Taxonomic diversity of benthic macroinvertebrates along the Oum Er Rbia River (Morocco): implications for water quality bio-monitoring using indicator species

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Abstract

The macroinvertebrates of the Oum Er Rbia River were studied from samples collected seasonally from September 2015 to September 2016 at 10 sampling sites. The macroinvertebrates found during the sampling period were distributed into twelve orders . The most abundant order was diptera, having 9618 individuals, followed by the order Ephemeroptera with 2985 individuals. Coleoptera, odonates and crustaceans represent only a small fraction of the total fauna. Hydropsyche, Chironomidae sp. and Simuliidae are numerically more inventoried. The composition and distribution of the species were directly or indirectly affected by the physicochemical variables and the quality of the habitat. Correspondence analysis results showed that habitat quality and quality of water represented species distribution patterns and species can be used as indicators to assess the quality of the Oum Er Rbia River system. Habitat management along the Oum Er Rbia river should be aimed at preserving native species, especially during the summer, when the biotope requirements are optimal. The results obtained in this study showed an alarming situation of the water quality of the Oum Er Rbia River and particularly in downstream segment. To solve this problem, we recommend the development of the wastewater discharge of Khenifra and Kasba Tadla and the purification of wastewater before it is discharged into the river.

Introduction

The identification of environmental factors influencing the composition and abundance of stream biological communities is an important point in a stream restoration (Richards *et al.*. 1993). Water chemistry and physical characteristics of stream have an impact on river communities (Meyer *et al.*., 1988 , Resh and Rosenberg, 1984) and the characteristics of the riparian zone affecting invertebrate communities (Gregory *et al.*., 1991). Obviously, the distribution of benthic macroinvertebrates is impacted by environmental factors (Benbow *et al.*, 2003) as well as chemicals and physical factors produced by human activities (Prat and Ward 1994). The substrate, flow regime, geomorphology and temperature are the physical factors that affect river macro-invertebrate communities (Minshall, 1984; Poff & Ward, 1989, Huryn & Wallace 1987; Stannz, Gore and Resh, 1988, Vannote & Sweeney, 1980, Ward & Stanford, 1982;). Macroinvertebrate communities change spatially and temporally (Townsend & Hildrew 1994) and the combination of local environmental characteristics and large-scale geographical factors bring occurrence of a species (Townsend *et al.*, 2003; Mykra, Heino & Muotka, 2007). Knowledge about distribution, diversity and composition of macro invertebrate assemblages in gravel-water interfaces are very important, because they are highly dependent on sediment particle size (Beauger *et al.*, 2006). Besides, stream bed structures, such as clusters and gravel pits that create stable habitats for benthic communities, affect the growth of macro invertebrates and biodiversity (Duan *et al.*, 2009). Urbanization, deforestation, construction, irrigation, drainage and pollution affect aquatic habitats. (Dudgeon, 2008). The organisms which live in the water respond to all environmental stresses (Veroli *et al.*, 2010), due to all these traits. Benthic macroinvertebrates have been

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widely used as indicators of water quality in river management. (Hellawell 1986, Metcalfe 1989, Jeffries and Mills 1990, Ro-senberg and Resh 1993), but the way functional diversity of macroinvertebrate assemblages influence processes in freshwater ecosystems needs to be broadened (De´nes *et al.*, 2016).

The use of macroinvertebrates in bioassessments has increased significantly (Cairns & Pratt, 1993 and Lenat & Resh, 2001). Macroinvertebrates represent a key indicator group for monitoring environmental change (Neville & Yen, 2007), but there is still much debate about the level of taxonomic identification and the sample size needed to determine anthropogenic impacts (Resh and McElravy, 1993) though the results depend on the particular objectives of the study (Daniel F. Buss and Anderson S. Vitorino, 2010). Generally, literature suggests that family classification is sufficient to detect impacts from point sources and other gross impacts in freshwater and marine systems (Wright *et al.* 1995, Vanderklift, Ward & Jacoby, 1996). Many studies have shown that the lowest level taxonomic resolution (genus) usually does not improve detection of impairment because of its reduced community variability when decreasing taxonomic resolution to the family level (Bowman and Bailey, 1997). Yet, the genre gave the same description of community models as family or order. Although identification of species have been more successful at classifying streams than the family, Furse *et al.* (1984) suggested that the family was sufficient to detect significant site-related environmental gradients. They also suggested that family identification could offer substantial savings in time and money over species identification. (Marchant, Barmuta and Chessman, 1995) found that the community pattern among 40 streams along an altitudinal gradient was preserved when quantitative species data were converted to quantitative or qualitative family data.

The main objective of the study was to establish as complete an inventory as possible of the different taxa that may be encountered in the aquatic system of the Oum Er Rbia River with the view to:

- enriching the list of Moroccan biodiversity,
- determining the taxonomic level (genus, family),
- detecting the gradient of pollution in Oum Er Rbia River and
- comparing the biodiversity of different freshwater ecosystems.

Materials and methods

Study area

The Oum Er Rbia River, one of the most important in Morocco , is located in the Mid-West of Morocco (Figure. 1). The River

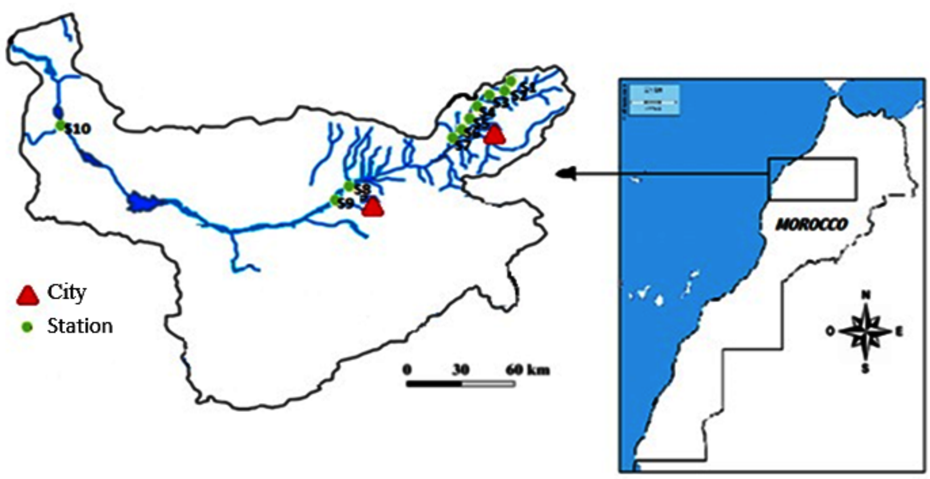

Figure 1: Location of the sampling station

originates from the Middle Atlas Mountains at 1800 m and flows into the Atlantic Ocean at Azemmour city. The Middle Atlas is characterized by a humid cold climate and is classified as Mediterranean mountain climate (Martin, 1981). Rainfall in the Oum Er Rbia basin varies between 1100 mm on the Middle Atlas and 300 mm in the downstream sections, with an average of 550 mm (USAID, 2010). Many dams and reservoirs have been constructed on the Oum Er Rbia River to generate hydroelectric power and to provide water for irrigation.

Sampling sites

The sampling sites (S1, S2, S3, S4, S5, S6, S7, S8, S9, S10) were marked out alongside the Oum Er Rbia Rivers (Figure 1). The samples were taken seasonally from September 2015 to September 2016. At each site, we made qualitative samplings of macroinvertebrates, using a Surber sampler (catching area: 0.025 m^2) (Berrahou *et al.*, 2000). At each site, eight samples were taken at different habitats. All captured organisms were placed in plastic bottles and preserved in 10% formaldehyde. The benthic macroinvertebrate identification was done to the lowest possible taxonomic level in the laboratory based on keys presented by Tachet *et al.*,(2000); Tachet *et al.* (2010). Physico-chemical data and heavy metals were obtained from the National Office for Electricity and drinking Water (ONEE) of Morocco. For each sampling site, data on pH, temperature, electrical conductivity (EC), dissolved oxygen (DO), chemical oxygen demand (COD), biochemical oxygen demand (BOD5) were collected. Total suspended solids (TSS) ,ammonium ($NH4^+$) and total phosphorus (P) were obtained.

Data analysis

Correlations between biological indices and chemical variables were computed using the Principal Component Factor Analysis of the Correlation Matrix. All statistical analyses were performed using the basis of Ward's method (H.Øyvind *et al.* , 2001).

Results and discussion

The physic-chemical factor values

The physical and chemical characteristics of the sites are presented in Table.1. However, except for Electrical Conductivity and COD, all measured parameters did not show any significant difference among the sampling occasions (Table 1). The measured temperature

TABLE 1
Mean values of physicochemical variables measured in the Oum Er Rbia River

Sites	(COD)	T°	pH	(NH_4^+) mg N/L	(EC) (µs/cm)	TSS mg/L	BOD5	(DO) mg O_2/L
S1	9.25±18.5	18.9±4.6	8.5±0.10	0.04±0.07	3450±685.3	99.8± 119.3	6.75 ± 5.9	6.4±0.6
S2	9.75±19.5	20.65±3.8	8.4±0.03	0.30±0.47	2340±105.5	98.6± 107.9	6.25 ± 4.9	6.9±0.5
S3	9.5±19.0	20.25±3.6	8.4±0.05	0.27±0.42	2390±150.1	106.3± 110.6	6 ± 5.0	6.9±0.4
S4	0±0.0	20.6±3.7	8.4±0.10	0.03±0.06	2405±147.3	1295.3±2470.2	4.5 ± 5.3	6.4±0.5
S5	4.75±9.5	20.55±3.0	8.4±0.11	0.26±0.16	2347.5±111.5	1394.8±2670.6	5.75 ± 7.6	6.5±1.1
S6	98.5±181.4	20.1±3.6	8.4±0.15	0.39±0.21	2310±202.2	1447.8±2768.6	34.5 ± 50.4	6.2±1.5
S7	0±0.0	17.67±2.0	8.4±0.15	0.30±0.13	2220±249.1	34.9±30.2	3.75 ± 4.8	6.2±0.7
S8	0± 0.0	16. 7±2.3	8.2±0.10	0.38±0.28	1987.5±130.0	34.3±28.2	0 ± 0.0	6.1±0.5
S9	0±0.0	20.8±4.8	8.3±0.13	0.45±0.29	2017.5±88.1	23.3±29.9	14.25 ± 7.8	6.0±0.3
S10	0± 0.0	24.55±1.8	8.3±0.09	0.02±0.04	1235±20.8	24.5±30.4	0 ± 0.0	7.3±0.3

values varied between 16.66 and 24.55°C, these measurements indicated that all water samples were of high quality as suggested by the Moroccan Standards for surface water Quality (2002).

High levels of Electrical conductivity were observed at all sites along Oum Er Rbia River and they ranged between 4220 and 1210 µS cm-1. This is due to the high content of dissolved salt in the major springs supplying Oum Er Rbia River. Site S1 which is located near the source of Oum Er Rbia River registered a very high conductivity (3810 µS cm^{-1}) and S10 showed the lowest electrical conductivity (1230 µS cm^{-1}). These results indicated that the water samples could be classified as moderate to highly polluted in terms of water quality (Moroccan Standards for surface water Quality, 2002). Electrical conductivity showed significant positive correlation with pH but negatively correlated with TSS and $NH4^+$ ions. The pH of this study was positively correlated with axis 3 of the CCA ordination of *Similudae* sp, *Beatidea* sp. On the other hand, Hydropsyche sp, noteridae gomophidae, chironomidae correlated nagatively with DO.

There were no significant differences between sampling sites for dissolved oxygen and pH. $NH4^+$ ranged between 0 and 0.625 mg/l, indicating that the river water had Excellent to Moderately quality (Moroccan Standards for surface water Quality, 2002). The higher $NH4^+$ are recorded at stations (S4, S5, S6, S7, S8, S9 and S10) close to a wastewater discharge of KssbaTadia. However, *Empididae* and *Anthomydae* were positively correlated with $NH4^+$ (Figure 1).

The BOD5 was used to quantify the amount of oxygen necessary for the degradation of the biodegradable organic matter by the development of micro-organisms (Maranda and J. L. Sasseville, 1999) . BOD5 in the various stations showed values between 0 and 34.5 mg/l with significant variations between seasons. COD showed contents between 0 and 149 mg/l, with variations between seasons, especially for the station (S6) which is situated downstream the abattoir wastewater in Khenifra. The TSS concentration showed a wide range of between 23.25 and 1447.75 mg/L, indicating that the river water had excellent to polluted quality according to (Moroccan Standards for surface water Quality, 2002).

Macroinvertebrate families found

The purpose of this census was to take an inventory of the different taxa that may be encountered in the waters of this aquatic

TABLE 2
Distribution of benthic macroinvertebrate taxa during the sampling period (September 2015 to September 2016) across sites

Order	Family	Code	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7	Sta. 8	Sta. 9	Sta. 10
Ephemeroptera	F/ Baetidae	Bear	+	+	+	+	+	+	+	+	+	+
	Baetis rhodani *Baetis sp*	Bea	+	+	+	+	+	+	+	+	+	+
	F/Caenidae *Caenis sp*	Cea	+	+	+	+		+	+	+		+
	F/Neritidae	Ner	+	+								
	F/Potamanthidae *Potamanthus sp.*	Pot	+		+							
	F/Oligoneuriidae	Oli	+	+								
	F/Heptageniidae	Epe	+	+	+	+			+	+	+	+
	Epeorus sp. *Ecdynurus sp*	Ecd	+									

Order (cont.)	Family	Code	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7	Sta. 8	Sta. 9	Sta. 10
Odonata	F/Gomphidae *Mesogomphus*	Mes	+	+			+	+				
	F/ Calopterygidae *Calopteryx sp*	Cal	+	+	+	+						
	F/Leptophlebiidae *Choroterpes*	Cho	+	+	+	+						
	F/Coenagrionidae *Coenagrion sp*	Coe	+	+	+	+						
Diptera	F/ Chironimidae	Chi	+	+	+	+	+	+	+	+	+	+
	Chironomus sp *Tanytarsus sp.*	Tan	+	+	+	+	+	+	+	+	+	+
	F/Simuliidae	Eus	+	+	+	+	+	+	+	+	+	+
	Eusimulium *Simulium*	Sim	+	+	+	+	+	+	+	+	+	+
	F/Ceratopogonidae *Culicoides sp*	Cul	+	+	+	+						+
	F/Tabanidae *Tabanus sp.*	Tab	+	+	+	+	+	+	+			+
	F/Anthomydae	Ant	+		+					+	+	
	F/Empididae	Emp	+	+	+	+				+		
	F/Rhagionidae	Rha	+	+	+							
	F/Tipulidae	Tip	+	+	+							
	F/ Athericidae	Ath	+	+	+							
	F/Stratiomyidae *Stratiomys sp.*	Str	+	+	+	+						
	F/Scatophagidea	Sca	+	+	+	+				+		
	F/Psychodidae	Psy	+	+	+	+				+		
	F/Ephydridae	Eph	+	+	+							
	F/Limoniidae	Lim	+	+	+							
	F/Syrphidae	Syr	+	+	+							
	F/Dixidae	Dix	+	+	+							
	F/Ptychopterida *Ptychoptera sp.*	pty	+	+	+							
Trichoptera	F/Hydropsychidae *Hydropsyche sp*	Hyd	+	+	+	+	+	+	+	+	+	
	F/ Hydroptilidae *Orthotrichia sp*	Ort	+	+	+	+	+			+		+
	F/philopotamidae *Chiamarra*	Chi	+	+	+							
	F/polycentropodidae	Pol	+	+	+							
	F/Leptoceridae *Setodes*	Set	+	+	+							
	F/Limnephilidae	Lim	+	+	+							
	F/Sericostomatidae	Ser	+	+	+							
Pulmonata	F/Physidae *Physa acuta*	Phy	+	+	+	+	+	+	+	+	+	+
Architaenioglosse	F/Viviparoidea Ss-F/viviparidae *Viviparus sp.*	Viv	+	+	+							+

Order (cont.)	Family	Code	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7	Sta. 8	Sta. 9	Sta. 10
Haplotaxida	F/ Haplotaxidae *Haplotaxis sp*	Hap	+	+	+	+	+	+	+	+	+	+
Coleoptera	F/Dytiscidae	Aga	+	+	+	+			+			
	Agabus sp.	Ily	+	+	+							
	Ilybius sp. *Hydrovatus sp*	Hyv	+	+	+							
	F/ Elmidae *Elmis sp*	Elm	+	+	+	+						+
	F/Gyrinidae *Gyrinus sp*	Gyr	+	+	+	+		+				+
	F/Chrysomelidae	Chr	+	+	+							
	F/ Hydrophilidae	Eno	+		+							
	Enochrus sp.	Hyr	+	+	+							
	Hydrochara sp.	Coe	+	+	+							
	Coelostoma sp. *Anacaena sp.*	Ana	+	+	+							
Amphipoda	F/ Gammaridae *Gammarus sp.*	Gam	+	+	+	+						+
Heteroptera	F/ Notonectidea *Notonecta maculate*	Not	+	+	+	+				+		
	F/Corixidae	Arc	+	+	+	+			+			
	Arctocorixa sp. *Corixa sp*	Cor	+	+		+						
	F/Aphelocheiridae *Aphelocheirus sp*	Aph	+									
	F/Nepidae *Nepa rubra*	Nep	+									
	F/Hydrometridae *Hydrometra*	Hym	+									
	F/Hydroptilidae *Orthotrichia sp*	Hyo	+	+		+						
	F/Hydraenidae	Hya	+									
Mecoptera	F/Boreidae	Bor	+	+		+				+		
Rhynchobdellida	F/ Glossiphoniidae Glossiphonia complanata	Glo	+		+		+	+	+	+	+	+

system and thus make it possible to enrich the list of Moroccan biodiversity.The faunistic inventory established groups and the distribution of stands in the different sampling stations (Table 2).

The macroinvertebrates found during the sampling period were distributed into twelve orders (Table 2). The most abandant order was *diptera* , having 9618 individuals (around 70% of the total), followed by the order *Ephemeroptera* with 2985 individuals (22%). The abundance of the order diptera was seen at all stations (Table 2) and during the whole sampling period, while the other orders were present occasionally. Station S3 had the highest relative abundance (Table 3), with a total of 2749 individuals reported (20%), followed by S6 with 2161 (16%), S7, 1757 (13%), S1, 1690 (12.1%) and S2, 1698 individuals (11.9%). Analysis of the entire population during the study period shows that the insects are numerically the most inventoried and

TABLE 3
Average values of the indices alculated on the 10 study stations

Sites	°/° EPT	PE	Pchiro	P hyd	PINS	IBGN	IHF	Sha	Marg	Indi
S1	24 .5	13,1	4	2,7	97,5	14	61	3.208	7.4	1690
S2	21 , 3	9,8	6	3,6	90	13.25	57	2.896	6.32	1698
S3	19,6	8,1	5	4,0	94,4	13.5	58	2.547	5.683	2749
S4	9	6,5	20	0,5	85,0	10.75	54	2.648	4.045	483
S5	6,5	3,27	21	5,3	53,8	6.5	50	1.81	1.375	695
S6	6 ,5	4,9	16	18,1	79,0	5.5	37	1.883	1.302	2161
S7	8,19	6,5	17	7,3	83,0	6	54	1.963	1.472	1757
S8	9,83	6,5	30	1,3	91,2	10.5	58	1.596	1.979	1182
S9	4,91	4,91	23	0,5	92,3	7.5	42	0.9978	1.143	1093
S10	8,1	6,5	4	0	61,7	11.5	62.7	2.392	2.458	198

%d'ephemeroptera :PE   Individuals :indi   % d'insectes : PINS   Shannon_H :Sha   °/° Hydropsychidae : P hyd   Margalef : Marg   %Chironomes : Pchiro

represent the highest percentage in all sites in Oum Er Rbia.

Table 3 shows the average values of the indices of diversity and biotic indices according to the stations. The highest mean values in ETP (*Ephemeres*, *Trichoptera* and *Plecoptera*) (19.6 to 24.5 taxa) are located at the stations where the species richness is the most important (S1, S2, S3). The stations disturbed (S5, S6, S9) had very low values, (6.5, 4.91). Also, the *Gammaridae* is more collected in upstream stations S1, S2, S3 (Table 2) represented by a single genus (*Gammarus*). We noticed that the taxonomic richness in Diptera was more diversified upstream than downstream, we had inventoried only five genera in medium stations. These spatial variations may be due to the various influences on the environment and also the nature of the different habitats. In fact, poor water quality can create favourable conditions for certain organisms which are more tolerant of pollution (polluoresistants).

Relative percentages of *chironomids* are lower at Oum Er Rbia source and bass stations (S1, S2, S3 and S10) than medium stations (Table 2). The medium stations were characterized by the lowest biotic indices cx and diversity indices : Shannon :1.02 to 1.95, Margalef: close to 3.95, IGBN (Global Standard Biological Index) : less than 5.5. This is not surprising because pollution-sensitive taxa, e.g. *Ephemeroptera*, *Trichoptera* and *Odonata* disappeared at these sites, as a result of lower biotope quality at these sites compared to other sites of the river . This could be related to natural and / or anthropogenic factors influencing this watercourse. Indeed, the discharge of domestic untreated wastewater in Kasba Tadla and Khenifra, undoubtedly, contribute considerably to the occurence of unfavorable conditions for benthic population. The polluted stations are characterized by the lowest biotic indices and diversity indices confirming the poor quality of these environments: Shannon: 0.9 to 1.96, Margalef: close to 1.14, IBGN (Global Standard Biological Index) : less than 5.5. The loss of indicator faunal groups, such as the Plecoptera Perlodidae and the Trichoptera Philopotamidae, explains the low values of the IBGN at these stations. These indices of diversity and biotic indices have a significant

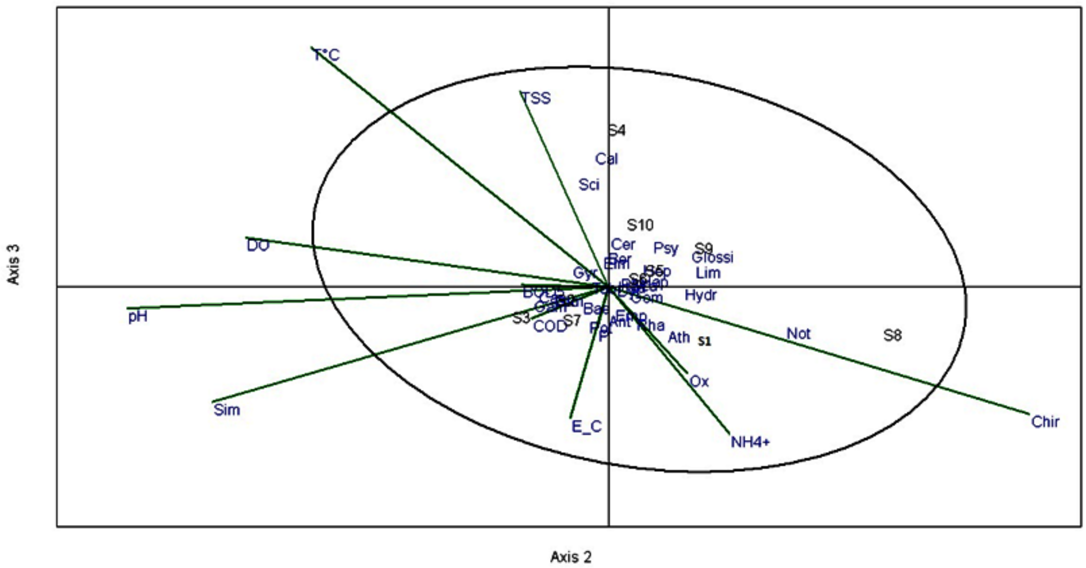

Figure 2: Correspondence analysis of stations , Macroinvertebrate families and environmental variables

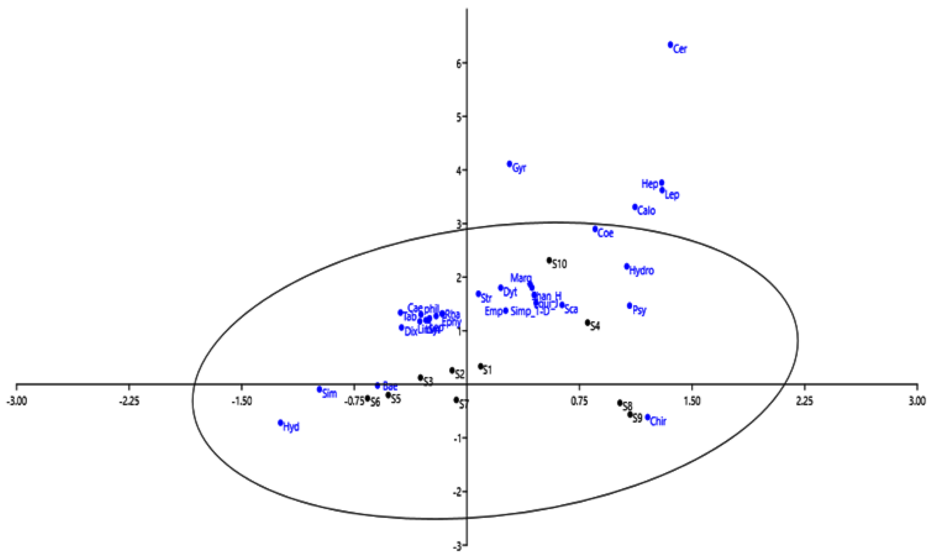

Figure 3: Correspondence analysis of stations and Macroinvertebrate families

linear relationship with the Oum Er Rbia stations (Fig. 2 and 4).

Figure 2 shows the relationship between the biotic indices and diversity indices and the IHF. This relationship is identical to that presented in Barbour *et al.* (1999). The condition of macroinvertebrate communities decreases with decreasing habitat quality. The River Habitat Index IHF shows a good relationship with the IBGN. These two indices, the IHF and the IBGN, have positive correlation respectively with the Shannon and Margalef (Fig. 4).

Using a variety of multivariate analysis, family and genus showed most of the same correlations to biotic indices and diversity indices (Fig. 4). Although the response to diversity indices was different, species were grouped in the center of the CCA ordinal triplate (Figu. 3). This suggests that no environmental variables explained species composition and distribution between sites. However, DO was negatively correlated with Chironomidae (Fig. 3).

According to diversity indices (Shannon , Taxa_S and Margalef), higher richness of benthic macroinvertebrates were recorded at the S1 ,S2, S3 with 10 genus restricted to

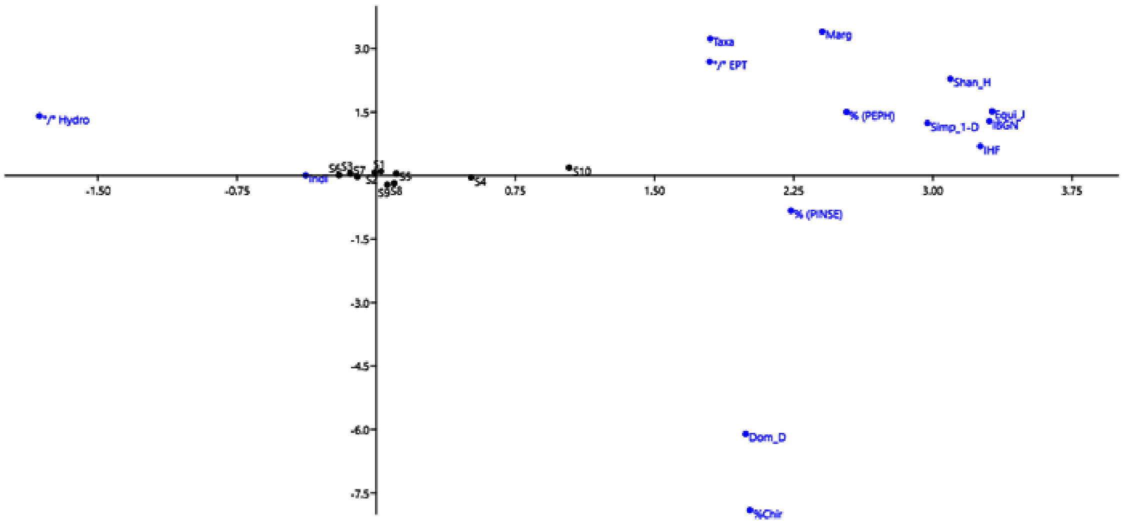

Figure 4: Correspondence analysis of stations and indices calculated on the 10 study stations

these sites, probably due to optimal habitat conditions, these sites are located upstream from major polluting source and can be considered as a local reference sites. In fact, the River Habitat Index IHF showed that these sites have good habitat quality (61 to 54) (Table 2). Riparian vegetation can also play a role in protecting benthic fauna from the direct effects of UV radiation (Quinn *et al.* 2004). In this study, although habitat quality was important across the sites (particularly at Headwaters), the habitat characteristics were positively correlated with benthic macroinvertebrates. Also, we noticed that percentages of ephemeroptera (PEPH) are higher at S1, S2, S3. However, most families belonging to the PEPH group are highly sensitive (Dickens and Graham 2002). Populations of benthic macroinvertebrate species responded differently to disturbance regimes and many species have different habitat requirements at each stage of their development cycle (Simaika and Samways 2011).

Conclusion

In summary, Oum Er Rbia River has a regime characterized by the irregularity of the flows and by brutal hydrological manifestations. The regime is marked by a poor flow in summer and autumn, and by a high flow in winter and spring. An inventory of the fauna carried out in the present study constitutes a first important database. The fauna studied is characterized by a variable taxonomic diversity according to the degree of water pollution. The fauna identified in this work consists of 52 families and belong to 3 faunistic groups (annelids, molluscs and arthropods). The benthic population showed that Diptera, Ephemeroptera and Trichoptera were dominant. Gammaridae, Heteroptera, Coleoptera and Odonata were only a small fraction of the harvested fauna. Hydropsyche, Chironomidae sp. and Simuliidae are the most numerically inventoried This is related to the relative resistance of these invertebrates to pollution and the fact that Hydropsyche larvae are a common component of water benthos (Verneaux *et al.*, 1976). The biological indices (IBGN, Shannon and Equitability) used for the characterization of the waters of the Oum Er Rbia River, made the study stations quite distinctive based on their level of pollution. The specific richness of the Oum Er Rbia

River depends on the ecological conditions at each station; it is even higher when the biotope is heterogeneous and less influenced by anthropogenic activities. Oum Er Rbia River can be considered as poor in wildlife (as to the presence / absence of taxa and their abundance); compared to the fauna inventoried by Chahlaoui in 1996 (Chahlaoui *et al.* 1996) and Karrouch in 2010 (Karrouch *et al.* 2010) in Oued Boufekrane.

In conclusion, we suggest that for the next studies in the Oum Er Rbia River sould focus on the selection of the indicator species and monitor them as substitutes for the entire community. However, it is not possible to develop a macroinvertebrate index that can be applied directly and without any adaptation or modification to all Marocco rivers. Some grouping of rivers based on ecological similarities which include both physical charctriestics and information on macroinvertebrate, can allow equivalent macroinvertebrate indices (IBGN) to be developed for similar river sections or in rivers in other parts of the country.

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