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Original Research Article

Abundance and Diversity of Pleurotus Species and Host Trees for Sustainable Management in Ngel-Nyaki Montane Forest Ecosystem

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Abstract: Abundance and diversity of Pleurotus species (Oyester mushroom) and host trees for sustainable management in Ngel-Nyaki montane forest was conducted with the view to examine how abundant and diverse are Pleurotus species and their host trees in Ngel-Nyaki montane forest. A preliminary survey across the montane forest was carried out using opportunistic sampling protocol. Shannon-Weiner Diversity Index (SWDI) was used to determined Pleurotus and host trees diversity. The species richness of the Pleurotus species and host trees spotted was determined as well as species evenness. SWDI for Pleurotus species was 1.15 and that of host trees was 0.74; species richness was 0.026 and 0.0125; while species evenness was 0.248 and 0.189 respectively. The Pleurotus species observed at Ngel-Nyaki montane forest were *Pleurotus pulmonarius*, *P. ostreatus*, *P. djamor* and *P. eryngii* and *Polyschias fulva*, *Anthonata noldeae*, and *Ficus lutea* as host respectively. Mushroom in general including Pleurotus species serves as a source of food and income for many locals as well as urban dwellers. Pleurotus host trees play important role in the survival of Pleurotus and also function as source of fuelwood, medicine, timber, global warming fight. Government, conservation societies as well as stakeholders should sponsor training workshops for the locals on how to raise mushroom farms in order to reduce their over dependence on the wild for services of Pleurotus and host trees.

Keywords: Abundance, Diversity, Pleurotus species, Host trees, Sustainable management, Montane forest.

INTRODUCTION

Scientific data on biodiversity such as Pleurotus species and host trees are indispensable for nature conservation and sustainable management of natural resources. Targets 1–3 of the Global Strategy for Plant Conservation [1] provide an example of this and are just as relevant for fungi as for plants. There is a serious and urgent need for these data to secure the survival of species and natural habitats providing ecosystem services, in the face of pressure from an increasing human population and anthropogenic activities causing land-use changes, pollution, and climate change as reported by [2]. Tropical forests are considered as the biodiversity rich communities on planet earth give the reason that they harbor a very good amount of global life forms [3, 4]. Forests offer numerous resources such as food, medicines, energy, aesthetic and timber [5] and they provide ecosystem services such as nutrient cycling, soil formation, erosion prevention or reduction, water supply, soil formation, habitats for plants and animals, species conservation and climate regulation [6, 7]. The overexploitation of forest resources is one of the major environmental and economic destructions that have resulted in the fast loss of forests as well as their resources [8]. Worldwide, tropical forests are declining at an alarming rate, whereby about 1 - 4% of their area is being reduced annually due to human anthropogenic activities [9]. The disappearance of forest areas is well connected to increased anthropogenic pressures that have led to the expansion of agricultural activities, firewood/charcoal demand increase, overgrazing and illegal timber logging due to increased human population living close as well as further away from the forests [10]. The loss of forest lands as well as their resources does not only endangers livelihood of people who depend on the forests for socio-cultural, ecological and economic services, but also affects the forest composition, structure and regeneration of trees as well as their existence [11, 12]. This leads to grave loss of biodiversity on the planet as reported by [13].

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It is of urgent need to design appropriate management as well as conservation schemes for forest ecosystem which is considered as the major habitat for macrofungi and other living organisms in order to preserve the remaining tropical rain forest which has been deforested through anthropogenic activities in the tropics because of the high increasing demand for land for agricultural activities as well as illegal logging practices. Sustainable forest management strategies can't take place without considering the economic and social interests of the forest dwellers, those close to it not leaving out those who benefits from it directly or indirectly as well as understanding the processes regulating the functioning of tropical rain forests [14]. For any meaningful and right use of resources, the living environment of every living organism must be taken into proper and crucial considerations. The continuous devastation of anthropogenic activities on forest and the environment as a whole because of the increasing population is contributing a lot to the loss in global biodiversity. These are situations which in many cases can't be reversed; this leads to a high possibility of loss of macrofungi (most especially Pleurotus) diversity and subsequent loss of knowledge of their existence and uses since they will no longer be there for humans to carryout studies on them [14]. Studies have shown that of the 1.5 million species of fungi estimated in the world only about 6.7% (that is, 100,500 fungi species) have been described with the majority of these being in the temperate regions. Mycodiversity in the tropical region which is undoubtedly fungi core host is considered inadequately sampled and the mycoflora poorly documented [15]. Looking at what has been done so far on fungi, it darkens the situation of macrofungi in the tropical forests [16]. However, more researches and findings are still in progress with new species still being discovered in the tropics [17] as reported by [14]. A study on the ecology of edible mushrooms of the Nigerian savannah was carried out by [18]. The major purpose of this study was for the optimal exploitation of mushrooms, the identification of the various microhabitats in which edible mushrooms grow, their fruiting pattern time, and to relate the findings to their optimal exploitation in a Nigerian savannah.

Increasing population and high level of poverty have led to more dependence on forest resources (timber, non-timber forest products) and the increased global discourse on issues of agricultural expansion, deforestation, forest degradation, biodiversity loss, and climate change. Tree species diversity plays a central or decisive function in ecosystem operations, delivering palpable and impalpable advantages. The periodical evaluation of forest trees is absolutely necessary for the management and conservation goals [19]. [20] in their report said adequate knowledge of mushroom diversity and distribution are imperative for successful conservation, management and optimum exploitation of the ecosystem for innumerable benefits to mankind [21]. Mushrooms (especially Pleurotus species) are important bio-resource with diverse nutritional, medicinal and ecological benefits according to [22] hence the need to embark on their study for better and sustainable conservation. In the natural environment, mushrooms grow on variety of substrates, especially those containing lignin and cellulose, often abundant during the rainy most especially the early and late rainy season [23; 24 and 25]. Their fleshy, spore-bearing fruiting bodies grow on soil or wood substrates whereas some exist in mycorrhizal relationship with trees [26]. Soil debris and dead woods are the most favorable environments for mushroom probably due to high content of degraded nutrients and capacity to retain moisture [27; 28; 21]. Mushrooms have been reportedly found growing on substrates like dead woods and base of dead woods, fallen trees, soil debris, palm trees and wastes, termite nests and cassava peels in forest and bush areas, grassy places, swamps, cocoa plantations, Fadama areas and burnt bushes [24, 21] as reported by [20] working on Ecology, diversity and seasonal distribution of wild mushrooms in a Nigerian tropical forest reserve. An estimate of mushrooms in the African continent is less than 1% of the total global estimate [29; 30; 31; 32 and 21]. In most countries of the region Africa especially Cameroon and Nigeria, there is paucity of information on the existing wild mushrooms most especially Pleurotus species and their host trees which are very important bioresources and deserve better attention through proper management.

In Nigeria and other African countries, mushroom production (Pleurotus species in particular) in natural forests is under threat as most of the indigenous species of mushrooms (Pleurotus species inclusive) are endangered. This is a serious problem because mushrooms (including Pleurotus species) occur naturally in narrow ecological niches within the tropical forests and savannahs of Nigeria as well as other African nations. Thus, most habitats of mushrooms are continuously being destroyed for agricultural purposes and other anthropogenic activities as well as increased in human population. The introduction of exotic cash crops (cocoa, rubber, cotton, and oil palm) into the traditional farming in the 1950s led to the massive destruction of natural forests which are the potential habitats of mushrooms including other non-timber forest products as reported by [33].

MATERIALS AND METHODS

Study area

Ngel-Nyaki Forest Reserve is located 7^0 05'N $11^0$04'E and 7.83^0N11.067̀E on the Mambila Plateau in Taraba State, Nigeria, at an elevation of approximately 1550 m.a.s.I. The mean annual rainfall is 1800 mm and occurs mainly between mid-April and mid-October (Nigerian Montane Forest Project Rainfall data). Mean monthly maximum and minimum temperatures for the wet and dry season are 26°C and 13°C, and 23°C and 16°C respectively (Chapman and Chapman, 2001). The reserve contains 7.5 km^2 of contiguous forest (the main forest) which is the largest on the Plateau [34]. The vegetation of the reserve contains a stand of rare dry type montane to sub-montane forest and is the only forest of its type left on the heavily populated Mambila plateau. The forest is an isolated fragment of approximately 7.5 km^2 [35]. The forest is diverse in species composition, amongst the most floristically diverse montane–submontane forest stands in Nigeria, [36] and has many tall emergents like Pouteria altissima, locally exclusive to this forest). Four tree species are Red Data listed (*Entandrophragma angolense, Lovoa trichilioides, Millettia conraui, Pouteria altissima*), and several, such as *Anthonotha noldeae* are new to West Africa and others new to Nigeria [34].

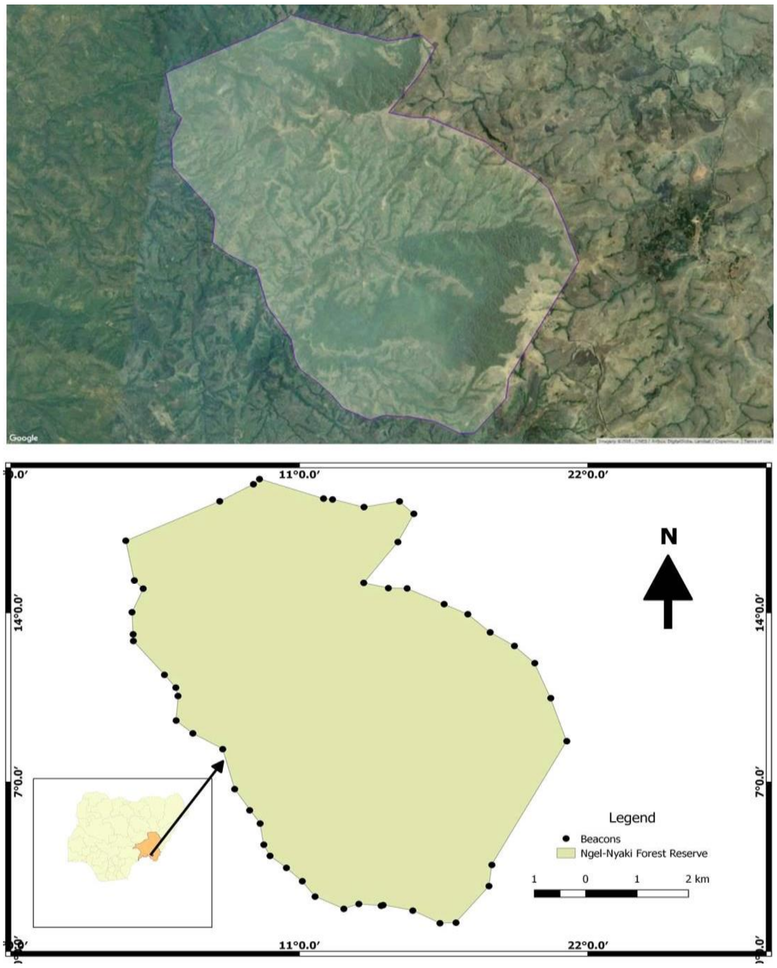

Figure 1: Map Showing Ngel-Nyaki Forest Reserve. Source: [37]

STUDY DESIGN

An ecological survey as reported by [38] was carried out to gain insight into the relative abundance and diversity of the Pleurotus species and host trees at Ngel-Nyaki montane forest. Since the focus was on one group of mushrooms-Pleurotus, opportunistic sampling protocol was used. That is, sample collection was done only in those sites where Pleurotus species were most likely to be found as adopted by [39]. Sporocarps exhibiting a range of developmental stages were examined for morphological characters. The collected specimens (fruiting bodies) were preserved in aluminum foil and packed in paper bags for later identification. A feasibility survey of the montane forest was made and where identified or suspected Pleurotus species were observed in the course of the survey, the points were marked using the Global Positioning System (GPS) and their coordinates recorded.

DATA ANALYSIS

The relative frequency of occurrence (RF) in percentage of each Pleurotus species and host trees was calculated with the help of R studio statistical packer version 4.2 using the formula:

$$F = \frac{ns}{Ns} \times 100 \qquad \ldots\ldots (1)$$

Where:
F is frequency % of occurrence,
ns is frequency value for a species and
Ns is the total frequencies for all species as adopted from [40].

Shannon-Wienner Diversity Index was used to analyze data on diversity of Pleurotus species host trees.

Shannon-Wiener Diversity Index, H':

$$H' = -\sum_{i=1}^{S} p_i \, ln(p_i) \ldots\ldots (2)$$

Where:
H' = Shannon-Weiner diversity index
S = Total number of species in the community
P_i = Proportion of S made up of the i^{th} species
ln = natural logarithm.

Species richness (SR) was calculated as follows:
TS ÷ TA ………………….. (3)
Where:
TS = Total number of species while
TA = Total area covered as adopted from [41].

Shannon's maximum diversity index was calculated using the equation:

$$H_{max} = \ln(S) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (4)$$

Where:
Hmax = Shannon's maximum diversity index,
S = total number of species in each of the ecological zone as reported by [42].

Species evenness refers tree species closeness equitability (mathematically) in an environmental niche. It was calculated using the following equation:

$$E_H = \frac{H'}{H_{Max}} = \frac{\sum_{i=1}^{S} P_i \, ln(P_i)}{ln(S)} \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where;
H_{max}= Shannon's maximum diversity index.
H' = Shannon-Wiener diversity index
E_H= Species evenness [41].

Descriptive statistics such as charts and tables were used to present the results.

Diagnostic Characters of Species

The Pleurotus species spotted had decurrent gills, were growing in clusters on the tree trunk, fan shaped basidiocarps, colour, and oyster- like appearance. The Pleurotus species were identified through the help of a mycologist and the use of field identification guides while the host tree species were identified through the help of a taxonomist.

Results

Pleurotus Species and Host Trees

A total of four (4) different Pleurotus species growing on three (3) host tree species was observed at Ngel-Nyaki montane forest. *Polyscias fulva* was observing hosting *Pleurotus pulmonarius* and *Pleurotus ostreatus* at two different locations. *Anthonotha noldeae* was spotted hosting *Pleurotus djamor* while *Ficus lutea* was observed serving as host to *Pleurotus eryngii*. Table 1 below shows the Pleurotus species and their respective host trees as well as the coordinates of the points where they were spotted. No two of the host trees spotted belonged to the same family as shown on Table 1 below.

Table 1: Pleurotus species and respective host trees observed at Ngel-Nyaki with their coordinates

Pleurotus Species	Host tree species	Family	Latitudes	Longitudes	Elevation (m)
Pleurotus pulmonarius	*Polyscias fulva*	Araliaceae	07°08[1]N	011°05[1]E	1505.79
Pleurotus djamor	*Anthonotha noldeae*	Fabaceae	07°06[1]N	011°04[1]E	1672
Pleurotus ostreatus	*Polyscias fulva*	Araliaceae	07°04[1]N	011°3[1]E	1602
Pleurotus eryngii	*Ficus lutea*	Moraceae	07°04[1]N	011°03[1]E	1632

Source: Field survey, 2021- 2023

Figure 2 below shows the frequency of each of the observed Pleurotus species at Ngel-Nyaki montane forest. *Pleurotus ostreatus* had the highest frequency of 52 with a relative frequency (RF) of 50.49%; *Pleurotus pulmonarius* was second with a frequency of 31 having a relative frequency (RF) of 30.09%. *Pleurotus eryngii* was next with 11 as frequency and a Relative frequency (RF) of 10.68% and finally *Pleurotus djamor* having a frequency of 9 and 8.74% as relative frequency (RF).

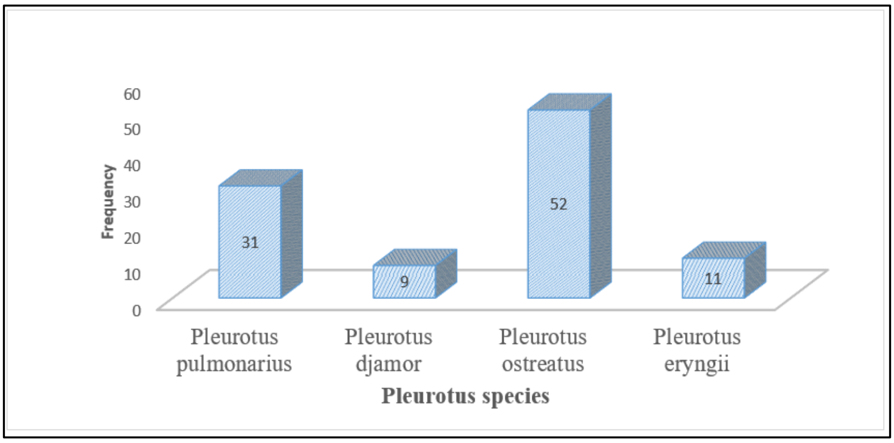

Figure 2: Abundance of Pleurotus Species at Ngel-Nyaki Montane Forests

Diversity Indices of Pleurotus Species

Figure 2 represents the diversity indices for Pleurotus species at Ngel-Nyaki montane forest. The respective values for Shannon-Weiner Diversity Index, Shannon's Maximum Diversity Index, Species Evenness and Species Richness are each represented accordingly.

Table 2: Diversity indices of Pleurotus species

Species	Abundance	Pi	LnPi	Ln*LnPi
Pleurotus ostreatus	52	0.5049	-0.683	-0.34
Pleurotus eryngii	11	0.1068	-2.237	-0.24
Pleurotus pulmonarius	31	0.3009	-1.201	-0.36
Pleurotus djamor	9	0.0874	-2.442	-0.21
Total	**103**			**-1.15**
			H'	1.15
			H_{max}	4.635
			E_H	0.248
			Species richness	0.026

H'= Shannon Wienner Diversity Diversity Index, E_H = Species evenness, H_{max} =Shannon's Maximum Diversity Index

Diversity indices of Pleurotus host trees

Table 3 represents the diversity indices for Pleurotus host trees at Ngel-Nyaki montane forest. The respective values for Shannon-Weiner Diversity Index, Shannon's Maximum Diversity Index, Species Evenness and Species Richness are each represented accordingly

Table 3: Ngel-Nyaki Montane Forest

Species	Abundance	Pi	LnPi	Ln*LnPi
Polyscias fulva	11	0.22	-1.51	-0.33
Ficus lutea	3	0.06	-2.80	-0.17
Anthonotha noldeae	36	0.72	-0.33	-0.24
Total	**50**			**-0.74**
			H'	0.74
			H_{max}	3.912
			E_H	0.189
			Species richness	0.013

H'= Shannon Wienner Diversity Diversity Index, E_H = Species evenness, H_{max} =Shannon's Maximum Diversity Index

From table 3 above, the relative frequency (RF) of each host tree species can be deduce respectively as follows *Polyscias fulva* (22%), *Ficus lutea* (6%) and *Anthonotha noldeae* (72%) represented as shown in Figure 3 below.

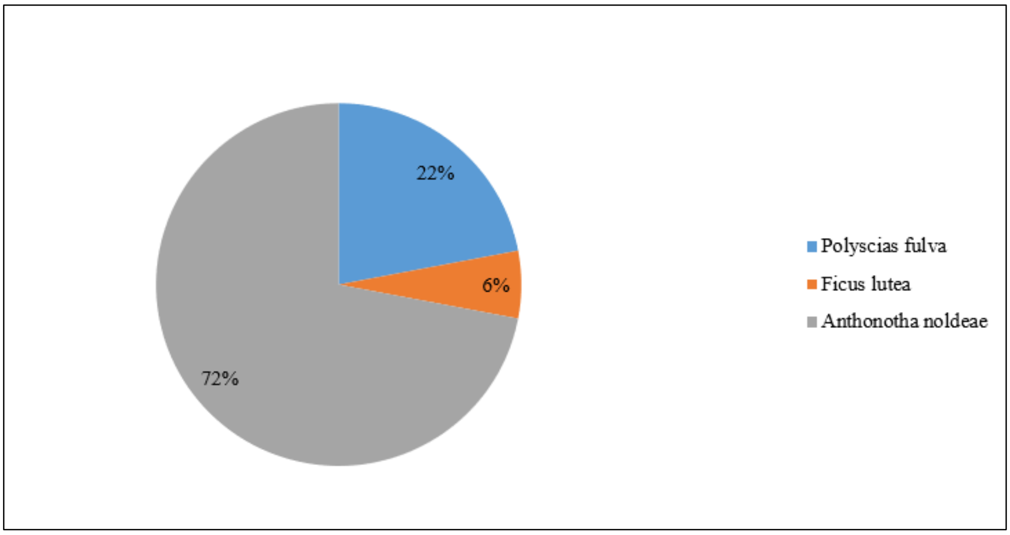

Figure 3: Relative frequencies of Pleurotus host trees

Diversity of Pleurotus Species and Host Trees

The Four (3) different Pleurotus species spotted at Ngel-Nyaki montane forest had a Shannon Wienner Diversity Index (SWDI) of 1.15 while the SDWI for host trees (3 in number) was 0.74 as shown on Table 4 and represented as shown on Figure 3 below. The results show that Pleurotus species and host trees diversity at Ngel-Nyak montane forest is low. This calls for stricter attention with regards to their conservation.

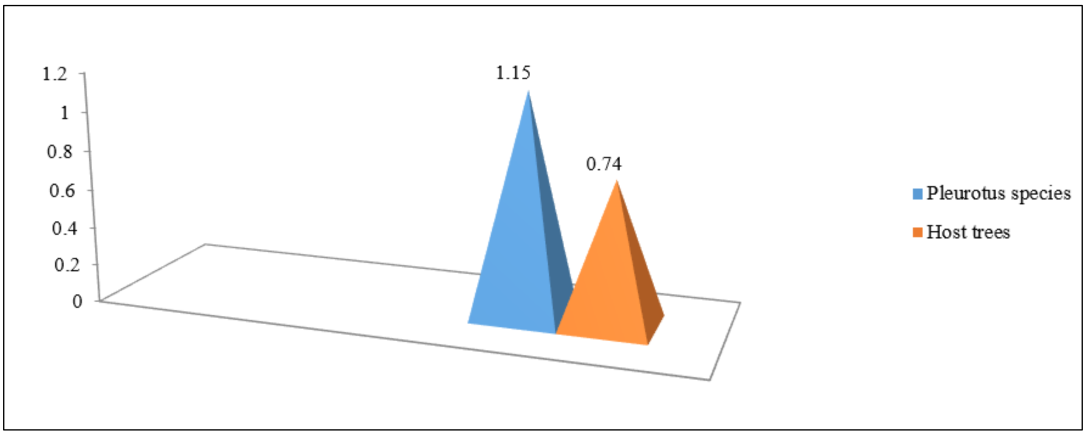

Figure 4:Diversty indices of Pleurotus species and host trees

Species Richness of Pleurotus Species and Host Trees

Table 5 below shows the results of Pleurotus species and host trees richness at the Ngel-Nyaki montane forest and are represented as shown on Figure 5 below. The species richness for Pleurotus species at Ngel-Ngel which had total of one hundred and three (103) counted fruiting Pleurotus was 0.026 while that of host trees where fifty (50) live trees were counted in the mapped out plots was 0.013.

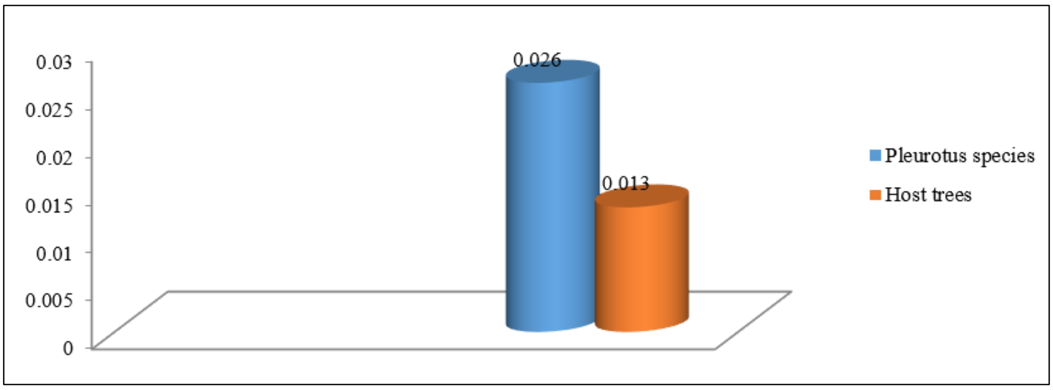

Figure 5: Species richness of Pleurotus species and host trees

Species Evenness of Pleurotus Species and Host Trees

The Pleurotus species at Ngel-Nyaki montane forest had and evennesss value of 0.248 while that of the host trees was 0.189 as shown in Table 4 below and represented as shown on figure 6 below. This is an indication that the Pleurotus species were more evenly distributed across the covered area than the host trees.

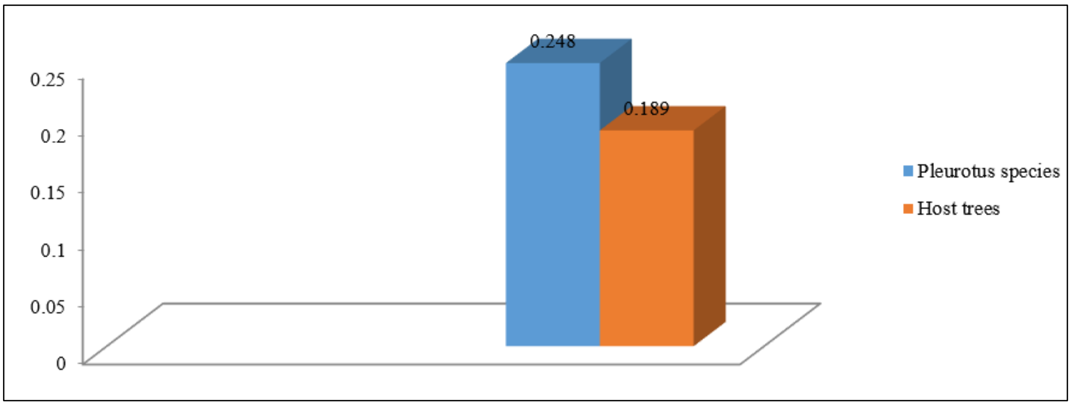

Figure 6: Species evenness of Pleurotus species and host trees

Table 4: Summary of diversity indices of Pleurotus species and host trees in both sites

Site	H'	H_{max}	E_H	Species richness
Pleurotus species	1.15	4.635	0.248	0.026
Host trees	0.74	3.912	0.189	0.013

Source: Field survey, 2021-2023

DISCUSSION

The Pleurotus species spotted at Ngel-Nyaki occurred at an elevation of 1500m and above. PLeurotus pulmoanrius was spotted at an altitude of 1505.79m, Pleurotus ostreatus at an altitude of 1602m, Pleurotus eryngii at an altitude of 1632m and Pleurotus djamor at an altitude of 1672m. This was a bit different from the work of [14] which spotted Pleurotus species at both low and high altitudes. Four (4) Pleurotus species were spotted being hosted by three (3) different host tree species which was different from [14] which spotted but five (5) different Pleurotus species though it could be as a result of area coverage and the different geographical location since they conducted their own study in the mount Cameroon area located in the Southwest Region of Cameroon while this study was conducted in the Mambilla plateau of Taraba State of Nigeria though Taraba State is a bordering state with the republic of Cameroon through the Northwest region. The work of [14] covered a larger area than this which was limited to the montane forest of Ngel-Nyaki forest reserve. [43] spotted four (4) Pleurotus species (*Pleurotus ostreatus, Pleurotus pulmonarius* , *Pleurotus sajor-caju* and *Pleurotus tuberregium*) at Kom of the North West region which has altitudes above of approximately 1500m and above from sea level same with this study where *Pleurotus ostreatus, Pleurotus pulmonarius* were also spotted.

All the host trees spotted in this study were standing decaying logs except one which was a lying log. The *Polyscias fulva* which was spotted serving as host to *Pleurotus pulmonarius* was a standing gradually dying log while the same host trees species hosting *Pleurotus ostreatus* was a standing dead log. *Pleurotus djamor* was spotted fruiting on a dead standing log of *Anthonotha noldeae*. Only *Pleurotus djamor* was spotted growing on a dead lying log of *Ficus lutea*. According to [44], eight different samples of Pleurotus species were collected in Southwestern part of Nigeria and characterized to species levels which were comprised of six (6) species of *Pleurotus ostreatus* and two (2) species of *Pleurotus pulmonarius* in line with this study which also came up with a more population of *Pleurotus ostreatus* (52) than that of *Pleurotus pulmonarius* (31). Upon all the numerous researches observed to have been conducted within Nigeria on mushrooms in general and Pleurotus species specifically, no particular research so far was conducted on the abundance and diversity of Pleurotus and host tree species within a montane forest. This study differs from that of [45] who worked on the isolation and characterization of *Pleurotus pulmonarius* (LAU09 - JF736658) and *Pleurotus ostreatus* (LAU10- JF736659) from a wild basidiocarp growing on dead palm oil tree inside a Nigerian cocoa plantation in Ogbomoso area (347m altitude) which also located in the Southwest Nigeria. *Pleurotus pulmonarius* (MF037415) and *Pleurotus ostreatus* (MF037419) were isolated on dead *Mangifera indica* log and dead *Elaeis guineensis* log respectively in Environmental Pollution Science and Technology (ENPOST) farm, Ilesa, Southwest Nigeria while this study spotted P*leurotus pulmonarius* growing but on *Polyscias fulva* and at an altitude of 1505.79m. The differences could be as a result of the marked differences in altitudes since this study was conducted at altitudes far more than that of [45] with lower altitudes.

[39] working on first record of the occurrence of *Pleurotus citrinopileatus Singer* on new hosts in Kenya observed *P.citrinopileatus* was spotted growing on three (3) different hosts *Antiaris toxicaria*, *Polyscias fulva*, *Ficus* thoningii but this study spotted Polyscias serving as host but to P*leurotus pulmonarius* and *Pleurotus ostreatus* while Ficus lutea (not *thonningii*) serving as hot to *Pleurotus eryngii*. [46] working on Diversity of Edible and Medicinal Mushrooms Used in the Noun Division of the West Region of Cameroon reported *Pleurotus pulmonarius* growing but on the soil as substrate while in the course of this study *Pleurotus pulmonarius* was observed growing but on a dead standing log of *Plolyscias fulva*, none of the four (4) spotted species of Pleurotus species was observed growing using the soil as substrate. The reason could be that the soil where they spotted this Pleurotus growing was made up of the remains of decayed woody tree species. None of the host trees in this study belonged to the same family. Each belong to a different family.

CONCLUSION

It was discovered in the course of this study that Pleurotus species as well as their host trees are not actually diverse as only a few (four) number of different Pleurotus species and host trees (three) were spotted in Ngel-Nyaki montane forest. The low diversity indices of the Pleurotus species (1.15) and the host trees (0.74) speak volume as well as the species richness values of 0.026 for Pleurotus species and 0.013 for the host trees. This should be as a result of over dependence of the local communities around this forest reserve on the wild for Pleurotus species as well as their host trees for the services they achieve from it. Majority of the locals around Ngel-Nyaki montane forest do exploit the wild mushrooms for food and income generation. Edible mushrooms species are termed as the poor man's meat because it serves as a source of protein for people who cannot afford other protein sources from animal products

[47]. This result of this study calls for an urgent improvement on the sustainable conservation and management these bio-resources in order to prevent it from becoming extinct in the nearest future. The host trees apart from serving as hosts to Pleurotus species play many other functions such in ecosystem services but also serve as a source of fuelwood, timber, medicine to the locals not leaving their fight against global warming. The government of the day in Nigeria, conservation societies as well as stakeholders should encourage the local communities (mostly those dwelling within, around and close to forest areas) to embark on mushroom (especially Pleurotus) farming by offering them financial aid and training to reduce their depend on wild Pleurotus species and host trees to the barest minimum.

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