Effect of anthropogenic pressure on grasshopper (Orthoptera: Acridomorpha) species diversity in three forests in southern Cameroon

Charly Oumarou Ngoute[1], Sévilor Kekeunou[1], Michel Lecoq[2], Armand Richard Nzoko Fiemapong[1], Philène Corine Aude Um Nyobe[1], Charles Félix Bilong Bilong[3]

1 Laboratory of Zoology, Faculty of Science, University of Yaoundé 1, Cameroon.
2 CIRAD, Montpellier, France.
3 Laboratory of Parasitology and Ecology, Faculty of Science, University of Yaoundé 1, Cameroon.

Corresponding author: *Charly Oumarou Ngoute* (coumaroungoute@yahoo.fr)

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Abstract

Grasshoppers are highly diversified in tropical rainforests and considered of both ecological and conservation importance. The population dynamics of central African grasshoppers, however, and the structure of their communities remain poorly studied. We report here on the impact of human activities on the diversity of grasshopper species from three localities in southern Cameroon: Ongot, more anthropized forest; Zamakoe, moderately anthropized forest; and Ngutadjap, less anthropized forest. Data were collected using sweep nets, quadrats, and pitfall traps. We analyzed how pressures from human activities affected the grasshopper species compositions using five statistical methods: (1) two non-parametric estimators for specific richness, (2) abundance, (3) abundance distribution model, (4) α diversity index, and (5) β diversity index. The results showed no significant differences in species richness between the sites (nine species at Zamakoe, seven each at Ongot and Ngutadjap). Among these species, one was specific to Ongot and Zamakoe, while one, two, and three species, respectively, were found only in Ongot, Ngutadjap, and Zamakoe. Abundance and species diversity of grasshoppers increased with anthropogenic pressure on the forests. We noticed a great similarity between the grasshopper communities of the two localities under the greatest anthropogenic pressure (Ongot and Zamakoe) compared to that of the less anthropized locality of Ngutadjap. The most common grasshopper species, *Mazea granulosa*, was most abundant where deforestation was highest. Species diversity was highest in the more and moderately anthropized forests, and the diversity index showed greater similarity between these two grasshopper communities compared with that of the less anthropized forest. This work enables us to better understand how the parameters of these insect communities reflect the degree of forest degradation in southern Cameroon.

Keywords

biodiversity, degradation rate, grasshopper communities, tropical rainforest

Introduction

Tropical rainforests shelter an important part of the world's biodiversity and represent an important stake for all countries, in particular with regard to the effects of anthropogenic disturbances and climate change. Forest biodiversity remains poorly studied throughout the African continent (Basset et al. 2001), where these ecosystems are heavily deforested, particularly in the Congo Basin. The rate of deforestation doubled in the Congo Basin between 1990 and 2005 (Tchatchou et al. 2015). These forests are subject to growing anthropogenic pressures leading to their fragmentation and progressive destruction (de Wasseige et al. 2012). The direct causes of deforestation include intensification of mining, population expansion, intensive agricultural practices, and construction of dams that severely alter the structure of the forest and its dependent biodiversity. As the primary means of livelihood for semi-subsistence farmers in the Congo Basin, shifting cultivation uses forest resources for agricultural production and as a source of non-wood products (Brown 2006). Cameroon loses about 140,000 hectares of forest per year (Ndoye and Kaimowitz 2000). In its southern part, industrial wood production has increased from 2.3 million m^3 in 1991 to more than 3 million m^3 in 2000 (de Wasseige et al. 2012). The destruction of these forests has altered the biophysical structure of the natural environment and leads to the breakdown of ecosystem equilibrium and the extinction of species as well as the modification of the structure of floral and faunal communities. The faunal composition is known to be negatively affected by this clearing, with reduction of canopy cover being the major factor of these losses (Scott et al. 2006, Steer et al. 2009). The habitat loss is predicted to greatly impact invertebrates' species diversity (Chinery 1993); these organisms are less mobile than vertebrates, have short life cycles, and are more specialized in micro-habitats due to their specificity to host plants.

Grasshoppers are a common and diverse invertebrate group worldwide (Gangwere et al. 1997, Song 2010, Zhang 2011). They are a dominant group of herbivorous insects with up to 20–30% of all arthropod biomass (Soliman et al. 2017) and occasionally constituting as much as half of the biomass in an environment (Gillon 1983). This group plays an important role in terrestrial food webs and is known to be a good source of protein for other animals such as amphibians, small reptiles, birds, and small mammals; therefore, their scarcity may disturb the trophic structure in an ecosystem (Schmidt et al. 1991, Soliman et al. 2017). Grasshoppers are important bioindicators of threatened environments because of their specific microhabitat preferences, functional importance in ecosystems, sensitivity to the modification of biotic and abiotic factors of their habitats, and the ease with which they can be sampled (Armstrong and van Hensbergen 1997, Samways 1997, Andersen et al. 2001, Guido and Gianelle 2001, Soliman et al. 2017). Diversity and community structure of grasshoppers as they relate to anthropogenic activities, types of vegetation, and climate change have been studied in many regions of the world (Otte 1976, Kemp et al. 1990, Clayton 2002, Torrusio et al. 2002, Gebeyehu and Samways 2003, Steck et al. 2007, Saha and Haldar 2009, Sirin et al. 2010, Branson 2011, Chen et al. 2011, Kekeunou et al. 2017). However, despite the high rate of deforestation observed, the bioindicator potential of grasshoppers in the Congo Basin area, and particularly in Cameroon, has been largely neglected. Apart from the recent works of Seino et al. (2013) and Kekeunou et al. (2017) on the diversity of acridoids in higher mountains in West Cameroon, abundance and grasshopper diversity have been poorly studied. The present article is a contribution to the understanding of the effect of anthropogenic pressure and forest degradation on the abundance and diversity of grasshopper species in southern Cameroon.

Materials and methods

Study sites.—Grasshoppers were collected over a year in three localities (Ongot, Zamakoe, and Ngutadjap; Fig. 1) in the forest area located on the margins of southern Cameroon plateau (3°27'N, 11°32'E and 4°10'N, 11°49'E). This area, about 650–700 m in elevation, is a part of the plateau that forms the northern and western edges of the Congo Basin (Westphal et al. 1981). The climate is typical of the Guinean zone with four seasons comprised of a long dry season (mid-November to mid-March), a short rainy season (mid-March to June), a short dry season (July to mid-September), and a long rainy season (mid-September to mid-November). Precipitation ranges from 1500–2000mm per year (Amou'ou et al. 1985, Santoir and Bopda 1995). The southern Cameroonian forest is dominated by Sterculiaceae and Ulmacae, and its undergrowth is made up of herbaceous plants such as Maranthaceae and Acanthaceae (Westphal et al. 1981). In this ecosystem, the natural vegetation is regularly degraded by the economic exploitation of wood and the practice of slash-and-burn agriculture (Santoir and Bopda 1995). The resulting bushy vegetation after degradation is less diversified and dominated by *Chromolaena odorata*, *Ageratum conizoides*, *Synedrella nodiflora*, and *Imperata cylindrica*. Plantain, cassava, yam, maize, and groundnut are the main food crops, while industrial crops include cocoa, coffee, sweet banana, and palm oil.

Grasshoppers were sampled in three forest ecosystems, each with different levels of anthropogenic pressure and degradation: Ongot forest, 14 to 88 inhabitants/km^2 located in the division of Mefou and Akono, near Yaoundé; Zamakoe forest, 10 to 41 inhabitants/km^2 in the division of Nyong and So'o, near Mbalmayo; and Ngutadjap forest, 2 to 15 inhabitants/km^2 in the division of Ntem Valley, near Ebolowa (Gockowski 1996). Plant species richness is higher in the less degraded Ngutadjap forest, lower in the Zamakoe forest, and lowest in the Ongot forest (Suppl. material 1). Gockowski (1996) showed that the residents of Ongot draw more income from paid work and extensive agriculture. In Ngutadjap, people depend more on hunting and fishing activities, while Zamakoe is a transition zone between the conditions of Ongot and Ngutadjap forests.

Grasshopper sampling.—The grasshopper species were sampled every month from the forests of Ongot, Zamakoe, and Ngutadjap using sweep nets, quadrats, and pitfall traps. Samples by net were made randomly for 30 min; grasshoppers were also captured by hand on the litter in 22 movable iron quadrats of 1 m^2 each.

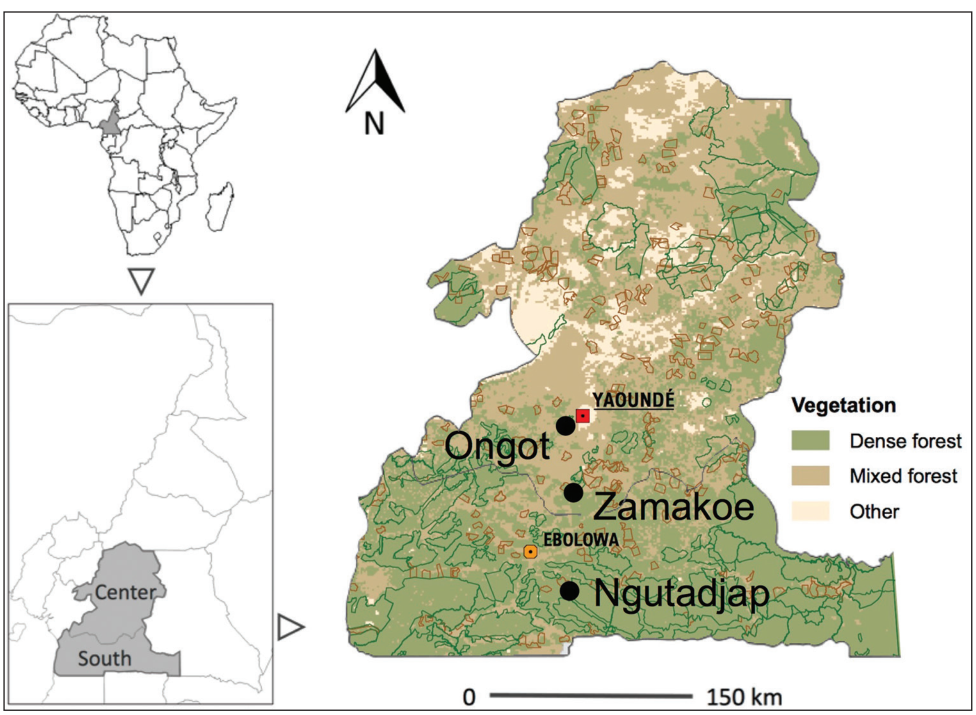

Fig. 1. Study sites in relation to vegetation types in Cameroon (see Mertens et al. 2012).

These quadrats were placed every 10m, on two parallel transects of 110m, separated from each other by 10m. Other specimens were collected in 10 pitfall traps (of 8cm diameter each), 1/3 filled with 5% formalin as a preservative; each trap was laid every 20m in the same transects after quadrat exploration.

Grasshopper identification.—The collected specimens were identified using keys from Dirsh (1956, 1961, 1965, 1966, 1970), Jago (1967), Kevan (1975), Hollis (1975), and Lecoq (1980).

Data analysis

Species richness, sampling efforts and species accumulation curves.—Species richness (S) is the number of species reported from each sampling site. We have estimated these theoretical values by the non-parametric estimators *viz.*, Chao1 and Abundance-based Coverage Estimator (ACE) (Marcon 2015) using the software EstimateS (Colwell 2013). The plots of cumulative species number per sample were generated using the same software with data randomized 100 times. We estimated the sampling effort as the ratio of observed species richness to theoretical species richness. Average efforts were compared using a Kruskal-Wallis H-test in the software PAST (Hammer et al. 2001).

Relative abundances.—The average relative abundances (Marcon 2015) were calculated using the following formula:

$$fx = \frac{\sum nx1 + nx2 + \cdots + nx17}{N} \times 100$$

$\Sigma nx1+nx2+...+nx17$ is the sum of abundances of species x from the first to the seventeenth month in a given site; N is the sum of abundances of all the species in the three sites. Mean abundance between the different sites and between species were compared by the Kruskal-Wallis H-test while comparisons of mean abundances for two samples were made by the Wilcoxon W-test using PAST.

Abundance distribution models.—The abundance distributions of the reported species were compared to the geometric distribution model of Motomura, the broken stick model of Mac-Arthur, and the log series model of Fisher (Carlo et al. 1998, Cielo Filho et al. 2012, Havyarimana et al. 2013, Marcon 2015) to find the one that fits most to our dataset. These models provide information on how species are distributed and on how they share the available resources in the ecosystem (Havyarimana et al. 2013). PAST software automatically generates the results from the row data. The χ^2 test was used in PAST to compare the observed abundance distribution to the expected for the three types of theoretical distributions tested.

Diversity.—Species diversity of grasshoppers was calculated in PAST and expressed as dominance (D), Shannon diversity (H), and evenness (H/Hmax) indexes (Carlo et al. 1998, Tadu et al. 2013, Marcon 2015, Kekeunou et al. 2017, Mbenoun Masse et al. 2017, Raghavender and Vastrad 2017). The Shannon index for two samples were compared using the Student t-test (Hutcheson 1970).

Similarity.—Similarities between the grasshopper communities were assessed by the Bray Curtis index (C_n) (Bray and Curtis 1957, Tadu et al. 2013, Tadu and Djiéto-Lordon 2014, Raghavender and Vastrad 2017) and the correspondence analysis of the species to the different communities (Yelland 2010). Cluster analysis was performed using the Paired Group Method (UPGMA) in PAST. PAST graphically generates the Euclidean distances between rows (species) and columns (sites/forests) for the correspondence analysis.

Results

Species richness.—A total of 12 grasshopper species were identified belonging to two families: Pyrgomorphidae (two species) and Acrididae (10 species) (Fig. 2A). The subfamily Catantopinae was the most diverse with six species following by the Oxyinae and Pyrgomorphinae (two species each), and Acridinae and Coptacrinae with only one species each (Fig. 2B).

Ten of the 12 identified species were collected by net, six species were collected in quadrats, and only two species in pitfalls (Table 1). Two species were collected only from the least disturbed forest of Ngutadjap (*Gemeneta opilionoides* and *Parapetasia femorata*).

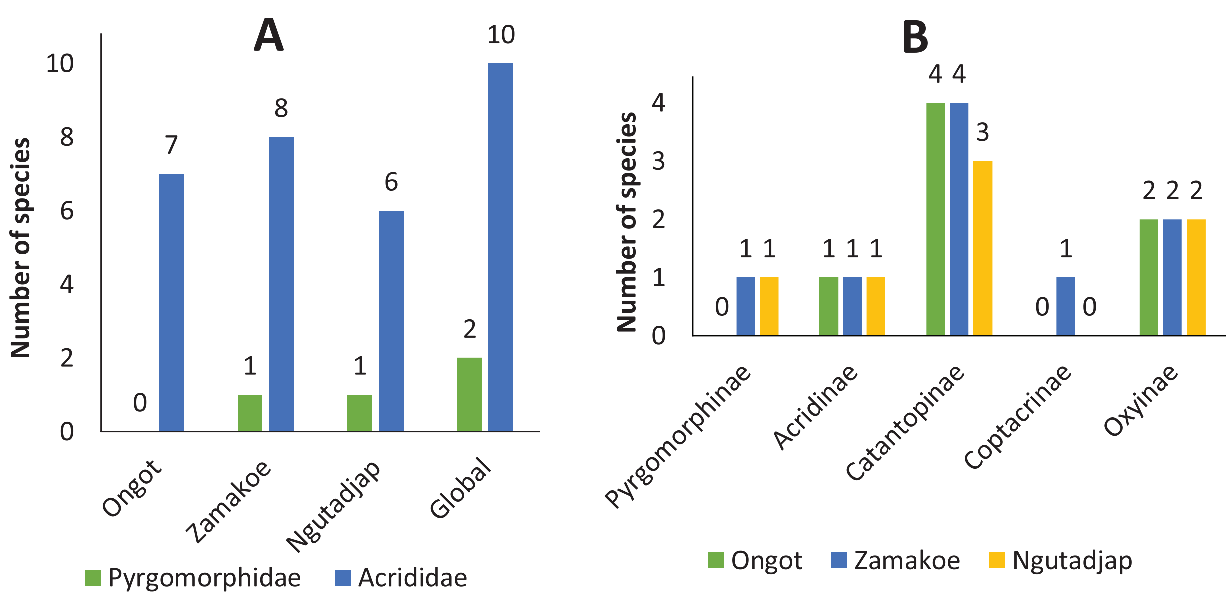

Fig. 2. Species richness from each study site. **A.** Families; **B.** Subfamilies.

Table 1. Species richness according to the different sampling methods in the forests.

Family	Subfamily	Species	Ongot			Zamakoe			Ngutadjap		
			net	quadrat	pitfall	net	quadrat	pitfall	net	quadrat	pitfall
Acrididae	Acridinae	*H. gerstaeckeri*	+	+		+	+		+		
	Catantopinae	*A. degener*	+	+							
		G. opilionoides							+		
		G. terrea	+			+					
		M. granulosa	+	+	+	+	+	+	+	+	+
		P. carnapi				+					
		S. opacula	+				+	+	+		
	Coptacrinae	*C. hopei*				+					
	Oxyinae	*D. fasciata*	+			+	+			+	
		P. apicalis	+	+			+		+		
Pyrgomorphidae	Pyrgomorphinae	*P. femorata*							+		
		T. ferruginea				+					
Number of taxa			7	4	1	7	5	2	6	2	1

+ indicates the presence of the species at the site for the collection method used.

Gemeneta terrea was collected from the two more disturbed forests of Ongot and Zamakoe, while *Apoboleus degener* was collected only from the most disturbed forest of Ongot. *Pteropera carnapi*, *Cyphocerastis hopei*, and *Taphronota ferruginea* were collected only from the moderately anthropized forest of Zamakoe (Table 1). The remaining five species were common to all three localities.

Sampling effort and species accumulation curves.—Sampling captured almost the entire estimated species assemblage (95.3 ± 1.42%). No significant difference (H = 2, P = 0.36) was observed between the localities: Ngutadjap (97.0 ± 3%), Ongot (96.5 ± 3.5%), and Zamakoe (92.5 ± 2.5%) (Table 2). The species accumulation curve of each forest started to flatten out towards the end of the sampling period (Fig. 3).

Relative abundance.—A total of 465 individuals were collected from the target localities (Appendix 1). We did not observe great differences in abundance between seasons (Appendix 1). Among these

Table 2. Sampling effort and diversity of grasshopper species from the study sites. The values in brackets represent the theoretical species richness; a and b: the results of Shannon diversity index test for two samples.

Diversity/Estimator	Ongot	Zamakoe	Ngutadjap
Taxa S	7	9	7
Individuals	167	226	72
Dominance D	0.54	0.71	0.47
Shannon H	0.97[ab]	1.18[b]	0.73[a]
Evenness H/Hmax	0.38	0.23	0.46
ACE	93% (7.52)	90% (10.00)	94% (7.40)
Chao1	100% (7.00)	95% (9.47)	100% (7.00)
Mean of Estimators	96.5±3.5% (7.26±0.26)	92.5±2.5% (9.73±0.26)	97±3% (7.2±0.2)

The same letter between two sites shows no significant difference between the values.

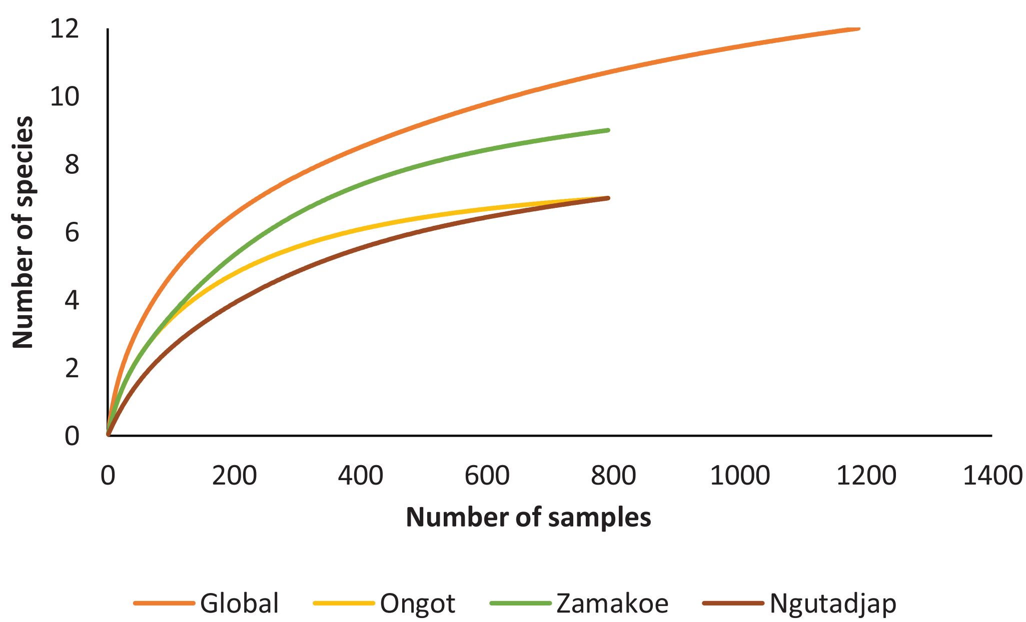

Fig. 3. Species accumulation curves of the study sites.

Table 3. The mean relative abundance (%) of species between the different study sites. Each value is: mean ± standard error; H-value: Kruskal Wallis test; P-value: probability; a, b and c: the results of the comparisons, with the Wilcoxon test, for two samples.

Family	Subfamily/ Species	Ongot	Zamakoe	Ngutadjap	H- value	P-value	Total
Acrididae	Acridinae						
	H. gerstaeckeri	1.1±0.4	2.07±0.9	1.65±0.8	0.14	0.91	4.82±1.7
	Catantopinae						
	A. degener	0.44±0.2	0	0	0.64	0.13	0.44±0.29
	G. opilionoides	0	0	0.45±0.4	0.16	0.36	0.45±0.45
	G. terrea	0.17±0.1	0.45±0.3	0	0.51	0.32	0.62±0.03
	M. granulosa	26.44±2.3^{b}	41.05±3.2^{c}	11.66±2.2^{a}	22.02	<0.0001	79.15±3.1
	P. carnapi	0	0.77±0.4	0	1.45	0.05	0.77±0.4
	S. opacula	4.8±1.9^{ab}	0.82±0.3^{b}	1.2±0.6^{a}	5.28	0.03	6.82±1.8
	Coptacrinae						
	C. hopei	0	0.37±0,3	0	0.16	0.36	0.37±0.3
	Oxyinae						
	D. fasciata	0.85±0.4	1.14±0.6	0.35±0.3	0.65	0.51	2.34±0.09
	P. apicalis	1.7±0.6	0.86±0.4	0.92±0.4	0.76	0.56	3.48±1.07
Pyrgomorphidae	Pyrgomorphinae						
	P. femorata	0	0	0.57±0.4	0.64	0.12	0.57±0.4
	T. ferruginea	0	0.17±0.1	0			0.17±0.1
H-value		62.5	50.02	37.62			85.58
P-value		<0.0001	<0.0001	<0.0001			<0.0001
Total		35.5±2.8^{b}	47.7±3.0^{c}	16.8±2.3^{a}	23.49	<0.0001	100

The same letter between two sites shows no significant difference between the values.

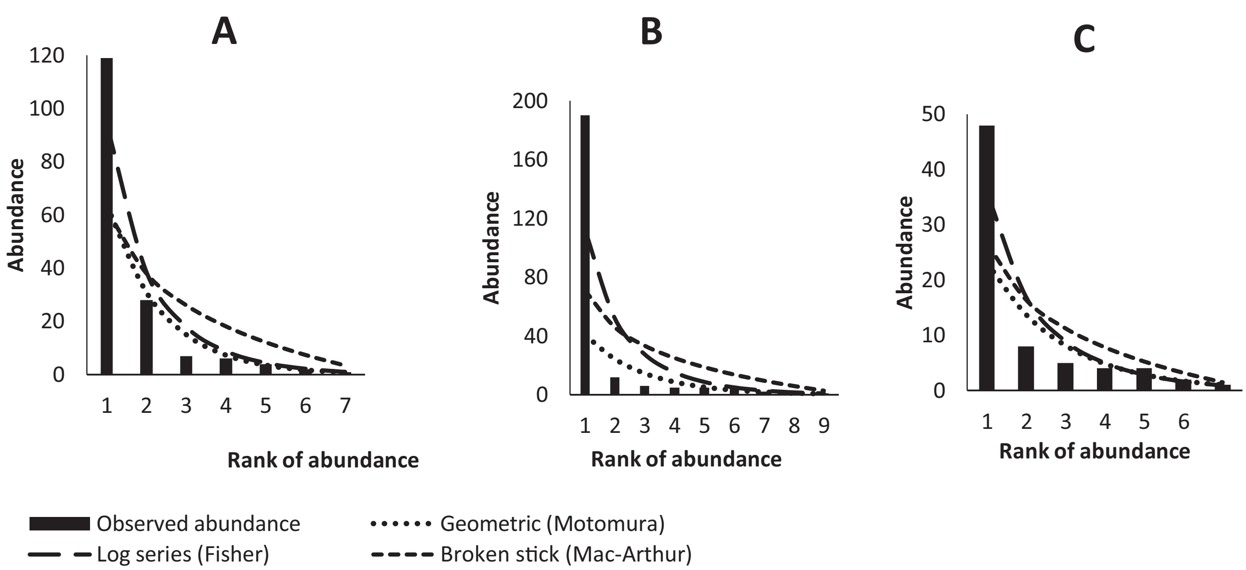

Fig. 4. Abundance distribution model of species in the different forests. **A.** Ongot; **B.** Zamakoe; **C.** Ngutadjap.

465 individuals, 72 (16.8 ± 2.3%) were collected from the low anthropized forest of Ngutadjap, 167 (35.5 ± 2.8%) from the more anthropized forest of Ongot, and 226 (47.7 ± 3.0%) from the moderately anthropized forest of Zamakoe (Table 3). The mean abundances were significantly higher ($H = 23.49$, $P < 0.0001$) in the grasshopper community from Zamakoe, and significantly lower in that of Ngutadjap. *Mazea granulosa* reported from all localities was the most abundant species (79.2%) (Table 3). The abundance of this species significantly differed among the three sites ($H = 22.02$, $P < 0.0001$): 11.7% in Ngutadjap, 26.4% in Ongot, and 41.1% in Zamakoe (Table 3). The common species *Holopercna gerstaeckeri* and *Serpusia opacula* were less abundant than *M. granulosa*. All other species were present with very low abundances in the different sites studied (Table 3).

Abundance distribution models.—The grasshopper species collected during this study were distributed into seven abundance ranks in the Ongot and Ngutadjap forests and in nine abundance ranks in Zamakoe forest. The distribution models of species abundance from the target localities were very different from the geometric model of Motomora: Ongot ($\chi^2 = 53.3$; $P < 0.001$; Fig. 4A), Zamakoe ($\chi^2 = 562.2$; $P < 0.001$; Fig. 4B), and Ngutadjap ($\chi^2 = 30.6$; $P < 0.001$; Fig. 4C); the broken stick of MacArthur model: Ongot ($\chi^2 = 88.6$; $P < 0.001$; Fig. 4A), Zamakoe ($\chi^2 = 290.8$; $P < 0.001$; Fig. 4B), and Ngutadjap ($\chi^2 = 27.4$; $P < 0.001$; Fig. 4C). All the observed abundance distribution models were closer to, though slightly different from, Fisher' log-series distribution model: Ongot ($\chi^2 = 17.1$; $P = 0.002$; Fig. 4A), Zamakoe ($\chi^2 = 110.5$; $P < 0.001$; Fig. 4B), and Ngutadjap ($\chi^2 = 11.1$; $P = 0.011$; Fig. 4C). The rare

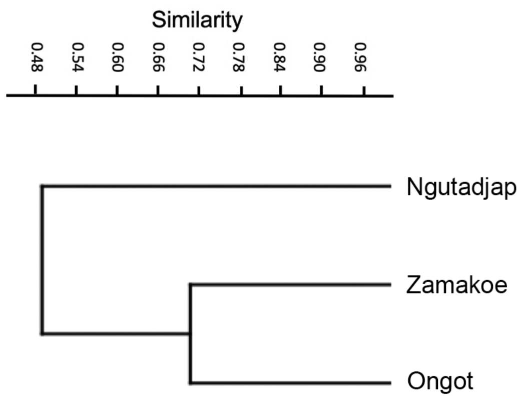

Fig. 5. Similarity between the different forest grasshopper communities using the Bray-Curtis index.

species (average relative abundance <1%) accounted for 58% of the species collected in all three of the studied forests.

Diversity.—The dominance index showed that there are fewer dominant species in Zamakoe (0.71) than in Ongot (0.54) and Ngutadjap (0.47) (Table 2). The Shannon diversity index (H) was higher at Zamakoe (H = 1.18, H/Hmax = 0.23) followed by Ongot (H = 0.97, H/Hmax = 0.38) and lower at Ngutadjap (H = 0.73, H/Hmax = 0.46) (Table 2). The Shannon diversity index of grasshopper communities of Zamakoe and Ngutadjap forests were significantly different ($t = 14.3$, $P = 0.005$) (Table 2). All the above shows that the species diversity has increased with the level of forest degradation in the study site.

Similarity.—The cluster analysis based on species composition performed on the basis of Bray-Curtis index revealed that the grasshopper communities of Zamakoe and Ongot forests are more similar to each other (Fig. 5). The disposition of species by correspondence analysis shows that most of the species studied were closer to these two most degraded forests of Ongot and Zamakoe (Fig. 6). *A. degener* was specific to Ongot; *P. carnapi*, *C. hopei*, and *T. ferruginea* were specific to Zamakoe; and *G. opilionoides* and *P. femorata* were specific to Ngutadjap (Fig. 6).

Discussion

Species richness and sampling effort.—The sampling efforts were high, varying between 87% and 93% in the forests studied, with no significant difference, which is consistent with the statement of Branson (2011) that evaluation and comparison of grasshopper diversities requires that all regions and ecosystems be studied in the same way. The species accumulation curve of each forest started to flatten out towards the end of the sampling period; this shows that almost all the species had been collected: all the common species were sampled. The missing species are likely to be all rare taxa corresponding to the expected low abundance nature of tropical forest faunas.

Overall, 12 species were identified: seven in Ngutadjap and Ongot and nine in Zamakoe. Seino et al. (2013) and Kekeunou et al. (2017) have identified, respectively, 28 and 27 species in the mountainous area of West Cameroon. This considerable difference in species richness can be explained by the fact that (1) previous studies collected grasshoppers in both fallows and forests and (2) the works cited were conducted in the upland area of western Cameroon with two climatic seasons, while we carried out the present work in the southern Cameroon plateau with four climatic seasons. The structure, biology, and ecology of the grasshopper communities are logically expected to be different in the two different habitats.

Grasshoppers are indeed recognized as abundant insects in open environments, which may explain the low species richness observed in our work. Joubert et al. (2016) recently reported that grasshoppers constitute a significant proportion of invertebrate diversity in grasslands; their abundance increases with burning, cattle grazing, and short vegetation. Spungis (2007) and Arya et

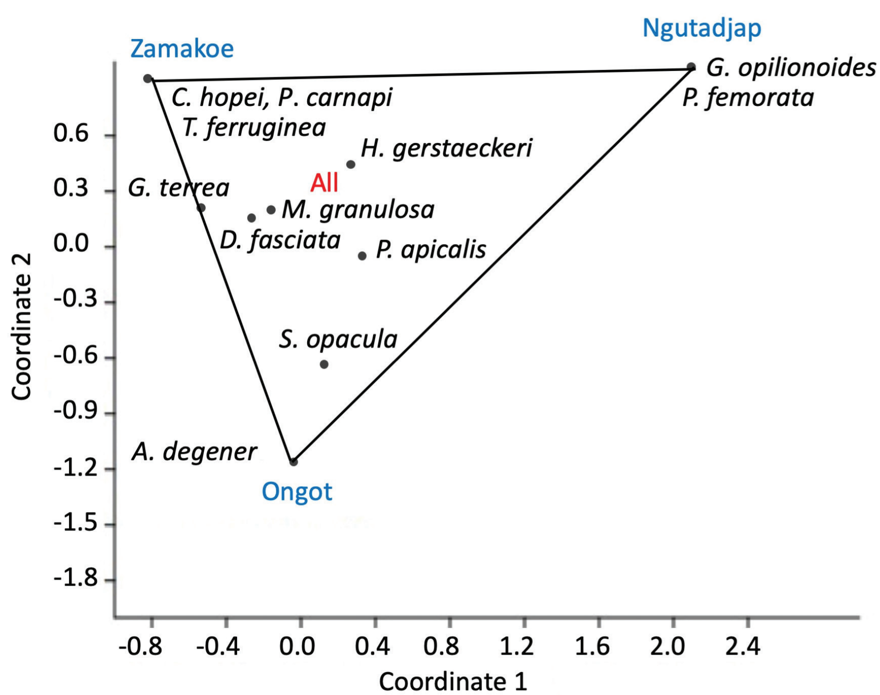

Fig. 6. Disposition of species between the different study sites using correspondence analysis.

al. (2015) also carried out studies in forests and found 14 and 12 species of grasshoppers identified, respectively, in the Western Himalaya in India and in the Ziemupe Nature Reserve forest in Latvia; the number of species of grasshoppers collected in these studies are similar to ours. Nevertheless, Raghavender and Vastrad (2017) report a high species richness, 30 species, in the forest of Dharwad in India. This difference may be explained by differences in the climate, types of vegetation, and grasshopper communities between southern Cameroon and the Dharwad region in India. In our study, the families were Acrididae (10 species) and Pyrgomorphidae (two species). Dirsh (1965, 1966, 1970) and Mestre and Chiffaud (2009) showed that these two taxa are the main acridid families in the fauna of both Cameroon and Congo Basin.

In the same way, Seino et al. (2013) and Kekeunou et al. (2017) found that Acrididae (18 and 22 species, respectively) and Pyrgomorphidae (four and six species, respectively) are the more speciose families in West Cameroon. The same results were given by Almeida and Câmara (2008) in Brazil, and by Arya et al. (2015), More and Nikam (2016), and Raghavender and Vastrad (2017) in India. The Catantopinae was the richest subfamily in the study areas with three species in Ngutadjap and four species in Zamakoe and Ongot. Seino et al. (2013) reported this subfamily as most speciose in West Cameroon. After the Oedipodinae, the Catantopinae was also the richest subfamily in both agriculture and forest ecosystems of Dharwad, India (Raghavender and Vastrad 2017). The above results are consistent with the findings by Dirsh (1965) more than fifty years ago in Cameroon and in Africa.

Relative abundance and abundance distributions.—The abundance of grasshoppers in the three study sites increased with human pressure. In fact, it is already known that grasshopper abundance increases in dry grassland habitats and forests used by humans (Latchininsky and Gapparov 1996, 2011, Spungis 2007, Latchininsky 2008). These results contrast with those of Soliman et al. (2017) who reported higher species richness, abundance, and diversity in the less disturbed sites in South Cairo, Egypt. We can therefore assume that the behavior of grasshoppers in response to the environmental disturbances is influenced by the eco-climatic zone and the structure of plant and even animal communities.

In fact, ecosystem changes strongly affect behavior, especially of poikilotherms such as grasshoppers that feed on plant materials (Bronwyn 2013). The increase in abundance as the forest is opened up by human agency that was observed in our work is not due to an invasion by grassland or forest edge species, but of forest forms due to increased light penetration and, thus, a change in understory vegetation. The positive correlations that exist between the population density of grasshoppers and plant species diversity can be explained by both feeding and sheltering requirements of grasshoppers (Spungis 2007).

Disturbed and new habitats can be important for the spreading of some grasshopper forms (Samways et al. 1997, Sergeev 1998, Latchininsky et al. 2011). At the same time, some grasshopper species are threatened by anthropogenic pressures, such as overgrazing and ploughing (Latchininsky and Gapparov 1996, 2011, Sergeev 1998). The abundance distribution of the species observed in this work were most similar to, though slightly different from, Fisher' log-series distribution model. Therefore, species with low abundance were the most numerous in the forests studied compared to the most abundant ones or those with intermediate abundance (Havyarimana et al. 2013). This distribution model shows that although they had different levels of utilization and degradation, these three forest ecosystems are disturbed by human activities (Hughes 1986). Under these conditions, the available resources may be immobilized by a small number of species that develop strategies of resistance to human disturbances (Ramade 2009, Cielo Filho et al. 2012, Havyarimana et al. 2013); this was the case of *M. granulosa*, *S. opacula*, and *H. gerstaeckeri* in the forests studied. The other species are relegated to the unfavorable areas (Ramade 2009), as was the case with *G. opilionoides* and *P. femorata*, two very rare species found only in the less degraded forest of Ngutadjap. It therefore seems necessary to reconstitute and conserve these different ecosystems in order to protect this forest biodiversity and its trophic structure.

Diversity and similarity.—In this work, species diversity increased with the level of human activity and use of forest resources: it was higher in the more anthropized forests of Zamakoe and Ongot and lower in the less anthropized forest of Ngutadjap. This result is presented by our cluster analysis based on species composition. Steer et al. (2009) also observed an increase in the invertebrate diversity, especially of diurnal Lepidoptera, with the level of forest degradation in Madagascar. Recently, Soliman et al. (2017) also reported significant differences between grasshopper community structures in moderately and highly disturbed sites in India, using one-way analysis of similarity. We therefore assume that invertebrate communities, especially of insects, are strongly influenced by increased human activities in forest ecosystems around the world; these invertebrates are recognized worldwide as indicative of the levels of natural habitat degradation (Clayton 2002, Gebeyehu and Samways 2003, Steck et al. 2007, Sirin et al. 2010, Chen et al. 2011).

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Supplementary material 1

Author: Charly Oumarou Ngoute, Sévilor Kekeunou, Michel Lecoq, Armand Richard Nzoko Fiemapong, Philène Corine Aude Um Nyobe, Charles Félix Bilong Bilong

Data type: plant species richness

Explanation note: Effect of anthropogenic pressures on floristic composition from the forests of three localities of southern Cameroon.

Link: https://doi.org/10.3897/jor.29.33373.suppl1

Appendix 1

Species composition and abundance of the grasshopper species in different seasons (Srs: Short rainy season; Sds: Short dry season; Lrs: Long rainy season; Lds: Long dry season).

Taxon	Srs (n = 2)	Sds (n = 2)	Lrs (n = 1)	Lds (n = 1)	Total
Caelifera					
Acridoidea					
Acridomorpha					
Acrididae					
Acridinae					
Holopercna gerstaeckeri (Bolivar, 1980)	9	13	3	1	26
Catantopinae					
Apoboleus degener Karsch, 1891	0	0	2	0	2
Gemeneta opilionoides (Bolivar, 1905)	0	0	2	0	2
Gemeneta terrea Karsch, 1892	1	1	1	0	3
Mazaea granulosa Stål, 1876	93	71	89	104	357
Pteropera carnapi Ramme, 1929	0	4	1	0	5
Serpusia opacula Karsch, 1891	8	15	8	7	38
Coptacrinae					
Cyphocerastis hopei Brunner, 1920	1	0	0	0	1
Oxyinae					
Digentia fasciata Ramme, 1929	5	1	3	2	11
Pterotiltus apicalis Bolívar, 1905	6	4	0	5	15
Pyrgomorphidae					
Pyrgomorphinae					
Parapetasia femorata Bolivar, 1884	3	1	0	0	4
Taphronota ferruginea (Fabricius, 1791)	0	1	0	0	1
Site					
Ongot	39	47	34	47	167
Zamakoe	58	49	64	55	226
Ngutadjap	29	15	11	17	72
Total	126	111	109	119	465

n indicates the number of seasons sampled.