Journal of Materials and Environmental Sciences
ISSN : 2028-2508

JMES, 2017 Volume 8, Issue 10, Page 3508-3523

http://www.jmaterenvironsci.com/

Ephemeroptera's diversity and ecology in streams of the ultramafic massif of Beni Bousera and in the adjacent non-ultramafic sites (NW, Morocco)

O. Khadri[1], M. EL Alami[1], R. EL Bazi[1] & M. Slimani[1]

[1]*Laboratory of Ecology, Biodiversity and Environment, Department of Biology, Faculty of Science, Abdelmalek Essaâdi University, Tetouan, Morocco.*

Received 25 Oct 2016,
Revised 08 Mar 2017,
Accepted 11 Mar 2017

Keywords

- ✓ Diversity;
- ✓ Ephemeroptera;
- ✓ Biotypology;
- ✓ Rif;
- ✓ Beni Bousera;
- ✓ Serpentine

O. Khadri
osamakhadri@hotmail.fr
Phone: **+212653440420**

Abstract

To contribute in the knowledge and the conservation of the faunistic biodiversity in streams of the ultramafic massif of Beni Bousera and in the adjacent sites, a faunal and ecological study of Ephemeroptera was started since autumn 2013 to autumn 2015 on 12 stations in this region and 14 others outside of this typical region in order to make a comparative study between the two types of watercourses and highlight the characteristics of the serpentine. This study enabled us to analyze the distribution of Ephemeroptera according to the substrate's nature crossed by these rivers (Peridotite, limestone or schist) and its influence on the physicochemical characteristics of water. The results obtained have allowed us to identify 6 families of Ephemeroptera distributed in 15 genus and 23 species. The Baetidae are characterized by a large spatiotemporal distribution, they are the most abundant and the most diverse family with 13 species, *Baetis rhodani* which is the most represented. However, the distribution of Ephemeroptera in the two study sites differs in terms of biodiversity. Thus, the species: *Acentrella Almohades, Baetis fuscatus, Baetis meridionalis, Ecdyonurus rothschildi, Caenis pusilla Rhithrogena sp.1* and *Serratella ignita* seems to be absent in the region ultramafic of Beni Bousera which is characterized by high levels of magnesium and richness of heavy metals, especially nickel, chromium and cobalt. Anyhow, the similarities in terms of species are limited to a small number of taxa such as: *Baetis maurus, Baetis pavidus, Baetis Rhodani* and *Caenis luctuosa* who have a wide distribution. Furthermore, *Centroptilum luteolum, Procloeon concinnum* and *Habroleptoides assefae,* are exclusive species of the ultramafic region's rivers of Beni Bousera and which have a very localized distribution. Indeed, despite the proximity and contact between the two regions studied, the correspondence factorial analysis (AFC) has clearly demonstrated the separation of the 26 stations studied in two groups (on peridotite and non-peridotite) and on the basis of the spatial distribution of the species listed. Thus, this separation expresses the adaptability of the species in each group to the habitat and their ecological preferences.

1. Introduction

Since the 1990s, a growing interest is granted to the studies of the structure of the benthic invertebrate communities [1-3]. This structure is well studied in Europe and North America [4-10].

Nevertheless, the work available on North Africa generally limited in space and time is devoted mostly to systematics and rarely to their ecology or biogeography [11-28]. The South shore of the Mediterranean region seems to be very interesting and could be due to the climatic constraints specific to these environments, very different from the conditions in the South of Europe which could induce strong differences.

In addition, the larvae of Ephemeroptera are very abundant and fill the various biotopes of the current waters (rivers, streams and torrents). Various studies have shown that this group is a favorable material in ecological studies, in particular, in the estimation of the biological quality of water. They are characterized by their great bioindicative value to the nuisance undergoes by streams of water, because this group contains a high proportion of species with strict ecological requirements [29, 30]. In North Africa, due to the work of [31-33], a first faunistic list with 17 species and two subspecies was drawn up. Since then, few studies have been dedicated only to this group of insects. The main faunistic inventories are those made by: [30-35, 48, 67] having listed 69 species in the three countries of the Maghreb. The most recent work on the biology and ecology of these organisms is done by [30, 36 and 37].

In Morocco, the biotypological study of rivers date from the beginning of the 1980s; the first attempt at biotypology [38] concerned the central course of the upper Sebou. Since then, multiple works have been carried out on various atlasic networks and on the central plateau: Bouregreg [39], Ourika wadi [40], Tensift wadi [41], the whole high Sebou [42-44], N'fis wadi [45], upper and middle courses of the wadis Tensift, Dr'a, Souss [46] and Moulouya wadi [47]. The Rif also has known four biotypical studies: the first concerns the main rifain watersheds [30] and the other three have been carried out on one of the largest hydrographic networks leading to the Mediterranean, the Oued Laou [48-50].

The purpose of this work is to contribute to the knowledge of the effect of the physicochemical characteristics and the serpentine substrate of the Beni Bousera rivers on the diversity, distribution and ecology of the Ephemeroptera, and this, by a comparative study between two types of watercourse (on serpentine or on limestone) in order to reveal the differences and the similarities characterizing them while carrying out a typological study by means of a principal component analysis, a biotypological examination by the factorial correspondence analysis (AFC) in order to see the spatial structure of this group of insects according to the characteristics of the prospected areas. Moreover, due to the richness of serpentine in heavy metals, we studied their impact on the distribution and diversity of Ephemeroptera that are sensitive to changes in the environment (presence or absence of heavy metals). Thus, the study set out to highlight the specific richness of the two prospected areas by comparing them on the one hand between them, and on the other hand, with other regions of Morocco and other countries of the Maghreb.

2. Material and methods

2.1. Presentation of the study area

The study zone covers an area of more than 1200 km² extending along the Mediterranean coast from Oued Laou to Jebha between latitudes 35°05'N and 35°30'N and longitudes 5°10'E and 4°40'E (Fig. 1). 50 km to the east of Tetouan. This area is situated at the tip north occidental of the northern chain of Morocco, the Rif which contains the Beni Bousera massif (Fig. 1).

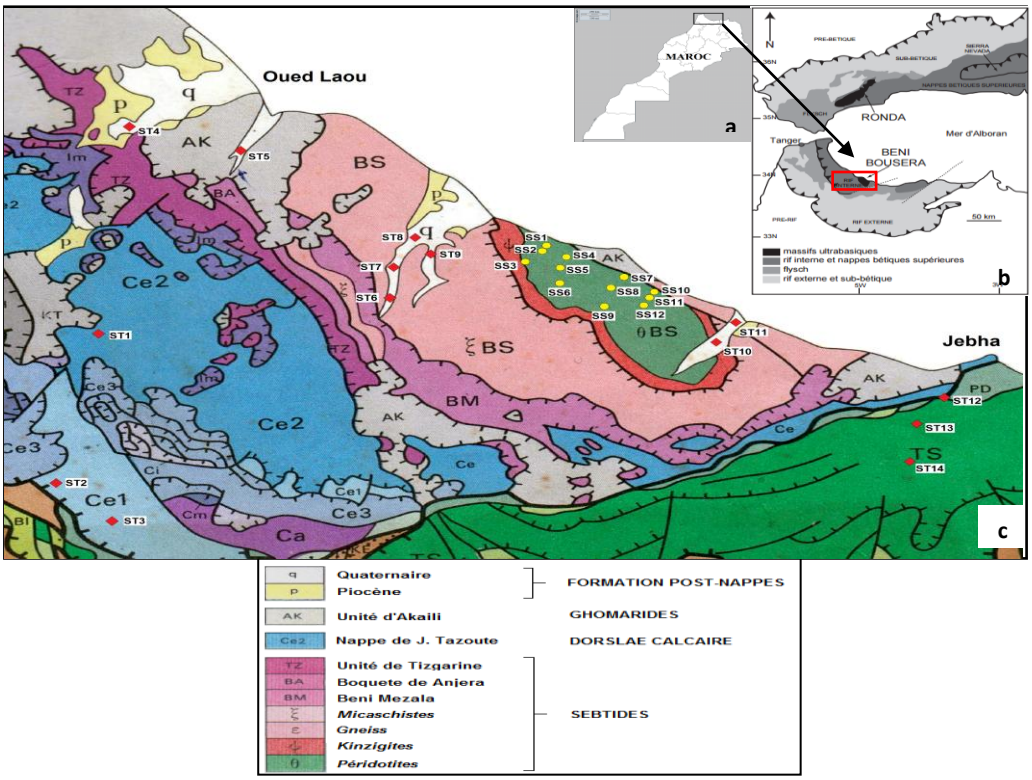

Figure 1: (a) Map of Morocco; (b) Study area; (c) Location of the prospected stations

The relief is characterized by an altitudinal gradient which rises up to 1174 m at Jbel Karbous. The study area consists of two adjacent zones: an area located at the ultramafic substrate (U) of the peridotite in the Beni Bousera massif, and an adjacent zone situated on a non-ultramafic (NU) substrate dominated by kinzigite and micaschists (Fig. 1). The climate is typically Mediterranean with oceanic influence [51]. It becomes more and more arid as it moves eastwards. Indeed, precipitation drops from 634 mm at Oued Laou to 337 mm at Jebha.

The average temperature is between 8°C and 30°C [52]. The bioclimatic of the study area is thermo-Mediterranean. The dominant plant communities matorrals corresponding to the different stages of degradation of climax communities *Tetraclinis articulata* [53-55].

2.2. Sampling stations and methods of analysis used

The choice of the selected stations was made at the base of the accessibility of the stations and the spacing between the source and the lower course by way of the average course. Thus, 12 stations in the ultrabasic region of Beni Bousera and 14 others outside this typical region were surveyed seasonally from autumn 2013 to autumn 2015 (Fig. 1) in order to determine the effect of the serpentinized substrate and the physicochemical characteristics of the streams of the ultrabasic massif of Beni Bousera crossing this substrate on the Ephemeroptera. The results obtained are compared with those of the rivers of the adjacent region not passing through the serpentine and which is totally different at the substrate.

For each station, physicochemical water parameters were measured in situ (temperature, pH, electrical conductivity, salinity, turbidity and dissolved oxygen), while Mg, Ca and TH were analyzed at the laboratory of the Loukkos Hydraulic Basin Agency within 24 hours of sampling (Tab. 1). For the metal trace elements (Nickel, Chromium, Cobalt and Iron), sampling of water and substrate (only the surface layer of the bed substrate of the river to a depth of 20 cm) achieved. The analyzes were carried out within the laboratory of the Technical Support Unit for Scientific Research (UATRS). The analytical techniques are presented in Table 1.

Table 1: Analytical methods for physico-chemical parameters and traces of heavy metals

Analyzes	Parameters	Code	Unit	Technical
In situ	Temperature	T°	°C	Measured in situ by a multi-parameter analyzer of the EUTECH INSTRUMENTS type PCD650
	Hydrogen potential	pH	-	
	Conductivity	Cond	µs/cm	
	Total dissolved solids	TDS	ppm	
	Salinity	NaCl	-	
	Dissolved Oxygen	D.O	mg/l	
	Oxygen saturation rate	D.O	%	
	Turbidity	Turb	NTU	Turbidimeter
At the laboratory	Calcium	Ca	mg/l	Determination by the molar titration method of Sodium Hydroxide, EDTA and calcon reagents
	Hydrotimetric Title	TH	°F	Determination by the molar titration method of reagents of ammoniacal buffer solution, EDTA and Eriochrome black
	Magnesium	Mg	mg/l	Difference between total hardness and calcium
	Nickel	Ni	mg/kg	Atomic emission spectrometry ICP AES (Ultima 2 - JobinYvon)
	Chromium	Cr	mg/kg	
	Cobalt	Co	mg/kg	
	Iron	Fe	mg/kg	

2.3. Sampling and determination of Ephemeroptera

In order to study the distribution of Ephemeroptera in the study area, a seasonal sampling was carried out using the net kind with 500 µm mesh, spread over two consecutive years: from March 2014 to April 2016; which allowed the prospecting of the different biotopes and to obtain a series of representative samples of each station. In the field, a preliminary sorting was conducted during which the sample was stripped of coarse material and the benthic fauna was introduced in plastic pots and fixed with 96% alcohol. A fine sorting was carried out in the laboratory during which the rest of the samples were examined under a binocular lens and all specimens identified were recovered and stored in 70% alcohol in properly labeled tubes. The identification of taxa was done using the identification keys [30, 56-59].

2.4. Statistical analysis

Statistical analyzes were performed using Statistica V6 software (StatSoft®). In order to establish a typology of rivers studied and to identify the parameters of the environment responsible for the spatial distribution of the

Ephemeroptera, a principal component analysis (PCA) of a matrix of 17 measured mesological parameters in the 26 Stations studied was carried out (Tab. 2). In order to study the spatial structure of the Ephemeroptera and the cenotic affinities between their stands in our different stations, the results were exploited using factorial correspondence analysis (AFC). A binary matrix consisting of "23 species X 26 stations" was used, where each species is represented in each station by the presence-absence criterion (0 or 1), regardless of the season in which it was recorded (Tab. 3).

3. Results

3.1. Mesological analysis

The principal component analysis (PCA) of the matrix of the mesological components shows that the first two axes F1 and F2 hold the majority of the information since they represent 50.52% of the total inertia (Fig. 2a). The examination of the correlations between the axes and the various mesological parameters studied allows to explain the significance of each axis in the structured distribution of the cloud of the stations and the relationship between the typological structure and the environment variables.

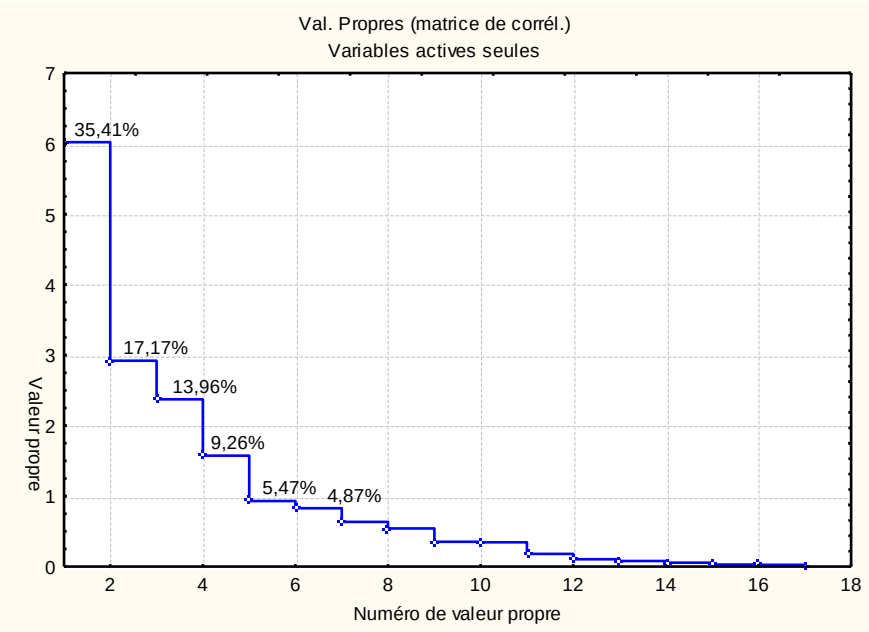

Figure 2a: The eigenvalues of the PCA

The F1 axis (32.31% of total inertia) is mainly correlated with metal trace elements (Ni, Cr, and Co), mineralization, magnesian hardness, average width and average depth. The F2 axis (18.21% of total inertia) is mainly explained by pH, dissolved oxygen, calcium hardness, temporality, average slope, temperature and altitude (Fig. 2b). Thus, the plane F1-F2 makes it possible to discriminate two groups of the stations. Ultrabasic stations are placed to the left of the factorial plane while the non-ultrabasics are positioned to the right (Fig. 2c).

Group 1: contains the 12 stations in the ultrabasic region of Beni Bousera (SS1, SS2, SS3, SS4, SS5, SS6, SS7, SS8, SS9, SS10, SS11 and SS12) (Fig. 2c) which are permanent and semi-permanent mountain rivers of low altitude and very steep. They are characterized by a small width (0.2 and 1.6 m) and temperate waters (15.30 and 20.25°C). This group is subdivided into 3 subgroups (Fig. 2c):

- Subgroup 1.a: contains station SS3 which has the highest conductivity value (1404.00 µs/cm) and Ca (206.32 mg/l).
- Subgroup 1.b: includes stations (SS4, SS5, SS6, SS8, SS9 and SS12) with an average altitude (100 and 560 m). They have high Ca concentrations (95.92 and 168.18 mg/l).
- Subgroup 1.c: encompasses stations (SS1, SS2, SS7, SS10 and SS11) of low altitude (90 and 250 m). They are characterized by a high mineralization (961.15 and 1190.75 µs/cm), having a high magnesian hardness (85.43 and 152.14 mg/l) and high contents of metal trace elements (MTE) mainly of nickel (622.93 and 1102.30 mg/kg), chromium (46.42 and 98.54 mg/kg) and cobalt (26.29 and 56.72 mg/kg). They are thus very enriched by metals by contribution to the other stations of the same group (Gr1).

Group 2: gathers the 14 stations in the non-ultrabasic region (ST1, ST2, ST3, ST4, ST5, ST6, ST7, ST8, ST9, ST10, ST11, ST12, ST13 and ST14) (Fig. 2c). They have an average mineralization (548.64 µs/cm) and a low magnesian hardness (10.98 mg/l). They are characterized by low levels of MTE and also by high levels of organic matter, which leads to the excessive development of algae (Fig. 2b). This group, in turn, is subdivided into 2 subgroups (Fig. 2c):

- Subgroup 2.a: counts the stations (ST1, ST2, ST3, ST4, ST6, ST7, ST8, ST13 and ST14) with high calcium hardness (92.20 and 234.64 mg/l) and an average width (0.3 and 20 m).
- Subgroup 2.b: includes stations (ST5, ST9, ST10, ST11 and ST12) of low altitude (10 and 80 m). They are characterized by a high degree of dissolved oxygen (5.80 and 78.40%) and alkaline waters (7.71 and 8.62).

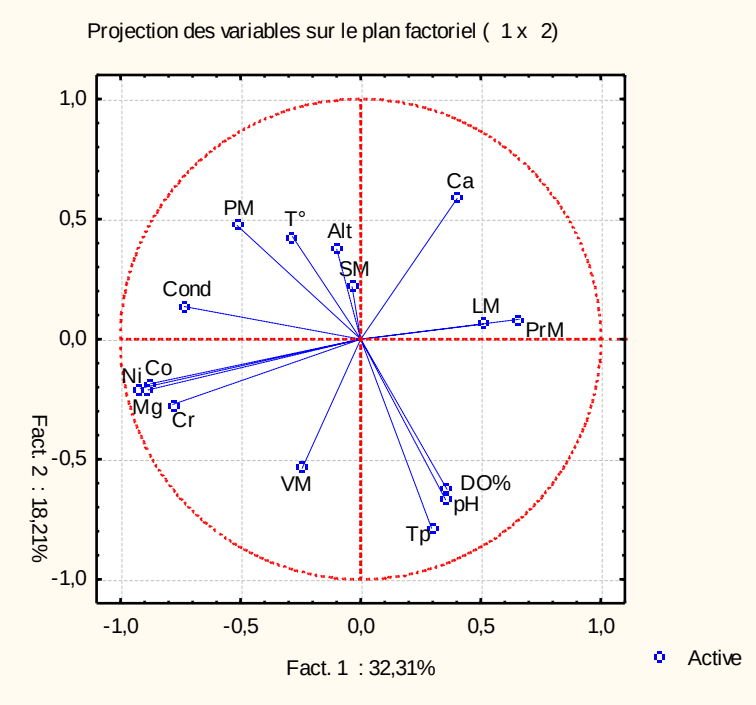

Figure 2b: Plan F1-F2 of the PCA: structure of the cloud-mesological parameters of the study region

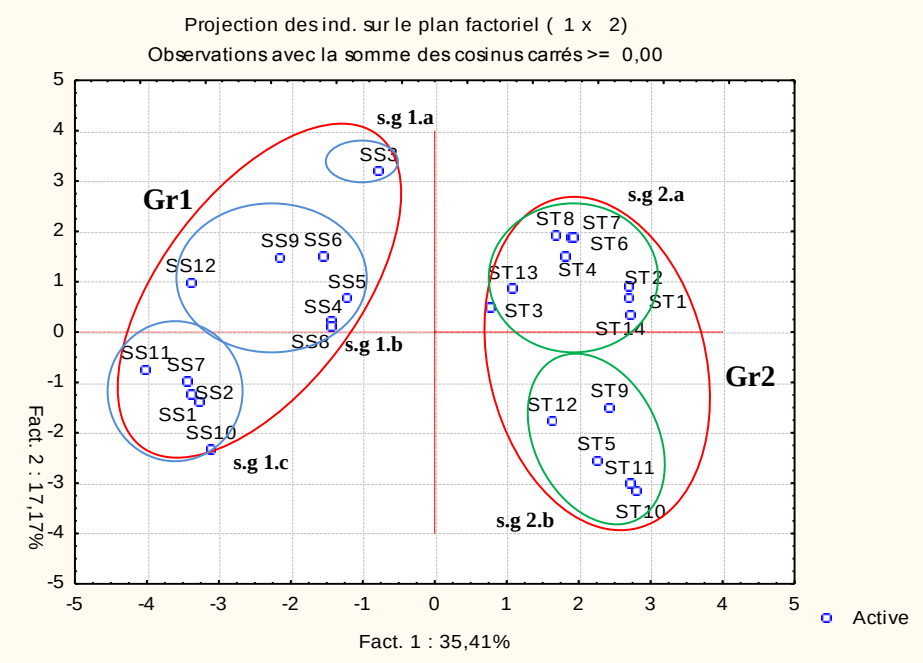

Figure 2c: Plan F1-F2 of the PCA: structure of the cloud-stations of the study region

Table 2: Matrix of the mesological data used to establish the typology of the studied stations.

Stations	KE	S.M	S.M.F	TZ	QA	KSU	KMO	KIN	BO	AMS	AMI	OI	OM	OS	AZI	AZM	AZS	SYI	SYM	SYS	JNI	JNM	JNS	AAI	AAM	AAS
Code	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	ST12	ST13	ST14	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	SS10	SS11	SS12
Mesological parameters																										
Rock (Non-Peridotite (1), Peridotite (2))	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2
Altitude (m)	460	872	1600	12	72	105	68	38	35	40	10	25	60	95	166	240	484	107	181	348	93	215	560	128	200	305
Average slope %	100	140	170	5	6	15	10	7	7	10	6	7	8	10	75	100	240	60	100	180	50	125	270	60	100	250
Average width (m)	6	0.5	0.3	20	1.4	3	4.7	3.8	4.6	3.8	3	2.7	1.9	5.6	1	1.3	0.2	1	2.3	1.6	0.8	0.6	0.4	0.5	0.4	0.8
Average depth (m)	0.5	0.2	0.1	0.2	0.15	0.3	0.25	0.15	0.3	0.3	0.15	0.15	0.2	0.4	0.1	0.1	0.1	0.15	0.2	0.25	0.1	0.1	0.1	0.1	0.1	0.1
Current Speed (s/m)	4.4	3.6	5.9	9.4	6.2	3.8	3.4	4	4.2	7.5	8	7.8	6.9	4.2	11.5	10.8	3.4	5.9	4.6	3.1	7.6	7	6.4	5.3	5	4.8
Temporality (Temporary (1), Semi-temporary (2), Permanent (3))	3	3	3	3	1	3	3	3	2	2	2	1	2	2	3	3	3	3	3	3	2	2	3	2	2	3
Mineral substrate (Thin (1), Medium (2), Coarse (3))	2	2	2	1	2	3	3	3	2	3	3	3	3	3	2	2	3	3	3	3	2	3	3	2	3	3
Conductivity (uS/cm)	523.40	388.10	356.85	514.25	627.40	661.48	635.68	631.20	509.25	399.10	463.50	644.40	660.60	665.80	1180.50	1190.75	1404.00	956.03	938.93	907.33	972.70	654.83	645.35	1005.00	961.15	906.63
Degree of dissolved oxygen (%)	23.21	7.33	22.05	25.58	62.40	24.25	25.33	9.60	37.50	71.20	78.40	5.80	5.85	6.70	30.35	30.15	9.93	28.94	29.61	17.40	15.53	13.23	12.75	9.20	8.70	13.78
pH	8.01	7.59	7.79	7.01	8.10	7.08	7.17	7.41	7.71	8.48	8.62	8.29	6.72	8.36	7.70	7.71	7.03	7.70	7.69	7.61	7.27	7.23	6.83	8.35	6.63	7.12
T°	15.05	13.93	13.80	20.38	15.00	19.73	20.30	20.03	17.00	14.90	15.00	15.00	18.70	15.50	18.78	18.60	16.98	18.70	19.23	20.25	20.17	17.13	16.73	15.30	16.80	18.68
Calcium hardness (mg/l)	148.48	134.37	92.20	224.82	100.48	210.66	211.66	228.62	60.04	71.04	157.92	98.56	166.24	234.64	139.18	124.92	206.32	165.38	158.82	129.08	141.60	168.16	123.08	24.40	19.32	95.92
Magnesium hardness (mg/l)	15.06	4.15	1.02	12.65	17.41	3.01	12.36	7.10	43.86	21.25	0.00	2.87	12.96	0.00	96.92	152.14	51.60	86.62	69.36	89.47	85.43	46.06	38.80	137.61	147.21	78.44
Ni teneure (mg/kg)	6.41	6.85	109.35	13.25	20.33	21.96	20.12	19.93	14.74	72.17	76.74	31.32	30.29	31.21	698.71	622.93	0.00	349.06	381.80	352.67	1046.37	509.09	526.99	1102.30	961.71	972.73
Cr teneure (mg/kg)	33.43	9.33	42.77	19.96	21.34	27.15	23.59	22.21	18.00	29.87	32.14	38.34	37.11	40.62	98.54	84.70	0.00	56.98	56.42	51.20	70.30	58.42	49.68	46.42	80.50	53.12
Co teneure (mg/kg)	4.91	6.78	13.01	4.63	7.58	7.13	5.91	6.13	4.95	8.80	9.09	9.95	9.30	9.32	30.37	26.29	0.00	22.70	21.62	21.34	56.72	26.71	30.79	45.69	40.23	41.10

Table 3: Faunistic matrix used in the AFC for the establishment of a biotypology of the hydrographic networks of the study region. The numbers represent the presence-absence criterion (0 or 1).

	Code	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	ST12	ST13	ST14	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	SS10	SS11	SS12
Acentrella almohades	**AAL**	0	0	0	0	0	0	0	0	0	0	**1**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alainites muticus	**AMU**	0	**1**	**1**	0	0	0	0	0	0	0	0	0	0	0	**1**	0	0	**1**	0	**1**	**1**	**1**	**1**	0	**1**	**1**
Baetis fuscatus	**BFU**	**1**	0	0	0	0	**1**	**1**	0	**1**	**1**	**1**	**1**	**1**	**1**	0	0	0	0	0	0	0	0	0	0	0	0
Baetis maurus	**BMA**	**1**	0	0	0	**1**	**1**	**1**	0	**1**	0	**1**	**1**	**1**	0	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Baetis meridionalis	**BME**	0	0	0	0	**1**	**1**	**1**	**1**	0	0	**1**	0	**1**	**1**	0	0	0	0	0	0	0	0	0	0	0	0
Baetis pavidus	**BPA**	0	0	0	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	0	0	0	0	**1**	**1**	0	**1**	0	0	**1**	0
Baetis rhodani	**BRO**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Baetis punicus	**BPU**	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cheleocloeon dimorphicum	**CHD**	0	0	0	0	0	0	0	0	**1**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Centroptilum luteolum	**CLT**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	**1**	0	0	0	**1**	0	**1**	**1**	0	0	0
Cloeon dipterum	**CDI**	**1**	0	**1**	0	0	0	**1**	**1**	0	0	0	0	0	0	**1**	**1**	**1**	**1**	0	**1**	**1**	**1**	0	0	0	**1**
Cloeon simile	**CSI**	0	0	0	0	0	0	**1**	0	0	0	0	0	0	0	0	**1**	0	0	0	0	0	0	0	0	0	0
Procloeon concinnum	**PCO**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	0	0	0	0	0	**1**	0	0	0	0
Ecdyonurus rothschildi	**ERO**	0	**1**	0	**1**	0	**1**	**1**	**1**	**1**	**1**	**1**	0	**1**	0	0	0	0	0	0	0	0	0	0	0	0	0
Epeorus sylvicola	**ESY**	0	**1**	0	0	0	**1**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caenis luctuosa	**CLU**	**1**	0	0	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Caenis pusilla	**CPU**	**1**	0	0	**1**	0	**1**	**1**	**1**	**1**	**1**	**1**	**1**	0	**1**	0	0	0	0	0	0	0	0	0	0	0	0
Habrophlebia sp.1	**HSP**	**1**	**1**	0	**1**	0	0	0	0	**1**	0	0	0	0	0	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Choroterpes atlas	**CCA**	0	0	0	**1**	0	0	0	0	**1**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Habroleptoides assefae	**HAS**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	0	**1**	0	0
Rhithrogena sp.1	**RSP**	0	0	0	0	0	0	0	0	0	0	0	0	**1**	**1**	0	0	0	0	0	0	0	0	0	0	0	0
Serratella ignita	**SIG**	**1**	0	0	**1**	0	0	0	0	0	0	**1**	0	**1**	0	0	0	0	0	0	0	0	0	0	0	0	0
Pothamanthus luteus	**PLU**	0	0	0	**1**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

3.2. Biotypical structure

3.2.1. Faunistic list with comments

We were able to identify 6 families in 15 genera and 23 species, with 20 species in stations in the NU region and only 11 species in stations in region U (Fig. 3).

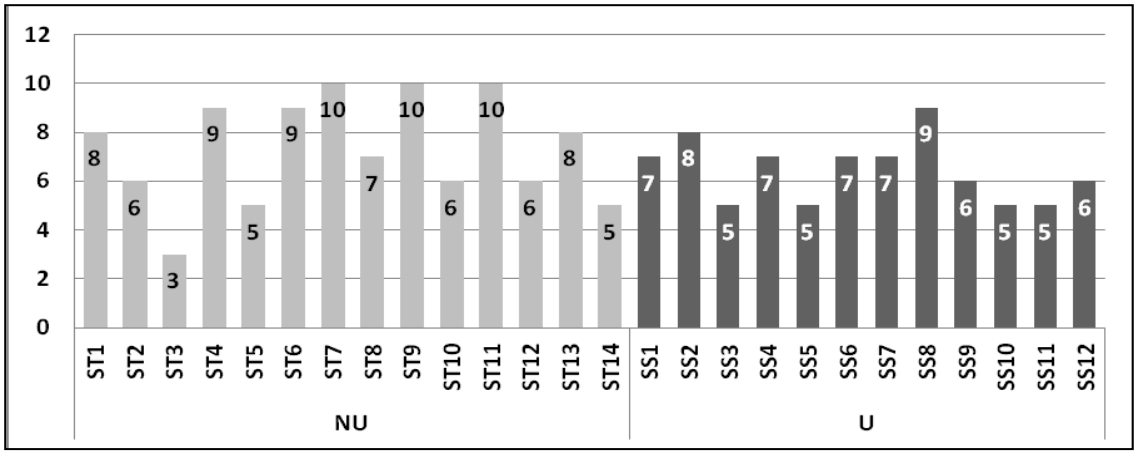

Figure 3: Specific richness of Ephemeroptera in the different studied stations

F. BAETIDAE

It is the most diverse family in our study area. It is represented by 13 species:

Acentrella almohades Alba-Tercedor and El Alami, 1999

Has a very restricted distribution since it is harvested in a single station (ST11). It is a large river from low altitude (10m) to temperate winter.

Alainites muticus Linné 1758

Larvae of this species apparently prefer source emissaries [50]. A strong presence is observed at the permanent and semi-permanent stations (SS1, SS4, SS6, SS7, SS8, SS9, SS11, SS12) of the ultrabasic region and two permanent stations of the non-ultrabasic region (ST2 and ST3), the substrate of which consists of encrusted rollers covered with foams and whose current is moderate in places.

Baetis fuscatus Linnaeus 1761

It has a clear preference for temperate waters (mean 15 to 19°C) of Amter (ST10 and ST11) and Ouringa (ST12, ST13 and ST14) and permanent temperate waters of Laou (ST1) and Tihissasse (ST6, ST7 and ST9).

Baetis maurus Kimmins, 1938

It is confined to cold and fast waters. Mountain streams are his favorite habitat. It has a clear preference for rhithral [61]. In our study area, it inhabits the temperate and highly mineralized waters of the ultrabasic region and has an average distribution between 10 and 560 m altitude. Furthermore, in the High Atlas, it was sampled between 1500 and 2300 m [46].

Baetis meridionalis Ikonomov, 1954

This species has a very restricted distribution and has been found in seven stations in the non-ultrabasic region distributed over the lower reaches of the different Mediterranean river systems (Tihissasse, Amter and Ouringa). However, it appears to be absent in the rivers of the ultrabasic region.

Baetis pavidus Grandi 1949

Thermophilic, this taxon is present in all the stations of the NU region with the exception of stations ST1, ST2, ST3 and eight stations of the ultrabasic region, probably due to the freshness of their water.

Baetis rhodani Pictet 1984

It is the most eurytope of the harvested species and is found in very varied biotopes (sources, emissaries of springs, rivers) and distributed in an altitudinal margin between 10 and 1600 m.

Baetis punicus Thomas, Boumaiza & Soldan, 1986

It was harvested only in station ST2, it is a permanent fresh source (13°C) of medium altitude (880 m) and strongly shaded.

Cheleocloeon dimorphicum Soldan and Thomas, 1985

In Algeria, this taxon mainly inhabits permanent watercourses where it prefers areas with stony bottom, rich in plant debris and with relatively strong current [62]. In the Rif, he was represented by a single individual collected for the first time at the Oued Laou [48]. In our study area, we were able to harvest one individual in a temporary stream (ST9).

Centroptilum luteolum Müller 1776

It was harvested in the calm waters of the borders of five stations in the ultrabasic region. A dozen individuals were harvested at two stations (SS8 and SS9). The distribution of this species appears to be related to soft substrates, low currents, high temperatures, and biotopes rich in filamentous algae and upper foam mosses [63].

Cloeon dipterum Linné 1761

It was collected at eight permanent and semi-permanent stations in the ultrabasic region (SS1, SS2, SS3, SS4, SS6, SS7, SS8 and SS12) with calm temperate water biotopes and four stations in the non-ultrabasic region (ST1, ST3, ST7 and ST8). This species has a very wide distribution, between 30 and 1400 m altitude.

Cloen simile Eaton, 1870

This species was found only in two stations, one in the ultrabasic region of Beni Bousera (SS2) at 250 m altitude and the other in the adjacent non-ultrabasic region (ST7) at 60 m altitude. These two stations are permanent of the average course having an average width (1.3 and 4.7 m).

Procloeon concinnum Eaton, 1885

It is also very rare in our sample collections and presents a discontinuous distribution, affecting the temperate and warm waters of the permanent and semi-permanent stations of the middle course of the two watersheds Amazithen and Jnane Niche.

F. HEPTAGENIIDAE

We harvested three species in our study area belonging to three different genus:

Ecdyonurus rothschildi Navas 1929

In the non-ultrabasic region, it is very widespread in temporary and permanent stations of low and medium altitude (25-800 m) with strong current; However, it is absent in all stations in the ultrabasic region, probably because of the low current and high mineralization of their water.

Epeorus sylvicola Pictet 1865

It is confined to the emissaries of sources of the upper course of the Laou (ST2) and middle of Tihissasse (ST6) and does not appear in the rivers of the ultrabasic region.

Rhithrogena sp.1

This species is located in two permanent stations of the middle course of Ouringa, located at an altitude of 60 to 100 m, characterized by low mineralized water, highly oxygenated and a stony river bed.

F.CAENIDAE

Caenis luctuosa Burmeister, 1839

Eurytope and eurytherme, in the study area, this taxon swarms as in other Moroccan [30, 34, 48, 67], Tunisian [12, 66, 68-70] and Algerian hydrographic networks [18, 26, 35, 80 and 95] in the mineralized waters of the middle and lower courses. It appears to be absent in two stations (ST2 and ST3) of the non-ultrabasic region at high altitude (900 and 1600m), fast current and very fresh water.

Caenis pusilla Navas, 1913

This species has an average altitudinal distribution ranging between 25 and 400 m. It inhabits the permanent and temporary stations of the non-ultrabasic region; Nevertheless, it appears to be less tolerant to thermal variations than *C. luctuosa* [18, 96, 97] and adapts better to fast flows. However, it is absent in all stations in the ultrabasic region, probably because of the high mineralization of their water.

F. LEPTOPHLEBIIDAE

Habrophlebia sp.

In the study area, it is the species of Leptophlebiidae the most alticole (900 m), but it can go down to 12 m (ST4). It swarms in all stations in the U region corresponding to the most mineralized biotope in the study region. Similarly, we harvested it in four permanent stations of the NU region.

Choroterpes (Choroterpes) atlas Soldan and Thomas 1983

It is a thermophilic species that has been located in two temporary stations (ST4 and ST9) of the lower course characterized by a relatively low flow rate and temperate waters (17 to 21°C).

Habroleptoides assefae Dartori and Thomas, 1986

It was harvested only in two stations (SS8 and SS10) of emissaries of source of ultrabasic rivers: Jnane Niche and Aârkob.

F. EPHEMERELLIDAE

Serratella ignita Poda 1761

This species is essentially subservient to permanent or temporary source emissaries characterized by low mineralized waters, fresh and rich in mosses and filamentous algae. However, it was harvested in large permanent streams (ST1 and ST4) and temporary (ST11 and ST13) where the temperature is between 15 and 20°C.

F. POTAMANTHIDAE

Potamanthus luteus Linné 1789

It is a thermophilic species that has been harvested only in the permanent station (ST4) of the lower course of Laou where the thermal average is 20°C. It has a very low abundance in the facies of large river of low and medium altitude [30, 44].

3.2.2. Ephemeroptera biocenotic groups: *Biotypological analysis*

In a first analysis of table 3, it was found that the three stations: ST2, ST4 and ST9 showed high inertia due to the presence of exclusive species. This hid the bulk of the information about the clouds of stations and species, which prompted us to make a second analysis by considering these stations as additional elements.

The first three axes accumulate 48.41% of the total inertia of the points with 22.11% for the F1 axis and 14.91% for the F2 axis. Analysis of the biotypological structure shows that there is a clear structuring and differentiation in the stands of the two types of sites (Fig. 4a). Indeed, in the F1-F2 plan, two groups, each with a specific fauna and character, were differentiated (Fig. 4a and 4b).

Grouping I (Gr I) of stations of emissaries of perennial stenothermal sources of high and medium altitude and very steep of the U region of Beni Bousera. They are the most inclined of the study area. These stations are located in the left part of the factorial plane F1-F2 (Fig. 4a). They are characterized by temperate waters with high conductivity and calcium and magnesian hardness and high levels of ETM, with a fairly low current, low depth and a varying particle size (pebbles, gravel and sand). Their stands contain the species: *Centroptilum luteolum*, *Procloeon concinnum* and *Habroleptoides assefae*.

Grouping II (Gr2) of stations of the non-ultrabasic region, weakly mineralized, fresh and temperate, with strong current, with granulometry dominated by large pebbles, large width and medium depth. These stations are located towards the opposite side (right) of the plane F1-F2 (Fig. 4a). This grouping is home to the species *Acentrella almohades, Baetis fuscatus, Baetis punicus, Cheleocloeon dimorphicum, Ecdyonurus rothschildi, Epeorus sylvicola, Caenis pusilla, choroterpes atlas, Rhithrogena sp.1, Serratella ignita* and *Pothamanthus luteus.*

As for the permanent station ST2 of high altitude and low mineralization of the NU area, located on the upper course of the Maggo wadi characterized by very fresh water, moderate current, average depth, high slope and strong shade, is individualized by exclusive and rare species: *E. sylvicola* and *B. punicus*. This explains its distance from the origin of the axes (Fig. 4a).

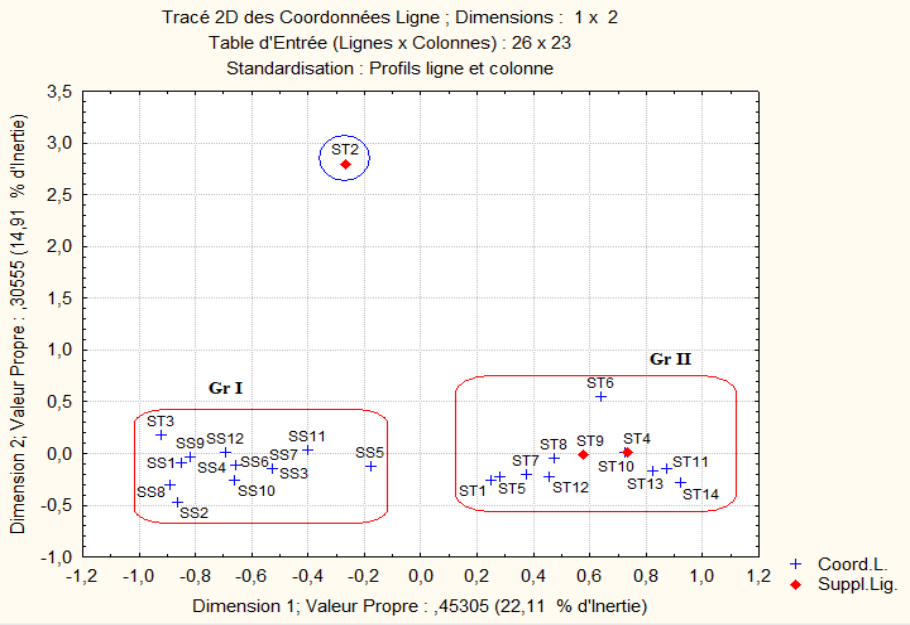

Figure 4a: Biotypology of the study area: structure of the cloud-stations in the F1-F2 plane of the AFC (ST2, ST4 and ST9 stations projected into additional elements).

For faunal groups, the distribution of species in the F1-F2 plane shows 3 groups (Fig. 4b):

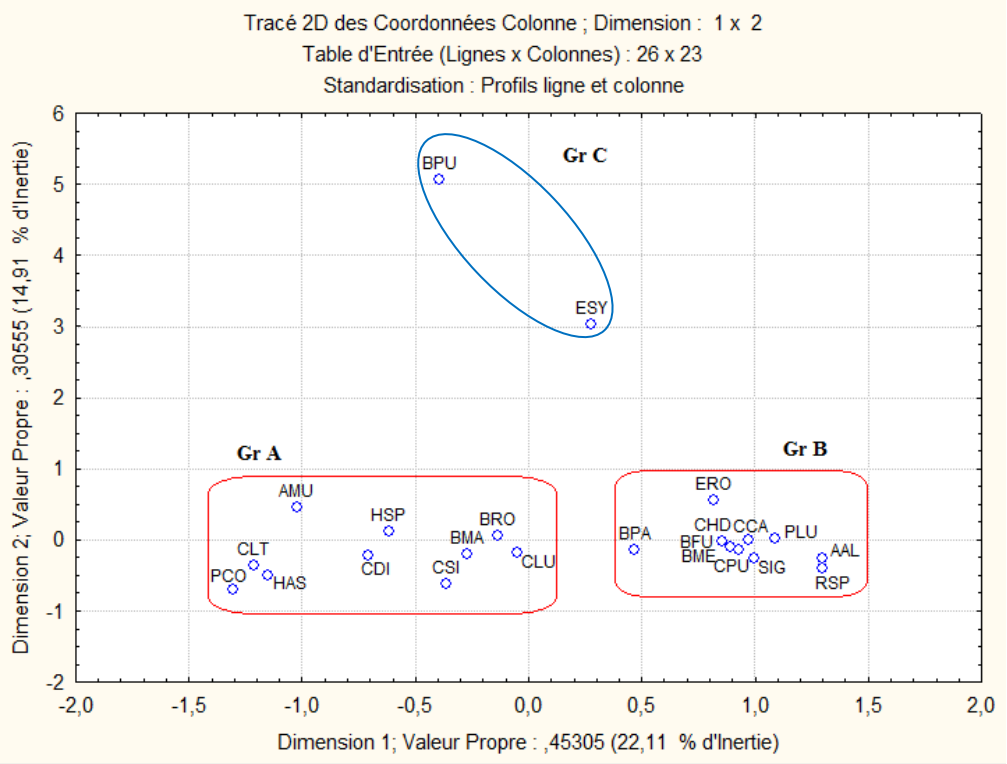

Figure 4b: Biotypology of the study region: structure of the cloud-species in the F1-F2 plane of the AFC

Grouping A: It is constituted by the species inhabiting the emissaries of sources that mark a preference to small streams of permanent water (20 to 40 cm wide and shallow). They are small mountain rivers of low altitude, with temperate winter and hot summer, very steep and highly mineralized water and very enriched by MTE and very alkaline from the U region of Beni Bousera: *A. muticus, C. luteolum, C. dipterum, C. simile, Habrophlebia.* Sp.1, *B. punicus, P. concinnum* and *H. assefae*. They are stenotopic, thermophilic and lenitophilic species which prefers the relatively calm waters with a stony bottom dominated by the gravels characterizing the stations of the rivers of the U region. While the last three species preferentially inhabit the emissary of the sources and are fond of SS1, SS2, SS6, SS8, SS9 and SS10 in the same region.
Indeed, *B. rhodani, B. maurus* and *C. luctuosa* are taxa with a wide latitudinal distribution in the study area. The first two prefer to live in the fresh flowing waters of the upper reaches. They have relatively wide ecological valency by inhabiting both strongly and moderately mineralized streams.

Grouping B: This group is ecologically heterogeneous. By grouping stands of taxa from medium to low altitude river stations. Their presence varies according to their degree of biotope preference. Thus, it consists of: A set of thermophilous and rare species preferring relatively calm waters, both very scanty and very infrequent: they are very localized species and exclusive to stations ST4, ST9, ST11, ST13 and ST14: *A. almohades, Ch. Dimorphicum, Ch. Atlas, Rhithrogena sp.1* and *P. luteus*. In general, species of well-specialized biotopes prefer low-mineralized and relatively fast-flowing waters with a stony bottom dominated by pebbles. *S. ignita* occupies an average altitudinal margin (10-500 m). In the study area, this species is mainly confined to permanent or temporary rivers with moderate current. It prefers fresh and mineralized waters rich in moss and filamentous algae. In addition, *B. fuscatus, B. meridionalis, B. pavidus* and *C. pusilla*, which are thermophilic and potamobiontes living in the middle and lower of plain course. They support much better the elevations of temperature and descend much lower in the lower course; *E. rhotschildi*, the most eurythermal and thermophilic species of Heptageniidae [44]. These taxa seem to tolerate pollution and flow disruptions.

Grouping C: It is represented by two exclusive and rare species: *E. sylvicola* and *B. punicus* preferring the permanent course of high altitude and low mineralization. Their preferred biotope is localized in the station (ST2) of the NU region which is characterized by very fresh water, a moderate current, an average depth, a large slope and a granulometry based on coarse gravel sand and is highly shaded.

4. Discussion

The species richness is influenced by environmental conditions [64 and 95]. Indeed, the fauna of the Ephemeroptera was qualitatively rich (23 species) which represents 12% of the total (in specific richness) of the ephemeroptera of Morocco. The richest stations are stations in the NU region with 20 species (7%), and the less rich are stations in the U region with 11 species (4%) (Fig. 5 and Tab. 4).

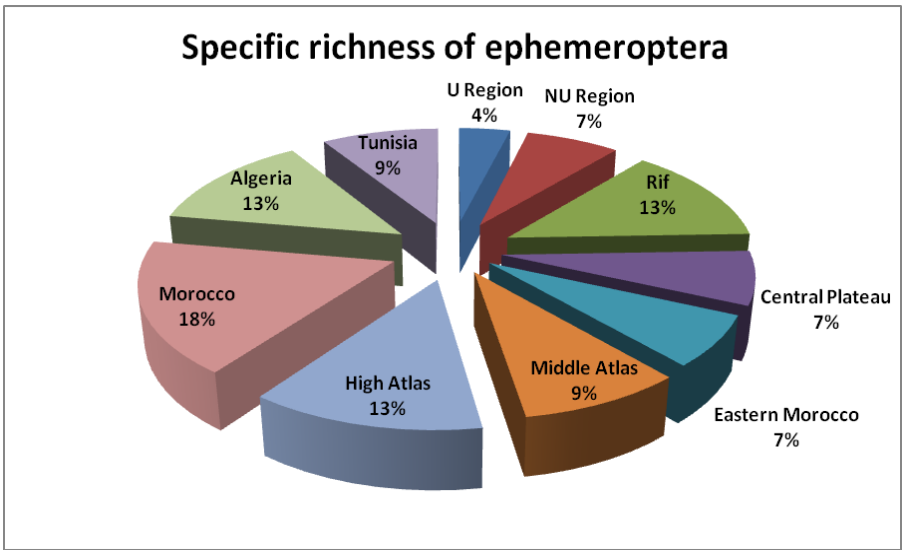

Figure 5: Specific richness of Ephemeroptera by regions of Morocco and the Maghreb

Table 4: Comparison of the specific richness (by genus) of the Ephemeroptera of the two study regions (U and NU) with those of other regions of Morocco and the Maghreb (Rif, Central Plateau, Eastern Morocco, Middle Atlas, High Atlas, Morocco, Algeria and Tunisia). [30, 79, 99-101, 14, 42, 44, 46, 65, 18, 26, 35, 80, 95, 12, 21, 66, 68, 69, 70-73 and 113].

Genus	U Region	NU Region	Rif	Central Plateau	Eastern Morocco	Middle Atlas	High Atlas	Morocco	Algeria	Tunisia
Acentrella		1	1					1		1
Afronurus										1
Alainites	1	1	1				1	2	1	1
Baetis	3	6	7	4	4	5	7	7	7	3
Caenis	1	2	2	1	1	1	2	2	5	2
Centroptilum	1		1	1	1	1	1	1	2	1
Cheleocloeon		1	1				1	1	1	1
Choroterpes		1	3	2	2	2	2	3	2	2
Cloeon	2	2	2	1	1	1	1	2	3	2
Ecdyonurus		1	2	2	2	2	2	2	3	1
Epeorus		1	1				1	1		
Ephemera			1	1		1	1	1	1	1
Ephoron			1	1		1	1	1	1	1
Habroleptoides	1		1		1		2	2	1	
Habrophlebia	1	1	1	1	1	1	2	3		1
Labiobaetis			1	1		1	1	1	1	1
Nigrobaetis			2					2	1	1
Oligoneuriella						1	1	1	1	
Oligoneuriopsis			1	1	1	1	1	1	1	1
Paraleptophlebia				1	1	1	1	1	1	
Potamanthus		1	1			1	1	1	1	1
Procloeon	1		2	1	1	1	1	3	1	1
Prosopistoma							1	1	1	
Rhithrogena		1	4	1	2	2	2	7		1
Serratella		1	1	1		1	1	1	1	
Sparbarus					1	1	1	1	1	1
Total	**11**	**20**	**37**	**20**	**19**	**25**	**35**	**49**	**37**	**25**

The Ephemeroptera of watercourses in the study area presents overall a relatively rich diversity (23 species) compared to that of the other rivers of the Mediterranean basin. Indeed, the specific richness of the ephemeroptera of the rivers of the studied area is comparable to that of the northern shore of the Mediterranean: the Balearic Islands (10 species) [105, 111], northeastern Spain (17 species), Corsica (19 species), Argens (21 species) and Sicily (26 species) [74, 75 and 96]. However, it remains very weak compared with the European networks: 40 species in the Doubs basin [76, 96], 22 to 79 species according to the Polish networks [77], 64 species in southwestern France [78, 96] and 148 in the Iberian Peninsula networks [105-111]. In addition, compared with other regions of Morocco and the Maghreb countries (Tab. 4 and Fig. 5): 37 species in the Rif (13%) [30], 20 species in the Central Plateau (7%) [79] 19 species in Eastern Morocco (7%) [99-101 and 103], 25 in the Middle Atlas (9%) [44] and 35 in the High Atlas (13%) with a high proportion of endemic orophilic species [46, 102]. And in comparison with the other Maghreb countries (Tab. 4): 37 in Algeria (13%) [18, 26, 35, 80, 95] and 25 in Tunisia (9%) [12, 66, 68-70 and 113]. The Ephemeroptera community in the study area is diverse. This can be explained by a moderate climate and average rainfall (660 mm).

The parameters that seem to influence most the distribution of species in the two study regions are the nature of the substrate (serpentine or calcschist), the physicochemical parameters of the water (electrical conductivity, alkalinity, calcium and magnesian hardness) and ETM content (Ni, Cr and Co). In addition, temperature, altitude and riparian vegetation also play a non-negligible role in the distribution of the inventoried species. This has been demonstrated by Gagneur and Thomas [18] in the rivers of Orania West of Algeria (Tafna) and by Boumaïza [21] in Tunisia. Other factors combined with these, such as current velocity, slope and temporality, would also be responsible for this distribution as has been demonstrated by El Alami [30] in the rivers of the Oued Laou watershed in the Rif.

Thus, according to the analysis of specific richness (Fig. 3), stations with a high richness are stations in the NU region with 20 species. They are characterized by low mineralization, abundant riparian vegetation which ensures the control of the physical conditions of the aquatic environment by the supply of nutrients and organic debris, the regulation of water temperature, the retention of possible pollutants and the presence of biological support and shelter for adults. On the other hand, stations with a low richness are the stations of the U region of Beni Bousera with only 11 species. They are stations with hydrological stresses. Generally, riparian serpentinophilous vegetation is poor in biodiversity and number of individuals and characterized by low growth and dwarfism [81]. The growth of riparian vegetation may also be inhibited by a high level of MTE as well as calcium / magnesium depletion and consequently the increase in water temperature during the summer period (between 20 and 30°C), due to lack of shade of the ripisylve. In addition, all stations in this region are highly mineralized, highly enriched by MTE and located in an area that is under increasing human pressure (high agricultural activity, cultivation of cannabis on riverbanks, pasture, decrease in flow due to the diversion of water and the capture of sources, etc.). This high mineralization, high MTE concentrations and anthropogenic activities can significantly affect the structure and distribution of benthic fauna.

Also, in this typical region, two categories of ephemeroptera species are distinguished: species that are well adapted and subservient to serpentine, and preferential species that tolerate high levels of mineralization. In our study area, exclusive species are found only in the streams of the serpentine outcrop of Beni Bousera. However, they can be found in different rivers and in different regions of Morocco [30, 42-44]. As for preferential species, they are not found only in serpentine rivers, although they have a marked preference for them, but also in the NU region.

Moreover, among the 20 species of NU rivers, 5 endemic species were identified: *Cheleocloeon dimorphicum, Acentrella almohades, Choroterpes atlas, Ecdyonurus rothschildi* and *Epeorus sylvicola*. On the other hand, *Caenis luctuosa, Serratella ignita, Rhithrogena sp, Caenis pusilla, Pothamanthus luteus*, and *Habrophlebia* sp.1 mostly colonize the most diversified medium to rapid habitats. They are eurytherms and polluo resistant. In this region, ecological conditions seem to be favorable and the great diversity of habitats has allowed the development of a species-rich and fairly balanced community (20 species).

In addition, the genus Baetis is present in all stations in this region. The most constant species are *B. pavidus* and *B. rhodani*. They have a wide ecological valency. These two species coexist in 11 stations in the study area. Nevertheless, *B. rhodani* is the most eurytope and eurytherme of the fauna of the streams studied. Indeed, we harvested it in all the 26 prospected stations of the two regions (U and NU) spread between 10 and 1600 m of altitude.

Based on the longitudinal distribution of the species, the Ephemeroptera fauna of the study area can be divided into three categories: (1) Exclusive species of serpentine streams: *Centroptilum luteolum, Procloeon concinnum* and *Habroleptoides assefae*, (2) Species specific to non-serpentine rivers: *Baetis fuscatus, Baetis meridionalis, Baetis punicus, Cheleocloeon dimorphicum, Acentrella almohades, Choroterpes atlas, Ecdyonurus rothschildi,*

Epeorus sylvicola, Serratella ignita, Rhithrogena sp, Caenis pusilla and *Pothamanthus luteus* and (3) Species common to all stations: *Baetis maurus, Baetis pavidus, Baetis rhodani, Caenis luctuosa, Alainites muticus, Cloeon dipterum, Cloeon simile* and *Habrophlebia sp.*

The spatial distribution of the benthic macroinvertebrates of the hydrographic networks studied is dependent on environmental factors [30, 95, 98, 103, 110 and 112]. The variations observed in the structure of communities depend more or less directly on changes in these factors. Indeed, several studies have shown that the nature of the substrate [76, 82-85], chemical characteristics of water [94], altitude, slope, thermal regime, depth and the speed of the current [30, 38, 39, 42, 45-49, 86-88,] are the predominant parameters in the characterization of the species. Other factors also have a certain importance in the distribution of species: ripisylve [89] and biotic phenomena (growth rate, feeding rate, reproduction rate, duration of life, various metabolic capacities, endogenous activity rhythms, mobility) [90, 91].

Given this very large number of parameters that explain the biological structure, we agree with Ulfstrand [93], Bournaud and Keck [94], and Dakki [42], who assert that determinism of biocenoses cannot be explained solely by simple relationships between a mesological parameter and a particular species, for it is impossible to precisely determine the level action of each component along the biological structure, rather it is the combination of ecological factors manages this structure.

Conclusions

The fauna inventory carried out in this study constitutes an important database of the hydrographic networks of the Beni Bousera region and the adjacent networks. The fauna studied is characterized by significant taxonomic diversity. In fact, the richest stations are the stations of the non-serpentine region, and the less rich are the stations of the serpentine region simply because many species of Ephemeroptera do not tolerate the high rate of mineralization specific to this typical region.

A typology of the mesological and physicochemical parameters of the study stations has been demonstrated and in general two groups of stations have been identified: stations of emissaries of perennial stenothermal sources of high and medium altitude and very steep, highly mineralized with a fairly low current, with a low depth and a very diversified granulometry and very enriched by the MTE of the U region and the weakly mineralized, fresh and temperate NU stations with strong current, with diversified granulometry, large width and average depth.

In addition, a biotypology was revealed during the study and allowed to individualize the same groupings of the stations of the typological study in addition to a third grouping containing a single station of the NU region: the U region, which includes exclusive taxa with a more or less different ecology: *A. muticus, C. luteolum, C. dipterum, C. simile, Habrophlebia.sp.1, B. punicus, P. concinnum* and *H. assefae* preferring the highly mineralized waters and very enriched by MTE and highly alkaline; Stations in the NU region that contain *A. almohades, Ch. Dimorphicum, Ch. Atlas, Rhithrogena sp. 1, P. luteus, B. fuscatus, B. meridionalis, B. pavidus* and *C. pusilla*, who prefer weakly mineralized and relatively fast waters with a stony bottom dominated by pebbles; And those of the only station (ST2) which harbors two exclusive and rare species: *E. sylvicola* and *B. punicus*, preferring the permanent course of high altitude and low mineralization.

References

1. Barmuta L.A., *Freshwater Biol*. 21(2) (1989) 229.
2. Lugthart G.J., Wallace J.B., *J. N. Am. Benthol. Soc*. 11(1992) 138.
3. Bournaud M., Cellot B., Richoux P., Berrahou A., J. *N. Am. Benthol. Soc*. 15 (2) (1996) 232.
4. Wohl, D.L., Wallace J.B., Meyer J.L., *Freshwat. Biol*. 34 (3) (1995)447.
5. Malmqvist B., Eriksson A., *Freshwat. Biol*. 34(2) (1995) 285.
6. Guinand, B., Ivol J.M., Tachet H., *Hydrobiologia*. 317 (3) (1996) 231.
7. Nelson C.H., *J. Tenn. Acad. Sci*. 71 (2) (1996) 29.
8. Hawkins C.P., Hogue J.N., Decker L.M., Feminella J.W., *J. N. Am. Benthol. Soc*. 16 (4) (1997) 728.
9. Del Valls T.A., Conradi M., Garcia-Adiego E., Forja J.M., Gomez-Parra A., *Hydrobiologia*. 285 (1998) 590.
10. Jacobsen D., Schultz R., Encalada A., *Freshwat. Biol*. 38 (2) (1997) 247.
11. Berthelemy C., *Verh. Internat. Verein. Limnnol*. 18 (1973) 1544.
12. Boumaïza A., Thomas A.G.B., *Archs. Inst. Pasteur, Tunis*. 63 (4) (1986) 567.
13. Boumaïza A., Clergue-Gazeau M., *Annls. Limnol*. 22 (1) (1986) 31.
14. Dakki M., Thomas A.G.B., *Annls. Limnol*. 22 (1) (1986) 27.
15. Malicky H., Lounaci A., *Opusc. Zool. Flumin*. 14 (1987) 1.
16. Bouzidi A., Giudicelli J., *Annls. Limnol*. 23 (3) (1987) 185.
17. Gagneur J., Clergue-Gazeau M., *Annls. Limnol*. 24 (3) (1988) 275.

18. Gagneur J., Thomas A.G.B., *Bull. Soc. Nat., Toulouse*. 124 (1988) 213.
19. Clergue-Gazeau M., Lek S., *Rev. Hydrobiol. Trop*. 24 (1) (1991) 47.
20. Moubayed J., Ait-Mouloud S., Lounaci A., *NachrBl. Bayer. Ent*. 41(1992) 21.
21. Boumaïza M., Thèse de Doctorat es Sciences, Université Tunis II, (1994).
22. Lounaci-Daoudi D., Thèse de Magister, Université de Tizi-Ouzou, (1996).
23. Thomas A.G.B., *Bull. Soc. Nat., Toulouse*. 134 (1998) 13.
24. Lounaci A., Brosse S., Ait Mouloud S., Lounaci-Daoudi D., Mebarki M., *Bull. Soc. Hist. Nat., Toulouse*, 136 (2000) 43.
25. Mebarki M., Thèse Magister, Université Mouloud Mammeri de Tizi-Ouzou, (2001).
26. Arab A., Lek S., Lounaci A., Park Y. S., *Annls. Limnol*. 40 (4) (2004) 123.
27. Lounaci A., Vinçon G., *Ephemera*, 6 (2) (2005) 109.
28. Bebba N., El Alami M., Arigue S. F., Arab A., *J. Mater. Environ. Sci*. 6 (4) (2015) 1164.
29. Alba-Tercedor J., Picazo-Muñoz J., Zamora-Muñoz C., *Canadian Scholar's Press Inc., Toronto*. (1995) 41.
30. El Alami M., Thèse Doctorat d'Etat, Université Abdelmalek Essaadi, Fac Sci Tétouan, (2002).
31. Eaton A. E., *Ent. Month. Marg*. 35 (1899) 4.
32. Kimmins D. E., *Ann. Mag. Nat. His*. 11 (1) (1938) 302.
33. Lestage J.A. Bull. Soc. Hist. Nat. Afr. Nord, 16 (1925) 8-18.
34. Dakki M., El Agbani M. N., *Bull. Inst. Sci. Rabat*. 7 (1983) 115.
35. Thomas A. G. B., *Bull. Soc. Hist. Nat. Toulouse*. 134 (1998) 13.
36. Alba-Tercedor J., El Alami M., *Aquatic Insects*. 21 (4) (1999) 241.
37. Ben Moussa A., Chahlaoui A., Rour E., Chahboune M., *J. Mater. Environ. Sci*. 5 (1) (2014) 183.
38. Dakki M., Thèse de 3eme cycle, Aix- Marseille III, (1979).
39. El Agbani M., Thèse Doctorat 3éme cycle, Université Claude Bernard LyonA, (1984).
40. Mohati A., Thèse de 3ème cycle, Fac. Sci., Marrakech, (1985).
41. Badri A., Thèse de 3ème cycle, Fac. Sci. Marrakech, (1985).
42. Dakki M., Thèse Etat, Univ. Rabat, (1986a).
43. Dakki M., *Bull. Ecol*. 17 (1986 b) 79.
44. Dakki M., *Trav. Inst. Sci., Serie Zoologie*, 42 (1987) 99.
45. Ajakane A., Thèse de 3ème cycle, Fac. Sci., Marrakech, (1988).
46. Bouzidi A., Thèse d'état, Fac. Sc. Tech. St. Jérôme, Université d'Aix- Marseille III, (1989).
47. Berrahou A., Thèse d'Etat Uni. Mohammed I, Fac. Sci; Oujda, (1995).
48. El Alami M., Thèse Doctorat 3ème cycle. Univ. Mohammed V, Fac. Sci., Rabat, (1989).
49. Tayoub H., Thèse Doctorat 3ème cycle, Fac. Sci. Rabat, (1989).
50. El Alami M., Dakki M., *Bull. Inst. Sci., Rabat*, 21 (1998) 51.
51. APDN: Agence pour la Promotion et le Développement du Nord. Les Régions du Nord du Maroc : Etat des Lieux Territoriales, (2011).
52. UNEP-MAP RAC/SPA., Contrat CAR/ASP, n° 47, 48 et 49 (2009) 100.
53. Benabid A., Travaux de l'Institut Scientifique. Série Botanique 34 (1984) 1-64.
54. Deil U., *Dissertationes Botanicae*. 74 (1984) 1-179.
55. Quézel P., Barbero M., Benabid A., Loisel R., Rivas-Martinez S., *Ecologia Mediterranea*. 14 (1988) 77.
56. Tachet H., Bournaud M., Richoux P., *Association Française de Limnologie*. (1991)
57. Tachet H., Richoux P., Bournaud M., Usseglio-Polatera P., *CNRS Editions, Paris*, (2000).
58. Belfiore C., Guide pre il riconoscimente delle specie animali delle arque interne Italiane (24) Effemerotteri, (1983).
59. Gattolliat J. L., Sartori M., *Zootaxa*. 1957 (2008) 69.
60. Cayrou J., Compin A., Giani N., Céréghtno R., *Annls Limnol*. 36 (3) (2000) 189.
61. Alba-Tercedor J., *Eos*, 58, (1983) 9.
62. Soldân T., Thomas A.G.B., *Acta. Entomol. Bohemoslov*. 80 (1985) 180.
63. Alba-Tercedor J., jimenez Millan F., *Bol. Asoc. Esp. Entom*. 2 (1987) 91.
64. Legendre P., Legendre L., *Numerical ecology. Elsevier, Amsterdam*. (1998).
65. Dakki M., El Agbani M. N., *Bull. Inst. Sci. Rabat*. 7 (1983) 115.
66. Boumaiza M., Thomas A. G. B., *Bull. Soc. Hist. Nat. Toulouse*. 131 (1995) 27.
67. El Alami M., Dakki M., Errami M., Alba-Tercedor J., *Zool. Baetica*. 11 (2000) 105.
68. Zrelli S., Boumaiza M., Bejaoui M., Gattolliat J. L., Sartori M., *Revue Suisse de Zoologie*. 118 (2011a) 3.
69. Zrelli S., Sartori M., Bejaoui M., Boumaiza M., *Zootaxa*. 3139 (2011b) 63.
70. Zrelli S., Gattolliat J. L., Boumaiza M., Thomas A., *Zootaxa*. 3497 (2012) 60.

71. Lounaci, A., Brosse, S., Thomas, A. G. B., Lek S., *Annls Limnol*. 36 (2) (2000b) 123.
72. Maqboul A., Aoujdad R., Fekhaoui M., Fadli A., Touhami A., *Riv. Idrobiol*. 40 (2-3) (2001) 129.
73. Belaidi N., Taleb A., Gagneur J., *Annls. Limnol*. 40 (3) (2004) 237.
74. Giudicelli J., Dakki M., Dia A., *Verh. Internat. Verein. Limnnol*. 22 (1985) 2094.
75. Ferrito V., *Annls. Limnol*. 30 (1) (1994) 33.
76. Verneaux J., Thèse Docrorat es Sciences, (1973).
77. Sowa R., *Acta Hydrobiol*. 17 (1975) 223.
78. Thomas A.G.B., Thèse de Doctorat es Sciences, Université de Toulouse, (1981).
79. Qninba A.J., Thèse de 3ème cycle, Fac. Sci., Rabat, (1986).
80. Arab A., Thèse de Doctorat d'Etat, Université des Sciences et de la Technologie Houari Boumediene, Faculté des Sciences Biologiques, Alger, Algérie, (2004).
81. El Ghalabzouri A., Ater M., Marsili S., Roccotiello E., Mariotti M.G., *Bollettino dei Musei e degli Istituti Biologici de l'Università di Genova*. 75 (2013) 205.
82. Thorup J., *Spec. Publ. Plymatuning lab. Ecol*. (Univ. Pittsburg), 4 (1966) 59.
83. Hynes H.B.N., *Hydrobiologia*, 38 (1) (1971) 1-8.
84. Statzner B., Gore J.A., Resh V.H., *J. N. Am. Benthol. Soc*. 7 (1988) 307.
85. Mercier A., *Ephemera*, 1(2) (1999) 111.
86. Degani G., Herbst G.N., Ortal R., Bromley H.J., Levanon D., Netzer Y., Harari N., Glazman H., *Hydrobiologia*. 263 (1993) 163.
87. Dakki, M., *Bull. Ecol*., 16 (4) (1985) 285.
88. El Agbani M.A., Dakki M., Bournaud M., *Bull. Ecol*, 23 (1992) 103.
89. Berthelemy C., *Annls. Limnol*. 2 (2) (1966) 227.
90. Richardson J.S., *Ecology*. 72 (1991) 873.
91. Dobson M., Hildrew A.G., *J. Anim. Ecol*. 61 (1992) 69.
92. Tierney D., Kelly-Quinn M., Bracken J.J., *Hydrobiologia*. 389 (1998) 115.
93. Ulfstrand S., *Oikos*. 18 (2) (1967) 293.
94. Bournaud M., Keck G., *Acta Oecologia, Oecol. Gener*. 1 (2) (1980) 131.
95. Bebba N., El Alami M., Arigue S. F., Arab A., *J. Mater. Environ. Sci*. 6 (4) (2015) 1164.
96. Brulin M., *Ephemera*, 8 (1) (2007) 1-73.
97. Sartori M., Landolt P., *Fauna Helvetica.* 3 (1999) 214.
98. Lounaci A., Congrès annuel de la SZF, Parc Phoenix, Nice, (2011).
99. Berrahou A., Cellot B., Richoux P., *Ann. Limnol*. 37 (3) (2001) 223.
100. Lamri D., Hassouni D., Loukili A., Chahlaoui A., Belghyti D., *J. Entomol. Zool. Stud*. 4 (4) (2016) 1116.
101. Lamri D., Thèse de doctorat, Université Ibn Tofail faculté des sciences Kénitra, (2009).
102. Abdaoui A., El Alami M., Ghamizi M., *Série Zoologie*, Rabat, 47 (2010) 1.
103. Maamri A., Pattee E., Dolédec S., Chergui H., *Ann. Limnol. Int. J. Lim*. 41 (4) (2005) 247.
104. Puig M. A., Sabater F., Malo J., *Entomologica* 44 (1990) 255.
105. Alba-Tercedor J., Jáimez-Cuéllar P., Research Update on Ephemeroptera & Plecoptera, In: Gaino E. (Ed.), University of Perugia, Perugia, Italy. (2003).
106. Alba-Tercedor J., *Trab. Monogr. Dep. Zool. Univ. Granada*, 4 (2) (1981) 41.
107. Alba-Tercedor J., Báez M., Soldán T., *Eos*, 63 (1987) 7.
108. Alba-Tercedor J., González G., Puig M.A., *Limnetica* 8 (1992) 231.
109. Valladolid M., Arauzo M., Martinez-Bastida J. J., *Limnetica*. 29 (2) (2010) 393.
110. Vivas S., et al. *Limnetica* 21(2002) 149.
111. Alba-Tercedor J., *Revista IDE@ - SEA*, 40 (2015) 1–17.
112. Aguiar F. C., Ferreira M. T., Pinto P., *J. N. Am. Benthol. Soc*. 21 (2002) 43.
113. Zrelli S., Boumaiza M., Bejaoui M., Sartori M., Gattolliat J., *Biol. Inl. Wat. Suppl.* 3 (2016) 99-106.

(2017) ; http://www.jmaterenvironsci.com /