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Diversity of mesofauna and macrofauna in protected and disturbed soils of Ngel Nyaki forest, Nigeria

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ABSTRACT

High biodiversity of the soil fauna can be an indicator of soil fertility and its ability to sustain complex food chain, but fauna diversity alone is rarely used as a measure of these attributes. In this study we investigated the mesofauna and macrofauna diversity in protected and disturbed soil habitats as a measure of the soil ability to sustain high biodiversity, using the Shannon-Weiner's index (H). It was observed that $H = 1.4049 < 1.6494$, maximum diversity (H_{max}) = $3.1781 < 3.6889$, species evenness (H/Hmax) = $0.4421 < 0.4771$, species richness (S) = $24 < 40$ and equivalently common species (e^H) = $4.0751 < 5.2039$ were consistently lower in the disturbed soil compared to protected soil site. The distribution of fauna species was significantly different between the sites (Kolmogorov-Smirnov: $D_{max} = 0.233$, $D_{crit} = 0.0282$, $P < 0.05$). 17 fauna species identified in the protected soil were absent in disturbed soil habitat. These species could be used as indicator species in determining soil habitats that have been depleted by human activities in ecological areas with similar characteristics. These results demonstrate the need for proper soil management practices to restore biodiversity loss in disturbed soils.

Keywords: Fauna, species, biodiversity, community, abundance.

INTRODUCTION

Many organisms live in the soil and contribute to its quality and stability in an ecosystem (Lavelle 1996). These organisms interact in the soil enhancing its fertility, promoting primary production and creating a complex food web in the soil ecosystem that serves to sustain life within the soil and on the surface (Sackett et al., 2010). The increased biodiversity of life forms within a given soil habitat is a testimony to its fertility and an indicator of its ability to sustain divergent species. The activities of individual species of different classes of the soil biota have been investigated and their niches known under different conditions (Miura et al., 2008). Some species of the microbiota fix atmospheric nitrogen into usable form by the plants (Lal, 1999). Nitrogen is an important component of protein which is essential for the growth of the flora and fauna species in any type of biome. In addition to fixing nitrogen, many species of the microbiota provide carbon and energy sources and also participates actively in decomposition and recycling of nutrients in the soil (Nazir et al., 2010). The mesobiota and macrobiota species also perform various activities that increase the nutrients contents

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of the soils by breaking up and mixing plant materials, microbial materials and other matter in the soil which tend to accelerate soil mineralization (Lavelle, 1996, Bhadauria and Saxena, 2010). These activities preserve the integrity of the soil for the immediate utilization by the primary producers upon which the fauna depends for their nutrient requirements. Therefore it can be argued that the wide diversity of fauna species variation in any given soil habitat can also be used as an indicator of the healthy quality of the soil, given its ability to support different fauna species. Since animals do not photosynthesis food, but have to draw their food needs from the primary producers in the ecosystem, increased fauna diversity in a given habitat could imply that the primary producers are producing enough food in the habitat to generate a complex energy flow system that is capable of sustaining different fauna species at the secondary and tertiary trophic levels.

It is reasonable to expect that a more fertile soil would accommodate more divergent fauna species than a less fertile soil because of the better quality of primary biomass production the former can produce. Therefore, we reasoned that a protected soil habitat where the natural processes undertaken by the biotic community that promote soil fertility proceed without human interference should be relatively more fertile than its unprotected counterpart. Consequently, it should accommodate more fauna species diversity than the latter. Similarly, if habitat is degraded by human activities, it would be reflected in the low level of species richness and abundance of the habitat, compared to a habitat that has been conserved and shielded away from human degradation. The Shannon-Weiner's diversity index has been used to measure habitat quality which may be degraded by human activities (Shannon, 1948). A high diversity of the index implies a high degree of uncertainty in predicting the next organism that may be seen in the habitat as there may be many species in the habitat's community, while a low diversity of the index indicates a high degree of certainty in predicting the next organism that may be seen in the habitat as there may be comparatively lower abundance of species.

In this study, the Shannon-Weiner's diversity index was used to compare the mesofauna and macrofauna species diversity on a protected and disturbed soil habitat of Ngel Nyaki forest soil. The aim was to determine if fauna diversity composition alone could serve as a useful indicator of measuring the impact of human activities on the biodiversity composition of preserved and disturbed soil habitats.

MATERIALS AND METHODS

Study area

Was Ngel Nyaki forest area is located in the Mambilla plateau, Nigeria. The forest area lies between Latitude 6 ^{o} 3 ' N and 7 ^{o} 15 ' N; Longitude 11 ^{o} 00 ' and 11 ^{o} 30 ' E. Figure 1. This area has been described in details by Chapman and Chapman (2001). Briefly, the Ngel Nyaki forest area is divided into three compartments namely, the Grazing land, which is grassland (disturbed area) where, controlled human activities such as farming, grazing and collection of non timber products is allowed. This part measures 2000 hectares. The Forest Conservation Area (partially protected area) which measures 2 km^2 has mosaic forest and grassland with narrow strips along major rivers and valleys of various hills. Here exploitation activities are prohibited but pockets of illegal activities still persist within the area. The Montane Research Project Area (protected area) measures 7.2 km^2. It is a strict conservation area of undisturbed forest (Dowsett-Lamaire, 1989). Only research on plants and animals are allowed in the area. There are transects and research plots laid within the study area to cover the different bio-geographical features of this area.

Site selection

A 2 km transect was laid at each of the two study sites. The Montane Research Project Area (protected site) and the Ngel Nyaki grassland (distrurbed site). Each transect was divided into 20 points, 10 points were randomly selected from the 20 points at each study site. A 10 m^2 area was established at each of the 10 selected points with point of the transect at the centre for sample collection.

Soil sample collection for identification of soil mesofauna, and macrofauna

Soil collection for identification of the mesofauna (invertebrates 0.1-2.0 mm in diameter) was done at 5 randomly selected points along the transect with a trowel to the depth of 15 cm. Also for the macrofauna (organisms >2.0 mm in diameter) soils were collected down to the depth of 15 cm. However, 5 quadrats of 1 m^2 each were randomly laid at each selected points along the transect a trowel and board were then used to collect the soil. The soils were kept in sterile polythene bags and taken to the laboratory within 24 hours for analysis.

Extraction identification and estimation of soil mesofauna, and macrofauna

The Bukard model of Berless funnel extractor was used to extract mesobiota as described by Badejo (1996). Briefly, soil samples were poured on a sieve resting on steel sided aluminium funnel that led into a collecting tube containing 70% alcohol. A 25 W bulb was used to light and heat the soil. The heat and light drove the mesofauna which are negatively photoblastic through the sieve into the collecting tube. The contents of the tube were emptied on a petri dish for sorting, counting and identification using manuals and a dissecting microscope (Brower et al. 1998). Soil macrofauna were identified by spreading the soil sample on a flat board and sorting out all invertebrates. Soil vertebrates were identified and counted using both direct sighting and indices. The randomly selected 10 m^2 area points located at the centre of the transects were thoroughly searched for the physical presence or signs, indicating the presence of these vertebrates.

Data analysis

The Shannon-Weiner diversity index ($H = -\Sigma(p_i)\ln(p_i)$), species richness (S), maximum diversity possible ($H_{max} = \ln(S)$), evenness of species (H/H_{max}) and Equivalently common species (e^H) were calculated for each site. The fauna distribution between the two sites was further compared by two sample Kolmogorov-Smirnov test (Kolmogorov 1933, Smirnov 1948) at 5% level of significance.

RESULTS

The results indicated that 40 species of fauna were found in the protected soil compared to 24 fauna species in the unprotected or disturbed soil habitat (Tables 1 and 2). This represents a 25% difference in species richness between the two sites. Also, the total abundance of mesofauna and macrofauna found in the protected habitat was nearly 3 times higher than in the disturbed habitat. Statistical analysis of the fauna species distribution between the two sites showed a significant difference (Kolmogorov-Smirnov: $D_{max} = 0.233$, $D_{crit} = 0.028$, $P < 0.05$, Table 1).

However, species diversity within each site was low. The Shannon-Weiner's diversity index (H), maximum habitat diversity and evenness of species distribution were in each case marginally greater in the protected soil habitat than the disturbed habitat. The low diversity of 40 species community in the protected soil habitat was just equivalent to that of 5 species community with similar abundance. In the same manner, the diversity of 20 species community in the disturbed soil was similar to just 4 species with similar abundance as indicated by the values of equivalently common species at the two sites (Table 2).

At each site, the most abundant species were termites and ants. On the average, these species accounted for 83.83% of the total abundance of the fauna species in the protected and disturbed soils, giving rise to low species diversity as shown by sharp curves of the plot of the cumulative percentage and ranks of fauna species at each site (Figure 1).

Table 1: Comparison of fauna composition in protected and disturbed soil habitats.

Common name	Taxa/scientific name	Protected soil	Disturbed soil
Lizard	*Agama agama*	7	12
Mole	*Tachyoryctes sp*	9	7
Mice	Rodentia	16	13
Hare	*Lepus capensis*	12	5
Giant rat	*Cricetomys gambiance*	5	3
Cobra snake	*Naja* sp	2	-
Black mamba	*Dendroapsis polylepsis*	3	4
Ground squirrel	*Allanto xerus gentulus*	11	7
Porcupine	*Hystrix cristata*	7	-
Beetle	*Golianthus* & *Holiocopris* spp	102	248
Black ants	*Formica fusca*	772	1215
Soldier ants	*Dorylus* sp	2011	-
Butterfly pupa	*Lepidoptera* sp	22	5
Centipede	*Pachymerium ferrugineum*	114	26
Mole crickets	*Gryllotalpa Africana*	39	26
Earthworm	*Hyperriodrillus Africana*	161	32
Earwig	*Forticula auricularia*	16	24
Grasshopper	Caelifera	34	17
Moth larvae	*Arctia* sp	120	16
Millipede	*Archispiro streptus gigas*	151	3
Small snail	*Helix sp*	59	18
Giant snail	*Achatina achatina*	35	-
Spider	Araneae	85	21
Termites	*Hodotermes* sp	4582	1411
Bug nymph	*Anisopia* sp	16	-
Fly larva	Diptera	12	-
Praying mantis	*Othodera* sp	9	-
Sawfly larva	Symphyta	16	-
Wasp	*Vespula vulgaris*	11	-
Cockroach	*Paracoblatta* sp	35	-
Pillbug	*Armedillidium vulgare*	15	-
Caterpiller	*Lepidoptera* sp	39	-
Spring tails	Collembola	30	9
Mites	Acari	34	38
Diplura	Diplura	14	-
Protura	Protura	23	-
Lepidoptera	Lepidoptera	13	-
Unidentified A	Unidentified A	17	3
Unidentified B	Unidentified B	7	-
Unidentified C	Unidentified C	24	-
Bristletails	Thysanura	-	5

$D_{max} = 0.233$, $D_{crit} = 0.028$, $P < 0.05$

Table 2: Fauna diversity measures in protected and disturbed soil at Ngel Nyaki Forest.

Diversity Measures	Protected Soil	Disturbed Soil
Shannon-Weiner Index	1.6494	1.4049
Maximum diversity	3.6889	3.1781
Species evenness	0.4471	0.4421
Equivalently common species	5.2039	4.0751
Species richness	40	24
Total species abundance	8690	3168

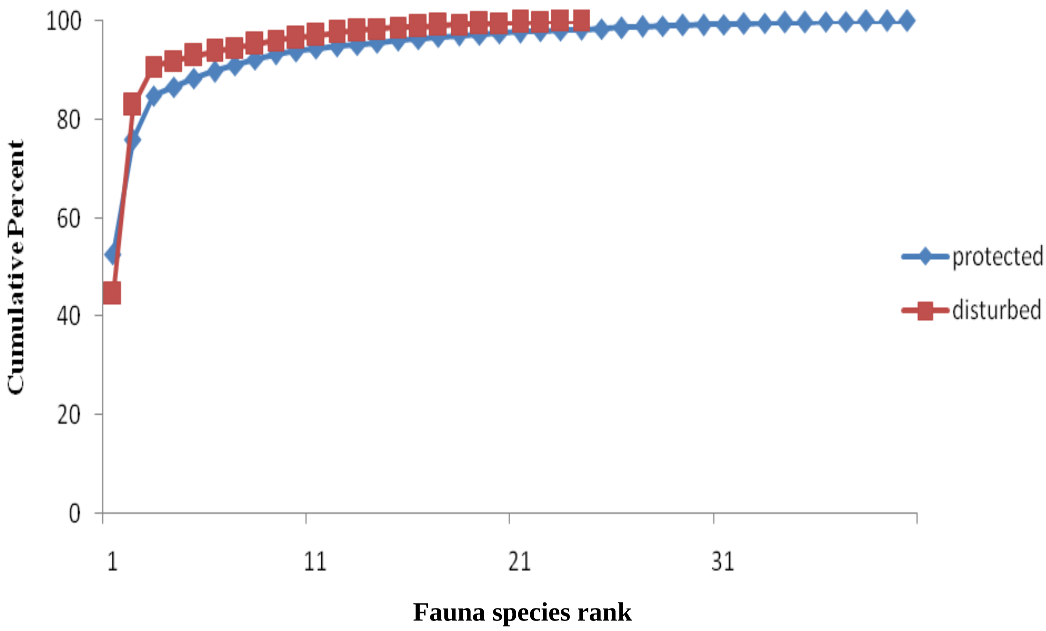

Figure 1: Plot of the cummulative percentage versus ranks of fauna species in the protected and disturbed soil sites at Ngel Nyaki forest area.

DISCUSSION

The present results have shown that despite the low diversity of the mesofauna and macrofauna species that was a common feature in both the protected and disturbed soil sites at Ngel Nyaki forest, the former had relatively greater diversity of soil's mesofauna and macrofauna species than the latter site. The uneven distribution of the fauna species between these sites was also demonstrated by comparably marginal, albeit higher values of several variable indices that were recorded at both sites. This observation mirrors the findings reported by Brown et al. (1996) who compared the biodiversity of soil biota in the protected and disturbed habitats; and observed that both vertebrate and invertebrate species diversity were higher in the former habitat than the latter. Although, the diversity differences between the two sites were low and largely insignificant, they nonetheless present a clear tendency towards higher fauna species diversity in the protected habitat. Many studies have found that the biodiversity of soil fauna increases as a result of existence of increased heterogeneity of microhabitat within the soil (Anderson, 1978a; 1978b; Niklas and Janne, 2006). These microhabitats are sources of a variety of food materials in the soil which are necessary for sustaining higher diversity of the soil fauna species. However, heterogeneity of the soil habitat could give way to homogeneity if the soil is frequently disturbed (Nielsen et al., 2010) leading to massive destruction of other soil biota that need heterogeneous microhabitat to sustain high fauna diversity. In the protected soil habitat, less soil disturbing activities would promote the retention of the heterogeneous microhabitat and consequently, the dependant soil biota which would continue to thrive, and also encourage the establishment of complex food webs that can serve diverse niches. It is therefore pertinent to reason that if soils are increasingly pressured from land cultivation, animal grazing, and other human activities that were very common in the disturbed soil habitat at the Ngel Nyaki forest, fauna species abundance and diversity would decrease. Perhaps, this could account for the decreased fauna species abundance and diversity that were recorded in the disturbed soil habitat in the present study. Previous investigations have reported similar observations (Brown et al., 1996; Beare et al., 1997).

The inability of the fauna component of the soil biota to synthesize food whether they are vertebrates or invertebrates, make them entirely dependent on the complete integrity of the soil biotic community to flourish. Thus, specific species among them would be very useful indicator species for measuring the integrity of soil or lack of it, occasioned by soil disturbance. For instance, the relative abundance of beetles and black ants each increased from the protected soil habitat to the disturbed soil habitat, conversely those of the earthworms and termites decreased (Table 1). These organisms are collectively referred to as ecosystem engineers, and contribute immensely to building structure in their habitat that impact positively on soil fertility. However it is apparent that beetles and black ants may require different microhabitats compared to earthworms and termites to effectively operate in order to enrich the soil and this may explain why their relative abundance tended to increase or decrease in the protected and disturbed soils. A large number of micro-arthropod species that were present in the protected soil were completely absent in the disturbed soil (Table 1) suggesting that perhaps their microhabitats had been eroded. Such a sharp decline in species richness was not established among the vertebrate species represented at the two sites indicating that on the face value, the presence or absence of vertebrates such as lizard, mole, mice, giant rat, cobra snake, black mamba snake, squirrel and porcupine may not be useful fauna species in determining major differences between protected and disturbed soil habitats.

It has been argued that the impact of land use on soil biota affects the quality and quantity of soil species biodiversity (Minor et al., 2004). Therefore, any human activity that homogenizes the soil such as land cultivation could destroy microhabitat diversity in the soil and decrease the diversity of soil fauna, since species richness is enhanced as a result of heterogeneity in the microhabitats of the soil structure (Niklas and Janne, 2006; Nielson et al., 2010). This argument is valid for species richness and is in tandem with species richness values of 40 and 24 recorded in the protected and disturbed soils respectively (Table 2). It may also explain the low fauna diversity in the disturbed soil. However, this argument does not clearly explain why there was low fauna diversity even at the site that was protected. For instance, the diversity of 40 fauna species community in the protected soil was just equivalent to 5 species community with high diversity, and similar abundance. Also in a community of 24 species in the disturbed soil, the diversity of these 24 fauna species was just equivalent to a 4 species community with high diversity and similar abundance as obtained for the 24 species, demonstrating the low level of species diversity at the disturbed site. A plausible explanation for the low diversity recorded at the protected and disturbed soil sites could be the overbearing dominance of few species such as the termites and ants, which on the average constituted nearly 83.83% in abundance at the two sites compared to other species. A pertinent question to ask is whether high abundance of ants and termites is often at the expense of other fauna species or it's an indication of some soil biotic or abiotic factors associated with these habitats that hinder the full potential diversity of other fauna species in the soil. These factors could be the composition of soil microbiota, soil texture or its chemical composition; all of which influence soil fertility and could influence the primary productivity and consequently fauna species abundance and diversity. If these were true, it could be possible after further determination of these factors to use fauna species that were distinctly present or absent in these two habitats as indicator species that could facilitate distinction to be made between protected and disturbed soil habitats in areas with similar ecological characteristics. Further studies are needed to verify this claim. In this regard, the most useful fauna species would be mainly arthropods species since many of these invertebrates are useful organisms that contribute significantly to the determination of soil quality (Stork and Eggleton, 1992) and the regulation of ecosystem productivity (Sackett et al., 2010) above the ground surface.

Conclusion

This study has demonstrated that soil fauna diversity was low in both protected and disturbed soil site. Fauna species abundance decreased in the disturbed soil habitat compare to protected habitat. A number of fauna species particularly arthropods may serve as useful indicators in identifying soil habitats that have been disturbed due to human activities. If these are identified, there may be a need to introduce proper soil management practices that would replenish or restore the integrity of the soil as well as the loss in fauna species diversity.

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