Final Report

Project N° 36690-B

Title: Conservation of the Giant African Millipede Community in the Cameroon's Rain-Forest Zones: distribution, threats and research needs.

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Acknowledgment

Abstract

The ongoing biodiversity crisis, characterized by high extinction rates, requires well-planned conservation efforts. Assessing key ecological parameters of species whose populations are in decline is the first step to improve their conservation strategies. This is especially true for soil invertebrates such as giant African, which generally retain little attention in conservation projects. We aimed to assess the extinction risk and conservation status of the giant African millipede species and identify habitats requiring conservation actions to suggest threat mitigation measures. We did a one-year field survey from April 2022 to March 2023 in the Dja Biosphere Reserve and the proposed protected area of Ebo Forest using a combination of ecological sampling methods commonly applied to survey soil-dwelling invertebrates. In addition, during the same period, we investigated the local ecological knowledge and use of giant millipedes through a questionnaires survey and conducted education and awareness raising campaigns on the role and importance of millipedes in the functioning of natural ecosystems. We recorded 10 giant millipede species belonging to seven genera and 2 families. The family Spirostreptidae was the most speciose, with 9 species out of the 10 recorded. The Dja Biosphere Reserve was the richest site (8 species) of the two prospected areas. The giant millipede species identified during this study mainly occurred in mature forests. Most of the recorded millipede species were under urge anthropic pressure in their distribution range and the most observed were cutting of trees for traditional medicine, deforestation for the production of charcoal as well as firewood, and the clear-cut practices for installing Cocoa, palm oil, rubber, Cassava, and plantain plantations. Concerning the perception and knowledge of the importance of the target species by the local population, results have showed that the majority of respondents knew the target species, but none of them knew their conservation importance. Giant African millipedes are negatively perceived by the local population, who believe that observation of some giant millipede species like *Spirostreptus servatius* is associated

with bad luck for those who saw it. Seven of the ten recorded giant millipede species extinction risk assessments were evaluated as Endangered (EN) and the three others as Least Concern (LC) under IUCN Criterion B with a cell width of 2 km. This project enables us to understand factors influencing giant millipede occurrence and distribution, which are crucial for appropriate and valuable conservation action plans. In light of all these results and findings, concrete and urgent actions must be taken by nature and wildlife conservation organizations and authorities to strengthen conservation strategies in Cameroon to preserve millipedes' species.

Introduction

The ongoing biodiversity crisis, characterized by high extinction rates, requires well-planned conservation efforts (Karam-Gemael et al., 2020). Assessment of the conservation status of species with inadequate conservation management, like giant African millipedes, has been acknowledged as a vital tool for determining threat threshold and guiding conservation objectives (Karam-Gemael al., 2020). Giant millipedes in Africa belong to two unrelated taxonomic groups: Spirostreptidae family (Order Spirostreptida) and the endemic tribe Pachyiulini (Family Pachybolidae, Order Spirobolida) (Nzoko-Fiemapong & Enghoff, 2018). Despite their prominent role in natural ecosystem functioning, they are underrepresented in African conservation projects (Reinecke and Reinecke, 2018). Most giant African millipedes have a weak dispersal ability and therefore express a high degree of endemism (Hamer & Slotow, 2002). Despite their importance in natural ecosystems functioning, they rarely attract conservation attention compared to plants and the more ''charismatic' vertebrates, such as birds and mammals. Invertebrates, which represent nearly 97 % of all animals worldwide, are neglected in the field of conservation biology despite their critical role in ecosystem processes (Myers et al., 2000). Habitat loss and overexploitation of natural resources are the main causes of species extinction (IUCN, 2023).

The conservation status of most millipede taxa is poorly known in the Afrotropical Region. Red-Listing of threatened species is the most objective approach for evaluating the extinction risk of living organisms which can be applied at global or local scales (Karam-Gemael et al., 2020). The current version of the IUCN Red List comprises ca. 200 millipede assessments over ca. 11000 described species (Minelli, 2015), representing only 1% of all described species. In Africa, most giant millipedes are threatened, and just a few of them benefited from protection strategies (Hamer, 2006). Apart from South Africa and Madagascar, where most millipedes are Red-Listed and generally in the top three IUCN categories (Rudolf & Wesener, 2017; Hamer et al., 2021), there is no particular conservation interest regarding these invertebrates in other parts of Africa. This is mainly due to scarcity and poor research dedicated to millipedes in this sub-region. This situation is partly due to difficulties in identifying species accurately. Since there is no conservation assessment of giant African millipede's species found in Cameroon, this study was initiated to assess their extinction risk and propose conservation measures to preserve them in this heavily disturbed biodiversity hotspot.

More specifically, this project aimed at (1) assessing the community structure, occurrence, distribution range, diversity, habitat preference and formulate propositions regarding the conservation status of giants' millipede species occurring in the Dja Biosphere Reserve and Ebo Forest two areas of conservation importance using collected and existing data by the IUCN criteria; (2) assessing anthropogenic threats to the target giant's millipede species in the study area; (3) assessing the perception and knowledge of the target species by the local population; (4) raise awareness among the local population through a sensitization and education campaign on the role

and importance of the target species in the functioning of the natural ecosystem and influence the local belief and superstitions around the target taxa; (5) design plans to protect the target species and its habitats in the Dja Biosphere Reserve.

Material and Methods

Study site

Our study was conducted in two localities of Cameroon's humid forest zones: Ebo-Forest and the Dja reserve forest. The Ebo forest is located in the Littoral Region of Cameroon and extends geographically between longitude 010°02′59.2′′E and 010°38′30.9′′E and latitude 04°05′09.5′′N and 04°31′01.6′′N. It covers about 2000 km2 of lowland and submontane forest (Morgan & Abwe, 2006) and represents about 50% of the Yabassi Key Biodiversity Area (BirdLife International, 2021). The area falls under the warm and humid tropical equatorial climate with two seasons (dry and rainy) and annual rainfall ranging from 2500 to 3000 mm (Abwe et al., 2019). The dry season extends from December to February, and the rainy season from March to November (Abwe et al., 2019). The Ebo forest is known for its plant diversity, including many endemic and threatened species (Mbouombouo-Mfossa et al., 2022). Although the Ebo forest is being considered for protection by the Cameroon government for its globally significant conservation values, all communities surrounding the proposed protected area are heavily dependent on the natural resources of this forest for their livelihoods for food and medicines (Morgan & Abwe, 2006; Whytock & Morgan, 2010).

The Dja Biosphere Reserve, which constitutes the Dja Faunal Reserve and surrounding buffer zones, is located in southern Cameroon. The Dja Biosphere Reserve covers an area of approximately 5,260 km2, extending between latitudes 2 ° 49'-3 ° 23'N and longitudes 12 ° 25-13 ° 35'E. The climate in the Dja Biosphere Reserve is of the equatorial type, with four seasons: the rainy season, which occurs from mid-September to December, followed by a three-month dry season, and then a small rainy season between mid-March and June then a short dry season from July to September. The average monthly temperature is between 23.5℃ and 24.5℃ and the annual rainfall is 1600 mm (Sonke & Couvreur, 2014). The vegetation of the Dja Reserve is of the Congolese type, with evergreen forest belonging to the Guineo-Congolese domain and consisting of large trees up to 60 m tall (Tabue et al., 2018). The Dja Faunal Reserve is home to rich biodiversity and also count numerous and threatened taxa.

While vertebrates in these areas have received considerable conservation attention, the invertebrate fauna in general, and millipedes in particular, remain understudied with no data that could provide a basis for making conservation decisions.

Data Collection and Analysis

Millipede sampling (Figure 1)

The occurrence and distribution of the target species as well as its habitat preference was assessed using two soil invertebrate survey methods (Quadrat and sixty-minute active searching) (Mwabvu, 2014; Means *et al.,* 2015). The survey aimed at recording species presence and estimating abundance fluctuations, population dynamics, diversity, and community structure of the target as well as all threats these target millipede species face. In the different vegetation types identified in our two study sites and for each field trip, 40 quadrats of 9 sq. m were regularly placed on 4 transects of 200 m long, with 10 quadrats per transect, 20 m apart from each other.

Each transect was set 10 m apart from the next. In addition to this method, a 1-hour active search was carried out (figure 3) along other transects (200m and 2m wide) to increase the chances of collecting the target millipede species and also to have the possibility of surveying the majority of micro-habitats and threats to the latter were conducted. All shelters and habitats suitable for millipedes, including under rocks, tree barks, fallen branches, leaf litter, or directly in soil monoliths were typically surveyed.

Figure 1. Field survey activities: giant African millipedes sampling and habitat charactarisation.

Data Analysis

Millipede diversity
The number of species by order, family, and genus was determined and percentages were calculated from the total number of individuals collected. Relative abundance was presented in terms of percentages. The observed species richness (S) hereafter was determined. The Alpha

diversity enabled us to characterize the giant millipede's communities by determining the Shannon–Wiever's index (H′). To compare the diversity of the two prospected areas, the Shannon t-test (Hutcheson, 1970) for two samples incorporated in PAST software was applied. We computed the evenness of the studied communities using Pielou's index. The Berger–Parker index was used to confirm the dominance status of species. The Beta diversity index (Jaccard-Distance) was used to visualize differences in community turnover between the two study areas.

To visualize the relationship between the two sites and millipede community, non-metric multidimensional scaling (NMDS) was performed based on Bray–Curtis dissimilarity index. The results were plotted in an NMDS ordination plane in a two-dimensional space. Differences in the millipede community among different prospected areas visualized with NMDS were analyzed using a permutational multivariate analysis of variance (ANOSIM) test. After a significant ANOSIM test ($p \leq 0.05$), a SIMPER analysis (Percent Similarity) was performed to examine which giant millipede groups were driving the differences in the community among the study sites.

Occurrence and Frequency Index

Species were classified into three categories (common, intermediate, and rare) based on their occurrence at the study sites surveyed. The analysis of the records was based on indices of frequency and constancy (Silveira-Neto et al., 1976). The Frequency Index (FI) is the ratio of the individuals' number of a given species on the total sample, $FI = n_i/N$, where n_i is the number of specimens of species i and N is the total number of specimens collected. The species were classified as dominant (D) or nondominant (ND) based on the FI values. Dominant species were those with a FI value higher than $1/S$, where S is species richness, i.e., the total number of species in the community. The Constancy Index (CI) is the percentage of samples unites in which a given species was present, $CI = p*100/N$, where p is the number of samples in which the species was recorded, and N is the total number of samples. Based on their CI values, the species were classified as constant (CT) when present in more than 50% of the samples (CI >0.50), accessory (AS) when present in 25–50% of the samples (CI = 0.25–0.50), and accidental (AC) when found in fewer than 25% of samples (CI < 0.25). The species were classified based on the combination of these two indices as common (D+CT), intermediate (D+AS; D+AC; ND+CT; ND+AS), and rare (ND+AC) (Pereira de Sousa et al., 2015).

Habitat characterization and threats

During field activities, within all survey transects, vegetation was characterized. We also assessed human pressures and threats to the target millipede species within each survey habitat. The following parameters were recorded: the number of culls and stripes, track marks, the number of live bases, agricultural practice, overgrazing, wood exploitation, the internal road network in reserve as well as all other human activities that can potentially affect the target species.

Distribution and extinction risk assessment

For each prospected habitat, geographical coordinates were taken. The distribution map of the target species was constructed using the recorded coordinates to visualize the distribution range of the species. The conservation status of each recorded giant African Millipede according to IUCN criteria was addressed via the R package red - IUCN Red listing Tools (Cardoso, 2017) by computing the extent of occurrence (EOO) and area of occupancy (AOO) of the target species. This package generates automated conservation assessments according to IUCN Red List categories. Criterion B, which concerns the geographical range in the form of B1 (Extent of Occurrence: EOO) and B2 (Area of Occupancy: AOO) was applied. The EOO is defined by the IUCN (2021) as "the area contained within the shortest continuous imaginary boundary that can be drawn to encompass all the known, inferred or projected sites of present occurrence of a

taxon". The AOO is defined as the area within the EOO that is occupied by the species, and this measurement recognizes that a species will usually be confined to a specific habitat and will not occur throughout the area where it is distributed. A location is defined as a "geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the taxon present in the area. The size of the location depends on the area covered by the threatening event". A location is, therefore, different from a locality, which is usually a collection point, and a location can include several localities if these are relatively close together. This extinction risk assessment was done using occurrence data collected during fieldwork and data from the literature.

Table 1. Summary of the criteria B used to evaluate the target millipede species in an IUCN Red List threatened category. Reproduced from the IUCN Red List Criteria Summary Sheet (https://www.iucnredlist.org/resources/summary-sheet).

B. Geographic range in the form of either B1(Extent of Occurrence) AND / OR B2 (Area of			
	Critically Endangered	**Endangered**	**Vulnerable**
B1. Extent of occurrence (EOO)	$<100km^2$	$<5000km^2$	$<20\,000km^2$
B2. Area of occupancy (AOO)	$<10km^2$	$<500km^2$	$<2\,000km^2$
AND at least 2 of the following 3 conditions:			
a) Severely fragmented OR number of locations	=1	≤5	≤10
(b) Continuing decline observed, estimated, inferred or projected in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) area, extent and/or quality of habitat; (iv) number of locations or subpopulations; (v) number of mature individuals			
(c) Extreme fluctuations in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) number of locations or subpopulations; (iv) number of mature individuals			

Perception, knowledge of *S. crenulatus* by the local population and awareness campaigns
The interviews in this study followed a protocol adapted from Nash et al. (2016). Local ecological knowledge on giant African Millipede was assessed in villages around Ebo forest and the Dja Biosphere Reserve. Participants were selected using a snowball sampling method. A questionnaire consisting of open-ended and closed questions was administered to participants to investigate their knowledge of the Giant African Millipede, its ecology, and conservation (Figure 2C, D). Awareness campaigns in the local communities living in and around the study site were organized, in order to increase the knowledge of local populations on the conservation importance of the target species in our study localities (Figure 2A). To better illustrate what we were talking about during awareness campaigns, printed photographs of the target species were presented to participants (Figure 2 B).

Figure 2. Community-based focus group discussions (A), interview (B) and questionnaires survey (C, D) in some villagers and school around the study areas**.**

Results

1. Giant African millipedes species richness, composition, and distribution in the Dja Biosphere Reserve and Ebo Forest

Our survey recorded 10 giant millipedes species belonging to seven genera and 2 families (Figure 3 and Table 1). The family Spirostreptidae was the most speciose with 9 species over the 10 recorded. The most species-rich genus was *Telodeinopus* with (3 species) followed by the genus *Spirostreptus* (2 species). Only one species represented every five other genera. The Dja Biosphere Reserve recorded the highest number of species (8 species) of the two prospected areas. Among the species collected during this study, *Brebitibuis polyptychus* was reported for the first time in the Cameroonian fauna. Two species (*Ophiostreptus* sp. and *Telodeinopus* sp.) have been formally identified as new to science and are being described for publication in a specialized journal.
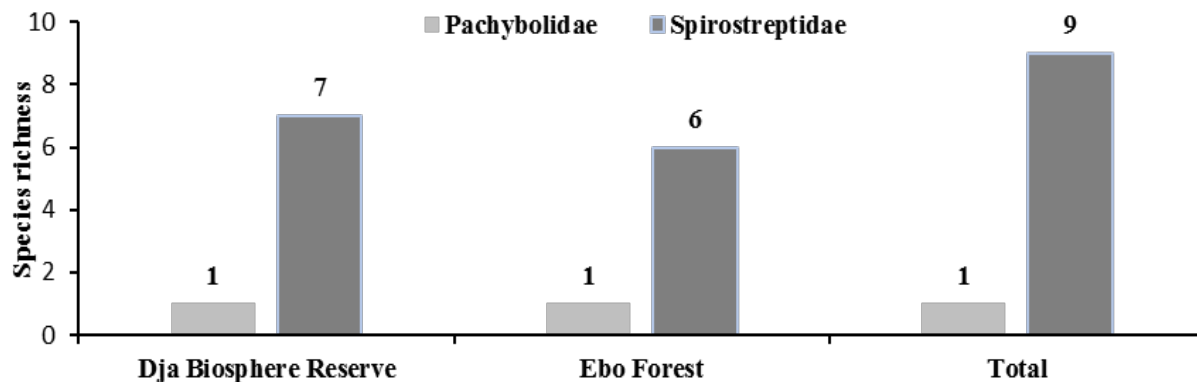
Figure 3. Giant millipede species richness within different families between study sites.

Table 1. Absolute and relative abundance (given in the brackets) of each giant Millipede in the two prospected areas in Cameroon (the Dja Biosphere Reserve and Ebo Forest)

| Family | Species | Sites | | |
		Dja Biosphere Reserve	Ebo Forest	Total
Pachybolidae	*Pelmatojulus excisus* (Cook, 1897)	83 (16.67)	135(27.11)	218(43.78)
Spirostreptidae	*Brevitibuis polyptychus* (Kraus, 1958)	2(0.40)	0(0.00)	2(0.40)
	Ophiostreptus sp.	4(0.40)	3(0.60)	7(1.41)
	Spiropoeus fischeri Brandt, 1833	12(2.41)	3(0.60)	15(3.01)
	" *Spirostreptus* " *pancratius* Attems, 1914	2(0.40)	7(1.41)	9(1.81)
	" *Spirostreptus*" *servatius* Attems, 1914	7(1.41)	0(0.00)	7(1.41)
	Telodeinopus bibundinus (Attems, 1914)	0(0.00)	9(0.181)	9(1.81)
	Telodeinopus canaliculatus (Porat, 1894)	61(12.25)	47(9.44)	108(21.69)
	Telodeinopus sp.	107(21.49)	0(0.00)	107(21.49)
	Treptogonostreptus intricatus (Voges, 1878)	0(0.00)	16(3.21)	16(3.21)
Total		278(55.82)	220(44.18)	498(100.00)

" ": represent species with uncertain generic position (Orphan species).

The most species-rich habitat was the primary forest vegetation (9 species), followed by the secondary forest (7 species) and the cocoa-base agroforest (3 species). In contrast, the less rich habitat prospected was the farmland with two species (*Telodeinopus canaliculatus and Telodeinopus* sp.). Differences in species richness for all these prospected vegetations were highly significant ($p<0.0001$). *Telodeinopus* sp. and *Telodeinopus canaliculatus* were widely distributed as they occurred in all habitats (Table 2). *Ophiostreptus* sp., *Spirostreptus pancratius*, and *Spirostreptus servitius* occurred exclusively in the primary forest (Table 2).

Table 2. Giant millipede species distribution among the four habitats/vegetations type prospected in Dja Biosphere reserve and Ebo forest (+ = present; - = absent).

Species	Primary forest	Secondary forest	Cacao-base Agroforest	Farmland
Pelmatojulus excisus (Cook, 1897)	+	+	+	-
Brevitibuis polyptychus (Kraus, 1958)	-	+	-	-
Ophiostreptus sp.	+	-	-	-
Spiropoeus fischeri Brandt, 1833	+	+	-	-
« Spirostreptus » pancratius Attems, 1914	+	-	-	-
« Spirostreptus » servatius Attems, 1914	+	-	-	-
Telodeinopus bibundinus(Attems, 1914)	+	+	-	-
Telodeinopus canaliculatus (Porat, 1894)	+	+	+	+
Telodeinopus sp.	+	+	+	+
Treptogonostreptus intricatus (Voges, 1878)	+	+	-	-

The mean sampling success of the two non-parametric estimators of the species richness Chao1 and ACE (Abundance-based Coverage) utilized in this study was 100% (Table 3). The individual rarefaction curves plotted for each site reached the species saturation plateaus. The curves of the Ebo forest were quite below that of the Dja Biosphere Reserve, suggesting a relatively low species richness of the former (Figure 4)

Table 3. Diversity indices in the prospected areas

Diversity indices	Sites		
	Dja_Biosphere_Reserve	Ebo_Forest	Total_
Total number of Individuals **"n"**	278[a]	220[a]	498
Maximal abundance "**nmax**"	107	135	218
Observe richness **"Sobs"**	8	7	10
Berger-Parker dominance **"D=nmax/n"**	0,3849	0,6136	0,4378
Shannon_**H**	1,422[a]	1,178[b]	1,527
Evenness_e^H/S	0,518	0,4638	0,4602
Brillouin	1,371	1,124	1,487
Equitability_**J**	0,6836	0,6052	0,663
Chao-1	8 (100)	7 (100)	10 (100)
ACE	8 (100)	7 (100)	10 (100)

n=Sampling size; S_{obs}: Observed Species richness; **nmax**=maximum abundance. H'=Shannon-Weaver's diversity index; J=Pielou's evenness index; SE=sampling effort. D=Berger-Parker's dominance index. The letters a and b represent the results of the pairwise comparison of Shannon-

Weaver index in the habitat types using Fisher T test. The values in the brackets represent the sampling success (observed species richness/theoretical species richness*100).
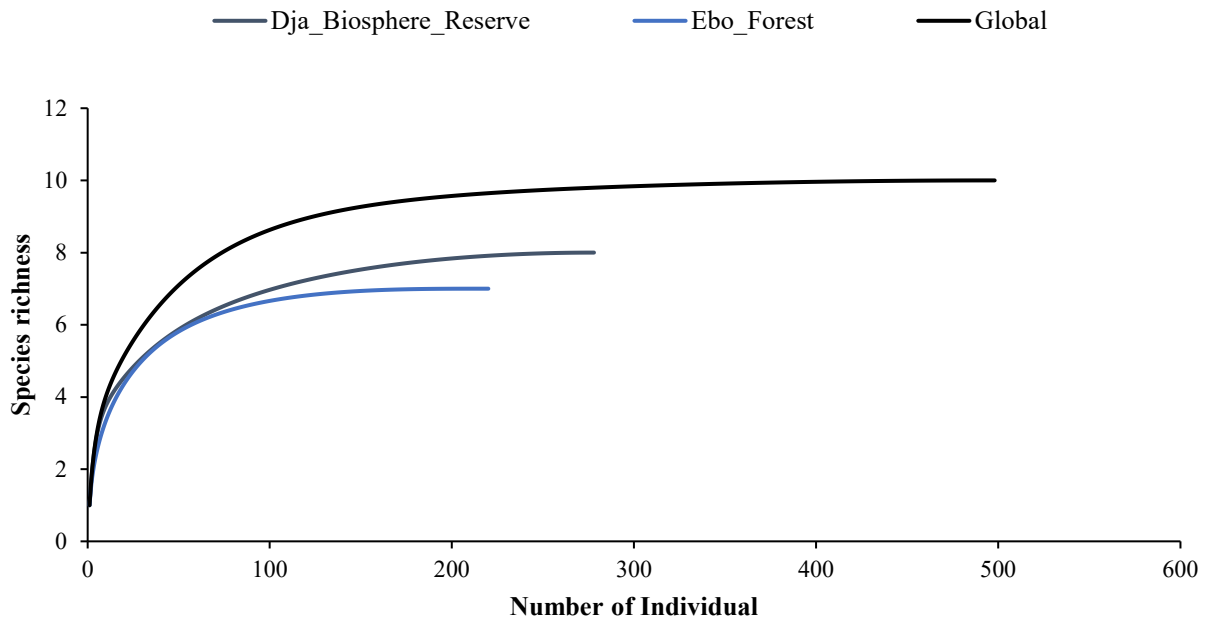

Figure 4. Species rarefaction curve among the Dja Biosphere Reserve and Ebo Forest.

Based on the classification of the frequency and constancy of the different species, three giant millipedes were considered intermediate in the Dja Biosphere Reserve and the other five species found in this area as rare (Table 4). When considering the Ebo Forest, the trend was a little different. Indeed, in the Ebo Forest site, we mentioned four species with intermediate status and three rare species. *Pelmatojulus excisus* was classified as intermediate because it was not considered to be dominant. When considering the two study giant millipede's communities, the rare group (nondominant and accidental) included most of the species.

Table 4. Composition and total abundance of Giant millipedes found in the study area.

Sites	Species	AA	FI%	1/S%	C	O	CI%	C	Category
Dja Biosphere Reserve	*Brebitibuis polyptychus*	2	0,71	12.5	ND	2	0,58	AC	Rare
	Ophiostreptus sp.	4	1,42	12.5	ND	4	1,17	AC	Rare
	Pelmatojulus excisus	83	29,54	12.5	D	48	13,99	AC	Intermediate
	Spiropoeus fischeri	12	4,27	12.5	ND	12	3,50	AC	Rare
	« Spirostreptus » pancratius »	2	0,71	12.5	ND	2	0,58	AC	Rare
	« Spirostreptus servatius »	7	2,49	12.5	ND	7	2,04	AC	Rare
	Telodeinopus canaliculatus	61	21,71	12.5	D	57	16,62	AC	Intermediate
	Telodeinopus sp.	107	38,08	12.5	D	45	13,12	AC	Intermediate
Ebo Forest	*Ophiostreptus* sp.	3	62,21	14.3	D	3	0,87	AC	Intermediate

		AA	FI	S	O			C	O
	Pelmatojulus excisus	135	1,38	14.3	ND	96	27,99	AS	Intermediate
	Spiropoeus fischeri	3	3,23	14.3	ND	2	0,58	AC	Rare
	Spirostreptus pancratius	7	4,15	14.3	ND	7	2,04	AC	Rare
	Telodeinopus bibundinus	9	21,66	14.3	D	7	2,04	AC	Intermediate
	Telodeinopus canaliculatus	47	7,37	14.3	ND	37	10,79	AC	Rare
	Treptogonostreptus intricatus	16	62,21	14.3	D	13	3,79	AC	Intermediate

AA: absolute abundance; **FI**: Frequency Index; **S**: observed species richness; **C**: class; **O**: occurrence; **D**: dominant; **ND**: not dominant; **AS**: accessory; **AC**: accidental.

2. Giant millipede species diversity in the Dja Biosphere Reserve and Ebo Forest

The Dja Biosphere Reserve showed the highest value of diversity indices (H'=1.42; E= 0.51) compared to the Ebo forest (H'=1.19; E=0.46) (Table 3). The Fischer Test of diversity revealed a significant difference between the two areas (P<0.004) (Table 3). The value of the Jaccard-Distance (1- Jaccard similarity) between the Dja Biosphere Reserve and Ebo Forest giant millipede communities was 1-J = 0.5, suggesting a good dissimilarity between these two study areas.

3. Giant millipede species abundance and dominance in the Dja Biosphere Reserve and Ebo Forest

Overall, 498 specimens of giant African millipedes were identified during the study period. The highest abundance of target millipedes was observed in the Dja Biosphere Reserve (278 specimens, representing 55.82 % of all giant millipedes collected in both sites) (Table 1). There were no significant differences in giant millipede abundance between the two prospected area tested through the student t-test (P >0.05). *Pelmatojulus excisus* (43.78%), *Telodeinopus canaliculatus* (21.69 %) and *Telodeinopus* sp. (21.49 %) were the most abundant species during the study period (Table 1).

The rank-abundance curves showed that species composition differed between the study sites (Figure 5). A few abundant taxa characterized the millipede community at the sampled sites. The distribution of giant millipede species abundance was uneven in the two study communities (Figure 5). The diagram may be divided into tiers. The first tier, including the most abundant species, accounted for three species for all sites. The second quartile comprises less abundant giant millipede species (1 to 10 % of the relative abundance), including two species at each site. The last tier comprised rare species (below 1 %).
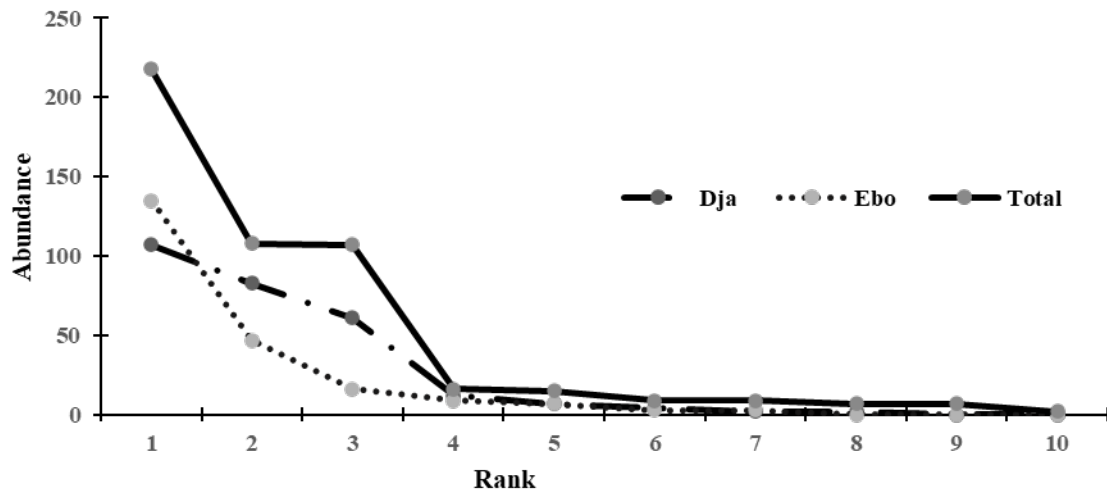
Figure 5. Species distribution curves in the two study sites based on the rank abundance distribution diagram.

4. Dissimilarity of giant millipede communities between the Dja Biosphere Reserve and Ebo Forest

The non-metric multidimensional scaling plot (NMDS) analysis allows us to visualize the two studied giant millipede communities and notice the clear distinction between them (Figure 6A). This was supported by a stress value of 0.14 (great representation of dissimilarities), clustered the two giant millipede communities (Figure 6 B). The quantitative analyses using ANOSIM indicated a different species composition among the two areas (one-way ANOSIM based on Bray-Curtis dissimilarity R = 0.28; p =0.0098). The difference in millipede communities' compositions can be respectively attributed to species such as *Telodeinopus* sp. (19.21%) *Pelmatojulus excisus* (15.81%) and *Telodeinopus canaliculatus* (11.90%) (Figure 6C).
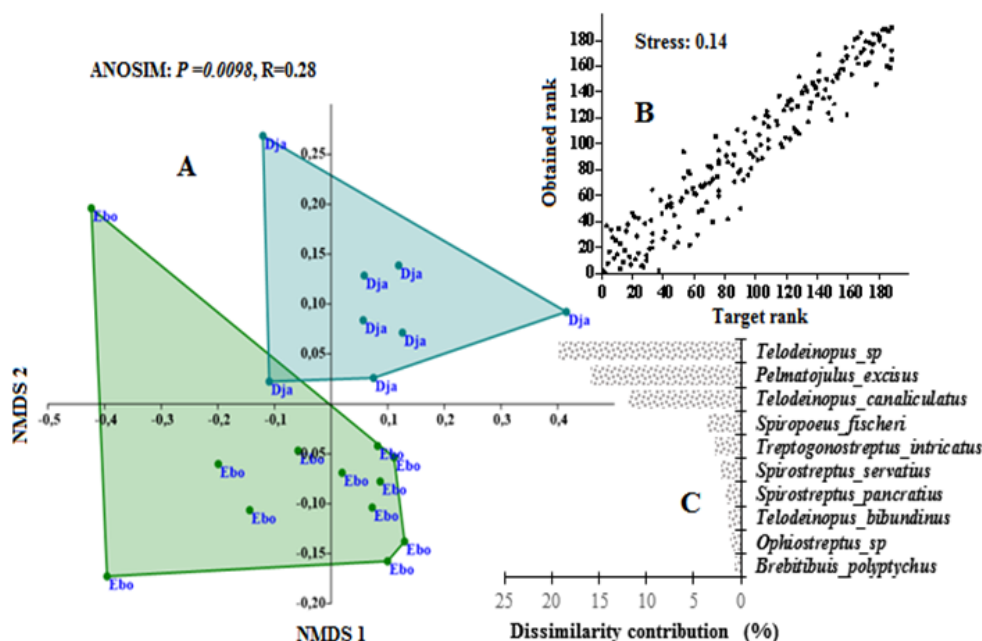

Figure. 6. Non-Metric multidimensional scaling plot (NMDS) clustering the two giant millipede communities (A), analysis of similarities (ANONSIM) (B) Shepard plot showing the great

ordination of the NMDS analysis (stress value <0.2). (C) Histogram depicting the contribution of each species to the dissimilarities of the study communities.

Based on the Species Abundance Distributions (Figure 7), the Dja Biosphere Reserve millipedes community fitted the Motomura Geometric model ($X^2 = 30.96$; P = 9.53×10^{-06}; k= 0.4817). The Fisher Log series model fitted the giant millipede community observed in Ebo Forest (α = 1.378; x = 0.9938; $X^2 = 3.65$; P = 0.4555), as well as the global community of the two protected areas taking together (α = 1.772; x = 0.9965; $X^2 = 59.97$; P = 4.57×10^{-11}).
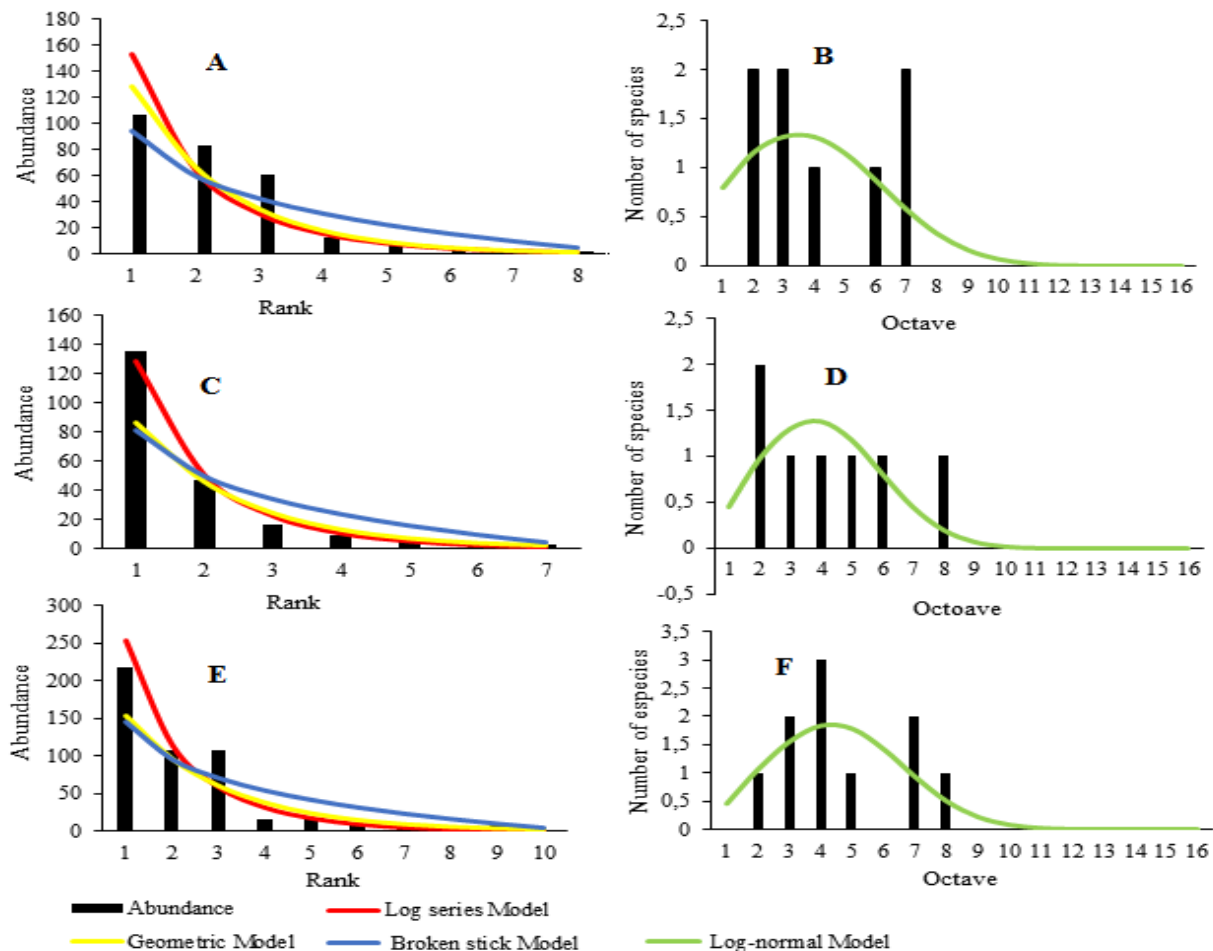

Figure 7. Abundance distribution models of giant millipedes in the Dja Biosphere Reserve (A, B) and Ebo Forest (C, D) in Cameroon, (E, F) represent the two communities putting together.

5. Threats faced by giant millipedes in the study areas

This study noted several threats principally due to anthropogenic practices that face giant millipede species. Harvesting of tree products, wood exploitation, slash-and-burn agriculture practices, and implantation of agro-industrial exploitation (e.g., palm oil, rubber, and Cocoa), were the major activities leading to the degradation of the forest cover in our two prospected areas that have a significant negative effect on the target millipede population. The majority of the population of the Dja Biosphere Reserve relies on hunting for food and income. When they go into the forest for hunting, they usually cut down trees to establish temporary dwellings, and the young stems are also used to prepare traps for animals, all of which harm the regeneration of plants within the reserve and thus on giant millipedes which usually has low dispersal ability. Slash-and-burn agriculture is a common practice in the southern forest region of Cameroon and principally in the

Dja Biosphere Reserve and Ebo Forest, where most of the local population depends solely on this practice.

Figure. 8. Some anthropogenic practices in the study: a) clear-cut for installation of banana plantation; b) Cocoa plantation (Dja biosphere Reserve); C slash and burn agricultural practice (Dja Biosphere Reserve); d) wood exploitation (Ebo forest)

They cut down trees and set them on fire to establish plots of Cassava, groundnuts, and plantains (Figure 8 a,b). The use of fire results in the destruction of soil organic matter. Consequently, there is a decrease in the productivity of the vegetation and the crops planted on the burnt plot. In addition, all invertebrate species with a low dispersal capacity and a high level of endemicity (e.g., such as most of the giant millipede species) would likely perish during these activities. The harvesting of tree products mainly for medicinal purposes is also a cause of canopy degradation due to unsustainable harvesting techniques. Although deforestation inside the Dja Biosphere Reserve is remarkably low, logging occurs at the entire periphery of this area, causing fragmentation of the forest habitat and therefore impacting biodiversity in general and especially on the populations of giant millipedes highly fragmented, with a low dispersal ability. Logging takes place within the framework of concessions granted to private operators on forest management units (FAU) or, depending on the case, directly to local communities (Figure 8d). Its peripheral infrastructure facilitates access to the reserve and poaching (road network, vehicles, increased demand for protein). Logging and the advance of agricultural exploitation in the study area have an immediate consequence on the accentuation of deforestation. This trend towards progressive deforestation is probably linked to an increase in the human population living on the periphery of the Dja Biosphere Reserve. The activities of the company "Sud Cameroun Hévéa" on the outskirts of the Dja Biosphere Reserve on nearly 44,000 ha of concession (for rubber, oil palm,

and cocoa plantations) have several negative impacts on the environment. The most significant of these activities are large-scale deforestation, the disappearance of certain animal and plant species, and the degradation of surface water resources and soil through the overuse of chemicals. Many explorations permit for mining projects granted in the reserve's periphery also seriously threaten the fauna and the giant millipede population. The main threats recorded during this study in Ebo Forest were the cutting of trees, principally ''ESSOK'' (*Garcinia lucida*), for exploiting the bark, which is very popular in traditional medicine in Cameroon. Another threat observed in the Ebo Forest is deforestation for producing charcoal and firewood, but also for the installation of Cocoa (Figure 8b) and cassava farms, which are the main cultures in the surrounding village of the proposed reserve of Ebo. Another threat to the target species observed in the Ebo Forest is hunting for marketing in Douala. Indeed, as we know, hunting is an activity done with disturbance of the natural environment that can negatively impact forest specialist species, such as is the case for many giant millipede species.

6. Habitat preference, distribution, and conservation of the giant millipede recorded in the Dja Biosphere Reserve and Ebo Forest

6.1. "*Spirostreptus*" *servatius* Attems, 1914
6.1.1. Habitat preference
This native species from Cameroon (Figure 9) occurred exclusively in the well-structured primary forest in the Dja Biosphere Reserve during this study. Closed canopies, clear undergrowth, and the presence of important leaf litter characterize this forest. This species was associated with leaf litter and fallen dry dead trunks. This specificity of habitat and micro-habitat makes this species highly vulnerable to human activities. *S. servatius* is a site-specific species with very low dispersal ability. These characteristics suggest that it may easily go extinct if there is no appropriate measure to monitor and protect the small population identified during this project in the Dja Biosphere Reserve, even though there is another population/subpopulation as mentioned in the section below.

Figure. 9. "*Spirostreptus*" *servatius* Attems, 1914 in natural habitats. © Nzoko Fiemapong A. R.

6.1.2. Distribution

Figure 10 shows the distribution of *S. servatius*. This distribution is based on exploring literature, the GBIF database, and the data collected during our previous study in Cameroon. Based on the available data, we mention 10 occurrences of this species concentrated in four Regions of Cameroon (Adamaoua, East, South, and Southwest region). In the Adamaoua region, one occurrence was mentioned near Nganha mountain. In the East Region where the most occurrence was mentioned during the present study, the species was recorded in the Primary Forest of the Dja Biosphere Reserve in the locality of Somalomo (6 occurrences) and in Deng Deng National Park (1 occurrence). One occurrence of S. servatius was mentioned in the South-West region of Cameroon in Bibundi (BGIF website), the type locality of this species. Finally, in the South Region of Cameroon, we recorded one occurrence of *S. servatius* in the locality of Engout' Adja. According to the GBIF database, this species is also present in Ghana without precision on the locality or coordinate.
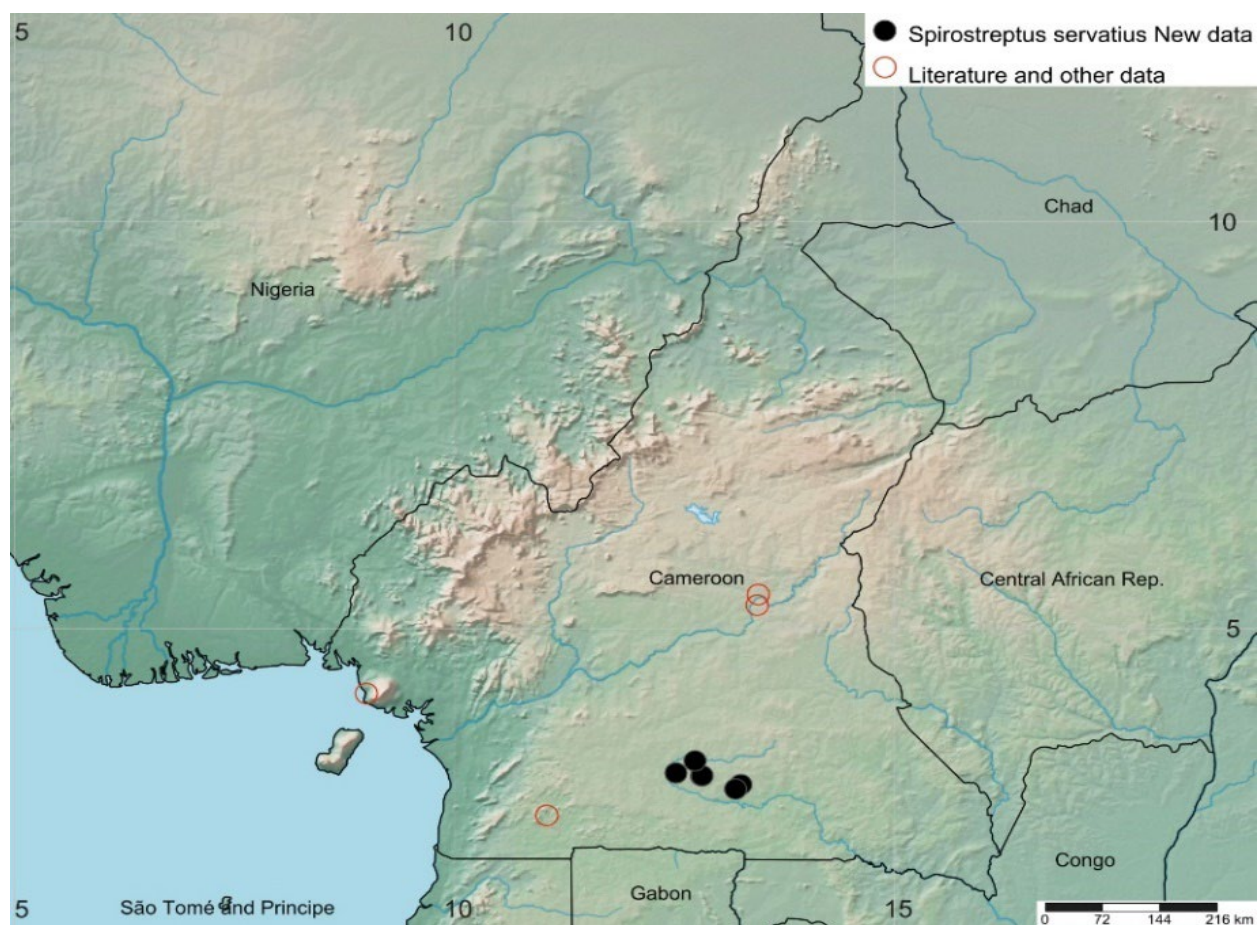

Figure 10. Distribution of the "*Spirostreptus*" *servatius* Attems, 1914 in Cameroon.

6.1.3. Conservation assessment of "*Spirostreptus*" *servatius* Attems, 1914

The giant African millipede *S. servatius* (figure 9) is an endemic species described in the locality of Bibundi South-West region of Cameroon in 1914 by Von C. Attems. This species is a rare species inhabiting forests habitat. The distribution area of this species includes two protected areas (Dja Biosphere Reserve and Deng Deng National Park). Other localities that arbor the species are not protected, and no conservation actions are in place. Harvesting plants for medicines and timber may result in the habitat degradation of the target species, but this is not a major risk. However, due to the small number of known range localities, this species is vulnerable to bush fire, slash-and-burn agricultural practices, mining, and inundation from hydro-electrical dams. These include the dam on the Dja River (which surrounds the Dja faunal reserve) and that of Lom Pangar, which

considerably affects the habitat and microhabitats suitable for the target Millipede in the Deng Deng National Park. The extent to which forest degradation continues in the prospected area is alarming. Also, many mining projects around the study area threaten the entire biodiversity. The most significant of these are large-scale deforestation, degradation of surface water resources and soil through excessive use of chemicals. The management level is poor despite the target species being located in two protected areas. The EOO is estimated as 288902.00 km² and AOO = 52.00 km². The number of known locations is presently equal to five (05). Considering the estimated AOO, the population of the target species, the number of mature individuals, and the recorded threats, this species may qualify as Endangered (EN) B2ab (ii, iii, iv).

6.2. "*Spirostreptus*" *pancratius* Attems, 1914
6.2.1. Habitat preference
This native species from the Democratic Republic of Congo (Figure 11) were sample during this study in the Dja Biosphere Reserve, a well-classified and fully protected area, and Ebo forest, which is not yet a fully protected zone in Cameroon. Forests that arbor this species are mature forests characterized by closed canopies and clear undergrowth with important leaflitter. *S. pancratius* was particularly associated with leaf litter and dead wood. This species, which tends to be a forest habitat specialist, is vulnerable to human activities for its low dispersal ability and its populations' fragmented and small size. These characteristics suggest that this giant African millipede species could go extinct if there is no appropriate measure to monitor and protect the two small populations identified during this project.

Figure 11. "*Spirostreptus*" *pancratius* Attems, 1914 in natural habitats. © Nzoko Fiemapong A. R.

6.2.2. Distribution
This giant millipede species has been recorded from the East and Littoral Region of Cameroon (Figure 12), two regions with different climatic conditions, and is largely restricted to forest habitats. In addition to the material examined, the exploration of literature, the GBIF database and

the website of the Royal Museum of Central Africa, where the type of this species is housed, provided other localities. In the Dja Biosphere Reserve, the species was recorded in mature (primary/near to primary) forest (4 occurrences). We also recorded two occurrences coordinates in the Ebo forest (Littoral Region) practically in the relatively same habitat as in the Dja Biosphere Reserve (mature forest). From the GBIF database, the species has been recorded in Gabon (2 occurrences) and Congo (4 occurrences) but without precision on localities or coordinates.
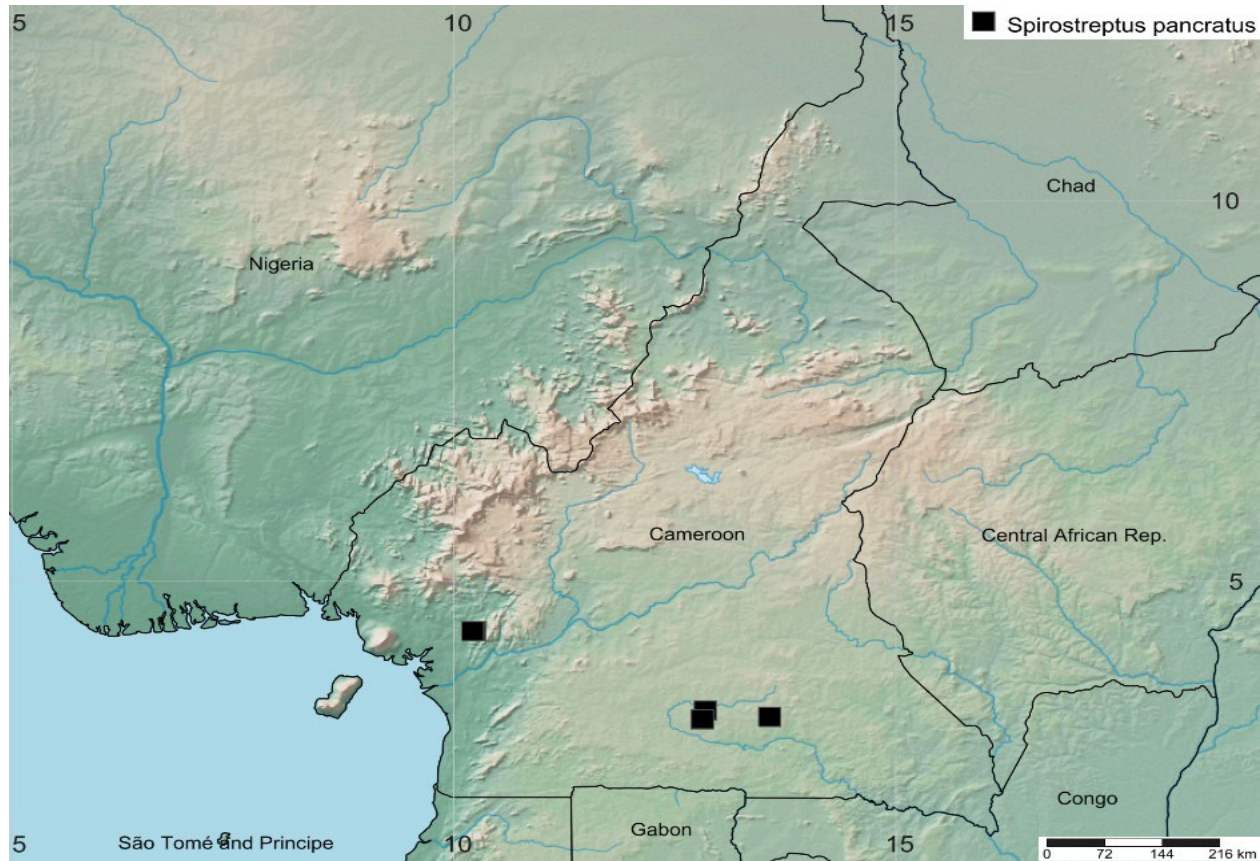

Figure 12. Distribution of "*Spirostreptus*" *pancratius* based on the available coordinates.

6.2.3. Conservation assessment

This giant African millipede was described for the first time from Congo by Von C. Attems (1914). According to our observation, *S. pancratius* inhabits mature forests. According to the Cameroon legislation, this species occurred in the prospected areas, which are all protected zones. The harvest of plants by local populations for medicines and timber may result in the habitat degradation of the target species, mainly around Ebo Forest, but this is not a major risk. However, due to the small number of known range localities, this species is vulnerable to practices such as bushfires, and inundation from hydro-electrical dams. These include the dam on the Dja River (which surrounds the Dja faunal reserve). The extent to which forest degradation continues in localities where we record this species is alarming, even though they are protected areas. The most significant of these are large-scale deforestation and soil degradation through excessive use of chemicals. Although *S. pancratius* is present in two protected areas, the management level in these areas is poor. The EOO is estimated as 6156.00 km² and AOO = 16.00 km². The number of known locations is presently equal to five (05). Considering the estimated AOO, the population of the target species, the number of mature individuals, and the recorded threats, this species may qualify as Endangered (EN) B2ab (ii, iii).

6.3. *Telodeinopus canaliculatus* (Porat, 1894)
6.3.1. Habitat preference

Telodeinopus canaliculatus (Figure 13) is a native species from Cameroon that occurred during this study in all the prospected areas and habitats. It is a cosmopolitan and generalist species that adapts to all habitats, whether degraded or not. This species colonizes the entire southern Cameroonian forest and has been reported in most of the diverse work carried out in recent years in Cameroon with considerable abundance (Mbenoun *et al.*, 2017, Mbenoun & Makon, 2019, Mbenoun *et al.,* 2022). This species prefers highly degraded secondary forests with significant decomposing litter and cocoa-based agroforests, proliferating mainly under leaves and decomposing dead wood on the ground. This species which seems generalist is less affected by anthropogenic activities, probably related to its adaptability. It is present in the natural environment all year round, with peak abundance in the rainy season.

6.3.2. Distribution

During this study, *T. canaliculatus* was collected in the two prospected study areas in all the localities visited. It is currently known in the Centre, East, South, and Littoral region of Cameroon regions (Figure 14), where it colonizes almost all vegetation types. In addition to the occurrence obtained during this study, the exploration of literature and the GBIF database provided other localities. The GBIF database signals the species in Gabon (6 occurrences) without precision on localities or coordinates.

Figure 13. *Telodeinopus canaliculatus* (Porat, 1894) in natural habitats. © Nzoko Fiemapong A. R.

6.3.3. Conservation assessment

This is a native species described by Porat (1894) from several localities in the lowland forest of Cameroon. This species' habitat appears to be mainly secondary forest, agroforest, and grassland. It has also been recorded from several localities in four of the seven regions of the southern forest zone of Cameroon (East, Center, Littoral, and South), so it appears to survive some development. There have been many agricultural developments in the areas where this species occurs, but this is small relative to the species' overall distribution. EOO = 85497.00 km 2 and AOO = 116 km 2, with more than 20 locations in Cameroon. The species has been recorded from five protected areas in Cameroon namely: Douala-Edea National Park, Dja Biosphere Reserve (World Heritage Site), Deng Deng National Park, Campo Ma'an National Park, and the Proposed protected area of Ebo Forest, and less formally protected areas of Mt Manemgouba. There is no evidence that the EOO or the AOO or the number of locations has declined or is continuing to decline. Therefore, the AOO and the number of locations are probably higher than currently known. Based on the EOO and the number of locations, *Telodeinopus canaliculatus* was assessed as Least Concern (LC).
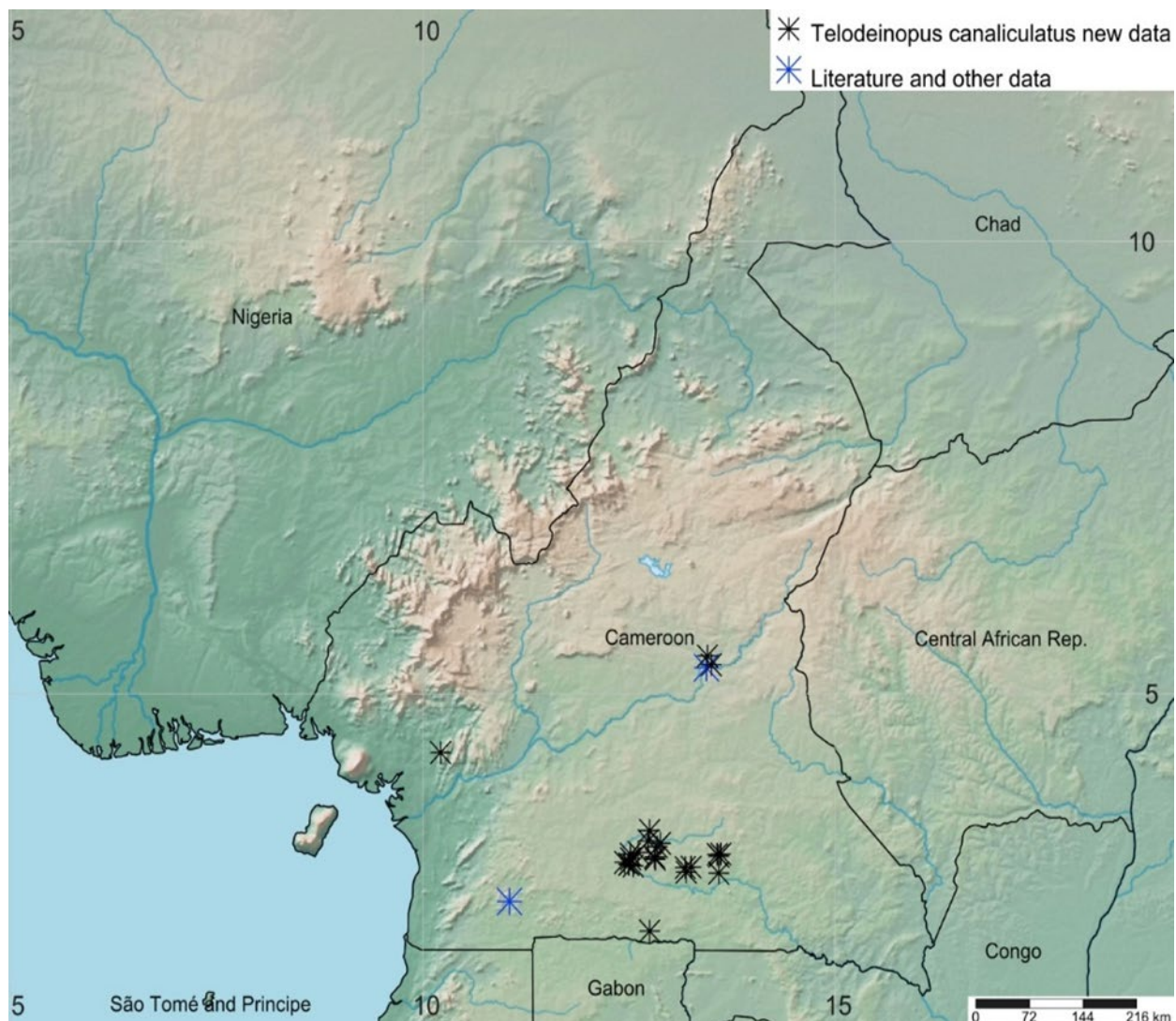

Figure 14. Distribution of *Telodeinopus canaliculatus* based on available coordinates.

6.4. *Telodeinopus bibundinu* (Attems, 1914)
6.4.1. Habitat preference

This endemic species from Cameroon (Figure 15) were sampled during this study in Ebo Forest. It is a forest species that prefers to colonize mature forests with clear undergrowth provided with

significant decomposing litter. The species which seems to be forest specialists is significantly affected by anthropogenic activities such as logging, which constitutes a danger for the latter. It was present in the natural environment exclusively during the rainy season.

6.4.2. Distribution

Telodeinopus bibundinus was only collected in the Ebo Forest (coastal Region of Cameroon) (Figure 16). It is also known from the southwestern Region of Cameroon, where the type locality Bibundi is found. This is the second report of the species since its original description in 1914, over 100 years ago. This study thus extends its distribution area in the Cameroon coastal region.

Figure 15. *Telodeinopus bibundinu* (Attems, 1914) in natural habitats. © Nzoko Fiemapong A. R.

Figure 16. Distribution of *Telodeinopus bibundinu*s (Attems, 1914) based on the available coordinates. © Nzoko Fiemapong A. R.

6.4.3. Conservation assessment

This native and endemic species described by Attems (1914) from the lowland forest of Cameroon at Bibundi appears to be a forest specialist. There has been much agricultural development in the areas where this species occurs. EOO =114.00 km 2 and AOO = 12 km 2, and only two locations in Cameroon. The species has not been recorded from protected areas. There is evidence that the EOO and AOO, and the number of locations are continuing to decline. Based on the EOO, AOO, and the number of locations, *Telodeinopus bibundinus* was assessed as Endangered (EN) B1+ B2ab (ii, iii, iv, v).

6.5. *Telodeinopus* sp.
6.5.1. Habitat preference

Telodeinopus sp. (Figure 17) is a probably new species for science recorded during this study in the Dja Biosphere Reserve. It is a cosmopolitan and generalist species that adapts to all habitats in its distribution range. This giant millipede prefers secondary forests and cocoa-based agroforests, where it proliferates under leaves and decaying dead wood. This species which is generalist is less affected by anthropogenic activities. This is probably related to its ability to adapt to all habitats. It is present in the natural environment all year round, with peak abundance in the rainy season.

6.5.2. Distribution

Telodeinopus sp. is only distributed in the Dja Biosphere Reserve (Figure 18), which covers two regions of Cameroon (The East Region at Somalomo, and the South Region at Meyomessala). This species was also collected during a sporadic field mission in Deng Deng National Park also located in the East Region of Cameroon. This giant millipede species, therefore, seems, given the available information, to be endemic to the regions of East and South Cameroon.

Figure 17. *Telodeinopus* sp. in natural habitats. © Nzoko Fiemapong A. R.
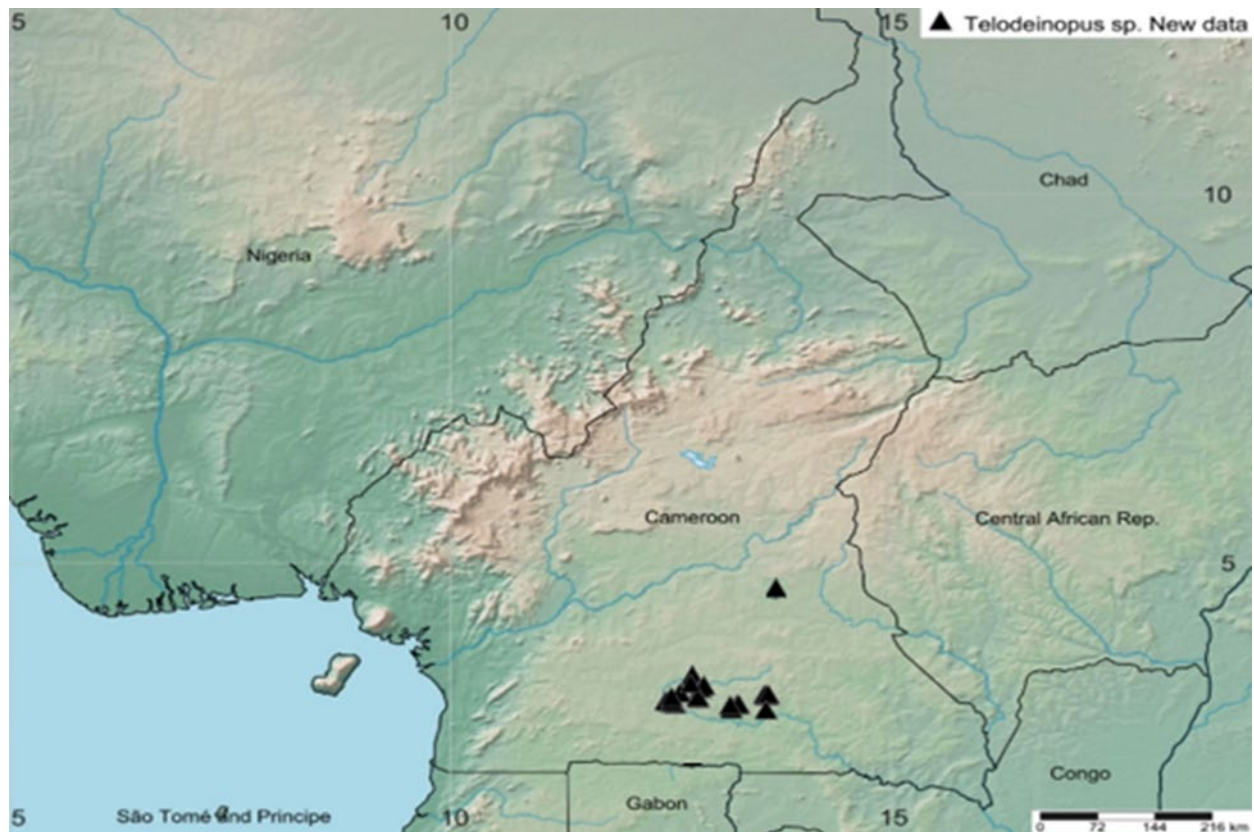
Figure 18. Distribution of *Telodeinopus* sp**.** based on available coordinates.

6.5.3. Conservation assessment

This species is probably new to science occurred from several locations in the lowland forest of Cameroon. It appears to be mainly associated with secondary forests, agroforests and farmland. There has been much agricultural development in the areas where this species occurs, but this is small relative to the species' overall distribution. EOO = 8975.00 km 2 and AOO = 96 km 2, more 4 locations in Cameroon. The species has been recorded from two protected areas, the Deng Deng National Park and the Dja Biosphere Reserve. There is no evidence that the EOO, the AOO or the number of locations has declined. Based on the EOO, AOO and the number of locations, *Telodeinopus* sp. was assessed as Endangered (EN) B1 +B2a b(iii, iv).

6.6. *Brevitibuis polyptychus (*Kraus, 1958)

6.6.1. Habitat preference

This native species from Katanga Province, Democratic Republic of Congo, was sampled for the first time out of its type locality in the Dja Biosphere Reserve in the eastern region of Cameroon. This species is very habitat-specific and was only found in this study in the mature secondary closed-canopy forest with significant litter in the understory. The few specimens examined during this study were captured during the main rainy season under deadwood. This rare species and specialist are significantly affected by the anthropogenic activities in the Dja Biosphere Reserve, mainly in the buffer zone where the specimens were collected.

Figure 19. *Brevitibuis polyptychus (*Kraus, 1958) in natural habitats. © Nzoko Fiemapong A. R.

6.6.2. Distribution

Brevitibuis polyptychus was only collected during this study in the Dja Biosphere Reserve (Eastern Cameroon region), a fully protected area. In addition to the material examined, the exploration of literature (Mwabvu et al. 2007) provided other localities (National Park of Upemba, Katanga Province (8°30'S, 26°20'E) (Figure 20).
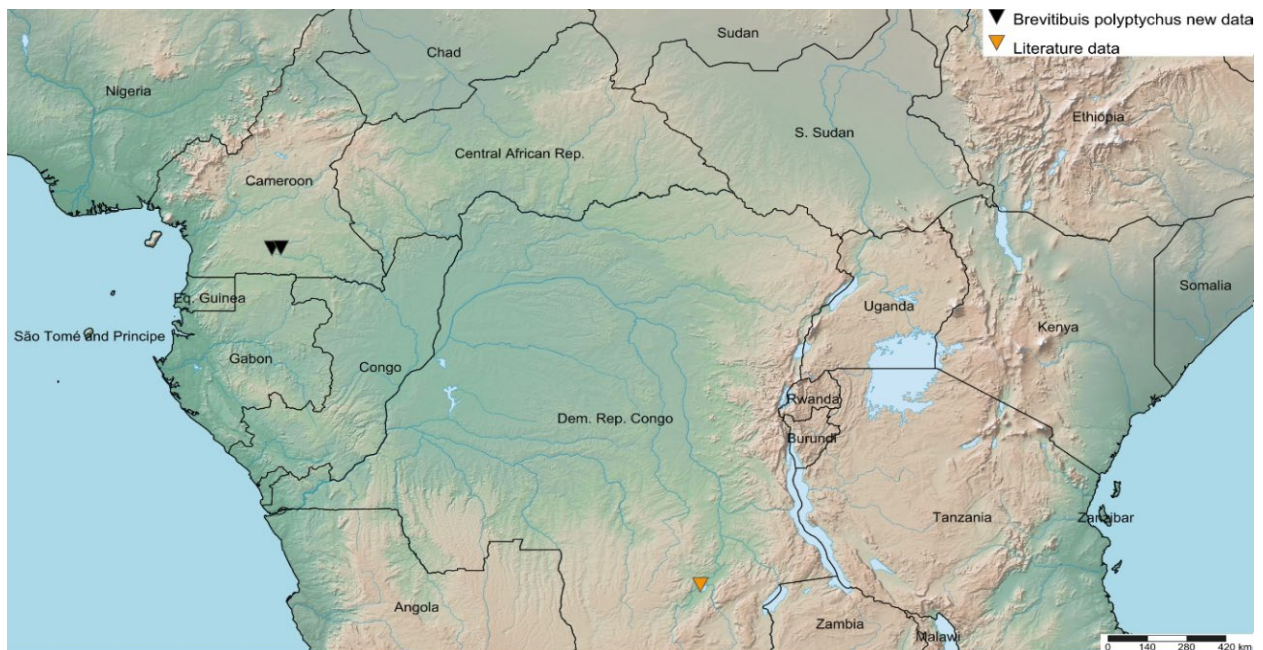

Figure 20. Distribution of *Brevitibuis polyptychus* based on the available coordinated.

6.6.3. Conservation assessment

This is a central African species described from Katanga Province (DR Congo) in 1958 and first collected in 1948. The species have a very restricted distribution area in Cameroon and RD Congo and have been from two protected areas, including the Dja Biosphere Reserve, where this study took place, and the National Park of Upemba, Katanga Province. However, no specific conservation actions are in place for this species. The major threats include habitat loss due to logging and forest degradation along the Dja Biosphere Reserve, mining, wood harvesting for

charcoal production, clearing of natural habitat for informal settlements, and subsistence farming. The EOO is estimated to be 4307.605km², and the AOO = 12 km². There are only two (02) locations, but these are highly fragmented. This species is therefore categorized as Endangered, (EN) B1+ B2ab (ii, iii, iv)

6.7. *Spiropoeus fischeri* Brandt, 1833
6.7.1. Habitat preference
This species, described by Brandt in 1833 (Figure 21), was identified during this study in the Dja Biosphere Reserve and Ebo forest. This species is very habitat specific and colonizes mature forests (Near primary/Primary Forest and old secondary forest). This species mainly colonizes decomposing forest litter. The specimens examined during this study were sampled during the rainy season. This rare species and forest specialist species is significantly affected by the anthropogenic activities that take place both in the Dja Biosphere Reserve and in the Ebo forest.

Figure 21. *Spiropoeus fischeri* Brandt, 1833 in natural habitats. © Nzoko Fiemapong A. R.

6.7.2. Distribution
Spiropoeus fischeri Brandt, 1833 was collected during this study in Somalomo and Meyomessala (Dja Biosphere Reserve), and in the locality of Njuma (Ebo forest). In addition to the material examined, the exploration of literature and the GBIF database provided other localities. This species is also present in Liberia, Guinea, Ivory Coast, Congo, Central African Republic, Gabon, and Sierra Leone.

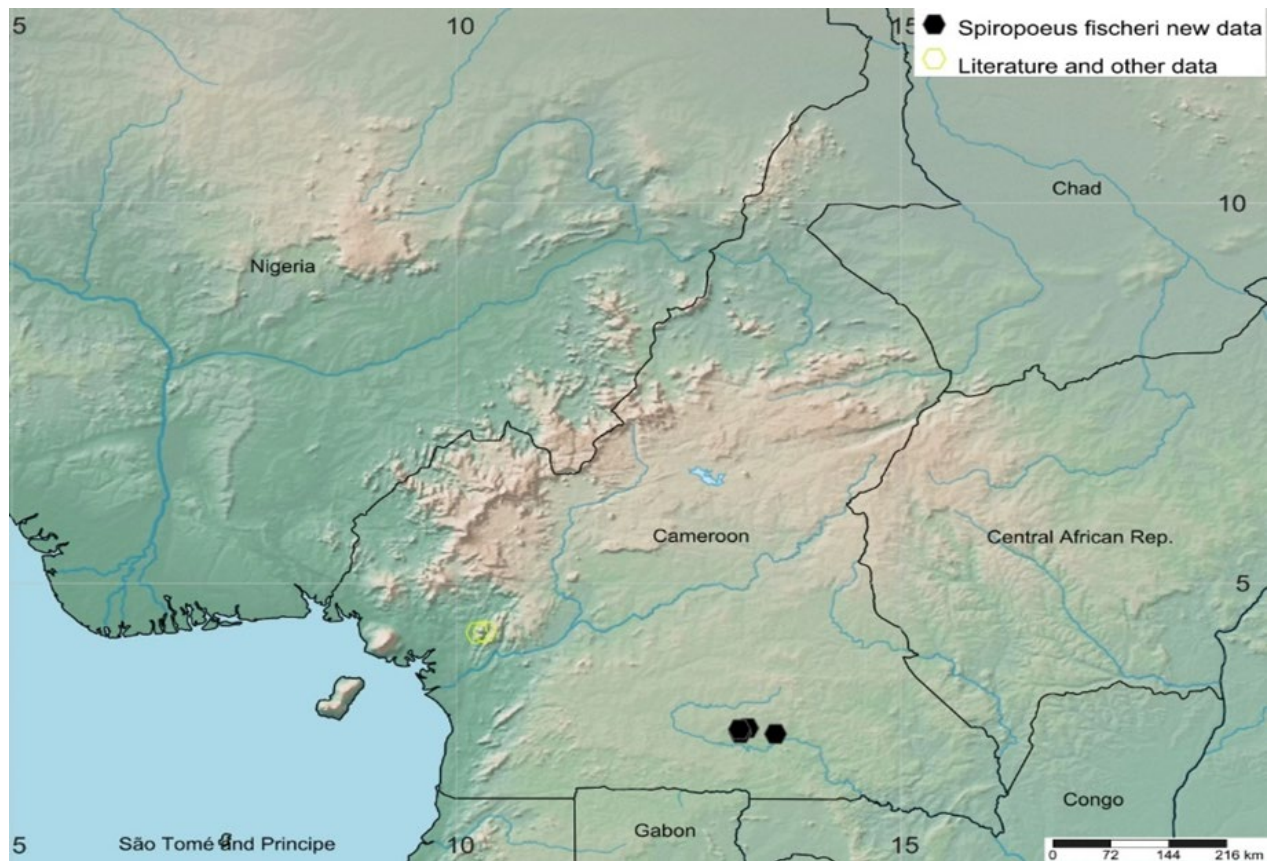The map below (Figure 22) considers just the data collected in Cameroon.

Figure 22. Distribution of *Spiropoeus fischeri* in Cameroon base on available coordinate. © Nzoko Fiemapong A. R.

6.7.3. Conservation assessment

This giant African millipede is widespread in western, central, and East Africa and has been recorded from several protected areas, including one of our study sites, the World Heritage site of the Dja Biosphere Reserve. The species is known to occur in forest habitats. However, no specific conservation actions are in place for this species. The major threats include habitat loss due to urbanization, mining, illegal wood harvesting, and clearing of natural habitat for informal settlements and subsistence farming. In addition, this species may be illegally collected for the international pet trade. As a result, habitat has been lost, especially along the buffer zone of the Dja Biosphere Reserve and this is likely to continue outside of protected areas.

The EOO is estimated to be 1712099.301 km², and the AOO = 56 km². Therefore, there are more than twenty locations. This species is thus categorized as Least Concern (LC) based on EOO and the number of areas.

6.8 *Treptogonostreptus intricatus* Voges (1878)
6.8.1. Habitat preference

This species described by Voges in 1878 from an unspecified locality of Cameroon, were identified during this study in the proposed protected area of Ebo forest, located in the littoral Region of Cameroon. This giant millipede species (Figure 23) is habitat-specific and colonizes mature forests. This species was mainly collected in the forest litter and under the tree trunks of decomposing dead trees in the forest undergrowth. The specimens examined during this study were mostly collected during the rainy season. This rare and forest specialist species is affected by illegal logging activities in the Ebo forest.

Figure 23. *Treptogonostreptus intricatus* Voges (1878) in natural habitats. © Nzoko Fiemapong A. R.

6.8.2. Distribution

During this study, *T. intricatus* was only identified in the locality of Njuma (Ebo forest) in the littoral Region of Cameroon. In addition to the material examined, the exploration of literature and our previous field survey data provided other localities: Bonge in the Southwest region of Cameroon and Mouanko in the littoral Region. This species is also present in Nigeria (Calabar) (Figure 24).
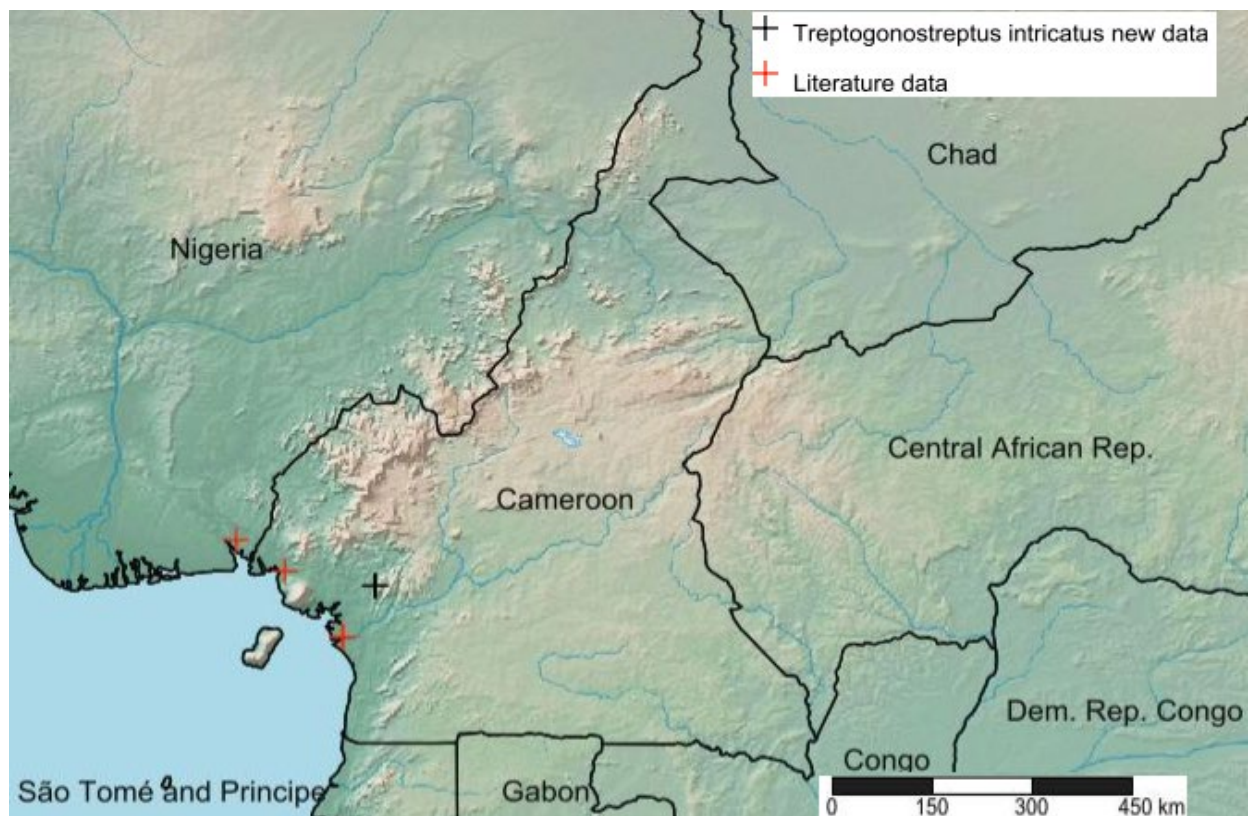

Figure 24. Distribution of *Spiropoeus fischeri* Brandt, 1833 based on the available coordinates.

6.8.3. Conservation assessment

This giant black leg-red African millipede *T. intricatus* is an endemic species to Nigeria and Cameroon and has been recorded in one protected area (Douala Edéa National Park). The species is known to occur in mature forest habitats. However, no specific conservation actions are in place for this species. The major threats include habitat loss due to urbanization, illegal wood harvesting, and slash-and-burn agriculture practice. Habitats lost are especially pronounced in and around the Ebo Forest and will likely continue in the future.

The EOO is estimated to be 11260.880 km², and the AOO = 24 km². There are four (04) locations, but these are highly fragmented. This species is therefore categorized as Endangered (EN) B2ab (ii, iii, iv).

6.9. *Ophiostreptus* sp.
6.9.1. Habitat preference

This species, probably new to science, was identified during this study in the proposed protected Ebo forest and the Dja Biosphere Reserve. This species is habitat-specific and colonizes mature forests (near primary/primary and old secondary forests). It was mainly collected in the forest litter and under the trunks of decomposing dead trees in the forest undergrowth. The specimens examined during this study were mostly collected during the rainy season. This rare and forest specialist species is affected by illegal logging and logging activities in the Ebo forest.

Figure 25. *Ophiostreptus* sp. in natural habitats. © Nzoko Fiemapong A. R.

6.9.2. Distribution

During this study, *Ophiostreptus* sp. was not identified in the two prospected study areas, in particular in the East region, precisely in the locality of Somalomo (Dja Biosphere Reserve) and of the coast in the locality of Njuma (Ebo forest) (Figure 26).

6.9.3. Conservation assessment

The giant African millipede *Ophiostreptus* sp. seems to be an endemic species to Cameroon and has been recorded in one protected area (Dja Biosphere Reserve). The species is known to occur in mature forests. There are several other forest and woodland patches in the Region where this species might occur, but it is likely to have a restricted distribution. There is agricultural practice surrounding the protected areas where the species was recorded. These activities seem to harm the forest habitat, much of which is along the buffer zone of the Dja Biosphere Reserve. No specific conservation actions are in place for this species. The EOO is estimated to be 11260.880 km², and the AOO = 24 km². This target species occurred in two (02) locations, but these areas

are highly fragmented. There is evidence that AOO as well as EOO will decline in the future if there is no conservation effort in place. Therefore, the extinction risk assessment of this species under the B category based on AOO and the number of locations is Endangered (EN) B2ab (ii, iii, iv, v).
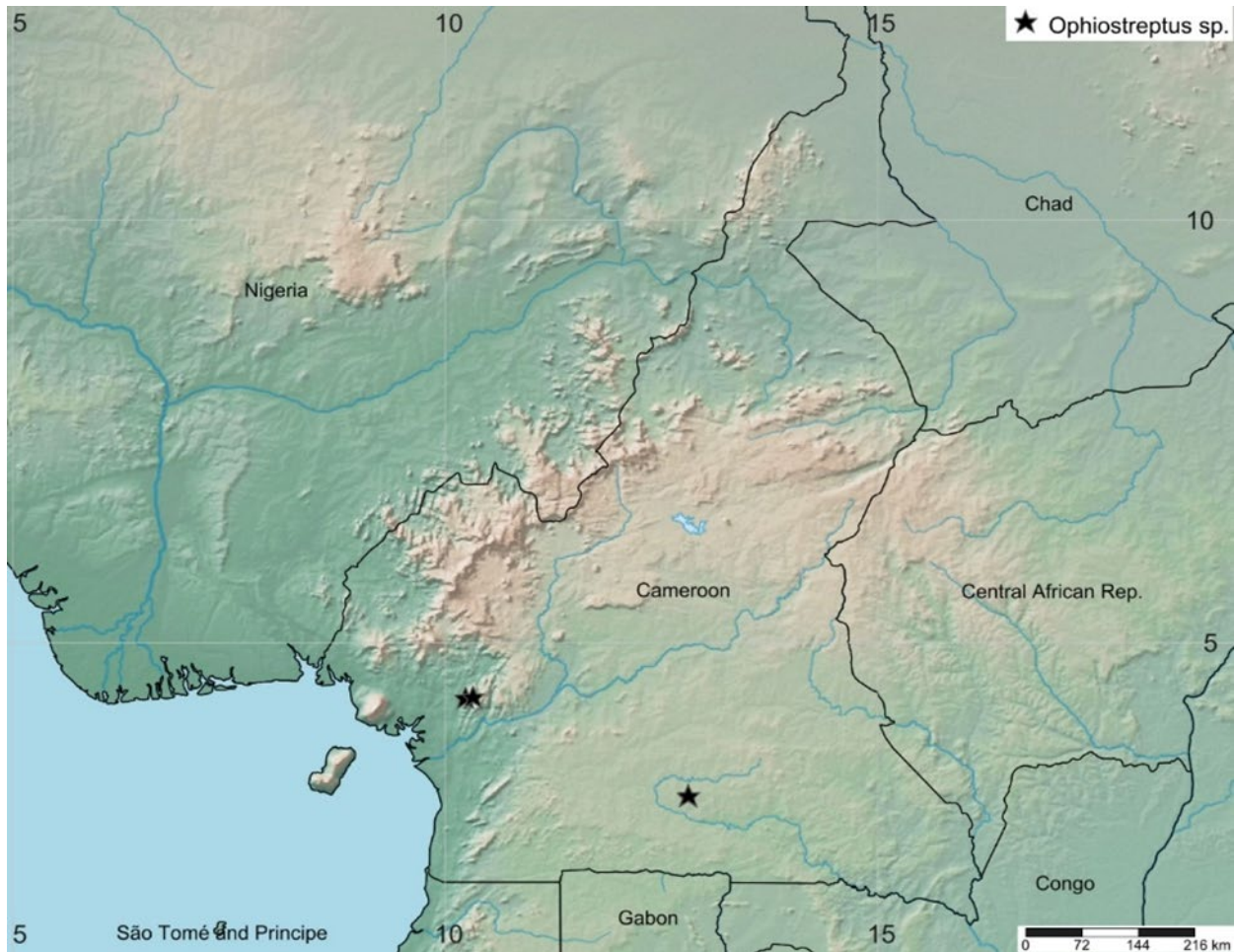

Figure 26. Distribution of *Ophiostreptus* sp. based on available coordinates.

6.10. *Pelmatojulus excisus* (Cook, 1897)
6.10.1. Habitat preference

This native species from Cameroon was described by Cook in 1897 from material collected by F. Braun, Dr. Weisseenborn, and Lieutenant Morgan and housed in the Berlin Museum. This species was identified during this study in the proposed protected Ebo forest and the Dja Biosphere Reserve, located respectively in the littoral and the East region of Cameroon and in all prospected Habitats except farmland. This species seems to colonize all forest types with important leaf litter. The specimens examined during this study were mostly collected during the rainy season. This species seems very adaptative and can be found in all habitats. However, certain anthropogenic activities such as excessive logging, slash-and-burn agriculture, and the excessive use of fertilizers and other chemical products could considerably reduce the size of its populations.

Figure 27. *Pelmatojulus excisus* (Cook, 1897) in natural habitats. © Nzoko Fiemapong A. R.

6.10.2. Distribution

Pelmatojulus excisus was identified in the two prospected study areas in all the localities visited (Figure 28). In addition to the occurrence obtained during this study, the exploration of literature and the GBIF database provided other localities. This giant millipede species has a very wide distribution in Cameroon and colonize practically all of the great forest south (the center, the South, the East, the Littoral, and part of western Cameroon). Nzoko Fiemapong and Enghoff (2018) have signaled the species from Equatorial Guinea, and the GBIF database provided an occurrence in Gabon without precision on locality or coordinates.

6.10.3. Conservation assessment

This giant fire millipede *P. excisus* seems to be an endemic species to the central Africa region and has been recorded in several protected areas, including the Dja Biosphere Reserve, Deng Deng National Park, Douala Edéa National Park, and Campo Ma'an National Park. The species occurs in closed habitats, including agroforests and mature and degraded forests. There are several other forest and woodland patches in the Region where this species might occur. Agricultural practice surrounds all the protected areas where the species was recorded. Therefore, no specific conservation actions are in place for this species. The EOO is estimated at 91978 km², and the AOO = 136 km². There are more than twenty locations. This species is therefore categorized as Least Concern (LC) based on EOO and the number of locations.
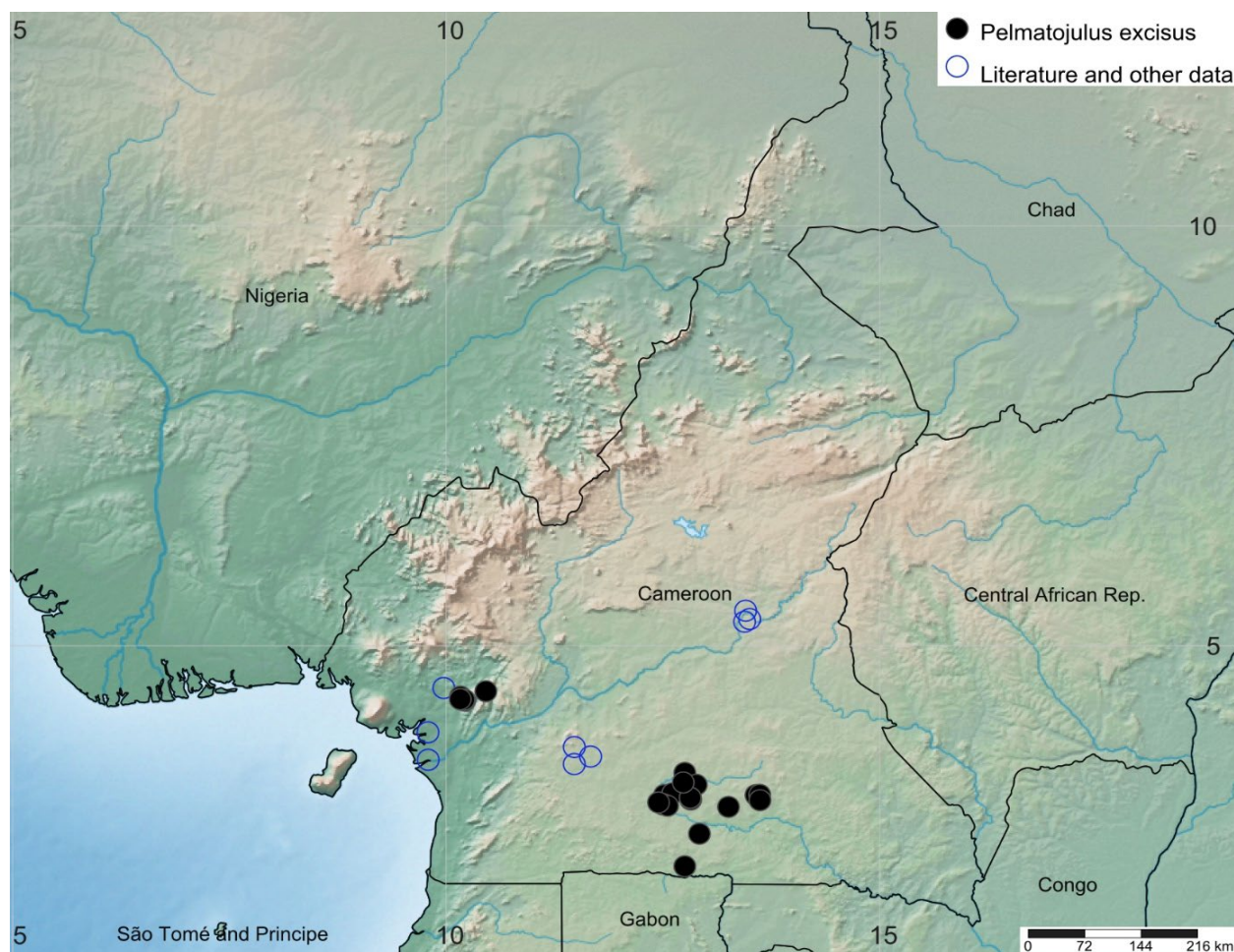
Figure 28. Distribution of *Pelmatojulus excisus* (Cook, 1897) based on available coordinates.

7. Perception, knowledge, and awareness campaign concerning giant millipedes in the local population

Conservation activities began in April 2022 with a planning meeting in Somalomo, a small village in the Dja Biosphere Reserve and Ndogbaguengue, a village around the proposed protected area of Ebo Forest. During this meeting, activities were planned and prioritized. Overall, 375 peoples were interviewed in these study areas. The respondents were between 18 and 79 years old and the population's average age was 43 years, suggesting its youthfulness. More than half of the respondents (57.5%) were women. The main livelihoods of the people in the study area were hunting fishing and subsistence slash-and-burn agriculture. Hunting was mainly practiced by men (92%), while women primarily carry out agricultural activities (100%), generally assisted by youngest.

Concerning the knowledge and use of giant millipedes by the local populations living in and around the Dja Biosphere Reserve and the Ebo forest area, the results revealed that all interviewees (100%) knew the giant African millipede species. They recognized these taxa in their natural habitat by their cylindrical form (100% of respondents), their large size (97% of respondents), their colorations (80% of respondents), and especially their large number of legs (100% of respondents). This study reveals that ca. 65% of the respondents acknowledged the usefulness of millipedes in general and that of giant millipedes in particular in soil functioning. Interviewed people recognized that Millipede usually contributed to soil fertilization by producing organic matter by leaflitter degradation in the natural environment. However, no medicinal or culinary use of giant millipedes

has been reported in both areas. Nonetheless, two non-native persons in Iboti, a village around the Ebo Forest, recognized that some millipede species are usually used to solve some health concerns such as whitlow, incurable wounds, and haemorrhoids.

Regarding the cultural aspect, answers from questionnaires and focus group discussions highlighted that the giant green Millipede (*Spirostreptus servatius*) is a mysterious species generally associated with bad luck. This species was well identified on images submitted during focus group discussions and interviews by 80% of respondents. However, about 98% of those who identified the species acknowledged that the concern species is rare and stated that they had not encountered the species since several years ago. This suggests that the species, although present, is very rare.

Respondents recognized that most giant millipede species are adapted to the forest environment and are mostly found on dead tree trunks and forest litter during the wet season. Regarding cultural knowledge, respondents indicated that some millipede species are mystical and that *Spirostreptus servatius* generally heralds misfortune, including the death of people close to the person who encountered it in the forest. The consequence of this situation is that this species often killed in retaliation by local populations when they are encountered in the forest. Contrarily, the fire millipede *Pelmatojulus excisus* called by the local people of Ebo Forest "Maria Gongong" usually announces good news that can concretely translate by capturing a big animal at a hunting party. Therefore, information collected from local populations living in and around our study sites provides sufficient data on the threat level to the target giant millipede species.

During awareness campaigns, we showed local populations the importance of the target millipedes' species in ecosystem functioning and the need to conserve and preserve them and their natural habitats. The populations were sensitized about threats to the target species and the necessity of reducing these threats for long-term survival of these species in their natural ecosystems.

The second awareness campaign showed that the perception and level of knowledge of local populations had significantly evolved regarding the target species. This sufficiently proves that the education and awareness of local populations are imperative for the efficient conservation of this taxonomic group, which is often neglected in conservation projects at the local level and for which no specific conservation measure exists in Cameroonian legislation.

Conservation Outcome

During this project, we worked closely with the local population of the study area. In addition to the short-term financial benefits that some local people (guides) benefited from the project in the form of guiding jobs, it is clear that they are predisposed to participate in other conservation projects. This is mainly due to the training received during field activities but also to the interest that some have in millipedes, which are a curiosity to them. By preserving their environment, the local people will gain more from the research that will be conducted in their localities in the future. There are currently no conservation actions in place in favor of giant millipedes in the study area. The assessment of the conservation status of these target species using IUCN Red List criteria B reveals that much of the majority of these target taxa (seven over ten recorded species) are endangered (EN) and restricted to forest environments where it is associated with leaf litter and dead wood in decomposition. Most of the recorded species have restricted distribution ranges and fragmented populations. These species are severely threatened by continuing forest degradation, agricultural practices, and Hydroelectric dams. In addition, the poor knowledge of the ecology and

behavior of all identified giant millipedes' species are important limitations to implementing conservation measures. Thus, developing conservation action to preserve this charismatics species in their natural habitat is urgently important.

In regard to the management plan for these target species, some proposals for better conservation of giant millipede are:

- Intensify the monitoring of target species in all sectors of the Dja Biosphere Reserve and in the proposed Ebo protected area as well as in adjacent areas in order to identify all existing populations.
- Encourage the consideration of these species in large projects which generally focus on birds, mammals, amphibians, and reptiles.
- Conduct regular missions in collaboration with wildlife conservation officers (MINFOF) to assess the size of populations of target species of giant millipedes with specific conservation needs.
- Initiate urgent measures with a view to reducing the threats to the target species. To this end, it should be noted that the localities prospected during our work, although being key areas for the conservation of biodiversity, are subject to enormous anthropogenic pressures.
- Continue to carry out awareness campaigns both at the level of local populations and of authorities and partners (NGOs) in charge of wildlife conservation with aiming at drawing their attention to the role of these invertebrates' species in natural ecosystems functioning and the need to pay attention to their population assessment during inventory programs.

Current and Upcoming Activities

- Use ecological modeling to predict the distribution and the conservation of the target species giant millipede species in different scenarios in the future and then provide a useful conservation strategy for the species.
- Revised the taxonomic status of the two giant millipede species of the genus "*Spirostreptus*" which no longer belong to the genus *Spirostreptus* and are considered as orphans.
- Described and published the two new giant millipedes recorded in this study.
- Publish these results in a peer-reviewed journal.

Conclusion

At the end of this study, it appears that the fauna of the giant African millipedes of the Dja Biosphere Reserve and that of the proposed protected area of Ebo Forest have a rich and diversified giant African millipede's fauna. The giant millipede community of the Dja Biosphere Reserve is richer than that of Ebo Forest. Two recorded species (*Telodeinopus* sp. and *Ophiostreptus* sp.) were identified as being new to science. Some species have a wide distribution while others have a very restricted one. However, most of the giant millipede's species preferably live in mature forests (near primary/primary forests and old secondary forests). These species are well known by the local populations, who associate them with high cultural values. Our study reveals that several species were threatened by anthropogenic disturbances, among which deforestation, slash-and-burn agricultural practices, and clear-cut practices for installing industrial plantations (Cocoa, Hevea, palm oil), which usually require an important quantity of chemicals. Based on the IUCN Criterion B, seven recorded giant millipede species were assessed as Endangered (EN) and three as Least Concern (LC). Thus, it is urgently important that nature and wildlife conservation

organizations and governmental authorities intensify conservation strategies and actions to preserve these giants' millipedes in natural ecosystems in Afrotropical Region.

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