Ecology of Edible Indigenous Mushrooms of the Lake Victoria Basin (Uganda)

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Abstract: The present study was conducted between (October, 2004) and (June, 2005) in two parishes of Kyebe Sub County in Rakai District located in the Lake Victoria Basin, Southwest of Uganda and west of Lake Victoria. The objective of the study was to assess the relationship between mushroom species occurrence, environmental factors and different vegetation types. Ten 1000 m² plots were established in each of three vegetation types (grassland, forest and garden) from where mushroom species and trees were assessed. Physical and chemical soil properties as well as canopy were determined in the sample plots. A total of 4,077 individual mushrooms belonging to 5 genera and 10 species were recorded in the plots. Three individuals that could not be identified were assigned to morpho species. Mushroom diversity and evenness were highest in the grassland while dominance was highest in the forest. Pluteus sp was found occurring only in the grassland, Agaricus sp 2 and K/K04/NI were found in the garden while three species (Termitomyces sp 1, Podabrella microcarpa and Agaricus sp 1) were found in all vegetation types. Termitomyces sp 1 and Pluteus sp were significantly correlated with some of the measured environmental factors. Indigenous edible mushrooms are an important aspect of ecology. The integrity of the grasslands should be protected to promote mushroom conservation. Field studies on mushroom species in this area in the future should target the rain season between September and December.

Key words: Mushroom ecology, mushroom diversity, mushroom distribution

INTRODUCTION

Mushrooms are fleshy conspicuous macrofungi that have provided food for millennia and are in many societies associated with potentiates and royalty because of their pleasant taste and flavour (Iga, 1978; Chang and Miles, 1989; Chang and Mshingeni, 2001; Sadler, 2003; DaSilva, 2005). Many societies have passed down knowledge on mushrooms from one generation to another. In China this knowledge has been the focus of research and constitutes what today is known as traditional Chinese medicine (Sadler, 2003; DaSilva, 2005).

The ecology of plants and animals is crucial in utilisation of resources. The ecology of fungi has not been extensively studied compared to their vascular plant counterparts though some studies have been carried out such as Bergmann and Largent (2000) as well as Bergius and Danell (2000). In Europe there is evidence showing that fungi are disappearing at distressing levels (Jerome, 1992; Eef, 1995). This has prompted increased research efforts and development of conservation action plans for selected fungi (Newton et al., 2003). Among the fungi, scientific research has mainly focused on mycorrhizae (Bergemann and Largent, 2000; Dahlberg, 2001; Kernaghan et al., 2003). There have been a few studies on community ecology (Packham et al., 2002) and relationships with environmental variables (Zamora and Cecilia, 1995) of macrofungi. Studies have also been done on polyopes at a community level (Ureelay and Robledo, 2004).

Since many biologists (Stamets, 2000) view mushrooms as indicator species, the first to fall leading to the failure of forest life support systems, data on their diversity in different vegetation types is important for planning and managing ecosystem biodiversity. In Uganda biodiversity has been documented for many

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localities including the Sango bay and Albertine rift (Pomeroy, 1993; Fuller et al., 1995; Bakamwesiga, 1998; Eilu et al., 2003; 2004a and 2004b). In the Sango bay for example, species lists do not include the fungi but cover flowering plants, insects, fish, amphibians, reptiles, birds and mammals (Fuller et al., 1995). Information on species richness and diversity of mushrooms is limited or is lacking in Uganda. Several questions are unanswered: for example, are the mushrooms occurring in specific vegetation types? Are the mushrooms influenced by environmental factors such as canopy cover and soil properties? Such information is required to design conservation strategies for indigenous mushroom species.

MATERIALS AND METHODS

Description of study area: The study was conducted in Rakai district (Fig. 1) in the southwestern region of Uganda, west of Lake Victoria between 31° 28' to 32° 43'E and 0° 47' to 1° 00'S. It is bordered by Masaka district in the north and northeast, Kanyanga district in the southeast, Mbarara district in the west and northwest, and the Republic of Tanzania in the south. The area is about 4,989 km² out of which, 1,089 Km² consists of water bodies (NEMA, 1998). This study was carried out in Kakuuto County, Kyobe Sub County (Fig. 2).

Climate: Kyobe sub-county lies in a modified equatorial climatic zone with high temperatures and heavy rainfall almost all year round. A relatively dry season occurs in January and February and another in June, July and August. A principal rainfall peak occurs in March, April and May, with the minor peak occurring in October and November. The mean annual recordings for maximum temperatures and rainfall are 25°C and a variation of 1,350 to 2,125 mm, respectively with a mean annual minimum temperature of 17.5°C (NEMA, 1998).

Geology and soils: Over 75% of the soils are ferrallitic with little or no mineral reserves left. Some heavy clay varieties have moderate fertility but sandy varieties are poor. Other types include lithosols, alluvial and lacustrine sands, and alluvial clays. Lithosols and loams are the dominant upland components while the gray sandy soils (derived from hill wash or river alluvium), gray clays of the valley bottoms and lacustrine sands dominate the lowland components. The soils are classified into four soil catenas and four soil series. The Sango series covers the whole of Kyobe (NEMA, 1998).

Fig. 1: The location of Rakai district in Uganda showing the demarcation of Kyobe sub county within the district, the districts bordering it and Kampala. (Source: Makerere University Institute of Environment and Natural Resources-MUIENR)

Flora: The vegetation of Rakai district varies from the medium altitude forests on the shores of Lake Victoria, through swamps, to savanna grasslands. The forests are mainly found in the Sango Bay area in the southern part of the district at the mouth of the Kagera river floodplain. They occupy part of the Kagera river floodplain, and are surrounded by swamp and seasonally flooded grassland communities. The canopy is generally lower than that of medium altitude mixed evergreen forests, although many of the component species are the same. Two tree species (Cordia millenii Bak. and Irvingia gabonensis (Aubry-Lecomte O’Rorke) Baill.), in these forests are listed on the International Union For Conservation of Nature (IUCN) Red lists as endangered (NEMA, 1998).

Study sites: Ecological studies were carried out in Kanabulemu parish of Kyobe sub county because it was more representative of the vegetation characteristics the study intended to incorporate. Ten plots of 50×20 m (0.1 ha) were established in grasslands and gardens while in the forest ten 5×200 m (0.1 ha) strip plots were used in order to facilitate the search for mushrooms. In total each of the vegetation types had an area of 1-ha. Wetlands were not sampled because edible mushrooms are not known to grow in such habitats (Hobbs, 1995).

The grasslands are dotted with many termite mounds and Phoenix reclinata Jacq. palms. The most common grass is Loudetia kagerensis although Themeda sp. and
Cymbopogon sp. also occur. The gardens are tilled using traditional agricultural techniques and family labour in smallholder farms. The most common crops are Phaseolus vulgaris, Musa sp., Ipomoea batatas, Zea mays and Mannihot esculentum. The forests have been encroached upon and degraded for timber especially, resulting in many forest gaps. Encroachment for agriculture is mainly around the forest edges. Trails also exist within the forests leading to sites where swamp forest fishery is done. Twenty five percent of the canopy cover is formed by Bactaea sp. (NEMA, 1998; Rodgers et al., 2002).

Ecological studies

Assessment of edible mushrooms: Mushrooms were assessed for 2 weeks a month for a period of eight months. Edible fruit bodies were identified by the local people in the field using local names, collected (as in Härkönen et al., 1995) and counted by species. The total number of mushrooms in each plot were used for calculating alpha diversity. Gregarious mushrooms were counted in plots of 1m² and extrapolated to obtain values for the 0.1Ha plot. Growth habits of mushrooms were recorded as solitary (all by themselves), scattered (grouped, 30 cm to 60 cm apart), gregarious (growing close together in groups not clusters), or esposite (growing in aggregated tufts, but tufts not growing together). Smith and Weber (1980) and Menser (1996).

Taxonomic identification was done in the Department of Botany Makerere University. Morphological characteristics (Härkönen et al., 1995) and spore print (using a white and black background cardboard. Fischer and Brown (1992) was determined for each mushroom species to aid identification. Mushrooms that could not be identified were assigned to morphor species.

Trees: Trees with diameter at breast height (DBH or 1.3 m high) greater than 10 cm (Tuxill and Nabhan, 2001) were enumerated. Diameter was determined using a diameter tape. Specimens were collected and identified in the Botany Department Herbarium at Makerere University.

Environmental factors: The canopy cover in the plots was estimated by eye as described by Kent and Coker (1996) and categorised as: open (0-25%), slightly open (26-50%), slightly closed (51-75%) and closed (76-100%). One kilogram soil samples were collected at a depth of between 0 and 20 cm from each vegetation type in duplicates and analysed for pH, organic matter, exchangeable cations (sodium (Na), potassium (K), Calcium (Ca), Magnesium (Mg)), and texture. Soil analyses were done in the Faculty of Agriculture Soil Science Department of Makerere University using methods similar to Bergemann and Largent (2000). Total nitrogen and phosphorus were determined using the Kjeldhal method. The reaction involved total oxidation of organic matter after addition of H₂SO₄ acid to allow digestion. This was followed by distillation and titration (Okalebo et al., 1993). Exchangeable bases were extracted using NH₄OAC at neutral pH and exchangeable extracts determined using flame photometry (Na and K) and atomic absorption (Ca and Mg). Organic matter was estimated from organic carbon, which was determined, by a mixture of H₂SO₄ acid and K₂Cr₂O₇ (mg). After heating, residual Cr₂O₃ was titrated against Fe(NH₄)₂(SO₄) and the difference between the added and the residual K₂Cr₂O₇ gave the amount of organic carbon (Okalebo et al., 1993). Consequent multiplication of the organic carbon with a calculated constant gave the organic matter content. The Bouyoucos/Hydrometer method was used for analysing texture (Okalebo et al., 1993) of air-dried soil samples based on the proportion of different particle sizes. pH was measured using a pH meter in which the soil was mixed with deionised water in the ratio of 2:5:1 (Okalebo et al., 1993).

Data analysis

Diversity and ecology of mushrooms: The Fisher’s alpha, Simpson’s and Shannon’s (H') diversity indices (Ludwig and Reynolds, 1988; Magurran, 1988) and Evenness or Equitability (E), were calculated to determine mushroom species evenness and diversity in the different vegetation types. Total species richness was also estimated using
Table 1: Mushroom species richness and diversity in three 1-ha plots of three vegetation types in Kyobe sub-county

<table>
<thead>
<tr>
<th>Vegetation</th>
<th>Density</th>
<th>Species</th>
<th>Jack 1</th>
<th>Chao 1</th>
<th>H*</th>
<th>Fisher*’</th>
<th>E</th>
<th>Ds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grassland</td>
<td>1441*</td>
<td>8*</td>
<td>12*</td>
<td>10*</td>
<td>1.674*</td>
<td>1.095</td>
<td>0.726*</td>
<td>3.951*</td>
</tr>
<tr>
<td>Garden</td>
<td>1387</td>
<td>8*</td>
<td>16</td>
<td>8</td>
<td>1.540</td>
<td>1.166</td>
<td>0.669</td>
<td>3.871</td>
</tr>
<tr>
<td>Forest</td>
<td>1329</td>
<td>4*</td>
<td>5</td>
<td>4</td>
<td>0.179</td>
<td>0.533</td>
<td>0.077</td>
<td>1.072*</td>
</tr>
</tbody>
</table>

Indicates the highest value; Jack 1 and Chao 1 are estimators of total species richness; H*, Fisher’s alpha, and Ds are Shannon’s, Fisher’s alpha and Simpson’s diversity indices; E represents pielou’s evenness

Table 2: Abundance and distribution of mushroom species occurrence, growth habits and substrates in the different vegetation types

<table>
<thead>
<tr>
<th>Species</th>
<th>Grassland</th>
<th>Garden</th>
<th>Forest</th>
<th>Species density</th>
<th>Growth habit</th>
<th>Substrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agaricus sp1</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>31</td>
<td>Solitary/Scattered</td>
<td>Soil</td>
</tr>
<tr>
<td>Agaricus sp2</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>35</td>
<td>Solitary/Scattered in lines</td>
<td>Soil</td>
</tr>
<tr>
<td>K/K/04/E1</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>33</td>
<td>Scattered</td>
<td>Soil</td>
</tr>
<tr>
<td>K/K/04/N1</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>3*</td>
<td>Solitary/Scattered</td>
<td>Soil/Decomposing wood</td>
</tr>
<tr>
<td>K/K/04/N2</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>174</td>
<td>Gregarious</td>
<td>Soil</td>
</tr>
<tr>
<td>Pluteus sp</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>17</td>
<td>Solitary/Scattered</td>
<td>Soil</td>
</tr>
<tr>
<td>Podabrella microcarpa</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>622*</td>
<td>Gregarious</td>
<td>Soil</td>
</tr>
<tr>
<td>Termitomyces sp1</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>103</td>
<td>Solitary/Scattered</td>
<td>Soil, decomposing wood</td>
</tr>
<tr>
<td>Termitomyces sp 2</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>323</td>
<td>Cepeitose</td>
<td>Soil</td>
</tr>
<tr>
<td>Volvariella speciosa</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>17</td>
<td>Solitary/Cepeitose</td>
<td>Soil, decomposing wood</td>
</tr>
</tbody>
</table>

(+) indicates presence; (-) indicates absence; (*) indicates the highest and lowest density

the Jackknife estimate 1 and Chao 1 estimate. These calculations were done using the computer program Species Richness and Diversity (SDR) version 3.02 (Henderson and Seaby, 2002). The first order jackknife estimator of species richness, Jack 1 was calculated based on 0.1-hectare (0.1-ha) subunits of the 1-ha vegetation types.

Ordination: Detrended Correspondence Analysis (DCA) was carried out using the computer program CANOCO version 4.0 (Ter Braak and Smilauer, 1998) to determine species distribution in the sample plot (Jongman et al., 1987), and infer indirectly about how the species data can best be explained (based on 0.1-ha subunits of the 1-ha vegetation categories). Detrending was done by segments and the mushroom abundance data were log transformed after adding a constant of one to all the values because the logarithm of zero is undefined (Jongman et al., 1987). Species’ points were taken as the optimum of its unimodal response using Hill’s sealing. There were 25 active samples (5 samples had zero abundance and were eliminated) and 10 species.

Correlation analysis using the SPSS computer program version 8.0 (p<0.05) was used to determine correlation between mushroom species and tree species abundance in the plots. While Partial correlation was used to assess the correlation between measured environmental factors and the abundance of mushroom species.

RESULTS

Ecology of indigenous mushroom species
Species richness and diversity: A total of 4077 individual mushrooms were recorded comprising 10 species in six genera. The genera Termitomyces and Agaricus were represented by two species. The species Podabrella microcarpa had the highest density and K/K/04/N1 the lowest. The highest density of mushroom species was recorded in the grasslands (Table 1). The number of species ranged between 4 and 8/ha in the three vegetation types (Forest, Grassland and Garden).

There was a general reduction in species richness and diversity from the first to the second rain season. The density of mushrooms recorded in the first rains was 3,568 and 509 for the second. The total number of species, Jackknife richness estimate and Shannon diversity index for the first and second rain seasons were 10, 13, 1, 53 and 3, 5, 0,416 respectively. Podabrella microcarpa was most abundant during both the first and second rain seasons while K/K/04/N1 and Pluteus sp were least abundant during the two rain seasons, respectively.

The highest density, Jackknife and Chao estimates, Shannon’s and Simpson’s diversity indices, and evenness of mushroom species occurred in the grassland (Table 1). The garden had the highest Fisher’s alpha and the forest had the lowest values for all the species diversity and richness measures.

Three species (Termitomyces sp1, Podabrella microcarpa and Agaricus sp1) occurred in all the vegetation types while another three (Agaricus sp2, K/K/04/N1 and Pluteus sp) occurred in only one vegetation type (Table 2).

Factors influencing mushroom species distribution: DCA - biplot of species and sites (Fig. 3) show a distinct separation of sites between the different vegetation characteristics along the first axis (eigenvalue of 0.617 and length of 4.332 SD). Grassland plots occur at the left, garden plots at the center and forest plots at the right of the ordination diagram. The first four DCA axes explained 39% of the cumulative variance in the species data (Table 3). The third and fourth axes with eigenvalues less than 0.1 were less important in ecological terms and not considered further.
Table 3: Eigenvalues of the first four axes of Detrended Correspondence Analysis (DCA) of all plots and the amount of variance explained of the species data by the DCA axes

<table>
<thead>
<tr>
<th>Axes</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Total inertia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eigenvalues (DCA)</td>
<td>0.617</td>
<td>0.276</td>
<td>0.1</td>
<td>0.064</td>
<td>2.709</td>
</tr>
<tr>
<td>Lengths of gradient (DCA)</td>
<td>4.332</td>
<td>2.627</td>
<td>1.943</td>
<td>1.972</td>
<td></td>
</tr>
<tr>
<td>Cumulative percentage variance of species data (DCA)</td>
<td>22.8</td>
<td>33</td>
<td>36.7</td>
<td>39</td>
<td></td>
</tr>
<tr>
<td>Sum of all unconstrained eigenvalues (DCA)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2.709</td>
</tr>
</tbody>
</table>

Fig. 3: DCA ordination diagram of mushroom species data with species shown as black circles and plots represented by stars and labeled by their number.

Plu sp-Pluteus sp; Ter sp1-Termotomycyes sp1; Ter sp2-Termotomycyes sp2; Aga sp2-Agaricus sp2; El1-K/K/04/El; Aga sp1-Agaricus sp1; N1-K/K/04/N1; Pod mic-Podabrellea microcarpa; Vol spe-Volvariella speciosa; N2-K/K/04/N2.

Pluteus sp occurs at the left of the DCA ordination diagram while K/K/04/N1, Podabrellea microcarpa and Volvariella speciosa occur on the right. From the ordination diagram rank orders for different species can be predicted as follows: The rank order for Termotomycyes sp1 is plots 1, 19, 9, 30 and 4. Termotomycyes sp2 is plots 15, 16 and 6. Agaricus sp1 is plots 20, 10 and 17. Podabrellea microcarpa is plots 26, 23 and 21. Volvariella speciosa is plots 25, 27 and 28. It can be predicted that plot 12 and plots 20, 23 and 25 hardly have any species in common while sites closer to each other such as plots 23, 26 and 21 have one or more species in common.

The soils were generally acidic soil (pH ranging from 3.8 to 4.5 in the garden and grassland, respectively). Calcium (6.12 cmol kg⁻¹) and Magnesium (2.6 cmol kg⁻¹) were highest in the forest while Sodium (0.08 cmol kg⁻¹) and Organic Matter (5.67%) were highest in the grassland. Available Phosphorus (28.43 mg kg⁻¹) and Potassium (0.56 cmol kg⁻¹) were highest in the garden. The soils in this study can be classified according to the United States Department of Agriculture as Sandy clay loam soil in the garden, Sandy loam in the grassland and Clay loam in the forest.

Termotomycyes sp.1 was significantly correlated with pH (-0.4623), phosphorus (0.4943), canopy cover (-0.4117) while Pluteus sp. was significantly correlated with organic matter (0.4807), potassium (-0.4073), sodium (0.4895), sand (-0.025), magnesium (-0.4005) and clay (-0.4855). The rest of the other mushroom species did not show any significant relationship with the measured environmental variables.

Six hundred and seventy-five individual trees were sampled in the plots (10 in the garden, 11 in the grassland and 654 in the forest). They belonged to 28 families, 43 genera and 46 species. Euphorbiaceae and Syzygium guineense (Wild.) DC. were the most common family and species respectively. The grassland was represented by three species, the garden six species and the forest 40 species. Phoenix reclinata Jacq. (Palmae) occurred most in the grassland while Beilschmeda ugandensis Rendle, (Lauretaceae) S guineense, (Myrtaceae) and Spondanthus preussii Engl. (Euphorbiaceae) were the most frequent in the forest.

Five forest trees were found in all the plots with mushrooms. These were B. ugandensis, Spondanthus preussii, Syzygium guineense, Whitfieldia elongata (Beauv.) De Wild, α Th. Dur (Acanthaceae) and Pseudospondias microcarpa (A. Rich.) Engl. (Anacardiaceae).

Shannon's, Simpson's and Fisher's alpha diversities, Jackknife species richness estimate and Evenness for tree species were calculated and compared with the alpha diversities of mushroom species in the plots. The species diversity and evenness was higher for the tree species compared to the mushroom species. The respective indices for the tree and mushroom species were H' (2.884 and 1.552); D, (10.92 and 3.444); α (11.18 and 1.28); Jack 1 (60 and 12) and Evenness (0.7532 and 0.674). There was no correlational relationship (r = 0.06) between the mushroom species and tree species occurrence within the plots.

**DISCUSSION**

Mushroom species diversity recorded by this study are lower than what was observed in other studies that
have been carried out in Tasmania (Packham et al., 2002), Scotland (Newton et al., 2003) and Mexico (Zamora and Cecilia, 1995). In Mexico for example, 29 edible mushrooms were recorded in an area smaller than what was sampled by the present study.

The DCA-biplot did not easily separate the grassland plots (11-20) from the garden plots (1-10) because they had species in common. Pluteus sp. is more commonly found in grasslands as shown in the DCA diagram whereas Podabrella microcarpa is mainly in the forest vegetation type. Species such as Agaricus sp. 2 that lie at the edge of an ordination diagram have been described by Jongman et al., (1987) to be rare or have a preference of extreme environments. However, it could be that this species falls at the edge of its natural range in the environment therefore its occurrence is more unpredictable.

In the present study pH, phosphorus, canopy cover, organic matter, potassium, sodium, magnesium, sand and clay were significantly correlated with abundance of mushroom species. Zamora and Cecilia (1995) noted that sandy loam texture, low soil bulk density, high organic matter and pH were properties that stimulated the development of fungi. The importance of organic matter is due to its water holding capacity and nutrient availability (Bergemann and Largent, 2000).

Zamora and Cecilia (1995) noted that acid soils and high organic matter stimulated decomposition function of fungi over other micro-organisms such as bacteria and actinomycetes. The soils in the present study were generally acidic which is consistent with findings of Ahn (1993), as well as Syers and Rimmer (1994) for tropical regions.

Härkönen et al., (1995) and Packham et al., (2002) reported mushroom seasonality in Tanzania and Tanzania, respectively. This is consistent with the findings of the present study. Different species were recorded at different times of the year. Packham et al., (2002) suggested that the total number of species present in an area might not be found until after 5 years of sampling. Seasonality in the present study was between the first and the second rains. During the second rain season (March-may) some plots were flooded particularly in the forest. This probably explains the low diversity recorded during the second rain season. Zamora and Cecilia (1995) noted that variation in rainfall affected fungal production. Maximum fungal production generally coincided with a slight decrease in rainfall during months with the heaviest rains.

Mushroom distribution in other studies has been found to be influenced by moisture, inundation, geology, temperature, dust depth, humus and relative humidity (Packham et al., 2002; Zamora and Cecilia, 1995; Bergemann and Largent, 2000).

CONCLUSION

Ecological studies recorded ten edible species in five genera and showed that mushroom species diversity was highest in the grassland. Some mushroom species were most commonly found in certain habitats for example, Pluteus sp. was found in the grassland. The most important environmental factors related to mushroom species abundance were pH, phosphorus, canopy cover, organic matter, potassium, sodium, magnesium and clay. Mushroom species are more abundant during the first rain season and the occurrence of mushrooms was not related to occurrence of tree species.

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