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Diversity and Ecology of Wild Mushrooms of Riparian Zone of Lake Kivu, Rwanda

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Abstract

Mushrooms are among the most diverse group of living organisms on earth, though inadequately studied worldwide. The objective of this study was to assess the diversity and distribution of mushroom species in riparian zone of Lake Kivu in order to develop a baseline helping for further studies on fungi in Rwanda. The diversity and distribution of mushroom species were studied by plot-based mushroom surveys in Mariri, Mpangara and Nyakarwa sites while a simple random search was used in the garden of the Museum, in different seasons from September 2016 to June 2019. Species similarity between sites was determined using the Sorenson's coefficients and Chao 2 estimator was used to estimate species richness. Among species collected, Agaricales (81%) is the dominant order in this zone. The total order/family ratio of 0.31, family/genus ratio of 0.65 and genus/species ratio of 0.63 is an indicator of high family and generic diversity in the collections. Most species were recorded in Nyakarwa Forest and Sorenson similarity matrix showed dissimilarity richness and distribution of mushroom species between sites. The diversity and distribution of species are related to habitat structure variability and species richness decreases from forest to grassland.

Keywords: Mushrooms, diversity, ecology, Lake Kivu, riparian zone.

Introduction

Fungi is one of the largest group of organisms on Earth. Even if fungi species are widely distributed in all ecosystems, the distribution of species, phyla, and functional groups has been poorly documented[1]. It is estimated that the total number of fungal species is between 2.2 and 3.8 million, but so far only 144,000 species are named and classified[2]. The most described species are in temperate regions; the tropical region which is undoubtedly hosting the highest fungi diversity has been inadequately sampled and scarcely documented[2-4]. In 2017 e.g., there were about 2189 new species described but only 4% are from Africa[2]. Regardless of the lack of enough research data, mushrooms constitute a significant part of terrestrial ecosystems, forming a large share of the world biodiversity richness and are key-players in ecosystem processes[5,6]. Nevertheless, mushrooms are currently highly threatened by habitat loss, pollution, over-exploitation and climate change[7,8]. Although the taxonomic knowledge of fungi is very incomplete and their ecological distribution has not yet been well studied in Africa, the preliminary observations on the taxonomic diversity and ecology have shown that Tropical Africa including Central and East African regions host a big number of mushroom species[8–10]. Moreover, this region hosts ectomycorrhizal genera whose representatives are completely endemic of tropical Africa, e.g. *Lactarius* and *Russula*[11]. Despite that mycological richness, according to our knowledge, only one research study on diversity and ecology of mushrooms was conducted in Rwanda. That is the study of Degreef et al[8] and it only focused on edible species and was restricted to montane forest ecosystems. According to Egbe Enow et al[12], mushrooms are not taken into consideration in many research works due to their largely hidden nature and frequently sporadic and short-lived sporocarps. In Rwanda and in the Albertine rift region, fungi have always been forgotten or ignored in biodiversity surveys and are not included in any scientific report on biological diversity. Riparian zones and islands of Kivu Lake, are ones of remnant natural habitats which are not yet included in biodiversity conservation policy in Rwanda while their species richness is high and particular[13,14]. The biodiversity survey revealed that this area constitutes a refugee area of damaged zones of the mainland and is home to different species which some of them having a particular status of being endemic or endangered[14]. In all biodiversity surveys done in this region, fungi were not considered while it is known that distribution of many African fungi is linked to the contrast between open woodlands and dense forests[9,15,16]. Based on habitat structures found in riparian zone of Kivu lake, those different vegetation types are expected to host mushroom species related to different habitat structures and ecological requirements. Thus, it is highly imperative to assess fungal diversity and species composition of this zone and to identify factors that influence species distribution in different habitats.

Materials and methods

Description of study sites: The riparian zone of Lake Kivu constitutes one of ecological habitats of the Albertine Rift region in western province of Rwanda and an area of high endemism hosting threatened species[17]. Lake Kivu is located at the topographic high point of the western branch of the African Great Rift Valley (Figure-1), at 1463m above mean sea level[18] and receives annual rainfall from 1100-1200mm. The rainfall follows a bimodal cycle with two rain seasons (February to mid-May and September to December) and two dry seasons (mid-May to September and December to February). The mean annual temperature ranges between 18 and 20°C[19]. The vegetation type of Mpangara Island (2.57ha) and Mariri peninsula (3.12ha) is composed of riparian woodland layer of indigenous plant species followed upward by a shrub layer dominated by *Lantana camara* (that is invading the area), and savannah grassland. The land is characterised by rocky, shallow and dry soil. A mixture of indigenous trees and shrubs (*Euphorbia candelabrum, Harungana madagascariensis, Dodonea viscosa, Phoenix reclinata, Ochna holstii,…*) with a canopy of exotic species planted in this natural vegetation for seed production (*Casuarina equisetifolia, Eucalyptus* ssp. and *Jacaranda mimosifolia*) composes the vegetation of Nyakarwa forest located on a peninsula of 4 ha. The forest also shelters important indigenous herbaceous and bryophyte species. The land is characterised by rocky, shallow and dry soil but covered by a layer of litter in the big part of this area. The garden of the Museum is located at the shores of Lake Kivu. The whole area is almost covered by *Paspalum notatum,* but mixed with some exotic and local ornamental trees, shrubs and herbs that were planted in the garden.

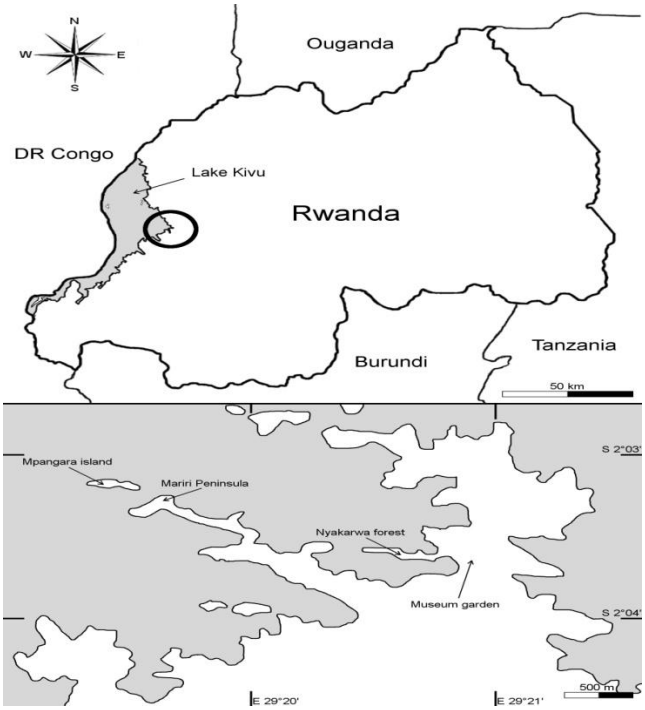

Figure-1: Site map of the study area.

Data collection and analysis: A reconnaissance survey was conducted during April-May 2016 to get an insight of the vegetation pattern and topography in order to locate sampling plots. A total of 18 plots (10mx10m), six from each site (Mariri, Mpangara and Nyakarwa), were established and sampled. Because the museum garden is very easy to survey, fruiting bodies were collected randomly all over during the study period. Plots were established randomly in each vegetation structure considering the accessibility of the site. This is the best method in areas with stratified vegetation structure allowing the collection of data on diversity and the comparison of abundance and diversity between habitat structures[20–22]. The plots were surveyed using presence-absence of fruiting bodies in systematic placement for the coverage of plots as it is recommended by Lodge et al[23]; Hill et al[21] and Halme[6]. From September 2016 to June 2019, the survey was conducted on every plot twice a month. Fruiting bodies were collected, and each fresh specimen was described (size, shape, colour, hymenium). Specimens were separated into species and/or genus by identifying their characters according to the keys and reference guides[9,24–26]. Specimens collected were photographed, dried, and preserved using standard methods[24] and constitute the first samples of the national fungarium established in the National herbarium of Rwanda.

The species frequency was recorded and computed for each species. Species similarity between sites was determined using the Sorenson's coefficients and Chao 2 estimator was used for estimating species richness[21,27]. The relative dominance and relative density were calculated formulas followed [28].

$$\text{Relative frequency} = \frac{\text{Number of plots containing species x in Site n}}{\text{Total number of plots in site n}} X100$$

$$\text{Relative density} = \frac{\text{Number of species of family x in site n}}{\text{Number of species of all families in Site n}} X100$$

Table-1 shows the frequency classes used to designate the frequency status of each species in different study sites. The species frequency indicates the number (%) of plots in which the species has been recorded.

Table-1: Scales used in rating mushroom species frequency.

Scale	Rating	Description
1	Rare	Species with relative frequency ≤ 20%
2	Occasional	Species with relative frequency between 21% and 49 %
3	Frequent	Species with relative frequency between 50% and 74%
4	Abundant	Species with relative frequency ≥ 75%

Results and discussion

Species diversity within macrofungi: A total of 64 species were collected from all four study sites and belong to 8 orders, 26 families and 40 genera. Agaricales with 16 families and 52 species represent 81% of all species collected (Figure-2), and is the order dominant in this zone. The total order/family ratio of 0.31, family/genus ratio of 0.65, and genus/species ratio of 0.63 indicate high family and generic diversities in the collections. The families highly represented in collections with the most number of species are Agaricaceae (18 species), Tricholomataceae (10 species), Psathyrellaceae (5 species) and Strophariaceae (4 species). Those four families account for more than 50% of collected species. Table-2 shows the total number of families, genera, species and relative density of species collected in this study. The high frequency of Agaricaceae family in study sites is attributed to adaptability of the species of this family in tropical areas and this is in agreement with the results obtained from other studies in tropical areas[29–31]. The dominance of species of this family is due to their efficient dispersal mechanisms and adaptation to ecological conditions as they have ability to colonize various habitats such as grassland, woodland and forest[4,29]. Photographs of some of recorded species are presented in Figure-3.

Figure-3: Photographs of some of recorded species.
1. *Chlorophyllum hortense*, 2. *Collybia piperata*, 3. *Gymnopilus zenkeri*, 4. *Lentinus brunneofloccosus*, 5. *Macrolepiota africana*, 6. *Macrolepiota procera*, 7. *Marasmius arborescens*, 8. *Parasola plicatilis*, 9. *Schizophyllum commune*, 10. *Suillus granulatus*, 11. *Termitomyces medius*, 12. *Termitomyces microcarpus*.

Table-2: Total number of families, genera, species and relative density of species collected in this study. Relative density represents the number of species of each family compared to the number of all species recorded.

Family name	Number of Genera	Number of Species	Relative density %
Agaricaceae	7	18	28.13
Amanitaceae	1	1	1.56
Bolbitiaceae	1	1	1.56
Boletinellaceae	2	2	3.13
Cantharellaceae	1	1	1.56
Entolomataceae	1	1	1.56
Ganodermataceae	1	1	1.56
Geastraceae	2	2	3.13
Gomphaceae	1	1	1.56
Hygrophoraceae	1	1	1.56
Hygrophoropsidaceae	1	1	1.56
Inocybaceae	1	1	1.56
Lyophyllaceae	1	3	4.69
Marasmiaceae	1	2	3.13
Mycenaceae	1	1	1.56
Nidulariaceae	1	1	1.56
Pleurotaceae	1	1	1.56
Pluteaceae	1	1	1.56
Polyporaceae	1	1	1.56
Psathyrellaceae	2	5	7.81
Repetobasidiaceae	1	1	1.56
Russulaceae	1	1	1.56
Schizophyllaceae	1	1	1.56
Sclerodermataceae	1	1	1.56
Strophariaceae	2	4	6.25
Tricholomataceae	5	10	15.63

Species distribution and ecology: Among the study sites surveyed, significant high number of species was collected in Nyakarwa Forest, where 40 species belonging to 18 genera in 16 families were recorded. Mariri follows Nyakarwa forest in species richness with 26 species belonging to 18 genera and 16 families (Figure-4). The high level of Nyakarwa fungal diversity may be attributed to its closed canopy and biodegrading ability of many recalcitrant substrates found in that forest. This result is in agreement with Verbeken & Buyck[16], Gómez-Hernández & Williams-Linera[32] and Sandhya et al.[31] that have highlighted the correlation of these ecological features with mushroom abundance in their study sites. The highest number of mushroom species of Nyakarwa and Mariri was collected on organic materials including decomposing plant litter and decaying shrubs (*Chlorophyllum hortense, Clitocybe* sp., *Collybia piperata, Cyathus stercoreus, Lentinus brunneofloccosus, Macrolepiota africana, Macrolepiota procera, Marasmius arborescens, Parasola plicatilis, Volvariella volvacea*, ...). Only 6 species were collected in the grassland habitat, *Cotylidia aurantiaca, Gymnopilus zenkeri, Parasola plicatilis, Phlebopus sudanicus, Pholiota* sp., and *Schizophyllum commune.* Three *Termitomyces* species were also collected (*Termitomyces medius, T. microcarpus* and *T. robustus*). The record of *T.medius* in the study site might be the first record in East Africa. The lowest species richness of Mpangara Island could be due to its isolation from mainland.

The distribution of mushroom species in study sites are relatively little similar, with Sorenson's similarity indexes ≤ 0, 39. The mushroom species collected in Nyakarwa Forest are distributed in other three study sites with Sorenson's similarity index of 0.36 and 0.39. The similarity of Nyakarwa and other sites should be attributed to the fact that this site represents ecological features of Kivu riparian zone and most species distributed in different sites of this zone are present in Nyakarwa Forest. The sites which are very dissimilar are Mpangara and Mariri, with a similarity index of 0.11 (Table-3).

Table-3: Sorenson's similarity matrices for species distribution in study sites

	Nyakarwa	Mariri	Mpangara	INMR Garden
Nyakarwa	1			
Mariri	0.39	1		
Mpangara	0.36	0.11	1	
INMR Garden	0.36	0.24	0.16	1

The difference in species richness between Mpangara Island and Mariri Peninsula is somewhat surprising because the structure of the natural vegetation of these two habitats is very similar. The dissimilarity in species richness may be caused by the isolation from mainland of Mpangara as it is an island while Mariri is a peninsula. This assumption is supported by previous results showing the effect of isolation on the distribution and abundance of species. Peay et al.[33], Henson et al.[34] and Jones et al.[35] have highlighted that isolation decreases species richness by reducing the number of potential colonists dispersing into an area and as consequence many islands lack species common on the mainland while they can support other species in great abundance, or harbour species largely restricted to islands given their land area.

In all study sites, occasional species made most of the collection and the distribution of dominant species were very low (Figure-5). The fact that most species recorded are ranged from rare and occasional species indicates that species distribution varies with vegetation structure. More species were collected in plots located in forest (Figure-6). On the other hand, the methodology used, surveying twice a month, did not lead to the missing of many records even the fructification of most mushroom species occurs at different times, the value of the Chao2 estimator calculated (64+3.6) was moderate. Most of the species were recorded in forest habitat, followed by woodland, garden and finally grassland. Most species recorded are saprotrophic and were recorded in plots with dead organic materials, decomposing plant litter and decaying wood.

In this study, a large number of records were correlated with precipitation. The most species were recorded and collected in November and December in the first rainy season (Agricultural season A) and in April and May in the second rainy season (Agricultural season B) (Figure-7). Comparing two rainy seasons, most mushroom collections were observed in November-December than in March-May.

Conclusion

The present study is an attempt to provide a preliminary picture of mushroom diversity in Rwanda, especially of riparian zones of Kivu Lake, and occurring in diverse natural habitat including woodland, grassland savannah and riparian forest. The list of mushrooms species collected and recorded in this study provides a baseline of information for further assessment on macrofungal diversity of the country. Record of the rare *Termitomyces medius* only known from Benin, DR Congo, Togo and Zambia [26] is also an additional record to the survey of edible mushrooms of Rwanda. The distribution of species in study sites, has led to think about several viewpoints to consider as main causes of unequal distribution and dissimilarity in species richness between sites. The diversity of habitat structure has the strongest impact on mushroom species richness and distribution in surveyed sites. The habitat structure influences the quality of substratum then the mushroom diversity according to species ecology.

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