
The effect of human disturbance on fungal diversity in the tropics

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An understanding of the effect of human disturbance on fungal diversity in the tropics is of paramount importance if we are to conserve renewable resources effectively. Sustainable development may provide renewable resources, but what is the effect of sustainable practices on fungal diversity? Are the fungi of a secondary rainforest as diverse as those found in a pristine forest? Do agriculture practices conserve fungal diversity? What is the effect of water pollution on aquatic fungi? In this paper an attempt is made to examine the effect of human disturbance on fungal diversity in the tropics. The fundamental lack of even basic knowledge of fungi in the tropics means that it is very difficult to explore this question and only a limited number of studies are available to provide relevant data. Fungal diversity appears to be related to plant diversity and therefore, loss of the plant diversity is likely to result in loss of fungal diversity. Fungal diversity may also be related to disturbance. Fungi on palms in a tropical pristine forest are a diverse assemblage. Fungi on agricultural palms or palms in botanical gardens, on the other hand, lack diversity and comprise a probable fungal weed component. We present the need for organized studies to look at the effect of human disturbance on fungal diversity.

Introduction

Disturbance is a common feature of many ecosystems, occurring at all levels of ecological organization and at numerous temporal and spatial scales (Zak, 1992), and may be anthropogenic or natural. Natural disturbance, from seasonal changes in rainfall and treefall, to hurricane damage, cause population shifts and changes to communities of fungi (Lodge and Cantrell, 1995). For example, only 3 of the 20 regularly surveyed mycelia of *Collybia johnstonii* could be found in the litter layer during 2 years following hurricane Hugo because of increased solar radiation and desiccation (Lodge and Cantrell, 1995).

There are several comprehensive reviews on the effects of human disturbance on fungal communities (Zak, 1992; Miller and Lodge, 1997), but most were restricted to the effects of disturbance on soil or mycorrhizal

communities in temperate regions. There is little information on the effect of disturbance on fungi in rainforests or mangroves, which are habitats unique to the tropics.

Tropical environments differ ecologically from temperate habitats in physical, chemical and biological attributes (Lacher and Goldstein, 1997). They are characterized by warmer temperature, with little or no seasonality, and heavy precipitation during at least part of the year. Although tropical habitats only occupy 25.7 % of the land area of the earth, they harbor the bulk of the world's species (Deshmukh, 1986). Raven (1988) suggested that 2/3 of the vascular plant species occur in the tropics. Biodiversity of fungi in the tropics is also very high. Numerous new taxa have been described from the tropics in the last decade despite the fact that few mycologists are located in these regions (Hyde and Hawksworth, 1997). There are probably 1 million fungal species on tropical plants alone yet to be discovered (see Hawksworth, 1993).

Many tropical environments are being heavily disturbed by human activity. This disturbance is often in the form of addition of chemicals, e.g. discharge of industrial effluents and organic fertilizers, and habitat degradation, e.g. slash and burn agriculture, selective logging, destructive logging followed by reforestation, or deforestation followed by agriculture or managed forestry, affect fauna and flora by reducing species numbers and evenness. What are the effects of these disturbances on the fungi in rainforest, mangrove and other habitats? So far very little published information is available. The purpose of this paper is therefore, to examine the effects of human disturbance on fungi in tropical habitats. Due to the paucity of tropical data on the effects of human disturbance we will target certain fungal communities for which there are some data (i.e. palm, soil, mangrove and freshwater fungi).

Deforestation and fungal communities

Soil fungi

In a study on the diversity of soil fungi on natural and cultivated stands in the eastern Amazon (north of Brazil), four sites were selected for comparative investigations of the populations of soil fungi (Pfenning, 1997). In all sites there was a low number of dominant species and a high proportion of rare species. The proportion of dominant species in relation to the total number of isolates was the lowest in the relic areas of primary forest (50 %), indicating a higher species diversity. The introduction of agricultural plants in cleared areas resulted in an increase of potential plant parasitic species (e.g. *Fusarium* spp.) and a higher proportion of dominant species in relation to the total number of isolates (60-70 %), indicating a lower species evenness.

However, Rambelli and coworkers (1983, 1984) have compared the soil mycota under shifting cultivation and that of natural ecosystems. They found that in four permanent plots in the Ivory Coast, the fungal community, if disturbed, had the ability to recover fast through a regular succession.

Palm fungi

Palms are very rich in fungi and there is an assemblage of fungi consistently associated with palms (Hyde, Fröhlich and Taylor, 1997). These fungi can be found on palms in a diverse range of habitats. Taylor (1998) investigated the fungi occurring on palms in both pristine rainforest and on cultivated land, or in botanical gardens. Fungal communities in natural stands of *Archontophoenix alexandrae* in rainforests of north Queensland were found to be significantly richer than those of palms outside their natural habitat, e.g. naturalized in new habitats in Hong Kong, or in botanical gardens (Taylor, 1998). Fungal communities in natural stands of palms in rainforests comprised a unique group of palm fungi, while those outside their natural habitat contained a few typical palm fungi and were colonized mostly by plurivorous weedy fungal species (e.g. *Lasiodiplodia*, *Pestalotiopsis*; Taylor, 1998).

Water pollution and fungal communities

Mangrove fungi

The location of mangroves at the sea-land interface makes the ecosystem vulnerable to disturbance from both regions. Some publications have reviewed the effects of disturbances on mangrove plants (Kongsangchai, 1984; Dicks and Westwood, 1987) and mangrove fauna (Garrity and Levings, 1993; Peters *et al.*, 1997). The effects of disturbance on mangrove fungi, however, have received little attention despite the fact that they are a very diverse group of organisms with more than 358 species (Jones and Alias, 1997).

Contamination by petroleum hydrocarbons from oil spills and oil refineries is a major threat to mangroves throughout the tropics (Scherrer and Mille, 1989; Garrity and Levings, 1993). Hyde (1989) reported that the presence of hydrocarbons reduced the diversity and numbers of saprotrophic fungi on intertidal mangrove wood. The presence of hydrocarbons on the substratum surface and mangrove mud reduces aeration and slows down the activity of micro-organisms such as fungi (Scherrer and Miller, 1989). The reduction in activity also slows down mineralization of organic matter, which causes deficiency of nutrients essential for the growth of the micro-organisms. However, in a study on intertidal manglicolous fungi in Mauritius, Beau Champ mangrove, a site contaminated with oil, showed a higher diversity with 36

species compared to nearby undisturbed mangrove where only 30 species were collected (Poonyth, unpubl.). These contaminants might not have reached levels whereby they could have deleterious effects on the mycota. They might even be providing conditions favourable for the fungi to flourish, hence the high diversity at this site. However, the absence of baseline studies prior to contamination makes it difficult to confirm this.

The mangrove ecosystems around the world have suffered massive destruction due to activities such as mining (Kongsangchai, 1984) and mariculture (Landseman, 1994). Destruction of mangrove forests will decrease the amount of substrates available for colonization, thus reducing the number of species of manglicolous fungi and their evenness.

Heavy metal pollution is also a major threat to many mangroves. Heavy metals reach mangroves mainly from industrial waste water (Hanley, 1992; Kadam, 1992; Tam and Wong, 1995). A high proportion of heavy metals from effluents is retained in the mangrove mud and causes die back when they are absorbed by the plants (Tam and Wong, 1995). To our knowledge there are no reports on the effect of heavy metals and pesticides on mangrove fungi. Extrapolation of observations in other ecosystems such as rainforest or freshwater to mangrove might not be valid as the latter are subjected to different and more variable environmental conditions.

Freshwater fungi

Freshwater fungi are a cosmopolitan group which include zoosporic fungi, ascomycetes, zygomycetes, deuteromycetes and basidiomycetes (Goh and Hyde, 1996). They play a crucial role in the freshwater ecosystem in nutrient cycling by breaking down leaves and woody substrates (Wong *et al.*, 1998). The effect of human disturbance (e.g. discharge of industrial and domestic effluents, indiscriminate use of pesticides, clearance of riparian vegetation) on the fungal communities, mostly in temperate regions, has been reviewed by Bärlocher (1992). Very little research has been carried out in the tropics.

Tan and Lim (1984) studied the mycota in water in two sites along a river in Singapore. Site 1 was identified as moderately polluted and site 2 as extremely polluted. The results showed that the diversity and the number of individuals were lower in site 2, the more polluted site. Similar results were reported from Au, Vrijmoed and Hodgkiss (1992a) in Hong Kong. They compared the fungi found on leaf baits in polluted and unpolluted streams located geographically close together. The species richness and conidial production was higher in the unpolluted stream. In the same study, Au, Vrijmoed and Hodgkiss (1992b)

found that the decomposition of leaf baits seemed to be suppressed in the polluted stream.

The effects of pesticides on the fungal community have been studied in India (Chandrashekar and Kaveriappa, 1989, 1994). Pesticides may leach into the river system during heavy monsoon rains. The herbicides, paraquat and 2,4-dichlorophenoxybutyric acid, and the fungicides, mancozeb and captafol, did not inhibit the growth of three aquatic hyphomycetes in culture (Chandrashekar and Kaveriappa, 1989). Chandrashekar and Kaveriappa (1994) demonstrated that the sporulation of 18 species of aquatic hyphomycetes was not inhibited by up to 5 mg/L of eight pesticides, mainly herbicides. In the same study, the germination of six species was shown not to be inhibited by up to 1 mg/L and species tended to show different sensitivity at higher concentration.

Human activities often increase the concentration of metals in the streams, and Bermingham (1996) has reviewed the sensitivities of aquatic fungi to certain metals but there were few tropical examples. Studies from temperate regions indicate that streams contaminated with metals often have a reduced fungal species diversity and the rate of leaf decomposition (Maltby and Booth, 1991), also the growth and sporulation of aquatic hyphomycetes would be retarded (Abel and Bärlocher, 1984; Chamier and Tipping, 1997).

Conclusions

The ability of soil fungal communities to recover following shifting cultivation has been demonstrated, however the effects on most other fungal groups is unknown. The effects of selective logging or total deforestation on the fungal community, is also unknown and it is not known if communities can recover after reforestation. In large areas of Brunei logged forests have recently been destroyed by fire following a long period of drought and the effects on the fungal communities is no doubt catastrophic. The soil mycota in one area under permanent cultivation has been shown to be more prone to dominance by a small number of taxa, than nearby soil under relic areas of primary forest. The evidence therefore indicates, that once forests become disturbed there is a long term loss of species diversity, which will be most pronounced where agricultural practices cultivating single plants (e.g. oil palm plantations) are introduced. Plants inside natural rainforest (e.g. palms) have rich fungal communities, but once they are removed to new habitats their fungal communities become impoverished and comprise mainly plurivorous weedy fungi. Therefore, there is a strong case for *in situ* conservation and the preservation of natural rainforest in order to conserve fungal resources.

With the exception of Ingoldian fungi, little is known of the effect of human disturbance on aquatic fungi, especially in the tropics. Whether fungi are sensitive to various pollutants and chemicals is unclear. We have little idea how long it takes for communities to recover after human disturbance. Habitat degradation may be a major threat to fungi since loss of habitat may wipe out the population and cause possible extinction. Even though studies of the effects of disturbance on freshwater fungi are presently carried out (Tsui, unpubl.), documentation of biodiversity and further research on the effect of disturbance on their ecosystem functioning are necessary.

The above examples illustrate the paucity of information that is available on the effects of disturbance on fungi in the tropics. These effects may range from minor to catastrophic although as there is so little data, any conclusive statements would involve unrealistic extrapolation. The evidence does indicate any disturbances will affect fungal diversity in one way or another, and therefore the need for *in situ* conservation of undisturbed habitat is obvious. The need for further studies that examine the effects of agriculture, and other types of disturbance on fungi in the tropics is paramount.

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