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Some Physical and Chemical Conditions Affecting the Distribution of Aquatic Beetles : Lake of Sidi Boughaba as a Case Study (Kénitra, Morocco)

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ABSTRACT

Wetlands present an important diversity of life and are very productive. Many biotic and abiotic factors intervene in their functioning. Thus, understanding this functioning requires, among other characteristics, physicochemical characterizations of their waters and the determination of the specific structure of the stand that inhabits those environments. In this work, the authors were interested in the characterization of the waters of Lake Sidi Boughaba, wetland and biological reserve registered with the RAMSAR convention. This lake is made up of three parts of unequal volume and duration of flooding. The results showed that the studied living environment is very heterogeneous physicochemical and that from one biotope to another the values of the majority of the physicochemical parameters can vary from single, to double, to three times, and even more. Only the pH, oxygen, and ammonium content are relatively stable. In addition, the results showed that the aquatic beetle population of the prospected environment consists of 34 species and subspecies, grouped into 9 systematic families and that the Dyticidae family and the Hydrophilidae family are the most represented. Likewise, the biotypological analysis of the population of beetles collected showed the distribution of the 34 inventoried species that are divided into four groups and that, among the 16 physicochemical parameters studied 10 intervene the determination of the specific structure of each of the groups of 'identified species.

INTRODUCTION

By ensuring the availability of water, biocenotic and biological diversity, wetlands are highly productive environments on the planet (**Deák, *et al.*, 2015**). The functioning of these zones depends on many factors, in particular their hydrology, their physicochemical characteristics, the taxonomic structure, and the dynamics of their biocenoses (**Gogoi *et al.*, 2019**). In Morocco, there are some 300 wetlands, some of which are included in the Ramsar convention. The Sidi Boughaba reserve (34 ° 12'56 "and 34 ° 15" 55 "N latitude and 6 ° 42" 32 "and 6 ° 45'27" W longitude) is one. It is located 13 km from the center of the city of Kenitra in a depression in a hilly region (Fig. 1) near the Atlantic coast of northwest Morocco. It is made up of a forest environment centered by a lake that stretches 5.5 km in length and varies in width from 100 to 250 meters; the depth varies between 0.5 and 2.50 meters maximum (**Slim *et al.*, 2016**). Likewise, this reserve is a biological reserve, included in the "Ramsar" list of wetlands, offering favorable conditions for the development of an important diversity of fauna. In addition, it is a point of passage, nesting, or hibernation for a large number of migratory birds and local birds (**Lahrouz *et al.*, 2011**).Thus, numerous studies have indicated its great biological diversity, particularly those of **Elkhiati *et al.* (2013)**, **Cherkaoui *et al.* (2015)** and **Slim *et al.* (2019)**. Additionally, insects, larvae, and adults often constitute a large fraction of the population of macro-invertebrates in aquatic environments and many of them have potential indicators of the quality of the environment (**Stein *et al.*, 2008, Hauer &Resh, 2017**). They are also a food source for many vertebrates and several species of fish and play an important role in the trophic balance of their hydro-systems (**Zha *et al.*, 2020**). Therefore, it can be considered that for any aquatic ecosystem, determining the structure of the insect population constitutes a basis for estimating the quality and productivity of the environment. Thus, this study attempts to contribute to the Physico-chemical characterization of the environment and to identify the taxa of the beetle insect communities of Lake Sidi Boughaba which, under its location in an urban geographic area, is under various anthropogenic actions (**Zha *et al.*, 2020**).

MATERIALS AND METHODS

Study area

Lake of Sidi Boughaba is limited to the north by the mouth of the Sebou wadi, and to the south by the marabout "Sidi Boughaba". Its formation is favored by the concave topographic surface of its site. Its water supply is provided by the coastal water table and runoff from the watershed. From north to south the lake is made up of three parts: a marshy area. It is fed by precipitation water and hardly persists for more than 6 months generally spread from the beginning of December to the beginning of May. A second part where water persists is the deepest points of relief and is fed by precipitation water and groundwater. A third part, more extensive, where the water is permanent and its supply is provided by the water table and precipitation water.

Choice of stations and sampling of water and insects studied:

The description of the aquatic environment studied focused on 8 stations (S1, S2, S3, S4, S5, S6, S7, and S8) distributed in such a way as to cover the main heterogeneity of the environment (Fig. 1 & Table . 1). The choice of these stations took into account the duration of the impoundment of the site, the abundance of its aquatic vegetation, its depth, and the apparent degree of its salinity of the water. Thus, the 8 stations selected belong to various hydrological facies such as freshwater, saltwater, temporary water, and permanent water. In addition, in order to obtain comparable homogeneous data, each station was sampled during a period during which the majority of aquatic micro and macroinvertebrates are present; namely, April, May, and June. Moreover, it is this period that is characterized by hydrological stability. Note that this same study strategy has been adopted by other authors in the study of aquatic environments such as **Frish *et al.* (2006)** and **Aoujdad *et al.* (2014**).

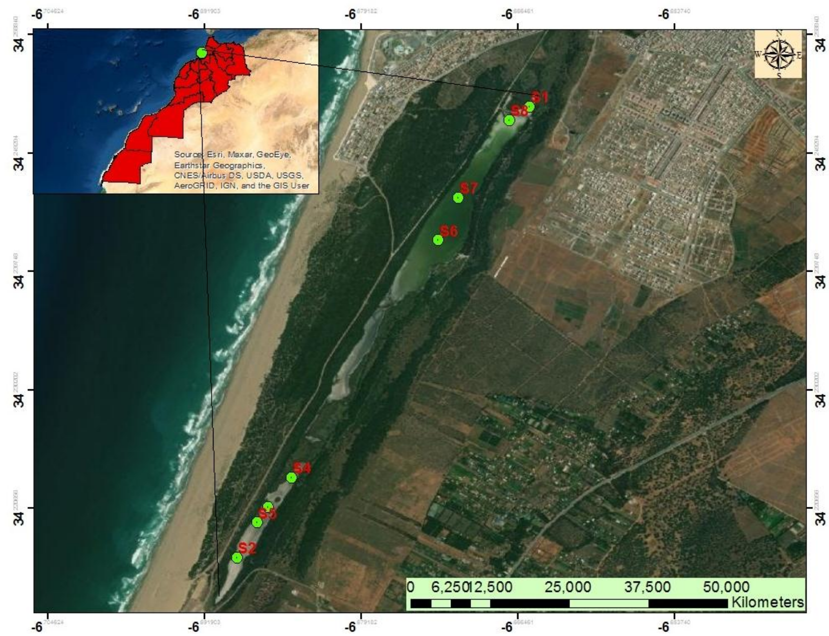

Fig. 1: Lake of Sidi Boughaba (Kenitra –Morroco)

Table 1: Main Characteristics of Surveyed Stations.

Stations to prospect	S1	S2	S3	S4	S5	S6	S7	S8
Average filling time (DME) (in months	5	7	8	9	12	12	12	8
The extent of vegetation cover (CV) (in%)	25	10	19	16	35	15	40	15
Maximum depth (Pmax) (in cm)	60	95	50	80	300	230	240	146

METHODS AND MATERIEL

This study aimed at three objectives: the determination of the specific structure of the population of aquatic Coleoptera insects, the physicochemical characterization of its waters, and the contribution to the determination of the physicochemical conditions which influence the ecology of the harvested species. At each of the stations studied, 16 physicochemical parameters were measured using electronic equipment or by volumetry. The temperature of the water was carried out using a mercury thermometer graduated in 1/10 of a degree Celsius. The pH was carried out using an Orion Research, Ionalyser model 607 pH meter with an Orion pH 91-05 specific electrode. The dissolved oxygen content was measured in the field using an ORION Research Pulse Oximeter, Ionalyser model 607 with specific O2 electrode. Additionally, conductivity was measured using a conductivity meter. The other chemical parameters were measured in the laboratory. Likewise, using a trouble net the authors swept several times and filtered the water at each of the stations surveyed, according to the chemical principles indicated by **Rodier *et al.* (2009**). In addition, the qualitative sampling of the fauna studied was carried out using a troubleau net with an opening of 30 cm and a mesh size. Then, in the laboratory, the zoological content of each filtrum was sorted and systematically determined. Once the data was collected, a multivariate statistical analysis through the use of software, "Minitab" version 19 was performed.

RESULTS AND DISCUSSION

The systematic structure of harvested aquatic beetles

As shown in Table (2), the aquatic beetle population in the prospected environment consisted of 34 species and subspecies grouped into 9 systematic families. With 13 species and 11 species, the *Dytiscidae* family and the *Hydrophilidae* family were the most represented. In contrast, half of the families noted were represented by only one species each, in particular, the *Hygrobiidae*, *Dryopidae*, *Noteridae*, *Helophoridae*, and *Gyrinidae* families.

Table 2: Stationary Distribution of the Species Collected (1 = presence; 0 = absence)

Family	Species	S1	S2	S3	S4	S5	S6	S7	S8
Gyrinidae latreille, 1910	*Gyrinus dejeani*	1	1	1	1	1	1	1	1
	Peltodydes caesus	1	1	1	1	1	1	1	1
	Haliplus lineaticollis	1	1	1	1	1	1	1	1
Haliplidae Aubé, 1936	Haliplus guttatus	1	1	0	0	0	0	1	1
Hygrobiidae	*Hygrobia tarda*	0	0	1	1	1	1	1	1

Stimpson, 186	*Hyphydrus aubei*	1	1	1	1	1	0	0	1
	Hydrovatus clypeal	0	0	1	1	1	1	1	1
Dytiscidae Leach, 1815	*Guignotus pusillus*	0	0	1	0	1	1	0	0
	Coelambus parallelogrammus	1	1	1	1	1	1	1	1
	Hygrotus inaequalis	1	1	1	1	1	1	1	1
	Hydroporus planus	1	1	1	1	0	0	0	1
	Laccophilus minutes	1	1	1	1	1	1	1	1
	Methley cribratellus	0	0	0	0	1	1	1	0
	Copelatus atriceps	1	1	1	1	1	1	1	1
	Rhantus hispanicus	0	0	1	1	1	1	1	0
	Colymbetes fuscus	0	0	1	1	1	1	1	0
	Cybester lateralimarginalis	1	1	1	1	1	1	1	1
	Cybester tripunctatus	1	1	1	1	1	1	1	1
	Ochthebius meridionalis	1	1	1	1	1	1	1	1
Hydraenidae Mulsant, 1844	*Ochthebius impressicollis*	1	1	1	1	1	1	1	1
Helophoridae Fabricius, 1775	*Helophorus viridicollis*	1	1	1	1	1	1	1	0
	Anacaena limbata nitida	0	0	0	1	1	1	1	0
	Anacaena globulus	1	1	1	1	1	0	1	1
	Enocrus melanocephalus	0	1	1	1	1	0	0	0

	Enochrus coarctatus	1	0	1	1	1	1	1	1
	Hydrobius convexus	0	0	1	1	1	1	1	0
	Limnoxenus neger	0	0	1	1	1	1	1	0
	Hydrous flavipes	1	1	1	1	1	1	1	1
Hydrophilidae Latreille, 1802	*Hydrous pistaceus*	1	1	1	1	1	1	1	1
	Berosus affinis	1	1	1	1	1	1	1	1
	Berosus affinis hispanicus	1	1	1	1	1	1	1	1
Dryopidae Billberg, 1820	*Dryops gracilis*	1	1	1	1	1	1	1	1
Noteridae C. G. Thomson, 1860	*Noterus laevis*	1	1	1	1	1	1	1	1
Richesse spécifique		23	24	30	30	30	29	28	24

Spatial physicochemical variation of the studied medium

The values of the measurements of the sixteen parameters evaluated are shown in Table (3). It was noticed that, the duration of the flooded phase of the environment studied varied according to the location of the station, from temporary, semi-temporary to permanent. The amount of plant covering the environment was not homogeneous and varied from 10 to 40%, and the thickness of the water layer varied from 0.5 to 3 m. The variation in maximum and minimum temperatures seems to be influenced by the depth of the medium. Generally, the pH is basic but it was less basic in the temporary parts of the lake than in its permanent or semi-permanent parts. The EC and contents of Cl^-, Ca^{2+}, Mg^{2+}, dissolved oxygen, COD, and BOD5 varied greatly from one station to another. The variation was the same for nitrogenous substances.

Table 3: Specific Variation of the Values of the Physicochemical and Biological Parameters.

Prospected stations	S1	S2	S3	S4	S5	S6	S7	S8
DME	5	7	8	9	12	12	12	8
CV	25	10	19	16	35	15	40	15
Pmax	60	95	50	80	300	230	240	146
Tmin	14.2	14	15	14	15	15.6	14.7	13
Tmax	27.4	26	25	29	25	25	27	29
pH	7.1	7.3	8.8	8.7	6.9	8.3	8.1	8.5

EC	5500	4540	7950	7900	2800	3250	4560	4600
Cl^-	510	493	4850	3930	992	1510	2121	3303
Ca^{2+}	12.2	14	17.7	16.2	25	20.3	19.6	22.1
Mg^{2+}	19.4	21	31	32.1	46	39.4	35.6	34
OD	12.7	9.6	7.3	6.6	10.5	9.2	6.8	5.5
DOC	71.5	102	151.3	121	89.8	127	120	99.4
DBO_5	32.5	43.1	72	62.1	54.5	66.2	55	57.5
NH_4^+	1.21	1.17	3.1	2.95	1.74	1.24	0.98	0.93
NO_3^-	7.5	8.1	9.5	12.1	12.5	11.5	13.5	6.9
NO_2^-	0.15	0.31	0.95	1.11	1.15	0.64	0.36	0.19

Moreover, **Raulings *et al.* (2010) and Schriever (2015)** nd reported that, the abiotic environment has a strong influence on the ecology of the aquatic biocenosis. They added that, the hydroperiod and the size of the ponds had a strong influence on the invertebrate communities. However, for the majority of the variables measured, the degree of variation could be from simple to double. Similarly, with a specific respect to the chloride content, which is a determining factor for the quality and quantity of species and the specific structures of the populations in the environment (**Ngugi *et al.*, 2012**). The values of certain stations were 4 to 9 times higher than the weakest ones. Roughly, the same is the case for many other estimated parameters. It should also be noted that, about the duration of the flooded phase, the stations studied were divided into three types of biotopes: temporary, semi-temporary, and permanent. However, according to numerous studies including those of **Williams (1996)** and **Anusa *et al.* (2012**), it should be noted that often, for the physicochemical parameters of the waters of the studied environment, the variation is inversely proportional to the duration of the flooded phase of the biotope.

Typological and biotypological analysis of the environment

a**. Assessment of the physico-chemical typology of the environment**:

The first three-factor axes together accumulated 83.6% of the total inertia (Table. 4). The two axes alone accumulated 70% or more than 50% of the cumulative information explaining the phenomenon studied. Thus, it was proposed to be satisfied with the physicochemical interpretation of the first two axes of C1 and C2 and of the plane of projection C1*C2.

Table 4: Characteristics of the First Three Principal Components.

Eigenvalue	6.0087	5.1892	2.1772
Proportion	0.376	0.324	0.136
Cumulative	0.376	0.7	0.836

Table 5: Loadings of the Principal Components 1 and 2 of 16 Experimental Variables**.**

Variables	PC1	PC2
DME	0,352	-0,187
EC	0,13	-0,241
Pmax	0,234	-0,339
Tmin	0,238	-0,149
Tmax	-0,149	0,177
pH	0,181	0,348
CD	-0,023	0,398
Cl^-	0,188	0,369
Ca^{2+}	0,295	-0,16
Mg^{2+}	0,356	-0,15
OD	-0,188	-0,257
DCO	0,273	0,254
DBO5	0,347	0,197
NH_4^+	0,161	0,294
NO_3^-	0,317	-0,118
NO_2^-	0,294	0,07

Moreover, taking into account the importance of the explanatory inertia accumulated by the two axes C1 and C2 (70%), the projection of the physicochemical variables, the stations, and the biological species collected in each of these stations allowed a statistical analysis showing the physico-chemical and biological diversity of the environment studied. This, in turn, would help to determine the environmental conditions that favor, or disadvantage, the presence of a particular species or associations of species. Thus, the analysis of Fig. (2) shows that, compared to the projection of the stations prospected on the axis C1, two groups of stations located on either side of the axis C2 and which vis-à-vis the studied variables showed different characteristics:

- A first group G1 formed by stations S1, S2, and S8 are all located on the negative side of the C1 axis. This is stationed with a temporary to semi-temporary filling time. The values found for the constituent variables of this axis were lower than those noted for the second group of stations G2
- The second group of stations (G2) was located on the positive side of the C2 axis; namely, S3, S4, S5, S6, and S7. These are satiations whose impoundment was temporary, semi-temporary or permanent. The values found for the constituent variables of this axis were higher than those noted for the group of stations G1.

This same analysis showed that, with respect to the physicochemical gradient represented by the C2 axis, the G1 group could be subdivided into two subgroups (G1a and G1b), and the G2 group into two subgroups (G2a and G2b). Thus, the subgroups of stations G1a and G2a, unlike the subgroups G1b and G2b, were characterized by pH, electrical conductivities, high chloride, and ammonium concentrations, and plant cover, maximum temperatures and lower oxygen concentrations.

b. **<u>Biotypological evaluation of collected beetles</u>**:

The distribution of those species in relation to the stations was not homogeneous. The analysis of the projection of those species on the C1xC2 plane (Fig. 3) contributes to the determination of the physicochemical conditions which could be responsible for the special distribution of the collected species. According to this analysis 4 groups of species could be differentiated:

- A first group G1 formed by stations S1, S2, and S8, which were all located on the negative side of the C1 axis. These were stations with a temporary to semi-temporary filling time. The values found for the variables constituting that axis were lower than those noted for the second group of stations G2

- The second group of stations (G2) was located on the positive side of the C2 axis; namely, S3, S4, S5, S6 and S7. These are satiations whose impoundment was temporary, semi-temporary, or permanent. The values found for the constituent variables of this axis were higher than those noted for the group of stations G1; For the biotypology distribution of the species collected (Fig. 3), the analysis shows the differentiation of 4 subgroups G1a, G1b, G2a, and G2b:

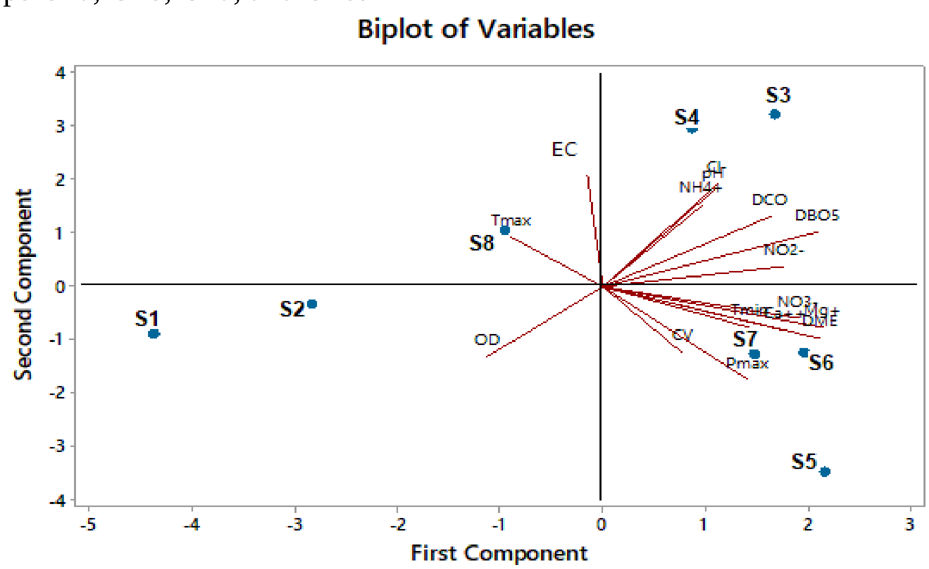

Fig. 2: Projection of the Points Representing the Stations Prospected and the Physicochemical Parameters Studied.

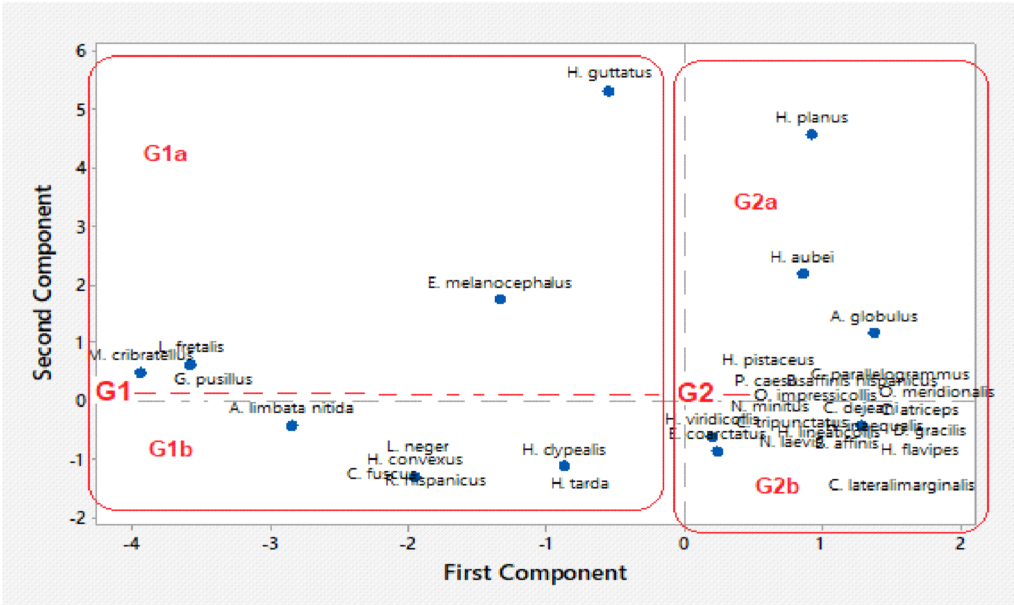

Fig. 3: Distribution of Species about the Surveyed Stations.

Species group G1a

Species requiring or preferring living environments with temporary to semi-temporary impoundment, relative to the physico-chemical conditions were prevailing in the studied environment. The values found for the minimum temperature, the contents of Ca^{2+}, Mg^{2+}, BOD, nitrates, nitrites and dissolved oxygen were low. Likewise, the degree of plant cover in the medium and the maximum water temperature was low, while the values of pH, EC, and concentrations of Cl^- and $NH4^+$were high.

Examples: *H. guttat*e and *E. melanocephalus*

Species group G1b

As for the group of species G1a, the living environment of the group species was temporary to semi-temporary impoundment and characterized by minimum water temperature, the contents of Ca^{2+}, Mg^{2+}, BOD, nitrates, nitrites and dissolved oxygen were low. However, the degree of vegetation cover in the medium and the maximum water temperature was high, while the values of pH, EC, and concentrations of Cl^- and $NH4^+$ were low. Examples: *H. dypealis* and *H. Tarda.*

Species group G2a

The living environment of this group was with temporary to semi-temporary impoundment. The values found for the variables constituting this axis were higher than those noted for the second group of stations G2a and G2b; namely, Tmin, Ca^{2+}, Mg^{2+}, BOD, nitrates, and high nitrates. The values of pH, EC, Cl^- and ammonium were also high while CV, Tmax, OD were low.

Examples: *H. planus and H. aubei*

Species group G2b

The living environment housing this group of species was temporary, semi-temporary or permanent. The values found for Tmin, Ca^{2+}, Mg^{2+}, BOD, nitrates, and nitrites were high. Moreover, CV, Tmax, OD were also high while the values of pH, EC, Cl^-, and $NH4^+$ were low.

Examples : *H. flavipes and C. laterimarginalis*

In addition, the importance of the flooded phase of the biotope, the local physico-chemical conditions and the richness of the environment in aquatic plants seem to be the main cause of the physico-chemical heterogeneity of the studied environment. It is worthy to mention that, **Schriever (2015**) stated that, there are biotic interactions and species life cycles that interact with abiotic factors.

Indeed, according to **Williams (1996**), the aquatic insects which live in these habitats are strongly influenced by physicochemical factors and the duration of the flooded phase of the biotope. **Likewise *et al.* (2012)** and **Schriever (2015**) added an effect of the area and depth of the biotope on the diversity of species and the physicochemical characteristics of habitats.

CONCLUSION

From a physicochemical point of view, the studied environment revealed to be very heterogeneous. From one biotope to another, for most of those parameters, the coefficient of variation could be double, quadruple, or even more. The authors cited the duration of the flooded phase of the studied environment which, from one biotope to another, could be temporary, semi-temporary, or permanent; the importance of the plant cover of the environment varied from 10 to 40%, the water depth varied from 0.5 to 3m and the Cl- content (very determining ecological factor in the ecology of the species) from 493mg / l to 4850mg. Only the pH, the dissolved oxygen content and the $NH4^+$ content were relatively stable. Moreover, the biotypological estimate of the species showed a distinction of 4 groups of species G1a, G2a, Gab, and G2b. Among the sixteen estimated variables, 10 variables intervened by the combination of their values in the specific structure constituting each group of species; namely, the duration of watering of the biotope, the importance of plant cover and conductivity, the pH, the temperature, and the contents of Mg^{2+}, Ca^{2+}, $NH4^+$ and DO.

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