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Research Article.

Diversity and Composition of Benthic Macroinvertebrate Communities in the El Abiod River (Northeastern Algeria): Influence of Physico-Chemical Parameters

Ghiles SMAOUNE [1, 3], Imane SAAL [2, 3]

[1] Laboratory of Management & Valorisation of Agricultural & Aquatic Ecosystems, Institute of Natural Sciences, University Center of Tipaza, Tipaza, Algeria

[2] Faculty of Sciences, University Ben Youcef Ben Khedda, Algiers 1, Algiers, Algeria

[3] Laboratory of Dynamics and Biodiversity/USTHB/FSB, LP 32 El Alia, Bab Ezzouar, Algiers, Algeria

ABSTRACT

The present study investigates the spatial and temporal variation of benthic macroinvertebrate communities in relation to physico-chemical parameters in the El Abiod River, located in northeastern Algeria. Nine sampling stations were selected along a 74 km stretch of the river, covering different altitudinal and environmental gradients. Monthly samplings were conducted from March to February, except during July and August due to the complete drying of the river. Physico-chemical parameters such as temperature, pH, conductivity, dissolved oxygen, suspended solids, salinity, and nutrient concentrations (nitrates, nitrites, calcium, magnesium, and chlorides) were measured in situ and in the laboratory. A total of 13,678 individuals belonging to 59 families were identified. Insects dominated the assemblages (98.46%), with Diptera (45.62%), Ephemeroptera (37.76%), and Trichoptera (12.86%) as the most abundant orders, followed by Coleoptera, Odonata, and Mollusca. The Shannon–Weaver diversity index (H') and evenness (E) revealed significant spatial and temporal variations. The highest diversity values were recorded at downstream stations (H' = 3.83; E = 0.85), particularly at Foum El Gherza, characterized by moderate mineralization and reduced anthropogenic pressure, whereas upstream sites, such as Medina 2, showed low diversity (H' = 1.02; E = 0.44) due to organic pollution and domestic wastewater inputs. Multivariate analyses (PCA and CCA) highlighted strong correlations between community structure and key environmental variables, particularly conductivity, calcium, magnesium, and nutrient concentrations. These results suggest that the distribution and diversity of benthic macroinvertebrates in the El Abiod River are primarily governed by physicochemical gradients and anthropogenic influences. Overall, this study provides valuable insights into the ecological functioning of semi-arid rivers in North Africa and supports the use of benthic macroinvertebrates as reliable bioindicators for assessing water quality and ecosystem health.

KEYWORDS

Benthic macroinvertebrates;
Diversity;
Physico-chemical parameters;
Water quality;
El Abiod River;
Semi-arid ecosystem.

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∗ Corresponding author. E-mail address: smaoune.ghiles@cu-tipaza.dz

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1. INTRODUCTION

Freshwater ecosystems are among the most threatened habitats worldwide due to increasing anthropogenic pressures, climatic variability, and land-use changes. In semi-arid regions, these pressures are particularly pronounced, as rivers are characterized by high hydrological irregularity and limited water availability. Understanding the ecological functioning of these ecosystems is therefore essential for sustainable management and conservation of aquatic biodiversity. Benthic macroinvertebrates, which include insects, mollusks, crustaceans, and annelids, are widely used as biological indicators because they respond sensitively to changes in water quality, habitat structure, and pollution gradients (Tachet *et al.,* 2000; Ramade, 2005).

In North Africa, particularly in Algeria, the study of aquatic macroinvertebrates has received increasing attention over the past few decades. However, most existing studies have focused on taxonomy or biogeography, while ecological investigations that link community structure to environmental factors remain scarce (Lounaci and Thomas, 1983; Arab, 2004; Samraoui *et al.,* 2009). The ecological integrity of Algerian rivers is increasingly threatened by human activities such as wastewater discharge, agricultural runoff, and habitat modification, all of which can alter the composition and distribution of aquatic fauna.

The El Abiod River, located in northeastern Algeria within the Aurès mountain range, represents a typical semi-arid hydrosystem. It flows from the highlands of Chelia and Ichemoul toward the Sahara plains, crossing diverse geomorphological and climatic zones. This river plays an important ecological and socio-economic role for the surrounding communities, providing water for irrigation and supporting local biodiversity. However, the combined effects of seasonal drought, pollution, and anthropogenic disturbances have likely led to a degradation of its ecological quality.

Despite its ecological importance, the El Abiod River remains poorly studied, and little is known about how environmental gradients and physico-chemical parameters influence its benthic fauna. Assessing the diversity and composition of macroinvertebrate communities along its longitudinal profile can provide valuable insights into the river's ecological status and identify the key drivers of biodiversity patterns in semi-arid systems.

The present study aims to evaluate the diversity, composition, and spatial–temporal distribution of benthic macroinvertebrates in the El Abiod River in relation to environmental variables. Specifically, it seeks to: (i) describe the main physico-chemical characteristics of the river; (ii) assess the taxonomic composition and diversity of macroinvertebrate communities across stations and seasons; and (iii) analyze the relationships between community structure and environmental factors using multivariate analyses. This work contributes to a better understanding of the ecological dynamics of semi-arid rivers in North Africa and highlights the use of benthic macroinvertebrates as effective bioindicators for water quality assessment.

2. Materials and Methods

2.1. Study Area

The study was conducted in the El Abiod River, located in northeastern Algeria between latitudes 35°16′56″N and 34°50′52″N and longitudes 06°31′55″E and 05°55′06″E. The river originates in the Aurès Mountains from the convergence of torrents descending from Mount Chelia (2326 m) and Mount Ichemoul (2100 m), flowing southward through the gorges of Ghoufi and M'chouneche before reaching the Saharan plain. The catchment area belongs to the Chott Melghir hydrological basin and covers a wide range of altitudes and climatic conditions.

The region is characterized by a semi-arid Mediterranean climate, with cold, wet winters and hot, dry summers. Mean annual precipitation varies between 300 and 400 mm in the northern highlands and less than 150 mm in the southern part of the basin. The river often experiences summer desiccation, with complete drying of certain reaches between May and November. Geological formations include limestone, marl, and sandstone, while vegetation ranges from cedar and Aleppo pine forests in the highlands to palm groves in the valleys.

Nine sampling stations were selected along a 74.5 km stretch of the river, from the headwaters (Medina 1) to the downstream section (Foum El Gherza). Station selection considered altitude, accessibility, pollution sources, and habitat characteristics such as substrate type, vegetation cover, and riparian conditions (Fig. 1).

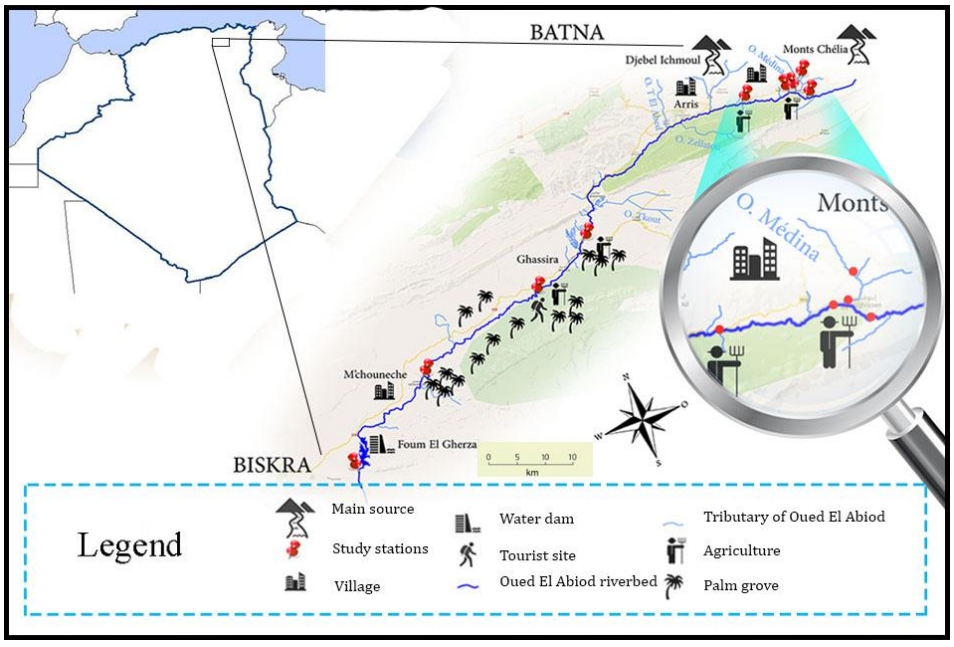

Figure 1. Location of the El Abiod River and the nine sampling stations in northeastern Algeria

2.2. Sampling Design

Sampling was carried out monthly from March to February, except during July and August due to the complete drying of the river. Each station was sampled in a representative 10× river width section to capture spatial variability.

Physico-chemical parameters were measured in situ using a multiparameter analyzer (WTW 340i), including water temperature (°C), pH, conductivity (µS/cm), dissolved oxygen (mg/L), salinity (‰), and redox potential (mV). Water samples were collected in polyethylene bottles (1 L) for laboratory analysis of total suspended solids (TSS), nitrates (NO_3^-), nitrites (NO_2^-), calcium (Ca^{2+}), magnesium (Mg^{2+}), and chlorides (Cl^-). Standard analytical methods were applied following Rodier (2005).

2.3. Biological Sampling and Identification

Benthic macroinvertebrates were collected using a **Surber sampler** (250 µm mesh, 0.05 m^2 area). At each station, eight subsamples were taken from different microhabitats characterized by combinations of flow velocity and substrate type (e.g., sand, gravel, cobble, vegetation). The collected samples were preserved in 5% formalin and transported to the laboratory for sorting and identification.

In the laboratory, samples were rinsed through a 250 µm sieve, and all organisms were sorted under a stereomicroscope. Identification was performed to the family level using standard identification keys (Tachet *et al.,* 2000). For each taxon, abundance (number of individuals) was recorded.

2.4. Data Analysis

The following community metrics were calculated for each station and sampling period:

- **Taxonomic richness (S):** total number of taxa present.
- **Abundance (N):** total number of individuals.
- **Relative abundance (Pi):** proportion of individuals of taxon *i* in the total sample ($P_i = n_i/N$).
- **Shannon–Weaver diversity index (H'):**

$$H' = -\sum p_i \ln(p_i)$$

- **Evenness (E):**

$$E = H' / H'_{max}$$

where Hmax′=ln S, whith S being the total number of taxa (Taxonomic richness)

2.5. Statistical analyses

Statistical analyses were performed using Principal Component Analysis (PCA) to summarize spatial variations of physico-chemical parameters, and Canonical Correspondence Analysis (CCA) to explore relationships between environmental variables and macroinvertebrate assemblages. These analyses were carried out using the statistical software XLSTAT 2014.

2.6. Quality Control

All sampling and laboratory procedures followed standardized protocols to ensure reproducibility and data quality. Physico-chemical measurements were calibrated before each field campaign, and replicate samples were taken randomly to assess sampling consistency.

3. Results and Discussion

3.1. Physico-Chemical Characteristics of the El Abiod River

The El Abiod River exhibited strong spatial and temporal variability in physicochemical conditions (Table 1). Temperature and conductivity increased progressively downstream, reflecting climatic gradients and ion accumulation. Dissolved oxygen was higher in cold, turbulent headwaters and lower in downstream reaches, where organic matter inputs and higher temperatures promoted oxygen depletion.

Similar longitudinal patterns were reported in other semi-arid rivers such as the Seybouse (Samraoui *et al.,* 2009) and the Oued Isser (Boumaiza and Thomas, 1995), where conductivity and salinity also increased downstream due to evapoconcentration and anthropogenic influences. Nutrient enrichment (nitrates, nitrites) at midstream stations suggested the influence of domestic effluents and agricultural runoff, confirming previous findings that such inputs can profoundly alter macroinvertebrate community structure (Ramade, 2005; Füreder *et al.,* 2001).

Table 1. Physico-chemical parameters measured at the nine sampling stations of the El Abiod River

Station (code)	T (°C)	Cond. (µS/cm)	pH	DO ($mg·L^{-1}$)	Salinity (‰)	TSS ($mg·L^{-1}$)	Nitrates ($mg·L^{-1}$)	Nitrites ($mg·L^{-1}$)	Ca ($mg·L^{-1}$)	Mg ($mg·L^{-1}$)	Chl ($mg·L^{-1}$)
M1 Medina 1	10.5 – 15.0	420	7.6	9.2	0.1	12	8.4	0.05	32.5	18.2	55
E1 Inoughissen	12.0 – 18.0	480	7.8	8.8	0.1	15	10.6	0.06	38	20	60
M2 Medina2	14.0 – 20.0	560	7.5	8.0	0.15	20	12.3	0.08	45	24	75
E2 El Abiod	16.0 – 23.0	680	7.8	7.4	0.2	25	11.0	0.09	52	28	90
E3 Hammam	18.0 – 25.0	890	8.0	7.2	0.25	28	15.4	0.10	60	32	110
E4 Tifelfel	20.0 – 28.0	1300	8.6	7.1	0.40	35	32.4	1.80	82	37	460
E5 Ghoufi	23.0 – 30.0	1650	8.8	6.8	0.60	38	25.0	0.20	95	46	280
E6 M'chouneche	27.0 – 32.0	2050	8.9	5.8	0.90	55	10.8	0.15	120	58	340
E7 Foum El Gherza	29.0 – 33.8	2540	9.0	5.3	1.20	60	1.7	0.10	320	238	410

The spatial distribution of chemical parameters such as nitrates, calcium, magnesium, and chlorides followed similar downstream gradients. Elevated concentrations of calcium and magnesium at downstream stations likely reflect both geological substrates (carbonate rocks) and evaporative concentration effects. High nitrate and chloride levels in some midstream stations suggest the influence of agricultural runoff and domestic effluents. These findings are consistent with other Algerian rivers under semi-arid conditions, where physicochemical variability is closely linked to hydrological intermittence and anthropogenic inputs (Lounaci *et al.,* 2000; Arab, 2004., Smaoune *et al.,* 2021).

3.2. Composition and Structure of Macroinvertebrate Communities

A total of 13,678 individuals belonging to 59 families and 10 taxonomic orders were collected during the study period. Insects largely dominated the assemblages, representing 98.46% of total abundance. The most represented orders were Diptera (45.62%), Ephemeroptera (37.76%), and Trichoptera (12.86%), followed by Coleoptera, Odonata, Plecoptera, and Hemiptera. Non-insect taxa such as Mollusca and Crustacea were less abundant and restricted to specific habitats.

Diptera were dominated by the families *Chironomidae* and *Simuliidae*, which are known to tolerate a wide range of environmental conditions, including organic pollution. In contrast, *Baetidae*, *Heptageniidae* (Ephemeroptera), and *Hydropsychidae* (Trichoptera) were abundant in well-oxygenated, fast-flowing upstream reaches. The presence of *Elmidae* (Coleoptera) and *Gammaridae* (Crustacea) at midstream stations indicates moderate water quality and diversified substrates.

The community structure reflected clear spatial patterns along the longitudinal gradient (Fig. 2). Upstream stations (Medina 1, Medina 2) were dominated by pollution-tolerant taxa such as *Chironomidae* and *Simuliidae*, while downstream sites (Tifelfel, Foum El Gherza) exhibited higher richness and diversity, with the co-occurrence of sensitive taxa including *Baetidae*, *Hydropsychidae*, and *Elmidae*.

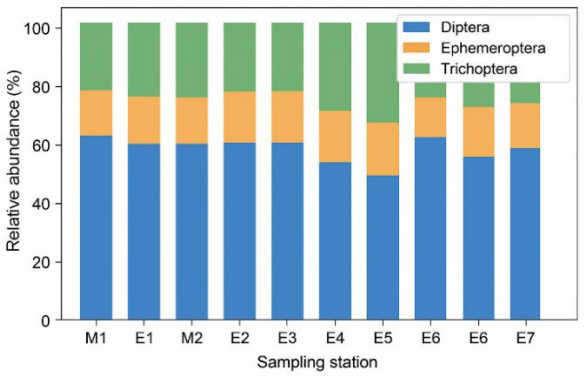

Figure 2. Relative abundance (%) of the major macroinvertebrate orders recorded along the El Abiod River

The community structure reflected clear spatial patterns along the longitudinal gradient (Fig. 2), with Diptera dominating upstream and a gradual increase of Ephemeroptera and Trichoptera downstream. This distribution pattern is consistent with the River Continuum Concept (Vannote *et al.,* 1980), suggesting that environmental gradients strongly shape benthic assemblages from headwaters to lower reaches. Similar longitudinal structuring has

been reported in North African rivers such as the Oued Isser and Seybouse (Arab, 2004; Lounaci *et al.,* 2000).

3.3. Diversity and Evenness Indices

Biodiversity indices showed marked spatial variation (Table 2). The Shannon–Weaver index (H') ranged from 1.02 at Medina 2 to 3.83 at Foum El Gherza. The Evenness index (E) varied from 0.44 to 0.85, indicating more balanced assemblages downstream.

Low diversity at upstream stations is likely due to organic pollution and reduced habitat heterogeneity caused by domestic wastewater discharge and hydrological instability. In contrast, downstream sections exhibited higher diversity associated with moderate mineralization, stable hydrology, and reduced anthropogenic impact.

Table 2. Diversity indices of macroinvertebrate communities across sampling stations of the El Abiod River

Station	Taxa richness (S)	Total individuals (N)	Shannon–Weaver index (H')	Evenness (E)
M1 – Medina 1	22	912	1.32	0.47
E1 – Inoughissen	28	1.048	1.85	0.56
M2 – Medina 2	17	684	1.02	0.44
E2 – El Abiod	24	850	1.46	0.51
E3 – Hammam	33	1.112	2.38	0.68
E4 – Tifelfel	41	1.437	3.42	0.81
E5 – Ghoufi	45	1.588	3.83	0.85
E6 – M'chouneche	39	1.326	3.14	0.78
E7 Foum El Gherza	44	1.472	3.76	0.83

These results are consistent with the "river continuum concept," which predicts that community composition and functional organization change predictably from headwaters to downstream reaches (Vannote *et al.,* 1980). Similar longitudinal patterns have been observed in other North African streams (Samraoui *et al.,* 2009; Boumaiza and Thomas, 1995).

The diversity indices showed a progressive increase downstream, indicating a gradual improvement in habitat heterogeneity and water quality. Low diversity at M2 and E2 may result from organic enrichment or unstable hydrological conditions.

In contrast, the high values recorded at Tifelfel, Ghoufi, and Foum El Gherza suggest well-oxygenated waters and complex substrates favorable to sensitive taxa (Mweemba *et al.,* 2025). Similar diversity gradients have been documented in Mediterranean rivers, where macroinvertebrate assemblages recover downstream through natural self-purification processes (Boix *et al.,* 2010).

3.1. Relationships between Environmental Factors and Macroinvertebrate Assemblages

Principal Component Analysis (PCA) of physicochemical parameters explained 72.3% of total variance, with the first two axes associated mainly with conductivity, calcium, magnesium, and nitrate concentrations (Fig. 3). Upstream stations were characterized by low mineralization and high oxygen content, while downstream sites exhibited higher ionic loads.

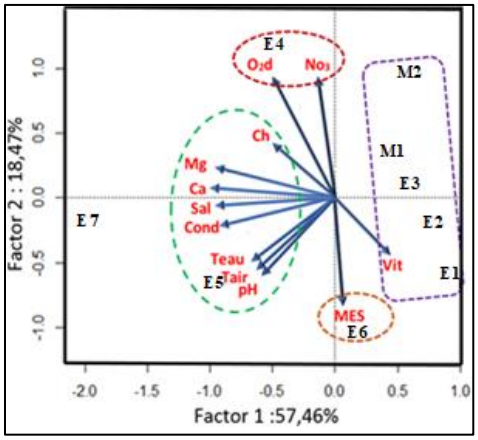

Figure 3. Principal Component Analysis (PCA) ordination of physicochemical parameters at the nine sampling stations. (Axis 1 and Axis 2 explain 72.3% of the total variance.)

The Canonical Correspondence Analysis (CCA) revealed strong correlations between certain taxa and environmental gradients (Fig. 4). Sensitive taxa such as *Baetidae* and *Heptageniidae* were positively correlated with high dissolved oxygen and low conductivity, whereas tolerant taxa like *Chironomidae* and *Simuliidae* were associated with increased conductivity and nutrient concentrations.

These relationships confirm that the structure of benthic macroinvertebrate assemblages in the El Abiod River is strongly influenced by both natural environmental gradients (altitude, temperature, mineralization) and anthropogenic factors (domestic and agricultural pollution).

The results highlight the ecological sensitivity of macroinvertebrate communities to multiple stressors in semi-arid rivers. The dominance of tolerant taxa at upstream polluted sites and the recovery of sensitive taxa downstream suggest that self-purification processes may occur along the river's course. However, seasonal desiccation and localized pollution continue to threaten biodiversity and ecosystem stability.

Overall, the diversity patterns and multivariate relationships emphasize that benthic macroinvertebrates are reliable bioindicators of water quality in semi-arid regions. Their use provides a cost-effective and ecologically meaningful approach for biomonitoring and river management in North Africa. These findings align with similar conclusions drawn from Mediterranean and Saharan ecosystems (Tachet *et al.,* 2000; Füreder *et al.,* 2001; Saal *et al.,* 2021).

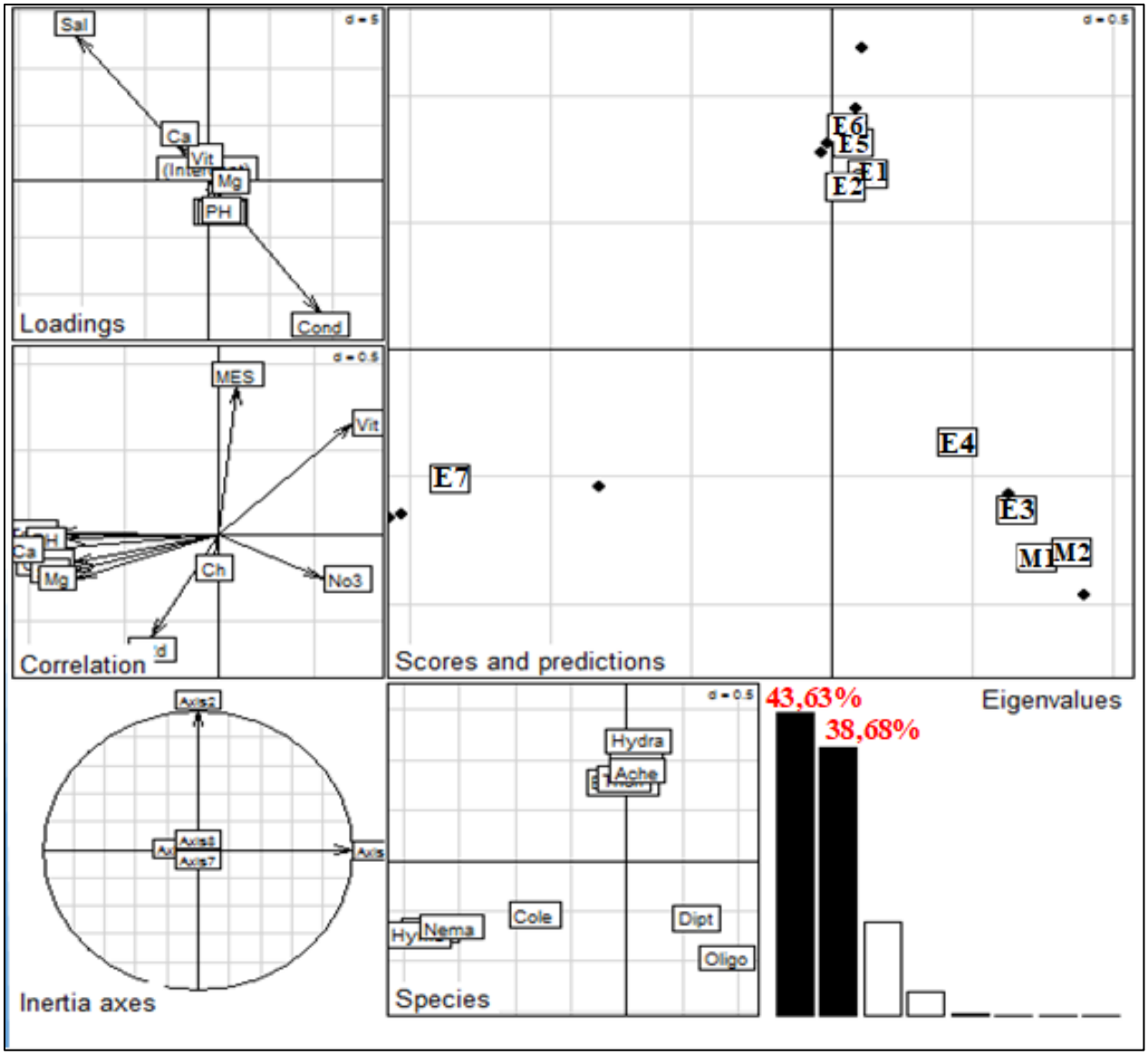

Figure 4. Canonical Correspondence Analysis (CCA) showing relationships between macroinvertebrate families and environmental variables

Multivariate analyses confirmed that conductivity, calcium, and nitrate were the key parameters influencing faunal composition.

Sensitive taxa such as *Baetidae* and *Heptageniidae* were associated with high oxygen and low conductivity, while tolerant taxa like *Chironomidae* dominated mineralized sites.

These findings agree with previous studies highlighting the influence of physicochemical stressors on benthic community structure (Tachet *et al.,* 2000; Bonada *et al.,* 2006; Smaoune *et al.,* 2025).

Overall, the observed patterns underline the ecological integrity of the El Abiod River and the resilience of its macroinvertebrate communities under semi-arid conditions.

The use of benthic invertebrates as bioindicators provides a reliable tool for assessing water quality and should be integrated into regional biomonitoring programs (Allan and Castillo, 2007; Samraoui *et al.,* 2009).

4. Conclusion

This study provides a comprehensive assessment of the diversity, composition, and environmental drivers of benthic macroinvertebrate communities in the El Abiod River, northeastern Algeria. The results demonstrate that the structure of macroinvertebrate assemblages is strongly shaped by spatial and temporal variations in physico-chemical conditions, reflecting both natural gradients and anthropogenic disturbances.

A total of 59 families were identified, with insect taxa (particularly Diptera, Ephemeroptera, and Trichoptera) dominating the community. Downstream sites exhibited higher taxonomic richness and diversity, associated with moderate mineralization and stable hydrological conditions, whereas upstream stations impacted by domestic wastewater and organic pollution showed reduced diversity and were dominated by tolerant taxa such as *Chironomidae* and *Simuliidae*.

Multivariate analyses (PCA and CCA) confirmed that conductivity, calcium, magnesium, and nutrient concentrations were the main environmental variables influencing community distribution. These findings emphasize the value of macroinvertebrates as reliable indicators of water quality and ecological integrity in semi-arid river systems.

From a management perspective, the study highlights the need for continuous ecological monitoring of the El Abiod River, particularly in areas exposed to human pressure. Integrating biological indicators with physicochemical monitoring would improve the effectiveness of water quality assessment programs in North African rivers. Furthermore, this research contributes valuable baseline data for future ecological modeling, conservation planning, and restoration strategies in semi-arid aquatic ecosystems.

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