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Impact of Habitat on the Development of Coprophagous and Xylophagous Coleopteran Insects in the Park of Bamimgui-Bangoran (Central African Republic)

Lucie Aba-Toumnou [a,b*], Solange Patricia Wango [a], Emmanuel Kamba Mebourou [a,b], Michaël Ngaraboume Temala [a], Jean Mbiko-Tanza [a], Seth Christ Molemba Bombai [a], Vanessa Gloria Rolande Sengue-Mogniabougnade [a] and Serge Florent Bolevane-Ouatinam [a]

[a] *Laboratory of Applied Animal Biology and Biodiversity, University of Bangui, Bangui, Central African Republic.*
[b] *Laboratory of Biological and Agronomical Sciences for Development, Bangui, Central African Republic.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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**Corresponding author: E-mail: toumnou@yahoo.fr;*

ABSTRACT

Coprophagous and Xylophagous Coleopterans are equally impacted by the fragmentation of ecosystems and are recognized for their character as indicators of certain ecosystem functions, such as the recycling of organic matter and pollination. Thus, as part of the program to restore degraded ecosystems in protected areas and others sectors of the Bamingui-Bangoran Prefecture in the Central African Republic (CAR), an inventory of insect species according to their ecological profile is needed. Insects were collected over 8 hectares corresponding to 6 different habitats in the Bamingui-Bangoran park. Sixty different traps were installed in each habitat with 100 meters of distance between the traps. The measured parameters are the number of individuals collected per week. As results, 8 coleopteran families (4 Coprophagous families and 4 Xylophagous families) were identified. The Coprophagous and Xylophagous Coleopterans were much abounded in grassy savannahs with much mixing trees with *Imperata cylindrica* and in grassy and shrubby savannas with many flowering plants (Melliferous) and less abounded in grassy and shrubby savannahs domined by *Imperata cylindrica*. However, repartitions of individuals fit uniform distribution in all coleopteran families belonging to Xylophagous group whereas in Coprophagous, uniform distribution fit was established only for one family.

Keywords: Habitat; ecology profile; insect development.

1. INTRODUCTION

Coleopteran insects are present throughout the terrestrial environment and they reveal a significant capacity for colonization and exploitation of their environment. They also occupy a large diversity of ecological niches (Ferrand et al, 2014) and are able to exploit a wide variety of food resources.

Coprophagous Coleopterans are insects that feed on the excrement of other animals. They play an essential role in the recycling of organic matter, because they are often the cause of the decomposition of excrement. Faeces are used as food for imagoes and larvae. Each Coprophagous Coleopteran generally has a relative trophic preference for a given type of excrement [1]. Indeed, the processes of aeration, mixing and burial of faecal matter by these insects directly stimulate fungi, bacteria, and microarthropods in the soil, whose combined actions are essential for the accomplishment of recycling of faecal matter [2,3].

The Xylophagous Coleopterans are insects that consume woody material during their development cycle. They form a more or less deep gallery inside the wood from the start of the colonization process or after a subcortical phase. These are phytophagous insects that live mostly at the expense of plants [4,5,6]. Xylophagous Coleopterans contribute to diversifying forest ecological niches and they play an important role in forest biological diversity, either directly or via numerous predators. In tropical zones, the Xylophagous Coleopteran species are threatened by clear cutting, forest fires and deforestation [7].

The Coprophagous and Xylophagous Coleopteran are equally impacted by the fragmentation of ecosystems and are recognized for their character as indicators of certain ecosystem functions, such as the recycling of organic matter and pollination [8,9,10].

Thus, as part of the program to restore degraded ecosystems in protected areas and sectors of the Bamingui-Bangoran Prefecture in Central African Republic (CAR), it is important to make an inventory of insects according to their ecological profile.

2. MATERIALS AND METHODS

2.1 Surveyed Site

Covering an area of approximately 86,000 km^2 (Fig. 1) a large part of the Bamingui-Bangoran park is covered by protected areas, classified as World Heritage (including approximately 90% in Bamingui-Bangoran and 60% in Vakaga) while the area occupied by family farming remains negligible. These are National Parks Bamingui-Bangoran and Manovo-Gounda St. Floris, an Integral Nature Reserve (Vassako Bollo), a Wildlife Reserve (Aouk Aouakalé), Sport Hunting Sectors and Areas Village Hunting. The climate of Bamingui-Bangoran is characterized by two distinct seasons and a rainfall of between 800 and 1600 mm (the number of rainy days varying from 95 to 130). The climate is linked to the Sudano-Guinean domain of AUBREVILLE (1949). The Saharan influence of the dry season (North-East harmattan) is opposed to the Guinean influence of the rainy season (South-West monsoon). The study took place between April and June 2017, in the parks of Bamingui-Bangoran.

A total of 8 hectares are delimited and are located respectively at a distance of 10 km in the Bamingui-Bangoran Park. In each hectare, sixty different traps are installed in the park with 100 meters of distance between the traps. Insects were collected from different habitats described in Table 1 from February to April 2017 corresponding to the dry season in the CAR.

2.2 Insect Trapping

For optimal sampling of coleopterans three trapping methods were used.

2.2.1 The barber trap

The Barber trap (Fig. 2a) is the most widely used and standardized method for trapping above ground soils [11,12]. It makes it possible to sample a variety of epigeal auxiliaries (Coleopteran, rove Coleopteran, spiders) and crop pests (slugs, wireworms, flea beetles Coleopteran, sitones). It is an easy to use and very effective method for obtaining specimens that would otherwise be difficult to obtain. To install the trap, simply dig a hole with a small hand shovel like those used for gardening and place the container in the hole.

2.2.2 The yellow bin

Many insects are attracted to the yellow colour [13,14]. Yellow bins (Fig. 2b) half-filled with water dish soap were pushed into the soil, flush with the surface.

2.2.3 The sweet liquid

Flying coleopterans may be found on flowering plants to feed on nectars [15]. In order to trap such insects, a sweet liquid (Foster® juice powder with fruit flavour dissolved in water and made with yellow dye) was poured into the bottom of a jar; the jar was then hung from a support (e.g. tree trunk; Fig. 2c).

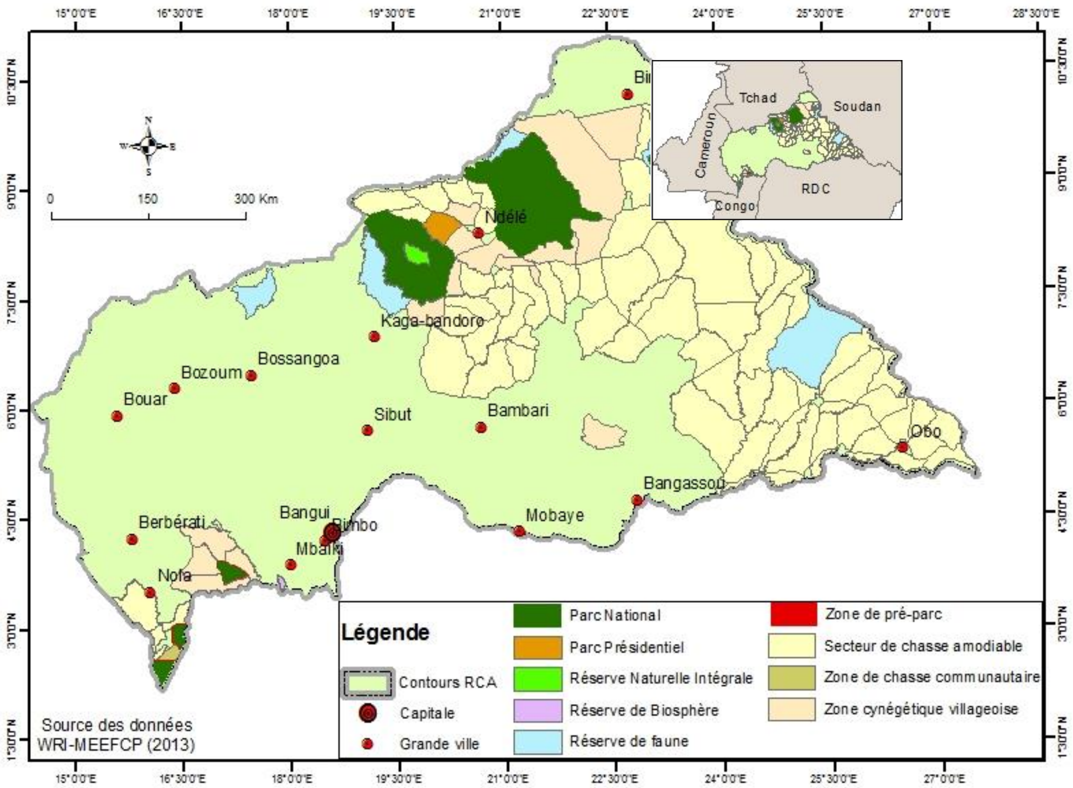

Fig. 1. Location of national northern park of Bamingui-Bangoran (ECOFAUNE, 2017)

2.3 Collection and determination of the families of Coprophagous and Xylophagous Coleopteran

The assessment of the diversity and abundance of insects was carried out by collecting the insects captured in the traps weekly and for six months. Certain characteristics of the insects were determined on the sites using a magnifying glass. The samples were stored in alcohol 70%. In the laboratory, the samples were processed immediately. The samples were washed and cleared of various debris (leaves, twigs, buds, etc.). The insects were sorted in a water tank and distributed by family then repackaged by family. For the most part, identification was based on morphological criteria, the observation of which requires the use of a magnifying glass or a microscope and an identification key.

The Coleoptera are well characterized by their hardened forewings, which have become elytra. This criterion is found in other orders, but what characterizes the Coleoptera (Jeannel in Traite de Zoologie de P. GRASSE) is that the sutural edges of the elytra are juxtaposed without overlapping. The prothorax is often free from the meso and metathorax which join the abdomen quite tightly. If the coxa does not extend to the elytra, and the antennae are placed between the eyes and the mandibles, the insect is of the Carabid family (Carabidae). When the antennae end in lamellae, it is case of Coleoptera of the superfamily Scarabaeoidea. The Bruchids are small insects, usually measuring around 4mm, with some larger species measuring just over 2cm. They are protected by an exoskeleton, and slightly shorter elytra that cover the abdomen, revealing the last abdominal segment (pygidium). They are generally brownish in color, some with more colorful patterns (Jeannelet Paulian, 1944; Balfour-Browne, 1956; Delvare and Aberlenc, 1989; Dajoz, 2002; Ingerson-Mahar, 2002; Bartolozzie and Werner, 2004).

2.4 Data Analysis

The measured parameters are the number of insects collected per week. The comparison of the number of insects according to the habitats was performed using One-Way Analysis of Variances (ANOVA) followed by Tukey's HSD tests in the event of significant differences. Results are expressed as means ± standard deviation. To establish probable trends to equal repartitions over the 6 habitats within a family, uniform distribution fit was performed using Chi-square tests for given probabilities. R software was used for all analyses. The differences are considered significant for $P < 0.05$.

3. RESULTS

3.1 Family Diversity and Abundance of Individuals

We identified 8 coleopteran families, 4 of which belong to the Coprophagous group and the other 4 belong to the Xylophage group. A total of 20562 individuals were collected during the survey period. The most abundant Coprophagous coleopterans belonged to the Cicindelidae family (3848 individuals) followed by the Geotrupidae family (3497 individuals); Aphodiidea and Scarabaeidae families totalized 3191 and 2782 individuals, respectively (Fig. 3). In Xylophagous group, the Tenebrionidae family was the most abundant (2287 individuals) followed by the Buprestidae family (1729 individuals); Scolytidae and Cerambycidae families were represented by 1635 and 1593 individuals, respectively (Fig. 3).

3.2 Repartition of Coprophagous Coleopterans in the Habitats

Globally in all Coprophagous coleopteran families, H6 was the habitat where significantly lower numbers of individuals were recorded (Table 1). The average repartition of insects in the Scarabaeidae family ranged between 40 and 47 individuals in H1 to H5 with no statistical difference ($P>0.05$). The same pattern of the average repartition in the habitats H1 to H5 was recorded in Geotrupidae (47-59 individuals) and in Cicindelidae families (57-61 individuals) with no significant differences ($P>0.05$) within the family. The exception was observed in the Aphodiidae family where the number of individuals in the habitat H3 (Grassy and shrubby savannahs with a few Shea trees) dropped to 41.7±27 but still significantly higher than that recorded in the habitat H6 (Grassy and shrubby savannahs domined by Imperata cylindrical). In spite of the difference in numbers observed for the habitat H6, only the repartition of individuals in the Geotrupidae family follow uniform distribution over the 6 habitats surveyed (X-square = 7.9, df = 5, $P=0.16$; Table 2). This means that even if the number of individuals in the habitat H6 is relatively low, the repartition tends to be the same over the 6 habitats surveyed for the Geotrupidae family. In the other Coprophagous families, the uniform distribution fit test failed ($P<0.05$; Table 2) showing no trend to equal repartition over the 6 habitats.

Table 1. Description of different ecological habitat

Codification of ecological habitat	Description of ecological habitat
H1	Dense to thorny thickets, very difficult to penetrate
H2	Herbaceous stratum domined by *Imperata cylindrica*
H3	Grassy and shrubby savannahs with a few Shea trees
H4	Grassy savannahs with much mixing trees with *Imperata cylindrica*
H5	Grassy and shrubby savannas with many flowering plants (melliferous)
H6	Grassy and shrubby savannahs domined by *Imperata cylindrica*

Fig. 2. (a) the Barber's trap; (b) a yellow bin; (c) a jar containing sweet liquid et (d) conservation of insects in alcohol 70%

3.3 Repartition of Xylophagous Coleopterans in the Habitats

The repartition of Xylophagous Coleopterans in the habitats was different from that observed in Coprophagous in the way that numbers of individuals in the habitat H6 were not statistically different from all the other habitats. Indeed, statistical differences were established only in H5 and H6 (29.4±19.9 and 15.7±2 individuals, respectively; P<0.05) for the Cerambycidae Family and only in H4 and H6 (36.7±10.7 and 25.6±16.2, respectively; P<0.05) for the Tenebrionidae family (Table 1). In the Buprestidae family, the average numbers of individuals in the 6 habitats ranged from 21 to 28 and no significant differences was established (P>0.05). The Scolytidae family was the only one where we recorded a higher number of individuals in the habitat H6 (30±10 individuals) compared to the other habitats (19.9-25.9 individuals). However, uniform distribution fit tests have established trends to equal repartition in all the Xylophagous families (P>0.05; Table 2).

4. DISCUSSION

The present work is the first step to the identification of coleopterans in different habitats existing in the CAR. The National Park of Bamingui-Bangoran is by excellence an ecosystem that bring together all types of biotopes that can be found across the country. Thus, we retained 6 pilot habitats where this study was performed. In Bamingui-Bangoran parc there are dung beetle habitat and resource preferences which is a mosaic of open and wooded patches where domestic (cows and horses) and wild ungulates (deer and wild boar) co-exist.

Trapping tools employed allowed to collected several coleopterans divided into 2 groups (Coprophagous and Xylophagous) over the 6 habitats surveyed. The Coprophagous group was represented by 4 families (Scarabeidae, Geotrupidae, Aphodiidae and Cicindelidae) totalizing 13318 individuals (64.76%). Each of these families are a higher number of individuals compared to families in the Xylophagous group. Although insects were collected during the dry season and only over 3 months (February – April 2017) where mammals and theirs droppings were hard to find, a consistent number of coleopterans, especially Coprophagous ones was collected.

Scarabaeidae were numerically dominant, accounting for 61.5% of the approximately 3000 individuals sampled (Aphodiidae accounted for 32.5% and Geotrupidae for only 6%). However, when species richness was considered, Aphodiidae were dominant, with 17 of the 27 species found (Scarabaeidae with eight and Geotrupidae with two). Assuming a null hypothesis of equal probability of colonizing any habitat or faeces, we found that most species were significantly associated with one of the four dung types or with one of the two habitats considered. On average, Scarabaeidae preferred cattle dung and open habitats whereas most Aphodiidae used deer lumps and wooded habitats [16-23].

According to theses authors (Spector & Ayzama 2003; [24-28] some Scarabaeinae beetles have highly specific habitat preferences, many of them being unable to occupy areas with open vegetation.

This tend to confirm the fact that none of Coprophagous beetles is considered rare species [29].

Barbero et al. [30] found that the Xylophagous group was represented also by 4 families with an abundance of 7244 individuals (35.23%). The low abundance of individuals in the xylophagous group may be explained by the fact that wood is extensively used as source of energy in households and field burns for cropping, thus directly impacts the density of vegetal covert. Indeed, Coprophagous and Xylophagous coleopterans pooled together were much abounded in the habitats H1 – H5 (3590 – 3861 individuals) than in the habitat H6 (1905 individuals) characterized by grassy and shrubby savannahs domined by *Imperata cylindrica*. The plant cover strongly modifies the parameters near the ground, thus influencing the distribution of beetles [31].

The grassy and shrubby savannahs domined by *Imperata cylindrica* of CAR offer grazing mammals varies in nutrient and moisture content according to the condition of the pasture on which the animals feed. Edwards [32], Schroeder et al. [33] investigated the effect of variation in quality of herbivore dung on the survival and reproduction of coprophagous insects. Seasonal variation was recorded in physical and chemical characteristics of zebra, wildebeest and impala dung. Dung was collected from free-ranging animals grazing in natural habitat in Mkuzi Game Reserve, a hot summer-rainfall region of South Africa. Interspecific differences in dung were related to the feeding ecology, digestive physiology and size of each species. Seasonal changes in water and nitrogen content of dung were related to patterns of rainfall and hence pasture growth [34-37]. Dung moisture was significantly correlated with the amount of rain that fell in the preceding 2 weeks for wildebeest, in the preceding 4 weeks for impala and in the period 2-6 weeks before collection for zebra dung. Seasonal variability in wildebeest dung affected the reproductive rate of the dung beetle *Euoniticellus intermedius* [38-42].

The family of Cicindelidae is most abundant H1 in (Dense to thorny thickets, very difficult to penetrate), H2 (herbaceous stratum domined by *Imperata cylindrica*), H3 (Grassy and shrubby savannahs with a few Shea trees) and H4 (Grassy savannahs with much mixing trees with *Imperata cylindrica*).

The Cerambycidae, commonly called beetles or capricorns because of the length of their antennae often exceeding that of the body, are a family of insects of the order Coleoptera [43-46]. Cerambycidae beetles belong to the phytophagoidea superfamily (sensu Jeanne and Paulian, entomologists). Most of the insects of this family are sylvicultural living in dead woods with the exception of a few species living in hot and dry places or even deserts.

Table 2. Statistical comparison of numbers (means ± SD) of Coprophagous and Xylophagous Coleopterans according to the habitats within each family

Different ecological habitat	Coprophagous Coleopterans				Xylophagous Coleopterans				Total of individuals/habitat
	Scarabaeidae	***Geotrupidae***	***Aphodiidae***	***Cicindelidae***	***Cerambycidae***	***Buprestidae***	***Scolytidae***	***Tenebrionidae***	
H1	46±13.2^{a}	47.4±34.2^{a}	46.5±28.3^{ab}	60.4±23.7^{a}	19.7±17.9^{b}	22.6±14.1^{a}	21.6±13.4^{b}	34.9±14.7^{ab}	3590
H2	47.4±15.5^{a}	51.9±33.1^{a}	54.4±25.8^{a}	60.1±17.8^{a}	19.8±18.4^{b}	21.9±12.6^{a}	20.4±1^{b}	31.2±9.1^{ab}	3686
H3	47.2±15.6^{a}	53.1±32.1^{a}	41.7±27^{b}	57.3±23^{a}	24.5±19.3^{ab}	28.8±18.9^{a}	25.9±18.7^{ab}	31.3±17.9^{ab}	3717
H4	40±15.9^{a}	59.3±43.9^{a}	52±23.5^{a}	61.1±22^{a}	23.5±19.5^{ab}	24.4±11.6^{a}	19.9±13.1^{b}	36.7±10.7^{a}	3803
H5	44.4±15.6^{a}	55±38.9^{a}	56.7±24.9^{a}	57.9±20.5^{a}	29.4±19.9^{a}	25.2±2^{a}	22.3±17.3^{ab}	30.9±15.4^{ab}	3861
H6	6.85±2.7^{b}	33.7±30^{b}	21±14.7^{c}	31±17.2^{b}	15.7±2^{b}	21.2±8.7^{a}	30±10^{a}	25.6±16.2^{b}	1905

Means followed by different letters are statistically different (ANOVA followed by the Tukey's HSD test, P<0.05); in bold the biggest means

Table 3. Uniform distribution fit test with the average repartition of individuals within each family over the 6 habitats

	Coprophagous Coleopterans				Xylophagous Coleopterans			
Statistical parameters	***Scarabaeidae***	***Geotrupidae***	***Aphodiidae***	***Cicindelidae***	***Cerambycidae***	***Buprestidae***	***Scolytidae***	***Tenebrionidae***
Chi-square value	32.3	7.9	19	12.4	5	1.6	3.25	2.3
P-value	5.10^{-6}	*0.16*	0.002	0.03	*0.41*	*0.9*	*0.66*	*0.8*

P-values in bold are superior to 0.5 indicating a trend to an equal repartition of individuals over the 6 habitats within the family

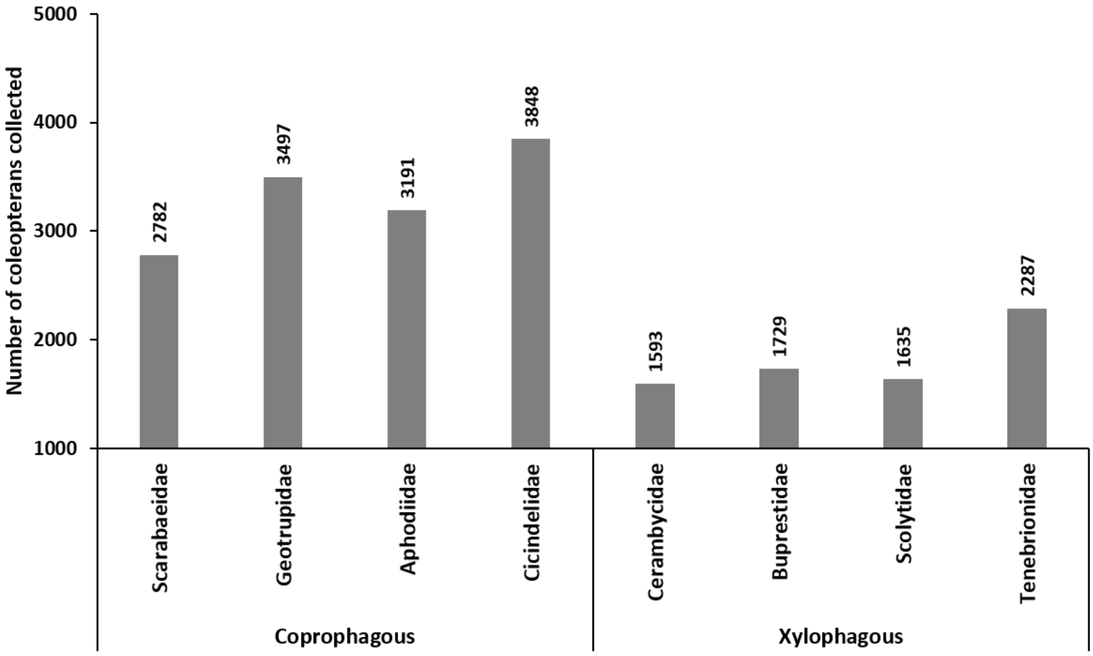

Fig. 3. Abundance of coprophagous and xylophagous coleopterans collected over the 6 months of survey

The Scolytidae family According to Benhalima (2006), this family is composed of xylophagous species and is placed at the forefront of the natural enemies of coniferous forests, and is responsible for 90% of the damage caused.

5. CONCLUSION

The cluster analysis showed that the herbaceous stratum domined by *Imperata cylindrica* and the grassy and shrubby savannahs with a few Shea trees are the most similar in relation to species composition and abundance, yet different from the Dense to thorny thickets, very difficult to penetrate with herbaceous stratum domined by *Imperata cylindrica* and the Grassy and shrubby savannahs with a few Shea trees.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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