Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2017; 5(5): 747-752

Received: 11-07-2017
Accepted: 13-08-2017

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Estimation of entomological biodiversity: the biological reserve of Sidi Boughaba as a case study (Mehdia, Morocco)

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Abstract
The present study evaluates the entomological biodiversity of the Sidi Boughaba biological reserve during the period of adult activities, based essentially on species richness and relative abundance during the month of April, May and September, 2015-2016. The research methodology adopted is that of inventory/quality in relation to the collection methods and the temporal variation season. For this reason, we used four sampling methods: sight hunting, mowing of herbaceous vegetation, barber pots and the quadrat. The results obtained show that the method of sight hunting and the mowing of herbaceous vegetation are the most effective for the sampling of Hymenoptera and Coleoptera. In addition, seven orders, twenty eight families, 75 taxa and 1782 adults have been identified. Among the most listed orders, the Hymenoptera and the Coleoptera, which are described as indicator taxa.
The present study concluded that the factors related to taxonomy, season and sampling method are very important parameters as long as they together explain the abundance and the biodiversity of insects in this study area.

Keywords: evaluation, entomological biodiversity, collection methods, biological reserve, sidi boughaba, mehdia

1. Introduction
Through the immense diversity, their major ecological role and the bio-indicative nature of some taxa, the taking into account of insects in the management and conservation of natural spaces is growing for a decade [1]**.** Thus, biodiversity measurements provide basic information on the distribution, the richness and relative abundance of taxa required for the conservation decisions, studies on ecosystem ecology, cladistic biogeography and phylogenetic measurements of the conservation value [2-5]. The species richness and abundance in particular are increasingly important in the evaluation of conservation [6-8]. But, the inventory of insects in the World is still very incomplete, since their total number is generally evaluated between 3 and 30 million species: it would therefore remain to discover and name between 70 and 97% of the living insects on the Earth. At the current rate of habitat destruction, many species will have disappeared even before they have been identified. Each year, about 7000 new species are described. However, the study of this group suffers from a lack of professional resources (professional entomologists, formation) and a knowledge that is still too incomplete on the part of managers, yet strongly interested in this large group [9].
The knowledge of the terrestrial entomofauna of the biological reserve of Sidi Boughaba is fragmentary and incomplete. The inventories date back to the 1980s have concentrated on aquatic entomofauna [10, 11], the terrestrial Coleoptera [12], the Odonata [13], and the mosquitoes [14]. No sub-sampling bias was quantified.
The present objective consists of evaluating the entomological biodiversity of the biological reserve of Sidi Boughaba, one of the most important wetlands in Morocco by using quantitative and/or qualitative measures permitting to increase the efficiency and effectiveness of the biological inventory.

2. Materials and Methods
2.1 Area of study
The present study was conducted in three separate periods during the month of April, May and

September (2015-2016) at the biological reserve of Sidi Boughaba (34° 15' N- 06 ° 39 'W). This reserve is situated in the Atlantic coast of northwestern Morocco, oriented NNE-SSW and located in an inter-dune depression (Fig. 1). The study was limited to the period of adult activities during the day. The appropriate collection methods in this study were sight hunting, mowing of herbaceous vegetation [15], Barber pots [16] and quadrats [17]. The species determination was carried out at the Nutrition, Health and Environment laboratory of the Faculty of Sciences, Kenitra (Morocco).

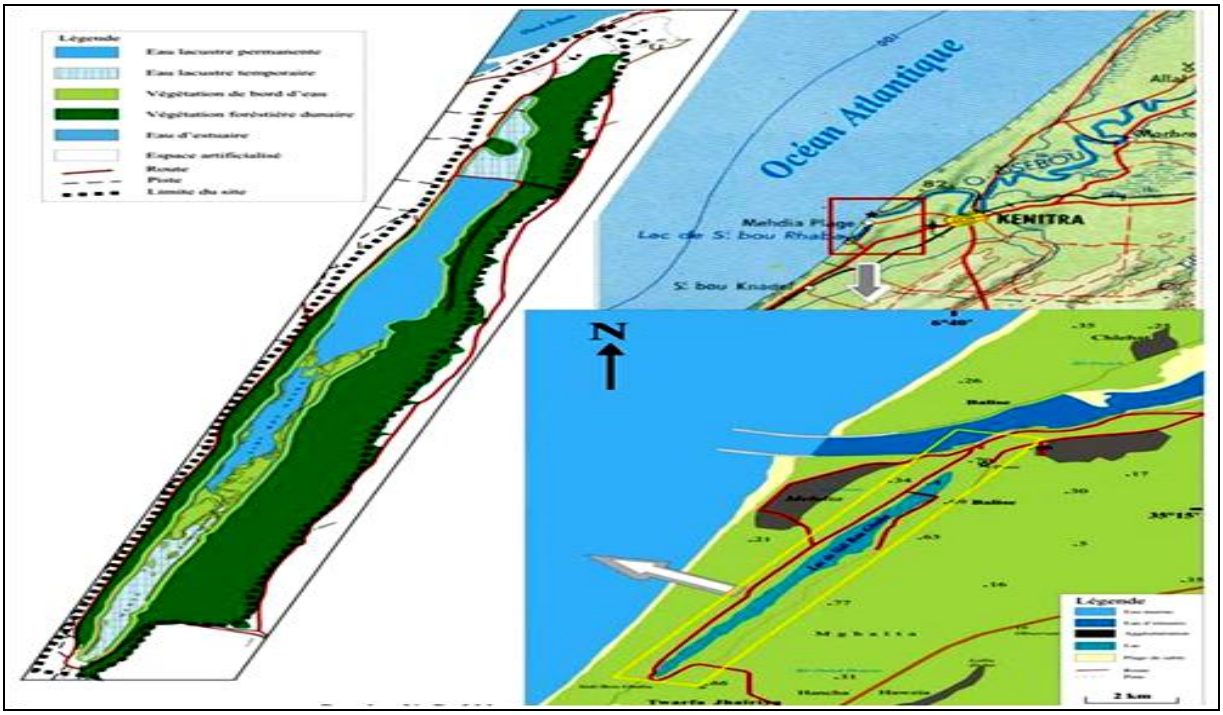

Fig 1: Geographical location of the Sidi Boughaba reserve [18].

2.2 Statistical analysis

The collected data was entered on Excel and then transferred to a software medium designed for parametric and non-parametric statistical analyzes. We use an analysis of variance in which the method and season were treated as independent factors. The number of adults and species per sample was respectively dependent variable. The chosen tests were of the decisional type such as the Fisher and Tukey tests, an MCA multiple correspondence analysis.

3. Results

The Table 1 below summarizes most of the taxa captured by the four sampling methods during the two seasons (spring and summer). However, the results of the sampling permitted to collect 1782 individuals, divided into 68 samples and rearranged in 75 species.

Table 1 : Main list of different taxa captured by the four methods during spring and summer 2015-2016

Order	Family	Taxa	Sampling technique							
			Sight hunting		Mowing		Barber pots		Quadrats	
			Sp	Su	Sp	Su	Sp	Su	Sp	Su
Hemiptera	Pentatomidae	*Chinavia hilaris*	0	0	7	17	0	2	0	0
		Graphosoma lineatum	*0*	3	11	40	0	0	0	0
		Dolycoris baccarum	0	0	2	8	0	0	0	0
		Euschistus servus	0	0	0	3	0	0	0	0
		Carpocoris mediterraneus	0	0	0	8	0	0	0	0
		Nezara viridula	0	0	7	17	0	3	0	0
	Pyrrhocoridae	*Pyrrhocoris apterus*	0	14	0	7	0	0	0	0
	Reduviidae	*Zelus tetracanthus*	0	0	0	0	0	1	0	0
Coleoptera	*Scarabaeidae*	*Oryctes nasicornis*	0	2	0	0	0	4	0	0
		Oxygrylius ruginasus	3	15	0	0	0	4	0	0
		Dasygnathus blattocomes	4	11	0	0	0	1	0	0
		Scarabaeus nitidicollis	5	17	0	0	0	0	0	0
		Scarabaeus cicatricosus	13	45	0	0	3	11	0	0
		Copris hispanus	0	8	0	0	0	1	0	0
	Geotrupidae	*Typhaeus typhoeus*	0	3	0	0	0	0	0	0
		Geotrupes auratus	8	16	0	7	0	0	0	0
	Carabidae	*Calathus melanocephalus*	18	27	7	9	0	0	0	0
		Carabus sp	0	5	0	0	0	0	0	0
		Hirticoli sp	8	18	0	0	0	2	0	0
	Scaritidae	*Scarites sp*	0	2	0	0	0	0	0	0
	Buprestidae	*Buprestis octoguttata*	18	34	0	0	0	0	0	0
	Dynastidae	*Dipelicus optatus*	0	4	0	0	0	0	0	0

	Coccinellidae	*Harmoniasp*	0	0	7	17	0	2	0	0
	Tenebrionidae	*Erodius carinatus*	8	20	0	0	0	5	0	0
		Tentyria maroccana	12	54	0	0	0	5	0	0
		Pachychila punctata	0	14	0	0	0	0	0	0
		Akis tingitana	2	15	0	3	0	1	0	0
Orthoptera	Acrididae	*Euchorthippus sp*	0	0	0	4	0	0	0	0
		Calliptamus barbarus	0	0	0	11	0	2	3	12
		Dociastaurus maroccanus	0	8	7	6	0	0	11	9
		Dociostaurus jagoi	8	7	3	6	0	0	13	28
		Heteracris lieutaghii	0	13	0	1	0	0	0	8
		Chorthippus juncadus	0	0	0	7	0	0	1	7
		Oedipoda sp	0	2	0	4	0	0	5	8
		Stenobothrus sp	0	0	6	8	0	0	0	0
		Paracinema tricolor	0	0	3	5	0	0	0	0
		Aiolopus puissanti	6	11	0	2	0	0	11	13
		Aiolopus strepens	8	8	4	9	0	0	12	18
	Gryllidae	*Nemobius sp*	0	1	0	4	0	0	0	0
	Mantidae	*Euchomenella sp*	0	0	1	4	0	0	0	0
		Sphodromantis viridis	0	0	0	2	0	0	0	0
		Mantis religiosa	0	0	1	0	0	0	0	0
Lepidoptera	Pieridae	*Pieris napi*	8	12	5	3	0	0	0	0
		Pieris rapae	13	6	2	1	0	0	0	0
		Pieris brassicae	5	8	2	8	0	0	0	0
		Colias crocea	11	23	5	2	0	0	0	0
		Colias hyale	4	11	3	7	0	0	0	0
	Lycaenidae	*Maculinea arion*	4	5	3	2	0	0	0	0
	Papilionidae	*Iphiclides podalirius*	1	3	0	0	0	0	0	0
	Zygaenidae	*Zugaena purpuralis*	0	3	5	18	0	0	0	0
Hymenoptera	Apidae	*Bombus pratorum*	5	3	15	23	0	2	0	0
		Bombus terrestris	9	8	18	32	1	0	0	0
		Bombus impatiens	1	0	5	12	0	0	0	0
		Anthidium lateral	3	5	2	5	0	0	0	0
		Crabro cribrarius	7	15	5	6	0	0	0	0
		Apis mellifica	4	13	11	26	0	2	0	0
	Formicidae	*Crematogaster scutellaris*	23	51	8	3	0	5	0	0
		Formica sp	9	9	6	20	12	4	9	0
Odonata	Aeshnidae	*Anax parthenope*	6	3	1	2	0	0	0	0
		Hemianax ephippiger	3	3	1	0	0	0	0	0
	Libellulidae	*Orthetrum trinacria*	13	3	2	0	0	0	0	0
	Lestidae	*Lestes virens*	7	2	1	0	0	0	0	0
	Coenagrionidae	*Ischnura graellsii*	5	2	0	0	0	0	0	0
Diptera	Asilidae	*Efferia sp*	14	34	4	4	0	0	0	0
	Cullicidae	*Culex pipiens*	0	0	5	0	0	0	0	0
		Culex theileri	0	0	3	0	0	0	0	0
		Culiseta subochrea	0	0	0	8	0	0	0	0
		Ochlerotatus caspius	0	9	0	0	0	0	0	0
		Ochlerotatus detritus	0	0	7	0	0	0	4	0
		Uranotaenia balfouri	0	4	0	0	0	0	0	0
		Uranotaenia unguilata	0	0	0	4	0	0	0	0
	Chironomidae	*Chironomus spp*	0	13	0	0	0	4	0	0
	Tabanidae	*Chrysops sp*	4	5	0	4	0	0	0	0
		Atylotus sp	2	6	0	3	0	0	0	0
		Tabanus sp	13	6	8	3	0	4	0	0
Total = 7	28	*75*	295	642	193	399	16	65	69	103

Sp =Spring, Su=Summer

3.1 Effect of order on the distribution of individuals

Table 2 shows the distribution of individuals according to orders, without taking account of the chosen method. It appears that hymenoptera were the most abundant with an average of 6.20 ± 1.162 individuals, followed by the Coleoptera with an average of 3.28 ± 0.637. However, the analysis of variance "order effect" shows a highly significant difference (Fisher = 3.98 and p <0.001). The comparison of the averages by Tukey brings out two overlapping groups, the most abundant group was the hymenoptera and a group of least represented insects, especially the Orthoptera (2.76 ± 0.427), and Lepidoptera (2.86 ± 0.585).

Table 2 : Analysis of variance with a single criterion of classification "order effect" on the distribution of individuals

Order	N	Average	Standard Error	Confidence interval to 95% for the average		Mini	Maxi	
				Inferior bound	Superior bound			Fisher
Hemipter	64	2.39(a)	0.779	0.83	3.95	0	40	3,98 (p<0,001)*
Coleoptera	152	3.28 (ab)	0.637	2.02	4.53	0	54	
Orthoptera	120	2.76(a)	0.427	1.91	3.60	0	28	
Lepidoptera	64	2.86(a)	0.585	1.69	4.03	0	23	
Hymenoptera	64	6.20(b)	1.162	3.88	8.53	0	51	
Odonata	40	1.35(a)	0.409	0.52	2.18	0	13	
Diptera	96	1.82(a)	0.460	0.91	2.74	0	34	
Total	600	2.99	0.260	2.47	3.50	0	54	

N :(effectifs), the orders with the same letters do not differ sidnificantly ; * : difference is very highly significant.

3.2 Effect of seasons on the distribution of individuals

Table 3 shows the distribution of individuals according to the seasons. Indeed, the analysis of variance with one dimension showed a highly significant difference (Fisher=17.55; p <0.000). Moreover, the average number of individuals caught in summer was 4.06 ± 0.463, with a maximum of 53 individuals caught, much higher than in spring (1.82 ± 0.22), with a maximum of 34 individuals captured.

Table 3: Analysis of variance with a single criterion of classification "season effect" on the distribution of individuals

Season period	N	Average	Standard error	Confidence interval to 95% for the average		Mini	Maxi	Fisher
				Inferior bound	Superior bound			
SPRING	301	1.91	0.224	1,47	2.35	0	23	17,55 (p<0,000
SUMMER	299	4.06	0.463	3,15	4.97	0	54	
Total	600	2.99	0.260	2,47	3.50	0	54	

N**: (**effectifs**)**

3.3 Distribution of individuals according to the catch methods

The results of the distribution of the individuals caught by the four sampling methods are illustrated in the Table 4. The analysis of variance showed a very highly significant difference between the average number of individuals caught by each selected method (29.78 and p < 0.000). The comparison of the averages by Tukey, permitted to rearrange the averages in three different groups.

- The first group gathers the methods of Barber pots and quadrat. These two methods display the averages of the lowest insect captured with respectively 0.54 ± 0.14 individuals (maximum = 12) and 1.15 ± 0.31 (maximum = 28).
- The second group consists only of the mowing method in which its average catch is 3.99 ± 0.51, with a minimum number of insects captured from 0 to a maximum of 40 individuals.
- The third group is essentially composed of the visual hunting method which shows significant performances compared to the other groups. In fact, the average of individuals caught by this method is 6.27 ± 0.754, with a minimum of 0 individuals and a maximum of 54 insects captured.

Table 4: Analysis of variance to a single classification criterion "effect of capture methods" on the distribution of individuals

	N	Average	Standard error	Confidence interval to 95% for the average		Mini	Maxi	Fisher
				Inferior bound	Superior bound			
Sight hunting	150	6.27 (c)	0.754	4.78	7.76	0	54	29,78 (p<0,000)
Mowing	150	3.99 (b)	0.512	2.97	5.00	0	40	
Barber Pots	150	0.54 (a)	0.138	0.27	0.81	0	12	
Quadrats	150	1.15 (a)	0.312	0.53	1.76	0	28	
Total	600	2.99	0.260	2.47	3.50	0	54	

N :(effectifs) ; the methods with the same letters do not differ significantly ; * the difference is very highly significant.

3.4 Tests of the inter-subjects effects

To better extract the inter-factor interactions, multiple analysis (three-factor ANOVA) was used (Table 5). Indeed, all separate factor sources and /or all the two to two interactions, except for the Season order* combination, were found to be significant at 5% error. However, the interaction between the three factors shows a highly significant effect on the distribution of insects in their sampling biotope (Fisher = 1.86; p <0.017) and the general linear model (GLM) accounts for 34.9% of the actual distribution of these insects.

Table 5: Univariate general linear model of three factors

Tests of the inter-subjects effects					
Dependent variable: Number of individuals caught					
Source	**Sum of squares of type III**	**Degree of freedom**	**Average of squares**	**Fisher**	**Signification**
Order	933.040	6	155.507	5.881	0,000
Season	396.800	1	396.800	15.005	0,000

Methode	2738.601	3	912.867	34.521	0,000
Order * Season	244.074	6	40.679	1.538	0,163
Order * Methode	3577.830	18	198.768	7.517	0,000
Season * Methode	251.849	3	83.950	3.175	0,024
Order * Season * Methode	886.870	18	49.271	1.863	0,017
Error	14385.453	544	26.444		
Total	29661.000	600			
Corrected Total	24314.865	599			

The projection of the whole modalities of the different variables according to the axes 1 and 2 of the multiple correspondence analysis (Fig. 2) permitted to extract two main groups:

- The first group situated in the positive side of axis 1 gathers the methods of the quadrat, the pots barber and the mowing. These methods arrive to count the orders of the Orthoptera, Odonata, Hemiptera, Diptera with intensities not exceeding 10 individuals, especially during the spring.
- The second group represented essentially by the sight hunting method, is supposed to be the most performed because of its efficiency on capturing insects, and this for the Coleoptera and Hymenoptera orders, especially during warm periods.

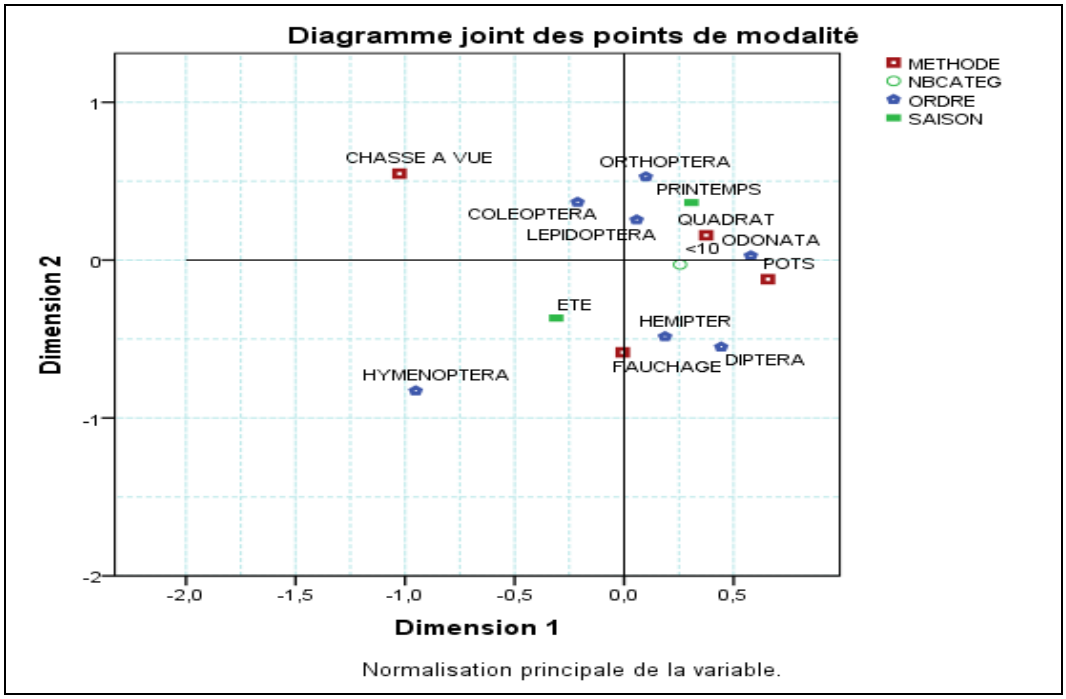

Fig 2: Analysis of multiple correspondence of the whole modalities of the different variables

4. Discussion

Seventy-five taxa were identified during the period of study including seven orders, the Coleoptera and Orthoptera were both highly diversified (17 species observed for the Coleoptera and 15 species for the Orthoptera), which is comparable to the results found by Slim *et al.* [19] who used two types of collection methods namely the sight hunting and mowing herbaceous vegetation as well as the Coleoptera which are the most diversified, likewise the Hymenoptera which are abundant of individual views. The Coleoptera and Hymenoptera are apparently the easiest to sample. This large taxonomic richness of the biological reserve of Sidi Boughaba in which these taxa groups is mainly linked to the presence of favorable conditions (temperature, humidity, trophic sources, etc.), which permit them to flourish.

As for the Coleoptera, this richness is certainly linked on the one hand to the presence of organized matter (coprophagous species) and vegetation cover for phytophagous species [20], and the nature of the substrate for sabulicol species [12, 21], and the used census methods.

In this inventory, the sight hunting and mowing of herbaceous vegetation have marginally captured more species and individuals in total.

The sampling methods [22] permit access to different components of wildlife, and these components may differ in number of species and to what extent they are sensitive to a particular collection method [23]. The attribution of an equal effort to all methods implies implicitly that the methods are equally effective and/or that targeted wildlife walls contain roughly the same number of species with the same abundance distribution.

The mowing of the herbaceous vegetation is more productive. This shows that most of the species caught are nectariferous, fruit-bearing and floricole insects, this is the case in particular of the hymenoptera.

Le Berre [24], has proved that the barber pots method is specific especially to the merchant arthropod, such as the scarabidae. Benkhelil [16] also found that the barber pots were the most effective techniques for sampling the invertebrate biocenoses, which move to the soil surface, particularly the carabids, and a large number of flying insects that come to land on the surface or fall away by the wind.

In Sidi Boughaba, the summer inventory found most species (Table 3), probably because the insects are more abundant at the end of summer. The abundance of insects during the summer period can be explained by the fact that they are

poïkilothermes organisms; their physiological activity is directly related to the external temperature. In case of thermal variation, their cycles, operations and behaviors will be modified. A high temperature permits faster growth and displacement [25]. The rarity of some species was probably present in the form of eggs or hidden in retreats that were not accessible to collection methods during the period of study.

In this inventory, the results show that the factors related to taxonomy, season and sampling method are very important parameters as they explain together the abundance and the biodiversity of insects, which confirms the results of Coscaron [26].

To this end, it appears that the Coleoptera and Hymenoptera are diverse and relatively easy to sample. As such, they can be the best candidate indicator group for the surveillance among the entomofauna of the biological reserve of Sidi Boughaba.

5. Conclusion

In the light of these results, it can be concluded that the Coleoptera and Orthoptera orders were the most diverse from the point of view taxon. Thus, the factors related to taxonomy, season and sampling method are very important parameters as long as they together explain the abundance and the biodiversity of insects in this study area.

6. Acknowledgements

I would like to thank Mr. Aberrazak Khadmaoui, Professor at the Faculty of Sciences, Ibn Tofail University (Kenitra, Morocco), Laboratory of Genetics and Biometry, Department of Biology, who corrected me the statistical part of my article. I would also give my special thanks to Mr. Tarik Couissi, Ph.D student at Ibn Tofail University (Morocco), who helped me in translating this article.

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