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Ecology, diversity and seasonal distribution of wild mushrooms in a Nigerian tropical forest reserve

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Abstract. *Adeniyi M, Odeyemi Y, Odeyemi O. 2018. Ecology, diversity and seasonal distribution of wild mushrooms in a Nigerian tropical forest reserve. Biodiversitas 19: 285-295.* This study investigated the ecology, diversity and seasonal distribution of wild mushrooms at Environmental Pollution Science and Technology (ENPOST) forest reserve, Ilesa, Southwestern Nigeria. Mushrooms growing in the ligneous and terrestrial habitats of the forest were collected, identified and enumerated between March 2014 and March 2015. Diversity indices including species richness, dominance, and species diversity were evaluated. Correlation ($p < 0.05$) was determined among climatic data and diversity indices. A total of 151 mushroom species specific to their respective habitats were obtained. The highest monthly species richness (70) was obtained in October 2014. While a higher dominance was observed in the terrestrial habitat during the rainy and dry seasons (0.072 and 0.159 respectively), species diversity was higher in the ligneous and terrestrial habitats during the rainy season (3.912 and 3.304 respectively). Overall, the highest carpophores in ligneous and terrestrial habitats were recorded in *Schizophyllum commune* (10,737) and *Mycena monticola* (760) correspondingly. Correlation analysis revealed that average monthly precipitation positively correlated with the relative abundance of mushrooms in the terrestrial habitat ($r = 0.716$, $p = 0.013$). This study shows the diversity of mushrooms at ENPOST forest, thereby necessitating strict and sustainable conservation measures especially those with great economic values.

Keywords: ENPOST forest, ecology, diversity indices, wild mushrooms, Nigeria

INTRODUCTION

Adequate knowledge of mushroom diversity and distribution are imperative for successful conservation, management and optimum exploitation of the ecosystem for innumerable benefits to mankind (Nwordu et al. 2013). Mushrooms are important bioresource with diverse nutritional, medicinal and ecological benefits (Odeyemi et al. 2014). According to Chang and Miles (1992), and Das (2010), they are regarded as visible fungi with distinctive carpophores which represent the reproductive stage in the life cycles of Basidiomycetes and some Ascomycetes. Usually, mushroom carpophore gains more attention than its mycelia (vegetative stage) as a result of its sudden appearance in nature, characteristics morphology and color (Straatsma et al. 2001).

In the natural environment, mushrooms grow on variety of substrates, especially those containing lignin and cellulose, often abundant during the rainy season (Gbolagade 2005; Gbolagade et al. 2006; Jonathan et al. 2013). Their fleshy, spore-bearing fruiting bodies grow on soil or wood substrates whereas some exist in mycorrhizal relationship with trees (Onuoha and Obi-Adumanya 2010). 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 (Ayodele et al. 2011; Tibuhwa et al. 2011; Nwordu et al. 2013). 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 (Gbolagade et al. 2006; Nwordu et al. 2013).

Globally, about 140,000 mushroom species are known to exist, with only about one-tenth taxonomically identified (Wasser 2002; Shelley and Geoffrey 2004). In Northern America, more than 70% in comparison with the globally identified mushrooms had been reported (CCB 2017). In India, about 10% had been investigated (Gurudevan et al. 2011).

Worldwide assessment of fungi diversity revealed that fungi distribution is mainly influenced by climates and certain types of habitat (Tedersoo et al. 2014); rainfall and temperature being the most important climatic elements (Straatsma et al. 2001). In contrast to what is obtainable in the temperate regions, mushrooms in the tropics are more diverse and are distributed over a smaller geographical area (Tedersoo et al. 2014). In Nigeria, mushrooms occur throughout the year (Ayodele et al. 2011) with the highest occurrence mostly in April to June (Nwordu et al. 2013). Onuoha and Obi–Adumanya (2010) stated that the boom of wild mushroom occurs once or twice a year and disappears within a month during the rainy season. However, desertification, deforestation, pesticides application, petroleum hydrocarbons and other environmental hazards contribute to the reduction in the quantities of mushroom growing in the wild in many developing regions of the world (Okhuoya et al. 2010; Odeyemi et al. 2014).

Till date, the estimated mushrooms in the African continent is less than 1% of the total global estimate (Odebode 2005; Osemwegie and Okhuoya 2009; Oyetayo 2009; Bankole and Adekunle 2012; Nwordu et al. 2013). In most countries of the region, especially the most populated black nation Nigeria, there is paucity of information on the existing wild mushrooms. It is in the light of this that the present study investigated the ecology, diversity and seasonal distribution of wild mushrooms at ENPOST (Environmental Pollution Science and Technology) forest conservation.

MATERIALS AND METHODS

Description of the study area

The site of study for this research was the forest conservation section of ENPOST, located at Ido-Ijesa, along Ife-Ilesa expressway, Ilesa, Southwestern Nigeria (Latitude 4°42'30'E to 4°42'45''E longitude 7°36'55''N to 7°37'10''N) (Figure 1). The forest conservation section of ENPOST has over 300 living species of trees. The predominant plant species in the forest is *Cleistopholis patens* (salt and oil tree). Others include *Elaeis guineens*is (palm tree), *Theobroma cacao* (cocoa tree) and *Cola nitida* (kolanut tree). Most trees within the forest are canopy-forming and some deciduous during the dry season. Green vegetations, dead wood logs, and tree debris such as fallen leaves and twigs which constitute soil debris are also abundant. Two different streams namely 'Aroni' and 'Eruru' flow along the forest making some areas marshy and muddy all year round. Interactions among fallen leaves and tree, moist soils, decayed matters, minimal inflow of anthropogenic activities and suitable environmental conditions make the forest suitable for the growth of different wild mushrooms.

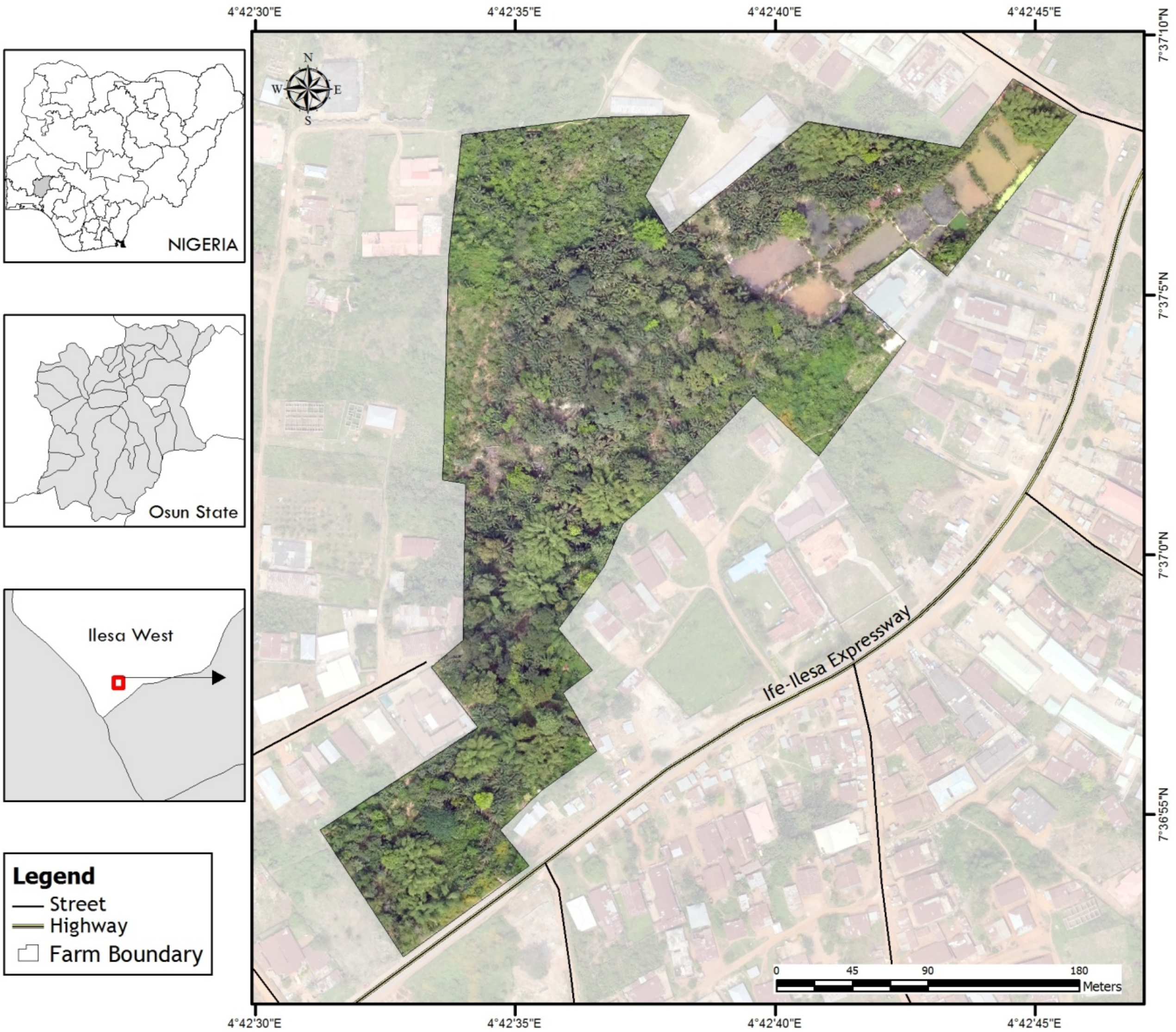

Figure 1. Map showing the location of ENPOST forest, Ilesa, Southwestern Nigeria

Presumptive identification of wild mushrooms

Specimens were initially photographed in their respective habitats and on growth substrates. Mushroom carpophores growing on soil and soil litter were carefully dug to prevent their bases from being bruised. Likewise, wood-rotting mushrooms were carefully detached from the bark of the trees. Representative mushroom specimens and wood substrates were collected in well-labeled sterile sampling paper bags and immediately taken to the laboratory for presumptive identification. Presumptive identification of mushroom samples was done using standard keys and by comparing the morphology of the carpophores with relevant literature (Rogers 1994; Nwordu et al. 2013).

Ecology of wild mushrooms at ENPOST forest, Ilesa, Southern, Nigeria

Different indigenous mushrooms growing on the forest conservation section of ENPOST forest were studied over a 13-month regime (March 2014 and March 2015). Exactly 20 plots of 1000 m^2 were strategically mapped out on the site of study. Morphologically different wild mushrooms growing on different growth habitats and substrates within each plot were noted and counted three times a week. To avoid multiple counting of same mushroom carpophore, the mushrooms were marked with methylene blue at first encounter. The identity of wood substrates was done at the Herbarium unit of the Department of Pharmacognosy, Faculty of Pharmacy, Obafemi Awolowo University, Ile-Ife, Southwestern Nigeria.

Monitoring of climatic conditions of the site of study

The daily temperature and relative humidity of the study site were monitored using hygrometer (Fluke, 1620A, US), while daily rainfall data was obtained using rain gauge.

Data analysis

Diversity indices including species richness and diversity, relative abundance, dominance, and evenness were determined using BioDiversity Pro 2.0 software (McAleece et al. 1997). Species similarity between rainy and dry seasons was determined using the Jaccard's similarity coefficient (Cj). Mathematically, Jaccard coefficient (Cj) = a / (a + b + c). Where a = number of mushroom species common to both rainy and dry seasons; b = number of mushroom species unique to rainy season; and c = number of mushroom species unique peculiar to dry season. Correlation was also performed to identify relationships among monthly climatic data, mushroom species richness and relative abundance using Statistical Package for Social Sciences [(SPSS) IBM version 22 software]. Statistical significance was set at $p < 0.05$.

RESULTS AND DISCUSSION

Enumeration of wild mushrooms found growing at ENPOST forest, Ilesa, Southwestern, Nigeria

During the period of this study, a total of 151 different mushroom species belonging to phyla Basidiomycota and Ascomycota were found. Out of the 151 mushroom species, 143 (94.70%) belong to phylum Basidiomycota and 8 (5.30%) to phylum Ascomycota (Figure 2). Representative pictures are shown in Figure 3.

All the mushroom samples surveyed belong to 68 genera and include: *Agaricus*, *Amanita*, *Anthrodiella*, *Auricularia*, *Cantharellula*, *Cantharellus*, *Clavatia*, *Clavariadelphus*, *Clitocybe*, *Clitopilus*, *Collybia*, *Coprinus*, *Coriolus*, *Cortinarius*, *Crepiotus*, *Cyathus*, *Dacrymyces*, *Daldina*, *Dichometus*, *Dictophora*, *Ganoderma*, *Gleophyllum*, *Hapalopilus*, *Hericium*, *Heterobasidion*, *Hydnellum*, *Hydnum*, *Hygrocybe*, *Hypholoma*, *Hypoxyl*on, *Inocybe*, *Inonotus*, *Laccaria*, *Lactarius*, *Lentinus*, *Lenzites*, *Lepiota*, *Leucocoprinus*, *Lycoperdon*, *Lyophyllum*, *Maramiellus*, *Marasmius*, *Micromphale*, *Mycena*, *Nidularia*, *Nolanea*, *Oxyporus*, *Panaeolina*, *Peziza*, *Phellinus*, *Piptoporus*, *Pleurotus*, *Pluteus*, *Polyporus*, *Psathyrella*, *Schizophyllum*, *Schizopora*, *Scleroderma*, *Stereum*, *Suillus*, *Termitomyces*, *Trametes*, *Trichoglossum*, *Tricholoma*, *Tricholomopsis*, *Tuber*, *Volvariella* and *Xylaria*.

Ecology of wild mushrooms at ENPOST forest, Ilesa, Southwestern, Nigeria

Mushrooms grew in two major habitats, i.e., ligneous (woody) and terrestrial (land). The species that grew in the ligneous habitats was 82 (54.31%) and higher than those on the terrestrial 68 (45.03%) (Figure 4). Interestingly, 1 (0.66%) species grew on termite nest (terrestrial) found on a living tangerine tree (ligneous) (Figure 5). All the mushroom species observed were habitat specific.

The ligneous and terrestrial habitats comprise different growth substrates. While the terrestrial habitat consists of soil debris, termite mound and nest, bank of fish pond, soil heap, and sclerotium buried or on soil surface (Figure 6), it was root, stump, stem log, branch, leaves, and twig of dead *Cola nitida*, *Mangifera indica*, *Pseudospondias microcarpa*, *Elaeis guineensis, Triplochiton scleroxylon, Bambusa vulgaris, Cordyline australis, Gliricidia sepium*, *Musa paradisiaca, Pycnanthus angolensis* trees and some unidentified dead wood for the ligneous habitat (Table 1). All the mushrooms species from the terrestrial habitats were substrate specific with soil debris and heap having the highest 54 (79.41%) and lowest 1 (1.47%) number respectively (Figure 6). Of the 82 species that grew on the ligneous habitat, the highest number 59 (71.95%) grew on one type of growth substrate with Dead *Elaeis guineensis* supporting the highest number of species (25; 30.49%), 11 (13.41%) on two wood substrates simultaneously or at different times, 1 (1.22%) on 3 different substrates whereas 11 (13.41%) on unidentified substrates (Table 1). It was also observed that more than one mushroom species grew on some ligneous substrates at different times during this study. However, the succession pattern of mushrooms on each of the substrates was not studied. Notably were 3 mushroom species namely; *Hapalopilus nidulans*, *Lentinus subnudus* and *Pleurotus pulmonarius* that grew on erect dead trees (Unidentified tree, *Cola nitida*, *Cordyline australis* respectively) about 10 m above ground (Figure 7). All *Termitomyces* sp. both in the ligneous and terrestrial habitats were associated with termite mound or nest.

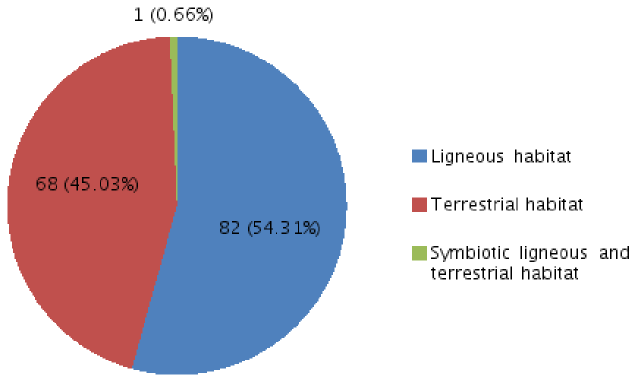

Figure 2. Percentage frequency of mushrooms in phyla Basidiomycota and Ascomycota

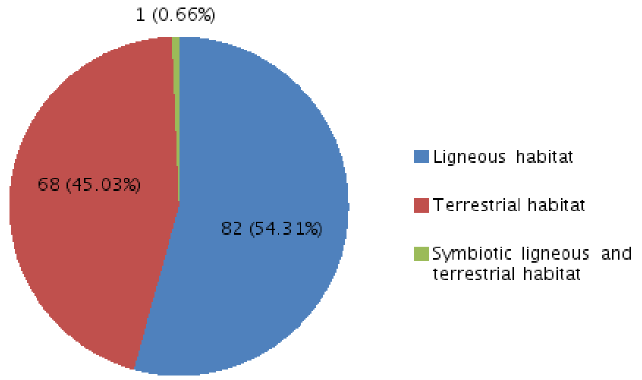

Figure 4. Distribution of mushroom species on different growth habitats at ENPOST forest, Ilesa, Southwestern Nigeria

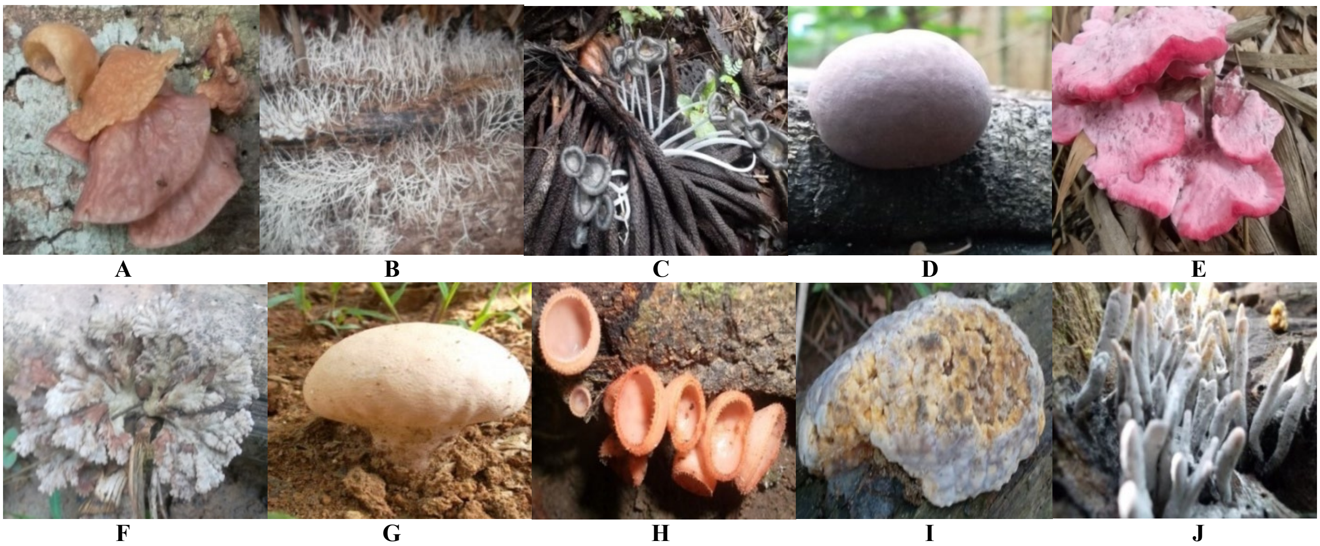

Figure 3. Representative pictures of wild mushrooms growing at ENPOST forest Ilesa, Southwestern, Nigeria. A. *Auricularia auricula-judae*; B. *Clavariadelphus junceus*; C. *Coprinus lagopides*; D. *Daldina concentric*; E. *Hydnellum peckii*; F. *Schizophyllum commune*; G. *Lycoperdon spadiceum*; H. *Peziza aurantia*; I. *Tuber excavatum*; J. *Xylaria hypoxylon*

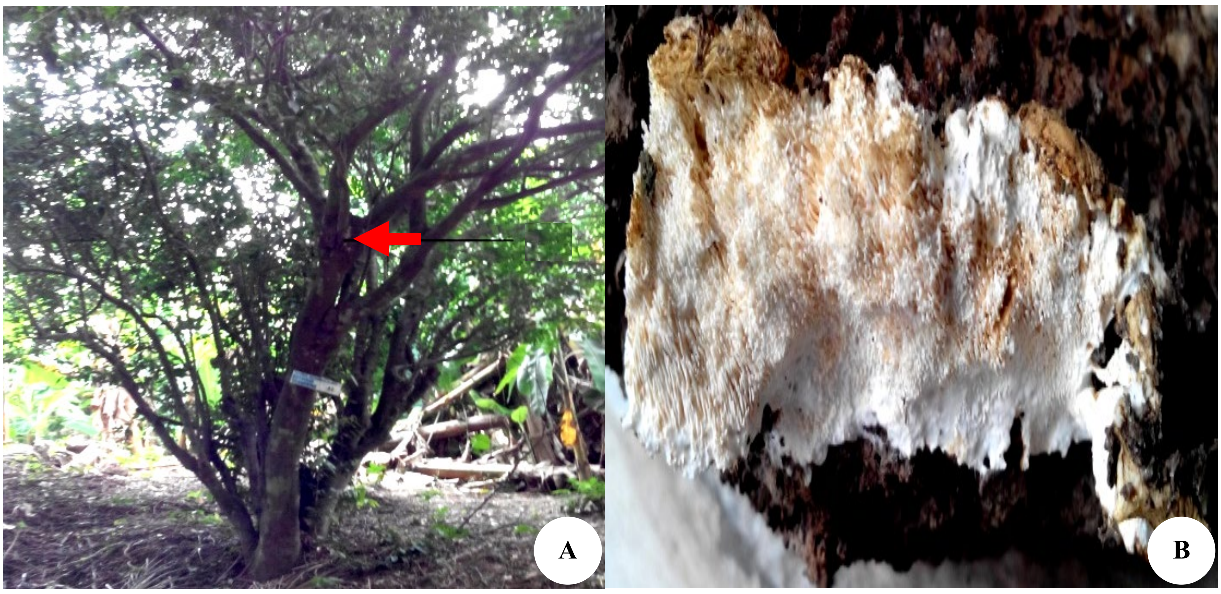

Figure 5. A. *Stereum gausapatum* growing on termite nest on a living tangerine tree; B. Close-up view

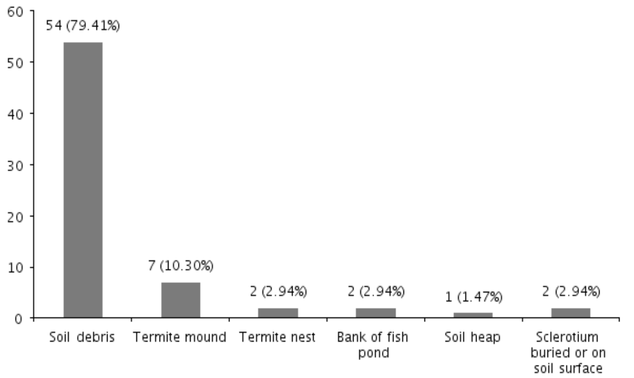

Figure 6. Frequency of mushroom species on the different terrestrial growth substrates

Monitoring of climatic conditions of the site of study

The lowest temperature (23°C) was obtained in August 2014 and the highest (28°C) in February 2015 (Table 2). The order of monthly precipitation was 16.85 >12.55 > 9.09 > 6.58 > 5.66 > 2.46 > 2.39 > 2.11 > 0.41 mm during May 2014, July 2015, October, August, September, June, April, March and November 2014 respectively. Only December 2014 and January 2015 had zero precipitation (Table 3). Based on the temperature and rainfall pattern of the site of study, March, April, November, December 2014 and January, February and March 2015 were grouped as dry season and May, June, July, August, September, and October 2014 as rainy season. Generally, the relative humidity was high throughout the study period. The highest (96.2 ± 2.2) and lowest (78.9 ± 3.2) values were recorded in July 2014 and March 2015 respectively (Table 2).

Diversity indices of mushrooms sampled at the site

Mushroom species richness and relative abundance

Table 3 shows the monthly species richness of mushrooms at ENPOST forest between March 2014 and March 2015. Species richness was very high in October (70), followed by May (66) and September (62), 2014 and low March 2015 (11), January (13) and July (14) 2014.

Generally, mushrooms in the terrestrial habitat were abundant and found higher than those in the ligneous habitat only in May, September and October 2014. The relative abundance of mushroom carpophores in the terrestrial habitat during the period of study ranged from 0 to 45.35% with May 2014 recording the highest value (45.35%) (Table 3). In the ligneous habitat, the monthly relative abundance of mushroom carpophores ranged from 1.99% (August 2014) to 18.79% (April 2014) (Table 3).

Mushroom dominance, species diversity and evenness

The dominance, species diversity, and evenness of the mushrooms studied in the rainy and dry seasons are presented in Table 4. Generally, a higher mushroom dominance was observed in the terrestrial habitat during the rainy and dry seasons (0.072 and 0.159 respectively) when compared to the ligneous habitat. On the contrary, species diversity was higher in both seasons in the ligneous habitat. Though the value obtained for evenness in the two seasons were higher in the terrestrial habitat with the highest evenness (0.581) during the dry season, no wide margin was noticed in both terrestrial and ligneous habitats during the rainy season where 0.261 and 0.264 were obtained respectively (Table 4).

A B C

Figure 7. Pictures of mushrooms growing on erect dead wood logs about 10 m above ground. A. Unidentified tree, B. *Cola nitida*, C. *Cordyline australis*

Table 1. Occurrence and percentage frequency of mushroom species on different ligneous substrates

Substrate type	Substrate	n	%
Single substrate	Dead *Cola nitida*	14	17.07
	Dead *Elaeis guineensis*	25	30.49
	Dead *Mangifera indica*	13	15.85
	Dead burnt *Triplochiton scleroxylon* associated with termite nest	2	2.44
	Dead *Cordyline australis*	1	1.22
	Dead *Pseudospondias microcarpa*	1	1.22
	Dead *Bambusa vulgaris*	2	2.44
	Dead *Gliricidia sepium*	1	1.22
	Total	59	71.95
Dual substrates	Dead *Cola nitida* and Dead *Elaeis guineensis*	1	1.22
	Dead *Cola nitida* and Dead *Mangifera indica*	4	4.88
	Dead *Elaeis guineensis* and Dead *Musa paradisiaca*	2	2.44
	Living *Cola nitida* and *Elaeis guineensis*	1	1.22
	Dead *Elaeis guineensis* and Dead *Pycnanthus angolensis*	1	1.22
	Dead *Elaeis guineensis* and Dead *Bambusa vulgaris*	1	1.22
	Dead *Bambusa vulgaris* and Dead *Mangifera indica*	1	1.22
	Total	11	13.41
Triple substrates	Dead *Mangifera indica*, Dead *Elaeis guineensis* Font, Dead *Cordyline australis*	1	1.22
	Total	1	1.22
Unidentified substrates	Unidentified dead wood substrates	11	13.41
	Total	11	13.41
	Overall total	82	100

Note: n - Number of mushroom species

Table 4. Seasonal variation in dominance, species diversity and evenness of mushrooms in the ligneous and terrestrial habitats during the rainy and dry season

Habitat	Rainy season			Dry season		
	Dominance	Species diversity	Evenness	Dominance	Species diversity	Evenness
Ligneous	0.033	3.912	0.261	0.093	3.019	0.220
Terrestrial	0.072	3.304	0.264	0.159	2.167	0.581

Table 2. Measurement of climatic elements of ENPOST forest, Ilesa, Southwestern Nigeria

Year	Month	Average monthly temp. (°C)	Number of rainfall (d) per month	Average monthly precip. (mm)	Average monthly relative humidity (%)
2014	March	27 ± 3	6	2.11	93.1 ± 2.7
	April	26 ± 3	6	2.39	92.7 ± 5.3
	May	26 ± 3	10	16.85	95.6 ± 2.8
	June	25 ± 3	9	2.46	94.9 ± 3.6
	July	24 ±2	11	12.55	96.2 ± 2.2
	August	23 ± 3	8	6.58	92.8 ± 2.3
	September	24 ± 2	12	5.66	96.1 ± 2.6
	October	25 ± 2	13	9.09	95.8 ± 1.1
	November	26 ± 4	2	0.41	89.3 ± 2.7
	December	26 ± 5	0	0.00	85.3 ± 3.3
2015	January	26 ± 6	0	0.00	83.7 ± 4.5
	February	28 ± 6	ND	ND	80.2 ± 3.6
	March	27 ± 7	ND	ND	78.9 ± 3.2

Note: ND – Not determined

Table 3. Species richness and relative abundance of mushroom during the period of study

Year	Month	Species richness	Relative abundance of mushrooms in the terrestrial habitat (%)	Relative abundance of mushrooms in the ligneous habitat (%)
2014	March	20	0.32	7.57
	April	38	11.82	18.79
	May	66	45.35	8.91
	June	24	0.77	9.67
	July	14	0.00	2.11
	August	17	0.94	1.99
	September	62	12.22	10.28
	October	70	24.54	14.36
	November	42	2.68	13.75
	December	17	0.20*	3.27
2015	January	13	0.00	3.29
	February	26	0.45	3.57
	March	11	0.72	2.43
	Total		100	100

Note: *Mushrooms in this month were found growing close to the stream flowing through the forest

Seasonal variation in the occurrence and similarity of mushroom species found growing in the ligneous and terrestrial habitats

The occurrence of mushroom species was higher during the rainy season in the terrestrial habitat (n = 43) than in the ligneous habitat (n = 29). Contrariwise, the occurrence of mushroom species in the dry season was higher in the ligneous habitat (n = 14) than in the terrestrial habitat (n = 10). In addition, the number of mushroom species that occurred in both the dry and rainy seasons was higher in ligneous (39) than terrestrial habitats (15). Jaccard's similarity index indicates fewer mushroom species grew in both rainy and dry seasons in the terrestrial habitat when comparison to the ligneous habitat (Table 5).

Generally in the ligneous habitat, the highest carpophores during the rainy and dry seasons was observed in *Coprinus disseminates* (7,675) and *Schizophyllum commune* (7,329) respectively (Table 6) while it was *Mycena monticola* (760; rainy season) and *Mycena sanguinolenta* (362; dry season) in the terrestrial habitat (Table 7). In addition, *Auricularia auricula-judae*, *A. polytricha*, *Cantharellus cibarius*, *Coprinus lagopides*, *Cortinarius paleaceus*, *Inonotus hispidus*, *Lenzites betulina*, *Nidularia farcta*, *Pluteus salicinus*, *Schizophyllum commune*, *Trametes pubescens*, *Hericium abietis*, *Hypoxylon fragiforme*, and *Hypoxylon* sp. had more carpophores occurring in the dry season in the ligneous habitat (Table 6).

Table 5. Frequency and relationship between mushroom species found during the rainy and dry seasons

	Habitat	
	Ligneous	**Terrestrial**
Rainy season	29	43
Dry season	14	10
Both seasons	39	15
Jaccard's similarity index	0.4756	0.2206

Table 6. Occurrence of mushroom carpophores in the ligneous habitat

Mushroom identity	**RS**	**DS**	**T**
Amanita bisporigera	300	269	569
Amanita solitaria	6	3	9
Anthrodiella hoehnelii	0	7	7
Auricularia auricula-judae	1177	1843	3020
Auricularia polytricha	13	57	70
Cantharellus cibarius	78	137	215
Clavariadelphus junceus	1469	0	1469
Clitocybe sp.	44	0	44
Coprinus disseminatus	7675	498	8173
Coprinus lagopides	70	132	202
Coprinus lagopus	16	0	16
Coprinus plicatilis	0	4	4
Coprinus sp.1	0	6	6
Cortinarius paleaceus	1452	1629	3081
Crepiotus mollis	0	14	14
Cyathus striatus	0	26	26
Dacrymyces sp.	586	0	586
Daldina concentrica	16	16	32
Dichomitus campestris	3	0	3
Ganoderma applanatum	6	3	9
Ganoderma resinaceum	39	29	68
Gleophyllum sepiarium	0	1	1
Hapalopilus nidulans	0	158	158
Hericium abietis	78	121	199
Heterobasidion annosum	2	2	4
Hydnellum peckii	71	6	77
Hydnum sp.	137	80	217
Hypoxylon fragiforme	23	38	61
*Hypoxyl*on sp.	28	44	72
Inonotus hispidus	7	31	38
Inonotus radiatus	45	32	77
Lactarius obscuratus	9	0	9
Lentinus subnudus	1011	407	1418
Lenzites betulina	119	210	329
Lepiota ventriosospora	24	0	24
Lycoperdon echinatum	15	0	15
Lyophyllum loricatum	6	0	6
Marasmiellus candidus	2081	2910	4991
Marasmius sp.1	22	0	22
Marasmius sp.2	0	67	67
Marasmius wynnei	12	0	12
Marasmius ramealis	1099	749	1848
Mycena galericulata	1	0	1
Mycena inclinata	426	0	426
Mycena maculata	0	137	137
Mycena sp.1	32	0	32
Mycena sp.2	279	2	281
Mycena tortuosa	13	0	13
Mycena vitilis	1421	721	2142
Nidularia farcta	67	78	145
Nolanea cetrata	168	0	168
Oxyporus populinus	26	0	26
Panaeolus foenisecii	23	0	23
Panaeolus semiovatus	9	0	9
Peziza aurantia	290	51	341
Phellinus igniarius	2	0	2
Piptoporus betulinus	1	0	1
Pleurotus florida	27	9	36
Pleurotus lignatilis	129	100	229
Pleurotus ostreatus	3	0	3
Pleurotus pulmonarius	0	78	78
Pluteus salicinus	1	5	6
Polyporus floccipes	3	0	3
Polyporus sp.	231	0	231
Polyporus varius	6	0	6
Psathyrella marcescibilis	0	1	1
Schizophyllum commune	3408	7329	10737
Schizopora paradoxa	15	33	48
Scleroderma areolatum	10	0	10
Sterum complicatum	22	20	42
Sterum hirsutum	9	20	29
Stereum sp.	3	0	3
Termitomyces sp.	0	2	2
Termitomyces striatus	0	3	3
Trametes ochracea	274	146	420
Trametes pubescens	18	20	38
Trametes versicolor	56	47	103
Trichoglossum hirstum	41	0	41
Tricholomopsis sp.	0	7	7
Tuber excavatum	5	0	5
Xylaria hypoxylon	1515	1178	2693
Xylaria longipes	3036	2372	5408
Total	29309	21888	51197

Note: Legend: RS – Rainy season; DS – Dry season;T – Total

Table 7. Occurrence of mushroom carpophores in the terrestrial habitat

Mushroom identity	RS	DS	T
Agaricus impudicus	0	20	20
Agaricus semotus	55	0	55
Agaricus silvicola	35	0	35
Amanita cokeri	4	17	21
Amanita muscaria	1	0	1
Amanita parcivolvata	0	6	6
Amanita phalloides	20	11	31
Amanita virosa	1	0	1
Cantharellula umbonata	6	31	37
Clavatia excipuliformis	1	1	2
Clitocybe nud	2	0	2
Clitopilus prunulus	6	0	6
Collybia distorta	0	9	9
Collybia erythropus	24	0	24
Collybia maculate	16	0	16
Collybia palustris	0	6	6
Collybia sp.	51	0	51
Coprinus palustris	0	1	1
Coprinus sp.2	24	22	46
Coprinus sp.3	1	1	2
Dictophora duplicata	8	0	8
Hygrocybe cantherelus	235	0	235
Hygrocybe conica	1	0	1
Hygrocybe miniata	31	0	31
Hygrocybe nigrescens	2	0	2
Hygrocybe vitellina	485	0	485
Hypholoma capnoides	17	0	17
Inocybe fastigiata	2	5	7
Laccaria laccata	375	0	375
Lactarius deliciosus	1	0	1
Lepiota adulterine	4	0	4
Lepiota felina	13	0	13
Lepiota konrandi	1	0	1
Lepiota mastoidea	13	0	13
Lepiota pseudohelveola	10	0	10
Leucocoprinus birnbaumii	2	0	2
Leucocoprinus brebissonii	0	5	5
Lycoperdon spadiceum	1	0	1
Macrolepiota procera	56	14	70
Marasmius epiphyllus	32	0	32
Marasmius sp.3	24	0	24
Marasmius sp.4	33	0	33
Marasmins sp.5	125	0	125
Micromphale brassicolens	0	2	2
Micromphale foetidum	420	0	420
Mycena acicula	3	0	3
Mycena aetitis	3	0	3
Mycena alcalina	1	0	1
Mycena crocata	12	21	33
Mycena galopus	78	9	87
Mycena haematopus	67	0	67
Mycena interrupta	69	0	69
Mycena monticola	760	0	760
Mycena pearsoniana	43	0	43
Mycena sanguinolenta	0	362	362
Panaeolina foenisecii	11	3	14
Pleurotus tuber-regium	20	8	28
Suillus sp.	16	0	16
Termitomyces aurantiacus	442	0	442
Termitomyces bulborhizus	4	0	4
Termitomyces letestui	202	0	202
Tricholoma inocybeoides	84	34	118
Tricholoma sp.	0	1	1
Tricholoma sulphureum	0	1	1
Tricholoma ustale	82	49	131
Tricholoma vaccinum	3	8	11
Tricholomopsis decora	3	0	3
Volvariella speciosa	1	0	1
Total	4042	647	4689

Note: Legend: RS – Rainy season; DS – Dry season; T – Total

Likewise, in the terrestrial habitat, *Amanita cokeri*, *Cantharellula umbonata*, *Mycena crocata* and *Tricholoma vaccinum* had more carpophores in the dry season (Table 7). Whereas *Schizophyllum commune* recorded the highest carpophores in the ligneous habitat (10,737), it was *Mycena monticola* in the terrestrial habitat (760) (Table 6-7). Overall, the total frequency of mushroom carpophores was generally higher in the rainy than dry season in both habitats (Table 6-7).

Correlations among monthly climatic data, mushroom species richness and relative abundance

The result obtained shows strong significant relationship among species richness, relative abundance of mushrooms in the terrestrial ($r = 0.829$; $p = 0.000$) and ligneous ($r = 0.679$; $p = 0.011$) habitat. Average monthly precipitation correlated strongly with relative abundance of mushroom carpophores in the terrestrial habitat ($r = 0.7018$, $p = 0.024$) and number of rainfall per month ($r = 0.730$; $p = 0.011$). Also, average monthly relative humidity correlated strongly with average monthly temperature ($r = -0.668$; $p = 0.013$), number of rainfall per month ($r = 0.952$; $p = 0.000$) and average monthly precipitation ($r = 0.689$; $p = 0.019$) (Table 8).

Discussion

Forest structure including degree of tree cover, humidification of soil, nature of substratum, acidity of soil and favorable environmental condition are pivotal to the growth, development and diversity of mushrooms in the biological world (Straatsma et al. 2001; Odeyemi et al. 2014; Djelloul and Samraoul, 2011; Johnsy et al. 2011). In the present study, the 151 mushrooms identified have been widely reported in India (Dwivedi et al. 2012; Pushpa and Purushothama 2012; Vyas et al. 2014), Bangladesh (Rashid et al. 2016; Rumainul and Aminuzzaman 2016), Cameroon (Andrew et al. 2013), Algeria (Djelloul and Samraoui 2011), Switzerland (Straatsma et al. 2001) and Mexico (LaRochelle and Berkes 2003).

In Nigeria, Zoberi (1973), Oso (1975, 1977a, b), Alofe (1985), Gbolagade et al. (2006), Ezeibekwu et al. (2009), Oyetayo (2009, 2011), Okhuoya et al. (2010), Adedayo (2011), Ayodele et al. (2011), Nwordu et al. (2013) had earlier reported mushrooms in the genera *Agaricus*, *Amanita*, *Auricularia*, *Clavatia*, *Collybia*, *Coprinus*, *Daldina*, *Dictophora*, *Ganoderma*, *Lactarius*, *Lentinus*, *Lepiota*, *Lycoperdon*, *Pleurotus*, *Psathyrella*, *Schizophyllum*, *Termitomyces*, *Tricholoma, Volvariella* and *Xylaria*. This is the first time mushrooms in the genera *Anthrodiella*, *Cantharellula*, *Cantharellus*, *Clavaria-delphus*, *Clitocybe*, *Clitopilus*, *Coriolus*, *Cortinarius*, *Crepiotus*, *Cyathus*, *Dacrymyces*, *Dichometus*, *Gleophyllum*, *Hapalopilus*, *Hericium*, *Heterobasidion*, *Hydnellum*, *Hydnum*, *Hygrocybe*, *Hypholoma*, *Hypoxyl*on, *Inocybe*, *Inonotus*, *Laccaria*, *Lenzites*, *Leucocoprinus*, *Lyophyllum*, *Maramiellus*, *Marasmius*, *Micromphale*, *Mycena*, *Nidularia*, *Nolanea*, *Oxyporus*, *Panaeolina*, *Peziza*, *Phellinus*, *Piptoporus*, *Pluteus*, *Polyporus*, *Schizopora*, *Scleroderma*, *Stereum*, *Suillus*, *Trametes*, *Trichoglossum*, *Tricholomopsis* and *Tuber* are reported.

Table 8. Correlations among monthly climatic data, mushroom species richness and relative abundance

		1	2	3	4	5	6	7
1	Species richness	1						
2	Relative abundance of mushrooms in the terrestrial habitat (%)	0.829** (0.000)	1					
3	Relative abundance of mushrooms in the ligneous habitat (%)	0.679* (0.011)	0.434 (0.138)	1				
4	Average monthly temperature	-0.148 (0.630)	-0.054 (0.861)	0.009 (0.977)	1			
5	Number of rainfall (d) per month	0.555 (0.076)	0.479 (0.136)	0.205 (0.546)	-0.542 (0.085)	1		
6	Average monthly precipitation (mm)	0.466 (0.148)	0.716* (0.013)	-0.089 (0.794)	-0.353 (0.287)	0.730* (0.011)	1	
7	Average monthly relative humidity (%)	0.534 (0.060)	0.453 (0.120)	0.467 (0.107)	-0.668* (0.013)	0.952** (0.000)	0.689* (0.019)	1

Note: Values in parenthesis are p-value of correlation coefficient

Majority of wild mushrooms are found on variety of organic substrates in ligneous and terrestrial habitats where they obtain nutrients for growth (Gbolagade et al. 2006; Johnsy et al. 2011, Nwordu et al. 2013). In the current study, a high occurrence of wild mushrooms was recorded in the ligneous compared to terrestrial habitat and their symbiotic association (Figure 4). This could be attributed to the abundance of woody substrates and their colonization with mushroom mycelia that are mostly saprophytic. Mushrooms can secrete hydrolytic and oxidative extracellular enzymes that digest lignin and cellulose present in the substrates into smaller organic compounds or minerals into usable forms (Altaf et al. 2010; Odeyemi et al. 2014). Similarly, the high prevalence of terrestrial mushrooms on soil debris (79.41%) (Figure 6) indicates presence of simple organic matter and massive mycelia colonization of the underground soil. Mushroom develop from undisturbed interwoven web of hyphae called mycelium, which often time is buried in or found on the substrate where it derives its nourishment (Wilkinson and Buezaeki 1982; Ramsbottom 1989; Adedayo 2011). Also, association of *Termitomyces* species with termite mound or nest was noted by other researchers (Gbolagade 2006; Johnsy et al. 2011).

Previous investigations have documented association of some mushrooms with a particular genus or family of trees (Arora 2008; Karwa and Rai 2010), suggesting mushroom substrate specificity. In this study, quite a high percentage of the observed mushrooms (about 72%) were associated with single substrate and about 15% with two or three substrates (Table 1) revealing that all mushrooms are not substrate-specific.

Spore dispersal is crucial for sustainability of mushroom in nature. During the reproductive stage in the life cycle of mushrooms, spores are released from blown out mushroom carpophores and settle on substrates where it establishes its mycelium and continues the cycle (Odeyemi et al. 2014). The growth of mushrooms on erect dead trees 5 feet above ground (Figure 7) revealed that some mushroom spores might be carried up in the air by current, settles on and colonize suitable wood substrate which can support their growth. Flying insects, pecking birds and crawling animals carrying mushroom spores might also be agent of dispersal (Abbott 2002; Lilleskov and Bruns 2005; Viljanen-Rollinson et al. 2007).

The ranges of temperature (from 23 to 28°C), precipitation (from 0.00 to 16.85 mm) and high relative humidity (from 78.9 to 96.1%) (Table 2) observed in this study fell within the established limits that support the growth of mushrooms (Odeyemi et al. 2014). However, the temperature and rainfall range slightly differ compared to the report of Straatsma et al. (2001) on the biodiversity of fungal carpophore in a Swiss forest plot over 21 years regime. They reported a temperature range of 16.1 to 20.6°C yearly and a range of 285.5 to 636.3 mm precipitation yearly on an average of 6 to 10 months. The occurrence of mushrooms in all the months of study showed their ready availability all-year-round at ENPOST forest. This is in agreement with the report of Adedayo (2011) who also noted the growth of mushrooms throughout the year.

Mushroom diversity expressed as species richness, relative abundance in ligneous and terrestrial habitats reveals the dynamic nature of mushrooms between months, habitats and seasons. Species richness peaked in May (66), September (62) and October (70) 2014 with corresponding high mushroom relative abundance, 45.35, 12.22 and 24.54%, in the terrestrial habitat, compared to the ligneous counterpart (Table 3). The boom of mushroom in May align with the report of Nwordu et al. (2013) who stated that highest occurrence of mushroom falls between April and June. Other diversity indices including dominance, species diversity, evenness and Jaccard's index give insight into preponderance, degree of representation and possible overlap of species and environmental stability in the forest (Kindt and Coe 2005). Dominance index indicated that more species dominated in the terrestrial habitat comparable to the ligneous habitat. The high species diversity index in ligneous (3.912) and terrestrial (3.304) habitats (Table 4) infer a more stable and less disturbed environment during rainy season; albeit, the community was more stable. Similarly, the high evenness index in the terrestrial habitat (0.581) indicated that species occurring during the dry season are common and abundant. Jaccard's index also revealed that more species of mushrooms occurred both in the rainy and dry seasons in ligneous habitat than the terrestrial.

A diverse mushroom community observed at ENPOST forest may not be a true representation of all the mushrooms present as some mycelia remain dormant underground or in their substrate until there is a prevailing environmental condition favorable for its growth (Adedayo, 2011; Andrew et al. 2013). Adequate moisture and water holding capacity of growth substrate are key factors to be considered for mushroom development (Ayodele et al. 2011; Tibuhwa et al. 2011; Bellettini et al. 2016). In this study, mushrooms found during rainy season were higher than dry season (Table 5). In the same vein, frequencies of carpophore obtained suggest that moisture requirement for the mushrooms differ, i.e., species can grow either under high, low moisture availability or both (Tables 6, 7). The present findings also reveal that monthly precipitation correlated significantly with relative abundance of mushrooms in the terrestrial habitat.

In conclusion, different mushroom species are still relatively abundant in Nigeria due to prevailing environmental and climatic conditions and copious availability of growth substrates which support their growth. The ecology, biodiversity and seasonal distribution of wild mushrooms at ENPOST forest were studied. Our study revealed for the first time in Nigeria a total of one hundred and fifty-one different mushrooms, a good representative of Nigeria's rich mushroom flora, which can be of diverse human and biotechnological benefits if properly harnessed. However, it should be noted that these bioresources are gradually going into extinction as a result of human activities such as deforestation, bush burning, use of pesticides and herbicides, urbanization and climate change. Hence, need for their urgent preservation and sustainability is advocated.

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