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Habitat preference and community structure of ants (Hymenoptera: Formicidae) in the Campo Ma’an national park, southern Cameroon

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Abstract

Tropical biodiversity is seriously threatened by habitat fragmentation and forest degradation. To date, there is relatively little research carried in the protected forest reserve in Cameroon. A monthly sampling of ants was conducted in two forest types (nearly primary forest and secondary forest) in the Campo Ma’an National Park between 2015 and 2016. Ants were monitored using pitfall traps as sampling methods. Overall, 38 species belonging to 21 genera, 5 subfamilies were collected in the two forest types. The most species-rich subfamilies were Myrmicinae (16 species), followed by Formicinae (11 species) and Ponerinae (6 species each). *Pheidole megacephala* was the most abundant species in both forests. The secondary forest had highest species richness and rare species than the primary forest. Both forests shared only nine species. In contrast, diversity and evenness indices were higher in the primary forest than in the secondary forest. This results show that each faunule had different ant assemblages. According to habitat preference, three species-specific groups were found in both forests: generalist species, specialist species (restricted in a particular forest) and disturbance specialists. Primary forest species such as *Odontomachus troglodytes* and *Paltothyreus tarsatus* were predominant in primary forest, while disturbance specialists including secondary forest species (e.g. *P. megacephala*, *Myrmicaria opaciventris* and *Anoplolepis tenella*) were the most abundant species-specific group in secondary forest. These taxonomic groups may be used to monitor ecosystem health and prevent disturbance at an early stage and over a long-term period.

Keywords: ants, community structure, fragmentation, campo ma’an national park, Cameroon

Introduction

Tropical forests occupy only one tenth of the world’s land area but are home to more than half of the world’s flora and fauna (Tilman, 2000; Thomas and balzer, 2002) [44]. It estimated to host about 10 million species of plants and insects. In the last few decades, the increasing of habitat fragmentation, due to rapid population growth and conversion of forest into agricultural farms, of the tropical forests has triggered a greater demand for timber and other forest products, making sustainable management of these remnant forests a major challenge (Wright and Muller-Landau, 2006) [54]. As consequence, fragmentation is recognized as the serious threat to biodiversity and the long-term survival of the biological diversity on earth (Myers, 1994; Nageswara Rao *et al.*, 2008) [36]. Moreover, fragmentation or conversion of forest into grassland or savanna due to forest harvesting, fertilization, atmospheric deposition, and climate change also affects soil dwelling animal diversity (e.g millipedes, ants, earthworms) and the nitrogen mineralization of the tropical forests (Wang *et al.*, 2004) [49]. Hence, there is an urgent need to protect, restore, conserve and improve the forest resources before they are irrevocably lost.

In the tropical forests, many conservation initiatives programs are striving to find management solutions to urgent global environmental issues including habitat loss, climate change and biological invasion. Among many strategies, one of the most popular has been to adopt indicator taxa, which are species or taxonomic groups whose can detect ecological changes both at an early stage and over the long term period (Landres *et al.*, 1988; Spellerberg, 2005) [28, 40]. Identifying changes in indicator species may allow scientists to react to unforeseen variation and to predict future conditions (Cairns and Pratt, 1993) [5]. Arthropods have been recognized as efficient indicators of ecosystem function and recommended for use in conservation planning (Kremen *et al.*, 1993; Finnamore, 1996) [26, 14]. They have diverse body sizes, short generation times, small sizes, occupy the widest diversity of microhabitats and niches, sensitive to narrow change of environment; these feature make them ideal indicator to monitor change in an environment (Williams, 1993; Andersen and Sparling, 1997; Longcore, 2003) [52, 1, 32].

Ants in particular are one of the most well represented groups of social insects (Hölldobler and Wilson, 1990) [22]. Estimated to about 30, 000 species, currently just more than 12, 500 ant species are described, accounting for less than 1% of all described insect species. Ants are omnipresent in virtually every terrestrial habitat. As eusocial organisms, they have evolved to partition reproduction and resource acquisition among different individuals. Ants can be very sensitive to habitat transformation and disturbance, and for this reason have been extensively used as indicator species (Hoffmann and Andersen, 2003) [21]. As many other social insects, ant biodiversity is threatened by human-driven and land-use changes. Disturbance effects on ant communities include loss of diversity, changes in species composition, alteration of interspecific interactions, changes in trophic interactions with ant-plants and honeydew-producing hemipterans, and modification of ant-provided ecosystem services such as seed dispersal, predation, and soil modification (Lach *et al.*, 2000).

The goal of this study is to identify the species-specific groups or species affect by human-driven and land-use changes. Because ant monitoring programmes are generally focused on species compositions rather than diversity, we investigated change in ant community structure across different forest types in the Campo Ma'an National Park the Campo Ma'a national park. This will allow for the assessment of the vulnerability of ant communities to human impact.

Materiel and methods

Study sites

This study was conducted in two locations at the Campo Ma'an National Park (CMNP) (2°10'N; 9°50'E; altitude 200 m a.s.l) (Figure 1): a nearly primary forest forest located in the protected zone (Dipikar island) and a secondary forest situated in one of the five logging concessions surrounding the CMNP. The CMNP covers about 776, 202 ha comprising a National Park (234, 064 ha), five forest management units (UFA), two agro-industrial plantations (Hevecam and Socapalm) and a so-called buffer zone. 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 CMNP 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 Sacoglottisgabonensis (Letouzey, 1985; Tchouto *et al.*, 2009) [30, 43]. In nonprotected area (SF), forest ecosystems are highly threatened by human activities through conversion to agriculture, timber production, pasture, over-hunting, collection of fire wood and construction materials, whereas in protected area (PF), the access and the uses of any of natural resources are forbidden.

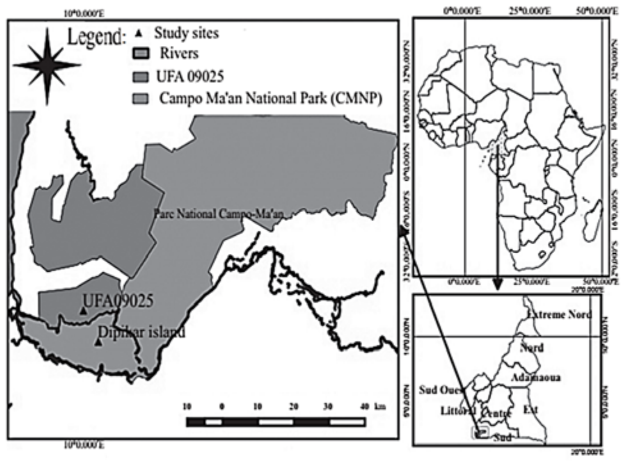

Fig 1: map indicating the location of study site

Sampling method

Pitfall trap was selected as suitable sampling technique because they takes little time, operate by themselves, sample continuously day and night and, as a consequence, can better estimate ant species richness and diversity (Bestelmeyer *et al.*, 2000) [2]. At each site, ten traps, 10 apart, were placed along a transect line (110 m length and 2 m width) of random direction. Each pitfall trap 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 ~75 ml of 50% ethanol and 5% glycerol as a preservative. Twenty traps were set in two rows with 10 traps in each row. Each pitfall was covered by an aluminium roof to prevent rain fall into the traps.

Specimen processing

At the laboratory of Zoology of the University of Yaoundé I, ants were identified to species level (or to morphospecies) using keys from Bolton (1994) [3] and Borowiec (2016) [4] for genera, and the web site ant sub-Saharan African (Taylor, 2010) [41] for species. Ant specimens were mounted on card board triangles and then kept in a reference collection at the laboratory.

Statistical methods of analysis

The number of taxa per category was evaluated and their relative abundance was computed for each site. Standard methods were used to calculate the richness and evenness of ant species across different forests. Alpha diversity was estimated with the help of the Shannon–Wiener index (H′), Pielou's Evenness index, and the Simpson and Berger–Parker dominance indices. Faunal similarity was calculated using beta-diversity developed by Harrison *et al.* (1992) [20]. This was calculated by using the following formulae: Beta = $(S/a_{max}) - 1$, where S = the total number of species in the two forests combined, and a_{max} = the maximum value of alpha-diversity (i.e., number of species) between the forests compared. The number of species unique to a forest and the number of species shared between forests were also compared. A simple t-test was used to compare statistical significance between diversity indices and evenness. To estimate the maximum species richness and sampling effort, the species richness estimators included in the Estimate S software (Colwell, 2005) [10] was used and species accumulation curves were plotted as a function of the number of samples.

Analyses were performed using SPSS software version 12.0 and the significant value was set at 0.05.

Results

Ant community

A total of 5,514 ants (from 123 occurrences) from 5 subfamilies, 21 genera and 38 species were collected in the two forests (Table 1). The Myrmicinae was the dominant subfamily in terms of species numbers (16 species) and abundance (4589 individuals), followed by Formicinae (11 species; 174 individuals) and Ponerinae (6 species; 444 individuals), and Dorylinae (4 species; 306 individuals). The most species-rich genera were *Camponotus* and *Tetramorium* (6 species each, respectively), followed by *Pheidole* (5 species), *Polyrachis*, *Crematogaster* and *Odontomachus* (2 species each, respectively).

Table 1: List of the species recorded in primary forest (PF) and secondary forest (SF) in the Campo Ma'an National Park, Cameroon (values in the table indicate occurrence of each species as function of forest types). Legend: PHS = primary forest specialist; SHS =secondary forest specialist; GS= generalist species; DHS =disturbance habitat specialist)

Subfamilies	Preferred habitat	PF	SF	Total
Dorylinae				
Axinidris sp.	SFS		1	1
Technomyrmex sp.4	PHS	1		1
Cerapachys sp.1	PHS	1		1
Dorylus (Anomma) nigricans Illiger, 1802	GS	10		10
Formicinae				
Anoplolepis tenella Santschi, 1911	DHS		2	2
Camponotus (Myrmacrhaphe) sp.	SFS		1	1
Camponotus (Myrmopelta) sp.1	GS	1	2	3
Camponotus (Myrmopelta) sp.2	GS	3	3	6
Camponotus (Myrmotrema) sp. 1	GS	1	3	4
Camponotus (Tanaemyrmex) brutus Forel, 1886	SFS		3	3
Camponotus (Tanaemyrmex) maculatus Fabricius, 1782	SFS		1	1
Lepisiota sp.2	SFS		1	1
Paratrechina sp.1	PFS	1		1
Polyrachis militaris Fabricius, 1782	PFS	5		5
Polyrachis decemdentata André, 1889	SFS		1	1
Myrmicinae				
Cataulacus egenus Santschi, 1911	SFS		1	1
Crematogaster (Atopogyne) sp. 2	SFS		1	1
Crematogaster (Crematogaster) sp.1	GS	1	1	2
Monomorium sp.2	PHS	1		1
Myrmicaria opaciventris Emery, 1893	DHS	2	2	4
Pheidole megacephala (Fabricius, 1793)	DHS	7	10	17
Pheidole sp.2	GS	1	1	2
Pheidole sp.3	PHS	1		1
Pheidole sp.4	PHS	1		1
Pheidole speculifera Emery,1877	SFS		1	1
Tetramorium aculeatum Mayr, 1866	SFS		2	2
Tetramorium coloreum Mayr, 1901	SFS		2	2
Tetramorium guineense Bernard, 1953	SFS		1	1
Tetramorium rugosum Taylor, 2007	PHS	1		1
Tetramorium sp.2	PHS	1		1
Tetramorium sp.4	PHS	1		1
Ponerinae				
Anochetus bequaerti Forel, 1913	SHS		2	2
Hypoponera cognata(Santschi, 1912)	SHS		1	1
Odontomachus assiniensis Emery, 1892	SFS		1	1
Odontomachus troglodytes Santschi, 1914	PFS	1		1
Pachycondyla (Xiphopelta) sp.4	GS	1	1	2
Paltothyreus tarsatus (Fabricius, 1798)	PHS	26	9	35
Pseudomyrmecinae				
Tetraponera sp.	SFS		1	1
Total		68	55	123

Preferred habitats

Species were broadly split into three categories according to their habitat preference: generalist species (found in all habitats), disturbance specialists, and specialist species (restricted either in primary forest or in secondary forest (Table 1). In primary forest, we found that primary habitat specialists (50% of the total of species-specific group) were the more represented category, followed with generalist habitat species (35%) and disturbance habitat specialists (15%). In contrast, opportunist species (Secondary forest species and disturbance species) (75%) were the most abundant species-specific group, followed by generalist species (25%).

Distribution patterns of species in the forests

A rank abundance plot was produced to analyse species distribution in the two forests (Figure 2). Nine species occurred in the two forests. Twelve of the species were unique to the primary forest: *Technomyrmex* sp. 4, *Cerapachys* sp. 1, *Dorylus (Anomma) nigricans* Illiger, 1802, *Paratrechina* sp. 1, *Polyrachis militaris* Fabricius, 1782, *Monomorium* sp. 2, *Tetramorium rugosum* Taylor, 2007, *Tetramorium* sp. 2, *Tetramorium* sp. 4, *Odontomachus troglodytes* Santschi, 1914, *Pheidole* sp. 3 and *Pheidole* sp. 4, whilst Seventeen seven species were peculiar to the secondary forest (*Axinidris* sp., *Anoplolepis tenella* Santschi, 1911, *Camponotus (Myrmacrhaphe)* sp., *Camponotus (Tanaemyrmex) brutus* Forel, 1886, *Camponotus (Tanaemyrmex) maculatus* Fabricius, *Lepisiota* sp.2, *Polyrachis decemdentata* André, 1889, *Cataulacus egenus* Santschi, 1911, *Crematogaster (Atopogyne)* sp. 2, *Pheidole speculifera* Emery, 1877, *Tetramorium aculeatum*

Mayr, 1866, *Tetramorium coloreum* Mayr, 1901, *Tetramorium guineense* Bernard, 1953, *Anochetus bequaerti* Forel, 1913, *Hypoponera cognate* (Santschi, 1912), *Odontomachus assiniensis* Emery, 1892 and *Tetraponera* sp.).

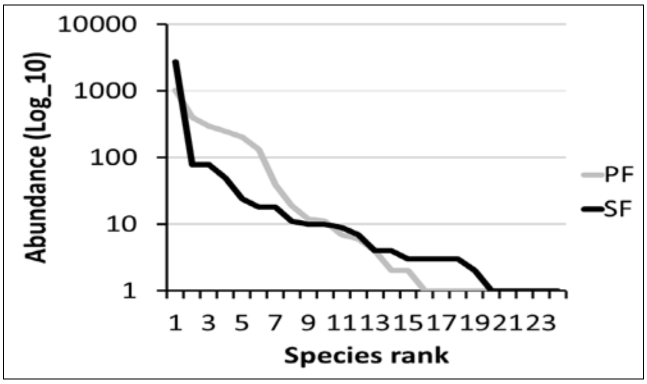

Fig 2: Species rank abundance distribution plot for the two forests (SF = Secondary forest; PF = primary forest).

Alpha and Beta diversities

The secondary forest had the highest ant species count, at 26 species, or 68% of the total, followed by the primary forest with 21 species (55%) (Table 2).Ant community was more diverse in the primary forest (Shannon–Wiener: *H'*=1.758) than in the secondary forest (*H'*=0.612) (Student-t test: t =26.34; *P*<0.05). A similar pattern was found in Evenness and equitability indices in the primary and secondary forests (E = 0.252; J = 0.560 and E = 0.068; J = 0.185, respectively) (t = 31.02; *P*<0.05, t = 23.12; *P*<0.05, respectively). In contrast, dominance indices were highest in the secondary forest (D = 0.792; B = 0.889) and lowest in the primary forest (D = 0.243; B = 0.423), suggesting that ant community in the secondary forest is largely dominated by a dominant and abundant species namely *Pheidole megacephala*. Beta diversity (Harrison index) showed a weak similarity between the two forest types (34%) thereby indicating high dissimilarity in ant community among forests.

Table 2: Variation of species richness, diversity and evenness indices among the two forest types in the campo Ma'an national Park, Cameroon.

Species diversity	Primary forest	Secondary forest
S	21	26
Dominance_D	0.243	0.792
Berger-Parker_B	0.423	0.889
Shannon_H'	1.758	0.612
Evenness_E=H/S	0.252	0.068
Equitability_J	0.560	0.185

Abundance of species

The most abundant species over all two forests were *Pheidole megacephala* (Fabricius, 1793) and *Paltothyreus tarsatus* (Fabricius, 1798), the two species represented more than 70% of the total of occurrence present in the area. In primary forest, the most represented species were: *P. megacephala* (42.42%), *P. tarsatus* (16.63%), *D. nigricans* (12.33%), *Monomorium* sp.2 (10.22%) and *Pheidole* sp.3 (8.44%). The species *P. megacephala* (88.922%), *A. tenella* (2.55%), *Myrmicaria opaciventris* (2.55%), *P. tarsatus* (0.77%), and *Camponotus (Myrmopelta)* sp.2 (0.58%) were numerically dominated ant community in secondary forest.

Richness estimator and Sampling success

Overall, sample efficiency using different richness estimators varied between 68.84% and 78.60% in the two forest types (Table 3). The highest sampling success was recorded in the secondary forest and the lowest in the primary forest. Accumulation curves calculated for all forests still rising at the end of the study indicating that additional sampling efforts would be required to reach a horizontal asymptote (Figure 3).

Table 3: Observed species richness and different richness estimators used to estimate the sampling efficiency in the primary and secondary forest in the campo Ma'an national park, Cameroon

	PF	SF
Sobs	21	26
Chao 2	27.88	21.34
Jack 1	36.54	44.46
Bootstrap	27.1	33.44
Mean	30.51	33.08
Sampling success (%)	68.84	78.60

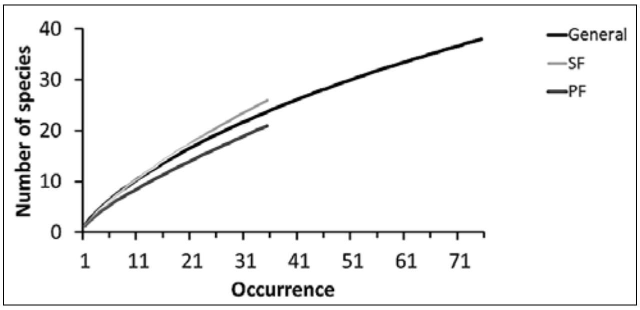

Fig 3: Sample-based accumulation curves for the two forest types in the Campo Ma'an national park, Cameroon

Discussion

Ant diversity and community structure

This study has analysed the ant community in two forest types in the Campo Ma'an National park in southern Cameroon. The observed species richness (38 species) was lower than that found in northern and center forest reserves in Cameroon. In the northern periphery of the Dja Biosphere reserve, Deblauwe and Dekonick (2007) and Tchoudjin *et al.* (2020) [42] were recorded 145 species and 306 species respectively. Similarly, Watt *et al.* (2002) [50] were recorded 111 species in Mbalmayo reserve. The difference in ant richness is probably due to the duration of the study period. The current study was conducted over a period of 12 months whereas ant community was sampled by Deblauwe and Dekonick (2007) for two consecutive years. Moreover, we used only two vegetation types while others authors have used either four (e.g forest, cocoa farm, banana farm, palm grove) (Tchoudjin *et al.*, 2020) [42] or seven vegetation types (near primary forest, very old secondary forest, old secondary forest, young secondary forest, *Raphia*-swamp, riverine forest and light gap forest) to monitor ant communities within a protected area (Deblauwe and Dekonick, 2007).

Sampling efficiency

Three richness estimators were used to evaluate the strength or the weakness of the sampling effort. All estimated ant richness was higher than observed species richness except value of Chao 2 in secondary forest. Although sampling effort was about 70%, rarefaction curves were still rising towards the end of experimentation suggesting that additional sampling effort is needed to reach a horizontal asymptote. Many studies have highlighted that sampling more individuals until no new species are found and the species accumulation curve reaches an asymptote is routinely impossible. It is argued that field sampling methods often record individuals from transects or point counts and never collect random individuals in sequence (Colwell *et al.*, 2012) [9], and the number of individuals that must be sampled to reach an asymptote can often be prohibitively large (Chao *et al.*, 2009) [8].

Sampling methods

For ant sampling, pifall trapping was used to estimate the abundance and species composition of ground-surface active ant species. This is one of the more reliable technique for assessing the diversity and abundance of ant communities in open habitat like forest (Vorster *et al.*, 1992; Lindsey & Skinner 2001; Hacala *et al.*, 2021) [48, 31, 19]. Although the high proportion of big and slower-moving ant species is well represented, this technique did not record all the leaf litter ant fauna occurs in the two forest types. Many cryptic or hypogaeic species were not caught in the pitfalls traps. This may also be an argument to justify the low species richness obtained during this study compared to studies that used a combination of many sampling methods (Fotso *et al.*, 2015; Tchoundjin *et al.*, 2020) [16,]. Indeed, the physical structure of the ground surface or heavy litter and numerous stones may affect the sampling success of ants in pitfall traps (Greenslade, 1973) [18]. There is now a general consensus among scientists that no single sampling method is adequate to sample all ant fauna; therefore many of them indicated the importance of using a variety of methods to obtain an adequate impression of the ant fauna (Lindsey and Skinner, 2001; Fisher 2004) [31, 15].

Dominant of ant species

In both forests, the big headed african species *Pheidole megacephala* was the most abundant ant species. This result consistent with those previously carried out in Cameroon, which found that *P. megacephala* is dominant native ant communities in different ecosystems it has invaded (Wetterer 2007; Dejean *et al.*, 2008) [51, 13]. Despite its tramp species and invasive species status (Lowe *et al.*, 2000) [33], recent studies have shown that that it able to coexist with other native and invasive ants (e.g *Wasmannia auropunctata*) with similar foraging and dietary requirements (Mbenoun *et al.*, 2017, 2019) [34, 35]. The success of *P. megacephala* depends on several characteristics, including their own biology and their ability to form huge supercolonies. This species nests in the ground, and many natural cavities, and have a generalized diet. The worker caste is dimorphic and made up of the small minors and the big-headed majors (Wilson, 2003) [53]. One important biological feature responsible for its ecological dominance, is the tendency to be unicolonial (Fournier *et al.*, 2002), that is, to form expansive and polygynous supercolonies that lack distinct behavioural boundaries among physically separate nests. Unicoloniality allows invasive species to attain high local abundances and consequently to dominate entire habitats (Holway *et al.*, 2002) [23].

Influence of habitat traits

Our study shows different ant assemblages in the primary forest and in the secondary forest. The secondary forest was more diverse than the primary forest. In addition, the secondary forest was dominated by disturbance habitat specialists, while the specialist species were more represented in the primary forest. Several studies have demonstrated that ant diversity in the forest is strongly influenced by a number of habitat variables including: geology, soil type, soil moisture, physiognomy, vegetation cover, plant and leaf litter cover (Koen and Breytenbach, 1988; Cardoso *et al.*, 2010; Vasconcelos *et al.*, 2000) [25, 6, 46]. Because of increasing of habitat fragmentation, there are usually changes in ant communities, namely, changes in species composition (Nakamura *et al.*, 2007; Palladini *et al.*, 2007; Vasconcelos 1999) [37, 38, 47] and demography (Kemel *et al.*, 2001) [24] of the native species. Ant community in the primary forest was dominated by the specialist species, such as *P. tarsatus*, *Odontomachus troglodytes,* and *Technomyrmex* sp. 4. These specific habitat requirement species are sensitive to narrow change in environment conditions and their populations decreased from primary forest to secondary forest indicating the negative effects of habitat transformation and fragmentation on their survival.

One of the most consistently reported effects of fragmentation is the increase of non-native, disturbance specialists or invasive species (Dejean and Gibernau 2000; Lessard and Buddle 2005) [12, 29]. The current study shows that, the secondary forest species and disturbance habitat specialist (e.g *Anoplolepis tenella, Myrmicaria opaciventris, Tetramorium* spp.) represented more than half of the total of ant collected in the secondary forest. In fact, the removal of vegetation or growth of weedy plants following disturbance can have a significant effect on ant assemblages through changes to the microclimate. In addition, feeding and nesting resources may become increasingly limited as natural habitats are disturbed or converted to agricultural farms. Consequently, habitat requirement species are merely replaced by generalists or opportunist species with large and aggressive colonies, and less sensitive and more tolerant to environmental changes than native ones (Carpintero *et al.*, 2003) [7].

Conclusion

This study is the first report of ant community structure in Campo Ma’an national park in Cameroon. Overall, observed ant species richness was lower than expected species richness using different estimators. Likewise, ant richness collected in the study area was lower than that obtained in others protected area in the country. Because only pitfall was used as sampling method, we have suggested that additional methods should be used to collect more soil and leaf litter-dwelling ant fauna. Interestingly, we found different ant community structure in both forest types suggesting that habitat fragmentation affects ant composition by reducing the diversity of specialist species in natural ecosystem thereby enhancing the establishment of disturbance habitat species and invasive species. Therefore, habitat requirement species may be used as indicator taxa to monitor ecological changes and reduce habitat loss and fragmentation of many forest ecosystems.

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