Revue d'Ecologie (Terre et Vie), Vol. 72 (3), 2017 : 303-313

ENVIRONMENTAL FACTORS INFLUENCING THE COMPOSITION AND DISTRIBUTION OF MAYFLY LARVAE IN NORTHERN ALGERIAN WADIS (REGIONAL SCALE)

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RÉSUMÉ.— *Facteurs environnementaux influençant la composition et la distribution des larves d'éphémères dans les oueds nord-algériens (échelle régionale)*.— Les relations entre la distribution des Éphéméroptères et les conditions de leurs habitats ont été étudiées dans 87 stations, dans les oueds du Nord de l'Algérie, en confrontant 17 variables environnementales et 27 espèces recensées (présence/absence). L'objectif de ce travail est (1) d'identifier les variables environnementales qui conditionnent la répartition des Éphéméroptères à l'échelle régionale ; (2) de définir leurs préférences écologiques le long de gradients environnementaux, en utilisant des outils statistiques récemment développés comme l'analyse Outlying Mean Index (OMI) et (3) de décrire les assemblages d'espèces qui se produisent dans des habitats similaires. La richesse spécifique est élevée (> 10), au printemps, dans les rivières de montagne (Atlas blidéen, Djurdjura) entre 300 et 600m d'altitude. La minéralisation des eaux et l'altitude sont les deux principaux paramètres qui affectent l'abondance spatio-temporelle des Éphéméroptères. À un degré moindre, les précipitations, la granulométrie des substrats, la pollution organique et l'ombrage expliquent également leur distribution. Cependant l'oxygène dissous, le pH et les facteurs hydrauliques (vitesse du courant, profondeur) semblent être secondaires. *Baetis rhodani*, *Caenis luctuosa*, *Ecdyonurus rothschildi* et *Baetis pavidus* sont les plus tolérantes vis-à-vis des variables considérées. La niche écologique la plus étroite appartient à *Rhithrogena* sp. (RTol = 0,39). Comme pour *Habrophlebia* gr. *fusca* et *Alainites* sp., elle est liée aux stations d'altitude. *Cheleocloeon dimorphicum*, *Choroterpes (Ch.) atlas* et *Procloeon* gr. *bifidum* occupent les eaux plus chaudes et *Cloeon* gr. *simile* semble tolérer les eaux à conductivité élevée. Enfin, *Caenis pusilla*, *Acentrella sinaica* et *Ecdyonurus rothschildi*, en dépit de leur faible marginalité, préfèreraient les sites ombragés, à substrat grossier et peu pollués.

SUMMARY.— Relationships between the assemblage structure of mayflies (Insecta: Ephemeroptera) and habitat conditions in wadis were explored in 87 localities of the North Algeria with 17 environmental variables and presence / absence data on Ephemeroptera species. The objective of this work is to (1) identify the environmental variables driving the composition of mayfly assemblages at the regional scale; (2) define the ecological preferences of mayflies species collected along environmental gradients, using recently developed statistical tools, including Outlying Mean Index Analysis (OMI) and (3) describe the assemblages of species that occur in similar habitats. 27 species of Ephemeroptera were recorded, about half of the entire Algerian mayfly fauna. Species richness is high (SR > 10), in spring, at stations located in mountain rivers (Blidean Atlas, Djurdjura) between altitude 300 to 600m. Water mineralization and altitude are the most important parameters which affected the abundance of Algerian mayfly species (North Algeria). In less extent, precipitation, substrate size, organic pollution and riparian vegetation explain also this distribution. However dissolved oxygen, pH and hydraulic factors (current velocity, depth) seem to be secondary. *Baetis rhodani*, *Caenis luctuosa*, *Ecdyonurus rothschildi* and *Baetis pavidus* are the most tolerant species against the considered variables. *Rhithrogena* sp. (RTol = 0.39) is characterized by narrow habitat tolerance. As for *Habrophlebia* gr. *fusca* and *Alainites* sp., they are linked to the headwaters (altitude), *Labiobaetis neglectus* and *Cloeon dipterum* to heavily mineralized waters (Cl and Mg). *Cheleocloeon dimorphicum*, *Choroterpes (Ch.) atlas* and *Procloeon* gr. *bifidum* occur in warm waters and *Cloeon* gr. *simile* is able to tolerate salty waters (high conductivity). Finally, *Caenis pusilla*, *Acentrella sinaica* and *Ecdyonurus rothschildi*, despite their narrow marginality, prefer the covered sites with coarse substrate and tolerate light pollution.

Ephemeroptera is an order of insects considered as biological indicators because they are highly sensitive throughout a wide range of pollution and habitat alterations (Landa & Soldán, 1991; Alba-Tercedor *et al.*, 1995; Buffagni, 1997; Arimoro & Muller, 2010; Vilenica *et al.*, 2015).

Therefore, Ephemeroptera or ETP group (Ephemeroptera, Plecoptera and Trichoptera), are used, throughout the world, in assessing the ecological integrity of rivers (Arimoro & Muller, 2010; Gabriels *et al.*, 2010; Alhejoj *et al.*, 2014; Stoyavona *et al.*, 2014; Dedieu *et al.*, 2015; Selvanayagam & Abril, 2016).

Several studies have been done on this group in North Africa since the end of 19th century (*e.g.*, Eaton, 1899; Lestage, 1925; Navãs 1929). Since the 1980's, interest has focused on taxonomic studies or biogeography rather than on ecological aspects. Systematic studies, in Algeria, have added to the former knowledge about mayflies and provided preliminary data, as Soldán & Thomas (1983, 1985), Soldán *et al.* (2005), Thomas (1998) and Lounaci *et al.* (2000a). These studies are excellent in their own right but they offered little information concerning the ecological dimension, notably the distribution patterns related to the issue, except few papers which have been limited in space and in time. These studies showed the influence of local environmental parameters on diversity of aquatic macroinvertebrates and revealed different gradients: altitudinal, seasonal, and pollution (Gagneur & Thomas, 1988; Lounaci *et al.*, 2000b; Chaïb *et al.*, 2013; Bebba *et al.*, 2015).

Our objective is (*i*) to evaluate how environmental gradients explain the distribution of mayfly species in northern Algerian's wadis, (*ii*) to determine the main environmental factors driving the Ephemeroptera community assemblage at the regional scale and (*iii*) describe the assemblages of species that occur in similar habitats.

The term "wadi" is generally used in North Africa to name the watercourses, and refers to the great variations in flow (Belaidi *et al.*, 2004).

MATERIALS AND METHODS

STUDY AREA

The study was carried out in northern Algerian wadis. The sampling area is delineated by the outer limits of 6 hydrographical basins (Tab. I): Chelif (Chelif wadi); coastal Algiers (Mazafran, El Harrach, and Sébaou w.), Isser (Isser w.); Soummam (Sahel w.), Constantine High Plateaus (Hamla, Bouilef, Chaaba and Berriche w.), Chott Melrhir (El Hai w.). The surveys performed at 87 stations are distributed over the northern part of Algeria between longitude 0°31'30"E and 6°12'16"E, and latitude 35°08'45''N and 36°50'24''N (Figs 1a & 1b).

TABLE I

Hydrological basins and number of sampled stations per basin in North Algeria

Basins	Area (km^2)	Number of sampled sites	Minimal altitude (m)	Maximal altitude (m)	Location
Cheliff	43750	8	28	630	North West
Coastal Algiers	11972	41	40	1680	North Centre
Issers	4149	5	4	336	North Centre
Soummam	9125	14	380	1660	North East
Constantine High Plateaus	9578	14	1010	1512	North East
Chott Melrhir	68750	5	360	1341	North East (southern limit)

Altitude ranges from 1m above sea level in lowland plains (Isser wadi) to more than 1680m in Djurdjura Mountains. The mountains of Northern Algeria are part of the Tellian Atlas and consist mainly of calcareous or dolomitic limestone. The valleys are occupied by cultivated lands, while the slopes are covered with scrubland and shrub vegetation.

The main feature of the northern Algerian wadis is the irregularity of the flows: high waters (floods) in winter and/or in spring and low waters in summer and/or in autumn. Contrary to European temperate streams, North African wadis are characterized by high water temperatures (high fluctuation in daily and seasonal amplitude in high mountain areas) inducing a high evaporation rate.

The most important source of pollution consists of domestic sewage, industrial sites (urban areas) and land use (farming, breeding).

SAMPLING TECHNIQUES AND DATA SET

Fauna samples were taken at different hydrological periods, between 1996 and 2012, in both main streams and their tributaries. We used a standard Surber nest (mesh size 250 µm; 0.09 m² sampled area). In the laboratory, the invertebrates were mostly identified on species level and counted.

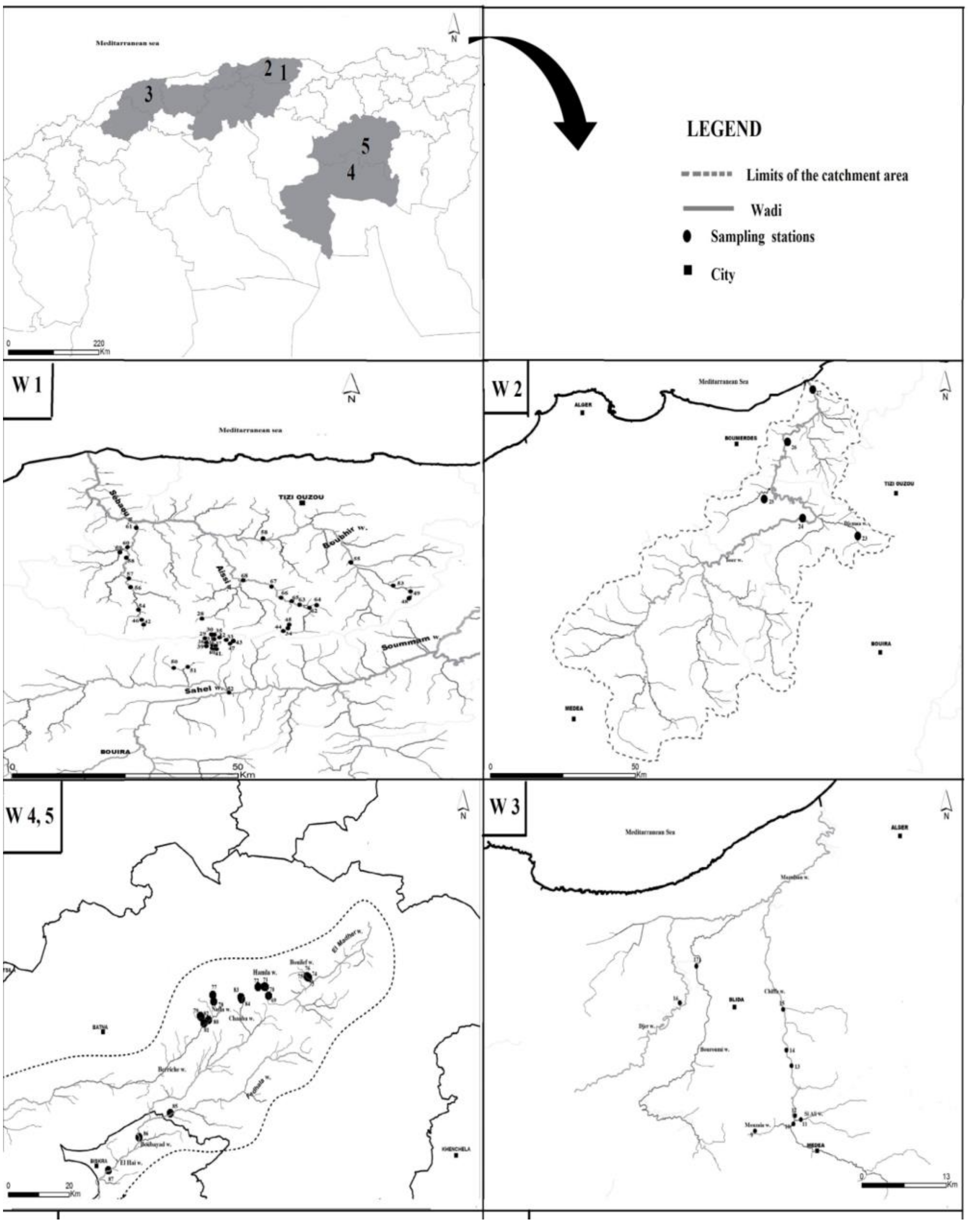

Figure1a.— Map of North Algeria showing location of sampling stations in coastal Algiers, Constantine high plateaus, Chott Melrhir, Soummam and Issers basins. w. = wadi ; W1: Sébaou, Djemaa and Sahel w. (Djurdjura, Kabylie); W2: Isser w.; W3: Mazafran w.; W4: Bouilef, Hamla, Chaaba, and Berriche w. (Belezma, Batna); W5: El Hai w. (Biskra).

Physicochemical measures were carried out during fauna sampling. Both fauna and water samples were collected monthly from each station over a 12-months period.

The data set used consists of 17 environmental variables and 27 Ephemeroptera in fact to determine ecological niches of each species. They refer to electrical conductivity (CON, measured in µS cm^{-1}), Mg, Ca, Cl, SO_4, NO_3 ions (in mg L^{-1}), pH, dissolved oxygen (O_2, in percent), water temperature (T, in °C), precipitation (P, in mm), mean current velocity (V, in m/s), river bed width (LAR, in m), water depth (Pr, in cm), altitude (ALT, in m), slope of the bottom (PEN, in percent), substrate size (percentage of pebbles=GG), percentage of coverage by terrestrial vegetation (REC).

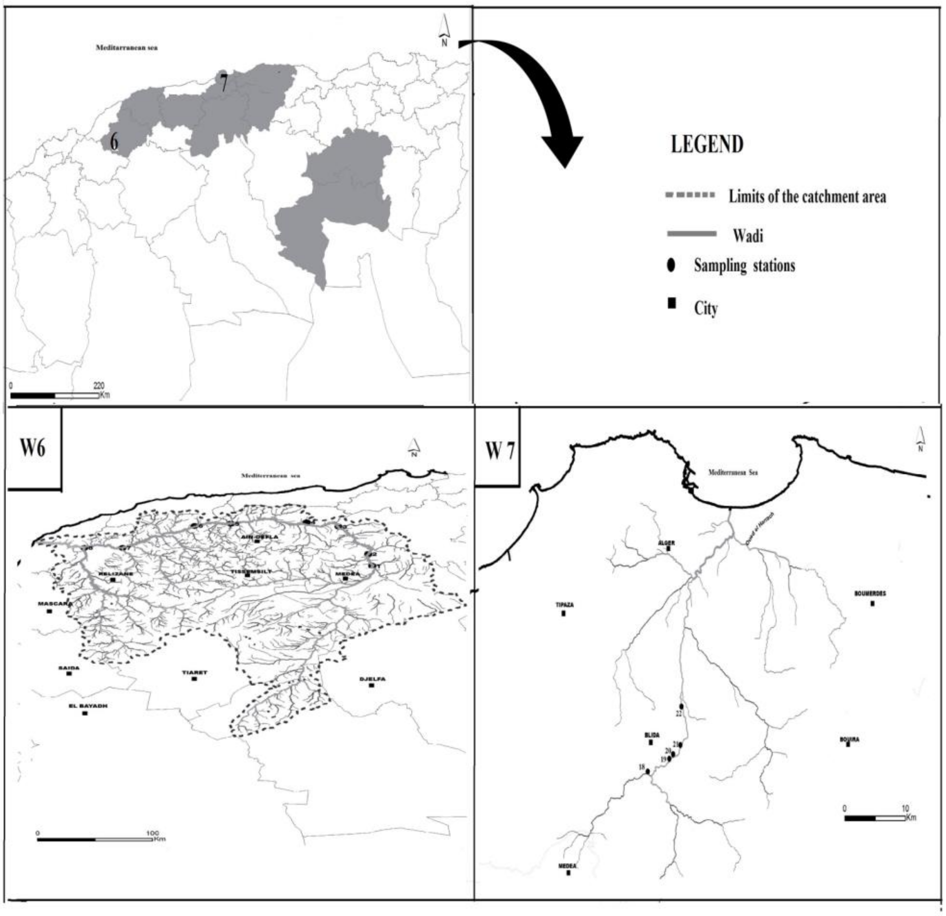

Figure 1b.— Map of North Algeria showing location of sampling stations in Cheliff and Harrach wadis. W6: Cheliff wadi; W7: Harrach wadi.

The present study identified altitude, as integrator of the longitudinal gradient, acting as one of the single factors although being a parameter related to other variables (temperature, slope, streambed width, and substrate size) owing to a large range of altitudinal and topographical features of the studied area.

DATA ANALYSIS

Descriptive statistics were calculated for the entire study sites and by catchment area for species abundance and occurrence. In order to obtain a more normal data distribution, all the variables were log-transformed. We used Outlying Mean Index analysis (OMI) to quantify species/environment relationships between environmental factors collected at regional spatial scale. This method was described by Dolédec *et al.* (2000). It gives equal weight to species-rich and species-poor sites. The OMI method, widely used in ecological studies (Grüner *et al.*, 2011; Heino & Grönross, 2014; Carbonell *et al.*, 2015; Hernandez-Farinas *et al.*, 2015), measures the marginality of species habitat distribution (habitat deviation), the distance between average habitat conditions used by species and the average habitat conditions of the sampling sites.

OMI represents species marginality, T1, marginal tolerance (habitat breadth of the species associated with environmental variables) and T2, the residual tolerance represents the variance in the species niche that is not explained by environmental variables (Dolédec *et al.*, 2000).

The statistical significance of the marginality of each species was tested by a Monte-Carlo permutation test with 100 000 permutations. OMI analysis was carried out using the ADE-4 software (Thioulouse *et al.*, 1997) available at http://pbil.univ-lyon1.fr/ADE-4/.

RESULTS

87 running waters stations were surveyed in Northern Algeria and 27 species of Ephemeroptera were recorded (Tab. II), about half of the entire Algerian mayfly fauna (Thomas, 1998). Baetidae is the most diverse family (15 species), with 2 widespread eurythermous species *B. pavidus* and *B. rhodani*.

TABLE II

List of 27 mayfly species collected in North Algeria

Families	Species	Codes	Ni	Ar.	Oc.
Baetidae	*Acentrella sinaica* Bogoescu, 1931	ACS	597	0.83	8.21
	Alainites sp.	ALA	686	0.95	4.63
	Baetis chelif Soldán, Godunko & Thomas, 2005	BCH	20	0.03	1.68
	Baetis pavidus Grandi, 1949	BPA	23578	32.74	44.63
	B. punicus Thomas, Boumaïza & Soldán, 1983	BPU	4559	6.33	9.47
	B. rhodani Pictet, 1843	BRH	17875	24.82	33.05
	B. sinespinosus Soldán & Thomas, 1983	BRS	73	0.10	0.42
	Centroptilum luteolum (Müller, 1776)	CEL	441	0.61	5.89
	Cheleocloeon dimorphicum (Soldán & Thomas, 1985)	CHD	183	0.25	6.95
	Cloeon dipterum (Linné, 1761)	CLD	277	0.38	5.68
	Cloeon gr. *simile* Eaton, 1870	CGR	292	0.41	4.63
	Labiobaetis neglectus (Navás, 1913)	LNE	189	0.26	3.58
	Nigrobaetis rhithralis (Soldán & Thomas, 1983)	NRH	56	0.08	2.53
	Procloeon stagnicola Soldán & Thomas, 1983	PRS	179	0.25	4.00
	*Pr.*gr. *bifidum* (Bengtsson, 1912)	PRG	169	0.23	5.89
Oligoneuriidae	*Oligoneuriella* sp. (? *O. skhounate)*	OLI	36	0.05	1.89
Heptageniidae	*Ecdyonurus rothschildi* Navás, 1929	ECR	1947	2.70	20.42
	Ecdyonurus sp.	ECD	590	0.82	6.95
	Rhithrogena gr. *germanica*	RHG	181	0.25	3.58
	Rhithrogena sp.	RHI	24	0.03	1.05
Caenidae	*Caenis luctuosa* (Burmeister, 1839)	CAE	17746	24.64	45.47
	C. pusilla Navás, 1913	CPU	349	0.48	7.16
Leptophlebiidae	*Choroterpes* (*Ch.*) *atlas* Soldán & Thomas, 1983	CH	214	0.30	8.84
	Ch. (Euthraulus) lindrothi Peters, 1980	CHL	847	1.18	9.47
	Habrophlebia gr *fusca*	HFU	445	0.62	4.42
Potamanthidae	*Potamanthus luteus* (Linné, 1789)	POL	415	0.58	4.84
Ephemeridae	*Ephemera glaucops* Pictet, 1845	EPG	43	0.06	4.21

Ni: total number of individuals; Ar.: abundance %; Oc.: frequency of occurrence %.

RELATIVE ABUNDANCE AND FREQUENCY OF OCCURRENCE

B. pavidus (32.74 %), *B. rhodani* (24.82 %) and *C. luctuosa* (24.64 %) are the most abundant species (Tab. II); *B. rhodani* is very common in running waters (Bauernfeind & Soldán, 2012) and *C. luctuosa* abounds in almost all streams, except in watercourses of Belezma, corroborating the observations of Bebba *et al.* (2015). *A. sinaica*, *Alainites* sp., *B. chelif*, *B. sinespinosus*, *E. glaucops*, *N. rhithralis*, *Oligoneuriella* sp., *Rhithrogena* sp., *L. neglectus*, *C. dimorphicum*, *C. dipterum*, *C.* gr. *simile*, *P. stagnicola*, *P.* gr. *bifidum*, *R.*gr. *germanica*, *C. pusilla*, *Ch.*(*Ch.*) *atlas* are of low abundance (Ar. < 1%).

B. punicus, *C. luteolum*, *Ecdyonurus* sp., *E. rothschildi*, *Ch. (Eu.) lindrothi*, *H.* gr. *fusca* and *P. luteus* are of low frequency and moderately abundant. However, *Alainites* sp., *B. punicus*, *Rhithrogena* sp. and *H.* gr. *fusca* are mainly restricted to headwaters (Djurdjura). *Baetis sinespinosus*, *B. chelif*, *L. neglectus* and *E. glaucops* are restricted to Chelif and/or to Mazafran, *N. rhithralis* to mountain rivers (Djurdjura, Djemaa w.) and Blidean Atlas (Mazafran w.). Finally, the most frequent mayflies are *C. luctuosa* (45.47 %), *B. pavidus* (44.63 %), *B. rhodani* (33.05 %), and *E. rothschildi* (20.42 %).

ENVIRONMENTAL GRADIENTS

The mayfly community structure was visualized using Outlying Mean Index (OMI) aiming to show the most important environmental variables and to determine affinities of each species (27) to 17 selected variables. Information brought by the selected variables is summarized by the OMI analysis on the first two axes (F1 and F2) (Fig. 2 left). The contribution of each variable is proportional to the width of the arrow. Brown arrows represent the contribution of these variables to the formation of the axis 2.

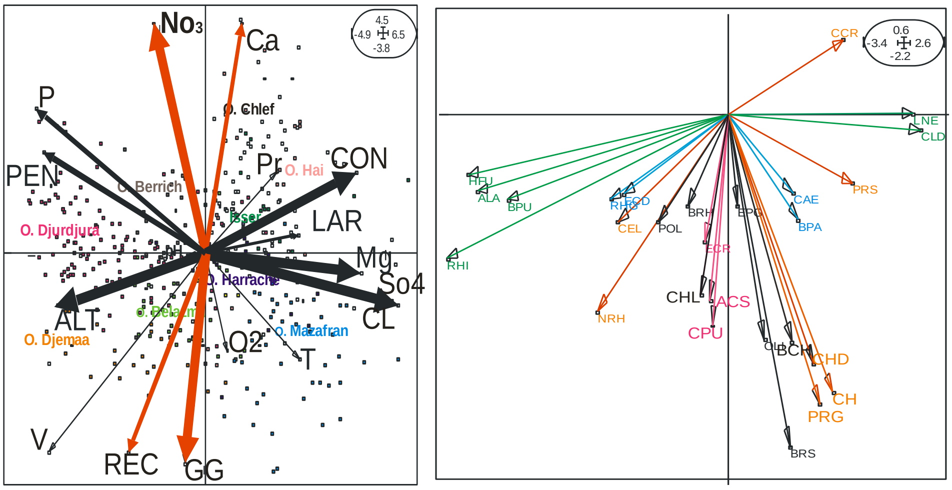

Figure 2.— F1xF2 plane (axis 1 and 2) of the OMI analysis. (Left): 17 environmental variables and their corresponding sampling stations (wadis). (Right): species marginality. The contribution of each variable is proportional to the width of the arrow. The direction indicates among-variable correlations (brown arrows represent the contribution of the variables to the formation of the axis 2). Full names abbreviation codes of *Ephemeroptera* taxa are given in Tab. II. Variables codes (see in the text "Sampling sites and data base).

The first two axes of OMI analysis show 82 % of the marginality of all taxa (62 % for F1). The 87 sites have been arranged along an environmental gradient represented by 5 important factors (Fig. 2 left) : ionic water composition (I) determined by ions SO_4 (CF1 = 0.94), Cl (CF1 = 0.93), Mg (CF1 = 0.93), inversely correlated with the land topography (II) characterized by altitude (CF1 = 0.82), slope (CF1 = 0.77) and streambed width (CF1 = 0.66), and climatology (III) where the most important factors are precipitation and temperature (respectively CF1 = 0.74; CF1 = 0.57); they determine the first axis which describes a compound topographical, thermal, and water mineralization gradient linked to the land uses and probably to geological nature of crossed land (calcareous sedimentary rock, dolomitic limestone, gypsum) opposing warm habitats and arid, flat and low altitudes (agricultural and residential areas) to cold habitats and wet forested areas and sites far away from agriculture, sloping and at high altitude (Fig. 2 left). Hydro-geomorphology interpreted by the substratum (CF1 = 0.75) (IV) and eutrophication (water quality, NO_3) (CF1 = 0.70) (V) determines mainly the second axis ; these parameters describe a gradient of both substrate size and pollution opposing low arboreous areas with homogeneous substrate (boulders, pebbles, gravel), sunny waters and rich in organic matter - streams located in lowland plains subjected to high disturbances induced by anthropogenic activities (farming and breeding) - (Isser, Berriche, El Hai and Chelif wadis) - to arboreous areas with heterogeneous substrate, few sunny waters, with a low nitrate content.

As it was reported by Arimoro & Muller (2010), the main ecological factors influencing Ephemeroptera assemblages are substrate composition, habitat, and water quality. Thus, stations located in urban and/or agricultural areas (Sébaou, Isser, Chelif, and El Hai) are polluted and show reduced species richness, agreeing with the observations of Zouggaghe *et al.* (2014). Moreover, diversity is also influenced by substrate heterogeneity. Our results confirm in part the observations of Dedieu *et al.* (2015) who suggested that variation in substrate composition is one of the most structuring factors of Ephemeroptera assemblages.

Finally, altitude and water mineralization are the main complex variables which affect the abundance of mayflies in northern Algeria. Both factors are related to other parameters so their influence is more important on the aquatic biota. Precipitation, water temperature, size substrate, eutrophication and riparian cover sustain to explain this distribution whereas dissolved oxygen content, pH and hydraulic parameters (current velocity and depth), have less effect at a regional scale.

Thus, patterns of structure and composition of mayfly species, at the regional scale, are topographical (related to the altitude), climatic, hydrogeological (linked to the climate) and physico-chemical parameters (influenced by land use).

ECOLOGICAL NICHE CHARACTERISTICS

Results of OMI's analysis are given in the table III. Index of marginality, of tolerance and of residual tolerance explains the figure 2 right.

TABLE III

Ecological niche characteristics

Species	Codes	InerO	OMI	T1	T2	d2*	T1*	T2*	P
Acentrella sinaica	ACS	15.27	2.09	1.03	12.15	137	68	796	NS
Alainites sp.	ALA	21.91	11.40	0.62	9.89	520	28	451	**
Baetis chelif	BCH	11.43	4.26	0.46	6.71	373	41	587	NS
Baetis pavidus	BPA	17.88	1.52	2.25	14.11	85	126	789	**
Baetis punicus	BPU	23.10	8.97	0.98	13.15	388	42	569	**
Baetis rhodani	BRH	17.50	0.60	1.89	15.01	34	108	858	**
Baetis sinespinosus	BRS	8.60	8.60	0.00	0.00	1	0	0	NS
Labiobaetis neglectus	LNE	22.00	8.22	2.57	11.22	373	117	510	NS
Ephemera glaucops	EPG	9.19	4.33	0.54	4.33	471	58	471	*
Nigrobaetis rhithralis	NRH	18.70	5.95	0.91	11.84	318	49	633	*
Cheleocloeon dimorphicum	CHD	22.04	6.04	3.84	12.16	274	174	552	**
Centroptilum luteolum	CEL	19.87	4.82	0.75	14.30	243	38	720	**
Cloeon dipterum	CLD	25.01	7.36	4.16	13.49	294	166	539	**
Cloeon group *simile*	CGR	22.35	3.89	2.56	15.90	174	115	712	**
Procloeon stagnicola	PRS	17.82	4.59	2.16	11.07	257	121	621	**
Procloeon group *bifidum*	PRG	19.62	6.16	3.17	10.29	314	161	525	**
Oligoneuriella sp.	OLI	20.29	4.13	0.66	15.50	203	33	764	NS
Rhithrogena sp.	RHI	24.38	15.23	0.39	8.76	625	16	359	**
Rhithrogena group *germanica*	RHG	15.51	2.94	0.66	11.92	189	42	768	*
Ecdyonurus sp.	ECD	17.47	2.53	2.22	12.72	145	127	728	**
Ecdyonurus rothschildi	ECR	14.96	1.36	1.44	12.16	91	96	813	**
Caenis luctuosa	CAE	17.71	1.15	2.55	14.02	65	144	791	NS
Caenis pusilla	CPU	16.83	2.07	0.78	13.98	123	47	831	**
Choroterpes (Ch.) atlas	CH	19.18	6.15	2.32	10.72	321	121	559	**
Choroterpes lindrothi	CHL	15.99	2.08	0.67	13.24	130	42	828	**
Habrophlebia group *fusca*	HFU	21.16	12.34	0.79	8.03	583	37	380	*
Potamanthus luteus	POL	15.92	2.31	0.97	12.64	145	61	794	NS

Inertia: variability of the niche; OMI: species marginality; Tol: tolerance; RTol: residual tolerance. InerO = inertia; OMI = outlying mean index; T1 = tolerance index (marginal tolerance: habitat breadth of the species associated with environmental variables); T2 = residual tolerance index (variance in the species niche that is not explained by environmental variables); z*=1000*z/InerO.

Percentage corresponds to the proportion of each parameter in inertia (inertia = OMI + Tol + RTol). The p-value (P) for the marginality is obtained by a swapping test (100 000 permutations).

The species are described by their codes (Tab. II); inertia, marginality index (IMO), the index of tolerance (Tol) and the index of residual tolerance (RTol) were calculated for each species. The last column represents the P value calculated by a Monte Carlo test 100,000 permutations (** $p < 0.01$, * $p < 0.05$, NS, not significant) (Tab. III).

Finally, 20 species of 27 mayfly taxa show a significant marginality (Tab. III). This suggests a high influence of environmental variables selected on species distribution. The global test of the mean marginality of all species is also highly significant ($P < 0.001$). Seven species have a very high marginality index ($7 < OMI < 16$); this difference is statistically significant for 5 of them; eight species showed an index included between 4 and 7 ($4 \leq OM I \leq 7$). At last, twelve species present a relatively small marginality ($1 < OMI \leq 3$). This suggests that they are either insensitive to variations of environmental factors measured, or sensitive to other non-measured parameters.

The highest tolerance indices are attributed to *C. dipterum*, *C. dimorphicum*, *P.* gr. *bifidum*, *L. neglectus*, *C.* gr. *simile*, *C. luctuosa*, *Ch. (Ch.) atlas*, *B. pavidus*, *Ecdyonurus* sp., *P. stagnicola*. All these species show also a high residual tolerance index; this indicates that a great deal of the variability of their occurrence is still unexplained by selected variables. Sixteen (16) of 27 species (60 %) have more than 50 % of their variability explained by the selected variables.

However, it is suitable to note that a great number of species, including the ones with a significant marginality, show a high residual tolerance (Tab. III). This case indicates that, through their distribution in studied areas, they are significantly correlated with the explicative variables used in analysis, but there are other unstudied factors which can probably affect the species distribution.

For example, *Rhithrogena* sp., *H.* gr. *fusca* and *Alainites* sp. are the most marginal species (OMI = 15, 12, 11) with also an important residual tolerance (RTol = 9.88, 8, 8.75), denoting that the considered variables explain largely the distribution of the three species. Nevertheless, *B. rhodani*, *C. luctuosa*, *E. rothschildi* and *B. pavidus* are the least marginal (respectively OMI = 0.6, 1.14, 1.35, 1.5) with a residual tolerance very high towards the studied variables. The least wide niche belongs to *Rhithrogena* sp. (Tol = 0.39).

Our results reveal clearly, on the one hand, marginal (high OMI index values) and non-marginal species (low OMI index values), and on the other hand, discriminate specialist (low values of tolerance) and generalist (high values of tolerance) species, agreeing with previous findings (Soininen *et al.*, 2011; Heino & Grönross, 2014).

Figure 2 right indicates that niches of *Rithrogena* sp., *H.* gr. *fusca, Alainites* sp. are associated with headwaters (altitude) while those of *L. neglectus* and *C. dipterum* are linked to heavily mineralized waters (Cl and Mg contents). *Ch. dimorphicum*, *Ch.(Ch.) atlas* and *P.* gr. *bifidum* colonize warmer waters and *C.* gr. *simile* is able to tolerate highly mineralized waters. Finally, *C. pusilla*, *A. sinaica* and *E. rothschildi*, with low marginality, rather prefer arboreous stations, with finer substrate and slightly polluted waters.

DISCUSSION

Water mineralization, linked to land uses (agricultural activities, pasture) and to geological nature, and altitude are the main environmental variables determining Algerian mayflies' assemblage at the regional scale (North Algeria), in agreement with the findings of other authors (Gagneur & Thomas, 1988; Boumaïza & Thomas, 1995). Certainly, altitude is one of the most important environmental factors; however, it does not act as a single factor on mayfly larvae but it combines the other variables (temperature correlated with oxygenation, slope with size substrate, and streambed width), as well as human impact. Therefore, altitude confuses probably the effect of such factors. Besides, only few studies have used geologic data to quantify how geology interacts with other environmental factors to produce different water chemistries. Therefore some authors (Egglishaw & Morgan, 1965; Olson, 2012; Selvanayagam & Abril, 2016) showed that catchment geology have a greater influence on water chemistry (ion concentrations and electrical conductivity), at a regional scale. On the contrary, several studies have indicated that land use changed stream chemistry, acting as an important factor in controlling the structure of the aquatic communities (Lenat & Crawford, 1994; Paul & Meyer, 2001). Temperature, precipitation, substrate heterogeneity, pollution and shade (cover streambed density) can also explain the distribution as it has been reported somewhere else (Rueda *et al.*, 2002; Buss & Salles, 2007), whereas dissolved oxygen content, pH and hydraulic parameters seem to have less influence on the Ephemeroptera distribution at our regional scale. Nevertheless, at a local scale, the availability of appropriate mesological conditions is one of the most important factor influencing the occurrence and distribution of Ephemeroptera (Bauernfeind & Moog, 2000; Dedieu *et al.*, 2015).

In the studied area, ionic water composition is strongly influenced by drainage from cultivated lands along the catchments; furthermore, the increase of mineralization in stream is related with the increment of irrigated areas and pasture land (Chelif, Issers and El Hai wadis) agreeing with the findings of Stepanonow & Chembarisov (1978). It is noteworthy that the water mineralization, in this study, combines various aspects of organic pollution (untreated industrial and domestic wastes) and nutrient input by sediment yields from agricultural land use.

So mayfly composition, at a regional scale (hydroecoregions), is controlled rather by topographical, climatic, hydrogeological, (agreeing Aschonits *et al.*, 2016), and physico-chemical factors.

B. rhodani, *C. luctuosa*, *E. rothschildi* and *B. pavidus* are the most abundant and the most frequent species with a high tolerance (ubiquistic and eurythermous). This is consistent with the observations of other researchers (Alba-Tercedor *et al.*, 1995; Korbaa *et al.*, 2009; Arimoro & Muller, 2010; Vilenica *et al.*, 2015). *A. sinaica, B. punicus, Ch. atlas* and *Ch. lindrothi* exhibit low frequencies (8-10 %); they are confined to cold waters and shady streams in Djurdjura (*A. sinaica, B. punicus*, and *H.*gr. *fusca*). *Rhithrogena* sp. is rare, related probably to the increase in swiftness of the current, occurs only in the Djurdjura region with *H.* gr. *fusca* and *Alainites* sp.; they are associated with upstream mountain areas. *L. neglectus* and *C. dipterum* are found in strongly mineralized waters. *C. dimorphicum*, *Ch.* (*Ch.*) *atlas* and *P.* gr. *bifidum* inhabit warmer waters. *C.* gr. *simile* is present in warm and highly mineralized standing waters in lowland areas; it could tolerate salty water according to Alhejoj *et al.* (2014). Finally, *C. pusilla*, *A. sinaica* and *E. rothschildi*, in spite of their low marginality, show a preference towards arboreous stations, with finer substrate and low eutrophic water. The distribution of mayflies in the studied area is significantly correlated with some explicative variables used in analysis, but there are other unstudied factors such as biological traits (Dedieu *et al.*, 2015), habitat type (Vilenica *et al.*, 2015), habitat alterations (Alba-Tercedor *et al.*, 1995; Arimoro & Muller, 2010; Stoyavona *et al.*, 2014) which can probably affect strongly the Ephemeroptera assemblages. It is also known that *P. luteus*, a non-marginal species with wide niche, and low residual tolerance, is scarce in Tunisia (Zrelli *et al.*, 2015), occurring among aquatic vegetation.

Dominant species (*B. pavidus*, *C. luctuosa* and *B. rhodani*) abound and occur in all northern Algerian streams. According to Heino & Grönross (2014), niche characteristics are important variables in explaining variation in the regional occupancy and abundance of stream invertebrates. Nevertheless, *B. punicus*, *Alainites* sp. and *H.*gr. *fusca* are characteristic of headwaters (cold waters) in the Djurdjura region. Mazafran wadi (Blidean Atlas) contains rare species such as *B. sinespinosus*, *B. chelif* inhabits permanent running waters, in piedmont areas, with coarse substrate. Other wadis include eurythermous or thermophilous species, which are able to tolerate heavily mineralized waters, and even polluted ones. Some lowland plain species reach back in altitude (up to1450m), fleeing the temperature rises of water (*C.* gr. *simile, B. pavidus*).

Distribution of mayfly larvae is locally affected by environmental parameters (flow, thermal regime, substrate, allochthonous inputs). Besides the altitudinal gradient, species diversity fluctuates with substrate composition size and riparian cover; species richness and diversity are low in stations strongly affected by anthropogenic disturbances (domestic wastewaters and farming activities), in agreement with Arimoro & Muller (2010), and also verifying Aschonits *et al.* (2016) who suggested that low polluted stations have higher taxonomic richness.

Contrary to temperate areas (Europe), in Northern Algeria, few rhithrophilic and ubiquistic species dominate in the upper reaches; the occurrence of potamophilic species increases but specific diversity decreases under anthropogenic impacts. The middle sections (piedmont stream) show the highest values of species richness.

Further works on the patterns of distribution of Ephemeroptera assemblages in hydroecoregions shall consider their biological and physiological (physiological performance) traits, and other variables such as aquatic vegetation and human disturbances (ecosystem alteration) but they shall avoid the macro-scale variable which could add noise and bias in the analysis. Regardless the niche position and the niche breadth, the occupancy and the abundance of mayfly species may be affected by other traits (feeding group, mobility, body size).

ACKNOWLEDGMENTS

We express our due thanks to Dr. Hamzaoui and Dr.Thomas for their help and to two anonymous referees for their useful comments on previous drafts.

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