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A comparative study of the Coleoptera biodiversity of three areas of the Gharb plain: The biological reserve of Sidi Boughaba, the Mamora forest and the merja of fourarat

Mostafa Slim, Najoua Zouaki and Mohamed Fadli

Abstract

The present work was dealt with the faunistic study of the spatial distribution of the Coleoptera population of three areas of the Gharb plain: the Mamora forest, the biological reserve of Sidi Boughaba and the Merja of Fouarat. The entomological population was dominated by the family Scarabaeidae which was the most represented and well adapted to different climatic conditions. The family Tenebrionidae which was the second of the most speciose groups of Coleoptera was principally sabulicolous. The species richness and abundance of Coleoptera in different types of habitats (The Mamora forest, the biological reserve of Sidi Boughaba and the Merja of Fouarat) and their relationship with the environment were discussed. A total of 999 Coleoptera belonging to 11 families and 28 species were collected. Thus, an analysis of similarity of the site which was based on species richness showed a spatial variation. Then, the Shannon-Wiener diversity index and the indices of regularity were calculated. The most abundant taxa were based on the *Scarabaeus cicatricosus*, *Tentyria marroccana*, *Calathus melanocephalus*, *Buprestis octoguttata*, *Akis tingitana*, *Carabus sp.*, *Aethiessa floralis* and the *Scarabaeus cicatricosus*. More importantly, the hierarchical classification highlighted faunal affinities between sites which revealed two main groups. Also, the temperature, the precipitations, the soil organic matter content, and the nature of vegetation appeared to be the major drivers that structure the Coleoptera assemblages and influence the abundance as well as the species richness. These results suggested that the habitat heterogeneity was the predictor of the Coleoptera assemblages, but the species richness could be predicted at the landscape scale using the abiotic characteristics.

Keywords: coleoptera, diversity, distribution, mamora forest, biological reserve of sidi boughaba

1. Introduction

The Coleoptera form a numerically important group of insects. This order, the richest in species on earth and form is considered as the major element of the wildlife biodiversity of many researchers. Among the authors who studied the Coleoptera in Europe: Ponel ^[1] studied the Coleoptera of the Maures Massif and the peripheral permian depression (France), Valladares *et al.*, ^[2] studied the aquatic communities of the La Nava Lagoon of Spain, Soldati ^[3] has compared the terricolous Coleoptera of four natural formations of the Northern France and Carron *et al.*, ^[4] were interested in the aquatic Coleoptera of some ponds of Ajoie.

For the African Coleoptera fauna, among the first authors who were interested, we find Bedel ^[5] who made a partial catalog of the Coleoptera of North Africa (Morocco, Algeria, Tunisia and Tripolitania), then Peyerimhoff ^[6, 7, 8, 9, 10, 11, 12, 13] who has presented numerous studies on the systematic of the Coleoptera in North Africa.

In Morocco, as in Algeria and Tunisia, the Colopopean population is a group of insects that is systematically and numerically very present among the entomological fauna of diverse environments. However, the majority of the work devoted to the study of this population was initially limited to establishing the systematic and geographical distribution of the different cataloged species. Thus, we quote the works of Alluaude ^[14], Peyerimhoff ^[10, 11, 12, 13], Antoine ^[15, 16, 17, 18, 19, 20, 21], Raymond ^[22], Kocher ^[23, 24, 25, 26], Pierre ^[27].

In the Gharb plain, a geographical area located in the north-west of Morocco, the studies carried out on the Coleoptera faun were a few compared to the other zoo-geographical areas of Morocco. Furthermore, the aim of the present study was to analyze the diversity and the biogeography of Coleoptera of the three study areas or "ecosystems" of this plain and to

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determine some environmental variables involved in the distribution of the Coleoptera.

2. Materials and Methods

The study was only limited to the spatial evolution of the harvested population during the period of adult activity (April-June, 2015), period during which the majority of the Coleoptera species was appeared.

2.1. Area 1.

The biological reserve of Sidi Boughaba, whose coordinates are 34° 15 'N - 06° 39' W, is situated in the Atlantic Coast of northwestern Morocco, oriented NNE-SSW and located in an inter-dune depression [28] (Figure 1). The collection site surrounds a wetland, the lake of Sidi Boughaba, covers an area of 600 hectares.

2.1.1. The terrestrial vegetation covering the slopes of Merja

The Merja of Sidi Boughaba (Figure 1). is one of the few coastal wetlands whose periphery is forested. Apart from a Eucalyptus plantation situated on the N-E shore, the rest of the vegetation is spontaneous. It is a beautiful Juniperia which is very dense and hard to penetrate particularly on the west shore, in the East it is often degraded, making way for a matorral *Retama monosperma* or even *chamaerops humilis*.

In addition to this, we find that there are other species for most Ornithochore: *Phillyrea angustifolia* and *Ephedra fragilis*, the herbaceous stratum of sciaphile and nitrophilic character include among others, *Mercurialis annua* and *Parietaria mauritanica*. In the voids, as in the degraded areas,

the flora is different and it comprises *Retama monosperma* and *Trisetaria panica* [29].

2.1.2. The hygrophilous vegetation of the borders of Merja

At the edge of the Merja, in the area alternately emerged and submerged according to the seasons, there is a bung of vegetation of variable width formed of the large Cyperaceae and Juncaceae which surrounds the shores in a way almost continuous. It is constituted of tufts more or less spaced from the mixed *Juncus actus*. The Phragmite is present, but rare. This formation is better developed at the northern end that it covers entirely as well as on the east shore because of its gentle slope. Behind these elements, an area at the *Cyperus laevigatus*, then at the *Panicum repens*, takes a certain extension on the shore and forms a real wet meadow.

On the highlands of the profound south party, the Typha (*Typha angustifolia*) settles in the company of some of the previous Cyperaceae and Juncaceae as well as Phragmites (*Phragmites communis*). There is also *Iris pseudocarus*, but it is very localized to the N-E of this area. All the elements of the vegetation do not appear a priori arranged according to a regular zonation [29].

Some beaches of vases that discover at the beginning of the summer season, develops a temporary vegetation of annual Chenopodiaceae, submerged in the autumn by the rising waters. In the following spring, the more or less decomposed remains of these plants are largely used by the crested Grebe and the Stilts for the making of their nests.

What is more, the S-E border of the Merja is occupied by a hygrophilous matorral with *Populus alba*, to which a Tamarix is associated.

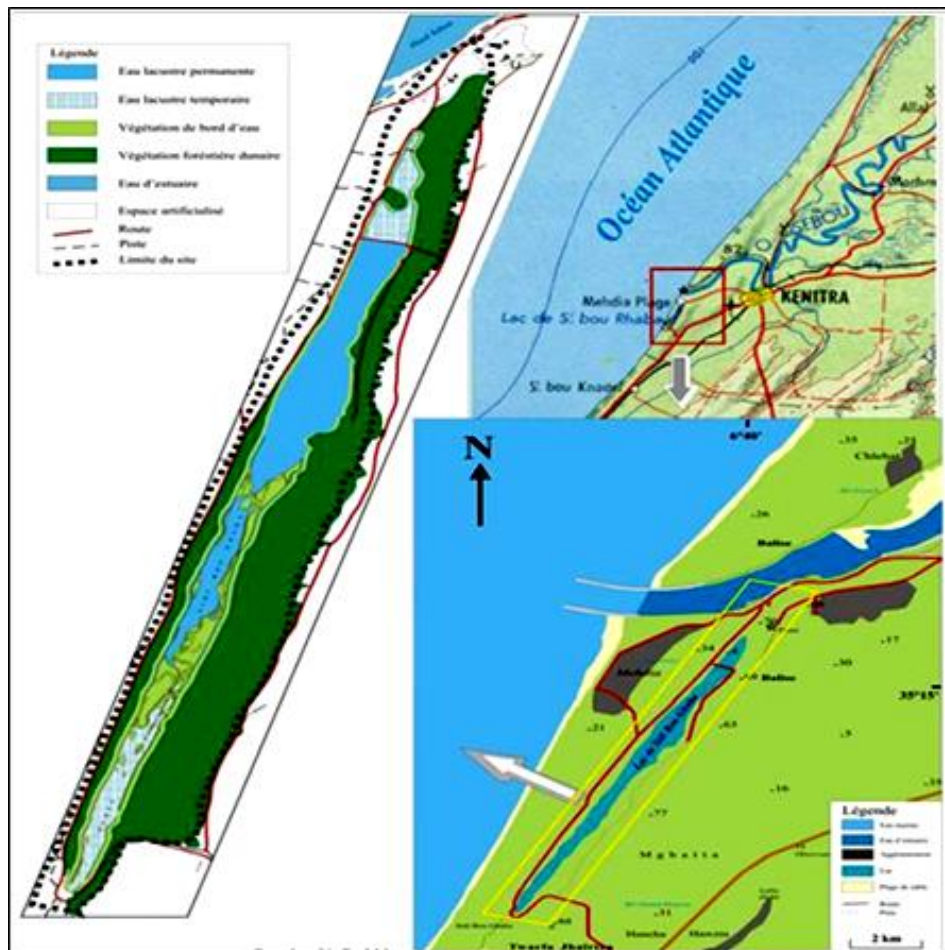


Fig 1: Location of the biological reserve of Sidi Boughaba.

2.2. Area 2

About 60 km long and 30 km wide, the Mamora forest (Figure 2) is located in northwestern of Morocco, bordering the Atlantic Ocean, between meridians 6° and 6° 45' west, and parallels 34° and 34° 20' north [30].

In the cork-oak ecosystem of the Mamora forest, Metro and Sauvage [31] distinguished two main plant formations: The forest of cork-oak or suberie, which is considered as the

most important plants, is exclusively situated on the sands more or less deep of the Mamora. The dominant arboreal element of this suberie is almost only the cork-oak. But, locally, we can note the eucalyptus, conifers and acacias of the quite extensive areas that are deprived of any undergrowth and offered only a rather poor herbaceous carpet and characterized most often by the abundance of the bulbous plants.

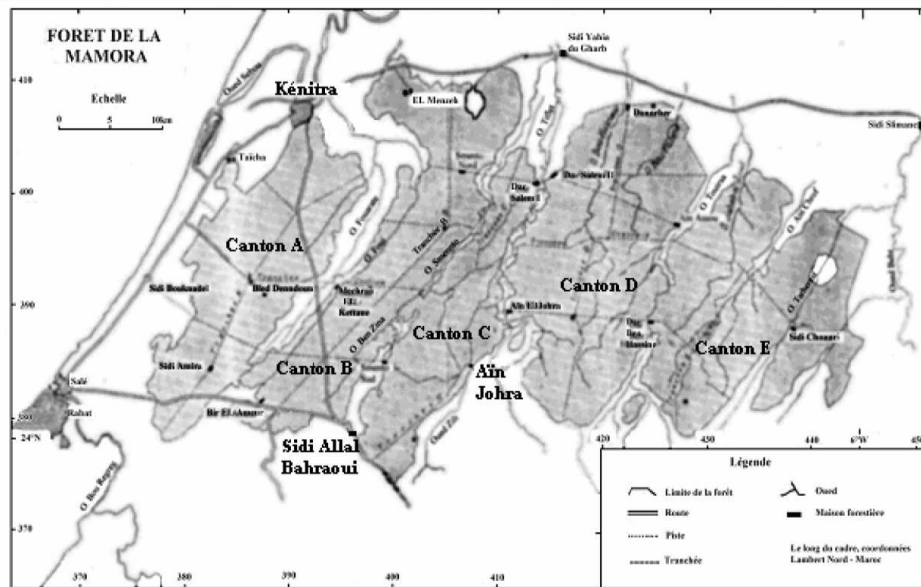


Fig 2: Location of Mamora forest

2.3. Area 3

The Merja of Fouarat (Figure 3), the wet area of Kenitra city, is located in the northwestern of Morocco, at the southwestern end of the coastal plain of Gharb, on the course of the Oued of Fouarat, a small tributary of the terminal course of the Oued

of Sebou [32]. The vegetation is marked by herbaceous and algal plants. This site is located near an industrial area characterized by the massive discharges of liquid and solid waste.

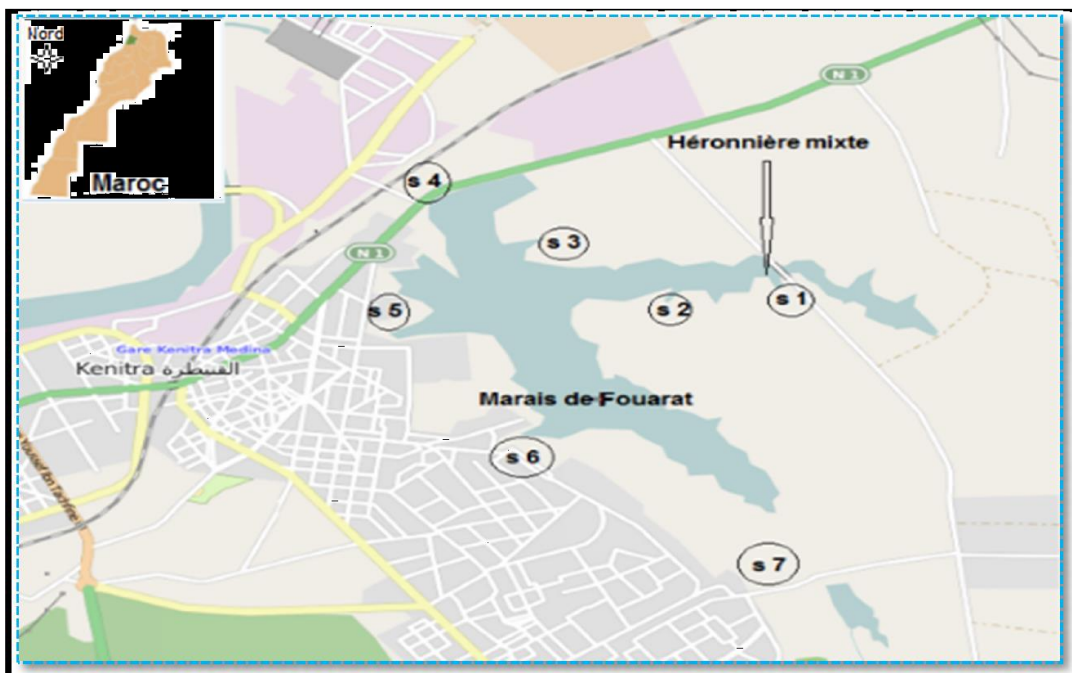


Fig 3: Location of Merja of Fouarat

Moreover, the collection of Coleoptera fauna was collected in the harvested sites located in the three study areas during 2015. The Coleoptera were sampled with the help of the net

fauchoir, sight hunting and Barber pots for the biological reserve of Sidi Boughaba. Besides, the captured specimens were prepared, labeled and identified by the Professor

Mohamed Fadli at the Laboratory of Health, Nutrition and Environment, Faculty of Sciences of Kenitra, University Ibn Tofail (Morocco).

The collected data are entered in Excel and then transferred to a software support designed for the statistical analysis. Several indices were calculated for each site in order to evaluate the following Coleoptera assemblages: abundance (N), species richness (number of species: S), richness of families (number of families), diversity (the Shannon-Weiner index H (Pi Log₂ Pi)) and the equitability E. The rarefaction curves explaining the dominance and richness of the three areas to find the diversity profile of the study areas.

3. Results

3.1. Taxonomic inventory

The list of Coleoptera species collected in the three study areas is given in the Table (1). We have inventoried 28 species represented by 999 individuals divided into 11 families of unequal difference (Table 1), the most represented family is the Scarabaeidae with 10 species (35.71%), while the family Tenebrionidae is represented by 4 species (14.28%), followed by the family Carabidae which is represented by 3 species (10.71%). The other families do not exceed 1 to 2 species, respectively (3, 57%; 7.14%) (Figure 4).

Table 1: List of the sampled Coleoptera species in the three study areas of the Gharb plain (2013-2014)

Family	Taxa	Sidi Boughaba	Forest of Mamora	Merja of Fouarat
Scarabaeidae	<i>Oryctes nasicornis</i>	6	6	8
	<i>Oxygryllus ruginasus</i>	22	0	0
	<i>Dasygnathus sp</i>	16	0	0
	<i>Scarabaeus nitidicollis</i>	22	37	12
	<i>Aethiessa floralis</i>	0	56	13
	<i>Scarabaeus cicatricosus</i>	72	16	7
	<i>Polyphylla maroccana</i>	0	4	13
	<i>Phylloganathus excavatus</i>	0	8	8
	<i>Thorectes distinctus</i>	0	23	13
	<i>Copris hispanus</i>	9	16	7
Geotrupidae	<i>Typhaeus typhoeus</i>	3	0	0
	<i>Geotrupes auratus</i>	31	0	0
	<i>Calathus melanocephalus</i>	61	0	0
Carabidae	<i>Carabus sp</i>	5	55	13
	<i>Hirticoli sp</i>	28	0	0
	<i>Scarites sp</i>	2	0	0
Scaritidae	<i>Scarites sp</i>	2	0	0
Buprestidae	<i>Buprestis octoguttata</i>	52	0	0
Dynastidae	<i>Dipelicus optatus</i>	4	12	14
Coccinellidae	<i>Harmonia sp</i>	26	23	12
Tenebrionidae	<i>Erodius carinatus</i>	33	0	0
	<i>Tentyria maroccana</i>	71	0	0
	<i>Pachychila punctata</i>	14	0	0
	<i>Akis tingitana</i>	21	68	15
Cerambycidae	<i>Cerambyx cedro</i>	0	5	0
	<i>Stenocorus sp</i>	0	14	8
Buprestidae	<i>Coroebus florentinus</i>	0	5	0
	<i>coroebus undatus</i>	0	4	0
Platypodidae	<i>Platypus cylindrus</i>	0	6	0
11	28	498	358	143

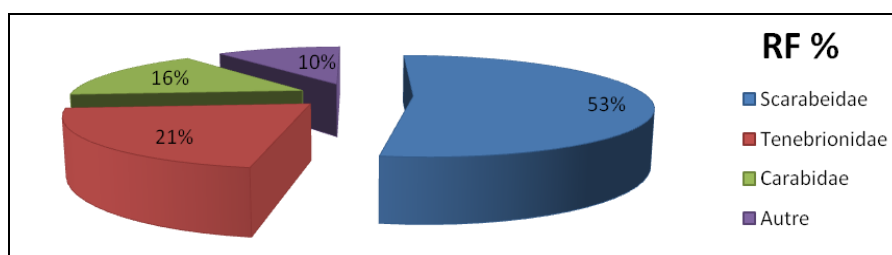


Fig 4: The richness of the most collected families during the period of study.

3.2. The spatial taxonomic richness

The results show a spatial variation in species richness, a relative abundance of species and richness in the family. Thus, we distinguished 28 Coleopteran taxa belonging to 11 families distributed unequally in the different study areas

(Figure 5). The biological reserve of Sidi Boughaba and the Mamora Forest have a diversification in family and species richness with an important relative abundance than those noted in the Merja of Fouarat.

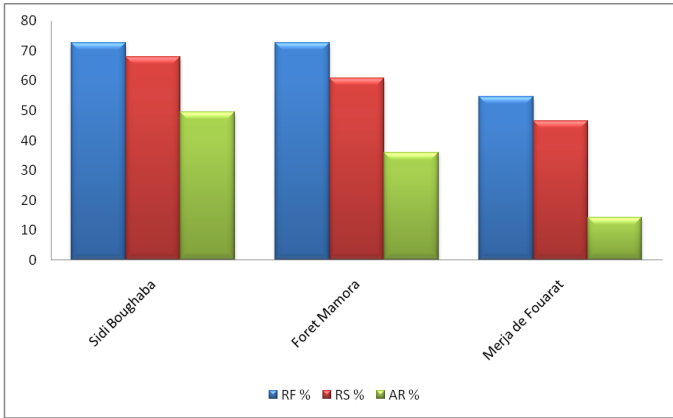


Fig 5: Spatial variation of species richness, relative abundance and family richness of Coleoptera. RF: family richness, RS: specific richness, AR: relative abundance

3.3 Exclusive species

The distribution of relative abundance of the Coleoptera among the different areas (Table 2), varies by the species and the studied areas. It is 14.25% and 14.75% respectively for *Tentyria maroccana* and *Scarabaeus cicatricosus* in the biological reserve of Sidi Boughaba, and 18.89% for *Akis tingitana* in the Forest of Mamora and 10.89% for the same species in the reserve of Sidi Boughaba.

Comparatively, the Biological Reserve of Sidi Boughaba and the Mamora Forest are the most diversified with respectively ($H = 2.88$ bits) and with the highest event ($E = 0.99$) (Figure 6). The Merja of Fouarat is moderately diversified ($H = 2.3$ bits) with respect to the former, but they also have a high flatness value (Equitability) ($E = 0.99$) (Figure 6). In addition, the value of the R^2 coefficient is correlated with Shannon-Weiner's index and the equitability for the three studied areas.

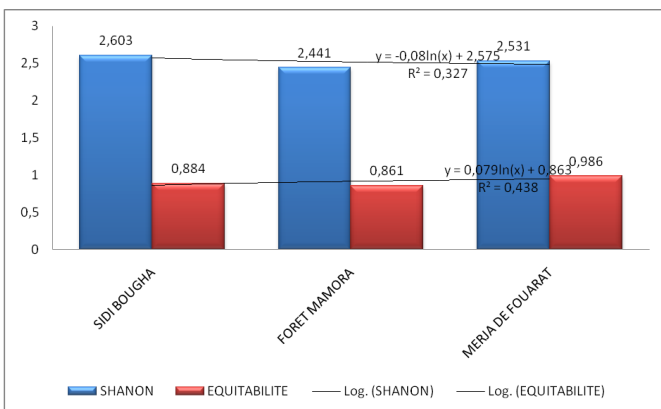


Fig 6: Variation of the Shannon-Weiner (H) diversity and the equitability J for the Coleoptera collected in the three study areas.

In the area of Sidi Boughaba and the Forest of Mamora, the relative abundance of the carabid species is slightly different: it varies between 10.33% and 18.99% in the Mamora forest, and between 10.44% and 14.7% for the most representative species, specifically for these two areas. Conversely, in the Merja of Fouarat, the relative abundance does not exceed 10.89% for the most representative species.

As shown in Table 2, seven species (24.2%) were commonly captured in the three study areas and six species (9%) were commonly captured in the two areas. The number of species recorded in one place was highest in the area of Sidi Boughaba (9, 61% of the species caught in this habitat), and included *Oxygryllus ruginasus*, *Dasygnathus blattocomes*,

Typhaeus typhoeus, *Geotrupes auratus*, *Calathus melanocephalus*, *Hirticoli sp.*, *Scarite sp.*, *Buprestis octoguttata*, *Erodium carinatus*, *Tentyria maroccana*, *Pachychila punctata*. Three species (*Coroebus florentinus*, *coroebus undatus* and *Platypus cylindrus*) exist exclusively in the Mamora forest, whereas the Merja of Fouarat did not show any specific Coleopteric species.

Table 2: Relative abundance of the Coleoptera species caught in the different study areas

Taxa	Sidi Boughaba AR %	Mamora Forest AR %	Merja of Fouarat AR %
<i>Oryctes nasicornis</i>	1.2	1.67	5.59
<i>Oxygryllus ruginasus</i>	4.41	0	0
<i>Dasygnathus blattocomes</i>	3.21	0	0
<i>Scarabaeus nitidicollis</i>	4.41	10.33	8.39
<i>Aethiessa floralis</i>	0	15.64	9.09
<i>Scarabaeus cicatricosus</i>	14.75	4.46	4.89
<i>Polyphylla maroccana</i>	0	1.11	9.09
<i>Phylloganathus excavatus</i>	0	2.43	5.59
<i>Thorectes distinctus</i>	0	6.42	9.09
<i>Copris hispanus</i>	1.80	4.46	4.89
<i>Typhaeus typhoeus</i>	0.6	0	0
<i>Geotrupes auratus</i>	6.22	0	0
<i>Calathus melanocephalus</i>	12.24	0	0
<i>Carabus sp</i>	1	15.36	9.09
<i>Hirticoli sp</i>	5.62	0	0
<i>Scarites sp</i>	0.4	0	0
<i>Buprestis octoguttata</i>	10.44	0	0
<i>Dipelicus optatus</i>	0.8	3.35	9.79
<i>Harmonia sp</i>	5.22	6.42	8.39
<i>Erodium carinatus</i>	6.42	0	0
<i>Tentyria maroccana</i>	14.25	0	0
<i>Pachychila punctata</i>	2.81	0	0
<i>Akis tingitana</i>	4.21	18.99	10.89
<i>Cerambyx cedro</i>	0	1.39	0
<i>Stenocorus sp</i>	0	3.91	5.59
<i>Coroebus florentinus</i>	0	1.39	0
<i>coroebus undatus</i>	0	1.11	0
<i>Platypus cylindrus</i>	0	1.67	0
28	100	100	100

AR: Relative abundance

The total number of the Coleoptera species caught in the study areas is summarized in the Table 3. The greatest similarity of species was observed in the areas: The Forest of Mamora and the Merja of Fouarat with 13 species. The common species to the areas of the biological reserve of Sidi Boughaba, the Forest of Mamora and the biological reserve of Sidi Boughaba and Merja of Fouarat are 8. In that case, the similarity among the three areas is 8.

Table 3: Number of species shared between the different study areas in 2015.

Combination of areas	Number of shared species
Biological reserve of Sidi Boughaba	19
Forest of Mamora	17
Merja of Fouarat	13
Biological reserve of Sidi Boughaba * Forest of Mamora	8
Biological reserve of Sidi Boughaba * Merja of Fouarat	8
Forest of Mamora * Merja of Fouarat	13
Biological reserve of Sidi Boughaba * Forest of Mamora * Merja of Fouarat	8
Total	86

The Figure 7 illustrates a comparison of the Coleoptera dominance curves in the study areas. The result of the dominance curves shows that the area of Sidi Boughaba is the most diversified, followed by the Forest of Mamora and the Merja of Fouarat. The hierarchical classification analysis, based on Bray-Curtis Similarity of the presence/absence of

the Coleopteran species matrix (Figure 8) reveals a single faunal group, but other isolated at 0.5 affinity. It includes the area of the Mamora forest as well as the Merja of Fouarat. However, the area of Sidi Boughaba shows no affinity with the other two areas studied.

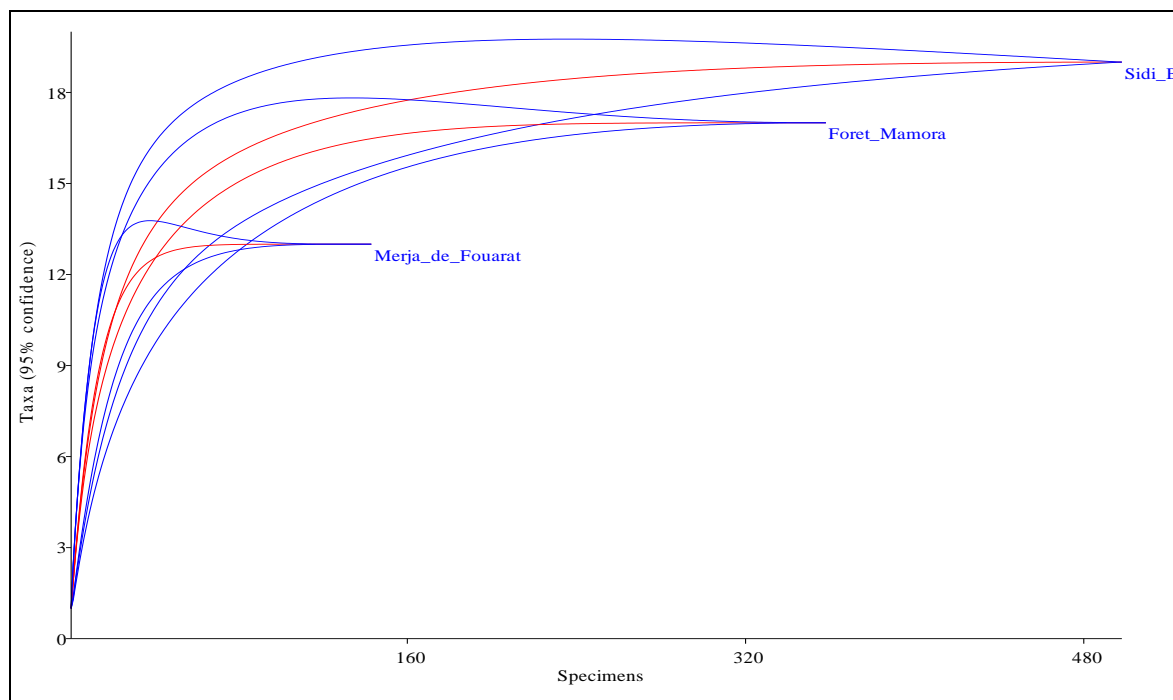


Fig 7: Abundance-rank curves of coleoptera populations in the study areas.

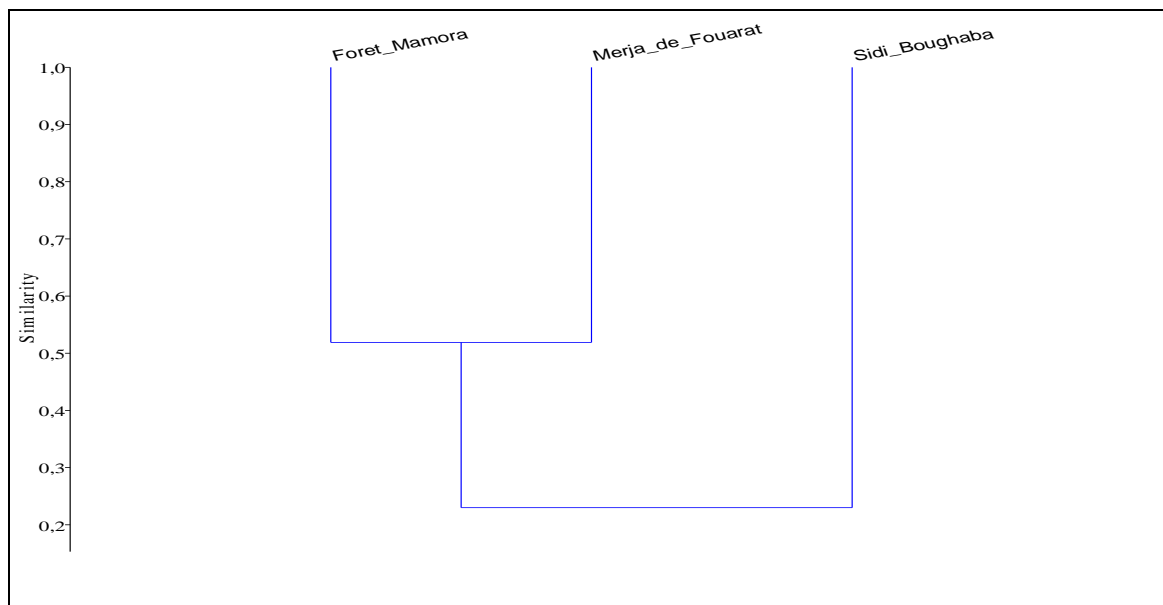


Fig 8: Dendrogram for the hierarchical analysis of the presence cluster / absence of Coleoptera species in the three areas of the Gharb plain (show the section at 0.5).

4. Discussion

Different aspects of species diversity suggest that the Coleoptera assemblages are distinct among all the studied sites [33, 34, 35], this is probably due to their heterogeneity in floristic composition and structure (and consequently, the composition and structure of the litter). These factors can affect local humidity and local temperature, determine the microhabitat availability and the feed resources [36]. These results highlight the response to Coleoptera disturbances and their response to the structure of habitat. Further, the

distribution of Coleopteran species is related to environmental conditions: the biological reserve of Sidi Boughaba can be considered as the best habitat type. This can be explained by the fact that this area offers the best combination of conditions (wet soil, moisture level, type of substrates, soil surface layer structure, soil organization stratum at ground level, composition of available prey, range of the microhabitats, availability of food, protection between predators, etc.). However, it is an undisturbed or polluted area. In the forests, the Coleoptera include several species with a tendency to

gregarism with diurnal activity [37]. More importantly, the Merja of Fouarat can be considered as a poor area in the Coleoptera, this can be explained by the fact that the studied area has undergone the anthropogenic actions of the liquid and solid rejection.

The leaf litter produced by the trees may be beneficial to Coleoptera. According to Loreau [38], the litter can offer a favorable microclimate and create a complex spatial structure by generating a stratification that can permit the coexistence of the Coleoptera species.

The Coleoptera have a high sensitivity to environmental changes [39], this characteristic makes them good bio-indicators. They are generally good dispersers, either flying or walking [40]. Furthermore, they are well adapted to deal with fragmented landscapes. The climate, the quality and quantity of litter and the structural stability of the soil and the litter habitats may reduce the density of other arthropods and, consequently, the food supply of Coleoptera. In addition, the richness and abundance of the Coleoptera are known to be lower in disturbed environments [35, 41, 42]. In fact, the significant reduction of the Coleoptera population recorded in the Merja of Fouarat area illustrates the threat of the Coleopteran species in their biotope. This result may be related to inadequate methods and at the time of sampling for some species. Also, the presence of disturbances does not allow the growth of Coleoptera larvae. Several parameters (type of soil and vegetation, litter and feeding method) affect the distribution of Coleoptera [43, 44]. Then, the abundance of the Coleoptera and the structure of the population may vary due to human activities, particularly the anthropogenic actions. Their mobility allows them to react and move quickly from one habitat to another so as to escape a possible change in habitat [45]. The anthropological activity and its extension have probably led to a disturbance of the environment (different types of pollutants released into the environment) leading to a decrease in species abundance. The species richness was not high in moderately disturbed areas.

Some species are present in one area, while others have been collected in two or three areas, this can be explained by different factors such as: altitude and vegetation [46]. At the community level, the habitat selection criterion is linked to the biotic factors whose combinations permit to describe how species share space. In that case, we suggest that the differences in local ecological factors among the sites studied are important and may alter species abundance.

In general, the abundance and the richness of Coleoptera are related to the biotic and abiotic factors such as: vegetation structure, temperature, humidity, light intensity and soil moisture [40]. The number of species caught also depends on the method and the intensity of sampling Slim *et al.*, [47].

5. Conclusion

This article reports 28 species belonging to 11 families of the Coleoptera sampled in three areas of the Gharb plain. The species richness varies from 13 to 19 species. The community analysis based on the dominance curves and the Shannon-wiener indicates that the Coleoptera are more diversified in the Sidi Boughaba biological reserve and the Mamora forest respectively 19 and 17 species than in the Merja of Fouarat which has 13 species. Although we did not sample the entire range of habitats in the different areas, the results showed that environmental conditions can structure the distribution of the Coleoptera. This spatial variation is influenced by the ecological heterogeneity of the study areas, particularly the

availability of plant debris, wood, litter, food and refuge for the Coleoptera. The sensitivity of the Coleoptera to environmental variables highlights the key role of Coleoptera in the dynamic of populations and their assemblage structure. They are very mobile and fast to occupy good quality habitats and to avoid environmental disturbance. The major species which have a wide distribution are presented as follows: *Oryctes nasicornis*, *Scarabaeus nitidicollis*, *Scarabaeus cicatricosus*, *Copris hispanus*, *Carabus sp*, *Dipelicus optatus*, *Harmonia sp*, *Akis tingitana*.

More long-term and periodic research could offer new data on the Coleoptera species. Consequently, additional efforts need to be made to obtain more information on the spatio-temporal distribution of the Coleopteran species in all ecosystems of the Gharb region, in order to better understand the endemic species, rare or endangered requiring conservation.

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