÕES FINAIS

O levantamento de espécies de Hymenochaetaceae na Amazônia brasileira realizado por meio de literatura científica e bancos de dados, permitiu mapear a distribuição das espécies e identificar importantes lacunas de amostragem em grande parte da região amazônica. Além disso, A maioria das espécies foi registrada apenas com base em dados morfológicos, os quais não consideram a baixa heterogeneidade fenotípica e não refletem a real riqueza do grupo. Assim, torna-se evidente a importância de revisões e identificações filogenéticas para ampliar o entendimento sobre a diversidade de Hymenochaetaceae na Amazônia.

A abordagem integrativa de caracteres fenotípicos e dados moleculares revelou evidências robustas para a descrição de quatro novas espécies, destacando o enorme potencial da biodiversidade amazônica. Dessa forma, analises que abranjam a maior quantidade de caracteres são indispensáveis para aprofundar a compreensão das relações filogenéticas de Hymenochaetaceae.