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TESIS

"Conocimiento Tradicional y Efecto del Aprovechamiento de Hongos Silvestres Comestibles sobre su Diversidad y Distribución en San Esteban Atatlahuca, Oaxaca"

PRESENTA

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ACTA DE REVISIÓN DE TESIS

En la Ciudad de Oaxaca siendo las 09:00 horas del día 5 del mes de junio del 2018 se reunieron los miembros de la Comisión Revisora de la Tesis, designada por el Colegio de Profesores de Estudios de Posgrado e Investigación de CIIDIR OAXACA para examinar la tesis titulada:

Conocimiento tradicional y efecto del aprovechamiento de hongos silvestres comestibles sobre su diversidad y distribución en San Esteban Atatlahuca, Oaxaca

Presentada por el alumno:

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Maestría en Ciencias en Conservación y Aprovechamiento de Recursos Naturales

Después de intercambiar opiniones, los miembros de la Comisión manifestaron ***APROBAR LA TESIS***, en virtud de que satisface los requisitos señalados por las disposiciones reglamentarias vigentes.

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RESUMEN

Las comunidades indígenas poseen conocimiento tradicional del que dependen para el aprovechamiento de hongos silvestres comestibles, lo que lo hace un recurso valioso, el cual se pierde a través de generaciones y debe ser documentado para su conservación. Los hongos al ser productos forestales no maderables funcionan como una fuente de alimento principal para pobladores locales, además de ser elementos culturales y comerciales. Es importante rescatar el conocimiento tradicional porque incorpora conocimientos ecológicos y de manejo. Asimismo, realizar estudios sobre la ecología es fundamental para la explotación de recurso, ya que existen pocos estudios de ecología de hongos silvestres comestibles. Para así generar información sobre aprovechamiento y sostenibilidad de hongos silvestres comestibles. El objetivo principal fue evaluar el conocimiento tradicional de macromicetos, así como el impacto en la diversidad y distribución de macroespecies como resultado del manejo que se da a los hongos de manera local. A través de entrevistas se obtuvo cómo se distribuye el conocimiento tradicional dentro de la comunidad. Asimismo, se realizaron 10 muestreos en 40 parcelas en dos sitios de aprovechamiento y dos de no aprovechamiento durante junio-octubre 2017, para evaluar la diversidad de macroespecies a partir de conteos de abundancia y riqueza, y distribución con variables microclimáticas y ambientales. Las características sociodemográficas, principalmente la edad, influyen en el conocimiento tradicional. Se obtuvieron 138 especies de macromicetos, de los cuales 23 son comestibles, los índices de diversidad verdadera para el sitio 1 y 2, donde no existe aprovechamiento de hongos silvestres comestibles fue de 14.82635 y 35.00029 respectivamente, los sitios 3 y 4 donde hay aprovechamiento 21.27931 y 34.00815, la estimación de chao 2 muestra los inventarios fungísticos completos por lo menos en un 50%, con el índice de Chao-Jaccard se muestra que el recambio entre los sitios fue bajo, los sitios 1 y 3 son más parecidos en composición de especies con 0.788 y estimado solo con las especies comestibles encontradas fue de 0.879. La correlación de Spearman con valores altamente significativo indicó que la riqueza fúngica disminuye al disminuir la temperatura del aire y aumenta al incrementarse la humedad relativa en el aire.

Palabras clave: Ecología, macromicetos, etnomicología, Mixteca, consumo local.

ABSTRACT

Indigenous communities have traditional knowledge that they depend on for the use of edible wild mushrooms, making it a valuable resource, which is lost through generations and must be documented for its conservation. Mushrooms, being non-timber forest products, function as a main food source for local inhabitants, as well as being cultural and economic elements. It is important to rescue traditional knowledge because it incorporates ecological and management knowledge. Likewise, conducting studies on ecology is fundamental for the exploitation of resources since there are few ecology studies of wild edible fungi. In order to generate information on the use and sustainability of edible wild mushrooms. The main objective was to evaluate the traditional knowledge of macromycetes, as well as the impact on the diversity and distribution of macro-species as a result of the management of fungi locally. Through interviews, we obtained how traditional knowledge is distributed within the community. Likewise, 10 samplings were made in 40 plots in two exploited sites and two non-exploited during June-October 2017, to evaluate the diversity and distribution of macrospecies with microclimatic and environmental variables. Sociodemographic characteristics, mainly age, influence traditional knowledge. 138 species of macromycetes were obtained, of which 23 are edible, the true diversity indexes for site 1 and 2, where there is no use of wild edible fungi was 14.82635 and 35.00029 respectively, sites 3 and 4 where there is use 21.27931 and 34.00815, the estimate of chao 2 shows the complete fungistic inventories at least 50%, with the Chao-Jaccard index it is shown that the turnover of species was low, sites 1 and 3 are more similar in composition of species with 0.788 and estimated for edible species found was 0.879. The Spearman correlation with highly significant values indicated that the fungal richness decreases with decreasing air temperature and increases with increasing relative humidity in the air.

Keywords: Ecology, macromycetes, ethnomycology, Mixteca, local consumption.

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A mis padres y hermanos por apoyarme siempre e incondicionalmente. AL Dr. Marko Aurelio Gómez- Hernández por darme la confianza de trabajar con él y sus enseñanzas. A mis revisores Dr. Antonio Santos, Dr. Etelvina Gándara, M.C Graciela González y M.C Gladys Manzanero Por el tiempo dedicado a revisar y comentar para hacer este trabajo mejor. A la comunidad de Independencia, San Esteban Atatlahuca, en la Mixteca Alta. Y finalmente a CONACYT por el apoyo con la beca de manutención.

Chapter 1:

"Distribution of traditional knowledge about wild edible macromycetes in a Mixtec community of Oaxaca"

Introduction

Mexico is one of the most culturally diverse countries in the world. There are 67 ethnic groups with its own indigenous language in this country, representing 10.1% of its total population. The state of Oaxaca is the region with the highest number of indigenous groups and population in Mexico (CNDI, 2015), and the Mixtec is the third most populated group in Oaxaca. Their language belongs to the Oto-Manguean linguist family and has 81 linguistic variants, and also it is known that the Mixtecs possess a broad traditional knowledge about the use of wild plants and mushrooms as elements in their diets (Casas et al., 1997; Katz, E. and Vargas, L.A., 1990).

The Mixtec region is divided in Mixteca Alta (highlands) and Mixteca Baja (lowlands), being the Mixteca Alta where the present work was carried out. A study in this area recorded 26 consumed species out of the 106 identified macromycete species, and obtained information on habitat and phenology of macrofungi from inhabitants. The study indicated that vegetation cover, socioeconomic and cultural factors affect species richness, knowledge and use of edible wild mushrooms, and concluded that it is necessary to maintain a traditional approach on the exploitation of macromycete species in order to conserve a sustainable management of the resource (Santiago et al, 2016). The relevance of traditional knowledge about the use or consumption of wild species relies on how it is interpreted by local people (users) and it is part of their daily lives, and how this knowledge can be useful for people that do not have experience on using wild species, as mentioned by Boa (2004) "The only reliable guide to edibility is the knowledge that someone has eaten a particular type and survived. Local practices and preferences are therefore another useful source of information".

Independencia, located in the Mixteca Alta of Oaxaca, is a village that belongs to the Mixtec people or Ñuu savi (which means the people of the rain), and its inhabitants are recognized by surrounding villages for the vast traditional knowledge they possess on wild edible mushrooms. In addition to collecting wild macromycetes for self-consumption, they sell them in nearby localities, which makes these organisms a source of food and alternative economic income. However, it has been shown that social variables like migration, age, sex, and educational level have an effect on the distribution of traditional knowledge in a population, and can be involved in the loss of this knowledge (González et al., 2010; Pacheco-Cobos et al., 2010; Silva et al, 2011).This makes of great interest to record the traditional knowledge, and assess how it distributes through a population with regard to sociodemographic factors (Garibay-Orijel et al., 2012; Reyes et al., 2013).

Therefore, the aim of this study was to evaluate how the traditional knowledge about wild edible fungi is distributed among the inhabitants of Independencia, using quantitative and qualitative information obtained from interviews with the people. We predict that 1) traditional knowledge is not equally distributed among the age groups, being more represented in elderly people, 2) the inhabitants who don't have an education degree have a greater knowledge on edible macromycetes, and 3) knowledge is not equally distributed among men and women.

Methods

Study area

Independencia belongs to the municipality of San Esteban Atatlahuca, placed within Tlaxiaco district in the Mixteca Alta region of Oaxaca, Mexico. It is located at the geographical coordinates 17°05'43" N and 97°39'35" W, with an elevation of 2670 m.a.s.l., and its main vegetation is Pinus-Quercus. The annual temperature ranges from 10 to 16 °C, and the annual precipitation variates from 800 to 1500 mm (INEGI, 2008). The community comprises 600 inhabitants, 48.3% men and 51.7% women (Independencia authorities, 2017). In the municipality ca. 91% of the population speaks an indigenous language, 99.2% are lacking basic services at home (water, public drainage, electricity, and use wood or charcoal for cooking), 29.8% have educational backwardness and 20.4%are facing food shortage (INEGI, 2015; SEDESOL, 2015).

Interviews with inhabitants

In order to document people's traditional knowledge about wild edible mushrooms, we selected to be our target population people older than 12 years, because the community is known for having traditional knowledge at early age, and several studies have recommended to gather information from most age ranges (Łuczaj and Nieroda, 2011., Somnasanc, P. et al., 2008., Montoya et al., 2003.). Following the method by León Andrade (2013), 80 informants were obtained to sample a population of 474 whose age was older than 12. The number of informants was standardized by age and gender; the age groups were 12-20, 21-40, 41-60 and older than 61 years old, comprised by 10 women and 10 men each group. They were selected randomly from a population list provided by the authorities. A number was assigned to each person and random numbers were generated for each gender and age group in R version 3.4.2 (R Core Team, 2017). From this sample we conducted 44 semi-structured interviews were conducted. Besides questions on socio-demographic features, the interviews included questions related to the morphological characteristics of traditionally consumed fungi, common name of each species (using high quality pictures of representative edible fungi), ecological aspects, and phenology of macromycetes (supplementary material 1).

Table 1. Total men and women population in Independencia, and number of interviewed inhabitants per age group.

	Men	***Women***
Population	290	310
Population older than 12	227	247
Group 1 (12-20 yrs) interviewed	9	6
Group 2 (21-40 yrs) interviewed	5	4
Group 3 (41-60 yrs) interviewed	5	6
Group 4 (>61 yrs) interviewed	4	5
Key informants	1	3

To obtain information on the management applied to the wild edible mushrooms a "snowball" method was carried out, we obtained 15 potential informants, and 4 of them were interviewed. The criterion for selecting the informants was that they must have been collectors for at last 5 years. The questions were in regard of their harvesting practices (supplementary material 2), including the topics mentioned above.

Analysis of traditional knowledge

The Spearman correlation coefficient was performed to obtain the relationship between the number of recognized edible species and age of the interviewee, and between the number of recognized edible species

and education level (categorized as 1 = no education degree, 2 = elementary school, 3 = middle school, 4 = high school and 5 = higher degree) . The coefficient was calculated for the total population sample, and separately for men and women. To show if the number of recognized edible species was statistical different between women and men Chi- test was made to compare answers, and between answers of how they classified mushrooms a t-test was performed. To represent on a geometrical plane the distance between age groups with respect to the composition of species known by each group, a Non-metric Multidimensional Scaling analysis (NMDS) with 10000 random starts was performed. All data was analyzed in R version 3.4.2 (R Core Team, 2017). Other answers that were relevant from interviews were described with the purpose of documenting the information.

Results

A total of 45 edible macrofungal species and 218 common names (127 in Mixtec and 91 in Spanish) were recorded from the interviews (Supplementary material table 1). Common names were linked to scientific names by asking taxonomically relevant macromorphological characters of mushrooms, and by showing fresh samples when possible.

The most recognized (44 mentions) and commonly consumed (43 mentions) species was *Amanita jacksonii*, which is most mainly named by its Mixtec name “Ji’i naa” (38 mentions). The most gathered species (40 mentions) was *Boletus edulis* “Ji’i pan” and the least collected was *Russula emetica* “hongo de borrego” which refers to lamb food (21 mentions).

38 people told that their knowledge about macrofungi was taught by their parents, and 4 people obtained the knowledge by their grandparents. We could not establish a timeline for mushrooms consumption in the community, the people say that they have consumed them “since always”.

Information from the interviews showed that inhabitants of Independencia are aware about the nature of the macromycetes: 23 people (13 women and 10 men) responded that these organisms are fungi, and 13 (11 men and 2 women) mentioned that they are plants. There were statistical differences between sexes on how people classified fungi as organisms, answers varied from plants, mushrooms, and other classifications, for plants we obtained t- values of -4.0249 and p- values of 0.00226, and when people responded that fungi belonged to a category of their own, we obtained t- values = 1.0392 and p- values = 0.3105, which tells us that there are significant differences between men and women regarding on how they categorize fungi in the kingdom of plants, as men statistically classified mushrooms as plants more than women did.

For the question about why the macromycetes are important, the answers were classified into the four ecosystem services described below, just as FAO (2018) has established them:

1. Cultural Services (non-material benefits). 15 answers pointing out that mushrooms are important "because they are attractive / beautiful", "they preserve part of the regional culture", “they are part of the culture we have ", and "collecting them makes people go out for a walk”.
2. Provisioning Services (the ecosystem provides a material benefit). 7 interviewees answered that mushrooms are food.
3. Supporting Services (maintaining diversity and give living space to organisms). 11 answers stated that "mushrooms maintain nature", "they are part of nature", and "they are food for wild animals and they keep them alive".

4. Regulating Services (regulation of ecosystem processes). 6 answers indicated that "mushrooms are part of nature cycles", "they maintain the forest growth", and "they balance the ecosystem".

The image of an agaricoid macromycete was shown to the interviewees for the recognition of mushroom parts and their names in Spanish and/or Mixtec (Figure 1). For the cap they mentioned the following names : head (cabeza), flower (flor) or little hat (sombrerito); Ring: (anillo), cloth (paño), bud skin (piel de capullo), neck (cuello) and umbrella (paraguas); Stalk: foot (pata), stick (palo), stalk (tallo) and little stem (tronquito); Volva: cowl (capucha), cap (gorro), egg yolk (yema), bud (capullo), foot (pata), layer that covered (capa que cubrió), root (raiz) and veil (velo); Margin: edge (orilla), face of the mushroom (cara del hongo), contour (contorno); Gills: center (centro), petals (petalos), gills (laminas), little color (colorcito), little leaves (hojitas), fungi cracks (grietas del hongo); Basidiospores: seed (semilla), fungi buds (yemas del hongo); ycelium: Root (raiz). One person did mention all parts of the mushrooms by its Mixtec name, she had claimed she took a workshop, however, most of part names for the fungi refer to plant parts, and as indicated 76% of women and 45% of interview men classified fungi as a different living organism from plants, so we suggest that part names weren't accurate because of lack of general information of the fungi kingdom.

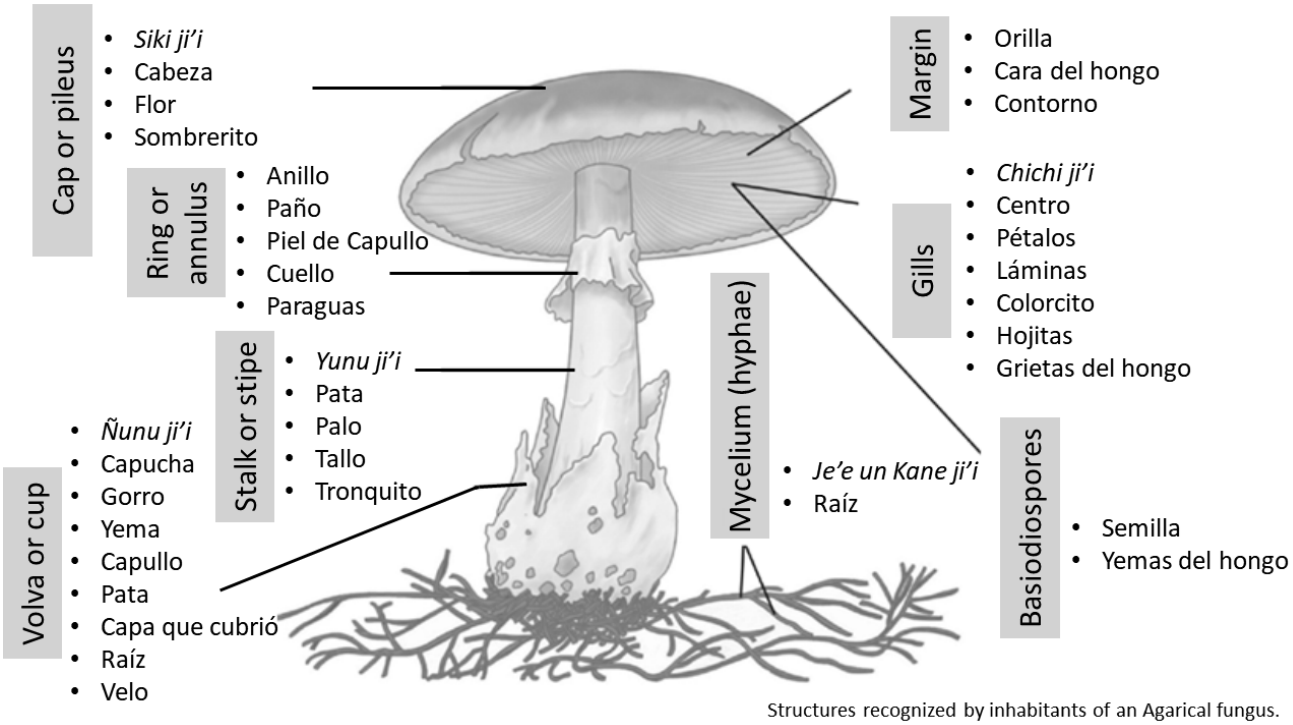

Figure 1. Mixtec and Spanish names for the parts of an *Amanita* sp.

Species of the *Amanita* genus were mostly identified as the same species. For *A. jacksonii*, 2% gave an exclusive name, 6% for *A. basii*, and 5% for *A. laurae*. For *Boletus* species, 0% gave an exclusive name for *B. pinicola*, 8% for *B. edulis*,and 19% for *B. projectellus*. *Craterellus tubaeformis*, 4% of the people gave an exclusive name, 10% for *Cantharellus minor* 10%, and 4% for *C. cibarius*. 17% gave one name for *Hellvela lacunosa* 17% and 0% for *H. crispa* 0%. *Laccaria amenthystina,* 20% of the people gave one name, and 13% for *L. laccata*. *Neolentinus lepideus* and *N. ponderosus* have the same naming according to locals. 0% gave one name for *Ramaria stricta* 0%, and 8% for *R. flava* 8%. For *Russula emetic*, 15% mentioned only one name, and 68% for *R. brevipes*.

People accustomed to give the same name to morphologically similar species within a genus, mainly for *Amanita*, *Boletus* and *Cantharellus* genera, which makes difficult to determine if they realize about the diversity

of macromycetes they consume. For species from the genera *Helvella, Laccaria* and *Russula*, which had the highest percentage in unique naming, and can be easily differentiated by their color people add a suffix to the name indicating the color, which suggests that they recognize different species belonging to the same group or genus (table 3 in the supplementary material). *Helvella lacunosa* (black-greyish cap) is named in Mixtec: "ji'i so'o nu" and in Spanish: "hongo oreja de conejo negro" which both mean "black rabbit ear fungus" indicating the black color. *Helvella crispa* (creamy-whitish cap) is named in Mixtec: "ji'i so'o " and in Spanish: "hongo oreja de conejo" which both mean "rabbit ear fungus" but without indicating color. *Laccaria amethystina* (purplish cap) is named in Mixtec: "ji'i tisu morado / Ji'i tisu n'tee" and in Spanish: "hongo moradito" which both names refer to the purple color. *Laccaria laccata* (yellow-orange cap) is named in Mixtec: "ji'i tisu cuee" which makes a reference for the orange color and no name in Spanish. *Russula brevipes (*white cap) is named in Mixtec "Ji'I cuiji" and in Spanish "hongo de Borrego blanco", which makes a reference in both names to the white color, in *Russula emetica* they call it in Mixtec "Ji'I lanchi cuee" which means red fungi of lamb.

By "snowball method" we interviewed 1 man and 3 women ranging from 50 to 60 years old. The information from the expert collectors about edible wild fungi was similar to the obtained from the general population, but we did get specialized information from the expert collectors about the collecting techniques. We resume the answers below:

1. The mentioned rules they have in the community for mushroom gathering were:
   a) Always cover the hole that is left after digging the mushrooms.
   b) Gathering is not allowed on private lands or where people has their seeding.
   c) Remove carefully the fruit bodies to not rake over soil and leaf litter.
   d) Before digging up, try first with a wooden stick. If the fruit body is not too buried and looks like it will come easily, you can collect the mushroom.
   e) It is forbidden to use machete or pocket knife when collecting lignicolous species in order to avoid damaging the tree bark.

2. How can we keep fungi growing in future collecting seasons?
   1) Not to fell trees.
   2) Avoiding forest fire.
   3) Collect carefully and not remove litter.
   4) Tread down on litterfall .

3. How must be the appearance of the macrofungi to be collected or when do you consider they must be collected?
   From the acquired answers they all agree that size and fully openness of the cap is a good indicator of maturity.

Distribution of traditional knowledge

From the selected people, a total of 44 were interviewed: 9 men and 6 women in the age-group 1, 5 men and 4 women in the group 2, 5 men and 6 women in the group 3, and 4 men and 5 women for group 4 (Table 1).

Spearman's Rank Correlation had a positive significant relation between number of recognized edible species and age (p-value = 0.007773, rho = 0.3961179), and no significant correlation with education level (p-value = 0.07618, rho = -0.2701129) . When considered sex, we found that men did not show any significant relation

between age or education level and number of recognized edible species, and for women age had a positive correlation (p-value = 0.01714, rho = 0.5140249) and a negative correlation with education level (p-value = 0.04735, rho = -0.4374614). We compared the number of correct answers of recognized edible species between women and men and found there were no statistical differences, X-squared = 213.5, df = 210, p-value = 0.4198 (Figure 2).

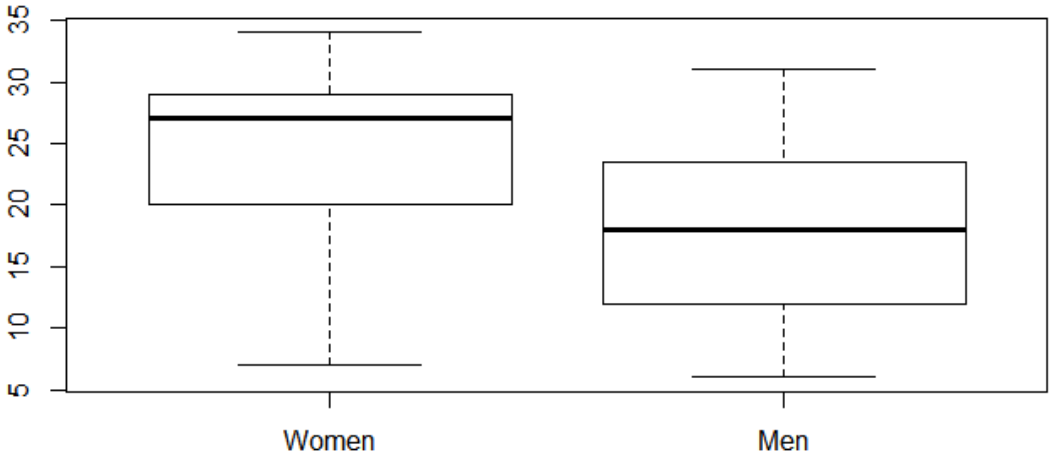

Figure 2. Boxplot of differences on the number of recognized edible species between women and men.

When comparing age groups by gender and the number of recognized species between sex, the smaller number of people interviewed in one of the groups was selected to standardize the other groups, women from groups 2 and 3 showed more knowledge on macromycete species, as well as group 3 of men (Figure 3).

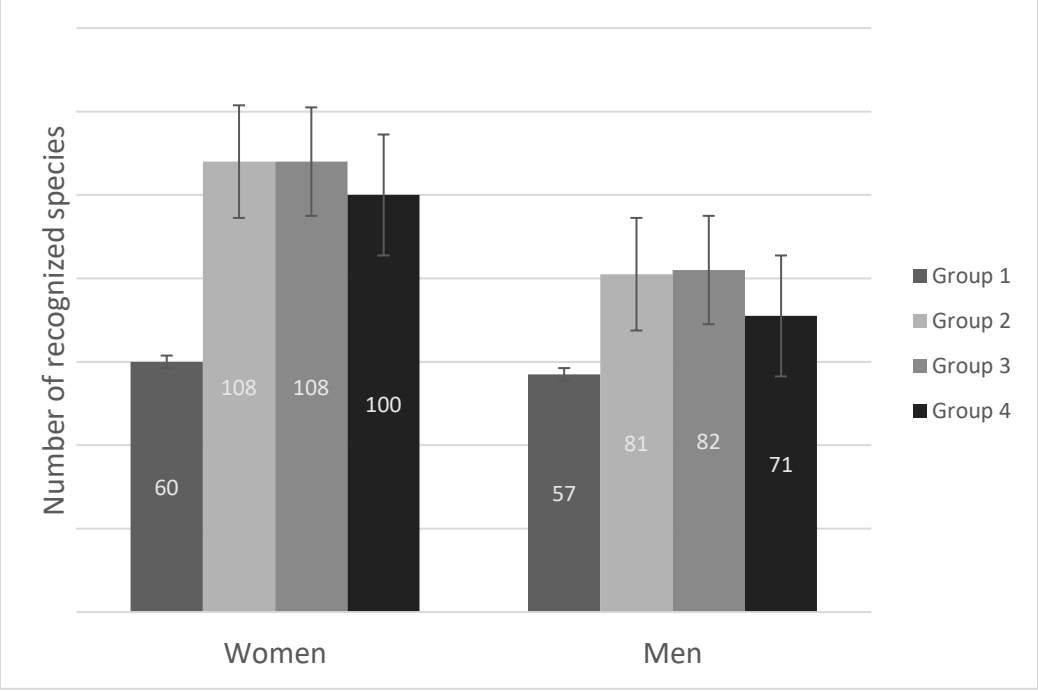

Figure 3. Differences in recognized edible species between women and men by standardized age groups, standard error bar is shown for each group.

Non-metric Multidimensional Scaling Analysis (NMDS) indicated that those groups that are closer to each other share recognition for the same asked species, along the two axes groups 3 and 4 can be found closer together, according to the statistical significant relation between variables, age and knowledge, those with more age show more knowledge and also similar composition in those recognized species (Figure 4).

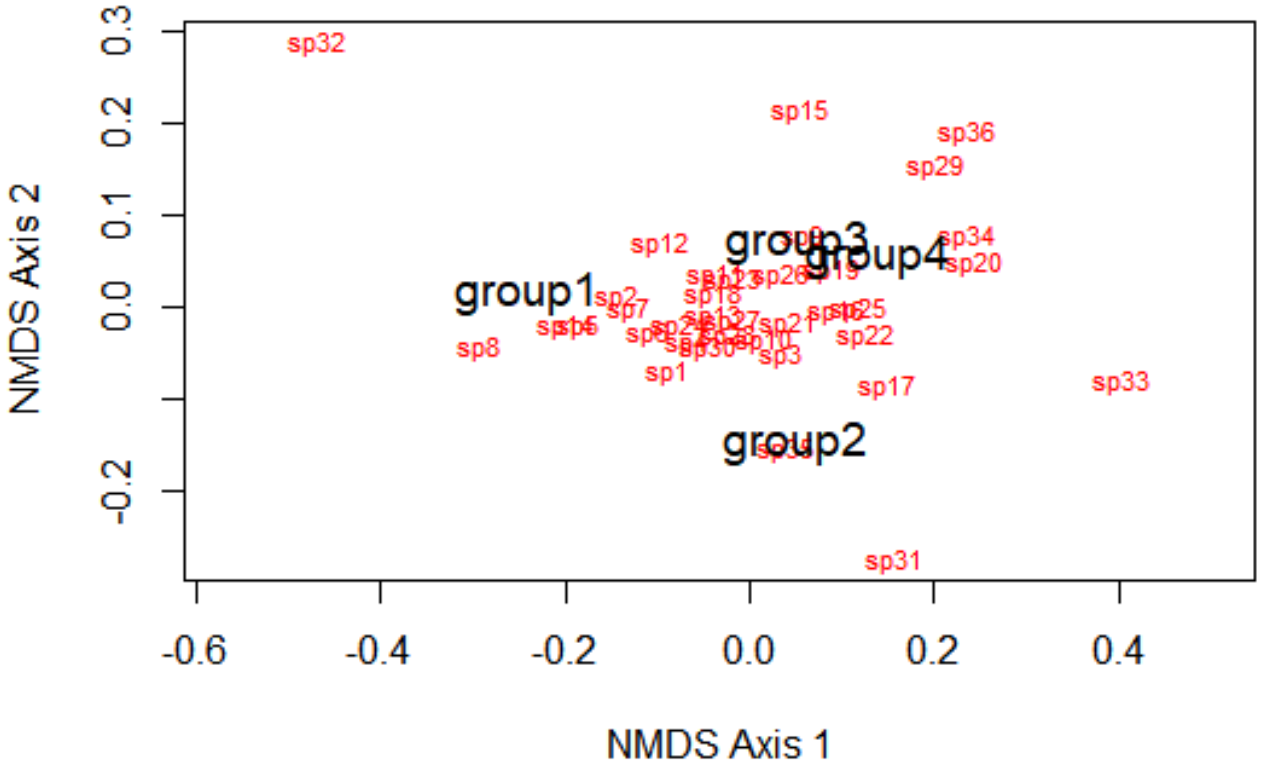

Figure 4. Groups are shown in black fonts, and fungi species shown in interviews are red.

Discussion

Our results suggest that people in Independencia have a broad knowledge on wild edible macromycetes, and this allow them to exploit a high diversity of species. In spite of being only indigenous Mixtecs in our study area, they consume 45 species of wild edible macrofungi. A study about the use of wild edible fungi in Chihuahua at the North of Mexico, identified 22 edible species and recorded 16 consumed locally among indigenous Raramuris, mestizos and other ethnic groups. Corresponding with our results, they found a high appreciation for the *Amanita cesarea* complex, however, 42% of their interviewed population told that they buy the mushrooms, whereas our interviewees stated that all the fungi they consume are obtained from personal gathering (Quinonez-Martinez et al., 2014).

At the central region of Veracruz, Mexico, a study reported the use of 14 wild edible macromycete species with 26 common names in Spanish and Nahuatl, but the names are different from the common names found in our study (218 names in Spanish and Mixtec). Some of their names also make allusion to the color of the cap or an animal, but the animals differ from the used in Mixtec names, for example, *Hypomyces lactifluorum* is named “Mouth of bull” in Veracruz, and “Mouth of pig” or “ear pig” in the Mixteca (Claire et al., 2004).

We found that women have more knowledge on edible fungi than men, and the knowledge in women increases with age. Contrary to other places where men are more involved in gathering activities (Łuczaj, Ł., and Nieroda,

Z., 2011), in our study area both sexes are involved in this activity, however, women seem to possess greater abilities for collecting mushrooms. A study made in Tlaxcala (central Mexico) by Pachecho-Cobos et al. (2010), observed that even thou men and women gathered the same number of fruit bodies, women made it more efficiently and had more mushroom species.

Five people from the general population and three key informants mentioned that the habitat of *Morchella angusticeps* (this species could have been confused with other from the same genus) is on burned forests or where there are ashes. Another 6 interviewees just mentioned that they grow on soil, which is consistent with previous research about the ecology of *Morchella* spp., where findings suggest that can be found on undisturbed (not burn) habitats, and can also be found on burn areas as it creates a suitable environment that triggers fruiting from previous stablished micelium pre-fire along with other factors, this kind of species that respond to fire are called phoenicoid or pyrophilic (Carpente and Trappe, 1985, Pilz et al 2007, Larson et al 2016).

Conclusions

We conclude that age is a determinant factor to explain how traditional knowledge distributes among the community but also that sex is influencing this pattern, as it was to be found that women did had significant relation between age and number of recognized species but men did not had this relation, and that in both sex it was to be found the highest number of recognized species among ages 21- 61, which we suggest it is because at that age range people are more active in gathering activities, as younger people spend time at school and those elderly they have more difficulties to go and harvest through the woods and therefore spend more time at home, and in the same time people who have received a higher degree on education known recognized less edible wild species as most of their time has been spent at school. Traditional knowledge is found at all ages among the Independencia community which tells us that knowledge is present in all generations and is a possible cause for the popularity that the community has throughout the municipality as wild edible mushrooms gatherers and experts.

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Supplementary material

1. Key informants interview format

Nombre del informante clave:

SECCIÓN I. Características sociodemográficas

1. Sexo_____

2. ¿Cuántos años tiene?_____

3. ¿Qué idiomas habla?

a. Mixteco

b. Español

c. Ambos

4. ¿A qué se dedica?_____

5. ¿Cuál fue su último grado de estudios?

a. Ninguno

b. Primaria

c. Secundaria

d. Preparatoria

e. Otro

SECCIÓN II. Listado de especies de hongos silvestres comestibles a reconocer con fotografías y características ecológicas

°1.Nombre(s):_____

2.Hábitat en el que crece:

a) Sobre árbol: b) Sobre suelo:

¿Cuál? I. ¿Cómo es el suelo? II. ¿Cerca de qué plantas?

3. ¿Lo consume? a) Si b) No

4. ¿Lo colecta? a) Si b) No

5. ¿En qué meses crecen estos hongos?_____

2. ¿Qué otros hongos silvestres comestibles no mostrados hay/conoce o colecta?

_____

3. ¿Cuál es/son los hongos de su preferencia?

_____

4. ¿Por qué es/son los hongos de su preferencia?

a. Sabor b. Valor económico c. Valor cultural d. Aspecto

SECCIÓN III. Forma de colecta (MANEJO)

1. ¿Cuánto tiempo tiene siendo colector?

_____

2. ¿Quién le enseñó a identificar cuáles hongos son comestibles y cuales son tóxicos?

_____

3. ¿Colecta para consumo personal (familia) o para la venta?

A. Personal B. Venta C. Ambos

¿Representa una fuente de ingreso importante/principal?

¿Dónde vende sus hongos?

¿Quiénes son los compradores que aportan más dinero?

¿Cuál es el hongo que más vende?

4. ¿Cómo deben verse los hongos para ser colectados/ cuándo considera que deben ser colectados? (Maduración)_____

5. ¿Cuál es la forma de recolección?

A. Cortar el pie/ tallo ¿Con qué instrumento?

B. Extraer

a. ¿Con qué instrumento?

b. ¿Cuánta profundidad?

c. ¿Se deja un hoyo?

6. Si hay más de un hongo en el mismo espacio (menor a 50 cm diámetro), ¿Cuántos son colectados?

A. Todos B. Los maduros o presentables

B. Otra:_____

7. ¿Cómo son transportados?

A. Papel B. Bolsa de Plástico C. Canasta D. Cubeta E. Tenate

8. ¿Tiene un sitio secreto o visita uno donde colectan más personas fuera de su familia?

A. Secreto B. Público C. Ambos

9. ¿Cuántos sitios de colecta tiene que visitar para obtener el número de hongos que usted considere necesarios?_____

10. ¿Cuánta cantidad de hongos obtienen por salida?

_____

11. ¿Con qué frecuencia realiza salidas de colecta?

_____

12. ¿Ha cambiado la cantidad de hongos que se ven en el campo en los últimos 5 años?

A. Si ha aumentado B. Si ha disminuido C. No

13. ¿Existe algún hongo en específico que se haya vuelto más difícil de encontrar? ¿Por qué?

_____

14. ¿Se puede conservar el crecimiento de los hongos en el campo para próximas colectas?

A. Si ¿Cómo?_____

B. No

15. ¿Existen normas establecidas por la comunidad para la colecta de hongos?

A. Si ¿Cuáles?_____

B. No

SECCIÓN IV. Conocimiento del grupo

16. ¿Hace cuánto tiempo que se consumen hongos en el pueblo?

_____

17. ¿De dónde obtuvo el conocimiento sobre hongos silvestres comestibles?

A. Padres

¿De dónde lo obtuvieron sus padres?_____

B. Escuela

C. Taller o curso

D. Otro: _____

17. ¿Para usted que son los hongos?

A. Animal

B. Planta

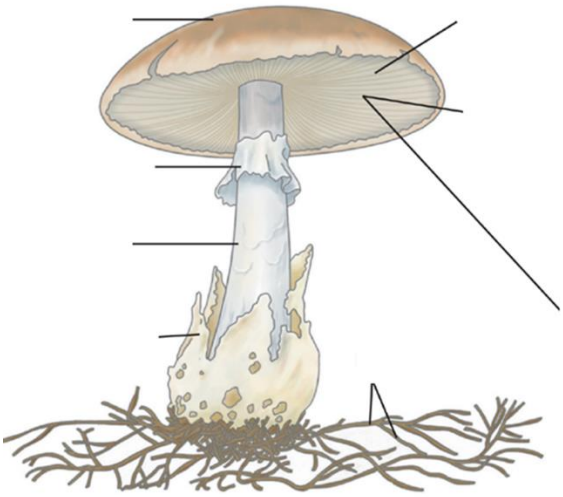
C. Otro:_____

18. ¿Cree que los hongos son importantes para el bosque?

A. Sí ¿porqué?_____

B. No

19. ¿Cuáles son las partes reconocidas y su nombre en la siguiente imagen?:



19. Nombre a las personas con quienes ha discutido sobre el tema y usted considera que tiene una experiencia mínima de cinco años y está involucrado actualmente en la actividad de colectar hongos

2. General population interview format

Nombre:

SECCIÓN I. Características sociodemográficas

1. Sexo_____

2. ¿Cuántos años tiene?_____

3. ¿Qué idiomas habla?

a. Mixteco

b. Español

c. Ambos

4. ¿A qué se dedica?_____

5. ¿Cuál fue su último grado de estudios?

a. Ninguno

b. Primaria

c. Secundaria

d. Preparatoria

e. Otro

SECCIÓN II. Listado de especies de hongos silvestres comestibles a reconocer con fotografías y características ecológicas

°1.Nombre(s):_____

2.Where does it grow?

a) Sobre árbol: b) Sobre suelo:

¿Cuál? I. ¿Cómo es el suelo? II. ¿Cerca de qué plantas?

3. ¿Lo consume? a) Si b) No

4. ¿Lo colecta? a) Si b) No

5. ¿En qué meses crecen estos hongos?_____

2. ¿Qué otros hongos silvestres comestibles no mostrados hay/conoce o colecta?

_____

3. ¿Cuál es/son los hongos de su preferencia?

_____

4. ¿Por qué es/son los hongos de su preferencia?

a. Sabor b. Valor económico c. Valor cultural d. Aspecto

5. Los hongos que consume:

a) Los colecta b) Los encarga (H/M) c) Los compra

6. ¿Con que frecuencia consume hongos?

SECCIÓN III. Conocimiento del grupo

1. ¿Hace cuánto tiempo que se consumen hongos en el pueblo?

2. ¿De dónde obtuvo el conocimiento sobre hongos silvestres comestibles?

A. Padres

¿De dónde lo obtuvieron sus padres?_____

B. Escuela

C. Taller o curso

D. Otro: _____

3. ¿Para usted que son los hongos?

A. Animal

B. Planta

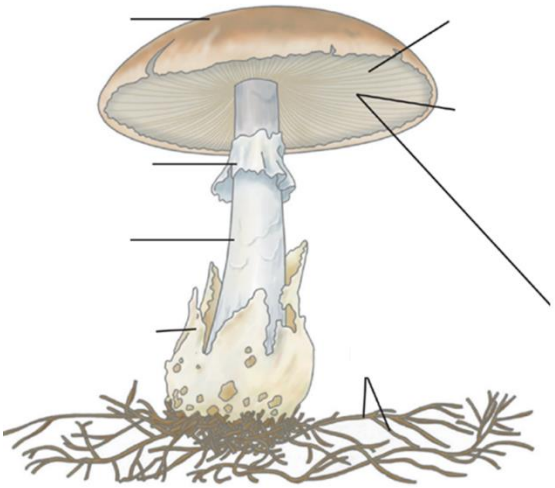
C. Otro:_____

4. ¿Cree que los hongos son importantes para el bosque?

A. Sí ¿porqué?_____

B. No

5. ¿Cuáles son las partes reconocidas y su nombre en la siguiente imagen?:



3. Identified species

Table 1. NM Number of mentions; NEM Number of edible mentions; NNEM Number of non-edible mentions; CM Collected mentions. Species 1-36 where asked with pictorial aid. 37-45 Where obtained from free listing and oral descriptions.

	Scientific name	Mixtec local name	Spanish local name	NM	NEM	NNEM	CM
1	*Albatrellus ellisii* (Berk.) Pouzar	ji'i stiki Ji'i yititi Ji'i ya'a stiki Ji'i ya'a	Hongo de toro Lengua de toro Hongo de Ocotal Hongo tripa de toro Panza de toro	21	21		19
2	*Amanita jacksonii* Pomerl.	Ji'i na'a kue'e Ji'i na'a	Hongo rojo Yema de huevo Hongo colorado Hongo de yema	44	43	1	38
3	*Amanita basii* Guzmán & Ram.-Guill.	Ji'i naa sa'a Ji'i naa Ji'i naa kua	Hongo de yema Hongo rojo Yema de huevo Hongo colorado	33	34		31
4	*Amanita laurae* Guzmán & Ram.-Guill.	ji'i naa ji'i naa kua ji'i sa'a ji'i naa sa'a ji'i naa naranja	Hongo de yema Hongo rojo Yema de huevo Hongo colorado	37	37		34
5	*Boletus pinophilus* Pilát & Dermek	ji´i pan ji´i tikajne ji'i nuyundu'u ji'i tikani nuyunde ji'i tiskaya ji'i scala ji'i tiskala	Hongo de zacate Pambazo Hongo de pan	36	39		39
6	*Boletus edulis* Bull.	ji'i nuyundu'u ji'i pan ji'i pan nukaji ji'i scala ji'i tikani ji'i tikani nukaji ji'i tikani nuyunde ji'i tiskala	Hongo de pan Hongo de zacate Pambazo	38	42		40

7	*Aureoboletus projectellus* (Murrill) Halling	ji´i pan ji´i tikajne ji'i scala yuje ji'i tikani nuyunde ji'i tika nunuñuje ji´i yuje ji'i tiskala ji'i scala	Hongo de árbol Hongo de yuja Hongo de pan	37	38		37
8	*Craterellus tubaeformis* (Fr.) Quél.	ji´i vaya nuyuje ji´i vaya ji'i nta´a nduji	Hongo patita/pata de pollo Pata de gallo	27	28	1	28
9	*Cantharellus minor* Peck	ji´i vaya kua ji'i nta'a ji'i nta'a nduji	Hongo patita/pata de pollo Pata de gallina Pata de pollo amarillo	21	23		23
10	*Cantharellus cibarius* Fr.	ji´i vaya kva ji´i vaya ji'i nta´a nduji ji'i ti vaya ji'i vaya amarillo	Hongo amarillo/amarillito	23	25	1	25
11	*Helvella crispa* (Scop.) Fr.	ji'i so'o iso ji'i iso	hongo oreja/orejita de conejo hongo de conejo oreja de venado	25	28	2	27
12	*Helvella lacunosa* Afzel.	ji'i so'o iso ji'i so'o iso nu ji'i sanñi ji'i so'o ji'i iso ji'i xinicolo	Hongo oreja/orejita de conejo Hongo de conejo Oreja de venado Hongo oreja de conejo negro Hongo de cabeza guajolote	23	25	2	23
13	*Hydnum umbilicatum* Peck	ji'i tindaku ji'i nutundaku	Hongo de gusanito/gusano	29	31	1	31
14	*Hipomyces lactifluorum* (Schwein.) Tul. & C. Tul.	ji'i kue'e	Hongo rojo Trompa de cochi Oreja de cuchi Hongo de chile Hongo colorado	37	38		34

15	*Hygrophoropsis aurantiaca* (Wulfen) Maire	ji'i vaya ya'a ji'i kue'e nuyuje ji'i vaya nuyuje ji'i cuiji yuje ji'i vaya kua		11	11	5	9
16	*Laccaria amethystina* Cooke	ji'i ntoyo ji'i tisu ji'i tisu inte'e ji'i tisu morado ji'i tisu nucaji	moradito / morado	25	24	2	24
17	*Laccaria laccata* (Scop.) Cooke	ji'i tisu kue'ee ji'i tisu nuyuje		15	8		16
18	*Lactarius indigo* (Schwein.) Fr.	ji'i xiku ji'i ixi ji'i yi'i ji'i ixiku ji'i tandichi	Hongo azul Hongo de pajaro azul Hongo de pajaro Azulito	38	32	6	30
19	*Lycoperdon curtisii* Berk.	ji'i lota ji'i tachi ji'i pompo ji'i kaka ji'i indaina ji'i xini	piel de perro hongo de bombón hongo de pelotita/pelota patita de perro hongo de cal	23	20	10	18
20	*Morchella angusticeps* Peck	ji'i sañi ji'i yiteñute ji'i ndixi ji'i ndoso iso	hongo de mazorquita/ mazorca hongo de elote	9	11	5	11
21	*Neolentinus lepideus* (Fr.) Redhead & Ginns	ji'i ntkañ'u	hongo de cuaresma hongo de palo	24	23		22
22	*Neolentinus ponderosus* (O.K. Mill.) Redhead & Ginns	ji'i ntkañ'u	hongo de casahuate hongo de cuaresma hongo de palo	21	20		20
23	*Ramaria stricta* (Pers.) Quél.	Ji'i taka. ji'i taka kua. ji'i taka na'nu.	Cuernito/cuerno de venado Hongo de escobetilla Hongo de tronco Hongo de venado	33	24	11	23

24	*Ramaria flava* (Schaeff.) Quél.	Ji'i taka. Ji'i taka bueno. Ji'i taka kua. Ji'i taka isu. Ji'i taka na'nu. Ji'i taka xini isu.	Hongo de escobetilla. Hongo de venado.	39	37	5	35
25	*Russula emetica* (Schaeff.) Pers.	ji'i kue'e lanchi ji'i dixu ji'i intibhu'u ji'i lanxi ji'i lanxi kue'e ji'i ndee	Hongo de borrego Hongo de chivo Hongo de chivo Hongo rojo	20	6	21	6
26	*Russula brevipes* Peck	ji'i cuiji ji'i cuiji lanxi ji'i cuiji yuje ji'i intibhu'u ji'i ishi ji'i lanxi ji'i ndee ji'i ndishuu	Hongo blanco Hongo de borrego Hongo de borrego blanco Hongo de chivo	28	13	20	13
27	*Sparassis crispa* (Wulfen) Fr.	ji'i nte ji'i koto ji'ñɨɨ ji'i ñuñu ji'i so'o nñtɨ ji'i sopa	Hongo de sopa	32	36		34
28	*Tricholoma magnivelare* (Peck) Redhead	ji'i yisu	Hongo de aguacate	37	38		34
29	*Clitocybe gibba* (Pers.) P. Kumm.	ji'i taya'a ji'i ndamiji ji'i yuji		18	16	5	16
30	*Ustilago maydis* (DC.) Corda	ti ka'ya ji'i tska'ya ti ka'ya negro ti ka'ya nu	Hijo de maiz Hongo de elote Huitlacoche negro Hongo de milpa Hongo de maiz Huitlacoche cuitlacoche	32	35		33
31	*Hydnum repandum* L.	ji'i kñu ji'i tindaku	Hongo de gusano/ gusanito	9	10	1	10
32	*Albatrellus ovinus* (Schaeff.) Kotl. & Pouzar	ji'i ñuñu	Lengua de toro Hongo de toro Tripa de toro Hongo de panal	9	8	2	8

33	*Schizophyllum commune* Fr.	ji'i nutixii ji'i nta'a kueñu ji'i tishi ji'i nucaji	Pata de ardilla Hongo uña de ardilla Hongo de tronco de encino	6	6	4	6
34	*Auricularia* sp. Bull.	ji'i so'o ji'i so'o la'le ji'i so nucaji ji'i nee	Hongo oreja de ratón Hongo de oreja	14	6	13	6
35	*Boletopsis* sp. Fayod	ji'i lili nu ji'i lili	Hongo de cresta de gallo negro Hongo de gallo Cresta de gallo Hongo de gallo negro	25	19	9	19
36	*Pleurotus* sp. (Fr.) P. Kumm.	ji'i yabu ji'i nucatu ji'i nukate ji'i nucaji	Hongo seta Hongo de encino	15	17		10
37	*Clavariadelphus truncatus* Donk	ji'i ndtoso'o isu	Chichi de venado	1	1		1
38	*Laccaria* sp. Berk. & Broome	Ji'i ixi nduyuu	Hongo de clavo	2	2		2
39	*Catathelasma* sp. Lovejoy	ji'i too ji'i ñuma		4	4		4
40	*Agaricus* sp. L.	ji'i ndeyu	Champiñón	3	3		3
41	*Boletopsis* sp. Fayod	ji'i lili blanco ji'i lili cuiji	Hongo de gallo güero	1	1		1
42	*Calocybe* sp. Kühner ex Donk	ji'i xe'e	Hongo de manteca	3	3		3
43	*Scutiger pes-caprae* (Pers.) Bondartsev & Singer	Ji'i ñuñu	Hongo de abeja	1	1		1
44	*Hygrophorus russula* (Schaeff. ex Fr.) Kauffman	ji'i ita	Hongo de flores	1	1		1
45	*Hericium* sp. Pers.	ji'i ñu kolo ji'i kolo		1	1		1

4. Communication and scientific dissemination poster for the community

Chapter 2:

"Effect of harvesting wild edible macromycetes on their diversity and distribution in the Mixteca Alta of Oaxaca"

Introduction

Fungi have a cosmopolitan distribution, and they can be found almost in all the ecosystems due to the distinct nutritional and reproductive strategies among the saprobic, parasitic, and symbiotic groups (Herrera and Ulloa, 2004). The fungal diversity estimated from soil samples ranges from 3.5 to 5.1 million, of which 53,000 to 110,000 are estimated to be macrofungal species (Mueller et al., 2007; O' Brien et al., 2005). The diversity of fungi in Mexico has been estimated to be ca. 200,000 species, with 4800 macromycete species (Guzmán, 1998). However, only 2,135 macrofungal species are registered to the country (Cifuentes, 2008).

These organisms play a main role in most ecosystems. As decomposer organisms, they contribute to balance the ecosystem functioning through biological interactions, soil formation and conservation, as well as nutrient cycling (Esqueda et al, 2013). Some fungi are saprobic inhabiting soil and wood, being the most important organisms decaying organic matter within ecosystems, and its mycelial cords act as translocators of mineral nutrients (Boddy 1999). Others form symbiotic associations, called mycorrhiza, through interactions with the root system of higher plants. These associations are important because fungi facilitate plant's uptake of water and nutrients, such as phosphorus (which is limitating in many soils) and nitrogen, promoting plant growth in exchange of carbohydrates(Bever et al., 2001; Högberg and Högberg, 2002; Hall et al., 2003).

In addition to their roles in ecosystem functioning, fungi are highly relevant for humans and human-related activities (Mueller and Bills, 2004). Wild edible species of macrofungi (fungi visible to the naked eye) have been collected and consumed by people for thousands of years and are considered non-timber forest products with a growing interest worldwide. Most of the important internationally-marketed wild edible fungi (e.g. *Tricholoma magnivelare* from Pacific Northwest United States and Mexican forests of Oaxaca) are obligated ectomycorrhizal, and some commercial fungi recognized for their potential as functional food for human health, are saprotrophic (e.g. *Lentinula edodes* and *Pleurotus* spp.) feeding on decaying wood, both functional groups uphold forest health and help sustain ecosystem ecological processes after a disturbance, (Mattila et al., 2000; Martínez-Carrera et al., 2002; Pilz et al., 2002; Caglarirmak, N., 2007; Azul et al., 2009). The harvesting effects on macrofungal populations and its sustainable management is a concern since wild edible macromycetes represent a food resource, a multi-dollar industry, have become an increasingly alternative income uptake for rural people, and some species are used in developing countries as substitute for meat due to their nutritional value (Boa, 2004).

The knowledge about the diversity and distribution of macrofungal species gives us valuable information to systematically rationalize this resource and avoid biological and economical loses. There are microclimatic factors (e.g. light, temperature and moisture) that influence the diversity and distribution of macromycete species, they can vary along forest types and it has been suggested that macromycete species turnover may be more related to these factors than to tree species composition (Pilz et al., 2006; Gómez-Hernández and Williams-Linera, 2011). Anthropogenic activities can influence the diversity and distribution of macrofungal species and may cause a decline in sporocarp number as a result of altering microclimatic factors, soil

compaction by hordes of pickers, damage or exhaust mycelia, shift competitive relations with other species, and diminishing reproduction by decreased spore production (Arnolds, 1995).

Mexico is the second country after China (600 reported species) with more traditional consumption of wild edible mushrooms (371reported species), and the 6th with the highest number of ethnic groups (Ruan-Soto et al, 2006; Garibay-Orijel and Ruan-Soto, 2014). The official Mexican standard NOM-010 declares that wild edible mushrooms show a commercial demand for the high value of some species such as *Tricholoma magnivelare*, *Boletus edulis*, *Cantharellus cibarius* and *Morchella* spp., which leads to an intensive and selective exploitation that can cause an overexploitation and put at risk the resource and other associated resources. Therefore, it establishes the criteria for the use, transportation, storage, and the quantities of fungi (in tons), where the owner or holder of the exploited area must carry out the management of the resource based on technical and scientific studies, through an advisor registered in Registro Forestal Nacional (SEMARNAT, 1996). The species mentioned above have been included in the official Mexican standard NOM-059-SEMARNAT-2010 in the risk categories for biodiversity as "Under Special protection" and "threatened". The state of Oaxaca is one of the most biodiverse regions in the planet, and the most biologically and culturally diverse region in Mexico (Flores-Villela and Gerez, 1994), but there is a lack on inventories of macrofungal species and any mycological information for Oaxaca (Garibay-Orijel et al. 2006). A study made in a Zapoteca community northeast of the city of Oaxaca (Ixtlán de Juárez) disclosed that people in the community have a vast knowledge of at least 43 macrofungal taxa, being *Amanita, Hydnum, Laccaria, Lactarius* and *Ramaria* recognized genera. They recorded 14 new species for Oaxaca, 3 new records of edibility, and 2 species were cited for Mexico for the first time (Garibay-Orijel et al., 2006). In the same community, the availability of edible mushrooms was measured within a Pinus-Quercus forest, the most abundant genera of macromycetes were *Laccaria, Gymnopus, Hygrophorus, Cantharellus, Suillus, Lactarius, Auricularia* and *Hygrophoropsis* (Garibay-Orijel et al., 2009). It is broadly known that many communities in Oaxaca traditionally use wild edible macrofungi, and this resource is an income uptake for several rural families. This makes of great importance to evaluate management strategies and be informed on the likely effect of the resource exploitation on macromycete diversity and distribution. However, studies about the harvesting effect on macrofungal communities/populations are scarce in the world, and inexistent in Mexico.

The present study will be carried out in the indigenous community of Independencia, Oaxaca, in Southeastern Mexico. This community, located in the highlands of the Mixteca region, is recognized for the vast knowledge the inhabitants have about wild edible macromycetes. Therefore, the aim of this study was to assess the effect on the diversity and distribution of macroespecies resulting from the local management given to wild mushrooms. Based on the existing information on this issue, we predict that 1) local management for wild edible fungi is likely influencing the diversity and distribution of macromycete species, 2) the diversity of macrofungal species is similar between gathering sites, but different to the diversity of sites where this activity is not performed, and 3) there is a high turnover of species between the gathering sites and sites where this activity is not performed.

Methods

Study area

Independencia was our study community. It belongs to the municipality of San Esteban Atatlahuca, placed within Tlaxiaco district in the Mixteca Alta region of Oaxaca, Mexico. It is located at the geographical coordinates 17°05'43" N and 97°39'35" W, with an elevation of 2,670 m.a.s.l. The physiography is comprised within Sierra Madre del Sur, characterized by Pinus-Quercus forests. The climate oscillates between 10 and 16 °C, it is

subhumid temperate, and to a lesser extent subhumid semicold with summer rains, with a precipitation range of 800-1,500 mm (INEGI, 2008).

Study sites

Four study sites were stablished in forests surrounding Independencia; two sites in areas where locals harvest wild edible mushrooms, and two where this activity is not carried out. The study sites were selected in aid of inhabitants who are mushroom collectors. In each site, 10 permanent plots of 10 m x 10 m located at least 10 m apart from each other were stablished, to encompass 0.1 ha per site. Site 1 is non-exploited located at 17° 3'53.97"N and 97°38'13.66"W at 2,620 m.a.s.l.. Site 2 is non-exploited, located at 17° 06.29' N and 97°39.59' W at 2,700 m.a.s.l.. Site 3 has been exploited for the at least 8-9 years, located at 17° 5'32.40"N and 97°39'17.82"Wat 2,750 m.a.s.l.. Site 4 has been exploited for at least 4-5 years, with 17° 5'18.25"N and 97°39'47.08"Wat 2,580 m.a.s.l. In order to avoid factors masking the likely effect of the harvesting practice on relevant variables related with macromycete communities, vegetation and environmental characteristics among selected sites were as similar as possible.

Macromycete sampling

Sampling was carried out in the rainy season June-October 2017. The sporomes were sampled every 2 weeks in each of the permanent plots, with a total of ten samplings per plot. Since the edible macromycetes are a valuable resource for local people, we took specimens for identification only when necessary. Fruiting bodies of the same species within a diameter < 50 cm, were recorded as a single individual. Sporomes were photographed with detail and described when fresh for identification by consultation of specialized taxonomists. When specimens could not be identified at species level, they were considered as morphospecies. Species were identified as edible by a literature review (Garibay-Orijel et al., 2009; Karun, N. C and Sridhar, K. R., 2017).

Vegetation structure

In each plot of every site, trees with diameter > 10 cm at 1.3 m above ground were counted. Diameter and height of every individual was measured. We determined basal area ($m^2 \cdot ha^{-1}$), density ($individuals \cdot ha^{-1}$), and mean and maximum height (m) of trees.

Microclimatic and environmental variables

Geographical coordinates and altitude of each of plot were taken. Each sampling date in each plot, microclimate was measured as air and soil temperature, relative and soil humidity, soil pH, and soil compaction. Soil texture for all sites was classified as sandy clay loam to clay loam, ideal bulk density for plant growth on this type of soils is <1.40 and affects root growth when 1.60 and restricts root growth when is >1.75. Environmental variables recorded per plot were slope, aspect, canopy openness, and percentage of moss, rockiness, and soil coverage. Litter depth was measured at the beginning, middle, and the end of sampling season.

Richness and diversity

The number of species in each site was recorded and expected species richness among sites was compared by means of rarefaction curves. The diversity of macrofungi was calculated with the Shannon diversity index and as the true diversity of first order (^qD) using the multiplicative diversity decompositions of effective numbers of species (Jost, 2006, 2007; Tuomisto, 2010),and a hierarchical cluster with single linkage based on composition and abundance of species were made in R version 3.4.2 (R Core Team, 2017). The completeness of macromycetes inventory was estimated using the richness estimator Chao 2 nonparametric and to measure similarity in species composition between sites and the Chao-Jaccard abundance-based similarity index was calculated with the program EstimateS 9.1.0 (Chao et al, 2005).

Statistical analysis

The Spearman rho correlation index was performed to observe relationship between microclimatic variables and macrofungal richness. To understand the distribution of macrospecies in relation to the set of environmental, microclimatic, and vegetation structure variables, a canonical correlation analysis was performed. Kolmogorov-Smirnov test was performed to evaluate differences between patterns of diversity and species richness. Lineal regression analyses were carried out to determine the relation between species similarity and geographic distance among sites. To observe the difference between Shannon diversity index between pairs of sites we used the t-test proposed by Hutchenson, all the analyses were performed in R version 3.4.2. (R Core Team, 2017).

Results

A total of 856 individuals were found, corresponding to 138 species, , from which 23 were identified as edible. From the recorded species, 22 were mycorrhizal, 19 saprobic, and 2 facultative saprobic. Edible macromycetes recorded 16 mycorrhizal and 7 were saprobic species. From the phylum Basidiomycota, we found 10 orders and 33 families. Agaricales was the richest order with 78 species, and the richest families were Cortinariaceae with 11 species, and Amanitaceae and Tricholomataceae with 10 species each. For the phylum Ascomycota, we registered 4 orders and 4 families, two genera *Hypoxylo*n sp. and *Tolypocladium* sp., and species *Leotia lubrica* and *Otidea alutacea.* (Supplementary material table 1).

Macromycete richness and diversity

Site 4 had with the highest richness of 72 species with 306 individuals and the site with the least richness was site 1 with 34 species and 115 individuals. Of the recorded edible species found the highest richness was found at site 4 with 14 species with an abundance of 86, and the site with the least richness was site 1 with 9 species and 66 individuals.

Highest Shannon index was for site 2 was 1.544072 and the lowest was for site 1 with 1.171034. Highest diversity of first order was for site 2 35.00029 and lowest for site 1 14.82635, and analysis made for edible species only showed same diversity patterns. With Chao 2 we obtained that all our sites where completed on at least 50 percent on their fungal inventories, site 1 with 53%, site 2 with 57%, site 3 with 63% and site 4 with 50% (Table 1).

Table 1. Richness, diversity and abundance of macromycete and wild edible fungi.

	Site 1	*Site 2*	*Site 3*	*Site 4*
Site status	Non exploited	Non exploited	Exploited	Exploited
Richness	34	64	48	72
Edible richness	9	12	10	14
Abundance	115	221	177	306
Edible abundance	66	36	84	86
Chao 2	64.5	112.95	76.59	145.25
H'	1.17	1.54	1.33	1.53
H' edible species	0.57	0.96	0.60	0.87
^{q}D	14.83	35.00	21.28	34.01
^{q}D edible species	3.70	9.08	4.02	7.47

Edible species abundance found at site 1 and 3 represented 57.4% and 47.5% of all individuals in each site and sites 2 and 4 which had the highest true diversity of first order and Shannon index had the least abundance of

edible species compared with the total of species per site with 16.3% and 28.1 %, although true diversity index and Shannon index at sites 1 and 3 is low, the proportion in abundance of the edible species with respect to all the sampled macromycetes by site is greater than in those sites with higher values of diversity. The proportions of the edible species richness compared to all species found at each site is 26.5% for site 1, site 2 is 18.8%, site 3 is 20.8% and site 4 is 19.4%, although the richness is low, the proportion of edible species found is the highest for site 1.

There were significant differences between Shannon diversity among all sites except for 2-4 as they had similar values 1.54 and 1.53, meaning it had the more equitable distribution of richness and were similar in diversity as they were the sites with highest richness (64 and 72 respectively) differences among other sites means each of them were unique in their diversity. For edible species t-test for Shannon index follow the same agglomeration pattern shown in the dendrogram, as sites pairs 1-3 and 2-4 showed no statistical differences. Site 1 had the lowest richness, Shannon index and true diversity, this could be explained because due to external circumstances we did 8 out of 10 samplings but is also inconsistent as site number 4 had the highest richness and highest diversity index values and we did 9 samplings, as for sites 2 and 3 we did all ten samplings and could not be found statistical differences among their Shannon diversity index.

We compared site richness with rarefaction curves at a standardized number of 115 individuals. Sites 1 and 3 showed 33 and 35 species, respectively). Sites 2 and 4 recorded 42 and 38 species, respectively. Species accumulation curves with plots as sampling effort for each site did not reached the asymptote, meaning that our inventories where were not completed as indicated by the richness estimator Chao 2 .

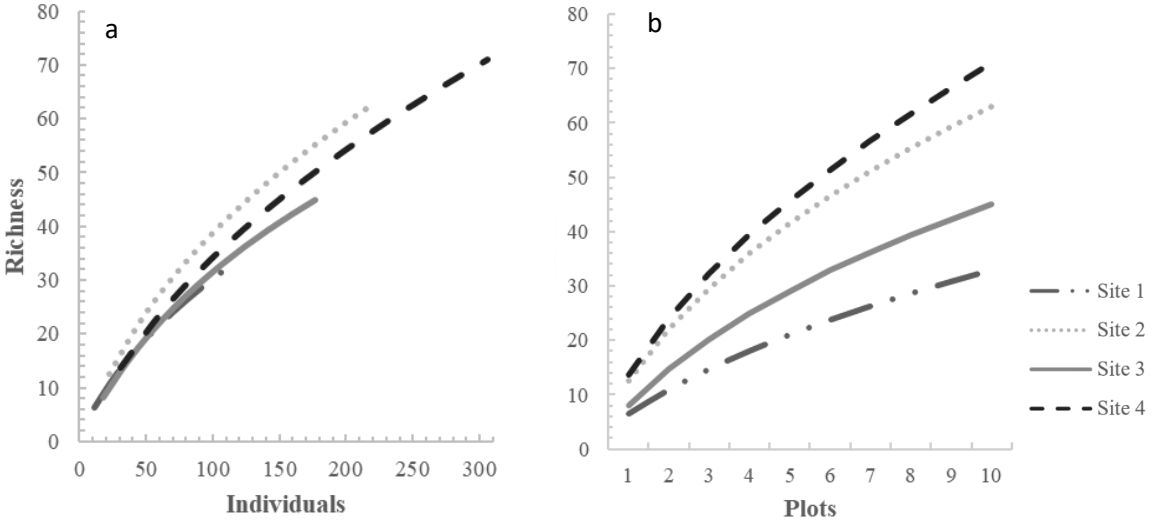


Figure 1. (a) Rarefaction curves among sites based on the number of individuals, and (b) accumulation curves of species richness based on plots.

We ran a hierarchical agglomerative clustering of the species with single linkage, with raw abundance data and our sites cluster on sites 1 and 3, and made another cluster for sites 2 and 4 (Figure 2).

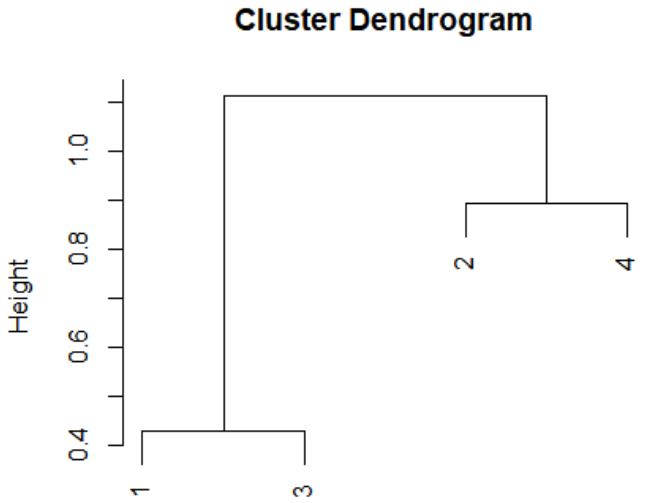


Figure 2. cluster single linkage dendrogram based on species abundance. Euclidian distance is indicated by height values.

We compared richness and air temperature per month for each of the sites and it was obtained that: site 1 lowest temperature was 15 °C with 5 species in October and highest of 20 °C with 19 species in September, site 2 with 14 °C lowest temperature and 20 species registered in June and highest of 16 °C with 32 species in September, site 3 with 16 °C of lowest temperature and 10 species in July and highest of 20 °C with 11 species in August, site 4 with 12 °C of lowest temperature and richness of 16 in August and highest temperature of 16 °C with 7 species registered in September (Fig. 3b)

We recorded for site 1 lowest air humidity was 53% with 19 species September and highest of 71% with 18 species August, site 2 lowest of 57% with 8 species in October and highest of 90% with 20 species in June, for site 3 lowest 59 % and richness of 11 in August and highest of 79% with 17 species in June, site 4 lowest of 60% and richness of 12 in July and the highest percentage of air humidity of 85% with 49 species registered in September (Fig 3c)

Soil temperatures for site 1 were 10 °C as lowest with richness of 5 in October and highest in June with 13.8 °C with 9 species registered, site 2 lowest of 10 °C with 8 species in October and highest of 13 °C with 20 species in June, site 3 lowest 11 °C in October with 11 species and highest in June with 14 °C in June with 17 species, site 4 lowest of 11 °C in October with 7 species and highest temperature in June with 13°C with 20 species registered (Fig 3d).

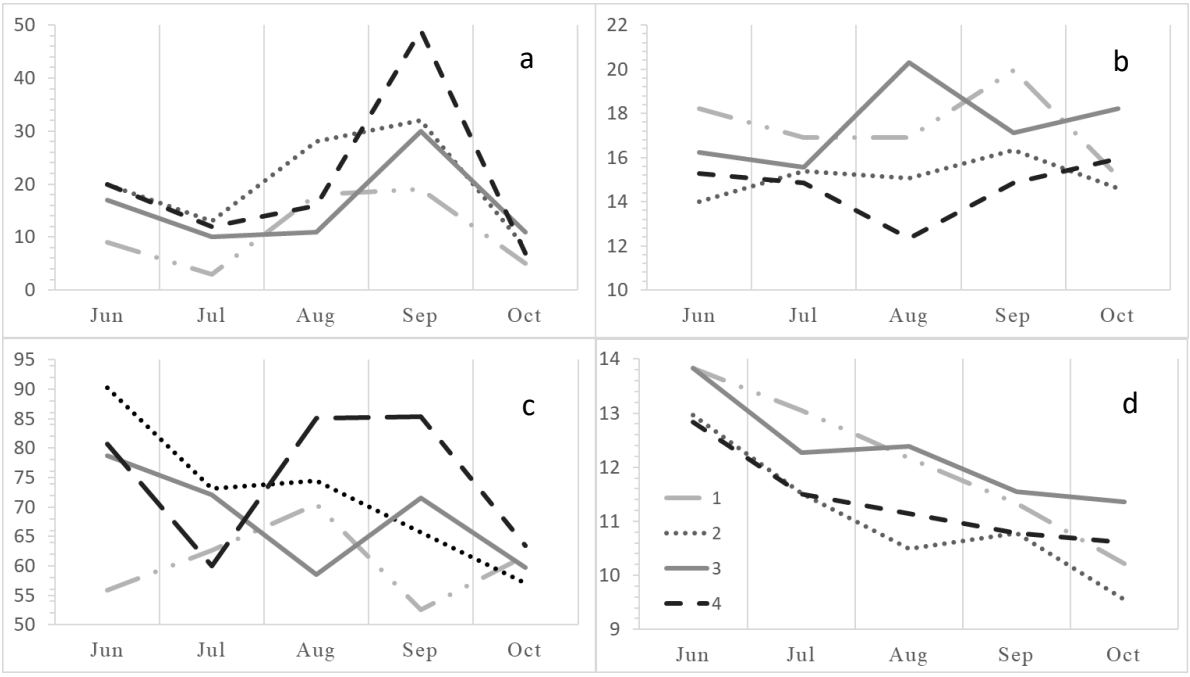


Figure 3 : a) Species richness b) Air temperature c) Air relative humidity, and d) Soil temperature through months of sampling by site.

Vegetation structure

Site 4 had the higher values in basal area, density and tree maximum height and site 1 had the lowest values in basal area, density, tree maximum height and tree average height (Table 2).

Table 2. Vegetation structure.

	Basal area $m^2 \cdot ha^{-1}$	Density individuals$\cdot ha^{-1}$	Tree average height (m)	Tree maximum height (m)
Site 1	235.6	3,500	10.4	18
Site 2	473.2	3,400	13.5	24
Site 3	402.2	4,800	15.5	27
Site 4	511.8	5,300	12.5	30

Environmental variables

The mean microclimatic values for the study area recorded during the sampling season are: air temperature 16.1°C (10.5° - 26.5°), air humidity 69.6% (36.7%- 99.9%), soil temperature 11.8°C (8.3° - 15.5°) and mean percentage of water content in soil 39.5% (8.6% – 78.5%).

Soil health characterization for site 1 showed 38.13% of soil water content, 84.94% of soil porosity, 28.26% of soil pore space filled with water and 0.4 of bulk density ; Site 2 showed 42.54% of soil water content, 85.64% of soil porosity, 30.83% of soil pore space filled with water and 0.38 of bulk density; Site 3 showed 39.53% of soil water content, 83.14% of soil porosity, 29.96% of soil pore space filled with water and 0.45 of bulk density; Site 4 showed 37.47% of soil water content percentage , 84.6% of soil porosity, 26.4% of soil pore space filled with water and 0.41 of bulk density.

Site 1 and 3 had the same pH with 6.7 and site 2 and 4 with 6.8, highest registered slope was for site 4, the same aspect was for all sites facing South East, for all sites: canopy coverage was between 72 – 86 %; Rockiness ground cover was between 1.3 – 6%; Moss ground cover was between 4 – 14%; Herbaceous ground cover 16 – 24% (Table 3).

Table 3. Environmental variables.

	pH	Slope	Aspect	Canopy	Rockiness	Moss cover	Herbaceous cover
Site 1	6.7	21.4°	122.5° SE	77%	5.5%	4%	16%
Site 2	6.8	31.9°	156° SE	72%	6%	14%	24%
Site 3	6.7	22°	120.5° SE	82%	1.3%	9%	19%
Site 4	6.8	32°	124.4° SE	86%	4.2%	5%	16%

Beta diversity

Chao-Jaccard index indicated a low turnover of species composition among study sites (Table 4). Sites 1 (non-exploited) and 3 (exploited) were the most similar (0.788), and sites 1 (non-exploited) and 4 (exploited) were the least similar in species composition (0.55). Sites 1 and 3 had also the highest similarity in edible species composition, and sites 1 and 2 had the least similarity (Table 4).

Table 4. Chao-Jaccard similarity index for all the recorded macromycete species and the edible species.

Sites	***All collected species***	***Edible species***
1-2	0.737	0.167
1-3	0.788	0.879
1-4	0.55	0.527
2-3	0.692	0.326
2-4	0.729	0.567
3-4	0.639	0.652

Statistical analyses

Geographic distance between sites and the values of Chao-Jaccard index were not significantly related (p-value = 0.6074).

The t test showed significant differences for the Shannon diversity index between all the pairs of sites except for sites 2-4. Sites 1-2 p-value <.0001, sites 1-3 p-value 0.0128, sites 1-4 p-value <0.0001, sites 2-3 p-value <0.0001, sites 2-4 P-value 0.3837, sites 3-4 p-value <0.0001 0. For edible species there were significant differences between all the pairs of sites except for the pairs of sites 1-3 and 2-4. Sites 1-2 p-value <0.0001, sites 1-3 p-value 0.3333, sites 1-4 p-value 0.0001, sites 2-3 p-value <0.0001, sites 2-4 p-value 0.1216, sites 3-4 p-value 0.0001.

Macromycete species richness and diversity distributed equally along the study area (Kolmogorov Smirnov, D =0.75, p-value = 0.2106), and were significantly related (Linear regression, R^2 = 0.9394, F = 31.02, p-value = 0.03076).

Spearman's correlation coefficient indicated that macromycete richness has a positive significant correlation with air relative humidity, cover of herbaceous plants, slope, tree maximum height and tree basal area, and has a negative significant correlation with air temperature and soil temperature (Table 5).

Table 5. Spearman correlation coefficients between macromycete species richness and microclimatic and environmental variables. * P \ 0.05, ** P \ 0.01, *** P \ 0.001.

Variable	***P***	***ρ***
*Air temperature****	0.00008558	-0.580678
*Air relative humidity****	0.00001108	0.6343051
*Soil temperature***	0.007909	-0.4140361
Soil water content percentage	0.5454	0.09850451
Soil porosity	0.9779	-0.004515966
Soil pore space filled with water	0.8541	0.0300124
Bulk density	0.9779	0.004516
pH	0.3888	0.1400227
Litterfall	0.6762	-0.06813
Rockiness	0.2947	0.1698493
Moss cover	0.1848	0.2140348
*Herbaceous**	0.03381	0.3363838
*Slope**	0.02238	0.3603094
Aspect	.5413	-0.09949
Canopy	0.6422	0.0757685
Tree average height	0.3274	0.1588883
*Tree maximum height**	0.01783	0.3728015
*Tree basal area**	0.03812	0.329101
Tree density	0.2858	0.1729788

The CCA for microclimatic explanatory variables was carried out for 138 macromycete species with air temperature, air humidity, soil temperature and percentage of water in the soil. The model retained only air temperature and soil temperature, but other variables contributed to explain the ordination. Axis 1 (eigenvalue = 0.4926) and axis 2 (eigenvalue = 0.3226) accounted for 37% and 24% of proportion explained of the species-microclimatic relationship (Figure 4).

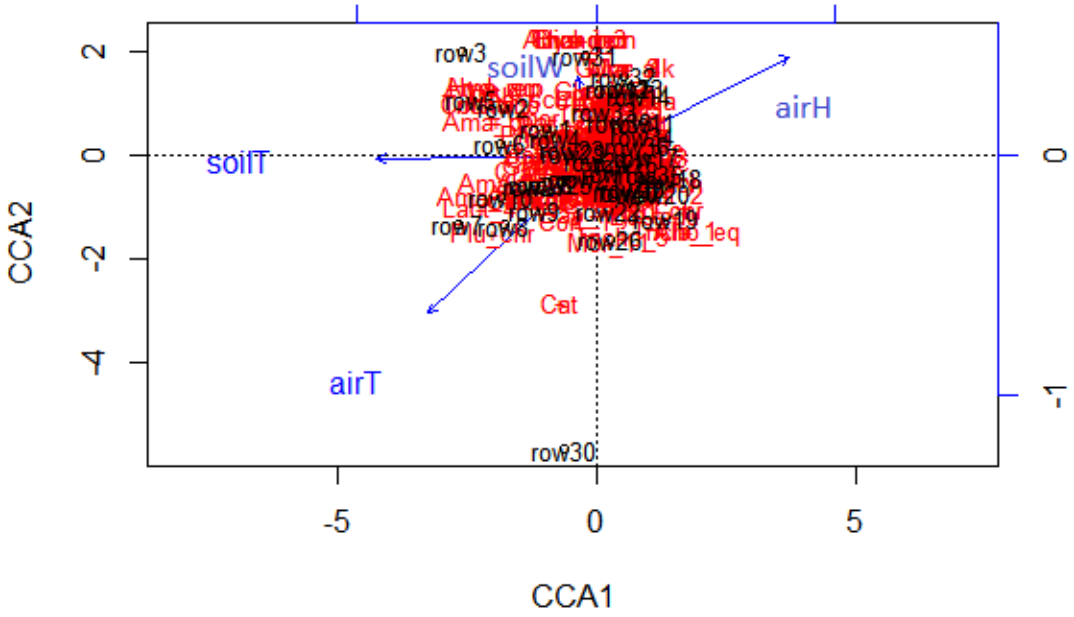


Figure 4. Canonical Correspondence Analysis of microclimatic variables.

The CCA for environmental explanatory variables was carried out for 138 macromycete species with litterfall, canopy, slope, aspect, rockiness, moss coverage, herbaceous coverage, bulk density, soil porosity and water filled pore space of soil. The model only retained moss coverage, but the other variables were included to better explain the ordination. Axis 1 (eigenvalue = 0.4213) and axis 2 (eigenvalue = 0.3545) accounted for 17% and 14% of proportion explained of the species-environmental relationship (Figure 5).

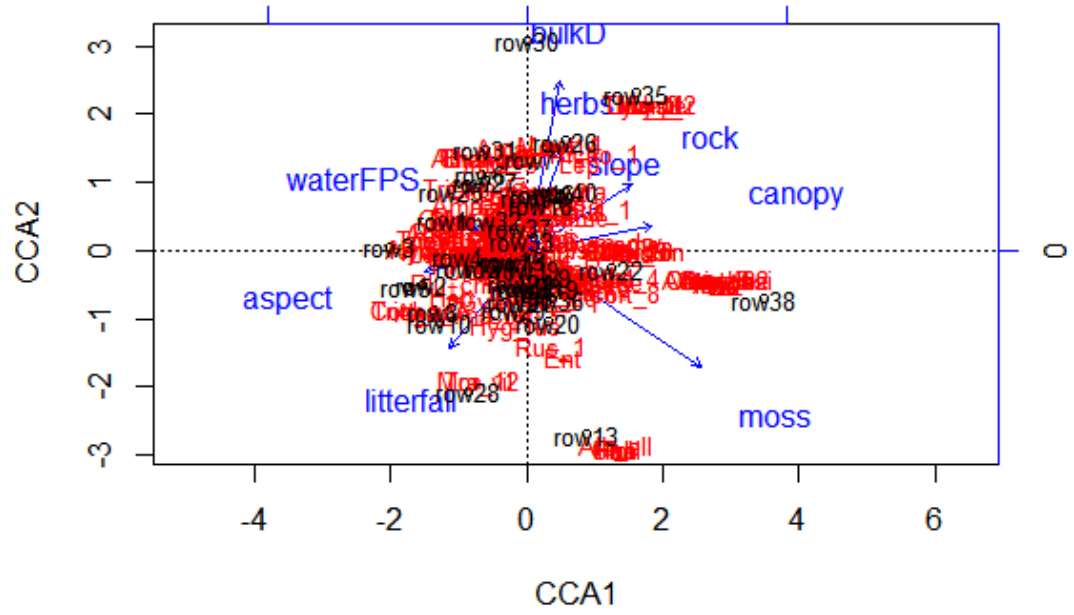


Figure 5. Canonical Correspondence Analysis for environmental variables.

The CCA for vegetation structure was carried out for 138 species with tree average height, tree maximum height, tree basal area and tree density. The model retained tree maximum height, but the other variables were included to explain the ordination. Axis 1 (eigenvalue = 0.4509) and axis 2 (eigenvalue = 0.3049) accounted for 38% and 25% respectively of proportion explained of the species-vegetation structure relationship (Figure 6).

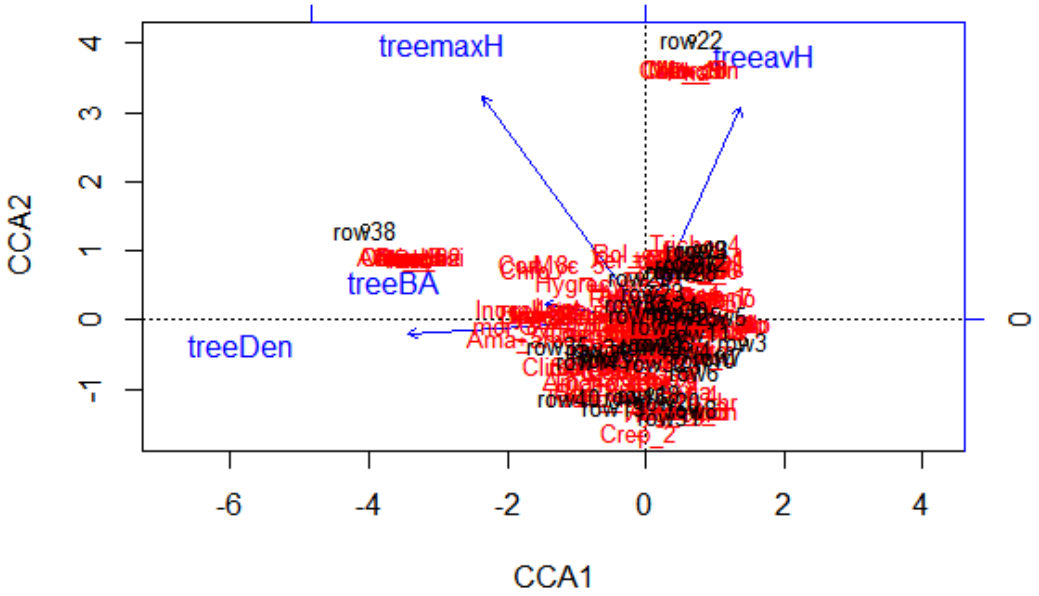


Figure 6. Canonical Correspondence Analysis for vegetation structure.

Discussion

We identified 43 macromycetes at species level, and 23 were recognized as edible by a literature review. the number of edible species in the study area is likely to be higher since 95 of the recorded species could not be identified at the species level, and the interviews to the local people showed that the population consumes at least 45 species from which 9 were present in our samplings. A study made in a temperate forest at La Malinche National Park, Tlaxcala, they found 93 macrofungal species, 91 of them reported as edible in the literature, and 74 used by locals in the study area (Montoya et al, 2004). In Ixtlán, Oaxaca they reported 159 macromycete taxa with anthropocentric use from which 113 were edible species (Garibay-orijel et al 2009). In Sierra del Ajusco, Mexico City, 29 wild edible species were found in 800 m^2 (Zamora-Martinez & Pascual-Pola, 1994). In Cerro El Zamora located between Guanajuato and Queretaro they identified 130 species from which 55 were recognized as edible by a literature review (Lande ros et al, 2006). In comparison to all the wild edible macromycete species recorded for Mexico we found 6.5 % at our study area (Garibay-Orijel & Ruan-Soto, 2014). In spite of the plots stablished in the exploited sites had a barricade tape and it was agreed with the inhabitants not to collect within the plots, we found traces of harvesting, and that could explain why our edible species richness was low.

Our results suggest that mushroom harvesting is sustainable and do not affect macromycete communities, which corresponds with the observed in several studies. In Europe, a study by Egli et al (2005), applied strong harvesting pressure like cutting and picking on edible species in specific sites for a period of 29 years, and compared them with no harvested sites, obtaining no adverse effects on abundance of fruit bodies or richness. They suggest this could have been caused by sporal dispersion from nearby areas or the sporal disperse from fruitbodies between harvesting intervals on the plots. In North America, Norvell (1995) did not find significant differences between harvesting per se nor between the different collecting techniques employed, on the productivity of wild edible mushrooms after a ten-year period, to whatever extant they did report and increase in yield of fruitbody production on the plots where the collecting technique was pulling fungi.. Collecting techniques like cutting and pulling could decrease sporal dispersal and damage or removal of mycelia, as sometimes they are dug up before full opening of the caps. Fruitbodies not transported in adequate vessels like baskets that allow spores outflow averts the establishment and development of new mycelia and prevents sexual reproduction, which is necessary for the genetic recombination of characters in individuals that promotes the evolution of the organism to deal with competition, environmental disturbances, and DNA damage repair

(Moore et al., 2008). Though, community collecting techniques and practices, which are discussed in chapter 1, could be one of the main causes for not having differences on diversity and distribution of macromycetes between exploited and non-exploited sites. Inhabitants carefully pull mushrooms from the soil instead of cutting, which is not detrimental and even beneficial to fruitbody production (Norvell 2005; Luoma et al 2006). Beta diversity showed species composition similarity between all sites on over 50%, which as suggested by Egli et al (2005) could be explained by sporal dispersal among sites, and because of the proximity between sites as variable of geographic distance and chao-jaccard index did not show a significant relation. Microclimatic and environmental variables between sites didn't have much variation, and as shown in other studies, fungal species composition is more related to environmental and microclimatic variables and might explained why our species turnover was low (Allen et al., 1995; Toljander et al., 2006).

In a study it was suggested that fungal richness and abundance was affected by how long unfavorable conditions lasted and that microclimate taken at field was a better predictor for fungal richness and abundance than nearby meteorological stations, they found that variables as air temperature and relative humidity were the best predictors for fungal richness, air temperature was negatively related to richness and relative humidity was highly positively related to richness (Talley et al., 2002), at our sites we found similar patterns, richness and air temperature had a highly significant negative correlation, air humidity and richness had a high positive correlation, as temperature was lower we had less species richness and as relative humidity incremented also did species richness, which was also shown when we compared these variables by months. Fruit bodies undergo desiccation caused by loss of turgor due to faster water loss owed to higher average temperatures causing fruiting bodies to remain less at field making it harder to observe and collect, and as temperatures decrease along does the metabolic rates as it is affected by it, making it more difficult for fungi enzymes to decompose compounds and consequently hindering the acquisition of nutrients and therefore inhibiting fructification (Kauserud et al, 2010; Lukac & Godbold, 2011).

Fruiting of macrofungal species is influenced by soil temperatures, at our study sites when soil temperatures were lower macromycete richness decreased, which is conclusive with a study of phenology of edible ectomycorrhizal species that showed high average temperatures and extreme variations delayed fructification of some species and duration of fruitbodies like *Boletus edulis* (found at our plots), but it also existed variation between species, as fructifications of *Hydnum repandum* (also found at our plots) was positively correlated with high average soil temperatures, thus fructification responds to variation in soil temperatures range and it depends on the autecology of the species (Pinna et al 2010). There is no accurate soil range temperature determinant for the fructification of all macromycete species, and could explain why our inventories were at most 62.2 % of completeness, because they only represented the soil temperatures ranges of the richness found, as we only sampled a season, and temperatures could’ve have been affecting the availability of fructifications and thus the richness on the days and standardized times we sampled.

Herbaceous coverage was positively correlated with species richness, corresponding with the study by Toledo et al. (2014) suggesting a tendency to increase the number of macromycete species with herbaceous. This correlation may be due to the herbaceous layer provides up to 16% of annual litter fall and influences the cycling rates of N, P, K and Mg, which are important for fungal growth (Gilliam, F.S., 2007). Canopy coverage was not significantly correlated with species richness along our study area, contrary to the findings indicating that a greater canopy cover provides more shade which is reflected in a higher humidity as well as more organic matter (Gabel & Gabel, 2007; Gómez-Hernández et al, 2012; Toledo et al, 2014). This might be explained because of

the similarity in canopy percentages among sites, as other variables related to canopy like litterfall and tree density didn't show a correlation to richness, but herbaceous did.

Tree basal area and tree maximum height had a positive correlation with species richness, we also found more fruitbodies with wider and taller trees as site 4 with the highest diversity index had the highest tree basal area values and also the highest tree maximum height values . Egli et al (2010) compared fruitbody production before and after thinning trees, and concluded that abundance of ectomycorrhizal species is positive correlated with the width of the tree ring, demonstrating the aid this symbiosis provides for tree growth and how it relates to fungal richness. Ph and fungal richness was not related, as shown in another study where they found not correlation but noted a trend to be negatively correlated (Talley et al., 2002).

Spatial distribution of species according to variables microclimatic, environmental, and vegetation structure around our sites in CCA, did not showed different relationships to the studied variables, meaning they did not represent which type of variable displayed similarity in species composition as species are associated or affected by the different types of variables in the same way.

Conclusions

knowledge about harvesting practices and its implications it is at a constant debate, as it is an increasingly activity in Europe and North America and is at open discussion that it might not be sustainable by itself and what is the correct way to be performed, either by pulling or cutting the mushrooms, however it is suggested that harvesting should be made in a careful manner where the environment is not impacted (Money, 2005; Bunyard, 2012). We propose that local practices are reflecting a good way to perform mushroom harvesting although they are for personal and commercial use, as we didn't find disturbs in the ecosystem due to exploitation of wild edible fungi, as there were no differences in diversity between exploited and no exploited sites as hypothesized, beta diversity analysis didn't show high turnover of species between exploited and non-exploited sites and CCA didn't show separation of sites along the ordination axes by the studied variables. Mushroom collectors mentioned that they carefully extract mushrooms from the soil with a stick and afterwards cover the hole, and they do not remove leaf litter when searching. And for the case of wood rotting mushrooms, they pick them up and do not use a knife, so it doesn't cause a damage. Only doing this once the caps are fully open or they have "flowered" (matured) and have good appearance (not rotten ones or parasitized by insects) and collect at 3-day intervals on rainy season. This suggests that they have a comprehension of how to sustain or take care of the environment and how to protect the mycelium and not to cause damage to the substratum, as they mentioned this helps the growth of more fruitbodies so in the next days they can visit the same spot to harvest more, which is reflected on microclimatic and environmental variables as they didn't had an effect over species distribution among sites, indicating there's no impact on the environment caused by the visit of harvesters. Nature conservation policies have ignored mushrooms because it's a recent field of science, as it fungi wasn't acknowledge as a kingdom and taxonomy, ecology, distribution and conservation status of wild organisms aren't fully known (Cooney, 2013), even thou research shows that there is no significant impact over richness and abundance caused by collecting, laws have been applied in the United States and European countries as it regulates collection seasons, quantities and whether it should be for personal or commercial use. For Mexico there's no existence of such policies or regulations, but traditional knowledge and harvesting practices seems to be a sustainable activity and support research in that there's no substantial impact over diversity and distribution of macrospecies caused by wild edible fungi harvesting.

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Supplementary material

1. Table species

Species	Family	Order	Phylum	Ecology
Hypoxylon sp. Bull.	Hypoxylaceae	Xylariales	Ascomycota	
Leotia lubrica Fr.	Leotiaceae	Helotiales	Ascomycota	Saprobic
Otidea alutacea (Pers.) Massee	Pyronemataceae	Pezizales	Ascomycota	Saprobic
Tolypocladium sp. W. Gams	Ophiocordycipitaceae	Hypocreales	Ascomycota	
Agaricales		Agaricales	Basidiomycota	
Agrocybe sp. Fayod	Strophariaceae	Agaricales	Basidiomycota	
Albatrellus ellisii (Berk.) Pouzar	Albatrellaceae	Russulales	Basidiomycota	Mycorrhizal
Albatrellus sp. Gray	Albatrellaceae	Russulales	Basidiomycota	
Amanita aff. *Phalloides* (Vaill. ex Fr.) Link	Amanitaceae	Agaricales	Basidiomycota	Mycorrhizal
Amanita basii Guzmán & Ram.-Guill.	Amanitaceae	Agaricales	Basidiomycota	Mycorrhizal
Amanita flavoconia G.F. Atk.	Amanitaceae	Agaricales	Basidiomycota	Mycorrhizal
Amanita fulva Fr.	Amanitaceae	Agaricales	Basidiomycota	Mycorrhizal
Amanita G. *arocheae*	Amanitaceae	Agaricales	Basidiomycota	Mycorrhizal
Amanita G. *pachycola*	Amanitaceae	Agaricales	Basidiomycota	Mycorrhizal
Amanita gemmata (Fr.) Bertill.	Amanitaceae	Agaricales	Basidiomycota	Mycorrhizal
Amanita rubescens Pers.	Amanitaceae	Agaricales	Basidiomycota	Mycorrhizal
Amanita sp. 2 R. Heim ex Pouzar	Amanitaceae	Agaricales	Basidiomycota	
Amanita sp. R. Heim ex Pouzar	Amanitaceae	Agaricales	Basidiomycota	
Aureoboletus projectellus (Murrill) Halling	Boletaceae	Boletales	Basidiomycota	Mycorrhizal
Auriscalpium vulgare Gray	Auriscalpiaceae	Russulales	Basidiomycota	Saprobic
Austroboletus gracilis (Peck) Wolfe	Boletaceae	Boletales	Basidiomycota	Mycorrhizal
Baeospora myosura (Fr.) Singer	Marasmiaceae	Agaricales	Basidiomycota	Saprobic
Boletus G. *edulis*	Boletaceae	Boletales	Basidiomycota	Mycorrhizal
Byssomerulius incarnatus (Schwein.) Gilb.	Phanerochaetaceae	Polyporales	Basidiomycota	Saprobic
Cantharellus cibarius Fr.	Cantharellaceae	Cantharellales	Basidiomycota	Mycorrhizal
Cantharellus G. *cibarius* sp. 1	Cantharellaceae	Cantharellales	Basidiomycota	Mycorrhizal
Cantharellus G. *cibarius* sp. 2	Cantharellaceae	Cantharellales	Basidiomycota	Mycorrhizal
Catathelasma sp. Lovejoy	Tricholomataceae	Agaricales	Basidiomycota	

Chalciporus sp. Bataille	Boletaceae	Boletales	Basidiomycota	
Chroogomphus sp. (Singer) O.K. Mill.	Gomphidiaceae	Boletales	Basidiomycota	
Climacocystis borealis (Fr.) Kotl. & Pouzar	Fomitopsidaceae	Polyporales	Basidiomycota	Saprobic – Parasite
Clitocybe gibba (Pers.) P. Kumm	Tricholomataceae	Agaricales	Basidiomycota	Saprobic
Clitocybula (Singer) Singer ex Métrod sp.	Marasmiaceae	Agaricales	Basidiomycota	
Coltricia cinnamomea (Jacq.) Murrill	Hymenochaetaceae	Hymenochaetales	Basidiomycota	Mycorrhizal
Cortinarius anomalus (Fr.) Fr.	Cortinariaceae	Agaricales	Basidiomycota	Mycorrhizal
Cortinarius sp. 1 (Pers.) Gray	Cortinariaceae	Agaricales	Basidiomycota	
Cortinarius sp. 2 (Pers.) Gray	Cortinariaceae	Agaricales	Basidiomycota	
Cortinarius sp. 3 (Pers.) Gray	Cortinariaceae	Agaricales	Basidiomycota	
Cortinarius sp. 4 (Pers.) Gray	Cortinariaceae	Agaricales	Basidiomycota	
Cortinarius sp. 5 (Pers.) Gray	Cortinariaceae	Agaricales	Basidiomycota	
Cortinarius sp. 6 (Pers.) Gray	Cortinariaceae	Agaricales	Basidiomycota	
Cortinarius sp. 7 (Pers.) Gray	Cortinariaceae	Agaricales	Basidiomycota	
Cortinarius sp. 8 (Pers.) Gray	Cortinariaceae	Agaricales	Basidiomycota	
Cortinarius sp. 9 (Pers.) Gray	Cortinariaceae	Agaricales	Basidiomycota	
Craterellus cornucopioides (L.) Pers.	Cortinariaceae	Agaricales	Basidiomycota	Mycorrhizal
Craterellus tubaeformis (Fr.) Quél.	Cantharellaceae	Cantharellales	Basidiomycota	Mycorrhizal
Crepidotus sp. (Fr.) Staude	Inocybaceae	Agaricales	Basidiomycota	
Crepidotus sp. (Fr.) Staude	Inocybaceae	Agaricales	Basidiomycota	
Cystolepiota sp. Singer	Agaricaceae	Agaricales	Basidiomycota	
Dacrymyces capitatus Schwein.	Dacrymycetaceae	Dacrymycetales	Basidiomycota	Saprobic
Entoloma sp. Fr. ex P. Kumm.	Entolomataceae	Agaricales	Basidiomycota	
Galerina sp. Earle	Hymenogastraceae	Agaricales	Basidiomycota	
Gymnopilus sapineus (Fr.) Murrill	Hymenogastraceae	Agaricales	Basidiomycota	Saprobic

Gymnopus alkalivirens (Singer) Halling	Omphalotaceae	Agaricales	Basidiomycota	Saprobic
Gymnopus dryophilus (Bull.) Murrill	Omphalotaceae	Agaricales	Basidiomycota	Saprobic
Gymnopus sp. 1 (Pers.) Gray	Omphalotaceae	Agaricales	Basidiomycota	
Hebeloma sp. (Fr.) P. Kumm.	Hymenogastraceae	Agaricales	Basidiomycota	
Hohenbuehelia sp. Schulzer	Pleurotaceae	Agaricales	Basidiomycota	
Hydnellum sp. P. Karst.	Hymenogastraceae	Agaricales	Basidiomycota	
Hydnum repandum L.	Pleurotaceae	Agaricales	Basidiomycota	Mycorrhizal
Hygrocybe sp. (Fr.) P. Kumm.	Hygrophoraceae	Agaricales	Basidiomycota	
Hygrophoropsis aurantiaca (Wulfen) Maire	Hygrophoropsidaceae	Boletales	Basidiomycota	Saprobic
Hygrophorus chrysodon (Batsch) Fr.	Hygrophoraceae	Agaricales	Basidiomycota	Mycorrhizal
Hygrophorus russula (Schaeff. ex Fr.) Kauffman	Hygrophoraceae	Agaricales	Basidiomycota	Mycorrhizal
Inocybe geophylla (Bull.) P. Kumm.	Inocybaceae	Agaricales	Basidiomycota	Mycorrhizal
Inocybe sp. 1 (Fr.) Fr.	Inocybaceae	Agaricales	Basidiomycota	
Inocybe sp. 2 (Fr.) Fr.	Inocybaceae	Agaricales	Basidiomycota	
Inocybe sp. 3 (Fr.) Fr.	Inocybaceae	Agaricales	Basidiomycota	
Inocybe sp. 4 (Fr.) Fr.	Inocybaceae	Agaricales	Basidiomycota	
Inocybe sp. 5 (Fr.) Fr.	Inocybaceae	Agaricales	Basidiomycota	
Inonotus sp. P. Karst.	Hymenochaetaceae	Hymenochaetales	Basidiomycota	
Laccaria amethystina Cooke	Hydnangiaceae	Agaricales	Basidiomycota	Mycorrhizal
Laccaria bicolor (Maire) P.D. Orton	Hydnangiaceae	Agaricales	Basidiomycota	Mycorrhizal
Laccaria laccata (Scop.) Cooke	Hydnangiaceae	Agaricales	Basidiomycota	Mycorrhizal
Lactarius sp. 1 Pers.	Russulaceae	Russulales	Basidiomycota	
Lactarius sp. 2 Pers.	Russulaceae	Russulales	Basidiomycota	
Lactarius sp. 3 Pers.	Russulaceae	Russulales	Basidiomycota	
Lactarius sp. 4 Pers.	Russulaceae	Russulales	Basidiomycota	
Lentinus sp. Fr.	Polyporaceae	Polyporales	Basidiomycota	
Lycoperdon perlatum Pers.	Agaricaceae	Agaricales	Basidiomycota	Saprobic
Lepiota sp. (Pers.) Gray	Agaricaceae	Agaricales	Basidiomycota	
Leucoagaricus sp. Locq. ex Singer	Agaricaceae	Agaricales	Basidiomycota	
Marasmius sp. 2 Fr.	Marasmiaceae	Agaricales	Basidiomycota	
Marasmius sp. Fr.	Marasmiaceae	Agaricales	Basidiomycota	
Morfoespecie 10			Basidiomycota	

Morfoespecie 11			Basidiomycota	
Morfoespecie 12			Basidiomycota	
Morfoespecie 13			Basidiomycota	
Morfoespecie 14			Basidiomycota	
morfoespecie 3			Basidiomycota	
morfoespecie 4			Basidiomycota	
morfoespecie 5			Basidiomycota	
morfoespecie 6			Basidiomycota	
morfoespecie 7			Basidiomycota	
morfoespecie 8			Basidiomycota	
Morfoespecie 9			Basidiomycota	
Mycena G. *epipterygia*	Mycenaceae	Agaricales	Basidiomycota	Saprobic
Mycena G. *pura*	Mycenaceae	Agaricales	Basidiomycota	Saprobic
Mycena sp. 1	Mycenaceae	Agaricales	Basidiomycota	
Mycena sp. 2	Mycenaceae	Agaricales	Basidiomycota	
Mycena sp. 3	Mycenaceae	Agaricales	Basidiomycota	
Mycena sp. 4	Mycenaceae	Agaricales	Basidiomycota	
Mycena sp. 5	Mycenaceae	Agaricales	Basidiomycota	
Mycetinis sp. Earle	Omphalotaceae	Agaricales	Basidiomycota	
Osmoporus mexicanus (Mont.) Ryvarden	Gloeophyllaceae	Gloeophyllales	Basidiomycota	Saprobic
Phaeolus schweinitzii (Fr.) Pat.	Fomitopsidaceae	Polyporales	Basidiomycota	Saprobic - Parasite
Phaeolus sp. (Pat.) Pat.	Fomitopsidaceae	Polyporales	Basidiomycota	
Phellodon niger (Fr.) P. Karst.	Bankeraceae	Thelephorales	Basidiomycota	Mycorrhizal
Phellodon sp. 1 P. Karst.	Bankeraceae	Thelephorales	Basidiomycota	
Phellodon sp. 2 P. Karst.	Bankeraceae	Thelephorales	Basidiomycota	
Pholiota sp. (Fr.) P. Kumm.	Strophariaceae	Agaricales	Basidiomycota	
Pluteus chrysophlebius (Berk. & M.A. Curtis) Sacc.	Pluteaceae	Agaricales	Basidiomycota	Saprobic
polyporales Gäum.		Polyporales	Basidiomycota	
Ramaria sp. 1 Fr. ex Bonord.	Gomphaceae	Gomphales	Basidiomycota	
Ramaria sp. 2 Fr. ex Bonord.	Gomphaceae	Gomphales	Basidiomycota	
Ramaria stricta (Pers.) Quél.	Gomphaceae	Gomphales	Basidiomycota	Saprobic
Rhodocollybia butyracea (Bull.) Lennox	Omphalotaceae	Agaricales	Basidiomycota	Saprobic
Russula brevipes Peck	Russulaceae	Russulales	Basidiomycota	Mycorrhizal
Russula G. *emetica* Peck	Russulaceae	Russulales	Basidiomycota	Mycorrhizal
Russula sp. 1 Pers.	Russulaceae	Russulales	Basidiomycota	
Russula sp. 2 Pers.	Russulaceae	Russulales	Basidiomycota	
Russula sp. 3 Pers.	Russulaceae	Russulales	Basidiomycota	

Stereum aff. o*strea* (Blume & T. Nees) Fr.	Stereaceae	Russulales	Basidiomycota	Saprobic
Stereum sp. Hill ex Pers.	Stereaceae	Russulales	Basidiomycota	
Suillus sp. 1 Gray	Suillaceae	Boletales	Basidiomycota	
Suillus sp. 2 Gray	Suillaceae	Boletales	Basidiomycota	
Trametes aff. *Villosa* (Sw.) Kreisel	Polyporaceae	Polyporales	Basidiomycota	Saprobic
Trichaptum abietinum (Pers.) Ryvarden	Polyporaceae	Hymenochaetales	Basidiomycota	Saprobic
Tricholoma equestre (L.) P. Kumm	Tricholomataceae	Agaricales	Basidiomycota	Mycorrhizal
Tricholoma sp. 1 (Fr.) Staude	Tricholomataceae	Agaricales	Basidiomycota	
Tricholoma sp. 2 (Fr.) Staude	Tricholomataceae	Agaricales	Basidiomycota	
Tricholoma sp. 3 (Fr.) Staude	Tricholomataceae	Agaricales	Basidiomycota	
Tricholoma sp. 4 (Fr.) Staude	Tricholomataceae	Agaricales	Basidiomycota	
Tricholoma sp. 5 (Fr.) Staude	Tricholomataceae	Agaricales	Basidiomycota	
Tricholoma sp. 6 (Fr.) Staude	Tricholomataceae	Agaricales	Basidiomycota	
Tricholoma sp. 7 (Fr.) Staude	Tricholomataceae	Agaricales	Basidiomycota	
Xeromphalina campanella (Batsch) Kühner & Maire	Mycenaceae	Agaricales	Basidiomycota	Saprobic
Xerula sp. Maire	Physalacriaceae	Agaricales	Basidiomycota	

2. Table edible species

Species	**Family**	**Order**	**Phylum**	**Ecology**
Albatrellus ellisii (Berk.) Pouzar	Albatrellaceae	Russulales	Basidiomycota	Mycorrhizal
Amanita basii Guzmán & Ram. -Guill.	Amanitaceae	Agaricales	Basidiomycota	Mycorrhizal
*Amanita rubescen*s Pers.	Amanitaceae	Agaricales	Basidiomycota	Mycorrhizal
Austroboletus gracilis (Peck) Wolfe	Boletaceae	Boletales	Basidiomycota	Mycorrhizal
Aureoboletus projectellus (Murrill) Halling	Boletaceae	Boletales	Basidiomycota	Mycorrhizal
Cantharellus cibarius P.	Cantharellaceae	Cantharellales	Basidiomycota	Mycorrhizal

Craterellus cornucopioides (L.) Pers.	Cortinariaceae	Agaricales	Basidiomycota	Mycorrhizal
Craterellus tubaeformis (Fr.) Quél.	Cantharellaceae	Cantharellales	Basidiomycota	Mycorrhizal
Hydnum repandum L.	Pleurotaceae	Agaricales	Basidiomycota	Mycorrhizal
Hygrophorus chrysodon (Batsch).	Hygrophoraceae	Agaricales	Basidiomycota	Mycorrhizal
Hygrophorus russula (Schaeff. Ex Fr.) Kauffman	Hygrophoraceae	Agaricales	Basidiomycota	Mycorrhizal
Laccaria amethystina Cooke	Hydnangiaceae	Agaricales	Basidiomycota	Mycorrhizal
Laccaria laccata (Scop.) Cooke	Hydnangiaceae	Agaricales	Basidiomycota	Mycorrhizal
Phellodon niger (Fr.) P. Karst.	Bankeraceae	Thelephorales	Basidiomycota	Mycorrhizal
Russula brevipes Peck	Russulaceae	Russulales	Basidiomycota	Mycorrhizal
Laccaria bicolor (Maire) PD Orton	Hydnangiaceae	Agaricales	Basidiomycota	Mycorrhizal
Byssomerulius incarnatus (Schwein.) Gilb.	Phanerochaetaceae	Polyporales	Basidiomycota	Saprobic
Clitocybe gibba (Pers.) P. Kumm.	Tricholomataceae	Agaricales	Basidiomycota	Saprobic
Gymnopus dryophilus s.I (Bull.) Murrill	Omphalotaceae	Agaricales	Basidiomycota	Saprobic
Hygrophoropsis aurantiaca (Wulfen) Maire	Hygrophoropsidaceae	Boletales	Basidiomycota	Saprobic
Lycoperdon perlatum Pers.	Agaricaceae	Agaricales	Basidiomycota	Saprobic
Rhodocollybia butyracea (Bull.) Lennox	Omphalotaceae	Agaricales	Basidiomycota	Saprobic
Ramaria stricta (Pers.) Quél.	Gomphaceae	Gomphales	Basidiomycota	Saprobic