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ARTICLE

Impact of Beekeeping on the Wild Bee Diversity in Northern Ivory Coast (West Africa)

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ABSTRACT

In Ivory Coast, beekeeping takes an important place among the major economic activities. It contributes to improving the population's livelihoods thanks to its derived products which are honey, propolis, wax and royal jelly. However, the installation of honey bee hives could put pressure on wild bee species, which often live solitary. However, these wild bees are excellent pollinators of cultivated and wild plants. The study aimed to assess the effect of honey bee hives on the diversity of wild bees. The methodology approach consisted of capturing bees in three different plots inside the forest fragment of the botanical garden located at the University Peleforo Gon Coulibaly. The first plot was chosen approximately from 10 m to an apiary containing ten hives. The two other plots were chosen to be 200 m and 400 m from the apiary, respectively. Bees were captured once a month for three months using pan traps (UV—blue, yellow and white). A total of 17 bee species belonging to three families (Apidae, Megachilidae and Halictidae) were identified. The furthest plot from the apiary was the most diverse (H' = 2.49) and that near the apiary was the least diverse (H' = 0.11). Only, two wild bee species, *Hypotrigona* sp. and *Thrinchostoma petersi*, persisted inside the plot nearby the apiary where honey bees were most abundant. The furthest plots from the apiary seem to have the highest diversity of wild bees. These findings are very relevant because they can be used for the policies of conservation of wild bees and the management of beekeeping activities.

Keywords: Honey bee; Apiary; Hive; Conservation; Korhogo

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1. Introduction

Nearly 87.5% of angiosperms (flowering plants) require pollination for their reproduction [1]. Globally, pollination contributes to increasing crop yields by 5 to 8% [2]. Pollinating insects include beetles, butterflies, moths, and true flies, but it is primarily bees that are responsible for pollination [3]. Indeed, the morphology of bees (presence of branched hairs on the body), their diet consisting essentially of nectar and pollen and their foraging behavior (fidelity to a plant species during a trip) make them pollen vectors particularly effective and precise [4]. The mutualism (mutually beneficial relationship) that links bees to flowers has led to the co-evolution and the diversity of species that we know today [5]. More than 20,000 bee species worldwide contribute to the survival and evolution of more than 80% of plant species [4]. However, even if the honey bee Apis mellifera is traditionally used to massively pollinate crops, wild bees remain essential to pollinate many wild and cultivated plants [6]. Indeed, honey bees can excessively deposit pollen seeds on the stigma which can reduce the germination power of pollen seeds and create competition in the pollen tubes growth due to the diversity of pollen seeds [7]. As a result, wild bees are generally more active than honey bees. They pollinate earlier from March, during lower temperatures and, easily disperse collected pollen from other flowers because most do not have a "pollen basket". Although many bee species are able to travel more than one kilometer, their foraging radius is generally limited from 100 to 300 m for the small species and from 400 to 800 m for the large species. However, around 30% of bee colonies die each year and a decline in the richness of wild bees is observed in Europe and the North America [8,9]. Several studies have appeared to question the installation of bee hives in both urban and non-urban environments. Indeed, the colonies of bees would be detrimental to other pollinators [10–12]. The latter would take food resources from their wild cousins. Several studies demonstrate a competitive effect exerted by honey bees on wild bees in these environments, pushing some naturalists to call for the end of hives installation in several natural areas [13]. Our preliminary study aimed to assess the effect of honey bee hives on the diversity of wild bees in order to protect them in a beekeeping area. Specifically, it consisted (i) to determine the diversity of wild bees following a gradient of hives installation; (ii) to compare the specific composition of wild bees along this gradient and, (iii) to identify the most vulnerable wild bee species.

2. Material and methods

2.1 Study site

This study was carried out in Korhogo (9°26’47.06” LN; 5°38’40.74” LW) in northern Ivory Coast. The sampling plots were chosen inside a forest fragment (approximately 19.74 ha) located to the botanical garden of the university Peleforo Gon Coulibaly (**Figure 1**). Developed since 2007, it presents a heterogeneity of vegetation made up of grasses and shrubs. In certain places, it possible to encounter dead wood. The litter, moderately thick, is mainly composed of leaves from dead trees. This forest fragment has a thin and sparse canopy. There are several woody species among which, *Tectona grandis* (Lamiaceae), *Gmelina arborea* (Verbenaceae), *Parkia biglobosa* (Fabaceae-Mimosoideae) and *Vitellaria Paradoxa* (Sapotaceae) are the most abundant. Inside the forest fragment there is an apiary composed of ten hives. Three sampling plots were chosen taking into account the apiary location. The first plot was chosen nearby the apiary (approximatively 10 m). The other plots were chosen at 200 m and 400 m from the apiary, respectively. Each sampling plot consisted of four transects, each comprising six traps. In total, 24 traps were installed on each plot (72 traps for all sampling plots). The distance between two consecutive traps was 10 m and it was 15 m between two transects.

2.2 Capture and identification of bees

Bees were captured for three months using pan

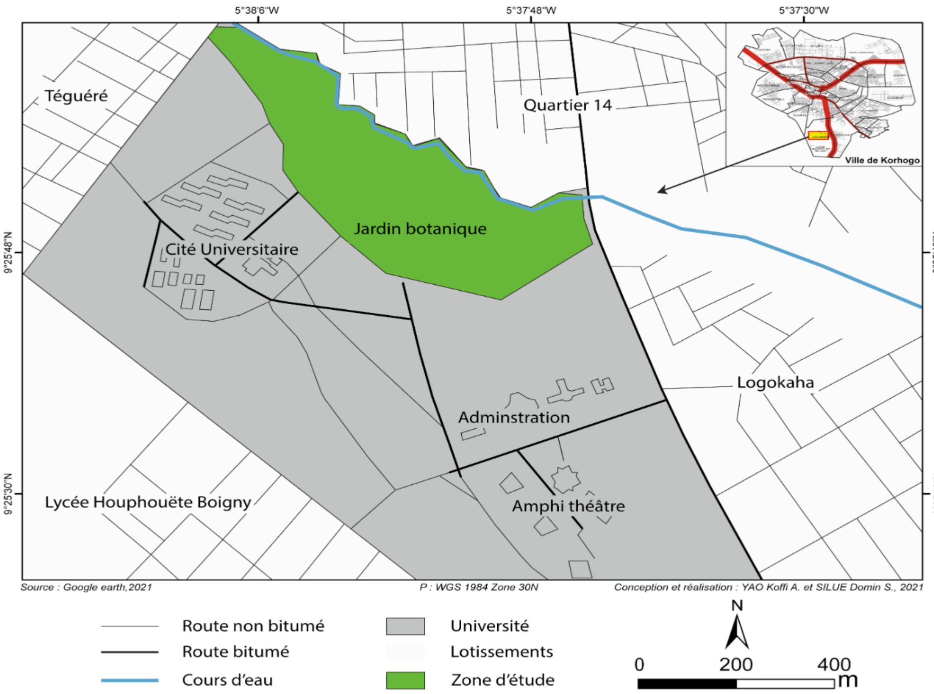

Figure 1. Location of the study site.

traps. Bee sampling was carried out once a month on each plot, simultaneously. Each pan trap consisted of one UV-bright yellow, white and blue 500 ml plastic bowl that was filled with salt (NaCl) saturated water and a small drop of detergent. The traps were left activated for 72 hr during each sampling turn. Specimens of bees were collected, stored in ethyl alcohol (70%), and thereafter pinned and identified to genus or species if possible [14]. Bees were identified in the laboratory of "Pôle Scientifique et d'Innovation de l'Université Félix Houphouët-Boigny" of Bingerville using a binocular glass, a reference collection of West African bees and some keys of identification [15].

2.3 Data analysis

The species richness and the relative abundance of bees were calculated. "Shannon" entropy ($H = -\Sigma ((Ni/N) * \log2 (Ni/N))$ and Pielou's species evenness ($E = H/H'max$ with $H'max = Log2S$)) were used to assess diversity components of bee species communities found in the three plots. The Jaccard similarity index ($J = Nc/(N1 + N2 + Nc)$) was used to compare the specific composition of bees between the different plots.

3. Results

3.1 Taxonomic richness

Overall richness: In total, 17 bee species belonging to 16 genera and three families (Apidae, Megachilidae and Halictidae) were caught during the study. Apidae (7 species) were the most diverse family, followed by Halictidae (6 species) and Megachilidae (4 species) (**Figure 2**).

Richness per plot: Three bee species *Apis mellifera, Hypotrigona* sp. and *Thrinchostoma petersi*, belonging to three genera and two families (Apidae and Halictidae) were recorded in the plot near the apiary (**Figure 2**). We recorded seven bee species belonging to seven genera and two families (Apidae and Halictidae) in the intermediate plot located 200 m from the apiary. The richness of bees in this plot was relatively higher than that of the plot near the apiary (**Figure 2**). In the furthest plot located 400 m from the apiary, we recorded 14 bee species belonging to 14 genera and three families (Apidae, Halictidae and Megachilidae). The richness of bees in this plot was highest compared to that on the other plots. This latter is the single plot where three families of bees were recorded (**Figure 2**).

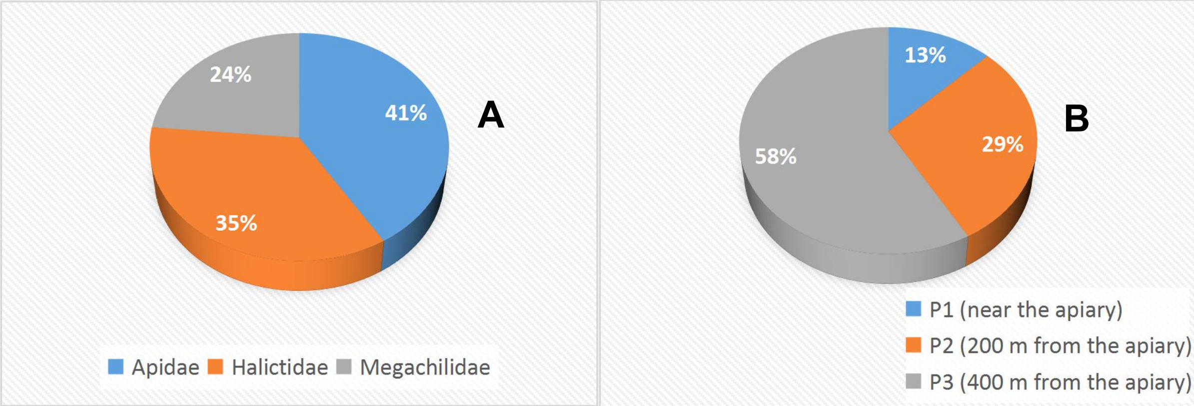

Figure 2. Proportion of bee richness by family (A) and by plot (B).

3.2 Relative abundance

Overall relative abundance: In total, 147 specimens of bees belonging to three families (Apidae, Halictidae and Megachilidae) were caught during the study. Apidae (128 specimens) were the most abundant family representing 87.07% of all specimens, followed by Halictidae (15 specimens; 10.20%) and Megachilidae (4 specimens; 2.72%) (**Figure 3**). At the specific level, honey bees (116 specimens) were the most abundant species. It represented 78.91% of all specimens.

Relative abundance per plot: We recorded 101 specimens of bees (approximately 68.70%) in the plot near the apiary (**Figure 3**). Apidae (99% of bee specimens) were the most abundant family. Concerning the species, honey bees (98.02%) were the most abundant. In the intermediate plot, we recorded 23 specimens of bees (approximately 15.65%) (**Figure 3**). Apidae (86.96% of bee specimens) were also the most abundant family. Concerning the species, honey bees (56.52%) were also the most abundant, followed by the wild bee species *Hypotrigona gribodoi* (21.74% of bee specimens). We recorded the same abundance (23 specimens; 15.65%) in the furthest and the intermediate plots from the apiary (**Figure 3**). Halictidae were the most abundant family with 47.83% of bee specimens, followed by Apidae (34.78%) and Megachilidae (17.39%). Concerning the species, we recorded approximately the same abundance for all bee species. However, we recorded the highest relative abundances to the honey bee *Apis mellifera* (17.39%), and the wild bees *Lipotriches* sp. (13.04%) and *Pseudapis interstitinervis* (13.04%).

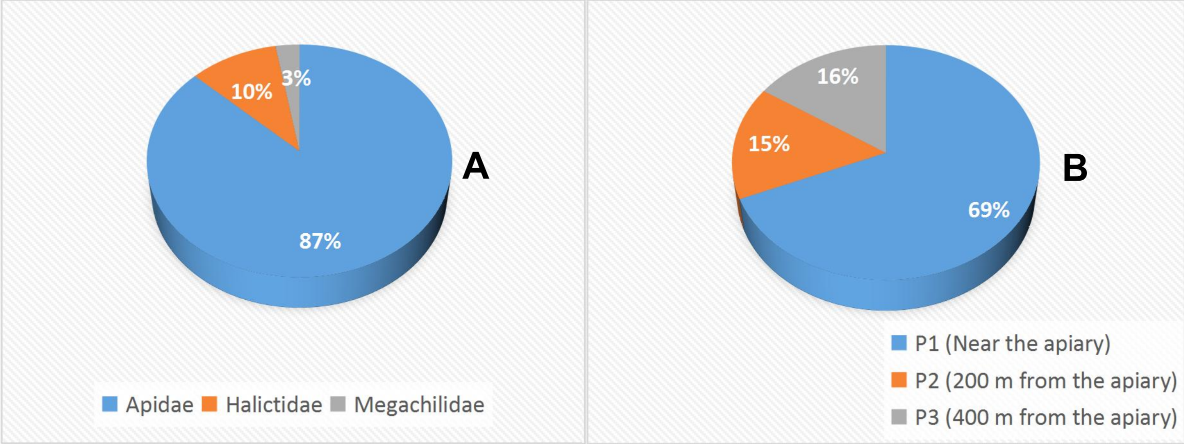

Figure 3. Proportion of bee abundance by family (A) and by plot (B).

3.3 Analyses of diversity

Shannon index values differed highly from one plot to another. These indices showed that the furthest plot from the apiary was the most diverse (H' = 2.49) (**Table 1**). In fact, the more we moved away from apiary, the more bee diversity was high. Pielou's species evenness was maximum for the furthest plot from the apiary (E = 0.94) compared to the other plots. That means a good distribution of the abundance of bee species in the furthest plot from the apiary. On the other hand, Pielou's species evenness was lower for the plot near the apiary (E = 0.10) (**Table 1**).

Table 1. Diversity measurements.

Plots	P1	P2	P3
Shannon (H')	0.11	1.34	2.49
Pielou's species evenness	0.10	0.69	0.94

Note: P1: close to the apiary; P2: 200 m from apiary; P3: 400 m from apiary.

3.4 Specific composition of bees in the sampling plots

According to the Jaccard indices, the specific composition of bees on the three plots was almost similar. However, the plot near the apiary was less similar to the other two plots. Likewise, the intermediate and the furthest plots from the apiary were strongly similar (**Table 2**).

Table 2. Similarity indices.

Plots	P1	P2	P3
P1	1		
P2	0.76	1	
P3	0.52	0.80	1

Note: P1: near the apiary; P2: 200 m from apiary; P3: 400 m from apiary.

Honeybees were the single species encountered in the three plots. Apart from honey bees, no other species were common to the plot near the apiary and the intermediate plot. However, apart from honey bees, there is a wild bee species Thrinchostoma petersi, common to the nearby and the furthest plots from the apiary. There were also, apart from honey bees, four wild bee species common to the intermediate and the furthest plots from the apiary which were *Amegilla* sp., *Lipotriches* sp., *Halictus* sp. and *Pseudapis interstitinervis* (**Table 3**).

Table 3. Specific composition of bees.

Family	Species	P1	P2	P3
Apidae	*Apis mellifera*	X	X	X
	Amegilla sp.		X	X
	Meliponula sp.		X	
	Dactylurina staudingeri			X
	Hypotrigona sp.	X		
	Hypotrigona gribodoi		X	
	Xylocopa olivacea			X
Megachilidae	*Heriades* sp.			X
	Creightonella discolor			X
	Lithurgus sp.			X
	Megachile sp.			X
Halictidae	*Thrinchostoma petersi*	X		X
	Lipotriches sp.		X	X
	Halictus sp.		X	X
	Leuconomia granulata			X
	Pachynomia atrinervis			X
	Pseudapis interstitinervis		X	X

Note: P1: near the apiary; P2: 200 m from apiary; P3: 400 m from apiary.

4. Discussion

In our study, Apidae were the most abundant family, probably because, they include solitary, social and very social species [16]. This social character could explain their abundance. The same results were reported by Coulibaly in Burkina Faso [15]. He found that Apidae were the most abundant family in all study sites in the south of Burkina Faso. The honey bee *Apis mellifera* was more abundant in the plot near the apiary. That seems obvious because of the strong colonies of *Apis mellifer*a inside the hives. Indeed, the colonies of honey bees in an environment could lead to competition with wild bee species when searching for food [13]. The honey bees being naturally more aggressive, would cause the dispersion of wild species far from the apiary. In fact, if honey bees have the same range of diets as wild bees, they can push aside or even exclude the latter by exploiting pollen and nectar more efficiently. Wild individuals then struggle to harvest resources and must potentially travel longer distances or exploit less nutritious or less accessible resources, which can affect reproduction due to a lack of reserves for larvae [17]. From then on, we understand why the plot close to the apiary is the least rich in wild bee species. The same results were reported by Geslin et al. [18] which revealed that the introduction of honey bees in the environment could generate competition phenomena by reducing the frequency of plant visits and leading to changes in the choice of visited flowers by the wild bees. In addition, it appears that the trade of bee colonies can convey exotic parasites and pathogens which can affect the wild bees [19]. Natural bee parasites play an important role in the population dynamics of their hosts. However, the introduction of unknown parasites has more significant effects on wild bees which then present too little resistance [20]. However, it seems that small bees are subject to less pressure from the honey bees. This is confirmed in the plot near the apiary, by the presence of the two species *Hypotrigona* sp., and *Thrinchostoma petersi* which are smaller in size than the honey bees. With the distance from the apiary, the intermediate and the plot furthest from the apiary are respectively richer in bee species. This could be explained by the fact that by moving away from the apiary, we reduce the effect of competition thanks to a drop in the population of honey bees. Also, bee richness in the distant plot could be due to the fact that very few activities take place around this plot compared to the two others. A diverse bee community requires a good possible diversity of nesting and foraging resources, and this is in a landscape where the mobility and dispersal of individuals is easy [21]. Indeed, a greater floral diversity generates a greater diversity of bees because the offer is adapted to a greater number of bee species. In addition, the resource of nesting sites would also be an important element concerning the structuring of bee communities [22].

5. Conclusions

Despite a potential co-evolution between wild bees and honey bees in Africa, competition may arise following the breeding of honey bees in beekeeping. This competition may be due to the distribution and availability of food resources (melliferous plants). The findings showed that the diversity of wild bees increased when we moved away from the hives. The honey bees, although encountered in all plots, remain more abundant in the apiary. Its presence severely affects the proliferation of other wild bee species. This study was carried out in a small landscape matrix and in a site where beekeeping is not widely practiced. However, the findings encourage us to target sites where beekeeping activity is more intense and permanent. The findings are very relevant because they can contribute to improving the policies of conservation for wild bee communities.

Authors' Contributions

DC and YT designed the study. DC and KS collected data in the field. DC determined insect specimens and their traits. DC and KS analyzed and plotted output data. DC wrote the first draft of the manuscript. MK, and KHK contributed to improve the draft. All authors contributed substantially to revisions.

Conflict of Interest

None declared.

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