Incentives and challenges for mycologists in the tropics

Meike Piepenbring, Hermine Lotz-Winter and Tina Antje Hofmann

Abstract: Because of a relatively late start, a high number of fungal species, a low number of mycologists, and difficult working conditions, mycology in the tropics is still in a pioneer phase. Basic investigation consisting of field work, collections, identifications, isolation of living fungi in pure cultures, and the retrieval of molecular sequence data is lacking for most tropical fungi. However, taxonomic data, information on the morphology and ecology of the fungi as well as on their geographical distribution are required for any further research on phylogenetic, genetic, biochemical, or biotechnological characteristics of fungi as well as for applied mycological investigation. Scientific data and experience of the authors from fieldwork in Panama are used to illustrate the specific situation of mycologists in the tropics. The present publication includes some primary data, i.e. new records of fungi for Panama and a statistical analysis of identification data concerning fungi in Panama versus Germany. The main focus of this contribution is an analysis of the incentives and challenges that mycologists typically experience in the tropics and the urgent need to enhance teaching and research activities on tropical fungi that are threatened by extinction due to habitat loss.

1. Introduction

1.1. Diversity and functions of fungi in the tropics

Tropical ecosystems harbour an overwhelming diversity of animals, plants, fungi, and other microorganisms. The diversity of fungi is supposed to be higher in the tropics than in extratropical areas, due to the following aspects (comp. Piepenbring 2015):

– Mycological fieldwork in the tropics reveals high numbers of different fungal species. Apparently, it is impossible to obtain complete inventories, as shown by Piepenbring et al. (2012a). In the context of this study, at least two days of laboratory work were necessary after every two hours of fungal foray. DNA metabarcoding data of soil samples revealed diversity maxima in the tropics for most fungal groups (Tedersoo et al. 2014).

– Numerous fungi are associated with plants and insects that are more diverse in the tropics than in extratropical regions. Long-lasting leaves allow the colonization by numerous epi- and endophyllous fungi (e.g. Arnold & Lutzoni 2007).

– High humidity values are favourable for the growth of fungi and a high diversity of different climatic zones provides numerous niches.

This high diversity of fungal species correlates with a complex systematic diversity, a kaleidoscope of different forms and developmental patterns, colours, secondary metabolites, and corresponding physiology as well as genetic

backgrounds, as well as ecological diversity reflected by diversity of substrates, interactions with plants, animals, other fungi, or other microorganisms.

Worldwide, diversity of fungi is estimated to exceed 1.5 million species (Hawksworth 1991, 2001), about five times more than plant species. Based on second generation sequencing, estimations of up to 5.1 million species of fungi were made (O'Brien et al. 2005).

Fungi play crucial roles in natural ecosystems, because they decompose all types of dead organic material contributing to nutrient cycles, promote the development of plants as mycorrhizal mutualistic symbionts, are a food source for fungivorous animals, and control animal populations as parasites. Further ecosystem services provided by fungi are protection of soil against erosion, water filtration, degradation of complex chemical compounds, such as lignin, and contributions to maintain plant diversity. Lichens are pioneer organisms colonizing substrates in extreme living conditions and supply organic compounds to their habitat by photosynthesis and nitrogen fixation. For human beings, fungi are potentially harmful as pathogens of humans, livestock, pets, or cultivated plants and beneficial as food, medicine, for pharmaceuticals, for biotechnological purposes, and for biological control, among others. Mycological knowledge is needed to better understand the role of fungi in ecosystems, to profit from useful fungal capacities, and to gain a better control over harmful fungal species.

1.2. History of mycological investigation in the tropics

The investigation of fungi in the tropics was not important during the history of mycology as is evident by the almost complete absence of this subject in historical reviews of general mycology (Ainsworth 1976, Dörfelt & Heklau 1998). While tropical animals and plants were in the focus of interest of missionaries and explorers since the 16th century, only few mycologists were active in the tropics until the middle of the 19th century (comp. Piepenbring 2015). Until then, descriptions of tropical fungi were based on specimens collected by naturalists and investigated by European mycologists who mostly had never visited a tropical country. Afterwards, an increasing number of mycologists living in extratropical countries travelled to the tropics, collected fungi during short periods of time, and analysed them in their home countries. However, their number and activities never reached those of zoologists or botanists.

Due to a late start, relatively few mycologists confronted with the huge diversity of tropical fungi, investigation of specimens collected by other people, and short term forays by foreign mycologists mostly specialized on certain groups of fungi, mycological investigation in the tropics is still in a pioneer phase:

– Numerous areas of tropical vegetation have never been visited by mycologists who communicated their results in scientific publications (e.g. Piepenbring 2007, Piepenbring et al. 2011).

– Descriptions of tropical fungal species in literature are often incomplete, mainly by lacking data on characteristics of fresh specimens like original colours, texture, odour, or taste, substrates, ontogeny, life cycles, intraspecific variability of species, and DNA data.

– Checklists of fungi in tropical countries are incomplete or completely lacking.

– Monographs for most tropical groups of fungi are lacking and monographs on fungal groups occurring in temperate as well as tropical zones often do not include tropical taxa. As a consequence, for tropical fungi comprehensive keys are lacking and numerous synonyms still have to be recognized.

– Information for identification is scattered in more or less accessible journals all over the world or hidden in libraries as unpublished theses.

– Type specimens and other specimens are mostly deposited outside the original countries, often difficult to obtain, and often in bad condition (fragmentary).

– Only few cultures are available from tropical fungi and most tropical countries lack national culture collections.

– DNA sequence data are lacking for most tropical fungi and existing data might not be reliable (comp. Nilsson et al. 2006).

Today, an increasing number of investigators affiliated to universities and other research institutions in tropical countries face tropical fungal diversity and make important contributions, like field guides, specimens, descriptions of new species, etc. However, any mycologist working in the tropics is confronted with numerous challenges resulting from these historical facts and from the tropical environment.

1.3. Challenges for mycologists in tropical environment

As high humidity and temperature values in the tropics make preservation of fleshy fungal fruiting bodies difficult, the investigation of lichens apparently started earlier than the one of non-lichenized fungi, and knowledge on tropical lichens is somewhat more complete than the one of non-lichenized fungi. Among non-lichenized species, fungi with hard fruiting bodies that mostly retain their original shape and colours, produced by species of Polyporales or Xylariales, for example, were more frequently collected than fleshy macrofungi (e.g. Lodge et al. 2002). Still today, in times of plastic bags, silica gel, and electricity (although not everywhere), mycologists have to be well

organized. Especially fleshy specimens have to be studied quickly, dried and conserved in dry conditions, because otherwise they rapidly absorb humidity and are colonized by moulds. Small animals, like mites, cockroaches and ants have to be considered as fungivores as well as contaminants of cultures. Relatively high concentrations of contaminating spores in the air complicate the isolation and maintenance of pure cultures of fungi in the tropics.

Although fungi grow everywhere in the tropics and although an increasing number of national parks and other areas with natural vegetation are accessible by roads and equipped with trails, mycological field forays in the tropics are still a challenge today, due to hot climate, heavy rains, landslides and other logistical problems, as well as physical efforts necessary to reach remote areas. In addition, tropical countries might have a problematic political environment and/or mycologists might be threatened by tropical diseases and poisonous animals. Last but not least, there are increasing bureaucratic challenges to be faced to obtain collection and export permits according to national legislations.

2. Materials and methods

Material relevant for the subject of the present paper are specimens of fungi collected in tropical areas. The fungi are discovered during field trips to more or less remote areas, photos are taken of the fungi in situ and in the lab, specimens are collected, and notes are made of the exact place of collection (GPS), substrate, and observed interactions. In the laboratory, characteristics like colour, taste, odour, spore prints, and specific reactions with chemical reagents are recorded immediately, while other characteristics can be investigated on fresh or dry specimens. Specimens are dried and enclosed in plastic bags with silica gel.

For taxonomic identification based on morphology, sections of different parts of the fungal specimens are mounted in water, KOH, or other media and analysed by light microscopy. Anatomical characteristics are documented by text, measurements, drawings, and microphotographs for comparison with data in literature.

Morphological characteristics can be combined with molecular sequence data, that help with identification when reliable data are available in public sequence databases, e.g. GenBank.

In order to further investigate a given fungus, it is very important to obtain living cultures from fresh specimens.

Relevant research questions in this context:

What is the name of the fungus? Is it a known species or might it be new to science?

To which systematic group does it belong?

What are the substrates (plant, animal), substrate (host) specificity, the way of nutrition (saprotrophic, parasitic, or mutualistic) and associated organisms? Is the substrate (host) known or new to science?

What is the area of known distribution of this species? Does it correspond to a new record for the area of collection?

For an analysis of taxonomic results obtained by the authors, species lists of the Majagua project in Western Panama (Piepenbring et al. 2012a, 2015, plus results obtained by H. Lotz-Winter, T. Hofmann and S. Rudolph in 2014 and 2015 as well as by Piepenbring in 2015; comp. Appendix A) and of the Taunus project in Hesse, Germany (Rudolph 2016) were analysed concerning the level of identification of the different species. Only sexual states of fungi were considered on the levels of division (class), order (family), genus and species.

Specimens illustrated and/or representing new records for Panama (deposited in UCH and/or PMA; HLW = H. Lotz-Winter, MP = M. Piepenbring, TH = T.A. Hofmann; all collected in Panama, Chiriquí province, if not otherwise indicated):

Astrocystis mirabilis Berk. & Broome on dead stems of *Chusquea* sp. Volcán, Paso Ancho, N 08° 48' 56.6" W 82° 34' 43.8", approx. 1900 m a.s.l., 1.8.2015, leg. TH, HLW, MP & students PA 528, det. HLW & MP based on Læssøe & Spooner (1993).

Battarrea phalloides (Dicks.) Pers. on soil in cloud forest. Bugaba district, corregimiento de Cerro Punta, Finca de Don Lara, N 8° 50' 55.2" W 82° 35' 33.6", 1830 m a.s.l., 1.3.2013, leg. MP, O. Cáceres, TH, F.A. Lara & M. Mardones 5167, det. H. Jüngling & MP based on Cortez et al. (2009) and Esqueda et al. (2002).

Dicheirinia panamensis J.R. Hern., M. Piepenbr. & Vega Rios (0) on *Cojoba rufescens*. Boquete, close to bridge in town, 25.4.2009, leg. MP & students 4725, det. MP based on Hernández et al. (2007).

Henningsomyces minimus (Cooke & W. Phillips) Kuntze on dead wood. Dolega district, Los Algarrobos, trail to the Majagua river, N 8° 29' 26.4" W 82° 26' 0.2", 111 m a.s.l., 13.6.2014, leg. HLW & S. Rudolph PA 135, det. HLW & S. Rudolph based on Agerer (1973) and Wei & Qin (2009).

Hygrocybe acutoconica (Clem.) Singer on soil. At the same place as PA 135, 13.6.2014, leg. HLW & S. Rudolph PA 132, det. HLW based on Cantrell & Lodge (2000) and Boertmann (2010).

Iodowynnea auriformis (Pat. ex Le Gal) Medel, Guzmán & S. Chacón on burnt soil. At the same place as PA 135, 25.5.2014, leg. HLW & S. Rudolph PA 16, det. HLW based on Medel et al. (1996).

Rigidoporus microporus (Sw.) Overeem on dead wood. At the same place as PA 135, 13.8.2015, leg. MP & J. del Carmen Quiel 5281, det. MP based on Guzmán & Piepenbring (2011).

Russula sp. on soil. Boquete district, path to the summit of Volcán Barú, N 8° 47' 54.4'' W 82° 30' 41.8", 2491 m a.s.l., 23.7.2015, leg. S. Cáceres & R. Valdés PAN 381, det. HLW.

Tetrapyrgos nigripes (Fr.) E. Horak on dead stick. At the same place as PA 135, 13.8.2015, leg. MP & J. del Carmen Quiel 5273, det. MP based on Pegler (1983).

Vezdaea sp. on dead parts of living leaves of *Arachnioides* cf. *denticulata* (Sw.) Proctor (det. R. Mangelsdorff). Parque Internacional la Amistad, Cerro Picacho trail (G2), N 08° 53' 24" W 82° 37' 36", approx. 2550 m a.s.l., 10.4.2006, leg. MP et al. ppMP 842, det. P. Döbbeler and lichenologists at Graz, conf. M. Piepenbring based on Poelt & Döbbeler (1975).

Xylaria comosa (Mont.) Fr. on dead wood. Panama province, Parque Nacional Soberanía, Sendero del Charco, approx. 50 m a.s.l., 5.8.2008, MP & participants of the tropical mycology course 4460, det. J. Fournier & MP based on Dennis (1956). Chiriquí province, Chorogo, Río Blanco, Finca of D. Cáceres, N 8° 20' 6.4'' W 82° 00' 10.6'', 214 m a.s.l., 13.7.2012, leg. MP, D. Cáceres, A. Krohn & M. Rosas 5117, det. MP based on Dennis (1956).

3. Mycological investigation in Panama

When the senior author decided that she wanted to obtain knowledge about any fungus found in the field for teaching mycology in Panama since 2003, she recognized a few species, like *Schizophyllum commune* or *Ceratiomyxa fruticulosa*, that are cosmopolitan, for some other fungi she recognized genera (e.g. *Ganoderma*, *Lactarius*, *Marasmius*, *Mycena*, *Russula*, *Xylaria*), but for many fungi she had no idea. There were even orders she was not able to recognize. There was nobody to ask, no mycologist at the local university, no amateur mycologists, no national mycological association. No field guide for macrofungi of Panama was available, but a few books for mushrooms in the neighbouring countries of Costa Rica and Colombia. The chance, however, that a given mushroom found in Panama was included in these books, was very low. The only flora available for the neotropics, the Fungus flora of Venezuela and adjacent countries (Dennis 1970) provides only few characteristics for identification, is incomplete, and needs to be updated. In contrast to the situation concerning vascular plants, with approximately 9,500 species being

listed by Correa et al. (2004), there was no checklist for fungi in Panama and only few fungal groups were covered by monographic studies.

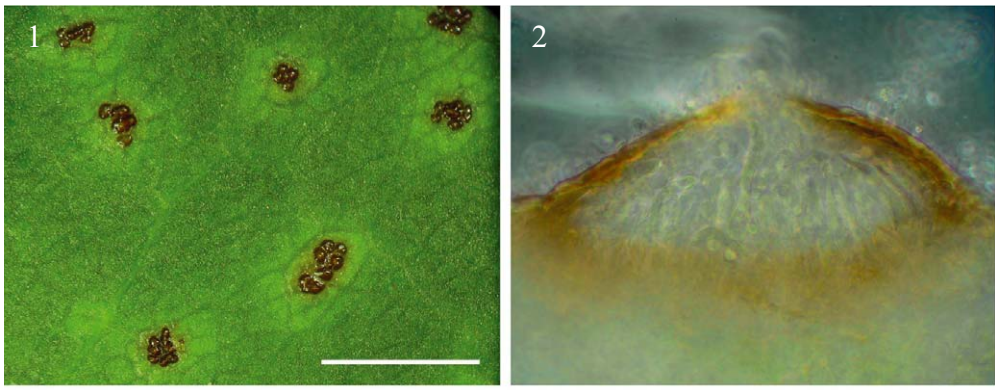
The best strategy to gain fungal species knowledge was the following: go to the field, recognize fungal groups (mostly orders), make good documentations of species (photos, key characteristics, drawings), send specimens and data to specialists of the respective group, and learn from their answers. Some specialists did a very good job and long-term collaborations resulted from this exchange. Others agreed to collaborate but did not contribute identifications, partly due to inadequate documentation and/or preservation of specimens. In recent years, internet became a very useful tool for this kind of exchange of information (photos, data vs. identification). However, it is very important to critically check identifications received via internet platforms against descriptions in literature.

Scientific identifications and records include at least the up-to-date scientific name, collection and identification data, citation of literature used for the identification, eventually critical remarks concerning the identification, and the specimen has to be deposited in an official herbarium in the country of origin. Molecular barcoding data should be obtained (at least LSU and ITS region of rDNA) and deposited in GenBank. In the case of microfungi, DNA analysis can be a challenge, because fungal structures present only small quantities of DNA and because they are often mixed up with other fungi.

Culturing fungi in the tropics often is difficult, too, because of the high amount of contaminating spores of fungi and/or bacteria and small animals (mites, ants) as well as sometimes rudimentary laboratory facilities, especially in field stations close to primary vegetation.

Research on citations of fungi for Panama in the Senckenberg library at Frankfurt am Main, Germany, revealed records of 1,807 species of fungi for Panama in about 300 publications in 2006 (Piepenbring 2006, 2007). This checklist was updated in 2011 and 2013 as more records were found in old literature and more records were published, so nowadays the checklist comprises 2,772 species of fungi for Panama in 460 publications (http://biogeodb.stri.si.edu/fungi).

Visits to Panama for at least one month every year as well as permanent work in Panama during 2008 and 2009, allowed the senior author, her students, and collaborators to make long-term observations of selected species or groups of species, resulting in phenological observations (Piepenbring et al. 2015) and details like the discovery of spermatogonia of *Dicheirinia panamensis* (Figs. 1–2).



Figs. 1–2: *Dicheirinia panamensis* (Pucciniales) on *Cojoba rufescens*: spermatogonia as seen by stereomicroscopy (Fig. 1) and in longitudinal section, as seen by light microscopy (Fig. 2). Uredinia and telia were described for this fungus by Hernández et al. (2007). By repeated observation of the rust at the type locality, in 2009 this new stage of the life cycle was discovered (Piepenbring et al. 4725). Fig. 1. Scale bar = 2 mm.

The elaboration of monographs requires long periods of time dedicated to the group, e.g. approximately nine years for the smut fungi of the Neotropics (Piepenbring 2003). Therefore, it is not possible to prepare monographs in the context of students' theses unless the group is small, like *Graphiola* with 12 species or *Favolaschia* (Gillen et al. 2012, Piepenbring et al. 2012b). For large groups of plant parasitic microfungi it is recommendable to cover fungal species on plant species belonging to a specific family or a geographical part of the diversity of the group.

The most common steps for the identification of a tropical fungus can be summarized in a key as proposed in the following (based on an idea by G. Hagedorn, pers. com.):

1 The fungus has evident, unique macroscopic characteristics and is represented by a good picture and/or description in a field guide available for local fungi ..... You luckily identified a common species.

1′ The fungus does not present evident, unique macroscopic characteristics and/or cannot be found in a field guide, or no local field guide is available..... 2

2 You are able to identify the order or another group of the fungus 3

2′ You are not able to identify the order or another group of the fungus 7

3 There is a monograph available for the order or other group of the fungus – get it! 5

3′ There is no monograph available 4

4 You have time and funding for investigation ..... Write the monograph!

4′ You do not have time and/or funding 7

5 You are able to use the key and you obtain an identification.....
..... You were lucky and did a nice job!

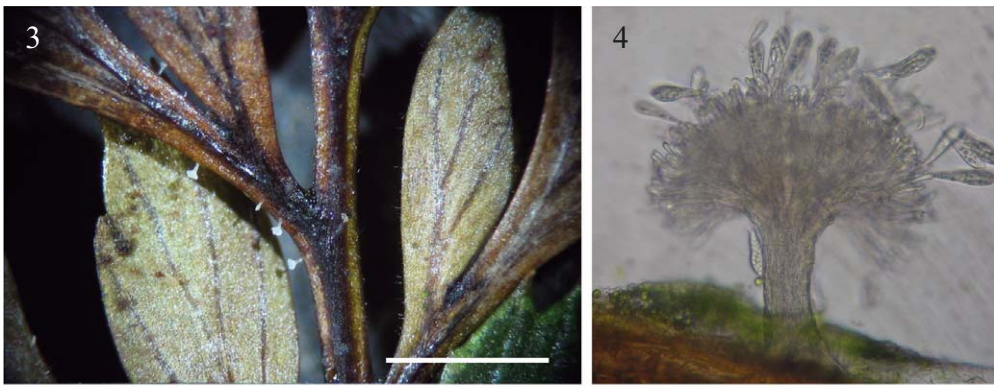
5′ You do not reach a convincing identification..... 6

6 You might have found a species that has been described after the monograph was published..... Revise recent literature in order to reach a conclusion or contact specialists (comp. 7)!

6′ You might have found a species new to science!

7 Make good pictures, investigate key characteristics, and place the data onto an internet platform assisted by specialists and/or send specimens with data to specialists.....
With some luck you might obtain a name that you can check – otherwise: open end.

We collected numerous enigmatic fungi that stayed without a name although strategies as explained above were applied. The ascomycete illustrated by photos in Figs. 3–4 and by drawings in Piepenbring (2015, as a species of Helotiales), for example, was collected in 2006. Since then, the first author showed it to many mycologists without result, until she met lichenologists at Graz and showed it to P. Döbbeler in 2015, who recognized a species of *Vezdaea*. *Vezdaea* spp. are lichenized fungi producing asci and paraphyses in small, loose hymenia without a gelatinous matrix and without marginal structures (Poelt & Döbbeler 1975). The identification of such fungi is often complicated by the fact that it might be very difficult or impossible to find them again in nature.



Figs. 3–4: *Vezdaea* sp. growing on a fern in Western Panama (Piepenbring et al. ppMP 842). It was very difficult to find a name for this fungus. Fig. 3. Scale bar = 2 mm.

4. Statistical analysis of taxonomic knowledge

To further illustrate the level of taxonomic knowledge, fungus identification lists available for the Majagua area in Panama (comp. Piepenbring et al. 2012a, 2015) and for the area Trockenborn in the Taunus, state of Hesse, Germany (Rudolph 2016) are compared concerning the level of identification of species. For the Majagua area further records obtained by H. Lotz-Winter, T. Hofmann, S. Rudolph in 2014 and 2015 and M. Piepenbring in 2015 are included (Appendix). Among the latter, there are four new records of fungal species for Panama, namely *Henningsomyces minimus*, *Hygrocybe acutoconica*, *Iodowynnea auriformis* and *Tetrapyrgos nigripes* (hitherto cited as *T.* cf. *nigripes*).

Tab. 1: Absolute numbers (n) and percentages (%) of morphospecies identified up to the level of the division (or class), order (or family), genus, or species, for a study area in the Taunus, Germany, and for a study area in the valley of the Majagua river, Panama. Cumulative numbers (cum. and cum. %) refer to all levels identified for all morphospecies.

	Taunus (Germany)				Majagua (Panama)			
	n	**%**	**cum.**	**cum.%**	**n**	**%**	**cum.**	**cum.%**
division/class	22	3	813	100	39	8	456	100
order/family	41	5	791	97	95	21	418	91
genus	174	21	750	92	196	43	323	71
species	576	71	576	71	126	28	126	28
sum	813				456			

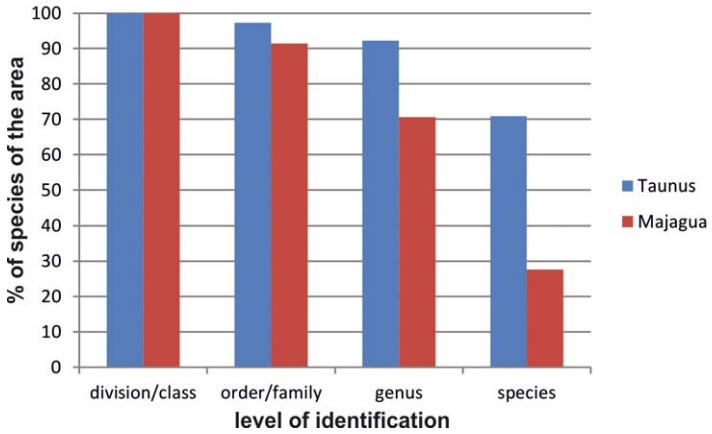


Fig. 5: Relative numbers (%) of species collected in a sample area in the Taunus (Germany; blue columns) and in a sample area in the Majagua valley (Panama; red columns) identified at different taxonomic levels (division/class, order/family, genus, species). 100 % correspond to the total number of sexual species collected in each area. For absolute values (cum. %) see table 1.

Data shown in table 1 and figure 5 show that for fungi from the sample area in Germany, about 70 % of the specimens could be identified to species

level, while for the area in Panama, species names could be applied with certainty only for less than 30 % of the collections, although several specialists collaborated (comp. Piepenbring et al. 2012a). In an analysis of macrofungi from Colombian Amazon forests by López-Quintero et al. (2012), 52 % of the species could not be identified to species level.

5. Personal incentives of mycologists working in the tropics

Knowledge deficiencies and difficulties identifying tropical fungi can be frustrating and results appear minimal when compared to the diversity that cannot be grasped, as stated by A. von Humboldt concerning his investigation of plants in the Amazonas region in 1800 (von Humboldt 1990). However, most mycologists having the opportunity to do fieldwork in the tropics are fascinated or even enchanted by tropical fungi! Here are some aspects cited as an attempt to explain this phenomenon:

– Tropical fungal diversity is overwhelming: Unknown fungi are discovered with any trip to the field, even in areas that have been visited several or many times before (Piepenbring et al. 2012a).

– Working with tropical fungi is captivating because species and structures are discovered that have not been seen by anybody before. A hunting instinct for fungi awakens and can develop into an addiction (comp. Handke 2013).

– Tropical fungi often are fascinating from an esthetic point of view (e.g. *Astrocystis mirabilis*, Xylariales; Figs. 6–7).

– Tropical fungi can be entertaining because of surprising structures (e.g. *Xylaria comosa*, Figs. 8–9).

– Tropical fungi can be surprising, because they do not care about ecological concepts made by mycologists. *Battarrea phalloides*, for example, a species supposed to grow in very dry places like caves, was found in a cloud forest in Western Panama (Figs. 10–11).

– Tropical fungi can irritate, because they do not care about morphological concepts, either. Example: A mushroom with straw coloured lamellae, no ring, no volva, scales on a brownish hat, a rooting stipe, discolouring to brown when handled and dried, with a strong odour of fried potatoes according to the students, of celery according to H. Lotz-Winter, was classified in the field as *Tricholoma* (Figs. 12–13), but observation by light microscopy revealed a species of *Russula*! A preliminary literature survey showed that it might be close to *Russula paxilliformis* S.L. Mill, M.C. Aime & T.W. Henkel, described in 2012 from Guyana, which also caused uncertainty about the genus in the field, reminding the collectors of *Paxillus involutus* (Miller et al. 2012).

Figs. 6–7: *Astrocystis mirabilis* (Xylariales), an art-work fungus recently found in Panama (Hofmann et al. PA 528). Fig. 7. Scale bar = 2 mm. Figs. 8–9: *Xylaria comosa*, an interesting fungus discovered in Panama (Fig. 8. Piepenbring et al. 4460, Fig. 9. Piepenbring et al. 5117).

Figs. 10–11: A fruiting body of *Battarrea phalloides* (Piepenbring et al. 5167) growing in a cloud forest in Western Panama.

– For known species of tropical fungi, numerous additional characteristics can be discovered. Example: Contrary to the names given by mycologists

working with dry specimens collected by other people, fruiting bodies of, e.g. *Rigidoporus* spp. (Polyporales, Fig. 14) are relatively soft when fresh.

Figs. 12–13: Fruiting bodies and cap of an unusual, not yet determined species of *Russula* with a tricholomoid morphology (Cáceres & Valdés PAN 381). Fig. 14: *Rigidoporus microporus* produces relatively soft fruiting bodies (Piepenbring & del Carmen Quiel 5281).

– Tropical fungi can deceive because there are cryptic species which can be confounded with species from other countries due to similar macro- and micromorphology. Molecular data reveal speciation, for example in *Amanita muscaria* (Geml et al. 2008) or *Artomyces* (Lickey et al. 2002).

– By hunting fungi in tropical countries, mycologists experience adventures like crossing wild rivers or getting wet under a thunderstorm and they discover fascinating vegetation, wild animals, as well as impressive landscapes. They have the possibility to share these experiences with local people, thereby increasing social and cultural competences and having fun together.

– The search of fungi in the field in fresh air combined with physical activity as well as the analysis of specimens with good optical equipment in a quiet, stress-free environment is relaxing and healthy.

6. The present situation of tropical mycology

As a result of historical facts, we are still in a pioneer phase concerning the documentation of tropical fungal diversity. Apparently, progress concerning the documentation is rather slow nowadays despite an increasing number of local mycologists in the tropics, a significantly improved accessibility of tropical vegetation as well as outdoor and laboratory equipment, and a sub-

stantially improved availability of literature and information by libraries and internet. These are some aspects that help to understand this paradoxon:

– During the last century, the focus of scientific investigation changed from the observation and description of diversity (natural history) to experimental sciences, so the documentation of species diversity is not in the focus of interest and considered old-fashioned.

– Although the knowledge of species is fundamental for any further investigation, results on species diversity (alpha-taxonomy) are difficult to publish. Mostly only local, low impact journals accept contributions on species inventories. Nevertheless, a new record should be considered as valuable as a species new to science, since a new record can help to improve species concepts and contributes to knowledge of geographic distribution ranges as well as substrate specificities.

– Valuation of this kind of investigation might be impeded by the fact that it is relatively cheap concerning equipment and consumables.

– The identification of fungal specimens by morphological characteristics and the analysis of literature is time-consuming and cannot easily be delegated to technical assistants.

– Monographic works or checklists are not esteemed although claimed by the 1992 Rio Convention on Biological Diversity (CBD).

– The CBD extends protection to all groups of organisms, namely animals, plants and microorganisms. Fungi, however, do not fit well in any of these categories. As a result, countries which signed the Rio Convention mostly have overlooked fungi when preparing their biodiversity conservation plans. Fungi are the orphans of Rio (Minter 2010).

– The CBD and following conventions as well as national legislations increasingly impede herbarium exchanges and cause complicate administrative procedures for collection and export permits.

– Teaching of mycology at most universities is deficient or marginal as it is frequently performed by professors lacking deep understanding of the group. The lack of a textbook on tropical mycology has only recently been amended by Piepenbring (2015).

In extra-tropical areas, fungal diversity is rather well documented for some countries, while to the majority of the countries outside the tropics, most of the aspects cited above apply as well.

7. Conclusions

Investigation in tropical mycology is necessary because of the high potential of hidden diversity and threat of species loss. Basic knowledge of fungal organisms including their identity (taxonomy), ecology, and life cycle is indispensable for any lasting use or control of fungal species.

As shown above, it is possible to obtain fascinating and ample results with curiosity, time, as well as simple and cheap equipment for fieldwork (handlens, knife, bags, boxes, camera) and in the laboratory (razor blades, stereo microscope, light microscope, pen, paper).

In order to increase mycological knowledge, it is necessary to teach mycology in the tropics – and worldwide – to enhance local manpower. Although it might be easier to teach the application of established molecular methods, it is of fundamental importance to take the time to teach morphology, ecology and systematics of fungi. The new textbook for mycology in the tropics (Piepenbring 2015) shall encourage and help teachers to gain personal experience and collect own specimens, increasing the attractiveness of their teaching. It is also necessary to provide knowledge and equipment for molecular investigation to mycologists in the tropics.

There is an urgent need of checklists as orientations for identifications and to recognize new records. Monographs are indispensable for correct identifications, increasing knowledge on geographic distribution of species, and recognition of species new to science.

By observing the destruction of natural vegetation, mycologists become aware of the fact that many fungal species disappear without having been reported by science and analysed for possible beneficial properties. This results in a motivation to increase general awareness of fungal diversity and potential uses, as an attempt to increase environmental protection incentives.

Given that tropical fungal diversity is threatened, it is recommendable to collaborate with national nature protection agencies and NGOs that offer many possibilities for research activities, the application of knowledge, and to reach general public. By illustrating ecosystem services provided by fungi, by showing practical uses of fungi (biotechnology, bioremediation, biological control, medicinal use), and their beauty as well as curiosities, it shall be possible to convince general public of the value of this group of organisms and the necessity to protect their natural habitats and last but not least to raise funds for further research.

8. Acknowledgements

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10. Appendix

Appendix A. Updated list of fungal species reported for the Majagua area. Names of records and identifications added to the list published by Piepenbring et al. (2015) are written with bold letters.

Level of identification	Division	Order (or class, family)	Genus	Epithet	Det. new
order	Ascomycota	Arthoniales	cf. *Herpothallon*	sp.	
genus	Ascomycota	Arthoniales	*Chrysothrix*	sp.	
species	Ascomycota	Arthoniales	*Cryptothecia*	*rubrocincta*	
species	Ascomycota	Arthoniales	*Dichosporidium*	*boschianum*	
species	Ascomycota	Arthoniales	*Herpothallon*	*rubroechinatum*	
order	Ascomycota	Botryosphaeriales	cf. *Botryosphaeria*	sp. 1	
order	Ascomycota	Botryosphaeriales	**cf. *Botryosphaeria***	**sp. 2**	H. Lotz-Winter, 2014
order	Ascomycota	Chaetothyriales	cf. *Herpotrichiella*	sp.	
genus	Ascomycota	Coniochaetales	*Coniochaeta*	sp.	
species	Ascomycota	Coronophorales	*Nitschkia*	*broomeana*	
order	Ascomycota	Coronophorales	cf. *Nitschkia*	sp.	
species	Ascomycota	cf. Diaporthales	*Valsaria*	*rubricosa*	
class	Ascomycota	Dothideomycetes	indet. 1		
class	Ascomycota	Dothideomycetes	indet. 2		
class	Ascomycota	Dothideomycetes	indet. 3		
class	Ascomycota	Dothideomycetes	indet. 4		
class	Ascomycota	Dothideomycetes	indet. 5		
class	Ascomycota	Dothideomycetes	indet. 6		
class	Ascomycota	Dothideomycetes	indet. 7		
class	Ascomycota	Dothideomycetes	indet. 8		
class	Ascomycota	Dothideomycetes	indet. 9		
class	Ascomycota	Dothideomycetes	indet. 10		
class	Ascomycota	Dothideomycetes	indet. 11		
class	Ascomycota	Dothideomycetes	**indet. 12**		M. Piepenbring, 2015
species	Ascomycota	Dothideomycetes Asterinaceae	*Asterina*	*davillae*	
species	Ascomycota	Dothideomycetes Asterinaceae	*Asterina*	*diplocarpa*	
genus	Ascomycota	Dothideomycetes Asterinaceae	*Asterina*	sp.	

Level of identification	**Division**	**Order (or class, family)**	**Genus**	**Epithet**	**Det. new**
genus	Ascomycota	Dothideomycetes Asterinaceae	*Asterina*	sp.	
genus	Ascomycota	Dothideomycetes Asterinaceae	*Asterina*	sp.	
genus	Ascomycota	Dothideomycetes Asterinaceae	*Asterina*	sp.	
species	Ascomycota	Dothideomycetes Asterinaceae	*Asterina*	*sponiae*	
species	Ascomycota	Dothideomycetes Asterinaceae	*Asterina*	*stipitipodia*	
family	Ascomycota	Dothideomycetes Asterinaceae	cf. *Asterinella*	sp.	
species	Ascomycota	Dothideomycetes Asterinaceae	*Asterostomella*	*dilleniicola*	
genus	Ascomycota	Dothideomycetes Asterinaceae	*Lembosia*	sp.	
order	Ascomycota	Dothideomycetes Capnodiales	indet.		
order	Ascomycota	Dothideomycetes Capnodiales	cf. *Phragmocapnias*	sp.	
genus	Ascomycota	Dothideomycetes cf. Parodiopsidaceae	*Dimerium*	sp.	
genus	Ascomycota	Dothideomycetes Englerulaceae	*Sarcinella* & *Mitteriella* synanamorphs		
genus	Ascomycota	Dothideomycetes Gloniaceae	*Glonium*	sp.	
family	Ascomycota	Dothideomycetes Micropeltidaceae	cf. *Micropeltis*	sp.	
genus	Ascomycota	Dothideomycetes Micropeltidaceae	*Stomiopeltis*	sp.	
family	Ascomycota	Dothideomycetes cf. Micropeltidaceae	indet. 1		
family	Ascomycota	Dothideomycetes Microthyriaceae	indet. 2		
family	Ascomycota	Dothideomycetes Microthyriaceae	indet. 3		
species	Ascomycota	Dothideomycetes Microthyriaceae	*Maublancia*	*uleana*	
genus	Ascomycota	Dothideomycetes Microthyriaceae	*Trichothyrium*	sp.	
species	Ascomycota	Dothideomycetes Parodiopsidaceae	*Balladynopsis*	*urtiagae*	

Level of identification	**Division**	**Order (or class, family)**	**Genus**	**Epithet**	**Det. new**
genus	Ascomycota	Dothideomycetes Pseudoperisporiaceae	*Epipolaeum*	sp.	
species	Ascomycota	Dothideomycetes Pseudoperisporiaceae	*Phaeodimeriella*	*guarapiensis*	
species	Ascomycota	Dothideomycetes Pseudoperisporiaceae	*Venturia*	*stevensii*	
genus	Ascomycota	Dothideomycetes Schizothyriaceae	*Schizothyrium*	sp.	
species	Ascomycota	Dothideomycetes Strigulaceae	*Strigula*	*antillarum*	
genus	Ascomycota	Dothideomycetes Strigulaceae	*Strigula*	cf. *nitidula*	
order	Ascomycota	Helotiales	cf. *Bisporella*	sp.	
species	Ascomycota	Helotiales	*Unguiculariopsis*	*ravenelii*	
order	Ascomycota	Hypocreales	aff. *Haematonectria*	*haematococca*	
species	Ascomycota	Hypocreales	*Bionectria*	*byssicola*	
order	Ascomycota	Hypocreales	cf. *Calonectria*	sp.	
genus	Ascomycota	Hypocreales	*Cordyceps*	sp.	
species	Ascomycota	Hypocreales	*Hirsutella*	*saussurei*	
genus	Ascomycota	Hypocreales	*Hypocrea*	sp.	
genus	Ascomycota	Hypocreales	*Hypocrella*	sp.	
order	Ascomycota	Hypocreales	indet. 1		
order	Ascomycota	Hypocreales	indet. 2		
order	Ascomycota	Hypocreales	indet. 3		
order	Ascomycota	Hypocreales	indet. 4		
species	Ascomycota	Hypocreales	***Lanatonectria***	***floucculenta***	H. Lotz-Winter, 2015
genus	Ascomycota	Hypocreales	*Nectria*	cf. *rubricarpa*	
species	Ascomycota	Hypocreales	*Nectria*	*pseudotrichia*	
order	Ascomycota	Hypocreales	cf. *Nectria*	sp. 1	
order	Ascomycota	Hypocreales	**cf. *Nectria***	**sp. 2**	H. Lotz-Winter, 2015
order	Ascomycota	Hypocreales	cf. *Nectriopsis*	sp.	
order	Ascomycota	Hypocreales	cf. *Podonectria*	sp.	
genus	Ascomycota	Hypocreales	*Torrubiella*	sp.	
division	Ascomycota	cf. Hypocreales	indet. 1		
genus	Ascomycota	incertae sedis	*Fuscidea*	sp.	

Level of identification	Division	Order (or class, family)	Genus	Epithet	Det. new
genus	Ascomycota	incertae sedis	*Rhynchomeliola*	sp.	
genus	Ascomycota	incertae sedis	*Rhynchomeliola*	sp.	
division	Ascomycota	indet.	indet. 1		
division	Ascomycota	indet.	indet. 2		
division	Ascomycota	indet.	indet. 3		
division	Ascomycota	indet.	indet. 4		
species	Ascomycota	Lecanorales	*Lecanora*	*subimmersa*	
order	Ascomycota	Lecanorales	cf. *Lecanora*	sp.	
species	Ascomycota	Lecanorales	*Lopezaria*	*versicolor*	
genus	Ascomycota	Lecanorales	*Phyllopsora*	sp.	
order	Ascomycota	Lecanorales	cf. *Rimelia*	sp.	
genus	Ascomycota	Meliolales	*Appendiculella*	cf. *sororcula*	
genus	Ascomycota	Meliolales	*Appendiculella*	sp. 1	
genus	Ascomycota	Meliolales	*Appendiculella*	sp. 2	
genus	Ascomycota	Meliolales	*Appendiculella*	sp. 3	
order	Ascomycota	Meliolales	cf. Appendiculella	sp. 4	
genus	Ascomycota	Meliolales	*Asteridiella*	cf. *longipoda* var. *minor*	
species	Ascomycota	Meliolales	*Asteridiella*	*pipericola*	
genus	Ascomycota	Meliolales	*Asteridiella*	sp. 1	
genus	Ascomycota	Meliolales	*Asteridiella*	sp. 2	
genus	Ascomycota	Meliolales	*Asteridiella*	sp. 3	
species	Ascomycota	Meliolales	*Asteridiella*	*usteriana*	
order	Ascomycota	Meliolales	indet.		
species	Ascomycota	Meliolales	*Irenopsis*	*pteridicola*	
genus	Ascomycota	Meliolales	*Irenopsis*	sp. 1	
genus	Ascomycota	Meliolales	*Irenopsis*	sp. 2	
species	Ascomycota	Meliolales	*Irenopsis*	*tenuissima*	
species	Ascomycota	Meliolales	*Irenopsis*	*tortuosa*	
species	Ascomycota	Meliolales	*Meliola*	*andirae*	
genus	Ascomycota	Meliolales	*Meliola*	cf. *annonae*	
species	Ascomycota	Meliolales	*Meliola*	*arrabidaeae*	
genus	Ascomycota	Meliolales	*Meliola*	cf. *atricapilla*	
genus	Ascomycota	Meliolales	*Meliola*	cf. *bicornis*	
genus	Ascomycota	Meliolales	*Meliola*	cf. *cissi-rhombifoliae*	
species	Ascomycota	Meliolales	*Meliola*	*diphysae*	
genus	Ascomycota	Meliolales	*Meliola*	cf. *malacotricha*	

Level of identification	**Division**	**Order (or class, family)**	**Genus**	**Epithet**	**Det. new**
species	Ascomycota	Meliolales	*Meliola*	*panici* var. *lasiacidis* and var. *major*	
genus	Ascomycota	Meliolales	*Meliola*	sp. 1	
genus	Ascomycota	Meliolales	*Meliola*	sp. 2	
genus	Ascomycota	Meliolales	*Meliola*	sp. 3	
genus	Ascomycota	Meliolales	*Meliola*	sp. 4	
species	Ascomycota	Meliolales	*Meliola*	*tabernaemontanae*	
species	Ascomycota	Meliolales	*Meliola*	*variaseta*	
genus	Ascomycota	Meliolales	*Meliola*	cf. *woodiana*	
genus	Ascomycota	Meliolales	*Meliola*	cf. *xylopiae*	
order	Ascomycota	Ostropales	cf. *Cryptolechia*	sp.	
species	Ascomycota	Ostropales	*Glyphis*	*cicatricosa*	
genus	Ascomycota	Ostropales	*Graphis*	sp. 1	
genus	Ascomycota	Ostropales	*Graphis*	sp. 2	
genus	Ascomycota	Ostropales	*Graphis*	sp. 3	
genus	Ascomycota	Ostropales	*Graphis*	sp. 4	
species	Ascomycota	Ostropales	*Myriotrema*	*wightii*	
genus	Ascomycota	Ostropales	*Tricharia*	sp.	
species	Ascomycota	Patellariales	*Rhytidhysteron*	*rufulum*	
species	Ascomycota	Peltigerales	*Coccocarpia*	*pellita*	
species	Ascomycota	Peltigerales	*Leptogium*	*phyllocarpum*	
species	Ascomycota	Peltigerales	*Leptogium*	*stipitatum*	
species	Ascomycota	Pezizales	***Ascobolus***	***scatigenus***	M. Piepenbring, 2015
species	Ascomycota	Pezizales	*Cookeina*	*speciosa*	
species	Ascomycota	Pezizales	*Cookeina*	*tricholoma*	
order	Ascomycota	Pezizales	indet. 1		
order	Ascomycota	Pezizales	indet. 2		
order	Ascomycota	Pezizales	indet. 3		
order	Ascomycota	Pezizales	indet. 4		
species	Ascomycota	Pezizales	***Iodowynnea***	***auriformis***	H. Lotz-Winter, 2014, rep. nov. Panama
genus	Ascomycota	Pezizales	***Plicaria***	**cf. *carbonaria***	H. Lotz-Winter, 2014
genus	Ascomycota	Pezizales	*Scutellinia*	sp. 1	
genus	Ascomycota	Pezizales	***Scutellinia***	**sp. 2**	H. Lotz-Winter, 2015

Level of identification	**Division**	**Order (or class, family)**	**Genus**	**Epithet**	**Det. new**
species	Ascomycota	Phyllachorales	*Camarotella*	*costaricensis*	
genus	Ascomycota	Phyllachorales	*Camarotella*	sp.	
order	Ascomycota	Phyllachorales	indet. 1		
order	Ascomycota	Phyllachorales	indet. 2		
order	Ascomycota	Phyllachorales	indet. 3		
order	Ascomycota	Phyllachorales	indet. 4		
genus	Ascomycota	Phyllachorales	*Ophiodotella*	sp.	
species	Ascomycota	Phyllachorales	*Phyllachora*	*guaniae*	
species	Ascomycota	Phyllachorales	*Phyllachora*	*ocoteae*	
genus	Ascomycota	Phyllachorales	*Phyllachora*	sp. 1	
genus	Ascomycota	Phyllachorales	*Phyllachora*	sp. 2	
genus	Ascomycota	Phyllachorales	*Phyllachora*	sp. 3	
genus	Ascomycota	Phyllachorales	*Phyllachora*	sp. 4	
genus	Ascomycota	Phyllachorales	*Phyllachora*	sp. 5	
genus	Ascomycota	Phyllachorales	*Phyllachora*	sp. 6	
genus	Ascomycota	Phyllachorales	*Phyllachora*	sp. 7	
genus	Ascomycota	Phyllachorales	*Phyllachora*	sp. 8	
genus	Ascomycota	Phyllachorales	*Polystigma*	sp. 9	
genus	Ascomycota	Pleosporales	***Byssosphaeria***	**cf. *schieder-mayeriana***	prelim. M. Piepenbring, 2015
genus	Ascomycota	Sordariales	***Bombardia***	**sp.**	H. Lotz-Winter, 2015
order	Ascomycota	Sordariales	cf. *Cercophora*	sp.	
class	Ascomycota	Sordariomycetes	indet. 1		
class	Ascomycota	Sordariomycetes	**indet. 2**		H. Lotz-Winter, 2015
genus	Ascomycota	Teloschistales	*Physcia*	sp.	
species	Ascomycota	Trypetheliales	*Trypethelium*	*tropicum*	
order	Ascomycota	Xylariales	cf. *Annulohypoxylon*	sp.	
species	Ascomycota	Xylariales	*Camillea*	*coroniformis*	
species	Ascomycota	Xylariales	*Camillea*	*obularia*	
genus	Ascomycota	Xylariales	*Camillea*	sp. 1	
genus	Ascomycota	Xylariales	*Camillea*	sp. 2	
order	Ascomycota	Xylariales	cf. *Camillea*	sp. 3	
species	Ascomycota	Xylariales	*Daldinia*	*caldariorum*	
species	Ascomycota	Xylariales	*Daldinia*	*eschscholtzii*	
family	Ascomycota	Xylariales, Diatrypaceae	indet.		

Level of identification	**Division**	**Order (or class, family)**	**Genus**	**Epithet**	**Det. new**
genus	Ascomycota	Xylariales	*Diatrype*	sp.	
genus	Ascomycota	Xylariales	*Diatrypella*	sp. 1	
genus	Ascomycota	Xylariales	*Diatrypella*	sp. 2	
genus	Ascomycota	Xylariales	*Diatrypella*	sp. 3	
genus	Ascomycota	Xylariales	***Diatrypella***	**sp. 4**	M. Piepenbring, 2015
species	Ascomycota	Xylariales	*Eutypella*	*scoparia*	
species	Ascomycota	Xylariales	*Hypoxylon*	*haematostroma*	
species	Ascomycota	Xylariales	*Hypoxylon*	*investiens*	
species	Ascomycota	Xylariales	*Hypoxylon*	*lenormandii*	
genus	Ascomycota	Xylariales	*Hypoxylon*	cf. *monticulosum*	
species	Ascomycota	Xylariales	*Hypoxylon*	*placentiforme*	
genus	Ascomycota	Xylariales	*Hypoxylon*	sp. 1	
genus	Ascomycota	Xylariales	*Hypoxylon*	sp. 2	
genus	Ascomycota	Xylariales	*Hypoxylon*	sp. 3	
order	Ascomycota	Xylariales	indet. 1		
genus	Ascomycota	Xylariales	*Nemania*	sp.	
species	Ascomycota	Xylariales	*Phylacia*	*sagrana*	
species	Ascomycota	Xylariales	*Podosordaria*	*truncata*	
genus	Ascomycota	Xylariales	*Xylaria*	aff. *corniformis*	
genus	Ascomycota	Xylariales	*Xylaria*	aff. *feejeensis*	
genus	Ascomycota	Xylariales	*Xylaria*	aff. *multiplex*	
species	Ascomycota	Xylariales	*Xylaria*	*anisopleura*	
species	Ascomycota	Xylariales	*Xylaria*	*arbuscula* group	
species	Ascomycota	Xylariales	*Xylaria*	*multiplex*	
genus	Ascomycota	Xylariales	*Xylaria*	cf. *scruposa*	
genus	Ascomycota	Xylariales	*Xylaria*	sp. 1	
genus	Ascomycota	Xylariales	*Xylaria*	sp. 2	
genus	Ascomycota	Xylariales	*Xylaria*	sp. 3	
division	Basidiomycota	“Aphyllophorales”	indet. clavarioid 1		
division	Basidiomycota	“Aphyllophorales”	indet. clavarioid 2		
division	Basidiomycota	“Aphyllophorales”	indet. clavarioid 3		
division	Basidiomycota	“Aphyllophorales”	indet. corticioid 1		
division	Basidiomycota	“Aphyllophorales”	indet. corticioid 2		
division	Basidiomycota	“Aphyllophorales”	indet. corticioid 3		
division	Basidiomycota	“Aphyllophorales”	indet. corticioid 4		
division	Basidiomycota	“Aphyllophorales”	indet. corticioid 5		
division	Basidiomycota	“Aphyllophorales”	indet. corticioid 6		

Level of identification	**Division**	**Order (or class, family)**	**Genus**	**Epithet**	**Det. new**
division	Basidiomycota	"Aphyllophorales"	indet. corticioid 7		
division	Basidiomycota	"Aphyllophorales"	indet. corticioid 8		
division	Basidiomycota	"Aphyllophorales"	indet. cyphelloid 1		
division	Basidiomycota	"Aphyllophorales"	indet. cyphelloid 2		
division	Basidiomycota	"Aphyllophorales"	**indet. irpicoid**		M. Piepenbring, 2015
division	Basidiomycota	"Aphyllophorales"	indet. stereoid 1		
division	Basidiomycota	"Aphyllophorales"	indet. stereoid 2		
division	Basidiomycota	"Aphyllophorales"	indet. stereoid 3		
genus	Basidiomycota	Agaricales	*Agaricus*	sp.	
order	Basidiomycota	Agaricales	cf. *Agaricus*	sp.	
order	Basidiomycota	Agaricales	cf. *Chaetocalathus*	*liliputianus*	
genus	Basidiomycota	Agaricales	*Chondrostereum*	cf. *purpureum*	
genus	Basidiomycota	Agaricales	*Chrysomphalina*	cf. *strombodes*	
genus	Basidiomycota	Agaricales	*Clavulinopsis*	cf. *aurantio-cinnabarina*	
order	Basidiomycota	Agaricales	cf. Clitocybe	sp. 1	
order	Basidiomycota	Agaricales	cf. Clitocybe	sp. 2	
genus	Basidiomycota	Agaricales	***Clitopilus***	**cf. *crystallinus***	H. Lotz-Winter, 2014
genus	Basidiomycota	Agaricales	*Collybia*	cf. *neotropica*	
genus	Basidiomycota	Agaricales	*Collybia*	sp. 1	
genus	Basidiomycota	Agaricales	*Collybia*	sp. 2	
genus	Basidiomycota	Agaricales	*Collybia*	sp. 3	
order	Basidiomycota	Agaricales	cf. *Collybia*	sp. 1	
order	Basidiomycota	Agaricales	cf. *Collybia*	sp. 2	
genus	Basidiomycota	Agaricales	*Conocybe*	cf. *albipes*	
genus	Basidiomycota	Agaricales	*Coprinellus*	aff. *disseminatus*	
species	Basidiomycota	Agaricales	***Coprinopsis***	***cinerea***	M. Piepenbring, 2015
species	Basidiomycota	Agaricales	***Coprinopsis***	***stercorea***	M. Piepenbring, 2015
genus	Basidiomycota	Agaricales	*Coprinus*	sp. 1	
genus	Basidiomycota	Agaricales	*Coprinus*	sp. 2	
genus	Basidiomycota	Agaricales	*Coprinus*	sp. 3	
genus	Basidiomycota	Agaricales	*Coprinus*	sp. 4	
order	Basidiomycota	Agaricales	cf. *Coprinus*	sp.	
genus	Basidiomycota	Agaricales	*Crepidotus*	sp. 1	
genus	Basidiomycota	Agaricales	*Crepidotus*	sp. 2	

Level of identification	**Division**	**Order (or class, family)**	**Genus**	**Epithet**	**Det. new**
genus	Basidiomycota	Agaricales	***Crepidotus***	**sp. 3**	H. Lotz-Winter, 2014
genus	Basidiomycota	Agaricales	*Cyathus*	sp.	
order	Basidiomycota	Agaricales	cf. *Cystoderma*	sp.	
genus	Basidiomycota	Agaricales	*Deflexula*	sp.	
order	Basidiomycota	Agaricales	cf. *Entoloma*	sp.	
genus	Basidiomycota	Agaricales	*Filoboletus*	sp.	
order	Basidiomycota	Agaricales	cf. *Galerina*	sp.	
order	Basidiomycota	Agaricales	cf. *Gloiocephala*	sp.	
genus	Basidiomycota	Agaricales	***Gymnopilus***	**sp.**	H. Lotz-Winter, 2015
order	Basidiomycota	Agaricales	cf. *Gymnopilus*	sp.	
order	Basidiomycota	Agaricales	cf. *Hemimycena* or *Delicatula*	sp.	
genus	Basidiomycota	Agaricales	***Henningsomyces***	***minimus***	H. Lotz-Winter 2014, rep. nov.
order	Basidiomycota	Agaricales	cf. *Hydropus*	sp.	
order	Basidiomycota	Agaricales	cf. *Hygroaster*	sp.	
species	Basidiomycota	Agaricales	***Hygrocybe***	***acutoconica***	H. Lotz-Winter 2014, rep. nov.
genus	Basidiomycota	Agaricales	*Hygrocybe*	sp. 1	
genus	Basidiomycota	Agaricales	*Hygrocybe*	sp. 2	
genus	Basidiomycota	Agaricales	*Hygrocybe*	sp. 3	
order	Basidiomycota	Agaricales	indet. 1		
order	Basidiomycota	Agaricales	indet. 2		
order	Basidiomycota	Agaricales	indet. 3		
order	Basidiomycota	Agaricales	indet. 4		
order	Basidiomycota	Agaricales	indet. 5		
order	Basidiomycota	Agaricales	indet. 6		
order	Basidiomycota	Agaricales	indet. 7		
order	Basidiomycota	Agaricales	indet. 8		
order	Basidiomycota	Agaricales	indet. 9		
genus	Basidiomycota	Agaricales	*Inocybe*	cf. *curvipes* var. *ionipes*	
order	Basidiomycota	Agaricales	cf. *Lactocollybia*	*epia*	
genus	Basidiomycota	Agaricales	*Lepiota*	sp. 1	
genus	Basidiomycota	Agaricales	*Lepiota*	sp. 2	
order	Basidiomycota	Agaricales	*Lepiota/Cystolepiota*	sp.	
genus	Basidiomycota	Agaricales	***Leucoagaricus***	**sp.**	H. Lotz-Winter, 2015

Level of identification	Division	Order (or class, family)	Genus	Epithet	Det. new
order	Basidiomycota	Agaricales	cf. *Leucoagaricus*	sp.	
species	Basidiomycota	Agaricales	*Leucocoprinus*	*birnbaumii*	
genus	Basidiomycota	Agaricales	*Leucocoprinus*	cf. *cepistipes*	
species	Basidiomycota	Agaricales	*Leucocoprinus*	*fragilissimus*	
genus	Basidiomycota	Agaricales	*Leucocoprinus*	sp. 1	
genus	Basidiomycota	Agaricales	*Leucocoprinus*	sp. 2	
species	Basidiomycota	Agaricales	*Leucopaxillus*	*gracillimus*	
species	Basidiomycota	Agaricales	*Lycogalopsis*	*solmsii*	
order	Basidiomycota	Agaricales	cf. *Lyophyllum*	sp.	
order	Basidiomycota	Agaricales	cf. *Marasmiellus*	sp. 1	
order	Basidiomycota	Agaricales	cf. *Marasmiellus*	sp. 2	
order	Basidiomycota	Agaricales	cf. *Marasmiellus*	sp. 3	
species	Basidiomycota	Agaricales	*Marasmius*	*haematocephalus*	
genus	Basidiomycota	Agaricales	*Marasmius*	sp. 1	
genus	Basidiomycota	Agaricales	*Marasmius*	sp. 2	
genus	Basidiomycota	Agaricales	*Marasmius*	sp. 3	
genus	Basidiomycota	Agaricales	*Marasmius*	sp. 4	
genus	Basidiomycota	Agaricales	*Marasmius*	sp. 5	
genus	Basidiomycota	Agaricales	***Marasmius***	**sp. 6**	H. Lotz-Winter, 2014
genus	Basidiomycota	Agaricales	***Marasmius***	**sp. 7**	H. Lotz-Winter, 2015
genus	Basidiomycota	Agaricales	***Marasmius***	**sp. 8**	M. Piepenbring, 2015
order	Basidiomycota	Agaricales	cf. *Marasmius*	sp.	
genus	Basidiomycota	Agaricales	*Mycena*	sp. 1	
genus	Basidiomycota	Agaricales	*Mycena*	sp. 2	
genus	Basidiomycota	Agaricales	*Mycena*	sp. 3	
genus	Basidiomycota	Agaricales	*Mycena*	sp. 4	
order	Basidiomycota	Agaricales	cf. *Mycena*	sp. 1	
order	Basidiomycota	Agaricales	cf. *Mycena*	sp. 2	
order	Basidiomycota	Agaricales	cf. *Mycena*	sp. 3	
order	Basidiomycota	Agaricales	cf. *Nothopanus*	*hygrophanus*	
species	Basidiomycota	Agaricales	*Oudemansiella*	*platensis*	
genus	Basidiomycota	Agaricales	*Panaeolus*	sp.	
species	Basidiomycota	Agaricales	***Pleurotus***	***djamor***	M. Piepenbring, 2015
genus	Basidiomycota	Agaricales	*Pluteus*	cf. *phlebophorus*	

Level of identification	**Division**	**Order (or class, family)**	**Genus**	**Epithet**	**Det. new**
genus	Basidiomycota	Agaricales	*Pluteus*	sp. 1	
genus	Basidiomycota	Agaricales	*Pluteus*	sp. 2	
genus	Basidiomycota	Agaricales	*Pluteus*	sp. 3	
genus	Basidiomycota	Agaricales	*Psathyrella*	aff. *candolleana*	
genus	Basidiomycota	Agaricales	*Psathyrella*	sp. 1	
genus	Basidiomycota	Agaricales	*Psathyrella*	sp. 2	
genus	Basidiomycota	Agaricales	*Psathyrella*	sp. 3	
species	Basidiomycota	Agaricales	*Pseudofistulina*	*radicata*	
genus	Basidiomycota	Agaricales	***Pterula***	**sp.**	H. Lotz-Winter, 2015
order	Basidiomycota	Agaricales	cf. *Rhodocollybia*	sp.	
species	Basidiomycota	Agaricales	*Schizophyllum*	*commune*	
genus	Basidiomycota	Agaricales	*Schizophyllum*	cf. *umbrinum*	
genus	Basidiomycota	Agaricales	*Stropharia*	cf. *albonitens*	
genus	Basidiomycota	Agaricales	*Tetrapyrgos*	cf. *longicystidiata*	
species	Basidiomycota	Agaricales	***Tetrapyrgos***	***nigripes***	M. Piepenbring, 2015, rep. nov. Panama
species	Basidiomycota	Agaricales	*Trogia*	*icterina*	
genus	Basidiomycota	Agaricales	*Xeromphalina*	sp.	
genus	Basidiomycota	Agaricales	*Xerula*	cf. *furfuracea*	
genus	Basidiomycota	Agaricales	*Xerula*	sp.	
species	Basidiomycota	Atheliales	*Athelia*	*rolfsii*	
species	Basidiomycota	Auriculariales	*Auricularia*	*fuscosuccinea*	
species	Basidiomycota	Auriculariales	*Auricularia*	*mesenterica*	
species	Basidiomycota	Auriculariales	*Auricularia*	*polytricha*	
genus	Basidiomycota	Auriculariales	*Auricularia*	sp.	
genus	Basidiomycota	Auriculariales	*Myxarium*	sp.	
genus	Basidiomycota	Cantharellales	*Multiclavula*	sp.	
order	Basidiomycota	Dacrymycetales	cf. *Dacryomitra*	sp.	
species	Basidiomycota	Dacrymycetales	*Dacryopinax*	*spathularia*	
genus	Basidiomycota	Exobasidiales	*Kordyana*	sp.	
species	Basidiomycota	Geastrales	*Geastrum*	*saccatum*	
genus	Basidiomycota	Geastrales	*Geastrum*	sp.	
species	Basidiomycota	Geastrales	*Geastrum*	*triplex*	
species	Basidiomycota	Geastrales	*Sphaerobolus*	*stellatus*	
order	Basidiomycota	Gloeophyllales	cf. *Gloeophyllum*	sp.	
genus	Basidiomycota	Gomphales	*Ramaria*	cf. *reticulata*	
genus	Basidiomycota	Gomphales	*Ramaria*	sp.	

Level of identification	**Division**	**Order (or class, family)**	**Genus**	**Epithet**	**Det. new**
order	Basidiomycota	Hymenochaetales	indet.		
genus	Basidiomycota	Hymenochaetales	***Onnia***	**sp.**	H. Lotz-Winter, 2014
genus	Basidiomycota	Hymenochaetales	*Phellinus*	cf. *cinchonensis*	
genus	Basidiomycota	Hymenochaetales	*Phellinus*	cf. *crocatus*	
species	Basidiomycota	Hymenochaetales	*Phellinus*	*gilvus*	
genus	Basidiomycota	Hymenochaetales	*Phellinus*	sp. 1	
genus	Basidiomycota	Hymenochaetales	*Phellinus*	sp. 2	
division	Basidiomycota	incertae sedis	**cf. *Cotylidia***	***pusiola***	H. Lotz-Winter, 2015
division	Basidiomycota	indet.	indet.		
species	Basidiomycota	Phallales	*Phallus*	*indusiatus*	
order	Basidiomycota	Polyporales	cf. *Amauroderma*	*sprucei*	
species	Basidiomycota	Polyporales	*Coriolopsis*	*caperata*	
order	Basidiomycota	Polyporales	cf. *Coriolopsis*	sp.	
genus	Basidiomycota	Polyporales	*Dichomitus*	sp.	
species	Basidiomycota	Polyporales	*Earliella*	*scabrosa*	
species	Basidiomycota	Polyporales	*Favolus*	*tenuiculus*	
species	Basidiomycota	Polyporales	*Flavodon*	*flavus*	
species	Basidiomycota	Polyporales	*Ganoderma*	*colossus*	
genus	Basidiomycota	Polyporales	***Gloeoporus***	**cf. *sulphuricolor***	H. Lotz-Winter, 2014
genus	Basidiomycota	Polyporales	*Hexagonia*	sp.	
species	Basidiomycota	Polyporales	*Humphreya*	*coffeata*	
order	Basidiomycota	Polyporales	indet. 1		
order	Basidiomycota	Polyporales	indet. 2		
order	Basidiomycota	Polyporales	indet. 3		
order	Basidiomycota	Polyporales	indet. 4		
order	Basidiomycota	Polyporales	indet. 5		
order	Basidiomycota	Polyporales	indet. 6		
species	Basidiomycota	Polyporales	*Lentinus*	*crinitus*	
genus	Basidiomycota	Polyporales	*Lentinus*	sp. 1	
genus	Basidiomycota	Polyporales	*Lentinus*	sp. 2	
species	Basidiomycota	Polyporales	*Lentinus*	*strigosus*	
species	Basidiomycota	Polyporales	*Lenzites*	*elegans*	
order	Basidiomycota	Polyporales	cf. *Podoscypha*	sp.	
species	Basidiomycota	Polyporales	*Polyporus*	*ciliatus*	
species	Basidiomycota	Polyporales	***Polyporus***	***dictyopus***	M. Piepenbring, 2015
genus	Basidiomycota	Polyporales	*Polyporus*	cf. *leprieurii*	

Level of identification	**Division**	**Order (or class, family)**	**Genus**	**Epithet**	**Det. new**
genus	Basidiomycota	Polyporales	*Polyporus*	sp. 1	
genus	Basidiomycota	Polyporales	*Polyporus*	sp. 2	
genus	Basidiomycota	Polyporales	*Polyporus*	sp. 3	
species	Basidiomycota	Polyporales	*Polyporus*	*tricholoma*	
species	Basidiomycota	Polyporales	*Pycnoporus*	*sanguineus*	
species	Basidiomycota	Polyporales	***Rigidoporus***	***microporus***	M. Piepenbring, 2015
genus	Basidiomycota	Polyporales	*Rigidoporus*	sp.	
genus	Basidiomycota	Polyporales	*Trametes*	cf. *modesta*	
genus	Basidiomycota	Polyporales	*Trametes*	sp. 1	
genus	Basidiomycota	Polyporales	*Trametes*	sp. 2	
genus	Basidiomycota	Polyporales	*Trametes*	sp. 3	
species	Basidiomycota	Polyporales	*Trichaptum*	*perrottetii*	
species	Basidiomycota	Polyporales	*Trichaptum*	*sector*	
genus	Basidiomycota	Pucciniales	*Aecidium*	sp.	
species	Basidiomycota	Pucciniales	*Cionothrix*	*praelonga*	
species	Basidiomycota	Pucciniales	*Dasyspora*	*gregaria*	
species	Basidiomycota	Pucciniales	*Dietelia*	*portoricensis*	
species	Basidiomycota	Pucciniales	*Puccinia*	*arechavaletae*	
species	Basidiomycota	Pucciniales	*Puccinia*	*cordiae*	
genus	Basidiomycota	Pucciniales	*Puccinia*	cf. *heliconiae*	
species	Basidiomycota	Pucciniales	*Puccinia*	*paupercula*	
species	Basidiomycota	Pucciniales	*Puccinia*	*synedrellae*	
species	Basidiomycota	Pucciniales	*Puccinia*	*urbaniana*	
species	Basidiomycota	Pucciniales	*Pucciniosira*	*dorata*	
species	Basidiomycota	Pucciniales	*Uredo*	*rubescens*	
genus	Basidiomycota	Pucciniales	*Uredo*	sp. 1	
genus	Basidiomycota	Pucciniales	*Uredo*	sp. 2	
genus	Basidiomycota	Pucciniales	*Uredo*	sp. 3	
genus	Basidiomycota	Pucciniales	*Uredo*	sp. 4	
genus	Basidiomycota	Pucciniales	*Uromyces*	sp. 1	
genus	Basidiomycota	Pucciniales	*Uromyces*	sp. 2	
genus	Basidiomycota	Pucciniales	*Uromyces*	sp. 3	
genus	Basidiomycota	Pucciniales	*Uromyces*	sp. 4	
genus	Basidiomycota	Pucciniales	*Uromyces*	sp. 5	
genus	Basidiomycota	Pucciniales	*Uromyces*	sp. 6	
species	Basidiomycota	Pucciniales	*Uropyxis*	*diphysae*	
order	Basidiomycota	Russulales	indet. hydnoid		
genus	Basidiomycota	Russulales	*Peniophora*	sp. 1	

Level of identification	Division	Order (or class, family)	Genus	Epithet	Det. new
genus	Basidiomycota	Russulales	*Peniophora*	sp. 2	
genus	Basidiomycota	Sebacinales	*Sebacina*	sp.	
genus	Basidiomycota	Trechisporales	*Tubulicium*	cf. *vermiferum*	
genus	Basidiomycota	Tremellales	*Tremella*	*lilacea* or *T. rhytidhysterii*	
genus	Basidiomycota	Tremellales	*Tremella*	sp. 1	
genus	Basidiomycota	Tremellales	*Tremella*	sp. 2	
order	Glomeromycota	Glomerales	cf. *Glomus*	sp.	
species	Myzetozoa	Liceida	*Cribraria*	*costata*	
species	Myzetozoa	Liceida	*Lycogala*	*epidendrum*	
order	Myzetozoa	Physarida	cf. *Fuligo*	sp.	
species	Myzetozoa	Physarida	*Physarum*	*daamsii*	
genus	Myzetozoa	Physarida	*Physarum*	cf. *globuliferum*	
species	Myzetozoa	Physarida	*Physarum*	*javanicum*	
species	Myzetozoa	Physarida	*Physarum*	*stellatum*	
species	Myzetozoa	Protostelida	*Ceratiomyxa*	*fruticulosa*	
species	Myzetozoa	Protostelida	*Ceratiomyxa*	*sphaerosperma*	
genus	Myzetozoa	Stemonitida	*Diachea*	cf. *radiata*	
species	Myzetozoa	Stemonitida	*Stemonitis*	*fusca*	
genus	Myzetozoa	Stemonitida	*Stemonitis*	cf. *herbatica*	
genus	Myzetozoa	Stemonitida	*Stemonitis*	sp.	
order	Myzetozoa	Stemonitida	*Stemonitis*	sp. or *Stemonitaria* sp.	
species	Myzetozoa	Stemonitida	*Stemonitis*	*typhina* var. *typhina*	
species	Myzetozoa	Trichiida	*Arcyria*	*denudata*	
species	Myzetozoa	Trichiida	*Hemitrichia*	*calyculata*	
species	Myzetozoa	Trichiida	*Hemitrichia*	*serpula*	
species	Myzetozoa	Trichiida	*Perichaena*	*depressa*	
order	Oomycota	Peronosporales	cf. *Peronospora*	sp.	
species	Oomycota	Peronosporales	*Pseudoperonospora*	*cubensis*	
division	Zygomycota		indet.		

M. Piepenbring, H. Lotz-Winter & T.A. Hofmann

Address of the authors:

Univ.-Prof. Dr. Meike Piepenbring
Department of Mycology, Cluster for Integrative Fungal Research (IPF)
Goethe University Frankfurt am Main, Biologicum
Max-von-Laue-Str. 13, 60439 Frankfurt am Main, Germany
Email: piepenbring@bio.uni-frankfurt.de

Mag. pharm. Hermine Lotz-Winter
Department of Mycology
Goethe University Frankfurt am Main, Biologicum
Max-von-Laue-Str. 13, 60439 Frankfurt am Main, Germany

Dr. Tina Antje Hofmann
Herbario UCH, Centro de Investigaciones Micológicas CIMi
Universidad Autónoma de Chiriquí, 0427, David, Chiriquí, Panamá