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Substrate specificity and phenology of macrofungi community at the university of Dar es Salaam main campus, Tanzania

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ABSTRACT
Objectives: Macrofungi substrate specificity and phenology are essential considerations for management of forest ecosystems. In this study, substrate specificity and phenology of macrofungi belonging to the Basidiomycota and Ascomycota groups collected at the University of Dar es Salaam (UDSM) main campus, Tanzania were examined.
Methodology and results: Macrofungi were collected throughout the campus during surveys done thrice per year (two rainy seasons, March-May, September- November, and one dry season July- August) from much 2008 to August 2011. Eight traditional morpho-groups based on fruiting bodies comprising more than 67 species distributed in 31 genera in 20 families were collected. The substrate specificity general trend showed that fungi prefer certain specific substrates. Puff fungi are restricted to the soil, fleshy fungi of the Lyophyllaceae on termite mounds soil, and jelly fungi restricted to tree logs although Agarics utilized all the substrates except the wood debris. Tree log substrate supported more macrofungi (28%) followed by soil (26%) and decaying leaf litter (22%). The live tree substrate supported least macrofungi (6%) followed by Wood debris (7%). The general phenology showed that polyporaceae and Ganodermataceae fruit bodies were the most frequently encountered throughout the year. The small sized species from litter-inhabiting genera such as *Coprinus*, *Marasmius* and *Mycena* fruited first with early rains compared to large sized fruit bodies.
Conclusion and application of findings: The observation of early fructification relative to fruit body sizes supports the well known finding in the laboratory that the stimulation of fructification is preceded by a marked increase of vegetative growth for mycelia accumulation before being triggered to fruit. According to these study results, this phenomenon seems also important *in situ* to initiate fruiting of macrofungi. The outcome of this study will contribute to the mycological database for further research and widen the knowledge of biodiversity and substrate relationship which is an efficient parameter in establishing priority for evaluation, utilization and conservation for sustainable forest ecosystem management.
Key words: Macrofungi, Substrates, Morpho-groups, Phenology

INTRODUCTION
Macrofungi substrate refers to any surface on which the macrofungi attach and grow whereas the macrofungi include fungi distinguished by having fruiting structures visible to the naked eye commonly referred to as mushrooms (Lodge *et al*., 2004). Macrofungi play significant roles as an integral part of the forest ecosystem. The fruit bodies are the most obvious sign of wood-decomposing fungi. Fruit bodies export nutrients such as Ca, Fe, K, Mn, N, P, Zn from the wood that are returned to the forest floor by insects and grazing animals ingesting them, or by the

senescence of the fruit body, which, for most fungal species takes only a few days to several weeks (Harmon *et al*., 1986; Holec, 1992; Vogt *et al*., 1992). Some forests flourish through mycorrhizal associations and forestry managers and conservationists have recently realized that dead decaying wood which is mostly facilitated by fungi, forms an important source of biodiversity and an integral part of the recycling of carbon and other nutrients (Gates, 2009).

Moreover, macrofungi fruit bodies have enormous use for the general welfare in human life (Boa, 2004). They are highly useful in pharmaceutical industry (Blackwell *et al*., 1993) and in mass production of cultivated fungi in the food industry (Lindequist *et al*., 2005), playing vital roles in biodegradation (de Boer *et al*., 2005) as well as in food processing industries. Edible mushrooms provide a wide range of minerals and vitamins although the total nutrient contents vary significantly among species. The diverse fungal population contributes to a diverse diet for wildlife and humans. The sustainability of macrofungi is thus important to maintain and promote productivity of croplands, rangelands and forests, and may be critical to maintenance of biodiversity (Allen *et al*., 1995).

Despite their importance in both natural and agro-ecosystems there is scanty information on macrofungi community structure, substrate specificity and dynamics especially in the tropics (Hawksworth, 1991; Osemwegie *et al.,* 2006; Muller *et al*., 2007). Fungal diversity, substrate specificity and phenology are usually overlooked during management of forest ecosystems, (Amaranthus, 1998); yet successful conservation of any ecosystem requires understanding of mushroom communities in terms of ecology and distribution.

In Tanzania, there are very few studies on macrofungi and unfortunately there are no comprehensive taxonomic treatments at the community level except for single genus studies such as Buyck *et al*. (2000) and Tibuhwa *et al*. (2008) who worked on the genus *Cantharellus* Fr. from the Miombo-woodland. Tibuhwa *et al*. (2010) also studied the genus *Termitomyces;* Magingo *et al*. (2004) studied Odumensiela species; Tibuhwa (2011) studied the *Sarcoscypha* species while Härkönen *et al*. (1995, 2003) recorded one hundred species randomly from different parts of the country.

To the best knowledge of this study, there are no studies in the country on the habitat and substrate preferences of macrofungi against which to compare the results from the present study. This study explores the substrate specificity and phenology of the macrofungi community found at the University of Dar es Salaam main campus hence provides the first baseline data for future studies.

MATERIALS AND METHODS

Sampling site: The study was carried out at the UDSM main campus (Figure 1) from 2008 to 2011.The university is situated on the western side of the city of Dar es Salaam around 6°48' South, 39°17' East (−6.8000, 39.2833), on the observation hill, 13 kilometers from the city centre. The main campus occupies 1,625 acres, within Kinondoni district in the Dar es Salaam region, Tanzania. A remarkable feature of the study area is its enormous orography, geological, floristic diversity as well as different land use units which gives rise to its macrofungi diversity. The area is endowed with different types of vegetation including natural trees, planted trees, and gardens including cleared fields (Tibuhwa, 2011). The University of Dar es Salaam lies in the eastern coast of the country and is geologically underlined by coastal plain Pleistocene sediments which include beach sands and coral limestone, without any extensive outcrops (Moore, 1962). The entire area has a tropical rainforest microclimate, with average rainfall of 1042 mm per year and with a broad range of temperatures 20-35 °C. The average annual relative humidity is 77.9% with 72% in January and 82% in April. Average sunlight hours per year are 2836 hours with an average of 7.8 hours of sunlight per day without any frost.

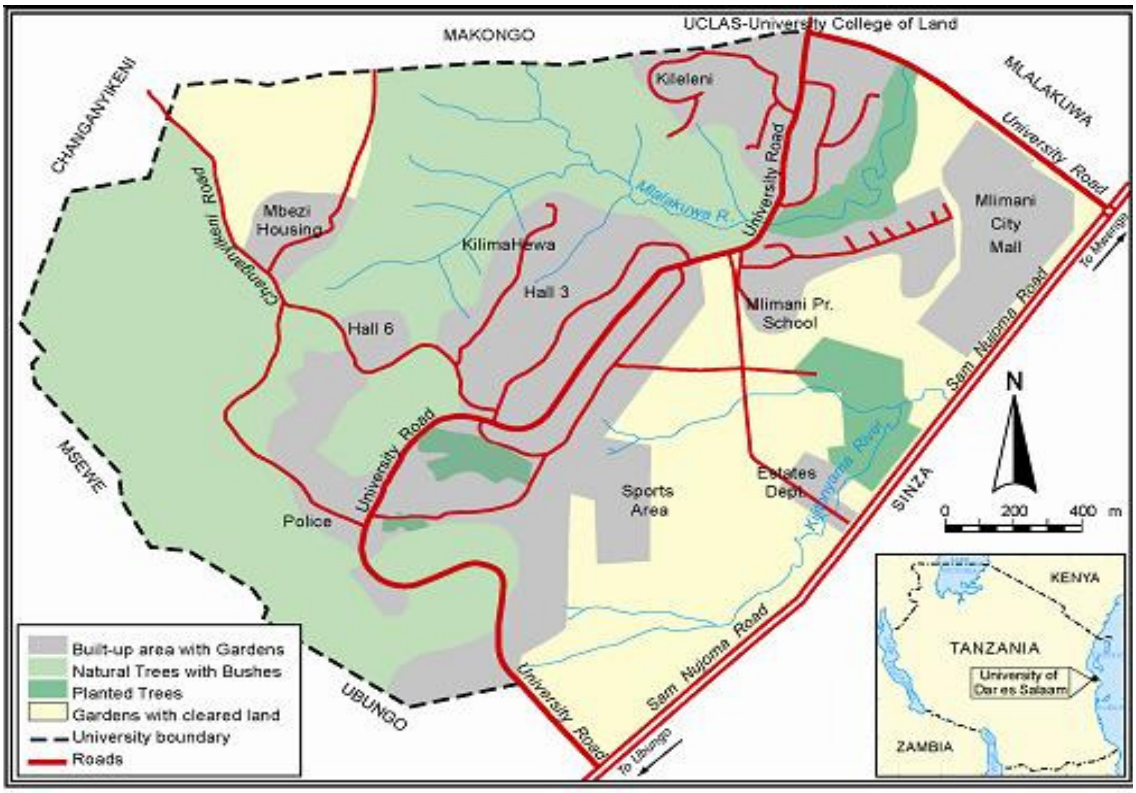


Figure 1: University of Dar es Salaam main campus showing the studied sites

Experimental design: The macrofungi communities supported by each of the five main substrates, viz. decaying leaf litter, woody, live tree, termite mound soil, tree log and soil found at UDSM main campus ecosystem were extensively examined separately. Macrofungi were expediently collected throughout the campus. Surveys were done three times every year (two rain seasons, March-May, September- November, and one dry season July- August) for all study period. Sampling methods complies with that of Tibuhwa *et al*. (2010) and consisted of collecting the basidiomata randomly throughout each specified habitat, photographing the macrofungi *in situ* and closely examining the substrate where it grows (Figure 2). Each collection point was recorded using the Global Positioning System (GARMIN 12 XL, USA).

The macrofungi nomenclature is based on Kirk & Ansell (1992) as well as the web site of CABI Bioscience Databases http://www.speciesfungorum.org/Names/Names.asp). Scientific names are those recognized by the Index Fungorum.

Each observed mushroom was photographed *in situ*, prior to picking from its substrate (Figure 2). Picking was done with the aid of a scapel blade and in a special case, long pseudorrhiza such as that of *Termitomyces* a hoe was used while Bush knife was used for hard wood inhabiting mushrooms. Visible macrofungi fruit bodies seen on all substrates were collected and recorded. The records were defined as 'present on' such that observations of the same species within a plot on different substrates were counted as separate records. The associated substrata of every collected taxa was carefully noted and the following data were recorded, TMS − substratum as termite mound soil, TL − tree log, DLL − Decaying leaf litter, WD − wood debris, Live − living tree and S − Soil. In addition macro habitat information such as associated plants and forest type, and other standard collection data such as date of sampling were also noted.

Picked mushrooms were then packed into collecting plastic containers, which were correctly labeled with collection number, collecting date, name of the collector as well as few field identification tips such as sporocarp shape, colour, smell, colour changing on bruising, and tentative name before it was brought to the Molecular Biology and Biotechnology laboratory of the UDSM for further identification.



Figure 2: Macrofungi growing *in situ* on different substrates.(a&b); *Ganoderma tsugae* and *Lentinulus* species on Tree log substrate; (c) *Termitomyces clypeatus* on termite soil; (d) *Marasmius species* on decaying leaf litter; (e) *Funalia polyzona* on *Ficus benjamina* live tree; and *Agaricus* species growing on soil. All photos taken by the author.

The collected macrofungi were identified using coloured field guide books, monographs (Arora 1986; Härkönen *et al*., 1995, 2003; Kirk *et al*., 2001; Lodge *et al*., 2004) and internet facility. Some of the mushrooms were dried after observation using an electric drier (STOCKLI CH- 8754, SWITZERLAND) at 50°C for 8 hrs and deposited at the UDSM mycological herbarium for specimen data base and microscopic work wherever necessary. Microscopic work was done with an Olympus© BH microscope. Fresh and dried fungal tissue sections were mounted in each of 10% NH_4OH, stained with Congo red (see Hawksworth *et al.,* 1999).

In order to facilitate the understanding for non-mycologist readers, taxa were also grouped in seven traditional morpho-groups according to the fruit bodies they produce (Table 1) as asserted by Michael and Stevens (2008). The morpho- groups were: (1) *agarics* (fleshy mushrooms with flat, radiating bladelike projections (gills) under the cap; usually with a stipe) attached to the cap), (2) *bolets* (Fleshy mushrooms with tubes rather than gills, the tube layer usually easily separable from the cap; stipe mostly central), (3) *jelly fungi* (fruiting bodies gelatinous in texture, convoluted, sometimes cupulate, spatulate, to ear-shaped, occasionally erect and branched mimicking coral fungi). (4) *puff balls* and *earth stars* (spherical to pear-shaped fruiting body, some with splitting outer layer into star-like rays; occasionally stalked), (5) *polypore fungi* (Leathery conks or brackets, typically perennial, occasionally annual and fleshy; fertile layer poroid, less commonly gill-like, labryinthoid, or tooth-like, not readily separable from the rest of the fruiting body), (6) *shelf*

fungi and *bracket* (Fungi that make shelves or brackets to produce spores above the ground. They are woody, leathery or fleshy polypores, having no or with only a short lateral stem) (7) *teeth fungi* (Fruiting bodies variously shaped; all with a fertile, lower surface composed of tooth-like projections), and (8) *Flask Fungi* (Saprophytic and parasitic fungi, fertile tissue consisting of minute asci-lined flasks embedded in variously shaped fruiting structures). The species that could not be identified were placed under the above mentioned groups with a reference number.

The macrofungi nomenclature, examination of the associated substrate and phenology were based on the fruiting bodies observed features thus missed the taxa that do not form conspicuous sporocarp which often requires molecular tools which were out of scope of this study.

Statistical analysis: Statistical analyses to determine the Shannon Wiener species diversity index among the four seasons of mushroom fructification [Throughout the Year, March –May, (both Sept-October + March-May) and Sept-October] depicting the studied macrofungi phenology were carried out according to Magurran (1988) using PISCES for species diversity and richness version 2. 65, under license of PISCES Conservation Ltd (2001).

RESULTS

Eight macrofungi traditional morpho-groups comprising 67 species distributed in 31 genera, in 20 families were collected and examined (Table 1). Agarics and polypore morpho-groups were the most frequently occurring group.

Table 1: Mushroom observed at the University of Dare s Salaam with their respective substrates.

Morpho-groups	Family	Genus	Substrate type	Fruit body phenology
Agarics				
"	Lyophyllaceae	*Termitomyces microcarpus* (Berk. &Broome)R. Heim	TMS	SEPT-OCT., MARCH-MAY
"	"	*T. aurantiacus* (R. Heim) R. Heim	TMS	SEPT-OCT., MARCH-MAY
"	"	*T. clypeatus* R. Heim	TMS	MARCH-MAY
"	"	*T. umkowaanii (*Cooke and Massee) D.A.Reid	TMS	SEPT-OCT.
"	"	*T. tyrelanus* Otieno	TMS	MARCH-MAY
"	"	*Lepista sordida* (Schum.: Fr.) Singer	TL	MARCH-MAY
"	Agaricaceae	*Agaricus campestris* L.:Fr.	TMS	SEPT-OCT., MARCH-MAY
"	"	*A. bisporus (*J.EE.Lange) Imbach	S	SEPT-OCT., MARCH-MAY
"	"	*A. xanthodermus* Genev.	TMS, S	SEPT-OCT., MARCH-MAY
"	"	*A. augustus* Fr.	DLL	SEPT-OCT., MARCH-MAY
"	"	*A. sylvaticus* J. Otto	DLL	SEPT-OCT., MARCH-MAY
"	"	*A. birnbaumii* Corda	S, DLL	SEPT-OCT., MARCH-MAY
"	"	*A. placomyces* sensu auct. mult.	TMS, S	SEPT-OCT., MARCH-MAY
"	"	*A. bitorquis* (Quél.) Sacc.	TMS, S	SEPT-OCT.
"	"	*A. volvatulus* Heinem. & Gooss	S	SEPT-OCT.
"	"	*Agaricus* sp.1	TMS, S	SEPT-OCT., MARCH-MAY
"	"	*Agaricus* sp.2	DLL	SEPT-OCT., MARCH-MAY
"	"	*Agaricus* sp.3	S, DLL	SEPT-OCT., MARCH-MAY
"	"	*Macrolepiota procera* (Scop.) Singer	DLL, S	MARCH-MAY
"	"	*Leucocoprinus fragilissimus* (Berk. & M.A. Curtis) Pat	DLL, S	MARCH-MAY
"	"	*Coprinus disseminatus* (Pers.) Gray	DLL	SEPT-OCT., MARCH-MAY
"	"	*C. comatus* (O.F. Müll.) Pers	WD,DLL	SEPT-OCT., MARCH-MAY
"	"	*Chlorophyllum molybdites* (G. Mey.) Massee	S	SEPT-OCT., MARCH-MAY
"	"	*C. rhacodes* (Vittad.) Vellinga	S	SEPT-OCT., MARCH-MAY
"	Tricholomataceae	*Tricholoma spectabile* Peerally & Sutra	DLL, S	MARCH-MAY
"	Mycenaceae	*Mycena pura* (Pers.) P. Kumm.	DLL	MARCH-MAY
"	"	*M. inclinata* (Fr.) Quél.	DLL, S	MARCH-MAY

"	"	*Favolaschia calocera* R. Heim	DLL, S	MARCH-MAY
"	Marasmiaceae	*Marasmius bekolacongoli* Beeli	S,DLL	MARCH-MAY
"	"	*Marasmius delectans* Morgan	S	SEPT-OCT., MARCH-MAY
"	"	*Marasmius aureus* Beeli	S	SEPT-OCT., MARCH-MAY
"	"	*Marasmius rotula (Scop.) Fr.*	DLL	SEPT-OCT.,
"	"	*Marasmius haematocephalus* (Mont.) Fr.	DLL	SEPT-OCT., MARCH-MAY
"	"	*Marasmius* sp.	DLL	SEPT-OCT.,
"		*Lentinulus* sp 1	TL	SEPT-OCT., MARCH-MAY
"		*Lentinulus* sp 2	TL	MARCH-MAY
"		*Lentinulus* sp 3	TL	MARCH-MAY
"	Pleurotaceae	*Pleurotus sajor-caju* (Fr.)	TL, LIVE	MARCH-MAY
"	"	*P. tuber-regium* (Rumph. ex Fr.) Singer	S	MARCH-MAY
"	Pluteaceae	*Volvariella volvacea* (Bull.) Singer	S	SEPT-OCT., MARCH-MAY
"	"	*P. eryngii* (DC.) Quél.	TL, S	SEPT-OCT., MARCH-MAY
"	Fomitopsidaceae	*Laetiporus sulphureus*	TL,LIVE	MARCH-MAY
"	Hymenochaetaceae,	*Phellinus gilvus* (Schwein.) Pat.	TL	TYR
"	Sclerodermataceae	*Scleroderma aurantium* (L.) Pers	TL	MARCH-MAY
Jelly Fungi	Auriculariaceae	*Auricularia delicata*	TL	MARCH-MAY
"	"	*A. polytricha*	TL	MARCH-MAY
"	Tremellaceae	*Tremella fuciformis* Berk	TL	MARCH-MAY
Polypore fungi	Polyporaceae	*Trametes elegans* (Spreng.) Fr.	TL	MARCH-MAY
"	"	*Earliella scabrosa* (Pers.) Gilb. & Ryvarden	TL	TYR
"	"	*Funalia polyzona* (Pers.) Niemelä	TL	TYR
"	"	*Polyporus moluccensis* (Mont.) Ryvarden,	TL, LIVE	MARCH-MAY
"	"	*Polyporus tenuiculus* (P. Beauv.) Fr	TL	MARCH-MAY
"	"	*Microporus affinis* (Blume & T. Nees) Kuntze	TL	TYR
"	"	*Pycnoporus sanguinus*	TL, LIVE	APRIL-MAY
"	Schizophyllaceae	*Schizophyllum commune* Fr.	TL	TYR
"	Ganodermataceae	*Ganoderma boninense* Pat.	TL	TYR
"		*Ganoderma tsugae Murrill*	TL, LIVE	TYR
"	"	*Ganoderma* sp.	TL	TYR
Bolete	Boletaceae	*Boletus satanas* Lenz	WD,DLL	MARCH-MAY
"	"	*Boletus pallidissimus* Watling	WD	MARCH-MAY
"	"	*Boletus rubripes* Thiers	WD, DLL	MARCH-MAY
Puff balls & earth star	Geastraceae	*Geastrum saccatum* sensu auct. brit.	S	MARCH-MAY
"	"	*G. triplex* Jungh.	S	MARCH-MAY
Teeth Fungi	Hydnaceae	*Hydnum repandum* L.	WD, TL	MARCH-MAY
"		*Hydnum* sp.	WD, TL	MARCH-MAY
Flask Fungi	Xylariaceae	*Xylaria* sp 1	WD	SEPT-OCT.
"		*Xylaria* sp 2	TL	MARCH-MAY

TMS: Termite Mound Soil; TL: Tree log; DLL: Decomposing Leaf Litter; WD: Wood Debris; S: Soil; LT: Live Tree; TYR: Throughout the Year.

Table 2: Shannon Wiener species diversity index depicting macrofungi phenology.

Fructification Season	Shannon Index	Variance	No. of species in each Macrofungi families
Both Sept-October & March-May	1.0336	0.031989	4
March -May	2.6062	0.013252	15
Sept-October	1.3297	0.059461	4
Throughout the Year	1.2555	0.051725	4

The distribution of fungal groups on different substrates showed differential substrates preference. Fleshy fungi (agaric) were widely and abundantly distributed on every substrate (Figure 4) except the wood debris, while polypore fungi occurred mainly on tree logs and wood debris (78.57%) and live tree (21.42%). The shelf and bracket fungi were restricted to tree log substrates, whereas puff fungi were found only on soil (Figure 3).

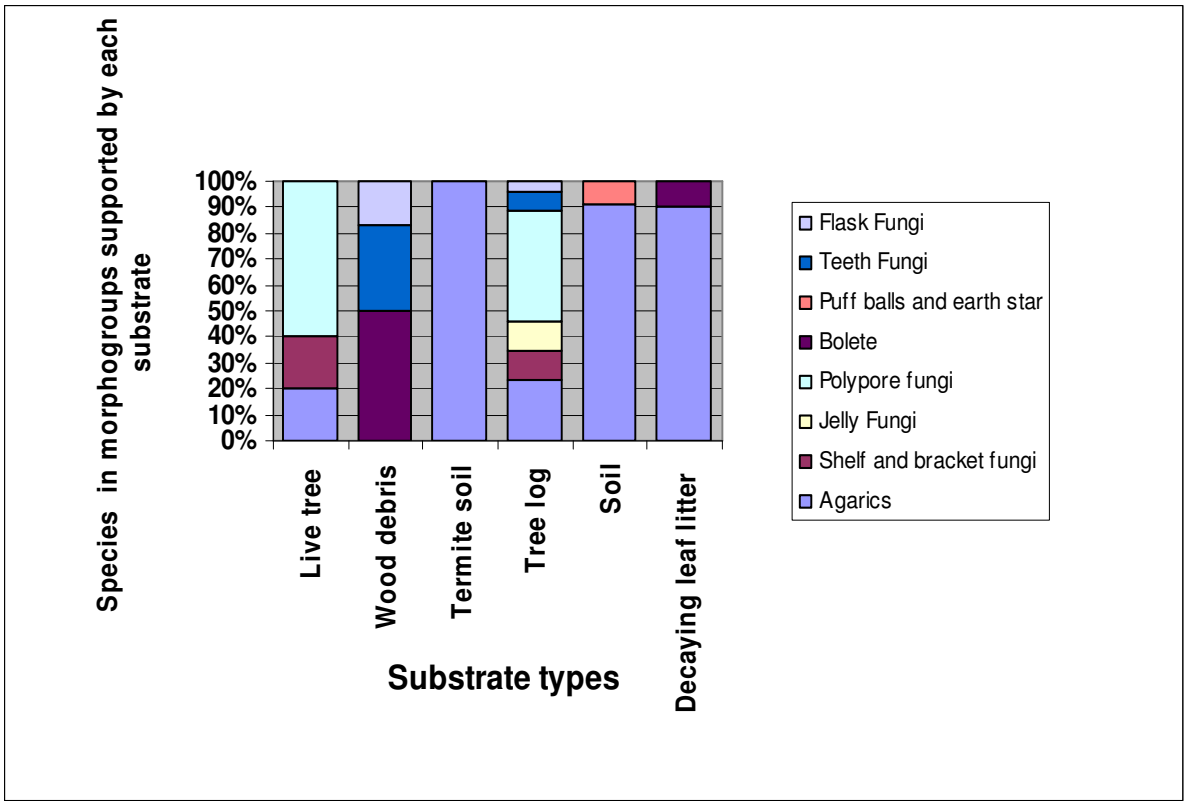


Figure 3: Distribution of macrofungi morpho-groups on different substrates. Agarics utilized all the substrate except wood debris.

With the exception of fleshy fungi in the family Lyophyllaceae which were specifically found on the termite mounds soil, and some species in Marasmiaceae like *Marasmius haematocephalus* (Mont.) Fr. which were found exclusively on leaves, generally fleshy fungi were more abundant on soil (37.5%) followed by decaying leaf litter (32.14%). Tree log substrate supported more macrofungi (28%) followed by soil (26%), wood substrate (22%) and decaying leaf litter (22%). The live tree substrate supported the least macrofungi (6%) followed by 7% on wood debris (Figure 4).

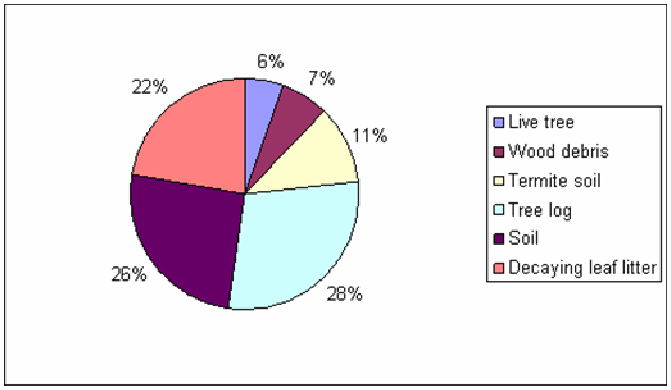


Figure 4: Percentage of mushroom species abundances obtained based on substrate.

The macrofungi general phenology observed in this study revealed a difference in time for onset of fructification among the species and noticeably correlated to their size and texture sturdiness. The small sized species from litter-inhabiting genera fruited early compared to large sized fruit bodies. The polyporaceae and Ganodermataceae fruit bodies phenology were the most found throughout the year (Figure 5 a) and were perceptibly tough and bigger in size compared to the rest of the collected fruit bodies. The long rain of March- May was the best season of macrofungi species fructification (Figure 5 b) with high species diversity depicted by high Shannon Winner index (2.6062).

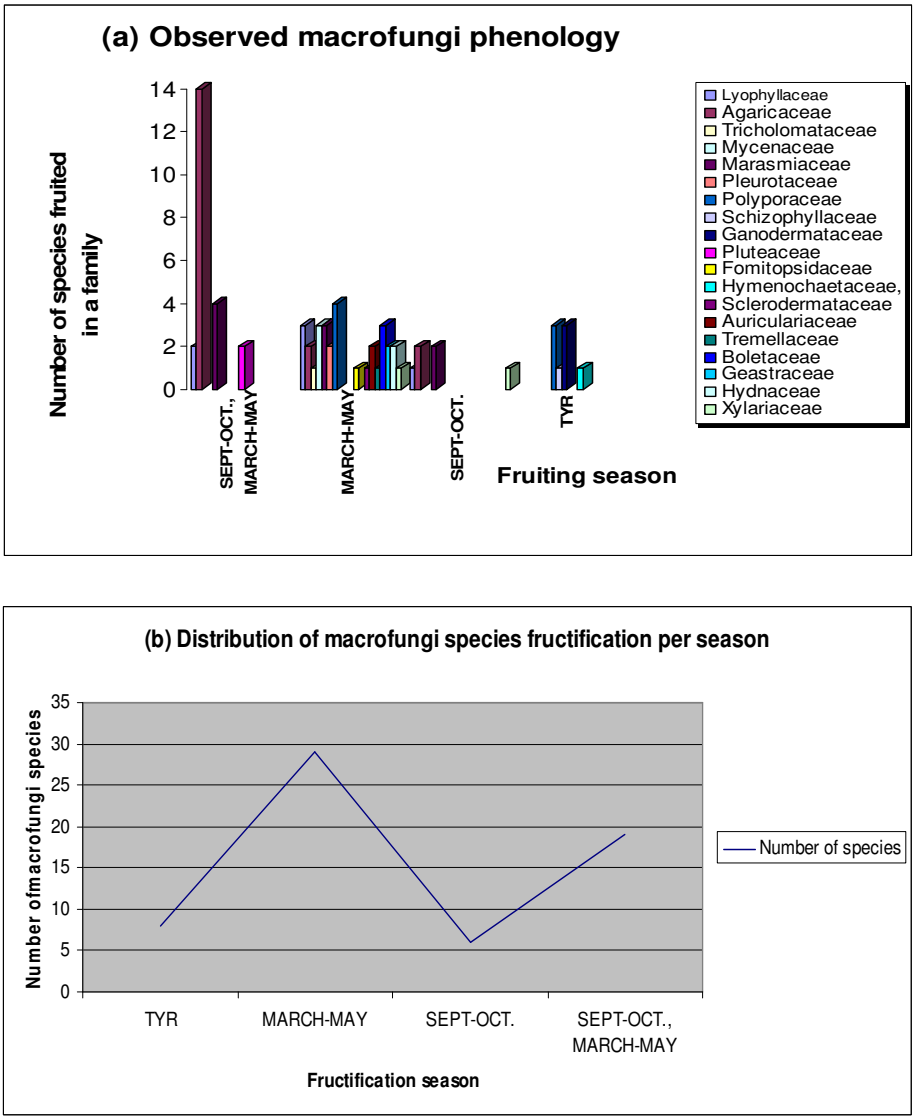


Figure 5: Macrofungi phenology (a) based on number of families (b) based on number of species with high fructification occurring during the long rains of March-May while some members of the families Polyporaceae, Ganodermataceae, Schizophyllaceae and Hymenochaetaceae were found throughout the year (TYR).

DISCUSSION

This is the first report of macrofungi substrate specificity and phenology in Tanzania. The study showed that majority of species prefer specific substrates, with puff fungi restricted only on soil, fleshy fungi of the Lyophyllaceae on termite mounds soil, and jelly fungi restricted to tree logs except the Agaricaceae which were found in all substrates except the wood debris. This finding is in line with the observation by Uzun

(2010) who noted species from Agaricaceae do not associate with a given habitat hence substrates, but are able to grow anywhere provided the conditions are favorable.

Nevertheless, this study found a considerable overlap of substrates which might have been attributed to lack of obvious classification of some substrates. For example, it was very difficult to separate the decomposers growing on soil but emanating on the surface via leaf litter especially in the Natural trees bush thickets. Lack of clear substrate stratification has been a challenge in determining substrate specificity in macrofungi as also noted by Gates *et al*. (2011). In their study on macrofungi substrates in *Eucalyptus obliqua* forest in southern Tasmania, Australia, they also noted that some fruit bodies especially the wood decomposers such as *Tricholoma* species often used leaf litter as a corridor habitat to a more solid woody substrate. This ability to move among substrates probably help them to survive in case of limited nutrients supplies, save spaces; resources and enable them to escape from unfavorable environmental conditions such as extreme drought that could hinder their fructification .

The general phenology observed in this study was that there is a difference in lag time between the onset of favorable fruiting conditions and fruit body production between different species of the macrofungi studied. Generally small sized species are delicate and fragile with small wiry stipes and frequently marcescent from litter-inhabiting genera such as *Coprinus*, *Marasmius* and *Mycena* fruited out first with early rains. These species appeared and disappeared very quickly while the large sized fruit bodies fruited after a continued period of rains of more than two weeks. This might be due to their small fruit bodies and their nature of forming fruit bodies at relatively shallow depth thus fluctuation in moisture has more effect on them than other groups of macrofungi, thus concurring with the suggestion by Hering (1982). This observation is also inline with the finding by Gates *et al*. (2011), Lange (1984), Salerni *et al*. (2002) who noted most macrofungi require a period of vegetative growth before fruiting during which the mycelia accumulate before being triggered to fruit. This fact has been also concluded from laboratory cultures (Lange, 1984) whereby the larger the fruit body the longer it takes to build up an appropriate amount of mycelia.

Despite the fact that other variables such as amount of light (Kües & Liu, 2000), genetic (Wösten & Wessels, 2006) or an interaction of variables contribute to fruit body fructification, this study found that large numbers of fruit body nascent has a strong correlation to the amount of rainfall received prior to fructification. The long rains of March- May in the year had the largest number of macrofungi species recorded (Figure 5 b) which was also depicted in the high Shannon Wiener species diversity index (2.6062) compared to other seasons (Table 2). The season also contained Fomitopsidaceae, Tricholomataceae, Pleurotaceae, Mycenaceae and Tremellaceae which were not observed during the short rains of September–October. Other species in the families Agaricaceae, Lyophyllaceae, Pluteaceae and Marasmiaceae, appeared inconsistently in both rain seasons of September–October and March–May over the surveyed period (Figure 5a). Thirty seven different species were collected during the long rains of March-May which seemed to be the favorable time for fructification of most macrofungi species (Figure 5b). Based on this result, with the exception of small differences specific to particular taxa, such as those growing throughout the year and when substrate is wood which can act as moisture reservoir (Gates, 2009), this study proposes the March- May rains to be the best season for macrofungi surveys and harvesting in the study area and probably in other parts in the region with similar rainfall pattern.

Compared to other morpho-forms, Polypore and Ganodermatacea were found capable to survive and overcome environmental changes including desiccation unlike other forms which produce simple short lived fruit bodies. This might be associated with their perceptible tough and large sized fruit bodies and their unique adaptations of surviving for several years producing a new layer of spore producing surfaces thus elevate above the ground ensuring a continuous supply of food material (Pegler, 1997).

Distribution of macrofungi based on substrate differed markedly with the Tree log substrate supporting more macrofungi (28%) followed by soil (24%). The observed higher number of macrofungi utilizing the tree log substrate may be associated with ready availability of the type of vegetation of the studied site having many trees both natural and artificial vegetation (Figure 1). The high percentage of macrofungi in the soil substrate may be attributed to the fact that with an exception of termite mound soil, soil substrates were not divided into various layers or diversified into soil types but rather were combined into one category the 'soil' substrate. The macrofungi species richness showed a correlation with the type of vegetation (Figure 1), whereby plots in

the natural trees recorded highest number of macrofungi as also noted by Tibuhwa (2011). Likewise the vegetation nature especially the natural tree vegetation supported mostly the wood decomposing species which might have attributed to high number of macrofungi supported by tree log. The high abundance of mushrooms in substrate associated with wood decay may also be related to their high moisture retention (Edmonds, 1991; Graham et al., 1994).

Some of the *Coprinus* species found in decomposing litter were also found inhabiting the fine wood. This suggests that theses species posses the lignocellulolytic enzymes for decomposing wood while the *Marasmius* species were specifically found on leaf litter. The area studied apparently has greater saprobic species than other species from other guilds. There were no any ectomycorrhiza species collected from the study area probably due to lack of mycorhizal symbionts as noted by Tibuhwa (2011).

Although differences in sampling protocol such as number, size of plots, and number of years sampled may account for some differences in species richness and hence substrate specificity, this study was conducted systematically from 2008 to 2011 consecutively in 9 different plots measuring 20 x 25 m which probably has minimized the chances of missing taxa and hence making it possible to reliably estimate the number of species of macrofungi that are present in these plots with their associated substrates and phenology.

CONCLUSION

The substrate specificity general trend showed that fungi prefer certain specific substrates. Tree log and soil substrate supported more macrofungi while live tree substrate supported the least macrofungi. The polyporaceae and Ganodermataceae fruit bodies' phenology were the most frequently encountered throughout the year. The phenological data will contribute to better targeting of surveys, recommended to be during the long rain season of March- May also for mushroom hunters to determine the optimal period to hunt a taxon of their interest. This study adds to the small existing amount of baseline data of macrofungi diversity, substrate specificity and phenology in Tanzania. The data especially on the wood rotting will be an indicator of ecological continuity of forest at the studied area and very useful for recording future changes in the vegetation, climate, and air composition.

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REFERENCES

Allen EB, Allen MF, Helm DY, Trappe JM, Molina R, Rincon E, 1995. Patterns and regulation of mycorrhizal plant and fungal diversity Plant & Soil 70: 47–62.

Amaranthus MP, 1998. The importance and conservation of ectomycorrhizal fungal diversity in forest ecosystems: lessons from Europe and the Pacific Northwest. Portland, OR, USA, USDA For. Serv., Gen.Tech. Rep. PNW-GTR-431: 15 p.

Arora D, 1986. Mushrooms demystified: A comprehensive guide to the fleshy fungi. Berkeley: Ten Speed Press 959 p.

Boa ER, 2004. Wild edible Fungi: A Global perspective view of Their Use and Importance to People. FAO Publishing Management Services, Rome.

De Boer W, Folman LB, Summerbell RC, Boddy L, 2005. Living in a fungal world: impact of fungi on soil bacterial niche development FEMS Microbiology Review 29: 795–811.

Gates GM. and Ratkowsky DA, 2009. Comparing indigenous and European-based concepts of seasonality for predicting macrofungal fruiting activity in Tasmania. Australasian Mycologist 28: 36–42.

Gates GM, Mohammed C, Wardlaw T, Ratkowsky DA, Davidson NJ, 2011. The ecology and diversity of wood-inhabiting macrofungi in a native Eucalyptus obliqua forest of southern Tasmania, Australia Fungal Ecology 4: 56–67.

Härkönen M, Niemelä T, Mwasumbi L, 1995. Edible Mushrooms of Tanzania. Karstenia 92p.

Härkönen M, Niemelä T, Mwasumbi L, 2003. Tanzanian Mushrooms: Edible, Harmful and Other Fungi. Norrlinia 200p.

Harmon ME, Franklin JF, Swanson F, Sollins P, Gregory SV, Lattin JD, Anderson NH, Cline SP, Aumen NG, Sedell JR, Lienkaemper GW, Cromack Jr K, Cummins KW, 1986. Ecology of coarse woody debris in temperate ecosystems. In: A. MacFadyen and E.D. Ford Editors, Advances in Ecological Research vol. 15, Academic Press, New York, 133–302 p.

Hawksworth DL, 1991. The fungal dimension of biodiversity: magnitude, significance, and conservation Mycological Research. 95: 641–655.

Hering TF, 1982. Decomposer activity of basidiomycetes in forest litter. In: Frankland, JC, Hedger, JN, Swift, MJ (eds), Decomposer Basidiomycetes: their biology and ecology. Cambridge University Press, London, 213–225 p.

Holec J, 1992. Ecology of macrofungi in the beech woods of the Sumava mountains and Sumava foothills Ceska Mykologie 46: 163–202.

Kirk PM. and Ansell AM, 1992. Authors of fungal names. A list of authors of scientific names of fungi with recommended standard forms of their names, including abbreviations. Index of Fungi Supplement. CAB International, Kew, Surrey, Great Britain. 95 p.

Kirk PM, Cannon PF, David JC, Stalfers JA, 2001. Ainsworth and Bisby's Dictionary of the Fungi. 9th Edn., CABI Publishing. Electronic version: htpp://www.speciesfungorum.org/AuthorsoffungalNames.htm Wallingford, UK.

Ku¨ es U, Liu Y, 2000. Fruiting body production in basidiomycetes Applied Microbiology and Biotechnology 54: 141–152.

Lange M, 1984. Fleshy fungi in grass fields: II. Precipitation and fructification Nordic Journal of Botany 4: 491–501.

Lindequist U, Niedermeyer THJ, Ju¨lich WD, 2005. The pharmacological potential of mushrooms eCAM 2: 285–299.

Lodge JD, Ammirati FJ, O'Dell ET, Mueller MJ, 2004. Collecting and Describing Macrofungi. Pages 128–158, In: Biodiversity of Fungi: Inventory and Monitoring Methods, Mueller, M.G., F.G. Bills and S.M. Foster (Eds.). Elsevier Academic Press, San Diego, CA.

Magingo FS, Oriyo N, Kivaisi AK, Danell E, 2004. Cultivation of *Oudemensiella tanzanica* nom.prov. on agric solid wastes in Tanzania Mycologia 96: 197–204.

Magurran AE, 1988. Ecological Diversity and its Measurement, Coastal Forest Research Programme Tanzania. The society for Environmental Exploration and The University of Dar es Salaam. Chapman & Hall, London.

Michael W. and Stevens F, 2008. The Fungi of California on a MykoWeb Page. Available from http://www.mykoweb.com/CAF/skey.html. (Cited on 5th March 2008)

Moore WR, 1962. Geology of Quarter Degree Sheet 168, Bagamoyo and a compilation of map of Tanganyika coastal sediments north of Dar es Slaam. Records of the Geological Survey of Tanganyika 10: 1–6.

Mueller G.M Schmit JP, Leacock PR, Buyck B, Cifuentes J, Desjardin DE, 2007. Global diversity and distribution of macrofungi Biodiversity and Conservation 16: 37–48

Mueller G M, Murphy J F, Schmit JP, 1999. Macrofungal diversity of a temperate oak forest: a test of species richness estimators Canadian Journal of Botany 77: 1014–1017

O'Dell TE, Lodge DJ, Mueller MG, 2004. Approaches to Sampling Macrofungi. Pages 163-168, In: Biodiversity of Fungi: Inventory and Monitoring Methods, Mueller, G.M., F.G. Bills and S.M. Foster (Eds.). Elsevier Academic Press, San Diego. CA.

Osemwegie OO, Eriyaremu EG, Abdulmalik A, 2006. A survey of macrofungi in Edo/Delta region of Nigeria, their morphology and uses Global Journal of Pure Applied Science 12: 149–157.

Salerni E, Lagona A, Perin C, Loppi S, De Dominicis V, 2002. Effect of Temperature and rainfall on fruiting of macrofungi in oak forests of the Mediterranean area Israel Journal of Plant Sciences 50: 189–198.

Tibuhwa DD, Buyck B, Kivaisi AK, Tibell L, 2008. *Cantharellus fistulosus* sp. nov. from Tanzania Cryptogamie Mycologie 29: 129–135.

Tibuhwa DD, Kivaisi AK, Magingo FFS, 2010. Utility of the macro-micromorphological characteristics used in classifying the species of *Termitomyces* Tanzania Journal of Science 36: 3–46.

Tibuhwa DD, 2011. Morphology and taxonomy of *Sarcoscypha ololosokwaniensis* sp. nov.: A

new Ascomycota species from Serengeti National Park-Tanzania. Journal of Yeast and Fungal Research 2: 1–6.

Tibuhwa DD, 2011. Diversity of macrofungi at the University of Dar es Salaam Mlimani Main Campus in Tanzania. International Journal of Biodiversity and Conservation (3 : 540-550) In press)

Uzun Y, 2010. Macrofungal diversity of Ardahan and Igdir Province (Turkey). International Journal of Botany 6: 11–20

Vogt KA, Bloomfield J, Ammirat JF, Ammirat SR, 1992. Sporocarp production by basidiomycetes with emphasis on forest ecosystems. In The Fungal Community its Organization and DT Wicklow, Dekker. New York. 563–581 p.

Wösten HAB. and Wessels JGH, 2006) The emergence of fruiting bodies in Basidiomycetes. In: Kues U, Fischer R (eds), The Mycota I growth, differentiation and sexuality. Springer, Berlin, 393–414 p.