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# Small plot surveying reveals high fungal diversity in the Ecuadorian Amazon – a case study

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**Abstract**

The diversity and ecology of macrofungi based on fruitbody collections in a small portion of a 25-year-old regenerating forest in tropical Ecuador was investigated over a period of 8 weeks. Maps are provided of the living trees of three 10 m x 10 m plots within the forest. All fungal fruitbodies within the plots were collected every third day, the major substrates being wood, litter and soil. There were 254 collections in total, representing 127 morphospecies of which 17 are Ascomycetes and 110 are Basidiomycetes. Wood supported the greatest number of species overall, but the mycota in the three plots of the study varied greatly, with one plot having twice as many species on litter as on wood. Using canonical analysis of principal components and permutational multivariate analysis of variance, the species assemblage in the plot with the greatest amount of standing and fallen wood was the most significantly different from the other sampling units. It is concluded that a detailed examination of even a small area can provide valuable information on the fungal diversity and assemblages of a forest. This is one of the few studies from Ecuador relating macrofungal diversity to forest structure.

**Key words** – ectomycorrhizal – litter – Neotropics – soil – wood

## Introduction

In Ecuador, the slopes to the east of the Andes descend to the tropical Amazon region where the tributaries of the Amazon River including the Rio Napo (Ecuador's largest river) wind eastwards, supporting tropical rainforests and their associated diverse array of organisms, including macrofungi.

The fungal flora of Ecuador has been studied in the past by many visiting mycologists (see Læssøe & Petersen, website http://www.mycokey.com/Ecuador/HistoryStart.html for a list of visiting and local mycologists until 2008), with the first reliable record being a rust from the Galapagos Islands in 1853 by NJ Andersson; the first agaric was a species of *Lichenomphalia* collected by E Whymper on Volcán Antisana near Quito on the mainland in 1890. Significant contributions include Singer (1975, 1978) on new species, Reid et al. (1980) who surveyed the Galapagos Islands, and Hedger (1985) on the ecology of litter fungi. The expedition of the British Mycological Society in 1993 to Cuyabeno brought forth a flurry of publications (Lodge & Cantrell

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1995, Lodge 1996, Lunt & Hedger 1996). Ullah et al. (2002) and Suárez-Duque (2004) examined fungi and woody substrate. Haug et al (2005) studied mycorrhizal formation in the Nyctaginaceae and Gamboa-Trujillo (2005) presented a seminal ethnomycological work for Ecuador on the species of fungi known to be used by the indigenous Kichwa community. In the past 5 years there have been publications from Ecuador of a taxonomic nature with descriptions of new species using molecular techniques (Barili et al. 2017a,b,c, 2018, Caicedo et al. 2018, Thomas et al. 2016, Flores et al. 2018, Guevara et al. 2018, Schüßler & Walker 2019) and on the edible fungi of Ecuador (Gamboa-Trujillo et al. 2019).

There are many studies from Europe (especially the Scandinavian countries) and North America relating fungal diversity to forest structure parameters such as volume and diameter and decay class of coarse woody debris (CWD), tree species and basal area of living trees (e.g. Renvall 1995, Høiland & Bendiksen 1996, Nordén et al. 2004, Iršėnaitė & Kutorga 2007). Studies in Ecuador are still more inventory focussed, gathering as many species as possible from a reserve or threatened area (e.g. Newman et al. 2019) and publishing new species rather than plot-based projects with regular visits relating variables to diversity. Itinerant visitors with an interest in mycology may contribute records, usually without herbarium material to substantiate the records, to databases, e.g. iNaturalist (https://www.inaturalist.org/) and Mushroom Observer (https://mushroomobserver.org/). The fungal inventories and other studies in Ecuador have covered only a fraction of the habitats that exist. For the most part the fungal flora and fungal ecology of this country is still unknown and will, according to Læssøe & Petersen (2008), take several generations before a clearer picture of Ecuadorian mycological diversity emerges. Unfortunately, this diversity is in danger of never being known, due to the fast disappearance of the Amazonian tropical forests by a continuing barrage of logging and mining activities and climate change.

The first author (GMG) visited the Finca Heimatlos, near Puyo, and made casual collections and identifications of wild fungi at the invitation of the owner of the property for 4 weeks in July–August 2018. The information gathered during that period suggested that a more formal study based upon field plots would be of interest. Therefore, the first author returned 12 months later to do a plot-based project over a period of 10 weeks. The work in 2018 also laid the foundational database of collections as a reference for the present study. As this study took place on the edge of the Amazon Basin it was expected that species in common with other countries such as Brazil and Peru, areas of which are also part of this basin, would be found which would extend the range of such species.

The aims of this plot-based project were:

- to gather information on the fungal species for the construction of a baseline dataset from a secondary forest 25 years of age which would be pertinent for other similar forest types throughout Ecuador,
- to see if there exists a relationship between fungal species richness and the forest structure, taking account of the vegetation within it,
- to examine the species assemblages present in small areas of the forest.

## Materials & Methods

### Site description

The study took place at the Finca Heimatlos (01° 37′ 05″ S, 77° 50′ 29″ W), an ecolodge and sustainable farming enterprise of 50 ha on Via Canelos ca. 30 km from the township of Puyo (Fig. 1). The climate is typically equatorial, with torrential rain occurring usually every night, even in the winter or ‘dry’ season (30 km away in Puyo the monthly rainfall averages for July–September are ca. 350 mm; https://weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine, puyo-ec, Ecuador, visited 8 December 2019). At an altitude of 800 m, the temperatures are pleasantly mild and uniform all year round with minimums of about 16°C and maximums around 27°C.

The forest surrounding the ecolodge is regenerating after logging operations in the mid-1990s. The topography is steep and rugged. Three plots measuring 10 m x 10 m were chosen adjacent to the track that descends to the small unnamed river that eventually joins the larger Bobonaza. As priority had to be given to securing the safety of the investigators, level ground, which was difficult to find, was sought for the placement of the plots. The final choice placed Plots 1 and 2 only 30 m away from each other on opposite sides of the track, with Plot 3 further down the slope closer to the river. A transect of 300 m of track commencing from Plot 1 was also surveyed for 0.5 m on either side of its median width to provide some comparison to the plot survey method, the transect area of 300 $m^2$ being equivalent to the sum of the areas of the three plots.


**Fig. 1** – Map of Ecuador; the red star depicts the approximate location of the study site.

**The mapping**

The location of all living and dead trees for each of the three plots was depicted on sheets of graph paper. The diameters of the live trees were measured, and their heights estimated. The live trees were named to species level when possible, as were some of the understory plants. Fallen wood ≥ 10 cm length and ≥ 10 cm diameter, also known as coarse woody debris CWD, was also measured and plotted on the same graphs.

**The fungal surveying, examination and identification**

The three plots and the transect were surveyed by at least 3 people for 30 minutes on the same day every third day from 28 July–20 September 2019 inclusive, except for a gap of 5 days between 6–12 August, for a total of 18 visits. A macrofungus was defined as one in which the fruitbody could be seen with the naked eye or occurred in troops, forming a visible group. A species was recorded as being present in a given plot if there was one or more fruitbodies of that taxon at the given visit. No attempt was made to count the number of fruitbodies present. Hence, our assessment of species

richness is confined to noting presence or absence of a species at each visit, rather than its abundance. Fruitbodies were physically removed to avoid recording them again in subsequent visits, but polypores were left in situ and not counted on the subsequent visits. Immature fruitbodies were not included in the survey. Fruitbodies were photographed in the field and their colours, odours and substrate noted. Substrates were categorised as follows: 1. soil; 2. wood, including fallen wood >10 mm diameter, and living trees; 3. litter, including twigs to 10 mm diameter, leaves, seeds, seed pods, bark; and 4. other, e.g. dung, dead animals, parasitised insects. Collections were taken back to the laboratory at the Finca where they were assigned a collecting number and macroscopically and microscopically described using Amscope binocular compound and binocular stereo microscopes.

The following stains were used for microscopic examination of tissues at 400x and 1000x, viz. Melzer's reagent, 10% KOH, 1% phloxine, and Congo Red. Photos were taken of the microstructures down the eyepiece using a Canon Powershot 120S digital camera. Field guides and online fungal sites were used to identify the fungi, with Index Fungorum (http://www.indexfungorum.org/names/names.asp) being the source of the most up-to-date names. In some cases, identification was difficult as the very small size (≤2 mm diam.) of some of the specimens prevented complete microscopic examination, such as sectioning of the pileipellis or spore print determination. Molecular work would probably be needed to accurately assign a genus to these collections. Those species that could not be identified to species level were given a 'tag name'. The difficulties of assigning Latin names to tropical species has been encountered by other researchers (Singer & Araujo 1979, Piepenbring 2015); more than 40% of litter agarics found by Lodge & Cantrell (1995) were undescribed species. The specimens were labelled and dried on a wire rack in a covered wooden box heated by two 100w light globes. They were then placed in plastic clip lock bags and are currently stored in the private herbarium at the Finca. Eventually they will be transferred to the herbarium of the University of Estatal Amazonia or UTPL Universidad Técnica Particular de Loja.

**Statistical analysis**

Descriptive statistics were used to produce summary tables of the number of records and the number of species collected in the three plots and the transect during the 18 visits. Species richness, taken to mean the numbers of species found in a sampling unit, was computed using the Mau-Tau estimator for 'sample-based rarefaction' available in EstimateS (Colwell 2013), a procedure that effectively removes random variation among the visits and produces a smooth species accumulation curve from the observed data. As there also proved to be differences in the rate of accumulation of records among plots and transect in the early visits, species accumulation curves based upon the visits in the order in which they actually occurred (i.e. non-random) were also prepared.

Species assemblages, which take account of how the species co-occur in space and time, were examined using CAP (canonical analysis of principal coordinates; Anderson & Willis 2003) and PERMANOVA (multivariate analysis of variance using permutations; Anderson 2001), both of which are available in the ecological software package PRIMER Version 6 (Clarke & Gorley 2006).

**Results**

**Vegetation of the plots**

Although the plots were in the same forest type and close to each other, detailed examination of the living vegetation and fallen wood revealed they were quite different. Plot 1 had a boggy patch that rarely dried up, a noticeable number of palms, viz. 6 living chontas (palms of the genus *Bactris* in the family Arecaceae), each ca. 2 m tall, 4 palms of another species of the Arecaceae, and although no clinometer was available to make measurements, it was steeper than the other two plots. Plot 2 had two *Cercropia* spp. and lots of seedlings, and a very large toquilla palm (*Carludovica palmata*) as well as tangled prickly vines evocative of disturbed areas. Plot 3 had the largest number of standing dead and living trees with 4 chontas, was easier to walk through and had the ambience of an older plot compared with the other two.

**The maps**

Plot 3 had the most wood on the forest floor (including a large log 52 cm diam.) and the only standing dead wood (4 stags or stumps), 14 small diameter living trees (ca. 4 cm) and 7 larger diameter trees (Fig. 2). Plot 1 had the next highest amount of downed wood and 17 living trees of ca. 4 cm diameter and 4 trees of larger diameter. Plot 2 was almost devoid of fallen wood and had 12 small diameter living trees and 2 larger diameter trees. Plot 2 had the smallest live tree basal area and CWD volume of the three plots (Table 1).

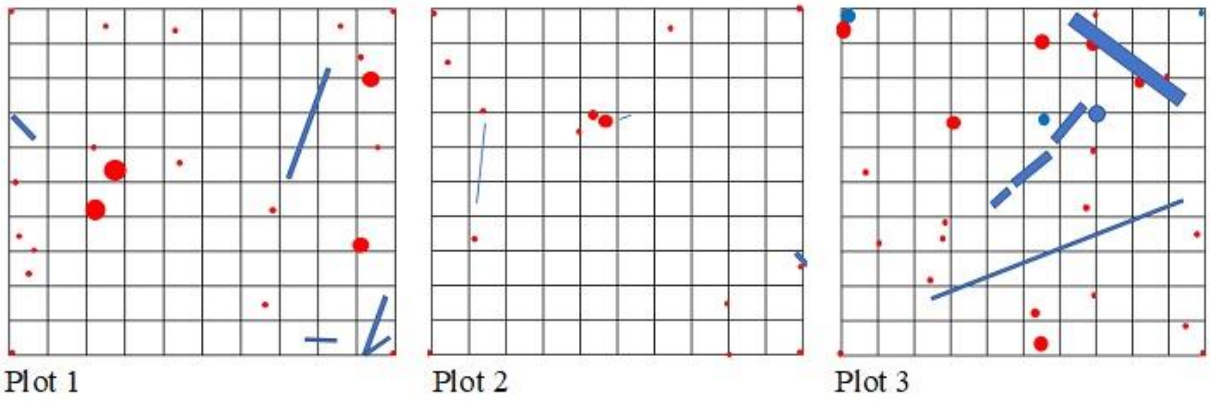


**Fig. 2** – Maps of the three plots of the study at the Finca Heimatlos, showing the location of the living trees (red dots), the fallen dead wood (blue rectangular shapes) and stags or stumps (blue dots). The 10 m x 10 m plots are divided into a 100 small squares, each of size 1 m x 1 m. Trees and stags of size 10 cm or more are drawn to scale, but trees of a smaller diameter are shown as same-sized dots.

**Table 1** Basal area of living trees and volume of CWD in each plot.

| Plot no. | Basal area of living trees, $m^2$ | CWD volume, $m^3$ |
|---|---|---|
| 1 | 0.261 | 0.122 |
| 2 | 0.097 | 0.021 |
| 3 | 0.374 | 1.077 |

**Fungal species identification and richness**

The 18 visits to the three plots and the transect produced a total of 254 collections (25 Ascomycetes and 229 Basidiomycetes), representing 127 morphospecies (17 Ascomycetes and 110 Basidiomycetes), of which 41 were formally described and 86 were identified using tag names (see Appendix 1 for a list of the species included in this study). Thirteen species could not be identified to the level of genus, although four could be assigned to an 'either/or' pair of closely related genera. Additional species found at the Finca but outside the area covered by the present study, including those from 2018, are listed in Appendix 2.

The highest number of both records and species were from the transect, 73 and 51, respectively. Each of the three plots gave a very similar number of species, viz. 42 from Plot 1, 42 from Plot 2 and 39 from Plot 3 (see Table 2b). Records had a greater range, with Plot 2 having the lowest number, viz. 50, compared to 64 for Plot 1 and 67 for Plot 3. The only species to occur in all 4 sampling units was the common wood-inhabiting species *Oudemansiella canarii*.

**Species accumulation curves**

Randomized species accumulation curves for each plot and the transect show the number of new species from each visit (Fig. 3a). None of the resulting curves, which randomize the order in which visits were made to result in smoother curves, suggests that an asymptote is being approached. When the visits are depicted in the order in which they were carried out, i.e. not

randomized, the resulting species accumulation curve is quite different (Fig. 3b). This shows that Plot 2 did not have any species present until the 5th visit. It had its major burst of fruiting activity on the 9th and 10th visits. Plot 1 had spurts at the 5th, 8th and 9th visits. Plot 3 had spurts at the 4th and 7th visits but then levelled off until it had a minor burst of fruiting activity at the 11th and 12th visits. The transect was different from the plots, with 11 species found at the very first visit and with other spikes at the 5th, 6th, 9th and 10th visits. The rate at which new species were added remained steady after that.

**Table 2** Fungi collected from the sampling units versus substrate (a) number of records, (b) number of distinct species.

(a) Number of records/percentage of row totals

| Sampling unit | Substrate litter | other | soil | wood | Totals |
|---|---|---|---|---|---|
| Plot 1 | 22/34.4% | 1/1.6% | 10/15.6% | 31/48.4% | 64 |
| Plot 2 | 24/48.0% | 2/4.0% | 15/30.0% | 9/18.0% | 50 |
| Plot 3 | 11/16.4% | 1/1.5% | 22/32.8% | 33/49.3% | 67 |
| Transect | 13/17.8% | 1/1.4% | 22/30.1% | 37/50.7% | 73 |
| Totals | 70/27.6% | 5/2.0% | 69/27.2% | 110/43.3% | 254 |

(b) Number of distinct species

| Sampling Unit | Substrate litter | other | soil | wood | Totals |
|---|---|---|---|---|---|
| Plot 1 | 16 | 1 | 8 | 21 | 42 |
| Plot 2 | 19 | 2 | 12 | 9 | 42 |
| Plot 3 | 10 | 1 | 13 | 18 | 39 |
| Transect | 10 | 1 | 16 | 25 | 51 |
| Totals | 45 | 4 | 36 | 54 | 127 |

Notes: Whereas marginal totals for the number of records are the sum of the entries in the body of the table, the marginal totals for the number of distinct species do not add up, as some species are present in more than one sampling unit or on more than one substrate.

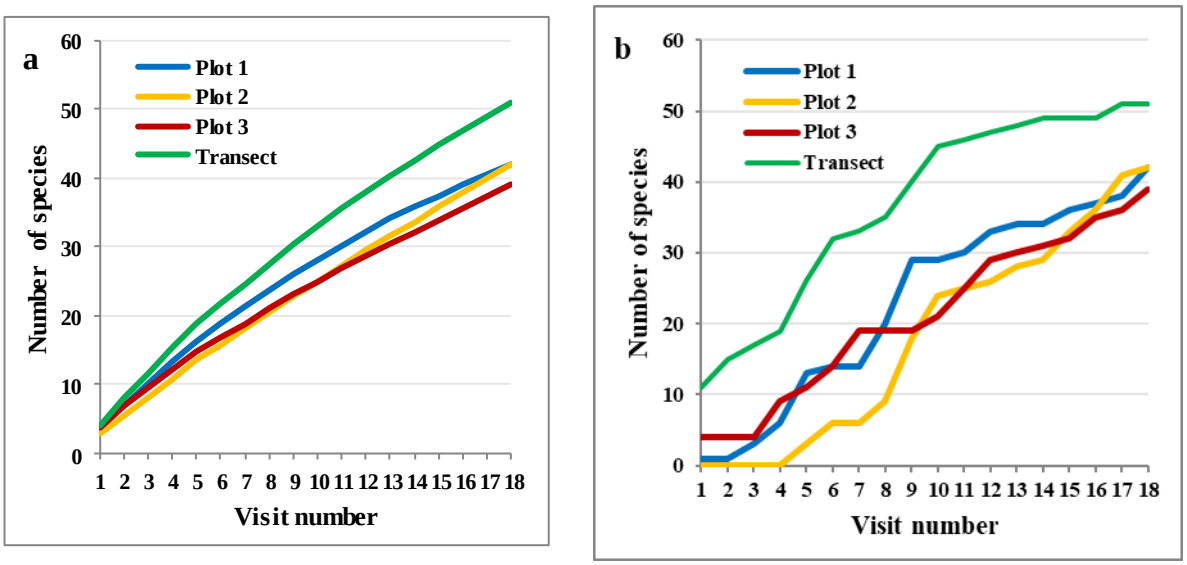


**Fig. 3 –** Species accumulation curves for the three plots and the transect at Finca Heimatlos. a Randomised. b Non-randomised. i.e. based on the visits in actual order of occurrence.

**Substrate specificity**

Eight species were found on more than one substrate, but none from more than two substrates. These 8 species included four species from Plot 1, three species from Plot 3 and one species from the transect. Four of them (*Xylaria* aff. *filiformis*, *Hohenbuehelia* 'white', *Marasmius* 'white with pink flush', *Mycena* 'tiny white with distant gills') were on both wood and litter, three (*Deconica* sp., *Marasmius* 'velutinous orange', *Mycena* cf. *pura*) were on both soil and litter, and one (*Galerina velutipes*) was on both wood and soil. From Table 2a it can be seen that in Plot 1 the percentages of records from wood (48.4%) and litter (34.4%) far exceeded that on soil (15.6%), whereas in Plot 2 litter records dominated (48%), being equal to the sum of the percentages on soil (30.0%) and wood (18.0%). In Plot 3, wood supported the highest number of records (49.3%) compared to soil (32.8%) and litter (16.4%). The transect also had the highest percentage of records from wood (50.7%), with soil and litter having 30.1% and 17.8%, respectively.

**Fungal species assemblages**

The two methods of examining the fungal species assemblages in the three plots and in the transect, viz. PERMANOVA and CAP, gave results that reinforce each other, as both of these permutational multivariate analyses indicate that Plot 3 has assemblages that are the most different from those in any of the other sampling units. The first axis of the canonical discriminant analysis CAP clearly separates Plot 3 from the other plots and from the transect (Fig. 4a), and the P-values from PERMANOVA for the comparisons of Plot 3 with each of the other two plots or the transect are highly significant (P=0.0001, Table 3). On the other hand, comparisons of Plot 1 vs. Plot 2, Plot 1 vs. Transect and Plot 2 vs. Transect all indicate a lesser degree of difference among the fungal assemblages, either pictorially (Fig. 4b) or via a formal statistical test (P>0.01, Table 3).

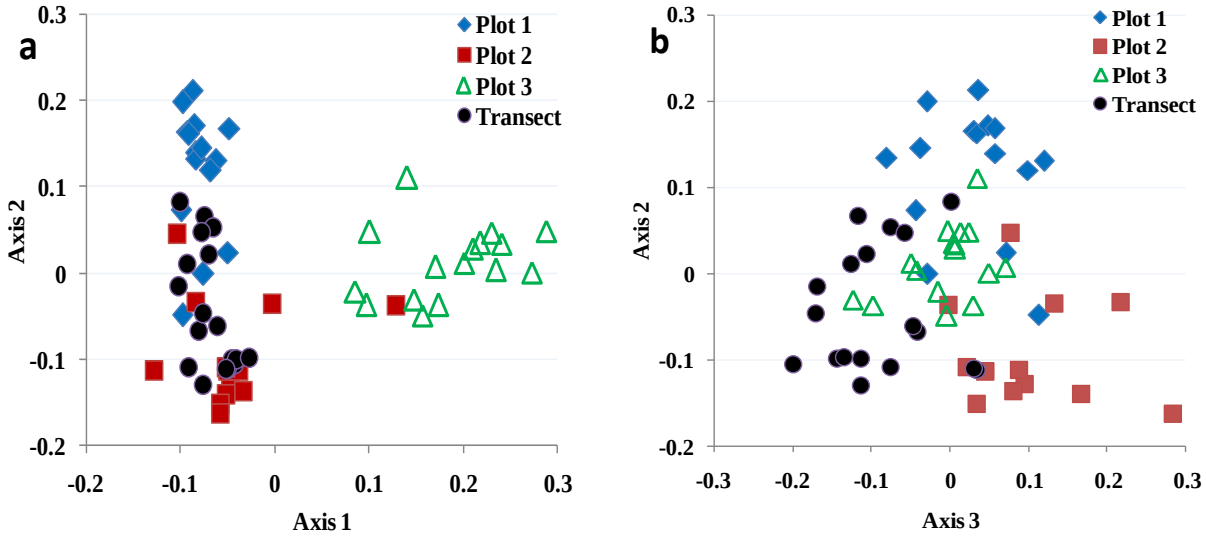


**Fig. 4** – Canonical analysis of principal coordinates (CAP) on the species collected during 18 visits to the three plots and the transect between 28 July – 20 Sept 2019; Bray-Curtis similarity calculated using presence-absence data. a Axis 2 vs. Axis 1. b Axis 2 vs. Axis 3.

**Table 3** P-values obtained from PERMANOVA (multivariate analysis of variance using permutations) on the species assemblages from the plots and transect.

| Sampling unit | Plot 1 | Plot 2 | Plot 3 | Transect |
|---|---|---|---|---|
| Plot 1 | — | 0.0177 | 0.0001 | 0.0664 |
| Plot 2 | | — | 0.0001 | 0.0215 |
| Plot 3 | | | — | 0.0001 |
| Transect | | | | — |

## Discussion

### Overall species diversity

The ever-increasing species accumulation curves and their steepness indicated that very few species were collected more than once, suggesting that sampling was in the early stages and with time it would be expected that the curves would start to level out as species were recollected. The number of Basidiomycetes was far greater than that of Ascomycetes. Many ascomycete species are very small and easily overlooked (Huhndorf et al. 2004). In fact, production of fruitbodies can be seasonal and very irregular; some fungi may not fruit for years (Straatsma et al. 2001). Culturing of substrate and molecular techniques have given greater insight into the diversity and ecology of fungi, e.g. Allmér et al. (2006) found that molecular techniques on wood revealed hidden ascomycete diversity; large numbers of litter-inhabiting fungal species in Panama were determined using 454 pyrosequencing by McGuire et al. (2012) and Kerekes et al. (2013); studies of above-ground fruitbodies and below-ground root tips have produced a different mycota with not much overlap (Dahlberg et al. 1997, Horton et al. 2017). Fungal ecology studies based on next generation sequencing of substrates have resulted in a huge number of unnamed molecular operational taxonomic units (MOTUs) which remain unnamed thereby limiting the knowledge of ecological functions, making it difficult to compare studies and impeding communication on fungal diversity (Wu et al. 2019). We had neither the financial resources nor the facilities to undertake either culturing or molecular work on any substrate. Fruitbody surveys are generally non-destructive, cheaper, and provide a picture of when the fungus is in a sexual stage of its development. Furthermore, fruiting patterns can be observed and, importantly, species can be targeted for conservation purposes, public education and citizen scientists' projects such as fungi mapping. The vouchered specimens deposited in a herbarium can be used later for molecular work and taxonomic studies. The differing survey methods should be viewed as complementary rather than mutually exclusive (Heilmann-Clausen & Vesterholt 2008); all methods provide important information.

### Species assemblages and plot differences

The differences in species and records among the plots show that a 10 m x 10 m area has a mycota different to another 10 m x 10 m area in the same forest. Each of the plots behaved in a distinctive manner, as can be seen from the non-randomized species accumulation curves and the CAP and PERMANOVA analyses. If one uses the randomized species accumulation curves as the basis for interpretation, one might conclude that Plots 2 and 3 are very similar, which would probably be misleading. The maps of the vegetation and wood (Fig. 2) are also very different. For example, Plot 2 had very little living vegetation or fallen wood and was dominated by litter-inhabiting species both in terms of species and as a percentage of its total mycota. Plot 1 was most similar to the Transect with 13 species in common of which 11 occurred on wood. It was not noted where along the Transect the species were found so any attempt to relate wood from inside Plot 1 with wood outside from the Transect as having come from the same large fallen tree was not feasible. It is not possible to tease out the factors responsible for these differences; many more plots would be needed with many more details of variables such as vegetation type and cover, light intensity, litter species, litter depth, litter moisture, soil type, soil pH and soil moisture, wood moisture and interactions of these variables. However, replication in a native forest is difficult, unlike experiments in monoculture plantation forests where trees are of the same species and the same age and are planted the same distance from each other, as well as being further compounded by the capricious nature of fungi.

### Wood-inhabiting fungi

In this study, wood was the most productive substrate for fungal diversity. Watling (1977) noted a higher percentage of lignicolous fungi occur in the tropics as in temperate regions related no doubt to the dominant ligno-cellulose habitat as noted by Hedger (1985). Many studies in boreal or temperate forest types have proven the value of leaving wood of different sizes and decay classes

on the forest floor to increase fungal diversity (e.g. Lindblad 1998, Heilmann-Clausen & Christensen 2003, Gates et al. 2011) as wood provides an array of habitats depending on the diameter, decay stage, bryophyte cover, and species. Wood, especially large diameter wood, also provides a buffered environment that withstands desiccation and maintains viable mycelium so that although the fruitbodies (except for the polypores) were removed at each finding in the present study, the mycelium of some species continued to produce fruitbodies for several visits e.g. *Auricularia fuscosuccinea* and *A. delicata* which could bias results. Another example is *Galerina velutipes*, which occurred 13 times in Plot 3 and only once in Plot 2. In Plot 3 it was found on remnants of well-decayed wood from a larger log which was the original colonised wood. It is highly likely that these individuals are genets of their respective original infection on the wood. The few polypore species that were found in this study were on standing dead wood in Plot 3. These stags could have been biological legacies from a pre-logged forest which would give a polypore the longer time needed to develop a hard substantial fruitbody (Heilmann-Clausen & Christensen 2004).

**Litter-inhabiting fungi**

A very important component of the fungal diversity in a tropical forest is the litter fungi and this is supported by our study. The 70 species found on litter included 22 species of *Mycena*/*Hemimycena* which usually have small delicate fruitbodies and 9 of *Marasmius*/*Marasmiellus* which are also small but tougher with very slender wiry stipes and are often marescent. These genera respond quickly to a rainfall event, by either rehydrating or producing new fruitbodies. The required spatial domain is very small and a piece of leaf from e.g. *Philodendron pastazanum* or *Caladium steudneriifolium*, understory plant species which have leaves with a very large surface area, or a fine twig, can support many fruitbodies of several species. Although leaf-litter substratum is prone to desiccation in a 24 hr absence of rain in tropical forests (Hedger 1985), torrential rainfall events occurred regularly every 1–2 days during the 8 weeks at the Finca and the litter quickly rehydrated. Litterfall in this patch of tropical forest was continuous. The torrential rain brought down small branches and palm leaves daily ensuring an ongoing supply of available substrate (pers. obs.).

Many litter-inhabiting fungi show preferential association with a substratum (Hering 1982, Boddy 1984, Lodge 1996) and this is the case with tropical decomposer fungi too (Hedger 1985, Lodge 1996); however, in the current study the overlap of substrates only occurred once and therefore is not considered to be of any significance.

**Soil-inhabiting fungi**

This substrate was dominated by species of Hygrophoraceae, Cantharellaceae or Entolomataceae, viz. *Hygrocybe*, *Neohygrocybe*, *Gliophorus*, *Cantharellus* (9 spp) and *Entoloma* (5 spp). No ectomycorrhizal species on wood or soil was found within the plots although the *Gloeocantharellus* sp. and *Albomagister* cf. *subaustralis* were found in the transect. An all-white *Russula* species *Russula* cf. *acuarum* species was collected several times in 2018 and 2019 from outside the study area as was *Clavaria* aff. *schaefferi*. According to Hedger (1985) many mycologists visiting the tropics observe the distinct lack of the larger ectomycorrhizal fungi such as *Russula*, *Lactarius* and *Cortinarius*. This is not surprising as only 6% of neotropical trees are estimated to form ectomycorrhizal associations (Corrales et al. 2016); however, members of the Nyctaginaceae (e.g. *Neea*) form ectomycorrhizal associations with species of the fungal families Russulaceae and Thelephoraceae (Haug et al. 2005) and *Neea* trees were observed in the forest if not in the actual plots. Given that an ectomycorrhizal fungus can fruit 20 m from its host tree (Dickie & Reich 2005) the absence of an ectomycorrhizal host in the plots would not necessarily preclude the fruiting of an ectomycorrhizal fungus species within a plot of 10 m x 10 m that had no host trees.

**Comparisons with other studies from Ecuador**

Hedger (1985) bemoaned the fact that there were few structured plot studies from Ecuador with which to compare his 2-year study of agarics in cocoa litter in Pichilinque where he surveyed 10 fixed 1 $m^2$ quadrats weekly for 88 weeks and found 30 species. Results from a litter agaric experiment in Cuyabeno (Lodge & Cantrell 1995) suggested that a single sampling from two areas of 12 1 m x 1 m plots over a period of 7 days was close to the optimum number needed for sampling and that 70% to 80% of the species present were found. They found 70 species of agarics in the litter but we assume these species (no list is given in the article) included species in the soil involved in decomposition of litter in the F layer whereas we assigned these species such as *Hygrocybe* spp. and *Entoloma* spp. to the soil-inhabiting substrate. Studies especially examining woody substrate variables and fungal species diversity are particularly rare.

Ullah et al. (2002), although the collecting was random, did distinguish between wood (all parts of the tree) down to 20 mm diameter, and small litter which included twigs <20 mm diameter, leaves, fruits and flowers and found that the overlap of species between the substrates was only 20% of the total in their study on the production of ligninolytic enzymes by species of macrofungi from Rio Palenque based on over 100 collections made in September 1997.

Suárez-Duque (2004), working in a forest (1600–1800 m asl) in a stage of regenerating of 17 years, collected macrofungi from 10 plots, each 10 m x 10 m, monthly for 5 months. He noted the fluctuations in abundance of the Agaricales and variables such as vegetation cover, volume, size (>10 cm diameter for large wood) and type of decay (whether brown or white rot) of the wood substrate but concentrated on the diversity of non-Agaricales (50 species). He also plotted where each species fruited in the plot to obtain space-time data. Although there was a relationship between abundance of fungi and vegetation cover, there was none with rainfall or wood characteristics; however, the detailed data could be used in further studies. The lack of significance further illustrates the difficulties of obtaining statistically significant data in a native forest.

Gamboa-Trujillo (2005) surveyed transects for an ethnomycological study in the Río Oglán Protector Forest (Arajuno Canton) in mature forest and a farm during April, June, July, August, September, October and November, each excursion involving 8–10 days of field work. The total area surveyed was 7000 $m^2$, which is more than 10 times larger than that of our study (600 $m^2$). He collected 185 species of which 64% grew on wood, 5% on soil, 18% on humus and 11% on leaves. We found 127 species, which suggests when the two studies are compared that intensively surveying smaller plots more frequently can capture the majority of the fungal species present. However, as the focus of Gamboa-Trijillo was on finding out which species were used by the local Kichwa community, the species list in his article contains only those 133 species, so genera that were not known to be used are missing, e.g. *Entoloma* and *Pluteus*, which makes it difficult to compare the two studies accurately. It is interesting to note that there are 15 *Marasmius* species and 12 *Mycena* species without specific epithets, similar to what we found in our study, suggesting that these species are difficult to identify and/or are very much understudied in Ecuador.

Compared to these other studies the detailed examination of the plots in our study yielded informative data on the fungal diversity in a relatively short period of time. Possibly the time interval between visits (3-day intervals) was ideal in this tropical forest to capture the species fruiting. Most of these species were collected only once and could be new to science. The natural world is facing an uncertain future with the rapidly accelerating effects of climate change. As well as the usual anthropogenic disturbances such as mining, logging, clearing of land for agriculture and housing, habitat is being destroyed by prolonged droughts, catastrophic weather events, and more intense and severe bushfires as experienced by Brazil (2019, even in the wettest Amazonian rainforest) and Australia (2019-2020). Fungal diversity may be affected and species could disappear along with habitat (Maltz et al. 2017). Fruiting patterns have already been noted as changing in the United Kingdom (Gange et al. 2007) and across Europe (Boddy et al. 2014); therefore, studies acquiring baseline data such as the current one should not be neglected.

## Conclusions

- There is valuable ecological information to be obtained at the small-scale level. This study provides a snapshot in time of the fungal diversity found in a 25-year-old forest in the Amazonia of Ecuador and is an important addition to the few structured fungal studies from Ecuador.
- Wood on the forest floor is a very important substrate for fungal diversity and this should be considered in the development of sustainable forestry practices in tropical Ecuador and other countries that are part of the Amazon basin as it has been in other parts of the world.
- More collecting projects are needed with molecular studies examining soil, root tips and woody substrates to further clarify the fungal diversity of Ecuador.

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## Appendices

**Appendix 1** List of species in the present study, and the sampling units and substrates in or on which they were found

Ascomycetes:
aff. *Cudoniella* 'small 3 mm diam. cream tacks, spores 7 x 2µm' = FH 167; Transect; litter
Ascomycete 'gelatinous greyish translucent discs ca. 2 mm diam.' = FH 77; Plot 1; litter & wood
*Beauveria locustiphila* = FH 89; Plots 2 & 3; insect
*Cordyceps* 'white branched on grasshopper' = FH 207; Plot 1; insect
*Cordyceps pruinosa*; Transect; insect
*Gibellula* 'spider pathogen'; Plot 2; spider
*Hymenoscyphus* 'tiny greyish stalked disc, spores 6 x 2.5µm' = FH 220; Plot 2; litter
*Hypocrea* aff. *gelatinosa* = 24 FH 2018; Plot 3; wood
*Hysterographium* sp., lichen = FH 206; Plot 2; litter
*Phillipsia domingensis* = FH 47; Transect; wood
*Scutellinia scutellata* = 96 FH 2018; Plot 1; litter
*Xylaria* 'slender black clubs to 12 mm tall, 6 mm at base, immature' = FH 170; Transect; wood
*Xylaria* aff. *filiformis* = FH 191; Plot 1; litter & wood
*Xylaria* aff. *griseo-olivacea* = FH 208; Plot 3; wood
*Xylaria cubensis* = 53 FH 2018; Plots 1 & 3 & Transect; wood
*Xylaria hypoxylon*; Transect; wood
*Xylaria polymorpha*; Plot 3; wood

Basidiomycetes:
*Albomagister* cf. *subaustralis* = FH 27; Transect; soil
*Armillaria* 'dark brown with darker centre, hygrophanous becoming yellow-brown, whitish gills, blackish stipe, spores 10 x 5µm' = 57 FH 2018; Plots 1 & 2 & Transect; wood
*Auricularia delicata* = 15 FH 2018; Plot 1 & Transect; wood
*Auricularia fuscosuccinea*; Plot 1 & Transect; wood
*Auriscalpium* cf. *villipes* = FH 100; Transect; wood
*Cantharellus* 'dry, white-cream concolorous, spores 7.5 x 7.5µm' = FH 69; Plot 3; soil
cf. *Cellypha* 'tiny, 2.5 mm diam., white with reduced gills, on twig' = FH 36; Transect; wood
*Clavaria* 'single slender white clubs, garlic odour, spores 7 x 7µm' = FH 169; Transect; soil
*Clavaria* 'white clubs, longitudinally grooved, spores 5 x 5µm, no odour' = FH 91; Plots 1 & 3; soil
*Clavulina* aff. *coralloides* = FH 119; Plot 3; soil
*Clavulinopsis* 'orange-yellow clubs to 47 mm tall, single or in groups, dry, spores 6 x 6µm' = FH 86; Plots 2 & 3; soil
*Coprinellus disseminatus*; Transect; wood
*Coprinellus* 'ochre cap, purplish spores 8 x 4µm with germ pore' = FH 164; Transect; wood
*Coprinellus* 'yellow cap, brown spores 5 x 3.5µm with germ pore' = FH 152; Plot 1; wood
*Crepidotus* 'white fan dorsally attached, spores 10 x 5µm, capitate cystidia' = FH 38; Plot 3; litter
*Cuphophyllus pratensis* = 7 FH 2018; Transect; soil
*Cyathus striatus* = FH 101; Plot 3; soil
*Deconica* 'brown, spores heart-shaped 6 x 4–4.5µm' = FH 151; Plot 2 & Transect; litter & soil
*Deconica horizontalis*; Plot 1 & Transect; litter & wood
*Eichleriella*/*Exidia* 'thin grey-brown resupinate jelly, longitudinally septate basidia, spores 15 x 5µm' = FH 162; Plots 1 & 2 & 3; litter

*Entoloma* ‘dark brown, deeply sulcate cap, dark grey-brown gills, finely squamulose brown stipe, spores 13 x 9µm, 6 angles’ = FH 128; Plot 2 & Transect; soil

*Entoloma* ‘grey cap and stipe, spores 10 x 7.5µm, spermatic odour’ = FH 116; Plot 2; soil

*Entoloma* ‘velutinous dark brown sulcate cap, pale grey-brown distant gills, grey-brown stipe, spores 6 angles 8 x 8µm, hymeniform pileipellis’ = FH 146; Plot 2; soil

*Entoloma* ‘white depressed cap, strong farinaceous odour, quadrate spores 10 x 10µm’ = FH 49; Transect; soil

*Entoloma* ‘yellowy brown cap, flesh pink gills, whitish stipe, awl-shaped cystidia, spores 5-angled tending to quadrate, 10 x 8µm’ = FH 41; Plot 3 & Transect; soil

*Favolus ianthinus* = FH 145; Plot 2; wood

*Favolus tenuiculus*; Plots 1 & 2 & Transect; wood

*Filoboletus gracilis* = 84 FH 2018; Plot 1 & Transect; wood

*Flaviporus brownii* = FH 110; Plot 3; wood

*Galerina* ‘orange-brown cap, pale brown cap and stipe, smooth spores 10 x 5µm’ = FH 132; Plot 1; soil

*Galerina velutipes* = 35 FH 2018; Plots 2 & 3; soil & wood

*Gloeocantharellus* ‘stout peglike, burnt-orange bruising brownish violet, whitish thick gills bruising violet-brown, mitre-shaped cystidia, spores with low warts 8 x 5µm’ = FH 159; Transect; soil

*Gloiocephala* ‘tiny 2–3 mm diam. white pileus ringed with hairs, no pores, no gills, spores 10 x 4µm, in troops’ = FH 133; Plots 1 & 3; litter

*Hohenbuehelia* ‘pale grey cap and gills, metuloids acuminate-lageniform, encrusted 52.5 x 22.5µm, spores 7.5 x 2.5µm’ = FH 64; Plot 1; litter

*Hohenbuehelia* ‘white fruitbody, metuloids with thickened walls, some crystals 75 x 17.5µm, broadly lageniform, spores 7.5 x 5µm’ = FH 67; Plot 3; litter & wood

*Hohenbuehelia* cf. *petaloides* ‘yellowy brown cap, greyish white gills, reduced stipe, no odour, metuloids ovoid-acuminate with encrusted apex 40 x 15µm, aculeate pileocystidia, spores 5 x 2.5–3µm’ = FH 81; Plot 3; litter & wood

*Hohenbuehelia* ‘lilac-grey fruitbody, spores 9 x 4µm, metuloids apically encrusted ice cream cones’ = FH 194; Plot 3; wood

*Hydnopolyporus fimbriatus* = 11 FH 2018; Transect; wood

*Hydropus irroratus* = FH 80; Plot 2; soil

*Hygrocybe* ‘dry orange-yellow cap, orange-yellow gills, stipe orange at apex, yellow at base, spores 10 x 7µm’ = FH 68; Plots 2 & 3; soil

*Hygrocybe* ‘dry, orange cap, orange decurrent gills, orange stipe spores 5 x 5µm’ = FH 180; Plot 2; soil

*Hygrocybe* ‘dry, red hygrophanous cap, golden yellow gills, golden yellow stipe, giant cystidia 75.5 x 17.5µm, spores 6 x 6µm’ = FH 113; Transect; soil

*Hygrocybe* ‘glutinous red cap, glutinous orange-yellow stipe, whitish gills, spores 8.7 x 5µm’ = FH 61; Plot 1 & Transect; soil

*Hygrocybe* ‘viscid pale orange cap to 8 mm diam., yellow decurrent gills, orange stipe, spores 7.5 x 5µm’ = FH 78; Plot 1; soil

*Hygrocybe conica* group = FH 168; Plot 2; soil

*Hymenochaete* ‘brown turning black in KOH, resupinate with setae, spores globose 5–6 x 5–6µm’ = FH 190; Plot 3; wood

*Lentinus ciliatus* (= *Panus ciliatus*); Plot 1 & Transect; wood

*Lentinus crinitis* = 19 FH 2018; Transect; wood

*Lentinus tricholoma*; Plot 1 & Transect; wood

*Lepiota* ‘golden brown woolly cap, white gills, golden brown stipe with some woolly scales, spores 10–12.5 x 3µm, trichoderm with clamps’ = FH 46; Plot 1; soil

*Leucocoprinus* ‘concolorous cream-yellow, torulose cheilocystidia 140 x 10µm, large spores

12.5 x 5µm' = FH 102; Plot 2; soil

*Leucocoprinus* 'greyish, brown at centre, just free pale brown lamellae, fragile whitish stipe, spores 7 x 6µm' = FH 224; Plot 1; wood

*Leucocoprinus* 'white with greyish flat scales, small basidia 12.5 x 5µm, spores 5 x 3.5µm' = FH 21; Transect; soil

*Lycoperdon* cf. *fuligineum* = 83 FH 2018; Plot 1; wood

*Marasmiellus* 'white cap with flush of pink-brown at centre, white gills, stipe pinkish at base, clavate cheilocystidia with excrescences, spores 10 x 6µm' = FH 157; Plots 1 & 2 & Transect; litter & wood

*Marasmiellus* 'white cap, two-tone stipe, giant narrowly lageniform cystidia 110 x 10µm, spores 22.5 x 5µm' = FH 37; Transect; litter

*Marasmius* 'creamy white sulcate cap, distant white gills forming a collarium, hairlike, brown stipe, sphaeropedunculate cystidia with excrescences, pip-shaped spores 6 x 4µm' = FH 75; Plots 1 & 2; litter

*Marasmius* 'distant gills with collarium, lacrymoid spores 7 x 4µm' = FH 153; Plot 1; litter

*Marasmius* 'grey-brown, velvety cap, distant gills forming a collarium, blackish hair-like stipe, spores 9 x 4µm' = FH 165; Plot 2; litter

*Marasmius* 'velutinous blackish brown cap, off-white crowded gills, wiry blackish brown stipe, no spores observed' = FH 131; Plot 2; litter

*Marasmius* aff. *crinis-equi* = FH 103; Plots 1 & 2; litter

*Marasmius haematocephalus* group = FH 15; Plots 2 & 3 & Transect; litter

*Marasmius* 'velutinous ochre orange cap, whitish orange gills, tough 2-tone stipe whitish at apex, brown at base, odour of wet dog, spores 13 x 4µm, broom cells in the pileipellis' = FH 143; Plots 2 & 3 & Transect; litter & soil

*Mycena* 'conico-convex with obtuse apex ochre cap, whitish gills, translucent white stipe, on wood, hyphal endings hastate in pileipellis, long basidia 50 x 7.5µm, spores 7.5 x 5µm' = FH 79; Plot 1; wood

*Mycena* 'golden yellow deeply sulcate cap, distant arcuate decurrent gills with brown margin, threadlike stipe, spores 8 x 4µm, cylindro-ventricose cheilocystidia with apical strangulation' = FH 213; Plot 2; litter

*Mycena* 'grey-brown cap 2 mm diam., with lageniform-acuminate cheilocystidia, with neck bisectioned to swollen base 17 x 6µm, spores 7.5 x 5µm' = FH 198; Plot 2; litter

*Mycena* 'grey-pink cap, with close narrow grey-pink decurrent gills, grey-pink stipe, broadly cylindro-clavate cheilocystidia, spores 6.3 x 3.8µm' = FH 39; Plot 3 & Transect; soil

*Mycena* 'pale yellow cap, distant fimbriate gills, white tough hairy stipe, narrowly clavate long spiny cheilocystidia 90 x 5µm and similar caulocystida' = FH 181; Plot 2; litter

*Mycena* 'pale yellow cap, thread-like stipe, spores 7 x 4µm, globose hyphae with excrescences' = FH 214; Plot 1; litter

*Mycena* 'pallid orange-yellow cap 2.5 mm diam., decurrent pallid orange-yellow subdistant gills, fragile pallid orange-yellow stipe, spores 7 x 3µm' = FH 202; Plot 2; litter

*Mycena* 'pinkish brown cap, pinkish brown intervenose gills, tough bright yellow stipe, spores 6.3 x 3.8µm, some apically forked ventricose-lageniform cheilocystidia' = 75 FH 2018; Plots 1 & 2 & 3; soil

*Mycena* 'small brownish pink cap, brownish pink gills, stipe with pale pink mycelium at base, broadly clavate spiny cheilocystidia, spores 7 x 4µm' = FH 70; Plot 3; litter

*Mycena* 'small grey-brown, very decurrent arcuate greyish white gills, whitish stipe, spores 7.5 x 3.75µm'= FH 73; Transect; litter

*Mycena* 'tiny white cap, distant white gills, white thread-like stipe, spiny clavate cheilocystidia, elongated lacrymoid spores 10 x 3µm' = FH 138; Plot 1; litter & wood

*Mycena* 'white cap 2.5 mm diam. distant white gills, white threadlike stipe, fusiform spores 8–10 x 4–4.5µm, narrow spiny clavate cheilocystidia with a heel' = FH 163; Plot 3; litter

*Mycena* 'white cap, distant white gills, pinkish stipe, spores 7 x 5µm, cystidia with finger-like

projections' = FH 205; Plot 2; wood

*Mycena* 'white, no gills, small stipe, spores 8 x 2.5–3µm, cheilocystidia narrowly lageniform with moniliform apex' = FH 155; Plot 1; litter

*Mycena* 'white, thread-like stipe, spores 7 x 4µm, spiny spherical hyphae' aff. FH 214; Plots 1 & 2; litter

*Mycena* 'yellowish with thread-like stipe, torulose or misshapen fusoid cheilocystidia, spores 9 x 5µm' = FH 209; Plot 2; litter

*Mycena* cf. *pura* 'pink-brown, distant vinaceous brown gills, vinaceous brown stipe yellowing at base, radish odour and taste, spores 7.5 x 5µm, on soil' = FH 40; Plots 1 & 3; litter & soil

*Mycena spinosissima* (= *Amparoina spinosissima*), white with granules = 74 FH 2018; Transect; litter

*Mycena* 'white club-shaped spiny cheilocystidia, spores 7 x 3µm'; Plot 2; litter

*Mycena*/*Hemimycena* 'creamy cap with subdecurrent yellowish gills drying deep yellow, raphanoid odour and taste and bitter, spores 5 x 2.5–3µm' = FH 48; Transect; soil

*Mycena*/*Hemimycena* 'small 3 mm diam., distant white decurrent gills, slender white stipe' = FH 76; Plot 1; litter

*Mycena*/*Marasmiellus* 'white fruitbody, spiny clavate cheilocystidia, spores 8 x 5µm' = FH 158; Plots 1 & 2; litter & wood

*Neohygrocybe* 'blackish grey-brown cap, ivory gills becoming blackish grey, greyish brown felty stipe, farinaceous odour, spores 4 x 4µm' = FH 149; Transect; soil

*Oudemansiella canarii* = FH 148; Plots 1 & 2 & 3 & Transect; wood

*Phanerochaete* 'bright yellow with yellow subiculum spores 4 x 3µm' = FH 185; Plot 3; wood

*Pholiota* 'viscid ochre with orange red centre cap and superficial scales, yellow-brown gills, stipe viscid yellow-brown, cheilocystidia clavate with projecting obtuse apex, spores 12.5 x 7.5µm' = FH 87; Transect; wood

*Pleurotus* cf. *djamor* 'white fan, crowded white gills, stipe much reduced, spores 7 x 4µm, clamps, thickened generative hyphae, no odour' = FH 58; Plots 1 & 2; wood

*Pluteus* 'brown velutinous cap, brownish pink free gills, translucent white stipe, bent utriform cheilocystidia, spores 5 x 4–5µm' = FH 130; Transect; wood

polypore 'cream, small, friable' = FH 161; Plot 2; litter

polypore 'with coffee hymenium' = FH 111; Plot 3; wood

polypore 'with subiculum' = FH 112; Plot 3, wood

*Polyporus* 'very thin-fleshed brown at centre becoming greyish cream, tough blackish dark brown velutinous stipe, very fine pores, binding and generative hyphae' = FH 211; Transect; wood

*Polyporus dictyopus*; Plots 1 & 3; wood

*Poromycena* 'small greyish brown caps to 12 mm diam. off white gills bifurcate and intervenose to almost poroid, stipe whitish at apex, reddish brown at base, narrowly fusiform cystidia 22.5 x 7.5–8µm, spores 3 x 2.5µm' = FH 42; Transect; wood

*Psathyrella* 'hygrophanous pinkish brown cap, dark brown gills, whitish slender, stipe to 1.5 mm wide with a sheen, spores 8 x 4.5µm, utriform cheilocystidia 23 x 11µm'= FH 199; Plot 3; soil

*Psathyrella* 'stoutish medium brown cap to 30 mm diam., dark grey-brown gills with whitish fimbriate margins, white stipe with a white annulus spores 10 x 5–6µm, cheilocystidia ventricose-fusiform 75 x 15µm' = FH 114; Transect; wood

*Psathyrella* 'pequenita, small grey-brown fruitbodies to 11 mm diam., spores 6.5 x 6µm, sphaeropedunculate cheilocystidia 20 x 12.5µm' = 15 FH 2018; Transect; wood

*Pterula* 'cream, to 15 mm tall, very finely branched, with hint of a stipe' = 3 FH 2018; Plots 1 & 2 & Transect; soil

*Rhizochaete filamentosa* = FH 223; Plot 3; wood

*Rigidoporus microporus*; Plot 3; wood

*Schizopora* 'pale ochre resupinate, poroid with very thin dissepiments, spores 4 x 3µm' = FH 104; Plot 3; wood

*Stereopsis* aff. *hiscens* = 72 FH 2018; Plot 3, Transect; soil
*Tetrapyrgos nigripes* = FH 124; Transect; litter
Tricholomataceae 'ca. 3 mm diam., concolorous orange, very stumpy basidia 15 x 8µm, spores 9–10 x 5µm, ventricose-fusiform cheilocystidia' = FH 192; Plot 2; litter
Tricholomataceae 'small brown cap 5 mm diam., greyish gills, white stipe, spores 6 x 5µm' = FH 184; Plot 1; litter
Tricholomataceae 'cap whitish to 1 mm across with 10 mm stipe, spores 3 x 2µm, cheilocystidia broadly utriform' = FH 182; Plot 3; litter
*Tricholomopsis aurea* = FH 53; Plot 2, Transect; wood

**Appendix 2** Other species found outside the present study, including records from 2018.

**Other species from 2018 not found in 2019**

*Agaricus* aff. *rufoaurantiacus*
*Beauveria diapheromeriphila*
*Conocybe* 'delicate; small stature, spores 10 x 5µm' = 55 FH 2018
*Coprinopsis* sp.
*Entoloma* 'ochre cap, bone stipe' = 41 FH 2018
*Entoloma* 'pale biscuit' = 58 FH 2018
*Entoloma* 'pale yellow' = 63 FH 2018
*Entoloma* 'silky hygrophanous' = 46 FH 2018
*Entoloma* 'steely blue' = 44 FH 2018
*Entoloma* 'stripy black' = 42 FH 2018
*Entoloma* aff. *asprellopsis* = 43 FH 2018
*Entoloma dragonospora* group 'spores 20 x 20µm' = 89 FH 2018
*Entoloma* sect. *Entoloma* 'grey-pink with ixocutis, isodiametric spores 6 x 6µm' = 85 FH 2018
*Entoloma* sect. *Inocephalus* 'with giant cystidia' = 92 FH 2018
*Entoloma* sect. *Pouzarella* = 65 FH 2018
*Gymnopilus* aff. *junonius*
*Helicogloea* aff. *lagerheimii* = 34 FH 2018
*Hohenbuehelia petaloides* = 14 FH 2018
*Hygrocybe* (aka *Gliophorus*) 'bruising green and black' = 100 FH 2018
*Hygrocybe* (aka *Gliophorus*) 'pale orange, lubricous cap and stipe, decurrent gills spores ca. 7.5 x 6µm, pustulate' = 54 FH 2018
*Hygrocybe* (aka *Gliophorus*) 'pink cap, gills and stipe, spores globose, ca. 7.5–8µm'= 73 FH 2018
*Hygrocybe* (aka *Gliophorus*) green = 25 FH 2018
*Leucoagaricus* cf. *bivelatus*
*Leucocoprinus* 'white with brown lubricous centre disc' = 51 FH 2018
*Leucocoprinus* 'with large spores 12.5 x 7.5µm' = 47 FH 2018
*Marasmius* 'greyish vinaceous' = 45 FH 2018
*Marasmius cladophyllus* = 4 FH 2018
*Mycena*/*Marasmius* 'very large pink, spores 22 x 4.5µm' = 93 FH 2018
*Mycena* sect *Caodentes* 'pale pink, on wood, distant gills'
*Parasola* 'pink'
*Peniophora* 'purplish brown' = 18 FH 2018
*Scytinopogon* 'soft, white' = 87 FH 2018
*Tremellodendropsis tuberosa* = 95 FH 2018

**Species found in 2019 outside of the plots or transect**

*Acervus epispartius*

aff. *Leotiomyces* = FH 134
aff. *Mycena* ‘orange with decurrent gills, globose spores 5 x 5µm’ = FH 180
aff. Stereaceae ‘pinkish brown, petaloid’ = FH 105
aff. Tricholomataceae ‘ochre fans, very bitter taste’ = FH 121
aff. Tricholomataceae ‘small, white-spored, petaloid, decurrent gills, no stipe’ = FH 82
aff. Tricholomataceae ‘tiny, ochre, hymeniform pileipellis’ = FH 212
aff. Tricholomataceae ‘velutinous brown on soil, trichoderm, globose spores 7 x 7µm, digitate cheilocystidia’ = FH 222
aff. *Trogia* ‘pale yellow on soil’ = FH 175
*Albomagister subaustralis* = FH 27
*Amauroderma*/*Humphreya* cf. *coffeata* = FH 43a
*Arrhenia* ‘greyish white’ = FH 166
*Ascocoryne* ‘pale pink’ = FH 8a
*Asterostroma* cf. *andinum* = FH 90
*Auricularia mesenterica* = FH 11
*Auriscalpium* cf. *villipes* = FH 29
*Clavaria* cf. *schaefferi* = FH 63
*Clitocybula azurea* = FH 122
*Conocybe apala* = FH 188
*Dacrymyces san-augustinii* = FH 32
*Dacryopinax* cf. *spathularia* = FH 21
*Deconica* ‘dark brown cap and stipe, spores 7.5 x 3.8µm’ = FH 28
*Dictyopanus pusillus* = FH 176
*Discina* sp. = FH 83
*Entoloma* ‘beige centrally depressed sulcate cap, spores 10 x 7.5µm’ = FH 51
*Entoloma* ‘black scaly, isodiametric spores 10 x 10µm, trichoderm with pileocystida, radish odour’ = FH 215
*Entoloma* ‘brown umbonate, isodiametric spores 8 x 8µm’ = FH 201
*Entoloma* ‘champagne blonde large heterodiametric spores 11–12 x 7.5µm’ = FH 1
*Entoloma* ‘grey cap, blue-grey stipe, 7–8 angled large spores 10–12 x 7–8µm, spermatic odour, cylindroclavate cheilocystidia’ = FH 57
*Entoloma* subg. *Entoloma* ‘viscid grey-violet-brown cap, 6 angled isodiametric spores 7–7.5 x 7–7.5µm’ = FH 18
*Entoloma* ‘ochre cap, golden brown thin stipe, spores 10 x 7.5µm’ = FH 16
*Entoloma* ‘ochre cap, pale translucent brown stipe, sub-isodiametric spores 7.75 x 7.5µm, narrow cylindro-clavate cystidia’ = FH 57a
*Entoloma* ‘brown umbonate cap, whitish stipe, spores cruciform 10 x 10µm, awl-shaped cheilocystidia’ = FH 19
*Favolaschia* ‘white’ = FH 147
*Galerina* ‘depressed cap, on soil’ = FH 120
*Ganoderma applanatum* = 33 FH 2018
*Geastrum* aff. *schweinitzii* = FH 187
*Gymnopus* ‘brown with smooth orange-yellow stipe’ = FH 196
*Gymnopus* ‘pinkish brown with velutinous brown stipe’ = FH 62
*Hohenbuehelia* ‘black’ = FH 92
*Hohenbuehelia* ‘white, encrusted metuloids, spores 8 x 7µm’ = FH 136
*Hydropus* sp. = FH 183
*Hygrocybe* (aka *Cuphophyllus’* ‘olive with grey gills’ = FH 4
*Hygrocybe* (aka *Gliophorus*) ‘red cap, orange-yellow stipe’ = FH 61
*Hygrocybe* (aka *Gliophorus*) ‘violet and grey-green’ = FH 141
Hygrocybe ‘blackish brown over orange red, orange gills’ = FH 179
*Hygrocybe* ‘dark reddish brown, with a trichoderm’ = FH 115

*Hygrocybe* ‘deep golden yellow’ = FH 95
*Hygrocybe* ‘dry, orange, yellow at base of stipe’ = FH 68
*Hygrocybe* ‘greyish red, ruby gills, very large sphaeropedunculate cheilocystidia 70 x 30µm, spores ca. 7 x 4µm’ = 59 FH 2018
*Hygrocybe* ‘green’ = FH 72
*Hygrocybe* ‘large dark red with very large basidia (52.5µm long), spores 12.5 x 7.5µm’ = FH 84
*Hygrocybe* ‘orange-red, bisporic’ = FH 26
*Hygrocybe* ‘orange-yellow with an ixocutis, spores 10 x 6–7µm’ = FH 118
*Hygrocybe* ‘pale lemon yellow’ = FH 94
*Hygrocybe mirabilis* nom. prov. ‘large, whitish with bright red distant gills’ = FH 85
Hymenochaetaceae ‘polypore thin, dark brown’ = FH 10
*Lactocollybia* cf. *albida* = FH 50
*Lentinus concavus*
*Leucocoprinus* ‘pink gills, bruising black’ = FH 8
*Leucopaxillus gracillimus* = FH 24
*Lyophyllum* ‘blackish brown, narrow crowded gills’ = FH 135
*Marasmiellus* ‘terracotta’ = FH 34
*Marasmiellus* ‘pale brown, tough reddish brown stipe’ = FH 210
*Marasmius* cf. *crinis-equi* = 28 FH 2018
*Moniliophthora perniciosa* = FH 6
*Morganella*/*Lycoperdon* ‘greyish cream, spores 4 x 4µm’ = FH 125
*Multiclavula vernalis*
*Mycena* ‘grey-brown with hastate cystidia’ = FH 74
*Mycena* ‘grey-brown’ = FH 33
*Mycena* ‘pink-brown, radish odour and taste, distant gills’ = FH 40
Mycena ‘whitish with bleach odour, orangy towards base of stipe’ = FH 60
*Mycena* aff. *chloroxantha* = FH 139
*Mycena* sect. Saccheriferae ‘grey-brown’ = FH 196
*Neofavolus* cf. *alveolaris* = FH 59
*Neohygrocybe* ‘dark brown’ = FH 45
*Panus* cf. *lecomtei* = FH 109
*Penicilliopsis* sp. = FH 173
*Phaeoclavulina* sp. = 30 FH 2018
*Pleurotus* cf. *djamor* = FH 7
*Pluteus* ‘large stature with large utriform cystidia 67.5 x 27.5µm, large sphaeropedunculate cystidia 70 x 52.5µm, spores 6.3 x 6.3µm’ = FH 44
*Pluteus* cf. *cervinus* = FH 22
*Pluteus* ‘small stature, digitate cheilocystidia, globose spores ca. 7 x 7µm, trichoderm of utriform pileocystidia’ = FH 222
*Polyporus* ‘thin-fleshed, very fine pores’ = FH 211
*Polyporus* ‘brown velvety cap, pore surface bruising brown, on very rotten wood’
*Psathyrella* ‘farinaceous odour’ = FH 129
*Psilocybe caerulescens* = FH 20
*Pulvinula* ‘brown-yellow smooth cushions on soil’ = FH 144
*Pycnoporus sanguineus* = 21 FH 2018
*Rhizochaete brunnea* = FH 2
*Rigidoporus* cf. *microporus* = FH 216
*Ripartiella brasilensis* = FH 9
*Russula* ‘pure white, spores 7.5 x7.5µm’ = FH 13
*Schizophyllum commune*
*Stereum* aff. *hirsutum* = FH 171
*Sulzbacheromyces* aff. *caatingae*

*Thuemenella* aff. *cubispora* = FH 195
*Trametes elegans* = 17 FH 2018
Xylariaceae ‘small black turbinate balls’ = 16 FH 2018