Title: Millipede Diversity, Distribution and Conservation Assessment in the Douala-Edea Wildlife Reserve, Cameroon

Final Report submitted to The Rufford Foundation

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Data Availability Statement

The datasets generated and analyzed during this study are not yet publicly available and could not be used without the author consent due to [REASON (S) WHY DATA ARE NOT PUBLIC] but will be available from the corresponding author on reasonable request.

Abstract

Biodiversity inventories are essential for planning, managing and monitoring of ecosystem, especially those located in tropical protected areas. Wildlife surveys and inventories are considered by conservationists as strong investments, since they are essential for determining the level of diversity within an area including communities' assemblages and species distributions. In the Afrotropical region, the effort of biodiversity conservation is mostly focused on vertebrates, compared to terrestrial

invertebrates such as millipedes which are largely endemic and indicators of habitat welfare. To have a real idea on the conservation status of millipedes in protected areas of Cameroon, this study was initiated with the objective to determining the diversity, distribution and conservation assessment of the millipede in the Douala-Edea Wildlife Reserve in Cameroon. After characterization of the habitats that potential sheltered millipedes, an ethnozoological study was carried out in order to have a clear idea on the knowledge and the perception of millipede by the populations who live around the Douala-Edea Fauna Reserve. To determine the diversity, distribution and level of conservation of diplopods in this protected area, three sampling methods were applied, namely active searching, pitfall trapping and litter sifting. For each collection site, the microhabitats sheltering the diplopods were characterized. The surveyed sites in Douala-Edea Wildlife Reserve revealed the presence of ca. 156 species of plants with a wide dominance of Euphorbiceae, Rubiaceae, Cesalpiniaceae and Fabaceae. Five types of vegetation were recorded including primary forest, secondary forest, mangrove, agroforest and open meadows. Concerning millipede species richness and distribution, we identified 36 millipede species belonging to 22 genera and 9 families from 799 individuals collected. The Chelodesmidae was the most representative family in terms of species richness (8 species). The most species rich habitat in this study was primary forest (24 species), followed by mangrove (17 species), secondary forest (13 species), open meadows (11 species), while agroforest was the less species rich habitat. Millipede species diversity among habitat types showed that the primary forest, mangrove and secondary forest has the highest values of diversity indices (H'= 2.86, E= 0.73 for primary forest; H'= 2.55, E= 0.76 for mangrove and H'= 2.31, E= 0.77 for secondary forest), while the agroforest and open meadows showed the lowest (H'= 0.97, E= 0.66 for agroforest and H'= 1.45, E= 0.39 for open meadows). The cluster analysis based on Bray-Curtis distance, revealed that there was a very weak dissimilarity among habitat types. Overall, 799 specimens collected during the study period, the highest millipede abundance being observed in open meadows (334 specimens, representing 41.80% of all millipedes collected). Next to this habitat were primary forest (215 specimens, representing 26.91% of all the specimens collected) and mangrove forest (179 specimens, representing 22.40% of all the specimens collected). Despite of high species richness and abundance, anthropogenic disturbances such as agricultural activities are ongoing which extend towards the forest in the Douala-Edea Wildlife Reserve area. Anthropogenic pressures that can affect millipede ranging from the clear-cuts to the anarchic exploitation of forest species as *Lophira alata*, *Pycnanthus angolensis*, and *Baillonella toxisperma*. In addition, intensive agricultural activity with destructive practices were noted, viz. slash-and-burn which is negative to millipedes. People living near and in the Douala-Edea wildlife Reserve known millipede and used them for several purposes. Conservation initiatives must be implemented to protect the endemic and rare millipede species in this study area.

Introduction

Monitoring biodiversity in protected areas forms an integral component of assessing their performance and providing the necessary information for effective management (McGeoch *et al.*, 2011). Invertebrates are useful, highly effective and informative indicators of other elements of biodiversity, ecosystem function and restoration, health system and associated threats (McGeoch 2007, McGeoch *et al.*, 2011; Hamer *et al.*, 2017). Although invertebrates occupy a wide variety of niches and provide many important ecological functions, they receive relatively little attention, mostly due to difficulties at different taxa identification. However, it is important to determine the level and patterns of diversity within an area including community assemblages and species distribution to gain information useful to conservation plan. One of the key reasons for conserving and monitoring invertebrates in their own right particularly in protected areas, is to ensure the adequate protection of rare and threatened invertebrate species and communities (Samways, 1993a). Invertebrates represent a sensitive, appropriate and logistically feasible target taxa for the monitoring of protected areas (McGeoch et. *al.,* 2011). Soil invertebrates significantly contribute to litter breakdown through their feeding and burrowing activities, thereby eating organic matter level in soils (Lavelle & Spain, 2001). Within this important soil component, millipedes (Diplopoda) with > 11,000 described species, form a highly diverse arthropod class, yet strongly understudied (Minelli, 2015). Nowadays, only ca. 20% of the global species diversity of millipedes are currently known, with the actual number of species being estimated between 50,000 and 80,000 species (Minelli & Golovatch, 2013). Being mainly represented by mesophilous forest-dwelling detritivores, millipedes have long been recognized as playing important ecological roles, mostly in temperate and tropical land ecosystems where their diversity is especially pronounced (Golovatch & Kime, 2009). The class encompasses 16 extant orders, 140 families, and ca. 2,000 genera (Minelli & Golovatch, 2013), while the distributions of higher taxa fully agree with the major biogeographic divisions of Earth into the Holarctic, Afrotropical, Oriental, Neotropical and Australian regions (Golovatch & Liu, 2020). Antarctica is completely devoid of millipede, whereas the Oriental Region appears to be the sole one to harbor all 16 orders (Golovatch & Liu, 2020). Being very ancient and diverse taxonomically, widespread present on all continents except Antarctica, virtually fully terrestrial, poorly vagile and highly limited in compensatory ecological faculties (strongly restricted by a single limiting ecological factor even if the others are favourable), millipedes have long been considered as an exemplary group for biogeographic studies and reconstructions (Shelley & Golovatch, 2011; Golovatch & Liu, 2020). Since millipedes are considered to be a key taxon in ecological processes, studying the diversity composition of their assemblages and their distribution is crucial (Edwards, 1974). They are sensitive to habitat changes resulting from forest disturbance, for instance in terms of changes in light regimes, microclimates, availability of dead wood and soil compaction, making them important indicators of ecological impacts of habitat disturbance (Paoletti *et al.*, 2007). Millipedes are relatively easy to collect and identify. The most important soil characteristics for millipedes are soil texture, soil moisture content, temperature, mineral content (especially calcium and magnesium), and humus type (Hopkin & Read, 1992; Kime & Wauthy, 1984). In the African continent, several studies have been conducted in the field of biodiversity conservation and revealed that most of the African millipede species are threatened and listed in the IUCN Red List. Nevertheless, despite the interest to these taxa, one of the problems faced by invertebrate conservationists is the lack of knowledge about the exact conservation status of these species. Despite increased awareness of millipede importance to global conservation planning, relatively little attention has been paid to inventory and monitoring of this terrestrial Arthropod group. The diversity and abundance of millipedes can provide a rich base of information to aid the efforts in the conservation of biodiversity, and in the planning and management of natural ecosystems. Since the coastal forests of Cameroon are being rapidly degraded, in large part by shifting ("slash and burn") cultivation which is an important driver of regional climate change in the Congo Basin of Central Africa, it is important to study millipede diversity, distribution and conservation in this part of globe. This study aims to determine the diversity, distribution, community structure and abundance variation of millipede species within various vegetation types, with different levels of naturalness, occurring in Douala-Edea wildlife Reserve. To assess the different land use system on millipedes' communities and also record the perception and knowledge of the local populations in and around the reserve to suggest the conservation actions that could helped to preserve millipede in their natural environment.

Material and Methods

Study site

The Douala-Edea Wildlife Reserve, which was recently promoted to a National Park, is situated in the Littoral evergreen forest of Cameroon. This area is located in the great forest belt of the Congo Basin. These forest regions represent one of the globe's largest biodiversity hotspots including a wealth of understudied and threatened species. These woodlands are crucial ecosystems for the future of the world, given that climate change is increasing due to human pressure which leads to their progressive destruction. The Douala-Edea National Park is under the responsibility of the Ministry of Forestry and Wildlife management. This reserve is located between 3° 14' and 3°50' N latitude and 9°34' and 10°03' E longitude. The area of the reserve is about 1,600 km^2 and its limits extend from the Atlantic coast with a distance of 35 km inland, its eastern boundary is along the Dipombé River. The reserve is located within a sedimentary lowland plain of 0-50 m elevation. Most of the northern area of the reserve is subject to tides. Streams occupy about 1% of the area of the reserve; the largest surface area of water is Lake Tissongo. Soils range from sandy to sandy-loam further inland. The reserve is located in a transitional climate zone. In the south of the reserve, the region is characterized by a typical equatorial climate with two rainy seasons and two dry seasons per year. The average annual rainfall ranges from 3 000 to 4 000 mm. The monthly average maximum temperature varies throughout the year from 24.6°C to 28.7°C. The reserve, which is adjacent to the Atlantic Ocean, is a littoral forest dominated by *Lophira alata* and *Saccoglottis gabonensis*. This type of vegetation covers most of the reserve.

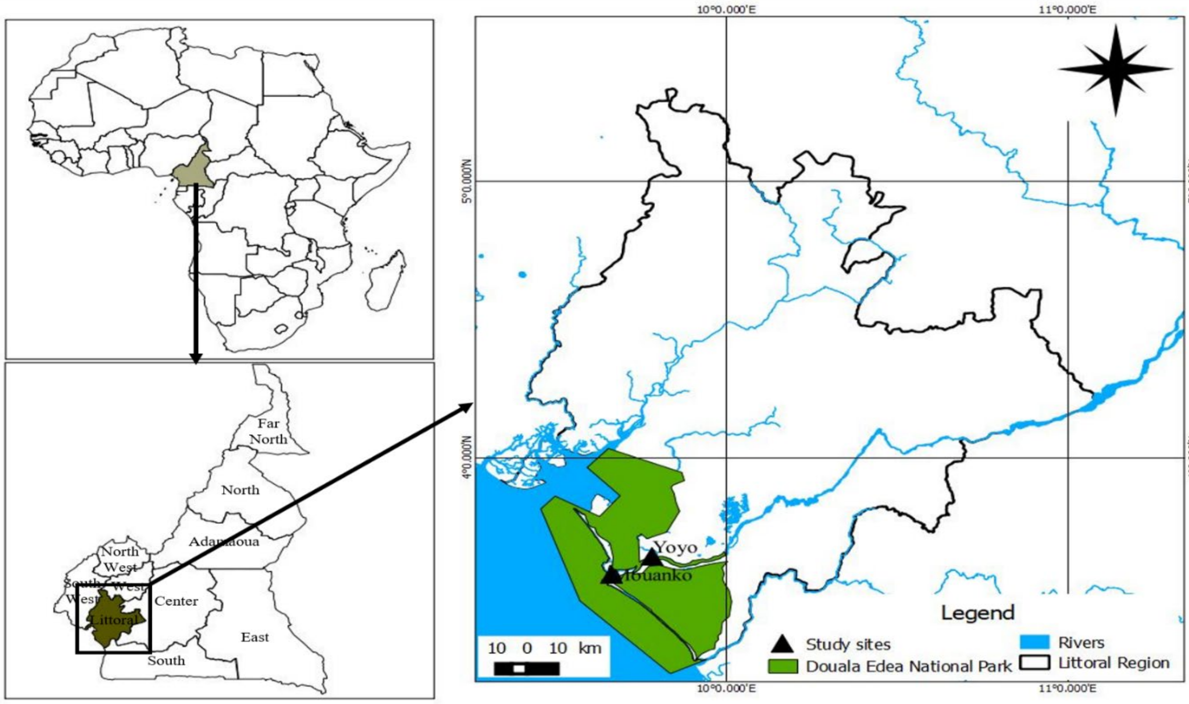

Figure 1. Study site

Millipedes sampling

Three common sampling methods were used for collecting the specimens (Active searching, pitfall trapping and litter sifting). In each ecosystem, two parallel transects (200 m and 20 m apart) was delimited. Eleven sampling spots were selected at a constant interval of 20 m on each transect. A total of 22 quadrats (9 sq.m) and 22 pitfall traps were set in each ecosystem every month during the study period.


Field session in Douala-Edea wildlife Reserve

Habitat characterization

Basic vegetation of the areas where millipedes was recorded were characterized, dominant and abundant species was recorded.


Some vegetation protected in Douala-Edéa Wildlife Reserve


Mangrove in Douala-Edéa Wildlife Reserve

Characterization and evaluation of human pressure and threat on the forests and millipede species

For the Characterization and evaluation of human pressure and threat on the forests and millipede species, each vegetation type and all human activities and pressures were recorded within and around the study area.

Perception and Knowledge of people about the importance and use of millipede

Concerning perception and Knowledge of people about the importance and use of millipedes in the study area, a structured interview involving the use of a questionnaire was administered to respondents. We recorded the knowledge of local people about the importance of invertebrates and particularly millipedes.

Identification of millipedes and plant species

Millipede species were identified in the field and in the Laboratory of Zoology at the University of Yaounde 1 using identification keys of African millipedes. Identification of plants was made in the field as well as in National herbarium of Cameroon.

Data analysis

We expressed millipede species richness, diversity, distribution, and community structure in accordance with all ecosystem types prospected in the study area.

Species richness data was analyzed using EstimateS Version 9 software. Different indices of diversity were computed using PAST 3.14. The Kruskal-Wallis test was used to compare the abundance of the different millipede species from all sampled sites. Both tests were performed using PAST 3.14 software.

Results

Habitat characterization

The plant specific composition of the Douala-Edea Wildlife Reserve in the prospected site during this study was ca. 156 species and morphospecies with a wide dominance of Euphorbiceae, Rubiaceae, Cesalpiniaceae and Fabaceae. Primary forests were characterized by the presence of large trees, under the feet of species such as *Coula edulis* and *Baillonella toxisperma*. The canopy was high and dominated by two species (*Coula edulis* and *Lophira alata*). The undergrowth of this strip was clear. In Douala-Edea Wildlife Reserve, secondary forests were usually disturbed due to anthropogenic actions. Inside the reserve, both access paths and installation of economic activities have led to the fragmentation of the ecosystem and various forms of pollution. The forests of this reserve have been affected by oil, rubber, and cacao exploration. Swamp forests were found in the vicinity of rivers. They are not very diversified, have clear undergrowth and only a few trees form the canopy. The agroforests were mainly made up of palm trees, cocoa trees. The open vegetation consisted mainly of fallow land and crop fields. The main crops grown by the populations living in the Douala-Edéa Wildlife Reserve are mainly corn, cassava, plantains and macabo. Millipede species was present in all types of environments and ecosystems found in the Douala-Edea wildlife reserve. Collected specimens were usually found under leaf litter and deadwood in decompositions.


Field survey in Douala-Edea Wildlife Reserve

Characterization and evaluation of human pressure and threat on the forests and millipede species

Various pressures on natural ecosystems by the local populations living in the Douala-Edea Wildlife Reserve, actually transformed into a National Park were assessed. These pressures ranging from the clear-cuts to the anarchic exploitation of forest species as *Lophira alata*, *Pycnanthus angolensis*, and *Baillonella toxisperma*. A very highly intensive agricultural activity with destructive practices, such as slash-and-burn was noted. These practices have negative effects on millipede which are generally vulnerable. We also noted an establishment of industrial companies such as SAFACAM which exploits rubber and SOCAPALM which exploits the palm oil around the Reserve. The activities of these companies require the use of a huge amount of chemicals that are generally harmful to the soil fauna in general and millipede in particular. It is also apparent from this study that populations living in and around the Douala-Edéa Wildlife Reserve are mainly engaged in the exploitation of clamshells. This activity seems to be harmful to the millipede insofar as the shells extracted from the Sanaga river are spread and burned over a large expanse of land which could considerably affect the survival of millipede species with a very slow dispersal ability. Indeed, during this research, we recorded a large number of dead specimens of millipede in a large stretch of land after the slash and burn. The major threats to millipede in the plantation around the Douala-Edea Wildlife Reserve of Cameroon are bushfire, agricultural practices, clear-cuts for the production of coal, use of chemicals in cocoa and palm oil plantations, but also artisanal timber exploitation.

Young trees for further rubber plantation in Douala-Edea Wildlife Reserve

Knowledge of people about the importance and use of millipedes in and around the study areas

People of the Littoral forest and particularly those living near and in the Douala-Edea wildlife Reserve known millipede and used them for several purposes. Among 150 persons interviewed during this study, we noted that millipede species are sustainable indicators of the degree of transformation of forest ecosystems. Over 92% of those interviewed reported that some of these millipede species seem to be dominant in farmlands and fallows. Other respondents reported the empirical use of millipedes as indicators of the season change. The treatment of some conditions or infections such as hemorrhoids and incurable wounds are done with certain species of millipedes. Millipede, like most invertebrates, are very important for the populations living in and around the Douala-Edea Wildlife Reserve. The most information with strong involvement in millipede conservation processes is some traditional taboos and proscriptions. In fact, the millipede arouses great fear among the populations interviewed, which is very often beneficial for the conservation of these species. Nevertheless, some people systematically kill millipede on the pretext that they bring bad luck. This perception of millipede suggested the fundamental problem of poor knowledge of these animals by the local populations and thus constitutes a considerable limit to their conservation in the natural ecosystem.

Millipede species richness and distribution

In total 36 millipede species belonging to 22 genera and 9 families were identified from 799 individuals collected (Fig. 1, Table 1). Chelodesmidae was the most represented in terms of species richness (8 species). Next to this family were Oxydesmidae and Spirostreptidae (6 species respectively), followed by Pyrgodesmidae (5 species) and Odontopygidae (4 species). Pachybolidae, Stemmiulidae and Trichopolydesmidae were represented by 2 species respectively, while Cyptodesmidae was monospecific (Fig. 1). In primary and secondary forests, the millipede community was dominated by Chelodesmidae (5 species respectively). In mangrove, the community was dominated by Chelodesmidae and Oxydesmidae (4 species respectively). While in open meadows (cultivated farms and fallows), the community was dominated by Pyrgodesmidae (5 species).

The most species rich habitat was primary forest (24 species), followed by mangrove (17 species), secondary forest (13 species), open meadows (11 species), while agroforest was the less species rich habitat with only 4 species (Table 1). Differences in species richness for all habitat types of combination were highly significant in pairwise comparison ($p<0.0001$). *Kartinicus colonus* was widely distributed as it occurred in all habitat types (Table 2). *Paracordyloporus trisolabris*, *Coenobothrus bipartitus*, *Laciniogonus* sp., *Heptadesmus granulosus*, *Spirostreptus pancratius*, *Urotropis carinatus*, *Urotropis* sp., *Stemmiullus nigricollis*, *Stemmiullus* sp. and *Hemispheroparia integratus* were restricted to primary forest. Similarly, *Diaphorodesmus dorcicornis* and *Systodesmus kribi* occurred exclusively in secondary forest. *Afolabina sanguinicornis, Diaphorodesmoides* sp., *Coromus barumbi* and *Treptogonostreptus intricatus* occurred exclusively in mangrove forest whereas *Monachodesmus longicaudatus, Monachodesmus* sp.1, *Monachodesmus* sp.2 and *Udodesmus* sp. were restricted to open meadows (Table 2).

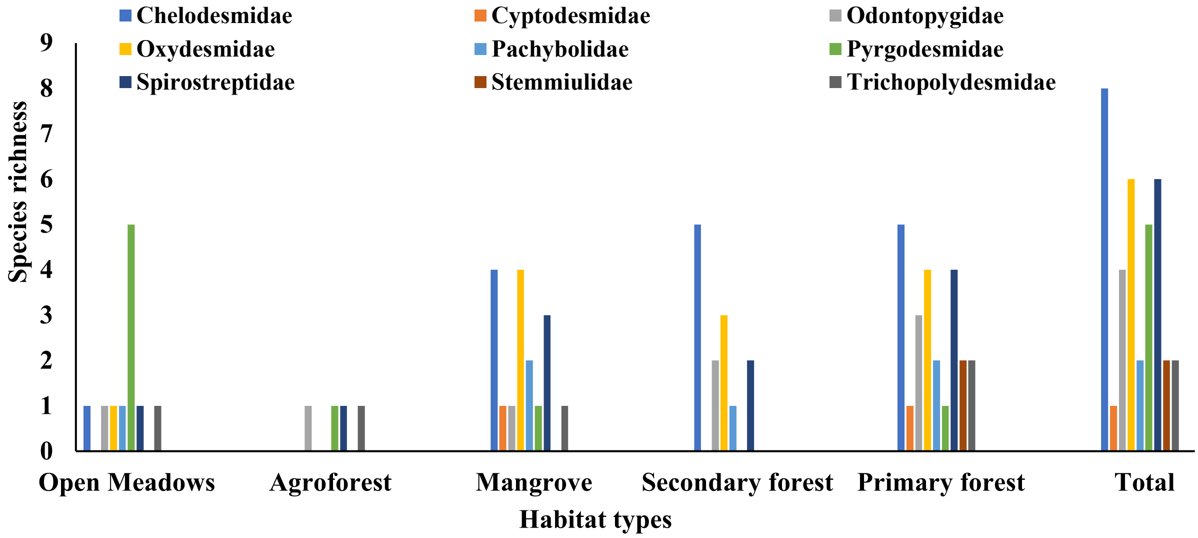

Figure 1. Millipede species richness for the different families between habitat types

Treptogonostreptus intricatus

Paracordyloporus sp.

The individual rarefaction curves were plotted for each habitat type. Species saturation plateaus were approached in the five habitat types. The curves of primary forest, mangrove forest and open meadows showed similar slopes. Besides curves of agroforest and open vegetations were situated faraway below that of primary forest, suggesting very low species richness at these sites compared to the primary forest (Fig. 2).

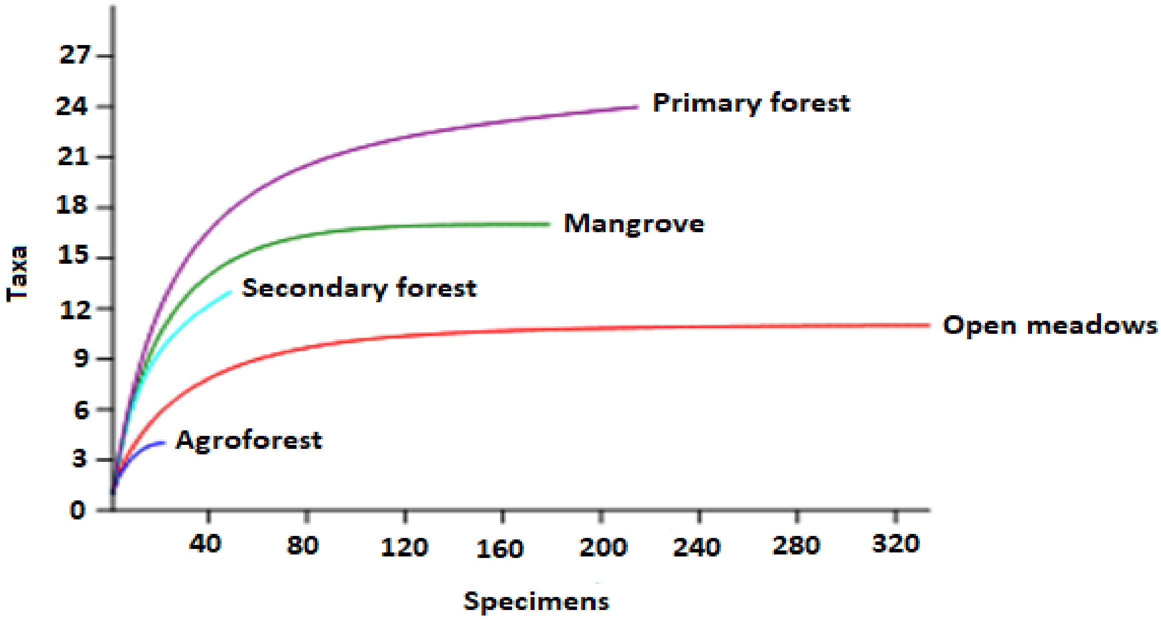

Figure 2. Species rarefaction curve among different habitat types

Kartinikus colonus

Kyphopyge granulosa

Millipede species diversity among habitat types

The primary forest, mangrove and secondary forest showed the highest values of diversity indices (H'= 2.86; E= 0.73 for primary forest; H'= 2.55, E= 0.76 for mangrove and H'= 2.31, E= 0.77 for secondary forest), while the agroforest and open meadows showed the lowest (H'= 0.97, E= 0.66 for agroforest and H'= 1.45, E= 0.39 for open meadows). Pairwise comparisons revealed highly significant differences among habitat types (Table 1). In agroforest, mangrove, secondary forest and primary forest, the Pielou Evenness is near 1, suggesting a very high homogeneity of the communities in those habitat types. Table 2 below also showed in general as well as in primary forest, secondary forest and mangrove, a negligible dominance of a particular species, and thus a very high species diversity of the communities. While in agroforest and open meadow, there is a strong dominance of a particular species, and thus a very low species diversity of the communities. The non-parametric estimator Chao1 revealed that in general, 36 species over 37 have been collected suggesting that only one rare species has not been sampled. Furthermore, in primary forest, 24 species over 26 have been collected suggesting that two rare species have not been collected. In secondary forest, 13 species over 15 have been recorded, suggesting that two rare species have not been collected. Whereas in mangrove, agroforest and open meadows, almost all species have been collected.

Table 1. Diversity indices among habitat types

Habitat types	N	S	Simpson	Shannon-Weaver			Pielou	Margalef	Berger-parker	Chao1
				H'	H' min	H' max				
Open meadows	334	11	0.40	1.45	1.30	1.57	0.39	1.72	0.61	11
Agroforest	22	4	0.50	0.97	0.55	1.23	0.66	0.97	0.68	4
Mangrove	179	17	0.10	2.55	2.40	2.62	0.76	3.08	0.23	17
Sec. forest	49	13	0.12	2.31	2.17	2.42	0.77	3.08	0.16	15
Prim. forest	215	24	0.07	2.86	2.74	2.92	0.73	4.28	0.15	26
Total	**799**	**36**	**0.10**	**2.93**	**2.83**	**2.99**	**0.52**	**5.24**	**0.26**	37

Pairwise comparison of Shannon-Weaver index among habitat types

Open meadows vs Agroforest:	t = 2.937	ddl = 29.789	P<0.001**
Open meadows vs mangrove:	t = -9.963	ddl = 512.65	P<0.0001***
Open meadows vs Sec. forest:	t = -5.576	ddl = 114.59	P<0.0001***
Open meadows vs Prim. forest:	t = -14.289	ddl = 537.65	P<0.0001***
Agroforest vs Mangrove :	t = -7.870	ddl = 26.263	P<0.0001***
Agroforest vs Sec.forest :	t = -6.103	ddl = 35.354	P<0.0001***
Agroforest vs Prim.forest :	t = -9.829	ddl = 25.536	P<0.0001***
Mangrove vs Sec.forest :	t = 2.083	ddl = 82.99	P<0.01*
Mangrove vs Prim.forest :	t = -4.779	ddl = 381.28	P<0.0001***
Sec.forest vs Prim.forest :	t = -5.377	ddl = 77.336	P<0001***

Based on Bray-Curtis distance, the cluster analysis revealed that the secondary forest, the primary forest mangrove and agroforest formed a cluster that was distinct from open meadows (Fig. 3). Moreover, the secondary forest, the primary forest and mangrove also formed a cluster that was distinct from agroforest. However, between both clusters the Bray-Curtis distance is too short suggesting a very weak dissimilarity among habitat types.

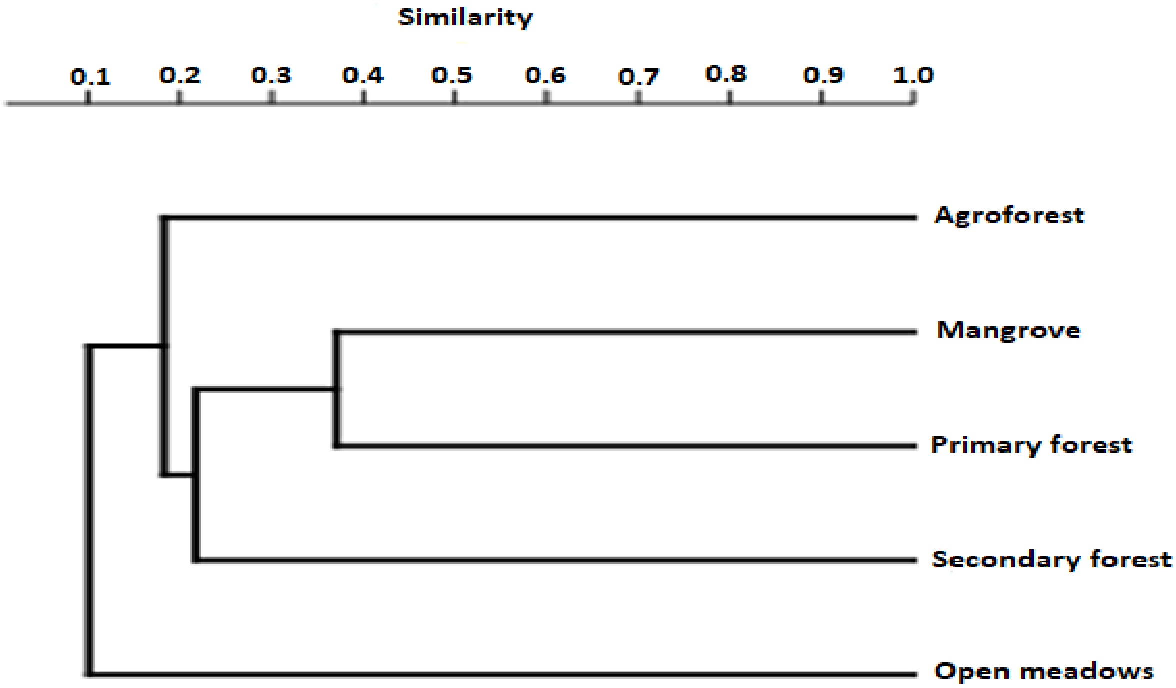

Figure 3. Cluster analysis based on Bray-Curtis distance showing dissimilarity in millipede community

Variation of millipede species abundance among habitat types

Overall, 799 specimens were collected during the study period. The highest millipede abundance was observed in open vegetations (334 specimens, representing 41.80% of all millipedes collected). Next to this habitat were primary forest (215 specimens, representing 26.91% of all the specimens collected) and mangrove forest (179 specimens, representing 22.40% of all the specimens collected). Whereas the secondary forest (49 specimens, representing 6.13% of all specimens collected) and agroforest (22 specimens, representing 2.75% of all specimens collected) showed the lowest millipede abundance. In general, differences of millipede abundance among habitat types were highly significant ($H = 20.05$; $P < 0.0001$).

Three species namely *Trichochalepuncus* sp. (25.91%), *Kartinikus colonus* (9.39%) and *Urodesmus cornutus* (8.01%) were the most abundance during the study period (Table 1). In primary forest, *Kartinikus colonus* 32(4.01%) and *Pelmatojulus tectus* 21(2.63%) were also the most abundant species, while *Paracordyloporus trisolabris, Hemisphaeroparia mouanko, Hemispheroparia integratus* 1(0.13% respectively) and *Spirostreptus pancratius* 2(0.25%) were the less abundant species. In secondary forest, *Systodesmus kribi and Telodeiopus cananiculatus* 8 (1.00% respectively) were the most abundant species while *Coromus* sp., *Paracordyloporus* sp. 1(0.13% respectively), *Kyphopyge granulosa* and *Coromus vitatus* 2 (0.25 respectively) were the less abundant species. In mangrove forest, *Afolabina sanguinicornis* 41 (5.13%) and *Kartinikus colonus* 20 (2.50%) were numerically dominant species while *Kyphopyge granulosa and Systodesmus valdaui* 3(0.38%) respectively, were the less represented species. In agroforest, *Kartinikus colonus* 15 (1.88%) was the numerically abundant species while *Trichochalepuncus* sp. and *Urodesmus cornutus* 2 (0.25%) respectively, were the less abundant species. In open vegetation, *Trichochalepuncus* sp. 204 (25.53%) was numerically dominant species while *Kartinikus colonus* 2 (0.25%) was the less abundant (Table 1).

When considering seasons, the abundance varied with no significant difference between seasons (Table 3). However, millipedes were more abundant during the dry season (11.83±3.53) than during the rainy season (10.36±2.63). Moreover, millipede communities of both dry and rainy seasons varied with highly significant differences among habitat types ($P<0.001$ for the dry season and $P<0.0001$ for the rainy season respectively).

Pelmatojulus tectus

Coromus vitatus

Table 2. Absolute and relative abundance of each millipede species in different habitats in Douala-Edea Wildlife Reserve

Families and Species	Open mead.	Agroforest	Mangrove	Secondary Forest	Primary Forest	TOTAL
Chelodesmidae						
Afolabina sanguinicornis	0	0	41 (5.13)	0	0	41 (5.13)
Diaphorodesmoides sp.	0	0	5 (0.63)	0	0	5 (0.63)
Diaphorodesmus dorcicornis	0	0	0	3 (0.38)	0	3 (0.38)
Kyphopyge granulosa	0	0	3 (0.38)	2 (0.25)	5 (0.63)	10 (1.25)
Kyphopyge sp.	0	0	0	6 (0.75)	16 (2.00)	22 (2.75)
Paracordyloporus porati	6 (0.75)	0	6 (0.75)	7 (0.88)	3 (0.38)	22 (2.75)
Paracordyloporus sp.	0	0	0	1 (0.13)	17 (2.13)	18 (2.25)
Paracordyloporus trisolabris	0	0	0	0	1 (0.13)	1 (0.13)
Cyptodesmidae						
Aporodesmus gabonicus	0	0	17 (2.13)	0	9 (1.13)	26 (3.25)
Odontopygidae						
Coenobothrus bipartitus	0	0	0	0	6 (0.75)	6 (0.75)
Coenobothrus detruncatus	0	0	9 (1.13)	1 (0.13)	4 (0.50)	14 (1.75)
Laciniogonus sp.	0	0	0	0	18 (2.25)	18 (2.25)
Trichochalepuncus sp.	204 (25.53)	2 (0.25)	0	1 (0.13)	0	207(25.91)
Oxydesmidae						
Coromus barumbi	0	0	14 (1.75)	0	0	14 (1.75)

Coromus sp.	9 (1.13)	0	13 (1.63)	1 (0.13)	8 (1.00)	31 (3.88)
Coromus vitatus	0	0	4 (0.50)	2 (0.25)	6 (0.75)	12 (1.50)
Heptadesmus granulosus	0	0	0	0	8 (1.00)	8 (1.00)
Systodesmus kribi	0	0	0	8 (1.00)	0	8 (1.00)
Systodesmus valdaui	0	0	3 (0.38)	0	4 (0.50)	7 (0.88)
Pachybolidae						
Pelmatojulus excisus	0	0	12 (1.50)	3 (0.38)	3 (0.38)	18 (2.25)
Pelmatojulus tectus	18 (2.25)	0	6 (0.75)	0	21 (2.63)	45 (5.63)
Pyrgodesmidae						
Monachodesmus longicaudatus	7 (0.88)	0	0	0	0	7 (0.88)
Monachodesmus sp.1	21(2.63)	0	0	0	0	21 (2.63)
Monachodesmus sp.2	7 (0.88)	0	0	0	0	7 (0.88)
Udodesmus sp.	8 (1.00)	0	0	0	0	8 (1.00)
Urodesmus cornutus	42 (5.26)	2 (0.25)	9 (1.13)	0	11 (1.38)	64 (8.01)
Spirostreptidae						
Kartinikus colonus	2 (0.25)	15 (1.88)	20 (2.50)	6 (0.75)	32 (4.01)	75 (9.39)
Spirostreptus pancratius	0	0	0	0	2 (0.25)	2 (0.25)
Telodeiopus cananiculatus	0	0	7 (0.88)	8 (1.00)	0	15 (1.88)
Treptogonostreptus intricatus	0	0	5 (0.63)	0	0	5 (0.63)
Urotropis carinatus	0	0	0	0	14 (1.75)	14 (1.75)
Urotropis sp.	0	0	0	0	7 (0.88)	7 (0.88)

Stemmiulidae						
Stemmiullus nigricollis	0	0	0	0	13 (1.63)	13 (1.63)
Stemmiullus sp.	0	0	0	0	5 (0.63)	5 (0.63)
Trichopolydesmidae						
Hemisphaeroparia mouanko	10 (1.25)	3 (0.38)	5 (0.63)	0	1 (0.13)	19 (2.38)
Hemispheroparia integratus	0	0	0	0	1 (0.13)	1 (0.13)
TOTAL	**334 (41.80)**	**22 (2.75)**	**179 (22.40)**	**49 (6.13)**	**215 (26.91)**	**799 (100)**

**The number in the bracket represent the relative abundance of the species recorded.*

Table 3. Seasonal variation of Millipede abundance within the Douala-Edea Wildlife Reserve

Seasons	Open Mead.	Agroforest	Mangrove	Sec.forest	Prim.forest	H	P-Value	Mean
Dry	5.50±3.26 0-116 (198)	0.61±0.43 0-15 (22)	2.72±1.07 0-35 (98)	0.36±0.24 0-8 (13)	2.64±0.82 0-21 (95)	10.19	P<0.001	11.83±3.53 0-119 (426)
Rainy	3.78±2.54 0-88 (136)	0	2.25±0.59 0-14 (81)	1.00±0.37 0-8 (36)	3.33±0.81 0-17 (120)	16.69	P<0.0001	10.36±2.63 0-88 (373)
H	1.32	0.657	0.043	1.097	0.472			0.03
P-Value	P>0.05	P<0.01	P>0.05	P>0.05	P>0.05			P>0.05
Mean	9.28±5.73 0-204 (334)	0.61±0.43 0-15 (22)	4.97±1.37 0-41 (179)	1.36±0.41 0-8 (49)	5.97±1.25 0-32 (215)			22.19±5.95 1-207 (799)

H is the value of Kruskal-Wallis test

Species Abundance Distribution (Fig.4)

In general, the millipede community distribution fitted the Preston Lognormal model (m = 1.073; v = 0.24; X^2 = 2.58; P = 0.46). The same trend was observed in open vegetations (m = 1.096; v = 0.29; X^2 = 0.51; P = 0.48). In primary forest as well as in mangrove forest, millipede community distribution fitted the Broken stick model (X^2 = 2.49; P = 1.00 and X^2 = 5.99; P = 0.95 respectively). In secondary forest, millipede community distribution fitted the Motomura model (m = 0.19; X2 = 1.35; P = 0.97). In agroforest, the millipede community distribution fitted the Fisher Log series model (α = 1.43; x = 0.94; X^2 = 1.25; P = 0.26).

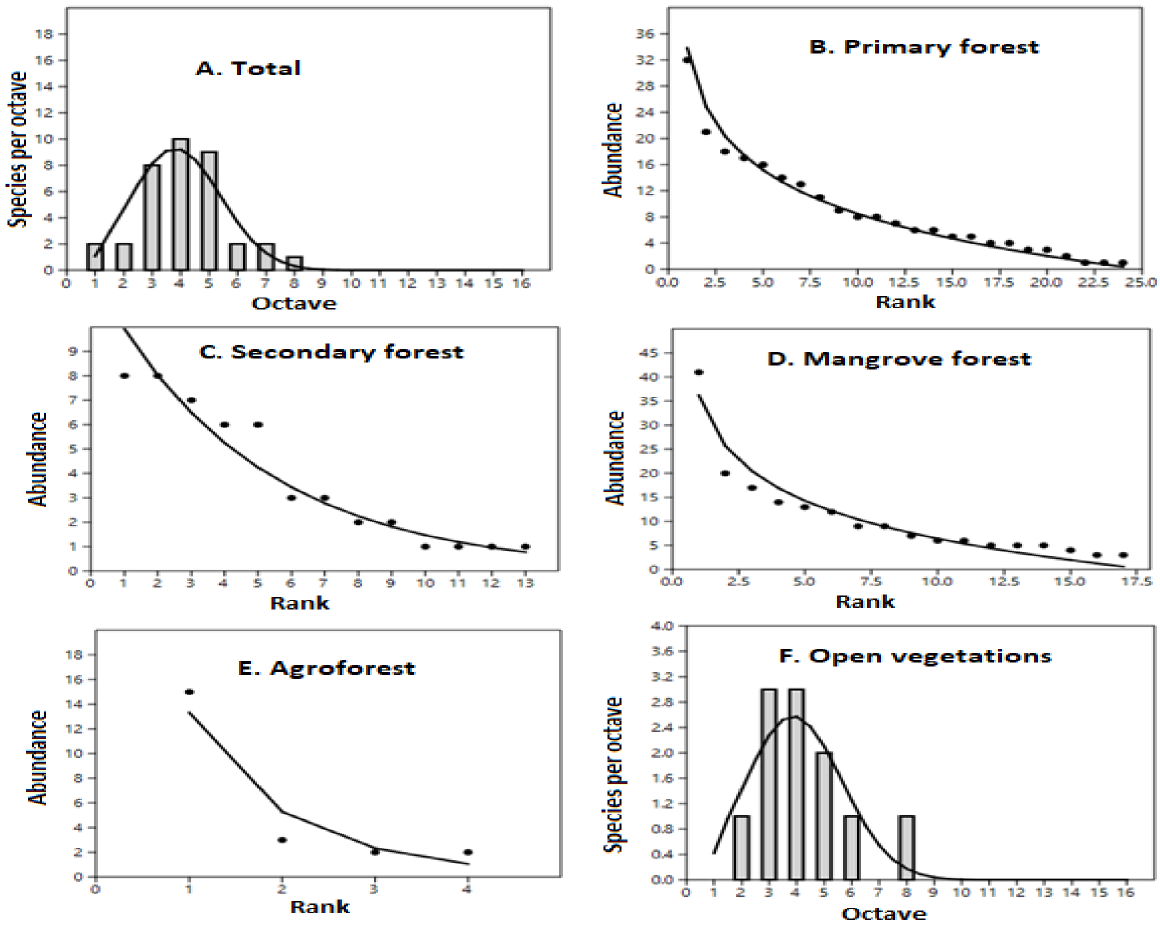

Figure 4. Species Abundance Distribution Model among habitat types in Douala-Edea Wildlife Region

Conservation implication

Habitat fragmentation and transformation are processes that constituted the most important threat to ecosystem-level services. Forest degradation results in soil erosion, and ecological instability due to loss of biodiversity, then of course impacts all forest dependent animal species. The importance of millipedes in soil fertility have long been recognized. In face of strong habitat modification rates in Douala-Edea Wildlife Reserve it is urgent to consider several management strategies to conserve millipede faunas in the area. In this case, strategies of conservation include the protection of forest remnants with the participation of local people and municipal authority in charge of wildlife conservation. This strategy should also include promotion and support of agroforestry and agro-ecological systems based on polycultures compatible with conservation and the inclusion of lengthy fallow periods, and the restoration of degraded lands. Also, long-term monitoring programs of species diversity within reserves and agricultural landscapes are necessary to assess population and community trends, as well as the conservation status of the species and the effects of land-use policies and practices on such status. Such actions could have a crucial positive impact for the conservation of the millipede fauna of Douala-Edea Wildlife Reserve and those of all the littoral forest of Cameroon.

Conclusion

We recorded five main predominant habitats in Douala-Edea wildlife Reserve during this study sheltered diplopoda; there are Primary forests, Secondary forests, Swamp forest (Mangrove), Agroforest and Open meadows. Millipede species were usually collected under leaf litter and dead wood in decompositions. Millipede species are threatened in Douala-Edea wildlife Reserve and the major threats to these species are bushfire, agricultural practices, clear-cuts, cocoa plantations, palm oil and over-use of chemical products. Local people of the Douala-Edea Wildlife reserve known millipede and used them for several purposes. In total we recorded 36 millipede species belonging to 22 genera and 9 families from 799 individuals. The most species rich habitat was primary forest (24 species), followed by mangrove (17 species), secondary forest (13 species), open meadows (11 species), while agroforest was the less species rich habitat (4 species). The cluster analysis base on Bray-Curtis distance revealed that the secondary forest, the primary forest, mangrove and agroforest form a cluster clearly distinct from open meadows. The highest millipede abundance was observed in open vegetations (334 specimens, representing 41.80% of all millipedes collected), suggesting the increasing of abundance of some species with habitat degradation this probably due to the pullulation of invasive pest species such as *Trichochalepuncus* sp. which represent in this habitat 204 over 334 (ca.2/3) specimens recorded during this study. *Trichochalepuncus* sp. is an invasive pest species which mostly colonized cultivated lands. Conservation initiatives must be implemented to protect the endemic and rare millipede species in this study area.

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