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Fungal community diversity and composition on logs in relation to log size and penetrability

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ABSTRACT

Very little is known about how macrofungal communities on logs vary depending on different log characteristics. This study tested whether macrofungal communities on logs in premontane wet secondary forest in Monteverde, Costa Rica, vary significantly with changes in log size and penetrability. Additionally, this study determined the regional species diversity and turnover of macrofungal communities on logs, and determined whether there were trends between groups of macrofungal species growing on logs of different degrees of penetrability. One hundred logs with macrofungi were sampled randomly and measured for size and penetrability. The fungi on each were recorded according to morphospecies. A total of 57 morphospecies were found, with the shelf fungus *Hexagonia papyracea* being the most common. There were no significant relationships between the number of species per log and log penetrability, or between the occurrence of *H. papyracea* and log penetrability. However, *H. papyracea* occurred on logs with smaller diameters, and the number of species per log increased as a function of log diameter. There were also trends indicating higher species turnover with higher penetrability. The results suggest possible community succession and host specificity among macrofungi that colonize logs, but further research is necessary to determine which log characteristics are important to host-specific macrofungi.

RESUMEN

Se sabe muy poco sobre cómo las comunidades de macrohongos que crecen en maderos varían dependiendo de diversas características del tronco. Se estudió la posibilidad de que las comunidades de macrohongos en maderos del bosque secundario húmedo premontano en Monteverde, Costa Rica, varíen significativamente con los cambios de tamaño y penetrabilidad del madero. Además, se determinó la diversidad de las especies y la sucesión de comunidades de macrohongos en árboles caídos. También, se encontraron tendencias entre los grupos de especies de macrohongos creciendo en maderos con differentes grados de penetrabilidad. Se muestrearon al azar cien maderos con macrohongos de acuerdo a su tamaño y penetrabilidad y se clasificaron de acuerdo a su morfología. Se encontró un total de 57 especies morfológicas, siendo el hongo de oreja (*Hexagonia papyracea*) el más común. No se encontraron relaciones significativas entre el número de especies de hongos por madero y la penetrabilidad del madero, o entre la ocurrencia de *H. papyracea* y la penetrabilidad del árbol caído. Sin embargo, *H. papyracea* fue en maderos con diametros más pequeños, y el número de especies por madero en función del diámetro del madero fue significativo y sepresentaron tendencias indicando una sustitución mayor conforme la penetrabilidad aumenta. Los resultados sugieren una posible cambio de comunidad y especificidad por el anfitrión entre los macrohongos que colonizan los árboles caídos, pero se necesitan investigaciones adicionales para determinar qué características del madero son importantes para la colonización por los macrohongos.

INTRODUCTION

The Kingdom Fungi contains an estimated 1.5 million species, but to date only 72,000 to 100,000 have been described (Hawksworth and Rossman 1997). Environmentally, fungi play a major role as parasites, food sources, and in nutrient cycling as decomposers (Hawksworth 1991). Economically, they have many commercial uses in agriculture and consumer products, and medically they hold great potential as useful drugs (Rossman 1994). However, literature on fungal diversity is sparse due to lack of systematic species

inventories. This inadequate body of information on fungi necessitates further studies if their biological relevance is to be fully realized.

In Costa Rica, there are an estimated 40,000 to 70,000 species of fungi, of which only 2,000 have been described. Several studies done in Costa Rica during the wet season have shown that fungal diversity decreases with altitude (Johnson 2001; Whitesides 1992) but few studies have been done on fungal diversity as it relates to substrate. Some fungi may have growth requirements that only certain types of substrate can provide; for example, fresh logs may have more nutrients than older, more rotted logs. Log penetrability (the ability to be penetrated by a sharp object) may be higher in more rotted logs because they are softer and have less structure. If log penetrability is related to rottenness, then logs with different penetrabilities may support different fungal species, indicating succession. Herz (2004) found that the majority of macrofungi in the Monteverde area occurred on dead wood substrates that had penetrabilities ranging from 0.5 to 3 cm. Whether there is a relationship between log characteristics and the fungal communities that grow on them is yet to be determined.

The purpose of this study was to determine whether a relationship exists between macrofungal communities on logs within a given area and the diameter and penetrability of those logs. In addition, this study determined the total macrofungal species diversity and turnover between logs, as well as between groups of logs with different degrees of penetrability.

METHODS

This study was conducted in patches of premontane wet secondary forest at the Rockwell farm in Monteverde, Costa Rica between October 24, 2004 and November 15, 2004. One hundred logs with macrofungi were randomly sampled. The length and diameter of each log were measured and the fungi on each log were photographed with a digital camera and recorded according to morphospecies. The penetrability of each log was determined by placing a one meter long hollow PVC tube over the log, dropping a weighted probe through the tube, and then recording the amount of probe that penetrated beneath the surface of the log. This was done three times for each log and from these values the mean penetrability of each log was calculated.

The number of species per log as a function of log penetrability and diameter were analyzed using simple linear regressions. The penetrability of logs with the most common fungus was compared with the penetrability of logs without the most common fungus using an unpaired t-test. The same test was also performed with diameter instead of penetrability. Logs were grouped into four penetrability categories: A (0-1 cm), B (1-2 cm) C (2-3 cm) and D (3-4 cm). Alpha-, beta-, and gamma-diversity were determined for each category, as well as for the entire community of 100 logs. Sorenson's Index (qualitative) was used to compare the species composition between the four penetrability categories.

RESULTS

On the 100 logs sampled, 57 morphospecies were present. The alpha-diversity for the entire community was 1.1 species per log, the beta-diversity was 0.52 and the habitat breadth was 1.92 logs. The majority of logs (91) supported only one species of fungus (Fig. 1). A simple linear regression testing the total number of species per log as a

function of log penetrability found no significant relationship (ρ = .001; P = .993; n = 100), but the same test using diameter instead of penetrability showed significance (ρ = .199; P = .047; n = 100): as log diameter increases, the number of species occurring on the log also increases (Fig. 2).

When considering the four penetrability categories as separate communities of logs, category D had the highest beta-diversity (1.0), category B had the highest number of species (22), and all four categories had an alpha-diversity of 1.1 (Table 1). Categories A and B together contained 74% of the logs (Fig. 4). Sorenson's Index was calculated for all pairs of categories and ranged from 0.09 to 0.23 (Table 2).

The two most commonly found fungi were the shelf fungus *Hexagonia papyracea*, which occurred on 24 logs, and *Xylaria polymorpha* ("Dead man's fingers") which occurred on 12 logs. Out of the 24 logs with *H. papyracea*, only one had *H. papyracea* co-occurring with another species (Fig. 3), while out of the 12 logs with *X. polymorpha*, three had a second species present (Fig. 5). An unpaired t-test for the presence of *H. papyracea* as a function of penetrability showed no significance (P = .089), but the same test using diameter instead of penetrability showed significance (P = .041): logs with *H. papyracea* had significantly smaller diameters than logs without it (Fig. 6).

Additional Observations

Hexagonia papyracea generally occurred in clusters on groups of logs that were near each other and that appeared to have originated from the same tree. *Xylaria polymorpha* did not follow this pattern; rather, it seemed to occur randomly. It was also observed to have a high degree of morphological variation.

TABLE 1. α–, β– and γ–diversity and number of logs for each penetrability category. There is a trend of higher species turnover (β–diversity) with higher penetrability.

	A (0-1 cm)	B (1-2 cm)	C (2-3 cm)	D (3-4 cm)
□□diversity	1.1	1.1	1.1	1.1
□-diversity	0.47	0.54	0.68	1
□-diversity	19	22	12	11
number of logs	37	37	16	10

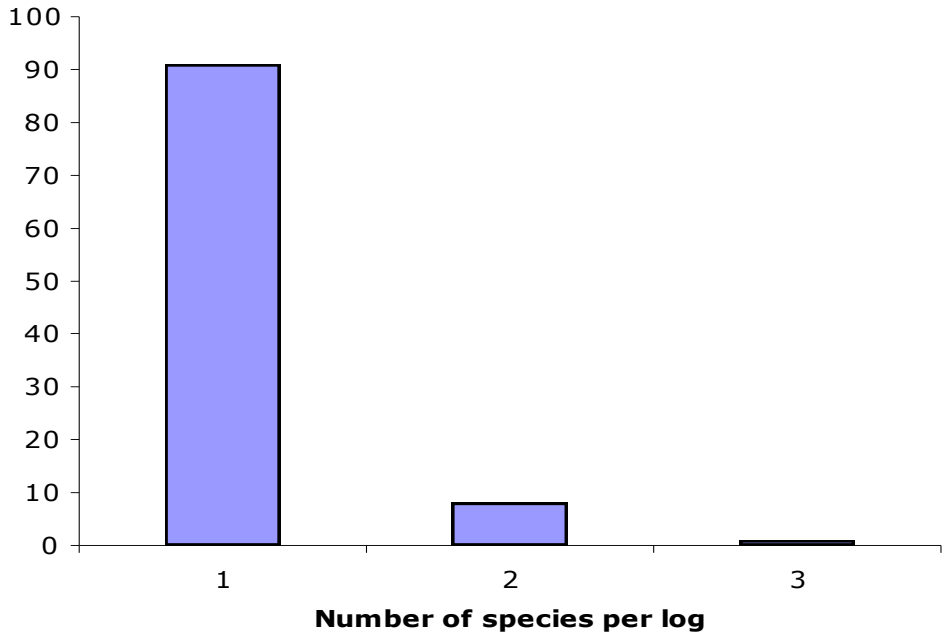

FIGURE 1. Frequency of logs supporting one, two or three macrofungal species in premontane wet secondary forest in Monteverde, Costa Rica. The majority of logs supported only one species.

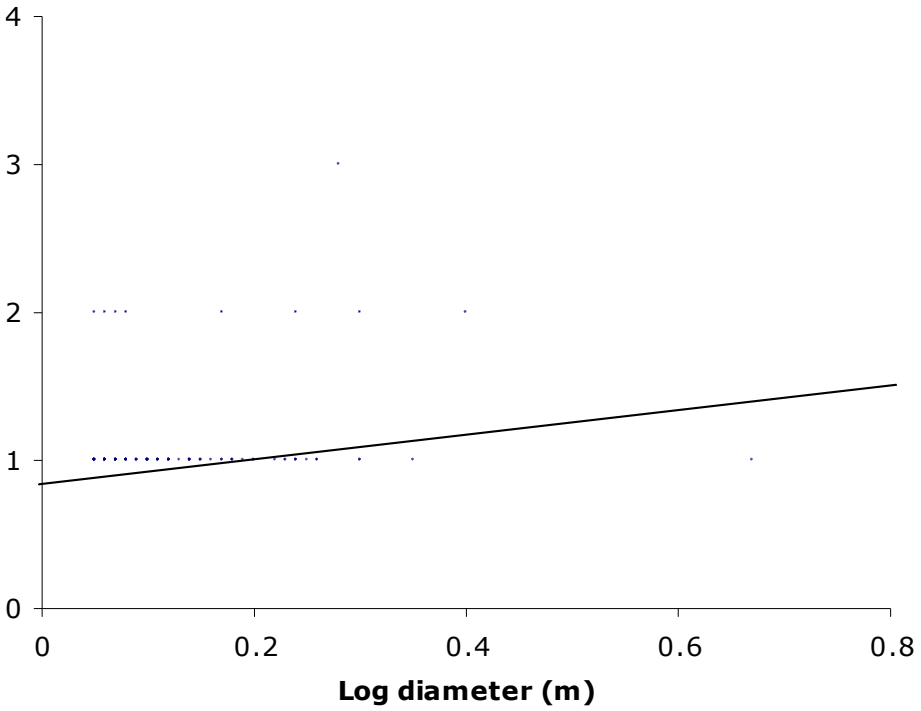

FIGURE 2. The number of macrofungal species per log changes significantly with log diameter.

TABLE 2. Sorenson's Qualitative Indices for each combination of penetrabililty category. Comparisons with Category D resulted in the lowest three values.

Category combination	Sorenson's Index
B:C	0.23
A:B	0.19
A:C	0.19
C:D	0.15
A:D	0.09
B:D	0.09

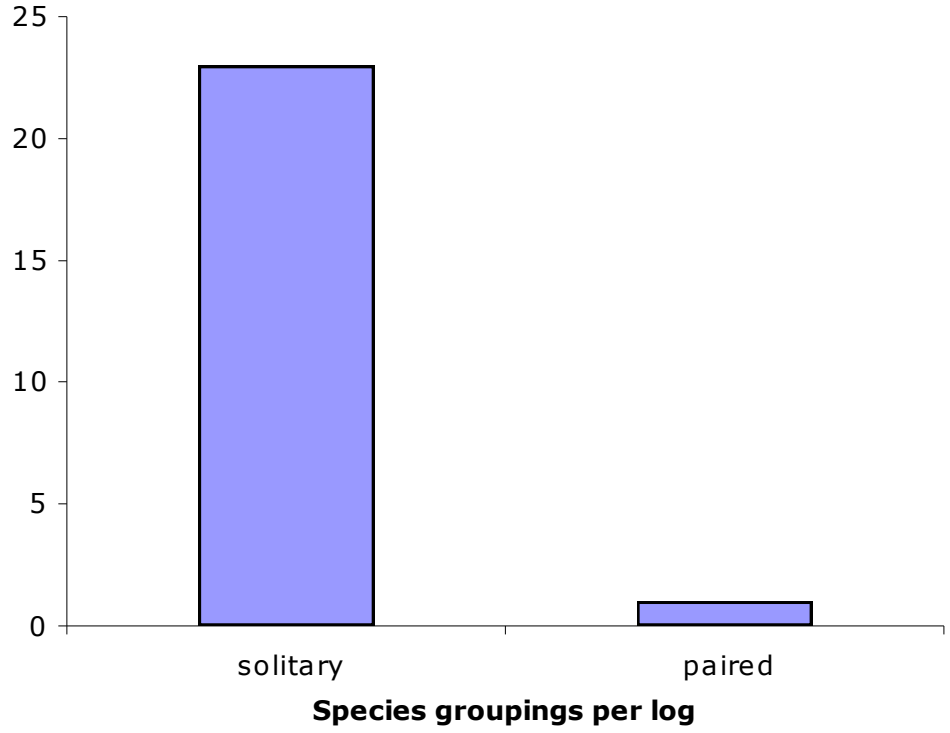

FIGURE 3. Frequency of logs with *Hexagonia papyracea* occurring solitarily and paired (with another macrofungal species) in Monteverde, Costa Rica. Ninety-six percent of *Hexagonia papyracea* occurred solitarily.

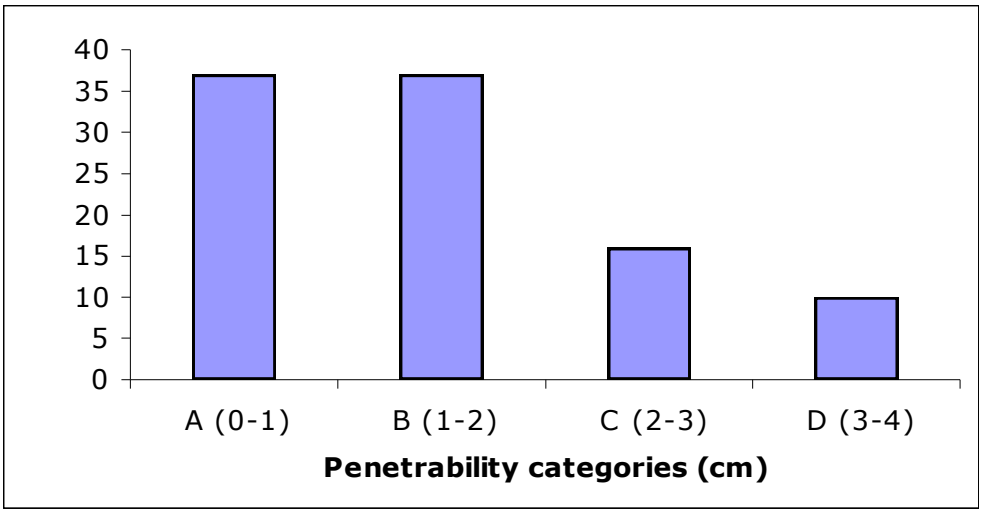

FIGURE 4. The number of logs supporting macrofungi in each penetrability category. Categories are ranges of log penetrability (cm): A (0-1), B (1-2), C (2-3) and D (3-4).

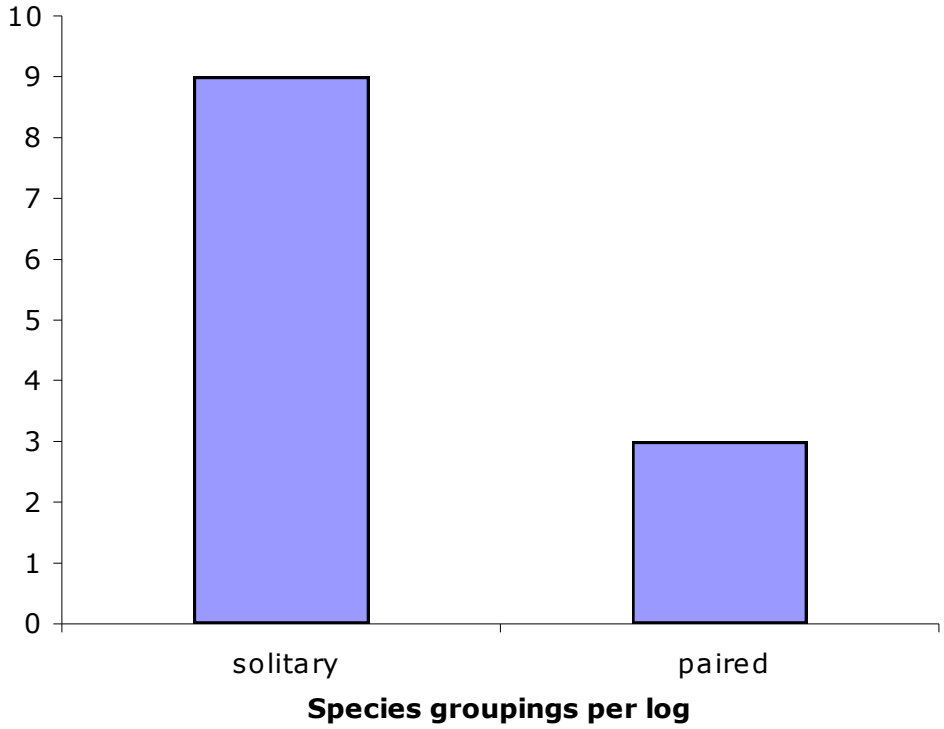

FIGURE 5. Frequency of logs with *Xylaria polymorpha* occurring solitarily and paired (with another macrofungal species) in Monteverde, Costa Rica. Seventy-five percent of *X. polymorpha* occurs solitarily.

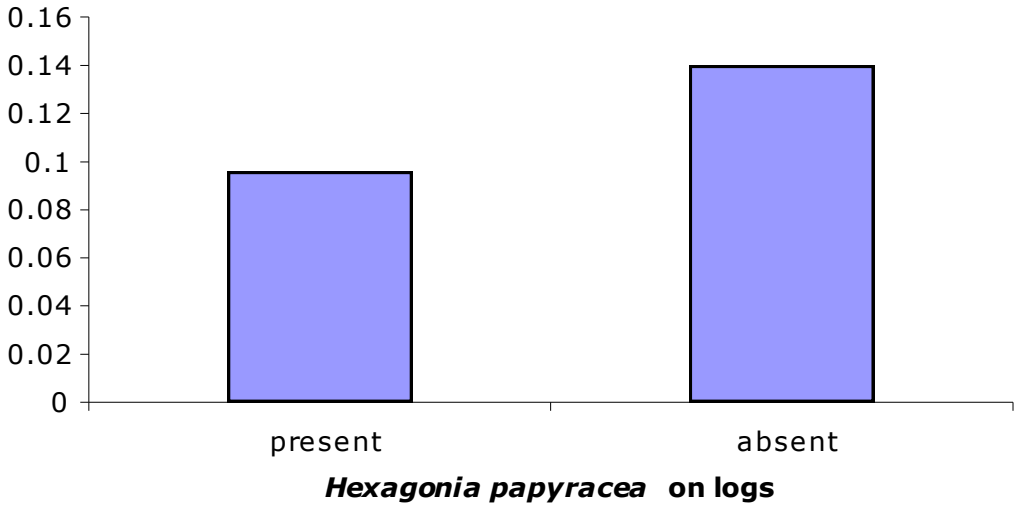

FIGURE 6. Mean diameter of logs with and without *H. papyracea.* Logs with *H. papyracea* had significantly smaller diameters than logs without it.

DISCUSSION

The relationship between log penetrability and the number of species per log was not significant. One possible explanation for this is that a fungus colonizes and dominates a log, preventing another species from establishing on the log. This could also explain why the relationship between log diameter and number of species on the log was significant, because logs with larger diameters have more surface area which might allow more than one species to colonize that space.

A beta-diversity of 0.52 and a habitat breadth of 1.92 logs for the entire community indicate a relatively high species turnover between logs; for penetrability categories, Table 1 shows a trend of increasing beta-diversity with increasing penetrability. This high turnover is possibly due to size constraints allowing very few species per log as described above. However, there is evidence that another factor is contributing to the high turnover: community succession. The Sorenson's Qualitative Indices calculated for all combinations of penetrability categories were all between 0.09 and 0.23, indicating strong dissimilarity in species composition between the four categories (Table 2). The three least similar pairs were A: D, B: D and C: D. The fact that the three lowest similarity indices were always a result of comparisons with category D suggests that logs with high penetrability can support fungi that are very different from the fungi that are supported by logs with lower penetrability. It is likely that logs with very high penetrability have a structure and nutrient composition that only certain types of fungi can grow on. Category A was also very different from the other categories (though to a lesser extent). This indicates that fresh logs and rotten logs support very different communities from each other (contributing to the observed high turnover) and from intermediately decomposed logs, suggesting that community succession might be taking place.

Among the four penetrability categories, categories A and B contained 74% of the logs, which indicates that fungi tend to colonize logs with lower penetrability. Logs with lower penetrability tend to have a lower moisture content (Herz 2004) and generally have more structure and nutrients because they are not far along in the decomposition process. This may provide the ideal habitat for many kinds of macrofungi and may be the reason the majority of fungi was found on logs with low penetrability.

The observation of the shelf fungus *Hexagonia papyracea* being very common and clustered agrees with current literature which describes *H. papyracea* as gregarious, fruiting during the wet season and occurring only on decomposing wood (Mata 1999). *Hexagonia papyracea* significantly occurred on logs with smaller diameters but did not vary significantly with changes in penetrability. This suggests possible substrate specialization based on size. However, several times it was observed to occur in groups of logs that appeared to originate from one species (e.g. a tree fall). Therefore, another possibility is that it colonizes logs based on factors that were not measured in this study, such as the nutrient composition or species of the log itself. Some fungi species are known to only colonize wood from specific plant species (Mata 2003).

Unlike *H. papyracea*, *X. polymorpha* did not seem to follow any pattern of occurrence. The logs were widely spaced and thus were less likely to belong to the same host species. However, it is difficult to draw conclusions about substrate specificity because there were only 12 samples of this species.

The results of this study suggest trends which need to be investigated by further research. Fungi are an integral part of ecosystems, they hold great economic and medical potential and yet they are poorly studied. Developing our knowledge of fungi is essential if we are to truly understand biodiversity and conserve it.

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