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Distribution patterns and diversity of leaf litter and soil-dwelling arthropods in a lowland rainforest in southern Cameroon

Mbenoun Masse P. S*, Yede, Mveyo Ndankeu Y. P

Laboratory of Zoology, Faculty of Science, University of Yaounde I, Yaounde, Cameroon

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Abstract

We investigated the effect of forest disturbance and leaf litter depth on arthropod group composition, abundance and density in a lowland rainforest in Cameroon. Arthropods were collected by hand collection and pitfall trapping, and litter depth was measured in two forest types (secondary and primary) from June 2015 to June 2016. A total of 1668 individuals belonging to five classes (Insecta, Diplopoda, Chilopoda, Arachnida and Malacostraca) and twenty orders were recorded in both forests. Insecta was the most abundant class that made up 61% of all captured animals, whereas Chilopoda was the most rare class (<1%). Hymenoptera and Coleoptera were the most abundant group among Insecta. Arthropod abundance and density varied between both forests, and appear to be related to the level of disturbance. The depth of leaf litter was correlated significantly with arthropod abundance in the primary forest. In both forests, Insecta and Diplopoda were dominant, but their abundance decreased significantly from the natural to the secondary forest. This suggests that these taxa are more sensitive to environmental change than others, and may be considered as useful for biodiversity assessments.

***Corresponding Author:** Mbenoun Masse Paul Serge ✉ masseserge@yahoo.fr

Introduction

Tropical forests are considered worldwide as biodiversity hotspots because of high levels of species richness and endemism (Myers *et al.,* 2000). Despite its biodiversity hotspot status, the forest ecosystems are highly threatened and are being lost through conversion to agriculture, timber production, pasture, collection of fire wood and construction materials (Dirzo and Raven, 2003; Foley *et al.,* 2005; Gibson *et al.,* 2011; Lamb *et al.,* 2005; Ravikanth *et al.,* 2009; Sapkota *et al.,* 2010; Sudarshana *et al.,* 2002; Wright and Muller-Landau, 2006). The loss of habitat and fragmentation of tropical forest, coupled with other global change phenomena, inevitably threatens the soil fauna (e.g. arthropods).

Soil and litter arthropods are important components of tropical ecosystems (Cole *et al.,* 2016; Wilson, 1987). They represent a large proportion of tropical biodiversity (Decaens *et al.,* 2006; Hamilton *et al.,* 2013). This diverse group of animals covers a range of taxa, comprising Diplopoda, Arachnida, Maxillopoda, Xiphosura and range of insects (Coleoptera, Diptera, Thysanoura etc.). Arthropods play diverse roles in terrestrial ecosystems, they are ecologically important as detritivores, scavengers, herbivores and participate in an astonishing array of associations with plants (Blower, 1985; Collins, 1983; Crawford, 1992; Edwards and Shipitalo, 1998; Hölldobler and Wilson, 1990; Huxley and Cutler, 1991; Jolivet, 1996). Soil arthropods are also an important food source for many predacious invertebrates and vertebrates (McNabb *et al.,* 2001; Pianka and Parker, 1975; Redford, 1987). For these reasons, and because of their sensitivity to environmental change, many arthropod groups have been considered as potential indicator taxa in studies of diversity and for monitoring ecosystem health (Agosti *et al.,* 2000; Alonso, 2000; Bouyer *et al.,* 2007; Hilty and Merenlender, 2000; Kime and Golovatch, 2000; Longcore, 2003; Siddig *et al.,* 2016).

Little information is available on the ground arthropods group of the lowland rainforest in Cameroon. Thus, the specific objective of the current study was to characterize the community structure of litter and soil arthropods in two forest types. In addition, evaluate the impact of forest disturbance on the abundance of litter and soil arthropods.

Materials and methods

Study area

This study was conducted at the Campo Ma'an National Park (CMNP) (2°52'N, 10°54'E), with an area that covers about 776-202 ha, located in southern Cameroon. Arthropods were collected every month from June 2015 to June 2016 in two sites located at the southern periphery of the CMNP and separated by the Ntem River: a nearly primary forest site (PF) located in the protection zone (Dipikar Island) and a secondary forest site (SF) situated in one of the five logging concessions surrounding the park ''UFA 09025'' (Fig.1). In general, the CMNP lies within the humid forest zone characterized by a bimodal rainfall distribution, and four distinct seasons: two wet seasons (from mid-March to early July, from September to mid-November) and two dry seasons (from July to the end of August, from mid-November to mid-March). Annual rainfall averages 2797 mm and the mean annual temperature is about 25°C. The vegetation of the site forms part of the Atlantic Biafran forest and Lowland evergreen forest of the Congo Basin and Equatorial Guinea, rich in Caesalpinioideae with *Calpocalyx heitzii* and *Sacoglottis gabonensis* (Letouzey, 1985; Tchouto *et al.,* 2009).

Arthropod sampling

Two common sampling methods were used to sample the arthropod communities: quadrat sampling and pitfall trapping (Domingo and Alonso, 2010). Two transect lines (100 m long and 10 m apart) were selected at each site in each habitat type (PF and SF) and two sampling events spaced 100 m apart were undertaken monthly over a period of 12 months. Twenty quadrat plots (1 m^2 each) were set in two rows (100 m long and 10m apart) with 10 quadrats in each row. Quadrats were spaced 10m apart.

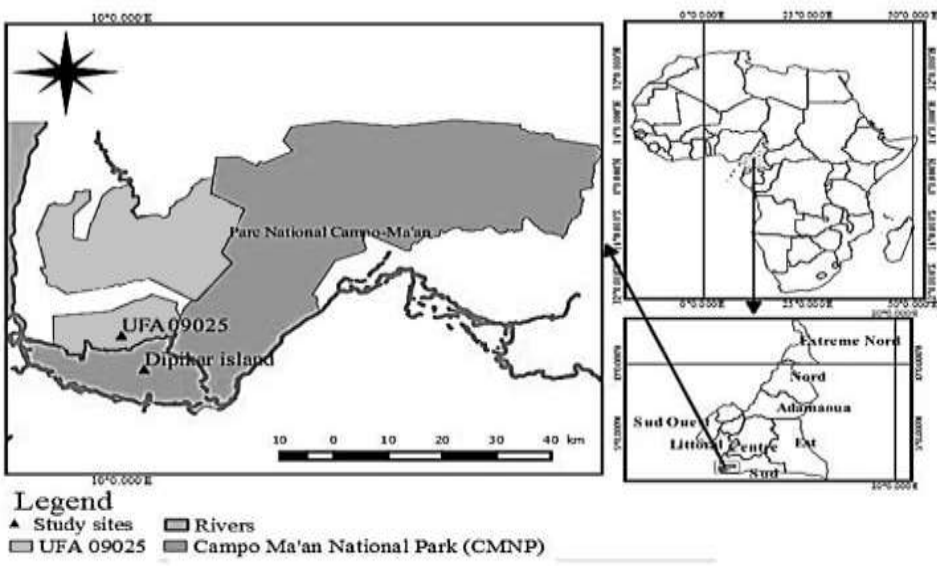

Fig. 1. Map of Campo'o Ma'an National Park, showing study sites.

In each quadrat, the depth of the litter was measured first and after, all shelters or microhabitats suitable for arthropods such as under stones, bark, fallen branches, layers of leaf litter were inspected. Arthropods were collected by two individuals for 60 minutes in each quadrat using forceps or mouth aspirator. In addition, pitfall traps were used in each site. Traps were consisted of a plastic drinking cup (85 mm top diameter) placed into a buried section of PVC pipe so that the rim of the cup was flushed with the ground surface. Prior to the beginning of trapping, the pitfall traps were left for 3 days to reduce 'digging-in' effects. After that, each trap was filled with c. 75 ml of 50% ethanol and 5% glycerol as a preservative. Twenty traps were set in two rows with 10 traps in each row. Traps were spaced 10m apart and 5 m from the nearest quadrat plot. Each pitfall was covered by an aluminium roof to prevent rain fall into the traps. Arthropods were preserved in labelled vials containing 70% ethanol and later identified in the laboratory to the class or order level using available dichotomic keys or other relevant literature. Voucher specimens were deposited within the reference collections of the Laboratory of Zoology at the University of Yaounde 1.

Data analysis

The relative abundance (%) of each class and order was determined at each site. Density is expressed as the mean number of arthropods/meter square. Difference in the abundance, litter depth, density for each class between secondary forest and primary were assessed by Student *t*-test and one -way ANOVA, non-parametric Kruskal-Wallis, was employed to assess the difference in abundance, litter depth and density of arthropods between secondary and primary forests. Pearson correlation was used to investigate the relationship between arthropod abundance and litter depth in each site. Analysis was performed using SPSS software version 12.0 and the significant value was set at 0.05. Throughout the text, results were expressed as mean ± standard deviation.

Results

Overall taxonomic group

A total of 1668 individuals belonging to five classes and twenty orders were recorded in both forests. Insecta was the most diverse (10 orders) and abundant (made up 61% of all captured animals), followed by Diplopoda (4 orders, 21%), Malacostraca (1 order, 9%), Arachnida (3 orders, 8%) and Chilopda (2 orders, 1%) (Table 1). The following orders were collected with insecta [Hymenoptera (the main abundant group), Coleoptera, Dictyoptera, Isoptera, Othroptera, Lepidoptera, Dermaptera and, with scarce representation, the Diptera, Hemiptera and Thysanoura orders] (Fig. 2).

Table 1. Classes and orders of Arthropods found in the Campo Ma'an National Park, Cameroon (n = total number of individuals).

Class	Order	n	Percentage (%)
Arachnida	Acari	1	8.51
	Araneae	125	
	Opiliones	16	
Chilopoda	Scolopendromorpha	13	0.84
	Geophilomorpha	1	
Diplopoda	Polydesmida	145	21.34
	Spirobolida	49	
	Spirostreptida	159	
	Stemmiulida	3	
Insecta	Coleoptera	264	60.79
	Dermaptera	18	
	Dictyoptera	112	
	Diptera	10	
	Hemiptera	10	
	Hymenoptera	378	
	Isoptera	100	
	Lepidoptera	17	
	Orthoptera	100	
	Thysanoura	4	
Malacostraca	Isopoda	142	8.51
Total		1668	100

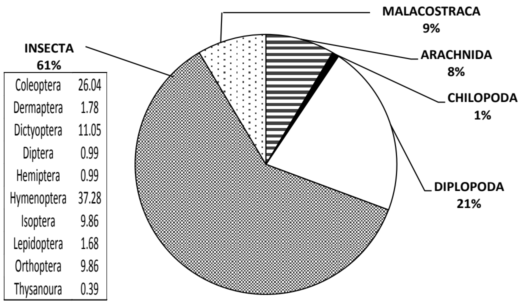

Fig. 2. Diversity patterns of Arthropoda (right) and percentage of insect orders (left) in the Campo Ma'an National Park in southern Cameroon.

Abundance

Overall, the number of classes and orders of arthropods were similar in natural and secondary forests. Besides the similarity, arthropod abundance was higher in the natural forest (1086 individuals) than in the secondary forest (579 individuals) (Fig. 3). In addition, there was a significant difference between the abundance of arthropods in both forests (t = 2.899; P = 0.0039). Both forests shared eighteen orders. Two orders were unique to natural forest, namely Acari and Geophilomorpha, whereas no order was unique in the secondary forest. Insecta and Diplopoda were dominant in both forests, but their abundance decreased significantly from the natural forest to the secondary forest.

In contrast, abundance was greater in the secondary forest than in the natural forest with Arachnida, Malacostraca and Chilipoda.

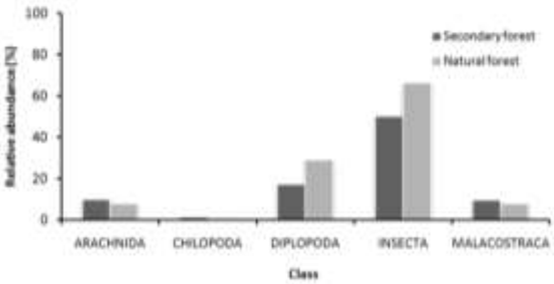

Fig. 3. Relative abundance of different insect classes recorded in the two forest types (natural and secondary) in southern Cameroon.

Litter depth and density

Results of leaf litter depth and arthropod density are presented in Table 2. Although the litter depth was slightly higher in the natural forest (5.44±1.38cm) than in the secondary forest (4.51±0.97cm), there was no significant difference between these forest types (t = 1.36; P =0.177). In the natural forest, litter depth was greater where Insecta were found (6.61±5.54 cm), while Diplopoda occurred in the higher litter depth in secondary forest (5.21±3.71 cm). There was significant correlation between the depth of leaf litter and arthropod numbers in primary forest (r = 0.779; P<0.001) compared to secondary forest where no significant difference was observed (r = 0.073; P>0.05).

Table 2. Litter depth and density of Arthropods in two habitat types of the Campo Ma'an National Park, Cameroon.

Class	Litter depth (cm)			Density (Individuals/m²)		
	Secondary	Natural	*p*-value	Secondary	Natural	*p*-value
Arachnida	4.25±3.12	5.33±3.85	>0.0.5	1.25±0.58	1.33±0.66	>0.0.5
Chilopoda	2.65±1.37	3.00±1.90	>0.0.5	1.16±0.41	1.00±0.00	>0.0.5
Diplopoda	5.21±3.71	5.54±5.31	>0.0.5	1.37±0.86	1.59±1.23	>0.0.5
Insecta	4.52±3.14	6.61±5.54	>0.0.5	1.47±1.06	2.30±4.76	<0.0.5*
Malacostraca	4.71±4.64	4.15±2.75	>0.0.5	1.41±0.76	1.63±1.10	>0.0.5
p-value	>0.0.5	>0.0.5		>0.0.5	>0.0.5	

Values are mean ± SD.

*significant value

Arthropod density varied significantly between primary and secondary forests (t = 2.19, P = 0.028). There was, on average, 1.32±0.12 arthropods m^{-2} in the secondary forest, while in the primary forest, there was 1.57±0.47 arthropods m^{-2}.In natural and secondary forests, a greater number of individuals per meter square was recorded with Insecta (2.30±4.76ind. m^{-2} and 1.47±0.76ind. m^{-2} respectively) compared to Chilopoda (1.0±0.0ind. m^{-2} and1.16±0.41ind. m^{-2} respectively).

Discussion

The litter and soil arthropods of the Campo Ma'an National Park are extremely diversified. We found five most dominant classes and twenty orders of Arthropoda that play an important role in ecosystem functioning. Diplopoda (millipedes), Dermaptera (earwigs), Isopoda (woodlice) are known as saprophagous arthropods (detritivores) and play a role in the rate of litter decomposition in terrestrial ecosystems (Wardle *et al.,* 2002), while Isoptera (termites) and Hymenoptera (ants) are considered as ecosystem engineers through their function in soil structure formation (Jouquet *et al.,* 2006; Mc Gill and Spence, 1985). Arthropods are one of the major components of soil fauna and they have a considerable ecological importance for litter breakdown within decomposition cycle (Crawford, 1992; Wardle *et al.,* 2002). Furthermore, arthropod density and biomass are highest among the soil fauna. Consequently, they may consider as the most diverse taxonomic group on earth (Decaens *et al.,* 2006; Wolters, 2001).

Although the number of class and order are similar between both forests in the Campo Ma'an National Park, soil arthropod abundance was higher in the natural forest than in the secondary forest. The secondary forest of park UFA 09025) is an area where many anthropogenic activities are performed such as logging, cultivation and over-hunting (Dame Mouakoale, 2011). The progressive destruction of natural forests and its replacement with agricultural fields was matched by considerable shifts in species assemblages, mainly of arthropods. These activities negatively affect the abundance, diversity and biomass of ground-dwelling arthropods (Dangerfield, 1990; McCabe and Gotelli, 2000; Mwabvu, 1997).

Surface living species may be largely regulated by abiotic factor (e.g. temperature, humidity, soil types, etc.) and rarely by biotic factor (e.g competition for food resource) (Warburg *et al.,* 1984). Arthropods are found in different shelters or habitat comprising leaf litter, rotting wood, bark, fallen branches, plant debris, compost, etc. By regulating the microclimate, the litter layer helps to maintain favourable conditions for decomposition (Sayer *et al.,* 2006) and creating habitats for most of arthropods (Arpin *et al.,* 1995). Anthropogenic activities may reduce plant species diversity thereby reducing availability of shelter sites and potential food items for soil arthropods (Mwabvu, 1997), they remove trees thus reducing tree diversity and litter input. This is confirmed by the difference of litter depth observed during this study between both forests. Other environmental factors, such as canopy gaps might explain the difference of arthropod assemblages in both forests.

The natural canopy gaps are defined as small openings on the canopy of forest due to the fall of large branches, they play some role in the structural and successional forest organization, creating successional environments for gaps colonization by tree and shrub species belonging to different ecological groups (Nascimento and Araújo, 2012). In contrary, the artificial canopy gaps caused by logging can affect litter quality and create hostile soil conditions to arthropods (pers. com).

This study showed that two taxonomic groups, namely Insecta and Diplopoda are the most abundant in both forests. Moreover, their abundance was decreased significantly from the primary to the secondary forest. This suggests that Insecta and Diplopoda are particularly more affected by habitat change compared to others. With regard to insects, they play a central and dominant role in all aspects of the complex tropical forest food web (Greenwood, 1987). The trend for higher insect abundance among Arthropod fauna is consistent with other tropical forest studies (Basset *et al.,* 2008; Burgess *et al.,* 1999). Loss of insect species will cause a cascade of other extinctions in the flora and fauna of the forests. Thus, insects are particularly suited for use in environmental impact assessment because of their high species diversity, ubiquitous occurrence, and importance in the functioning of natural ecosystems (Rosenberg *et al.,* 1986).

Among insects, ants (Hymenoptera) are particularly appropriate for inventory and monitoring programs because most species have stationary, perennial nests with fairly restricted foraging ranges. In contrast to other taxa or groups that move frequently between habitats in search of food, mates or nesting sites, ants have a more constant presence at sites and can thus be more reliably sampled and monitored (Alonso, 2000; Kaspari and Majer, 2000).

As insects, millipedes (Diplopoda) are important indicators among ground-dwelling arthropod, as they are sensitive to habitat change (Kime and Golovatch, 2000; Wytwer, 1992) and may be threatened by human activities (Dangerfield, 1990; Hopkin and Read, 1992; Mwabvu, 1997). They have high levels of endemism and restricted distributions as a result of their limited powers of dispersal. Millipedes are one of the major groups involved in the breakdown of organic matter (Crawford, 1992) and enhance microbial activities (Anderson and Bignell, 1980).

Conclusion

Litter and soil-dwelling arthropod studies in lowland rainforest in southern Cameroon revealed an important diversity of taxa and offer valuable opportunities for further studies. Change of arthropod assemblages in both forests is mainly caused by human disturbance. Arthropods form a major component of soil litter invertebrates and play important roles in the functioning of ecosystems. Insecta and Diplopoda are sensitive to environmental change and recognized as efficient indicators, but they have been long neglected by conservationists. Therefore, efforts should be made to recommend this major component of soil fauna in biodiversity conservation programmes and provide the protected status for invertebrates (arthropoda) missing in IUCN Red List.

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