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Edible Mushrooms of Peri-Urban Kichwa Communities in the Andes-Amazon Piedmont, Ecuador

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Abstract

Ecuador is a multicultural and megadiverse country where nearly 50 species of wild edible macrofungi (WEM), used by 12 indigenous peoples, have been reported. The Kichwa use 29 species of mushrooms, but aspects of their ecology are unknown. The aim of this study was to study the richness, use, substrates and fruiting seasons of WEM consumed by two peri-urban Kichwa communities settled in the piedmont between the Andes and the Amazon. Between May 2019 to April 2020, we conducted 56 interviews with adults and 12 walks in the chagras and forests. People recognized 26 fungal names related to 12 species of mushrooms, 11 basidiomycetes and one ascomycete. Three species were the most culturally important: *Favolus tenuiculus, Bresodolia paradoxa* and *Lentinus concavus*, defined by their abundance, economic importance and taste. Six mushroom species were newly reported for the Kichwa group and four species added to the list of species in the country. All the fungi were lignicolous; they were found on the trunks of 16 species of plants in the chagras. The plant-trees: *P. discolor*, *Inga edulis* and *C. alliodora* were the most common substrates. These species are abundant in the chagras and frequently used for their wood. Ecological and traditional knowledge related to WEM is important to enhance management practices *in situ* and *ex situ*.

Keywords

non-timber forest products, saprophytic fungi, cultural importance index, ecological interaction networks, quantitative ethnobiology

Introduction

The fungi form one of the most diverse kingdoms of eukaryotic organisms in the world, with an estimated 2.2 to 3.8 million species (Hawksworth and Lücking 2017); they provide multiple environmental, economic and social benefits in terms of ecosystem services (i.e., support, regulation, and provisioning) (Dighton 2016; Tomao et al. 2017). Useful fungi are those species with economic importance (Garibay-Orijel et al. 2009), including edible wild mushrooms (WEM), which are collected in more than 85 countries worldwide (Pérez-Moreno 2021).

In rural areas, edible mushrooms are important components of the subsistence of peasants and indigenous people (Boa 2005; Kamalebo and De Kesel 2020; López Camacho 2007; Melgarejo et al. 2014; Kaliyaperumal, Kezo and Gunaseelan 2018; Zent 2008). The extensive knowledge of this resource allows people to recognize and differentiate toxic species, ways of consumption, preservation and commercialization (Boa 2005; Kamalebo et al. 2018). Mushroom taxonomy is culturally constructed; people group fungi with common traits together, so they can quickly locate and identify edible mushrooms (Friedberg 1997). Some cultures arrange them as part of the plant or animal kingdom, or both (Hunn, Venegas Ramerez and Dávila 2015). Their ambivalent status in some societies as a plant-like growing cycle and also meat-like texture and flavor, allow them to be served with starchy ingredients (Zent 2008).

Edible mushrooms are quite nutritious with 27 to 48% of protein, 50–60% of carbohydrates and 2–8% of oils from 10% of their dry weight (Cano and Romero 2016). Since 1999, the Food and agriculture organization -FAO- has included edible fungi into the non-timber-forest products list (Boa 2005). They have promoted their sustainable use to contribute to the rational management of forests in the world, the conservation of their diversity and, to enhance the income and food sovereignty of rural peasants FAO 2000; Martínez-Carrera et al. 2000; Mayett and Martínez-Carrera 2010).

In Ecuador 50 species of wild edible mushrooms are used by 12 indigenous groups that recognize them with 32 vernacular names, related to animals, colors, forms, odors, plants, myths,

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among others characteristics associated with their surroundings. Amazonian Kichwa people recognize 29 different species of fungi (Andrade et al. 2012; Gamboa-Trujillo et al. 2019; Gamboa-Trujillo et al. 2014; Vicente-Perez and Peñuela 2022). These communities consume mushrooms in different ways. In the Amazon, mushrooms such as *Auricularia delicata*, *A. fuscosuccinia*, *Favolus tenuiculus*, *Lentinus concavus* and *Pleurotus djamor* are cooked in boiling water or wrapped in leaves *of Heliconia stricta*, whereas in the Andes region, those mushrooms are fried or prepared in a soup with chicken, fish or wild rabbit (Gamboa-Trujillo et al. 2019).

In Ecuador, mushroom cultivation has focused on non-native species such as *Agaricus bisporus, Lentinula edodes* and *Pleurotus ostreatus* (Boa 2005; Gamboa-Trujillo et al. 2014). The cultivation of native species of mushrooms does not exist. Indigenous people gather them from the forests for their own consumption and some Andean species such as *Gymnopus nubicola* and *Suillus luteus* are commercialized in popular markets, as an additional income for households (Gamboa-Trujillo et al. 2014).

Although general information on the species consumed is available, there is scarce information about the fungal ecology, cultural uses and management of native species (Gamboa-Trujillo et al. 2019). Therefore, the aim of this research was to contribute to the knowledge of the ecology and to the quantitative ethnomycology of the mushrooms used by the Kichwas of the Napo region in Ecuador by answering the following questions: 1) What are the mushrooms species consumed by the Kichwa and which are the most important? 2) What are the traditional management practices for edible mushrooms? 3) What are the plants (stems-substrates) associated with mushrooms? and, finally 4) Is the fungal fruiting production continuous or seasonal throughout the year?

Methods

We developed the study between May 2019 and April 2020, in two peri-urban Kichwa communities of Tena: Atacapi (77° 29” 44.46 S y 72° 57” 32.1753” E) and Pumayacu. (77° 53” 06.8532 S y 1° 00” 14.7168 E). These communities are located in the buffer zone of the Colonso Chalupas Biological Reserve (CCBR) (Figure 1), between 600 to 800 masl. in the evergreen piedmont forest of the North-Eastern Andes (Álvarez-Solas et al. 2018). The annual average temperature is 28.8 °C, annual rainfall of 4571 mm and relative humidity of 91.7% (Ikiamś meteorological station).

Ethnomycological Information

We registered the ethnomycological data by using two methods: semi-structured interviews (Russell 2000), and informative walks in the *chagras* (policulture-agroforestry systems) and forests with the local experts as used by Vasco-Palacios et al. (2008). We interviewed 56 adults, men and women, with knowledge of edible mushrooms using a snowball sampling (Russell 2000). Interviews had four parts following Burrola-Aguilar et al. (2012): 1-socioeconomic information of the interviewees (age, gender, education level and economic activity), 2-free listing of species known, 3-perceived ecological parameters (distribution, phenology, nutrient requirements and substrates) and 4th-aspects about practices and usages (searching techniques, ways of identification, gathering, preserving, culinary uses and trading). Local experts were identified by the snow-ball method, kichwa collaborators were bilingual, and our interactions were in Spanish.

Edible Mushrooms Diversity and Local Names

To establish the minimum attempt of interviewees to represent at least 70% of the estimated richness of edible mushrooms, we did a species accumulation curve, which shows the appearance of new species as the interviews (sampling) progressed, such that the stabilization of the curve at an asymptote, indicates that the total number of species has been captured (Thompson and Withers 2003). We stopped interviewing people when the data reached 90% of the species, using the non-parametric estimate CHAO2 (Figure 2_suplementary). All the analyses were developed in R (R Core Team 2020), we found an efficiency of 90%.

From May 2019 to April 2020 we conducted 12 walks in the *chagras*, each one with a different local expert, while we gathered wild-edible mushrooms (Ruan-Soto et al. 2009). We photographed, described fresh specimens, collected samples of the substrate on which the mushrooms were growing and compiled cultural information. Mushroom samples were collected based on the guide of fungi of Ricker (2019) and dehydrated plants and mushrooms at Ikiam´s University laboratory with the protocols established by Hawksworth (2004).

We identified the fungal specimens using conventional procedures of observation of microscopic characters and reagents such as red Congo, KOH and IKI-Metlzer (Robledo and Urcelay 2009); dichotomous keys (Gomes-Silva et al. 2012; Robledo and Urcelay 2009), and specialized books (Lodge et al. 2004; Franco-Molano et al. 2005). Names were up-dated based on Index Fungarum (Fungarum 2022). We identified plants by using plant booklets, taxonomic keys and herbarium databases such as TRÓPICOS (TROPICOS 2022), GBIF (GBIF 2022) and Fungiweb (Bio Web Ecuador 2022). Collection permits for both fungi and plants were obtained from the Ministry of Environment of Ecuador (MAAE-ARSFC-2021-1144) and the samples deposited in the National Herbarium from the Instituto Nacional de Biodiversidad (INABIO) in Quito.

Cultural Importance index

We organized the qualitative information from interviews and field observations in frequencies, in order to calculate the Edible Mushrooms Cultural Significant Index -EMCSI (Garibay-Orijel et al. 2007), as well as to plot the ecological interaction network. This index uses ordination and grouping techniques to reveal the behavior of species in a cultural multivariate dimension, and its relative position among a cultural significance gradient.

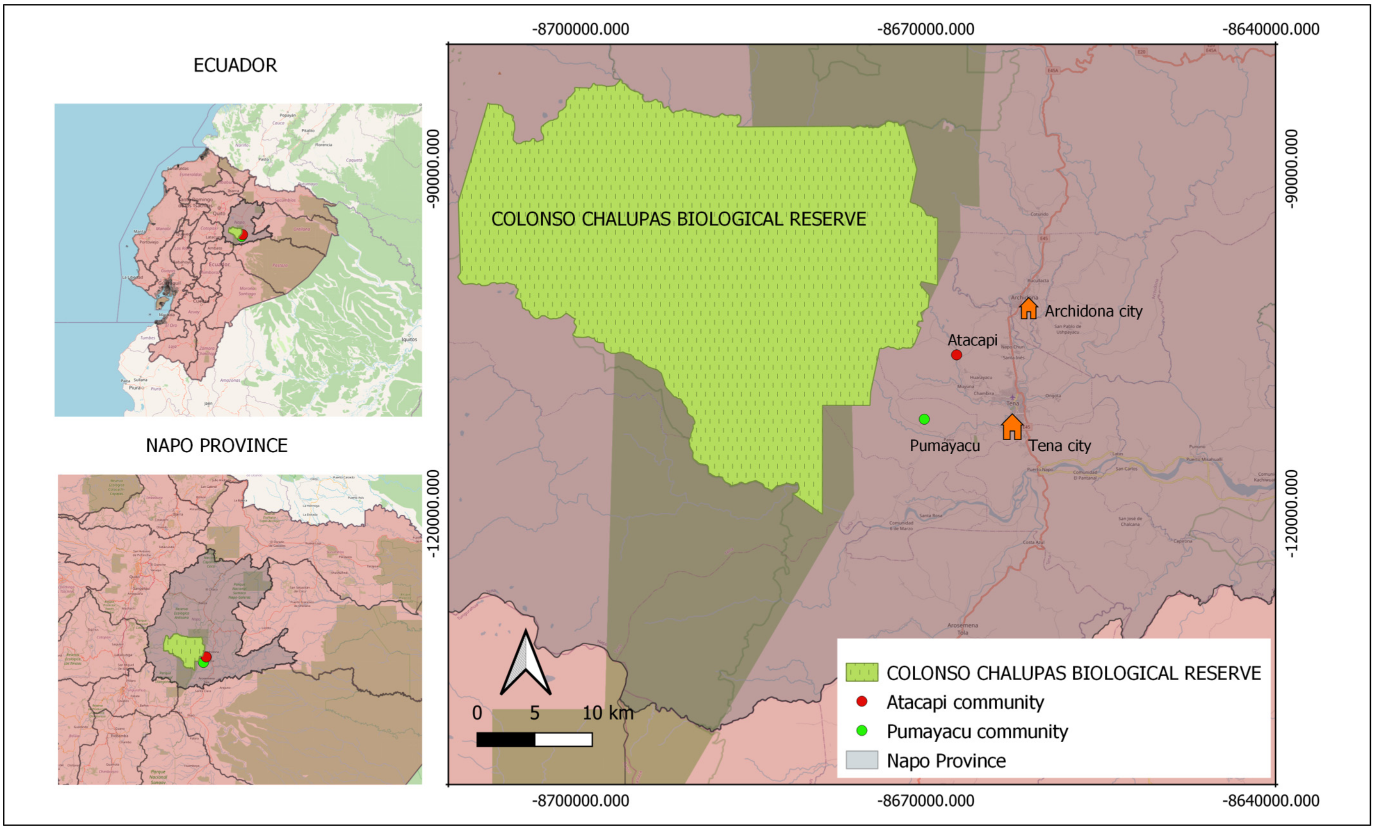

Figure 1. Study area. Peri-urban Kichwa communities of Pumayacu and Atacapi in the buffer zone of the Colonso Chalupas Biologic Station, Napo province, Ecuador.

The variables that compose the index are: Perceived Abundance Index (PAI); Frequency of Use Index (FUI); Taste Score Appreciation Index (TSAI); Multifunctional Food Index (MFFI); Knowledge Transmission Index (KTI); Health Index (HI); Economic Index (EI) and Mention Index (QI) (Garibay-Orijel et al. 2007).

We considered six of these variables (Table 1 Supplementary).

EMCSI = (PAI + FUI + MFFI + KTI + EI) × QI (Garibay-Orijel et al. 2007)

We assessed the relative value of mention (QI) from the Smith's Salience Index by using the Antrophaćs program (Anthropac 4.98) to divide the frequency of mention of the vernacular name in the free-listing data, by the place of it in the list of mushrooms species mentioned (Sutrop 2001).

To observe which variables better explain the cultural importance, we did a Pearson correlation between variables and then plotted a hierarchical cluster (Garibay-Orijel et al. 2007) by using the FactoMinerR package in R (R Core Team 2020).

Fungi Traditional Management

In order to observe if there were differences in traditional knowledge about mushrooms due to gender, educational level or economic activity, we applied a non-parametric Kruskal-Wallis test. Previously, we calculated normality of the three groups using the Shapiro-Wilk test and homoscedasticity using the Fisher and Bertlett tests, both of which were negative.

Fungi-Plant Substrates Association

The relation between plants and mushrooms was established according to people's local expertise. To graphically observe the associations, we used the bipartite package of "R" and calculated an interaction network (Dormann 2020), assessing *modularity* to identify the groups of species that have stronger interactions, and *connectivity* that shows the species that interact between the modules in the network (Ramos-Robles et al. 2018; Martínez-Falcón, Martínez and Dattilo 2019). Modularity (Q index) was calculated with a quantitative matrix of interactions by using the algorithm QuaBiMo (Dormann 2020). When the interactions clearly express modules the value is 1 (higher modularity) if not, the value is zero. The disposition of the modules can vary, given that the algorithm is stochastic. Therefore, of 50 iterations we chose the graphic with the highest Q value. We used 100 iteration values to calculate the Z-score, which is the number of standard deviations of a value that surpass the average of the 100 networks assigned at random (Ramos-Robles et al. 2018).

To evaluate the significance of the observed network we applied the null model of Patefield using the *bipartite* package

Table 1. Wild Edible Mushrooms Consumed by Atacapi and Pumayacu Kichwa Communities with Local Names.

Family	Species	Kichwa names	English translation
Schizophyllaneae	*Schizophyllum commune* Fr.	*aya ala*	Ghost mushroom
Polyporaceae	*Bresadolia paradoxa* Speg.	*busum ala*	Cow's stomach mushroom
Polyporaceae		*api ala*	Soft mushroom
		lumucha ala	Paca mushroom
	Favolus tenuiculus P. Beauv.	*chinchi ala*	Smooth mushroom
		busum ala	Cow's stomach mushroom and it's darker than the young fruit bodies.
	Lentinus crinitus (L.) Fr. *Panus strigellus* (Berk.) Overh.	*ilma ala*	Hairy mushroom
		chagra ala	Chagra's mushroom
	Lentinus concavus (Berk.) Corner	*guango ala*	Group of mushrooms
		taka ala	Bunch of mushrooms
		muku ala	Fist mushroom
	Lentinus tricholoma Berk. & Cooke	*tuyu ala*	Bone mushroom
		kaspi ala	Club mushroom
		sara ala	Corn mushroom
Auriculariaceae	*Auricularia delicata* (Mont. ex Fr.) Henn. *Auricularia fuscosuccinea* (Mont.) Henn.	*yushka ala*	Slippery mushroom
		rinri ala	Ear mushroom
		kaluk ala	Jelly mushroom
Pleurotaceae	*Pleurotus djamor* (Rumph. ex Fr.) Boedijn	*mishki ala*	Sweet mushroom
		damu ala	Balsa mushroom (i.e., soft wood)
Omphalotaceae	*Marasmiellus* sp.1	*pishku ala*	Bird mushroom
		pishkuchakituyu ala	Bird's foot mushroom
		urpi ala	Pigeon mushroom
Sarcoscyphaceae	*Cookeina speciosa* (Fr.) Dennis	*puka ala*	Red mushroom
Hymenogastraceae	*Gymnopilus* cf. *lepidotus* Hesler[a]	*chunda ala*	Peach palm mushroom
Hymenochaetaceae	*Hymenochaete* cf. *damicornis sensu* Spegazzini[a]	*sasi ala*	Fasting mushroom
		sisa ala	Flower mushroom
Hygrophoraceae	*Hygrocybe* cf. *helobia* (Arnolds) Bon 1976[a]	*llausa o lawsa ala*	Slime mushroom

[a]These mushrooms were not collected because we did not find them either in the chagras, or in the walks with the local experts. Therefore, they were not considered in the analysis because we were not 100% sure of their taxonomic identification.

using the r2dtable function in R-Studio 3.5 (Gabrielle et al. 2018; Dormann 2020). The value of modularity is significant when Z score > 2 (Gonzalez and Loiselle 2016). Species connectivity within modules was measured by z-grade value and between modules by the **c** coefficient (Martínez-Falcón, Martínez and Dattilo 2019). We used the 95% of **z** and **c** values to obtain the threshold that defines the species function (Gabrielle et al. 2018; Martínez-Falcón, Martínez and Dattilo 2019). Threshold values for **z** were 1.14 and 2.21 and **c** values were 0, 64 and 0, 70 for plants and mushrooms respectively. We used the compute-Modules-function in the bipartite package in R (Dormann 2020).

Mushrooms Fruiting Season

The phenological perception of the Kichwa based on the interviews, was evaluated using a Pearson's correlation between climatic variables such as monthly rainfall, relative humidity and monthly average temperature (taken from Ikiam´s meteorological station 2019–2020) with monthly fungal species richness, based on observations from the interviews and the walks in the *chagras*. We assumed that the cumulative humidity could have a major influence on fruiting, and this one is correlated with rainfall. Therefore, we correlate our observations with the precipitation of the previous month (e.g., May observations with accumulated precipitation from April).

Results

Edible Mushrooms Diversity and Local Names

We interviewed 56 people, 23 men and 33 women, between 18 and 69 years old. ***Ala*** is the generic kichwa name for all kinds of fungi that have fruit bodies. The Spanish translation "hongo" refers to those fungi that cause diseases to humans, animals or plants. Toxic mushrooms are called ***Miyuy***. Fungal names in kichwa are bimodals: the first word indicates a biological or ecological characteristic of the species such as texture, color, taste or if it resembles any environmental element and the final word ***ala*** which means fungi; for example, ***ilma ala*** means hairy mushroom.

From the interviews we registered 26 fungal names. During the visits to the chagras, we collected 22 mushrooms of those 26 vernacular fungi-names that corresponded to 12 species (Table 1 and Figure 2).

Eleven mushrooms (91.67%) belonged to Basidiomycota and one (8.33%) to Ascomycota. The most abundant families were Polyporaceae with 5 spp. and Auriculariaceae with 2 spp. The rest of the species belonged to the families Pleurotaceae (1 sp.), Panaceae (1 sp.), Schizophyllaceae (1 sp.), Omphalotaceae (1 sp.) and Sarcoscyphaceae (1 sp.).

Cultural Importance index

The Edible Mushrooms Cultural Significant Index (EMCSI) was calculated individually per species, and it was associated with the qualitative statements of local people. In two cases it was calculated in pairs because two species were named under the Kichwa categories: ***ilma ala*** (hairy mushrooms) and ***rinri ala*** (ear mushroom). Values of the indices varied from 5.32 to 215.34 (Table 2). *Favolus tenuiculus*, *Bresadolia paradoxa* and *Lentinus concavus* had the highest EMCSI index values from the two peri-urban Kichwa communities for their taste and abundant fruit bodies. On the other hand, *Panus estrigellus* with a lower EMCSI (30,76) is barely consumed due to its leathery and dry texture. *Pleurotus djamor* (39,86), although with a good taste and texture, is barely consumed due to its low abundance (See Table 2). Another tasty and soft fungi was *Marasmiellus* sp. 1 (35,84), but it is rarely consumed due to its small size (0.3–2 cm of pileous and 0.5–1.5 × 0.2–0.3 cm of stipe).

Our observations of the use and consumption of edible mushrooms in these communities suggest that the Kichwa of Napo prepare them as a main dish or in preparations with other ingredients. Most people indicated that mushrooms are prepared into ***maitos*** (wrapped in ***bijao*** leaves usually of *Calathea lutea*), grilled or simply boiled with salt, served with manioc, plantains or sweet potatoes and chili. Sixteen percent of the interviewers indicated that *F. tenuiculus, Favolus* sp. 1*, L. concavus* and *L. tricholoma*, are also prepared in *mazamorra* which is a soup with grated plantain.

The transmission of knowledge about fungi is given from parents to children, this is corroborated by the knowledge transmission index variable (**KTI**) of the species, which varied between 9 and 10. All the interviewers indicated that parents and grandparents teach their children and grandchildren the mushroom characteristics necessary to recognize them, fruiting times (if the mushroom is related to a plant growth and harvest such as maize -***sara ala***-) and the rain associated with moon phases, as well as forms of consumption. From all the activities developed we observed that the chagras and the kitchen are the main places of learning about the funga.

All mushrooms collected are used for self-consumption and there is no commercialization in the cities as is evidenced by the economic variable (EI) that ranged from 0 to 2.79 for all species. However, *Favolus tenuiculus*, *Favolus* sp.1, *L. concavus*, *S. commune*, *P. djamor*, *Marasmiellus* sp.1 and the groups of *Auricularia* are often sold to members of the community that work in the city and do not have time to go to the chagras to harvest them. They are usually sold in cooked or raw ***maitos***. The price ranges from one to two dollars for approximately 30 to 50 fruiting bodies. Therefore, selling is a sporadic activity, as mushrooms are only collected under request, and it constitutes an exceptional supplementary cash resource.

Pearson correlation showed that some variables are correlated with each other, which means that if one varies, the other also varies ($r > 0.5$). This is the case of the mention index (**QI**) and the economic importance index (**EI**) (0.71); as well as between **EI** and the perceived abundance index (**PAI**) (0.80); and finally, between **QI** and **PAI** (0.56). These variables are also the ones that influence the highest weight in the cultural importance index by species. After the correlation we assessed the hierarchical cluster which organized the species in four groups (Figure 3).

Fungi Traditional Management

We observed that independently of the gender, educational level or economic activity, the interviewed people showed similar fungi-knowledge (Table 3 supplementary). More than half of the people (57%) gather mushrooms in the chagras, (31%) in the forest, and (12%) in both sites. Generally, women manage the crops, and usually they collect mushrooms, although all family members can do it. Extracting mushrooms is an agricultural complementary activity that takes a maximum of an hour after daily duties.

As soon as a member of the community finds an edible mushroom, they gather fruiting bodies based on shape, smell, color, type of growth and substrate. They consider healthy mushrooms those without insects, and which are soft when pinched with the big toenail (Figure 4 A right).

> "My grandparents used to take me to the chagra and show me which mushrooms are eaten and which are not. We remember what the ones we eat look like. I go to the chagra, I can tell by their soft texture, and I can tell when they are on a trunk. We recognize that the tree is lying down and the mushroom is growing, so you know that the mushroom is edible" (Piedad Shiguango, Pumayacu)

In the case that the mushrooms are still primordia, they wait about four days to gather them. The fruit bodies are extracted with bare hands, without any tools, wrapped in *Calathea lutea* leaves (Figure 4 C and D3) and transported in their baskets on top of the remains of their chagra products to avoid damage.

Preparation of mushrooms depends on the species, texture and number of fruiting bodies.

> "If there are enough mushrooms (> 20 fruit bodies), we cook them in a pot to make caldito (stock) or mazamorra

Figure 2. Edible wild mushroom species used by the kichwa communities of Atacapi and Pumayacu, Napo, Ecuador.

Table 2. Variables Values and Edible Mushroom Cultural Significance (EMSCI).

Scientific names	FUI	KTI	EI	PAI	MFFI	QI	EMSCI
Favolus tenuiculus	7.21	9.66	2.73	4.19	6.90	6.72	215.34
Bresadolia paradoxa	6.00	9.70	0.91	3.94	7.20	5.53	153.47
Lentinus concavus	5.97	9.81	1.76	4.15	6.53	4.14	117.70
Schizophyllum commune	7.06	9.55	1.54	4.42	6.85	2.32	68.25
Lentinus tricholoma	6.09	10.00	1.82	4.38	6.65	2.04	60.87
Pleurotus djamor	5.84	10.00	0.83	3.96	7.06	1.44	39.86
Marasmiellus sp.	7.47	9.58	0.83	3.33	7.00	1.27	35.84
Lentinus crinitus Panus strigellus	6.36	10.00	0.00	1.54	6.85	1.17	30.76
Cookeina speciosa	3.76	9.09	0.00	2.73	6.67	1.08	24.03
Auricularia delicata Auricularia fuscosuccinea	6.71	9.29	1.43	3.57	7.00	0.19	5.32

Variables are: FUI: Frequency of use Index, KTI: Knowledge Transmission Index, EI: Economic Index, PAI: Perceived Abundance Index, MFFI: Multifunctional Food Index, QI: Mention Index and EMCSI: Edible Mushroom Cultural Significance Index.

(soup), but if there are few, we make ***maito"*** (Carmen Grefa, Atacapi).

In addition, those used for ***maito*** should have soft and fleshy texture, and those harder should be prepared in boiled water (Figure 4 D.2-3).

All people mentioned that they do not consume raw mushrooms, because they cause stomach illness. Mushrooms are prepared and consumed immediately, there are no conservation systems used for the fruit-bodies.

"When freshly grown mushrooms are soft and it is better to eat them, they are good to eat. We don't eat them raw because they make our bellies hurt and even cause diarrhea. My mother used to pinch the cap of the brim with her fingernail to know if it was good to eat" (Catalina Grefa, Atacapi).

Local Recognition of Edible Mushroom

According to people's descriptions of the mushrooms, the 26 species can be organized in 12 local categories.

1. Ghost mushrooms are associated with leaden color and beige or dark brown hairs. These characteristics make people dislike them and do not eat them. They mentioned one, which kichwa name is ***aya ala*** and corresponds to *Schizophyllum commune*.
2. Porous and smooth mushrooms are those whose hymenium has minute spaces or holes. Moreover, the color of the cap and the form of the hymenium are similar to the internal part of the cow's stomach. Three local varieties are ***busum ala, api ala*** and ***lumucha ala,*** which are *Bresadolia paradoxa*. People call the mushroom *Favolous teniuculus*, ***busum ala***, when its fruiting body presents a darker coloration, while when it is white to cream colored, they call it ***chinchi ala***."

   Lumucha ala is like a cow's belly, smooth and half-brown on top and white on the bottom. It is similar in shape to the ***chinchi ala"*** (Germania Grefa, Atacapi).
3. Hairy mushrooms are those whose pileus are covered with hair and have a leathery texture. Kichwa people used to name ***ilma ala*** and ***chagra ala*** for two species *Panus strigellus* and *Lentinus crinitus,* indistinctly. These two fungi are appreciated for their taste and have many fruiting bodies; however, they grow in open areas where they rapidly become dry and hard. These mushrooms are associated with cassava which serves as substrate. In the hierarchical cluster, *Lentinus crinitus* and *Panus strigellus* are grouped with *Cookeina speciosa* because of their low economic importance and low production of fruiting bodies.
4. Grouped mushrooms. This category of mushroom is characterized by cespitose growth and the production of numerous fruiting bodies. Its texture is soft and its flavor is sweet. *Lentinus concavus* has been named with three synonyms: ***guago ala, taka ala*** and ***muku ala***.
5. Thin mushrooms are those with little flesh and elongated stipe. There are three local names for the same species. *Lentinus tricholoma*. ***Tuyu ala*** and ***kaspi ala*** refer to thin stem and ***sara ala,*** because they grow in the same season that maize grows. "The ***tuyu ala*** comes out quite a lot in the month of August, it grows, produces many ***alas*** and a large trunk. When we sow corn, the ***tuyu ala*** grows quite a lot. When we sow corn, mushrooms grow. In August we remember to plant corn. If we don't sow corn, a little mushroom grows and it is damaged" (Carmen Grefa, Atacapi).
6. Ear mushrooms are those with the shape of human ear and a surface that feels wet, these traits are common to ***yushka ala***, ***kaluc ala*** and ***rinri ala*** which are *Auricularia fuscosuccinea* and *Auricularia delicata* species indistinctly. Storytelling is associated with these fungus, and one story is called "Grandma and the ***alas***":

"There was an old lady who turned into a lizard. That day she was walking from one side to the other. On the way, she saw an ***ala***.

-I will pinch this ***ala*** to see which ***ala*** it is. Grandma thought.

Then she heard a young man say, Granny, why are you pinching me?

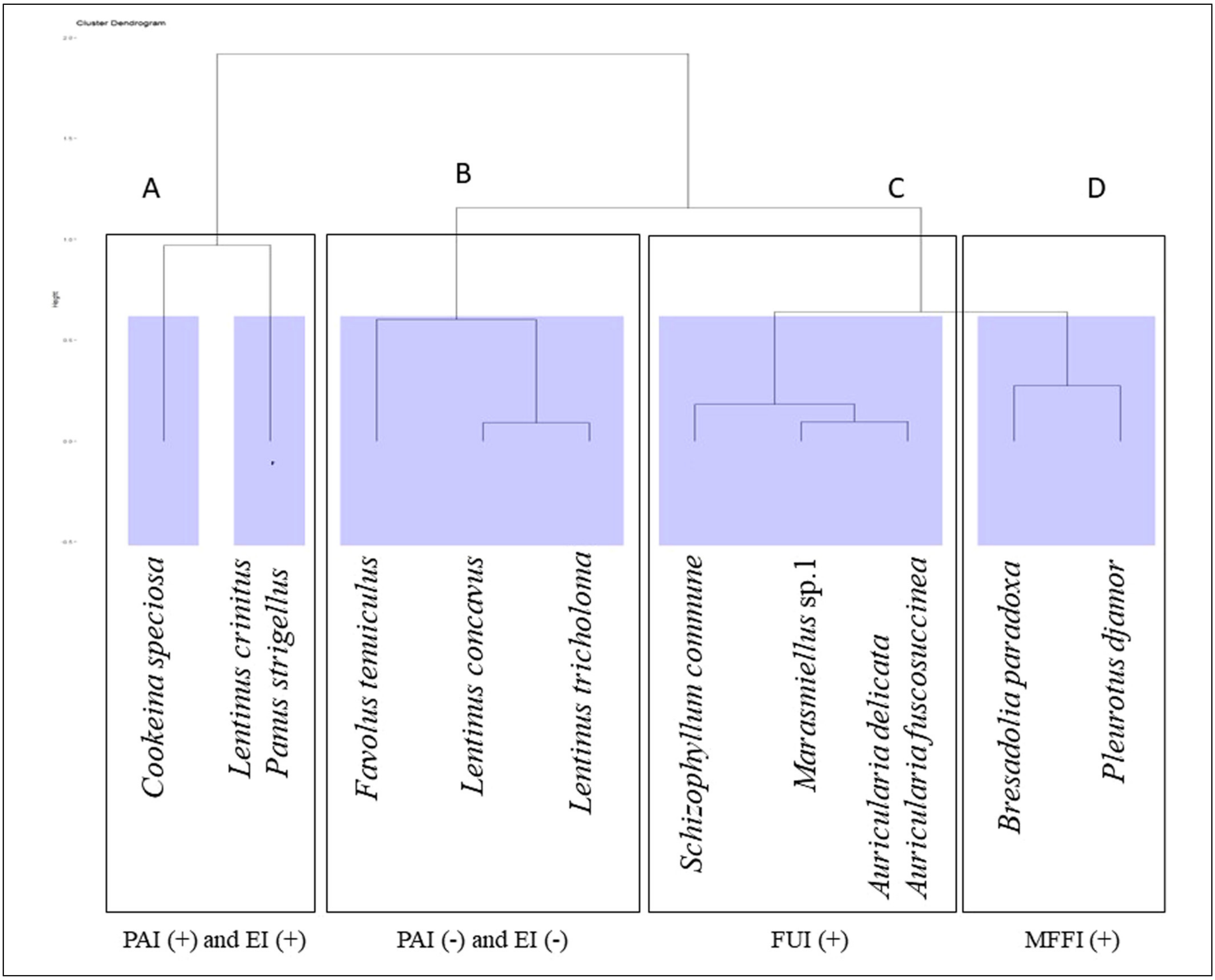

Figure 3. Diagram for hierarchical cluster showing four groups of edible mushrooms based on the variables perceived abundance Index (PAI), economic Index (ei) frequency of use Index (FUI) and multifunctional food sub-index (MFFI).

The ***ala*** was the ear of the young man who was hiding.

That is why the old people say that all these ***alas*** (mushrooms) look like ears.

Children who don't listen are often told: ***alas*** ears, because they don't hear anything" (Olimpia Vargas, Atacapi).

7.Sweet mushrooms are those with a sweet taste and a soft texture. In this category are ***mishki ala*** and ***damu ala*** identified as *Pleurotus djamor*.When these ***alas*** get old, little flies fly around and little worms appear, they usually are at the bottom of the little hat (Carmen Ajón, Pumayacu).
8.Bird mushrooms. Those are named in this way because when the fruiting body is turned upside down, the lamellae together with the stipe look like the leg of a bird. To this category belong ***pishku ala***, ***pishkuchakituyu ala*** and ***urpi ala*** (pisku = bird, urpi = pigeon, tuyu = bone/thin) from the *Marasmiellus* genus.
9.Red mushrooms, those whose fruit bodies are red or orange and in the shape of a cup. It corresponds to *Cookeina speciosa. Its local name is* ***puka ala***.
10.Chundás mushroom, mushrooms that grow on or around the plant ***chunda*** or peach palm (*Bactris gasipaes*) an example is *Gymnopilus* cf. *lepidotus*. Moreover, fungus and edible insects do not grow together: peach palm host the appreciated ***chonta kuru*** (*Rhynchophorus palmarum*) and ***willian kuru*** (*Rhinostomus barbirostris*), but if the former is present, mushrooms do not settle on the same stipe.
11.Flower mushrooms are those whose fruiting bodies resemble flowers such as *Hymenochaete* cf. *damicornis* locally named as ***sasi ala*** or ***sisa ala***.

12. Slime mushrooms are those species with jelly texture such as *Hygrocybe* cf. *helobia,* locally known as ***lausa*** or ***lawsa ala***.

Associated Substrates

From the interviews we found 70 interactions between mushrooms and their substrates (Figure 5). Edible species are saprotrophs and grow in decayed wood. The mushroom species grew on 16 plant species that belong to 11 families (Table 2_supplementary). The mushroom species associated with 50% or more plants were *F. tenuiculus* (12), *L. concavus* (10) and *Bresadolia paradoxa* (8); and the plants where more than 50% of mushrooms can grow are *Piptocoma discolor* (10) locally named *piwi*, *Ochroma pyramidale* (8) or *balsa*, *Inga edulis* (8) or *guaba*, *Cordia alliodora* (8) or *laurel*, *Cecropia sciadophylla* (7) or *buayura* and *Vochysia braceliniae* (7) or *tamburo*. On the other hand, there were also plants on which only *F. tenuiculus* was growing.

The interaction network showed the formation of three inner clusters between interacting species known as modules (Supplementary Figure 1). The modules were not randomized even though the modularity index was low ($Q_{obs} = 0.24$, $Q_z = 7.56$, $Z < 2$). Therefore, we tried to explain the modules considering three plant characteristics : 1) their capacity to live under high radiation (heliophytes) vs those with the ability to live under shadow conditions (sciophytes); 2) those that grow fast (pioneer) vs. those of slow growth 3) and plants with low, medium or high wood density, which is a trait related to xylem density, therefore to the absorption of water, growth rates and other dynamic variables, as well as to the resistance of the wood to fungi invasion (Supplementary Table 2).

Fruiting Season

The edible mushrooms produced fruiting bodies throughout the year except for *Cookeina speciosa* which fructifies for six months. All the months presented favorable conditions for these species to fruit. The temperature ranged from 22.01°C to 25.94°C and the relative humidity (RH) from 90.1% to 93.7%. Pearson's correlation analysis between mushroom species richness and mean monthly temperature and relative humidity were not significant with values of $r = 0.1$ and $r = -0.1$, respectively. However, we performed the correlation taking into account the precipitation of the month preceding the field observations, and in this case the correlation was positive and moderately significant, $r = 0.51$ suggesting that both conditions soil and humidity allows mushroom fruiting.

Discussion

Diversity and Cultural Importance

We identified 12 edible mushroom species in two kichwa peri-urban communities. Six species were already in the previous list of edible fungi of Amazonian Kichwa people, whereas *Bresadolia paradoxa*, *Cookeina speciosa, Panus strigellus, Marasmiellus* sp., *Lentinus tricholoma* and *Pleurotus djamor* were new reports for this ethnic and the first four are added to the country edible mushrooms total list (Andrade et al. 2012; Gamboa-Trujillo et al. 2014, Gamboa-Trujillo et al. 2019; Vicente-Pérez, Peñuela-Mora and Vasco-Placios 2020). In general, most of the mushrooms found in this study are also consumed by other indigenous groups in the Amazon such as the Yanomani of Brazil (Sanuma et al. 2016) Patamona in Guyana (Henkel et al. 2004*a*), Jotï in Venezuela (Zent 2008), Uitoto and Andoke in Colombia (Vasco-Palacios et al. 2008) and Machiguenga people of Peru (Dávila-Arenas, Sulca-Quispe and Herrera 2013). *Auricularia* and *Lentinus* were the most abundant genera in our study with two and three species respectively and they are also consumed by other eight indigenous groups in Ecuador (Gamboa-Trujillo et al. 2019), and by riparian people from the Amazon basin (Vargas-Isla, Ishikawa and Py-Daniel 2013). People from the communities studied do not consume *Rigidoporus amazonicus* and *Tremetes versicolor* (Gamboa-Trujillo et al. 2019) as in other Ecuadorian lowlands (i.e., Arajuno and Limonchocha), due to their woody-leathery, coriaceous texture.

The most culturally important mushrooms had high values in the frequency of use (FUI), economic importance (EI) and perceived abundance (PAI) variables (Figure 3, Table 2). The cultural importance index, in both peri-urban Kichwa communities, showed that *F. tenuiculus* was the most appreciated mushroom because it has three important characteristics: produces abundant fruiting bodies, it has good flavor and it is prepared in many forms. This species is also highly consumed by other 10 indigenous groups in Ecuador (Gamboa-Trujillo et al. 2019). Other species *L. tricholoma*, *Marasmiellus* sp., and *P. djamor,* although appreciated by the inhabitants of both communities, had a low EMCSI index. *Lentinus tricholom*a, is a small mushroom with a thin context (0.1 cm), a stipe up to 0.5 cm in diameter (Gamboa-Trujillo et al. 2019) and low production of fruiting bodies. *Marasmiellus* also has very small fruiting bodies compared to *F. tenuiculus* (0.6–6 cm of pileus and 0.5–1 × 0.2–0.5 cm of stipe) or *L. teniuculus* (0.1–4 cm of pileous and 4.8 × 0.2–0.5 cm of stipe) (Franco-Molano et al. 2005), and it gets damaged easily during transportation due to its very fine hyphal context. In the case of *Pleurotus djamor,* fruit bodies grow very fast and remain edible for just about two or three days, making them difficult to collect in the right state of softness and texture for consumption. This species requires much local attention given its good quality nutrients and other molecules related to improving health such as antioxidants, tannins, flavonoids, terpenoids (Nayak et al. 2021) with the advantage of having already a technology of cultivation developed in other parts of the world, that includes the use of crop wastes such as maize, coffee, rice and palm (Hutabarat et al. 2022; Vega et al. 2022), that also grow in these communities.

The ear-mushrooms had the lowest EMCSI and were barely consumed because they are quite insipid and scarce, in fact they

Figure 4. Gathering and preparation of edible mushrooms by the two peri-urban kichwa communities. A) With the hands they pull up the fruit body from the stipe. B y C) The fruit body is wrapped in ***bijao*** leaves, it is folded at all four ends and tied with a natural fiber. D) Ways of preparation of edible wild mushrooms: D.1) Stock of mushroom with ***sacha cilantro*** (*Eryngium foetidum*) and ***papachina*** (*Colocasia esculenta*). D.2) Mazamorra (soup) of mushrooms. D.3) ***Maito*** of mushrooms.

were found only on two different plants (substrates). Other indigenous groups dislike their muggy and jelly texture as happens in the Colombian Amazon (Franco-Molano et al. 2005). However, in northern Colombia *A. fuscosuccinea* produces abundant fruit bodies and is consumed and appreciated by peasants living in areas with *Quercus humboldtii* forest (Peña-Cañon and Enao-Mejía 2014), although no information about their taste or texture is reported. This is a topic that should be considered in future research.

Scores in cultural indexes suggest that in both kichwa communities' abundance of mushrooms is more important than taste. *Cookeina speciosa* with scarce fruit bodies, had a low cultural index, which has also been reported in Colombia (Franco-Molano et al. 2005) and *Schizophyllum commune,* despite its dry, woody and fibrous texture, which actually are characteristics the Machiguenga people of Peru (Dávila-Arenas, Sulca-Quispe and Herrera 2013) do not like either, had a higher index than the Auricularias. In our study no other uses of this species were mentioned. However, in other regions of Central America and Asia, *S. commune* is used as a medicinal product (Lampman 2007; Vargas-Isla, Ishikawa and Py-Daniel 2013; Kamalebo et al. 2018; Debnath et al. 2019), for its phenolic and antibacterial compounds. However, recently, this species was reported as a dangerous source of illness in humans (Fernández-Caso et al. 2020), so its use should be carefully considered.

It is important to emphasize that mushrooms are used as material for exchange between families, strengthening the relations of the members of a village. The species used to exchange have high frequency of use (FUI), high perceived abundance (PAI) and are prepared in different ways. In both communities, the sale of wild edible mushrooms is exceptional. However, there is a potential economic value of some other mushrooms that should be explored, as happens in other places in the Brazilian Amazon (Vargas-Isla, Ishikawa and Py-Daniel 2013) with mushrooms such as *Favolus tenuiculus*, *Lentinus concavus*, *Lentinus tricholoma*, *Lentinus crinitus* and *Panus strigellus* that are collected and sold in specialized markets in Brazil by the indigenous Sanöma (Sanuma et al. 2016). Therefore, it is clear that the Kichwa avoid harvesting small mushrooms because they are not enough to feed a household, which usually consists of about four to eight people, and they do not harvest degraded or overripe mushrooms to avoid intoxication, as other rural communities do in the Andean region of Patagonia in Argentina (Barroetaveña et al. 2016).

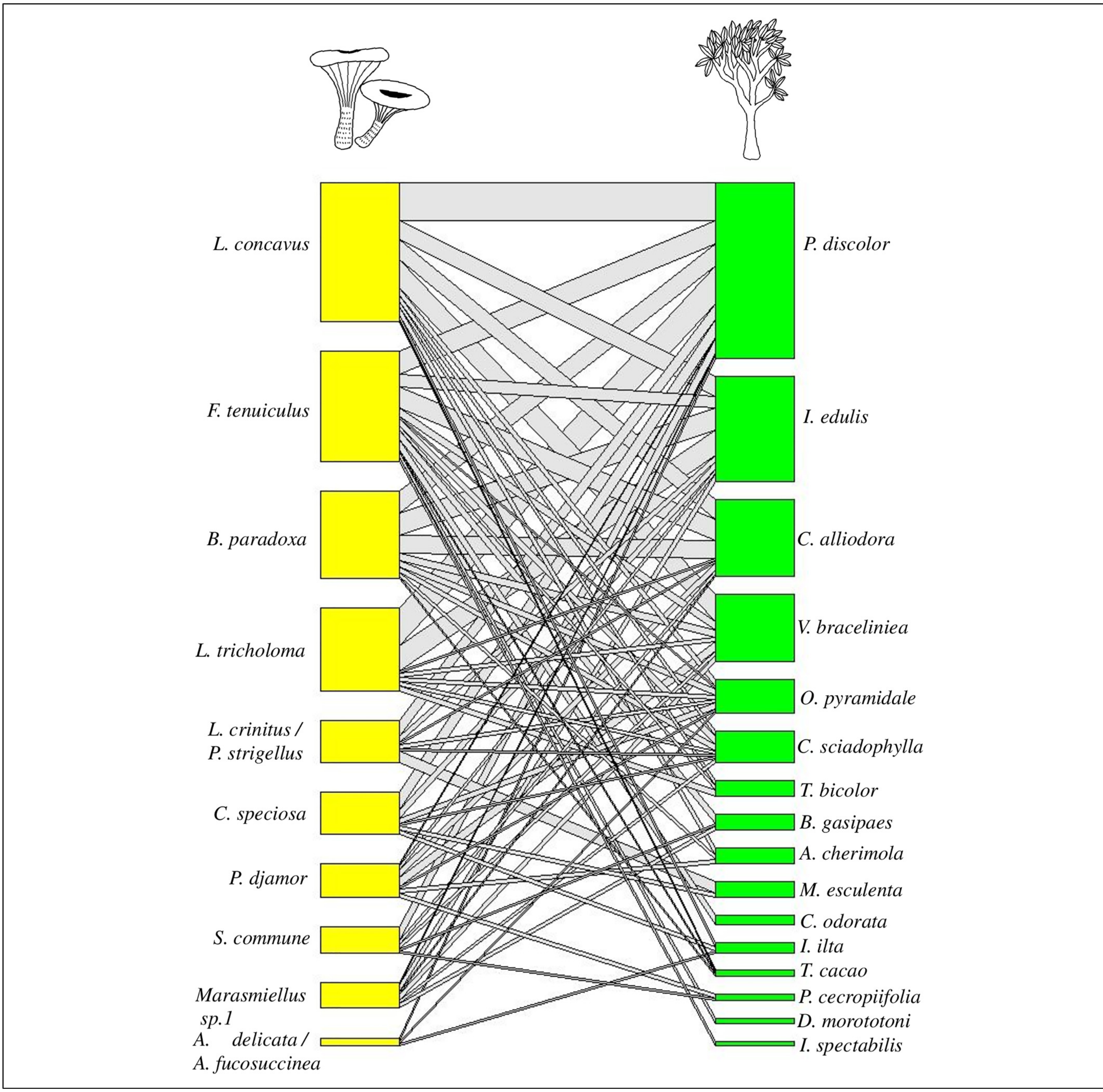

Figure 5. Network interaction between fungi and plants. The width of the rectangles show the interaction richness of the species and the wide gray-line represents the interaction frequency (number of times that the association was mentioned by interviewees). The graphic is presented in decreasing order of richness and frequency.

Species Management/Traditional Knowledge

Although WEM are not cultivated, the Kichwa intentionally create the conditions in the chagra agroforestry system, as has also been reported for the Yanomami in Brazil (Sanoma et al. 2016), to have access to this complementary ingredient for their diet. We found that the traditional knowledge of the two peri-urban Kichwa communities related to wild edible mushrooms is intergenerational, and similar among men and women as has also been reported by Zent (2008) for the Jotï in Venezuela and Gamboa-Trujillo et al. (2014) for the Andean Kichwa communities. This is very important since practically all the population has the knowledge and capacity to use and manage them.

However, one aspect that we believe could be improved in both communities is the recognition of the mycelium as part of the fungus as well as its function within the ecosystem, as it is recognized by the Uitoto people from Colombia, (Vasco-Palacios et al. 2008). Mycelia play a key role in terrestrial ecosystems, as they provide or enhance nutrients and water to most plants, and are the ones that, under the right conditions, form new fruiting bodies to be consumed by populations (Halbwachs, Simmel and Bässler 2016). It should be clarified that the practice of collecting the largest fruiting bodies does contribute to preserving the mycelium and allow the conservation of the species in these places for its continuous reproduction (Boa 2005; Barroetaveña et al. 2016).

In addition, the practice of pulling fruit-bodies up by hand could be detrimental for the species, as was experimentally proven for the production of *Thelephora ganbajun* by He, Zhou and Yang (2011) in Western China. They arranged a long-term experiment and observed the production of mushrooms under three conditions: when pulling them out, cutting without watering, and cutting then watering. They found that gathering with a knife and watering the area does not cause damage to the mycelium underground and increased the harvesting six times in the same plot, enhancing people's quality of life.

Both peri-urban Kichwa communities gather mushroom´ fruit bodies in early stages of development to avoid the hard consistency of the older ones and stomach illness. When eaten, wild edible mushrooms were cooked to soften the texture and enhance the flavor. Diverse types of soups and *maito*s are the main dishes in the studied sites as has been stated by Zurita-Benavides, Mogrovejo and Paukar (2020). People prefer to cook them in *maito*, which is also a way of consumption for other Amazonian groups such as the Machiguenga, Yanomami and Patamona (Dávila-Arenas, Sulca-Quispe and Herrera 2013; Vargas-Isla, Ishikawa and Py-Daniel 2013; Henkel et al. 2004; Sanuma et al. 2016).

Associated Substrates

Wild edible mushrooms consumed by both peri-urban kichwa communities are wood saprotrophs (Cardoso et al. 2010). Several ethnomycological studies indicate that rural and indigenous people of the Amazon basin (Henkel et al. 2004; Vargas-Isla, Ishikawa and Py-Daniel 2013; Cardoso et al. 2010; Zent 2008; Dávila-Arenas, Sulca-Quispe and Herrera 2013) and tropical regions of Africa (Kamalebo et al. 2018; Garden and Garden 2011; Osarenkhoe et al. 2014) consume wood saprotrophs species rather than ectomycorrhizal, because they are less diverse than in temperate systems (Corrales, Henkel and Smith 2018).

Lignicolous mushrooms have been associated with different plant substrates in the Amazon region. In Colombia the Uitotos associated six species of mushrooms with 16 species of plants of 9 plant families (Vasco-Palacios et al. 2008) and in Brazil the Yanomamis associated 15 species of mushrooms with 18 species of plants belonging to 10 plant families (Sanuma et al. 2016). We registered 12 mushrooms associated with 16 species of plants of 11 families. Plant species in the three communities mainly belonged to the families Euphorbiaceae, Fabaceae, Malvaceae and Urticaceae, and we add species from the Arecaceae, Asteraceae, Boraginaceae and Vochysiaceae families (Supplementary Table 2). In our study, we shared seven plant-families with the Yanomami and two with the Uitoto. The genera of plants *Cecropia*, *Inga* and *Pouroma* were shared with the Yanomami. The species of these genera are relatively common in secondary forests in the Amazon region, and usually used as shadow in agroforestry systems (Cabrera 2016). They are pioneer low-density woody species, with high germination rates, that grow fast (Vera, Cota-Sánchez and Grijalva Olmedo 2017; González et al. 2019) and host many macrofungi that grow in open to closed areas. Therefore, their remnants could be used for mushroom cultivation.

As expected for being plants of the chagras, most of them (12/16) are heliophytes. Light is a key environmental factor in the development of the pileus, as well as affecting the length and thickness of the stipe in many basidiomycetes and it can also induce or promote fruiting body production, suitable for effective spore dispersal (Sakamoto 2018). Temperature is another factor that affects fruiting bodies formation, in some cases it can trigger the formation, but extremely high temperatures and perhaps low relative humidity could induce autophagy. However these plants also have medium (10/16) to low (4) wood density, and recently, it has been shown that lower wood density plants suffer more mortality in the face of droughts, which is one of the clear consequences of climate change (Serra-Maluquer et al. 2022; Bennett et al. 2023). Therefore, it is necessary to monitor these climatic variables as well as the plants that serve as mushroom substrate because their changes could threaten the existence of this important interaction and their ecological and social function, as they are part of the diet and food security of the Kichwa people. Definitively, more studies of environmental factors that affect mushroom development such as stem-decomposition stage, distance from soil, diameter of stems, volume of wood and rot types (Kubartová, Ottosson and Stenlid 2015; Dossa et al. 2021) are needed.

In terms of species none was shared by all, only *Inga edulis* was shared with the Yanomami. What is clear and common to all these studies, is that the fungi that grow on the greatest number of plant species are *F. tenuiculus*, *Lentinus concavus*, *L. crinitus*, and *Panus strigellus* (Vasco-Palacios et al. 2008, Sanuma et al. 2016).

It has been shown that the low host exclusivity for saprophytic fungi in tropical forests occurs because of the high diversity of available hosts (Zhou and Hyde 2001), as opposed to environments with low plant species richness (Nogueira-Melo, Santos and Gibertoni 2017). In other cases, close phylogenetical relations and biochemical compounds can explain the presence of mushrooms such as Costa and Pascholati (2015) found in the Atlantic Forest of Brazil where two tree-species shared a significant number of saprophytic fungi. Wong and Hyde (2001) suggested that woody and persistent surfaces seem to favor high fungal presence, and that smaller, short-lived herbaceous plants are unlikely to host the same diversity of fungi. Dossa et al. (2021) found that the abundance of saprophytic fungi grew with time, after some years it doubled, probably due to content of lignin and wood density.

Most plant species associated with fungi are dicotyledonous. Although in the chagras there are some monocots such as several varieties of banana and plantain trees and sometimes other species of palms such as ***morete*** (*Mauritia flexuosa*), ***kili*** (*Wettinia maynensis*) and ***schiwa*** (*Oenocarpus bataua*) (Peñuela-Mora et al. 2016), we found mushrooms solely in *Bactris gasipaes*. This palm has high wood density and the most abundant mushroom on it was *F. tenuiculus*, which has high enzymatic capacity for wood and lignin degradation (Robledo and Urcelay 2009; Taylor and Sinsabaugh 2015). The mushroom ***chundu ala*** grew only on this palm but had a very low cultural index, perhaps because these palms are used to grow larvae of the beatles ***chonta kuru*** (*Rhynchophorus palmarum*) and ***willan kuru*** (*Rhinostomus barbirostris*), highly valued by the Kichwa communities for their fat and protein content (Guachamin-Rosero, Peñuela and Zurita-Benavides 2022).

Local Recognition of Edible Mushroom

Kichwa people clearly state the difference between edible (i.e., ***ala***) and toxic (i.e., ***miyuy***) mushrooms. This distinction is also registered in other Amazonian groups such as the Yanomami (Cardoso et al. 2010) and Jöti (Zent 2008). The function of categorization is to order, memorize and identify (Friedberg 1997) the wide fungus kingdom. The description and distinction of mushrooms with similar shapes, texture, odor, color, type of growth and/or host substrate are evidently local categories. Ordering names enable to show that kichwa as other Indigenous taxonomies are similar to the fungal phylogenetic systematics (Cardoso et al. 2010). The bimodal nomenclature pattern is common in Central and South America (Cardoso et al. 2010; Hunn, Venegas Ramerez and Dávila 2015), a description of the natural characteristics.

Fruiting Season. Meteorological data showed that all months have periods with favorable conditions for fruiting. These results are consistent with people's perception that most species fruit all over the year. Then, the availability of mushrooms is permanent and can supplement the food supply of the Kichwa families allowing for a longer harvest compared to temperate zones (Li et al. 2018) or areas with a marked seasonal environment as in eastern Brazilian Amazonia where the Yanomamis collect fewer fruiting bodies in the months of lower rainfall (Sanuma et al. 2016).

Conclusions

The present research contributes to the understanding of the traditional ecological knowledge of the Kichwa lowland people, and also of peri-urban communities who continue to practice mushroom management and gathering to enhance their food sovereignty. Pumayacu and Atacapi people distinguish 26 mushrooms in 12 categories that correspond to 12 species. The traditional knowledge on edible mushrooms of the two communities is intergenerational, and similar among men and women, although women participate more in the harvest, preparation and exchange of them with other community members. These mushrooms are saprotrophs that grow on decaying wood, usually in the chagra, but they can also be found in the forests.

The most important edible cultural species for the peri-urban Kichwa communities were *Favolus tenuiculus*, *Bresadolia paradoxa* and *Lentinus concavus*. The importance is mainly defined by the abundance of their fruit-bodies, economic value, and taste. Therefore, they are potential resources to be encouraged for production and marketing. Although Pleurotus *djmor* is also highly appreciated in these communities for its taste and texture, it produces low densities of fruiting bodies, and consequently has a lower importance value index related to other species. It grows only on three species, one is *Pourouma cecropiifolia* which is very common, and whose cultivation could be encouraged. Moreover, cultivation of these fungus species are possible and could bring many benefits to local communities for its nutritional and medicinal properties.

Fifty-one interactions between the 12 mushrooms and 16 plant species from 12 plant families were found. The tree species *Piptocoma discolor, Ochroma, Inga and Cordia* are the most generalist hosts for the wild edible fungi consumed by the Kichwa of Napo and all of them are heliophytes and pioneer species. These species are quite common in the *chagras* and are frequently used for their wood. Therefore, forest waste and agricultural residues of these and other species of the genera *Cecropia* and *Pouroma* can be used as substrates for the cultivation of saprotrophic fungal species. Moreover, the perceived abundance and uses of fungi depends on the preservation of traditional agroforestry systems. However, attention should be paid to the mortality rates of these species as it may also be threatening the survival of the fungi, at least in the ***chagras***.

Kichwa knowledge about mushrooms is associative and practical, integrating biological, social and ecological aspects. However, it is necessary to better understand the microenvironmental factors that condition the growth of these species to enhance their productivity, and consequently the consumption and even the commercialization of the species.

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