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# Biodiversity of freshwater invertebrates in an archaeological site (Roman Ruins of Hippone, Northeast Algeria) in relation to physical and chemical parameters of water

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**Abstract:** As part of an inventory of aquatic invertebrates, our work involved species sampled from an archaeological site protected by the Algerian Ministry of Culture. Samples were taken monthly during the five-month, rainy period (February 2019-June 2019), in five separate vestiges (stations) selected according to the presence of water (rainwater). Systematic identification was carried out on 14,890 individuals sampled, identifying 18 species belonging to 11 families and 4 classes: Insecta, Arachnidia, Chilopoda, Crustacae. And the last one was the most representative in terms of abundance and taxonomic richness. On the other hand, a physicochemical analysis of ten parameters (temperature, hydrogen potential, electrical conductivity, total hardness, alkalimetric titer, complete alkalimetric titer, chemical oxygen demand, chlorides, calcium and magnesium) was carried out to determine the distribution of species. Analysis of the data obtained showed that electrical conductivity seems to be the most influential factor in the distribution of the majority of species among the five studied stations.

**Keywords:** macroinvertebrates, inventory, abiotic factors, aquatic ecosystems

## Introduction

Freshwater covers less than one per cent of the Earth's surface and accounts for 10 per cent of all known species (Min & Kong 2020, Tickner *et al*. 2020). Macroinvertebrate organisms represent a significant part of the aquatic ecosystem and are of economic and ecological importance (Arimoro & Keke 2016). Over the past fifty years, freshwater populations worldwide have declined by an average of 84%, twice the rate of terrestrial or marine ecosystems (Lovegren 2022).

The composition, distribution and abundance of benthic macroinvertebrates are influenced by physical, biological and chemical factors of the aquatic habitat (Emeka *et al*. 2020). Benthic macroinvertebrates in rivers are one of the key biological links that have been identified throughout the EU Member States, to determine their ecological status (Beauger & Lair 2014). However, the referential constitution of data and the development of a biological index now well established theIBGN (The Normalized Global Biological Index) to define and assess the ecological status of the aquatic site (AFNOR 2009). Due to their sensitivity to environmental stressors and their abundance, macrobenthic invertebrates are considered good markers for the health of freshwater ecosystems (Piló *et al*. 2016, Odountan *et al*. 2019). In Africa, several studies on benthic macroinvertebrates in running freshwater have been carried out (Bredenhande & Samways 2009, Agboola *et al*. 2019, Nahli *et al.* 2022, Bendary *et al.* 2022, Raphahlelo *et al*. 2022) and some works in Algeria (Bouchelouche *et al.* 2017, Hafiane *et al.* 2017, Kechemire & Lounaci 2017, Saal *et al.*

2017, Baaloudj *et al.* 2020, Baaloudj & De los rios 2022).

Anthropogenic activities have negatively impacted the environment and human health (Hamida *et al*. 2021, Ekperusi *et al*. 2022) andfreshwaters are among the most threatened ecosystems, particularly in North Africa (Rouibi *et al*. 2021). In addition, stagnant freshwater is still little studied and needs to be explored. The analysis of physical and chemical parameters is widely used to diagnose problems of water pollution and habitat degradation (Zinsou *et al*. 2016). The recent studies made in several aquatic ecosystems in Northeast Algeria (Hafsi *et al.* 2021, Hamaidia & Soltani 2021, Mahmoudi *et al*. 2022, Ameur *et al*. 2022, Houmani *et al*. 2023, Boulares *et al*. 2023) show the importance of ecological indexes in the distribution of species.

In this context, the objectives of the present study made in continuation to our recent surveys work in the region, were 1/to characterize the structure and diversityof benthic macroinvertebrates from a stagnant habitat from the Roman Ruins of Hippone, a protected tourist site classified as a historic monument since 1968, located in the city of Annaba (Northeast Algeria) and 2/ to evaluate the impact of physicochemical parameters of water on the distribution of species collected from the five stations. The attempted results give us information on our understanding on the structure and diversity of macroinvertebrates in this particular aquatic habitat.

## Material and methods

### *Presentation of the studied site*

The city of Annaba is located on the southern shore of the Mediterranean basin, in the Northeast Algeria, 600 km from the capital Algiers. The ancient site of Hippone is located in the Southwest of Annaba, about 3 km from the city centre of the province. It is located in the plain, between two lower courses of the Oued Boudjema, to the Northwest and the Oued Seybouse to the Southeast. The ruins cover an area of approximately 9 hectares (Fig. 1). This site has very rich vegetation, as well as a diversity of fauna in the water stagnation formed by the walls of the ruins during the rainy seasons. Each stations was characterized by the following physical and chemical: Temperature, Hydrogen Potential, Electrical Conductivity, Total Hardness, Alkalimetric Titer, Complete Alkalimetric Titer, Chemical Oxygen Demand, Chlorides, Calcium and Magnesium.

### *Sampling method and systematic identification*

Qualitative and quantitative sampling was carried out at 5 stations (Table 1) during the five-month rainy period (February 2019 - June 2019). The collection technique was inspired by the dipping method, using a 0.5 mm mesh net immersed in the water and then moved in a uniform movement, avoiding eddies at accessible stations. For stations that were not accessible, a 5-litre capacity bucket attached to a rope was used. The sampled water is filtered through a 1 mm email strainer. The samples collected must be placed in hermetically sealed containers and labelled (date and station) and transported to the laboratory (Messai *et al.* 2010). Samples are sorting and kept in bottles containing 70% alcohol, for Cladocera, Diptera and Hydracaria, identification was made after clarification of the specimens, in a 10% NAOH solution for 48 hours. The number of individuals of certain taxa (Cladocera and Culicidae) exceeding well over 100 will be estimated (Hecq 1976). Systematic identification was carried out according to the keys according to Amoros (1984), the software of Schaffne *et al* (2001), Smith (2020), Meisch (2000), Heidemann & Seidenbusch (2002), Cham (2007), Picard (1929) and Rose (1933).

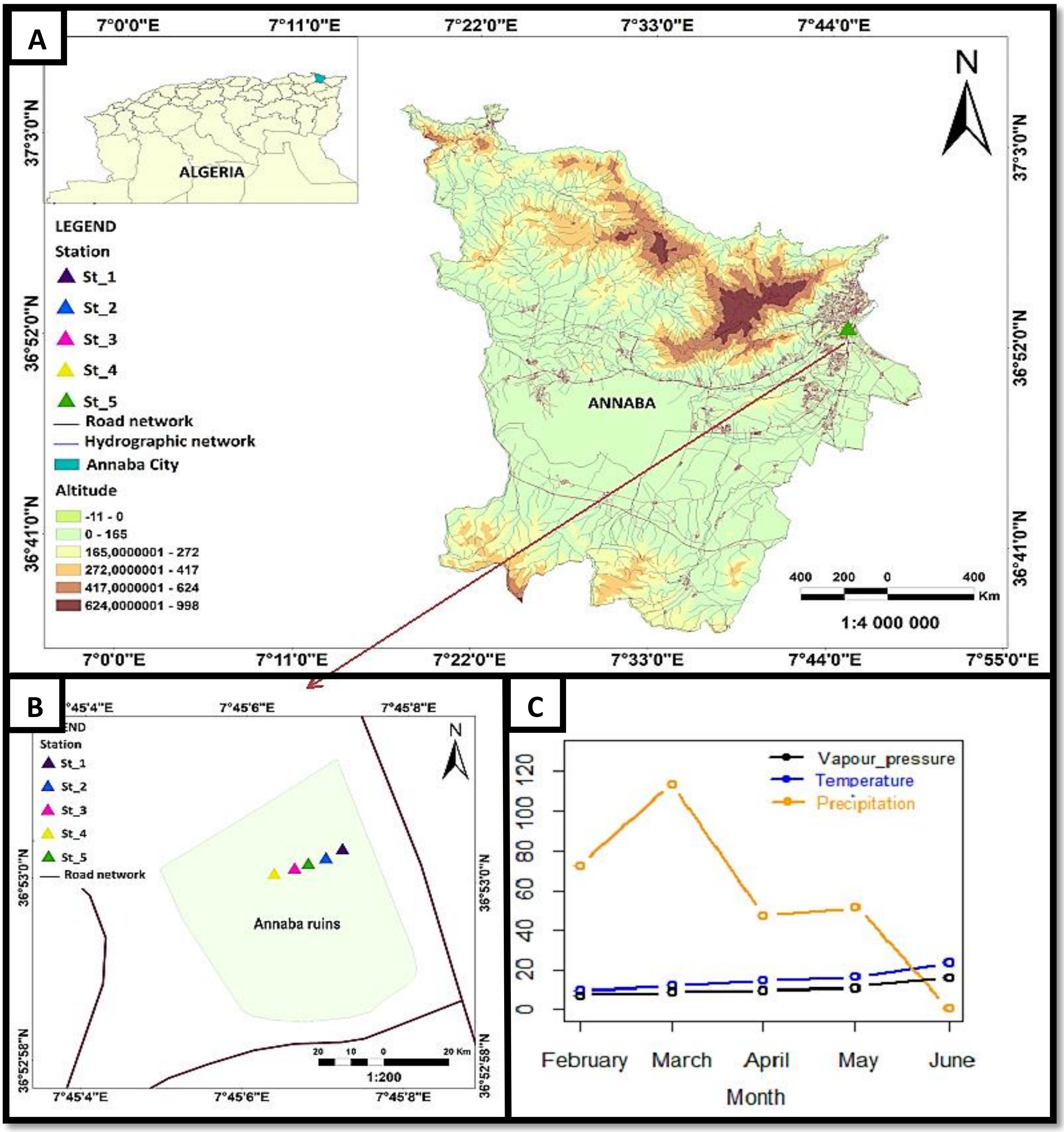


Fig. 1. Geographical location of the studied site, the Roman Ruins of Hippone **(A)**, positioning of the stations marked with triangle **(B)** and climatic characteristics **(C).**

Table 1. Geographical coordinates of studied stations

| Stations | Geographical coordinates |
|---|---|
| **1** | 7°45'7.37"E, 36°53'0. 36''N |
| **2** | 7°45'7.16"E, 36°53'0. 26''N |
| **3** | 7°45'6.78"E, 36°53'0.14''N |
| **4** | 7°45'6.52"E, 36°53'0.08''N |
| **5** | 7°45'6.94"E, 36°53'0.19''N |

### *Statistical analysis*

All analyzes were carried out using R software, version 4.0.1 (R Core Team 2020).The data concerning the determination of ecological indices like compositional ecological indices (species richness and relative abundance) and structural ecological indices (Shannon-Waever index, Simpson index & Piélou equitability index). AFC (Correspondent Factor Analysys) uses the singular value decomposition of a particular matrix to visualize words and documents in a reduced dimensional space, with a cloud of projected points (words and/or documents) of maximum inertia. In addition, CFA gives relevant indicators for interpreting the axes (Morin *et al*. 2004). Principal component analysis (PCA) is a factorial analysis that produces factors (principal axes) which are linear combinations of the original variables, hierarchised and independent of each other. These factors are often referred to as 'latent dimensions' because they are 'the expression of general processes directing the distribution of several phenomena which are therefore correlated with each other (Bourque *et al.* 2006).

## Results

### *Inventory and systematic identification of benthic macroinvertebrates*

The result of the systematic identification of the macrobenthic fauna collected is summarized in Table 2.

The results reveal a total of 14,890 individuals divided into 8 groups (Fig. 2) belonging to 11 families composed of Daphnidae, Culicidae, Lithobidae, Chironomidae, Cypridae, Copepodae, Leistidae, Micronectida, Hydrophilidae, Pleidae, Pionidae. The Cladocera group is the most abundant with 9,828 individuals, followed by the Diptera group with 4,409.

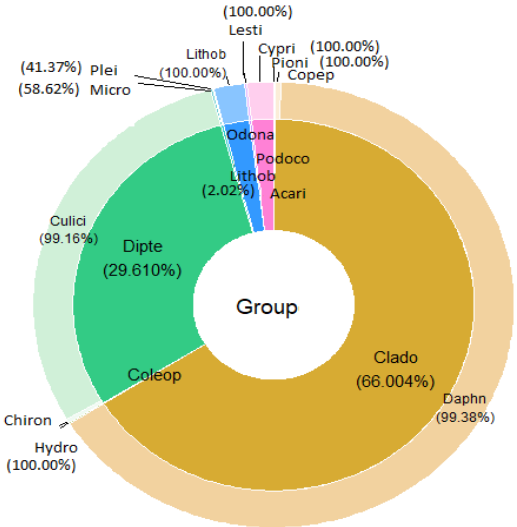


Fig. 2. Community composition of sampled benthic macroinvertebrates.

Table 2. Total species richness, abundance and frequency of occurrence of macrobenthic fauna at the Roman Ruins during the rainy season. (Abu: Abundance, Fr. oc: frequency of occurrence)

| Groups | Families | Species | Abu | Fr.oc [%] | Stations | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | S1 | S2 | S3 | S4 | S5 |
| Cladocera Latreille 1829 | Daphnidae Straus 1820 | *Daphnia magna* Straus 1820 *(D.mag)* | 4 | F ≤ 4 | - | 4 | - | - | - |
| | | *Daphnia similis* Claus 1876 *(D.sim)* | 185 | F ≤ 4 | - | 185 | - | - | - |
| | | *Simocephalus vetulus* Müller 1776 (S .vet*)* | 3262 | 5 | 2935 | 63 | 110 | 63 | 91 |
| | | *Simocephalus expinosus* koch 1841 *(S.exp)* | 6316 | 25 | 5865 | 94 | 254 | 34 | 69 |
| | Copepodae Milne Edwards 1840 | *Cyclops fuscus* Jurine 1820 *(Cy fus)* | 61 | F ≤ 4 | 36 | 5 | - | 18 | 2 |
| Diptera Linnaeus 1758 | Chironomidae Newman 1834 | *Chironomus plumosus* Linnaeus 1758 *(C.plu)* | 37 | F ≤ 4 | 3 | 4 | 24 | 2 | 4 |
| | Culicidae Meigen1818 | *Uranota eniaunguiculata* Edwards1993 *(Ur.ung)* | 10 | F ≤ 4 | - | 10 | - | - | - |
| | | *Culiseta longiareolata* Macquart 1838 *(C.rio)* | 4356 | 25 | 47 | - | 4309 | - | - |
| | | *Culex laticinctus* Edwards 1913 (C. lat) | 6 | F ≤ 4 | - | - | 6 | - | - |
| Lithobiomorpha Pocock 1895 | Lithobiidae Newport 1844 | *Lithobius forficatus* Linnaeus 1758 *(L.for)* | 313 | F ≤ 4 | 260 | - | 11 | 42 | - |
| Acari Leach1817 (Hydrachnidia) | Pionidae Thor1900 | *Piona uncata* Koenike 1888 (Pi.unc) | 11 | F ≤ 4 | 5 | 1 | 5 | - | - |
| Hemiptera Linnaeus 1775 | Pleidae Fieber 1851 | *Plea minutissima* Leach 1817 *(P.min)* | 12 | F ≤ 4 | 2 | 8 | - | 2 | - |
| | Micronectidae Jaczewski 1924 | *Micronecta poweri* Douglas & Scott 1869 *(M.pow)* | 17 | F ≤ 4 | 12 | 5 | - | - | - |
| Podocopida Sars 1866 | Cyprididae Baird 1845 | *Cypris bispinosa* Lucas 1849 *(C .bis)* | 237 | F ≤ 4 | 149 | 49 | 14 | 25 | - |
| | | *Eucypris virens* Jurine 1820 *(E.vir)* | 29 | F ≤ 4 | - | 8 | 20 | 1 | - |
| Odonata Fabricius 1793 | Lestidae Calvert 1901 | *Lestes virens* Charpentier 1825 *(L.vir)* | 20 | F ≤ 4 | 3 | 12 | - | 5 | - |
| Coleoptera Linnaeus 1758 | Hydrophilidae Latreille 1802 | *Anacaena globulus* Paykull 1798 *(A.glo)* | 9 | F ≤ 4 | - | 4 | 2 | 3 | - |
| | | *Berosus affinis* Brullé 1835 *(B.aff)* | 5 | F ≤ 4 | 3 | - | 2 | - | - |

## *Ecological composition indices*

***Spatial composition***: Table 3 shows the total richness, which varies between stations. It is important at the second station with 14 species, and drops to 4 at the fifth station. For the total number of individuals and the average richness, station 1 records the highest value with 9,320 individuals and 1,864 respectively followed by the third station with 4,757 individuals and 951.4; the minimum value was marked by station 5 with 166 individuals and 33.2.

***Relative abundance***: For the relative abundance of benthic macroinvertebrates. The results show that the species *Simocephalus expinosus* is in first place with 6,316 individuals, which is 42.41%, followed by *Culiseta longiareolata* with 4,356 individuals, that is 29.25%, and in third place is *Simocephalusvetelus* with 3,262 individuals, is 21.9% (Fig 3).Concerning Frequency of occurrence *Simocephalus expinosus* and *Culiseta longiareolata* belong to the Accessory category and *Simocephalus vetelus* belongs to the Accidental category and the rest of the taxa are in the Rare category (Table2).

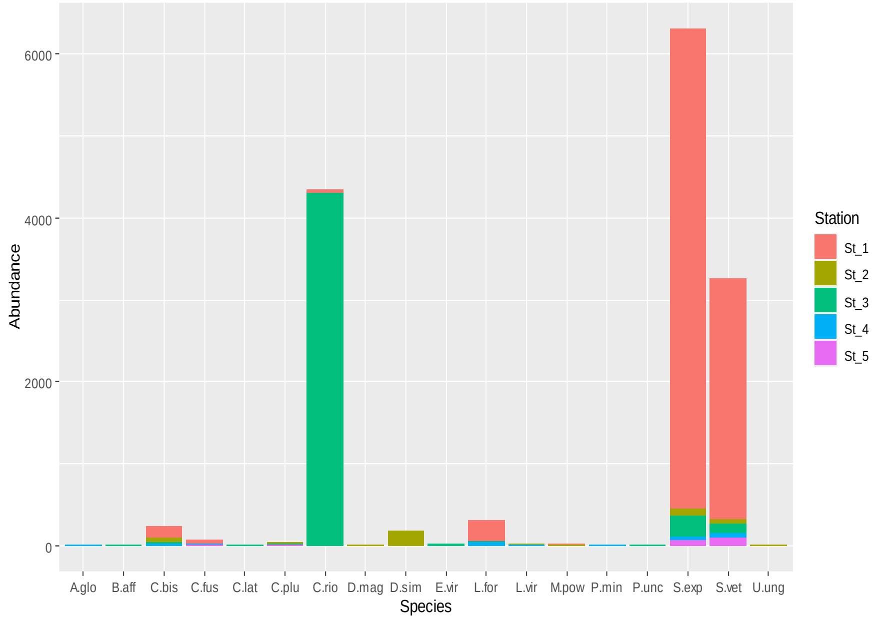


Fig. 3. Relative abundance of species per station of macrobenthic fauna inventoried (February – June 2019). *(P.min), (C.rio), (C.lat), (D.mag), (L.vir), (S.exp), (S .vet) (E.vir), (C.plu), (M.pow), (Pi.unc), (Cy.fus), (A.glo), (D.sim), (B.aff), (Ur.ung), (C .bis), (L.for).*

### *Structure Indexes*

***Diversity index and equitability***: The five-month sampling recorded a total of 14,890 individuals from the different stations. The total richness indicated presence of 18 species (Table 3). The diversity index shows values ranging from 0.436 for the third station to 1.796 for the second station which is rich in species (14 species). However, the equitability allows to compare the structures of the populations, it records values between 0.073 and 0.37 in the five stations; therefore the populations are not balanced. The Simpson index of the five stations is varied and ranges from 0.17 - 0.79. Overall the diversity according to Simpson can therefore be considered high at stations 2 and 4 and lower at the rest of the stations.

**Table 3.** Ecological indices of aquatic invertebrate community recorded in each station (S= Species, H=Shanon index, D= Simpson index, J= Equitability)

| Station | S | H | D | J |
|---|---|---|---|---|
| **1** | 12 | 0.891 | 0.504 | 0.202 |
| **2** | 14 | 1.769 | 0.756 | 0.286 |
| **3** | 11 | 0.436 | 0.176 | 0.073 |
| **4** | 10 | 1.763 | 0.793 | 0.344 |
| **5** | 4 | 0.837 | 0.526 | 0.379 |

## *Analysis factor correspondences*

CFA was applied to summarise distribution of [18 species (columns) X station (row)]. The results are expressed as a Dim1 vs Dim2 factorial design for the factor "station"

Dimensions 1 and 2 explain respectively 60.2% and 34.3% of the total inertia. This corresponds to a cumulative total of 94.5% of the total inertia retained by these two dimensions. Indeed, the graph in Figure 4 show:

-The species *Culiseta longiareolata, Simocephalus expinosus* and *Simocephalus vetulus* have a large contribution to axis 1, so axis 1 is mainly defined by these species. While *Daphnia similis,* has a strong contribution to axis 2 so axis 2 is mainly defined by this species.

-The species *Cyclops fuscus* and *Lithobius forficatus* have a poor representation quality (cos2<40%). While the species *Anacaena globulus, Chironomus plumosus* have a medium quality of representation. The rest of the species have a good representation quality.

-The species *Simocephalus expinosus, Simocephalus vetulus* are associated with station 1. The species *Lithobius forficatu s*and *Cyclops fuscus* are associated with stations 1 and 4. *Daphnia similis, Daphnia magna* and *Uranotaenia unguiculata, Plea minutissima, Lestes virens* are associated with station 2. The species *Micronecta poweri, Cypris bispinosa* are associated with stations 1, 2. The species *Culiseta longiareolata* and *Culex laticinctus, Eucypris virens and Chironomus plumosus* are associated with station 3. The species *Anacaenaglobulus*is associated with stations 2, 3, 4.

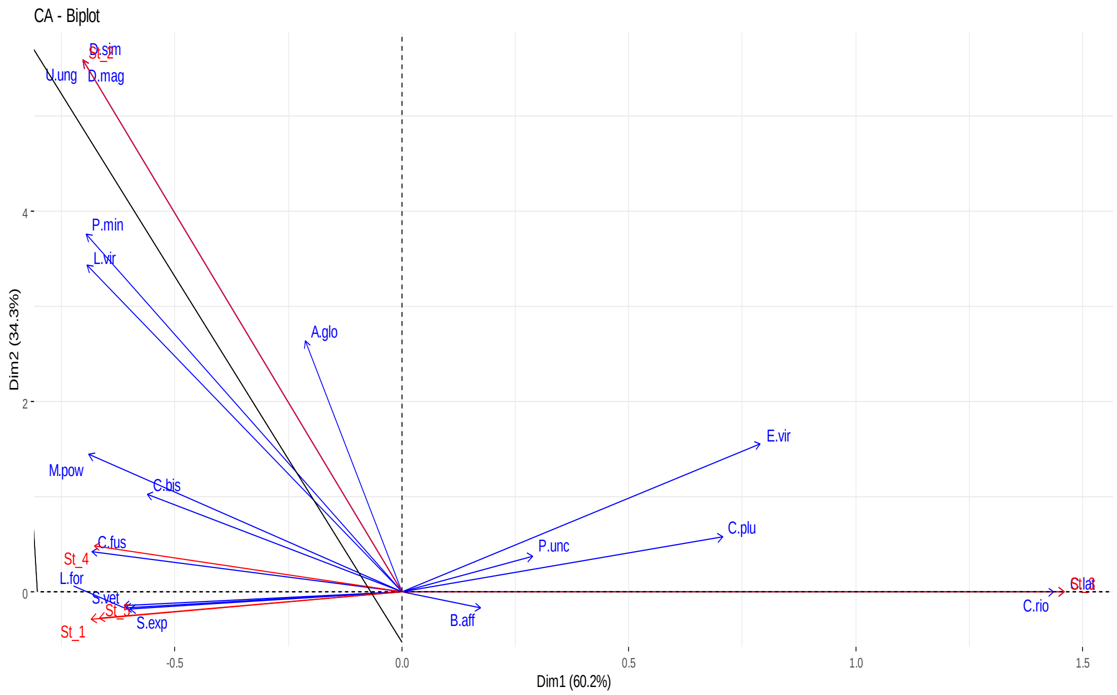


Fig. 4. Correspondence factor analysis (CFA) on the abundance data of the macrobenthic fauna inventoried at the five study stations. *(P.min), (C.rio), (C.lat), (D.mag), (L.vir), (S.exp), (S .vet) (E.vir), (C.plu), (M.pow), (Pi.unc), (Cy.fus), (A.glo), (D.sim), (B.aff), (Ur.ung), (C .bis), (L.for).*

### *Spatial hierarchical ascending classification*

The CAH dendrogram per station marked 3 main groups from 18 taxa. Group 1 consists of *Culiseta longiareolata* and *Culex laticinctus,* group 2 is composed of *Daphnia magna, Uranotaenia unguiculata, Daphnia similis* and the third group is formed by de *Simocephalus vetulus, Simocephalus expinosus, Berosus affinis, Piona uncata, Cyclops fuscus, Lithobius forficatus, Anacaena globulus, Plea minutissima, Lestes virens, Micronecta poweri*, *Cypris bispinosa, Chironomus plumosus Eucypris virens* (Fig. 5).

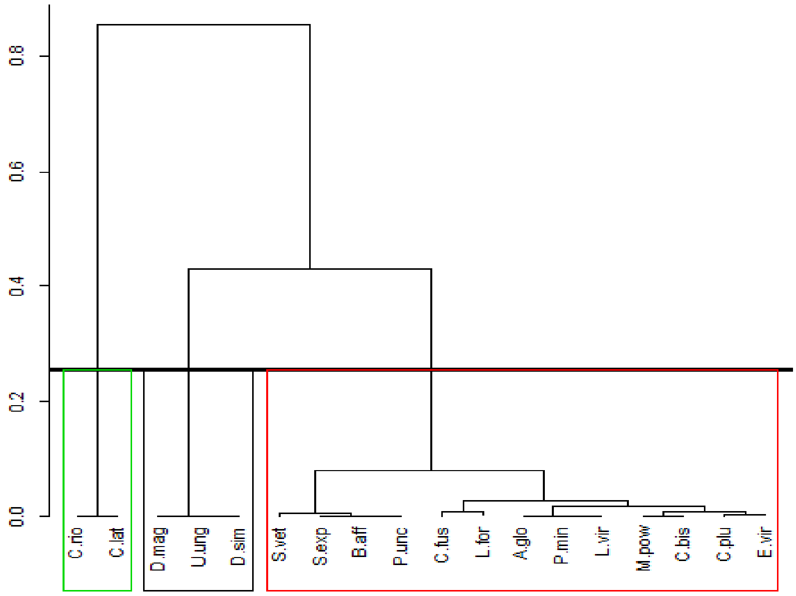


Fig. 5. Dendrogram from the bottom-up hierarchical classification of the species collected at the five studied site. *(P.min), (C.rio), (C.lat), (D.mag), (L.vir), (S.exp), (S.vet) (E.vir), (C.plu), (M.pow), (Pi.unc), (Cy.fus), (A.glo), (D.sim), (B.aff), (Ur.ung), (C.bis), (L.for).*

### *Multivariate analysis (Principal Component Analysis)*

The multi-variate analysis aims to examine the physical and chemical and biological structuring of the stations in this study and to examine the influence of physical-chemical parameters on the distribution of the macrobenthic fauna. However, abiotic parameters (Temperature, pH, Electrical Conductivity, Alkalinity (TA, TAC), Total Hardness (TH), Chemical Oxygen Demand, Chlorides, Calcium, Magnesium) (table 4) are used as quantitative explanatory variables, while the abundances of macrobenthic species are treated as explained variables (additional). Indeed, the application of PCA showed that 81.1% of the total variability (inertia) of our matrix of biotic and abiotic variables is explained by the first two principal components (Fig. 6, 7). The 1st PCA axis alone explained 48.3% of the total variability, it is positively correlated with Calcium (Ca) *(r=0.97; cos2=0.93)*, Total Hardness (TH*)(r=0.91; cos2=0.83);* Magnesium (Mg*) (r=0.68; cos2=0.46)*, Conductivity (COND) *(r=0.56; cos2=0.31).*On the other hand, this axis is negatively correlated with Alkalinity (TAC) *(r=-0.92; cos2= 0.85),* pH *(r=-0.72; cos2= 0.52)* and Chlorides Cl *(r=-0.56; cos2=0.31).* However, the 2nd axis alone explained 32.8% of the total variation and was positively correlated with COD *(r=0.74; cos2=0.55),* chloride (Cl) *(r=0.83; cos2=0.69)* and pH *(r=0.69; cos2=0.48).(COND) (r=-0.72; cos2=0.51).*

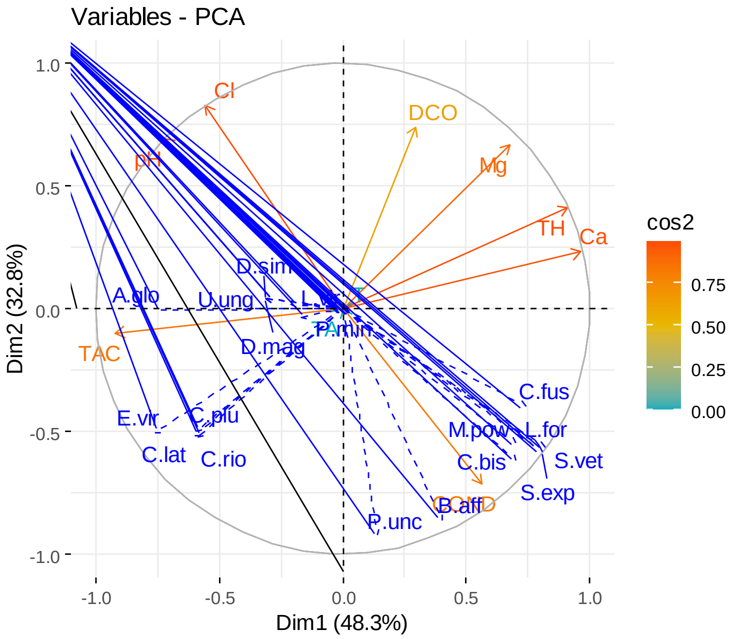


Fig. 6. Graphical of the 10 variables within the correlation circle of factorial design 1-2 obtained from the data of the 5 studied stations. *(P.min), (C.rio), (C.lat), (D.mag), (L.vir), (S.exp), (S .vet) (E.vir), (C.plu), (M.pow), (Pi.unc), (Cy.fus), (A.glo), (D.sim), (B.aff), (Ur.ung), (C .bis), (L.for),* [pH], [COND], [T], [TH], [$Ca^{2+}$],[TA], [TAC], [$Cl^{-}$],[DCO], [$Mg^{2+}$].

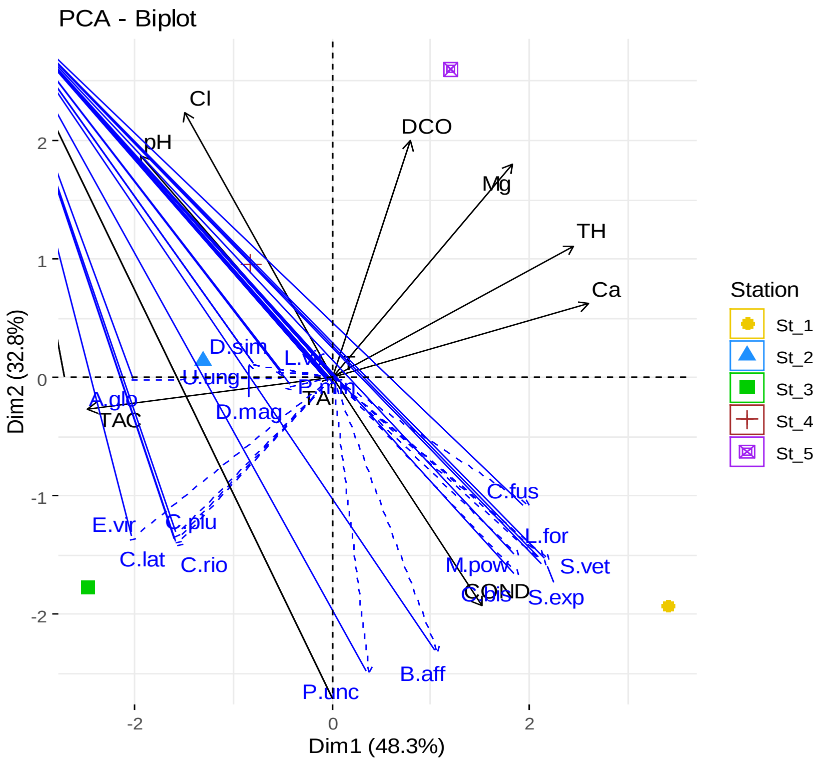


Fig. 7. Principal component analysis (PCA) representing the relationship between the physico-chemical parameters of the water and the macrobenthic fauna recorded at the five studied stations *(P.min), (C.rio), (C.lat), (D.mag), (L.vir), (S.exp), (S .vet) (E.vir), (C.plu), (M.pow), (Pi.unc), (Cy.fus), (A.glo), (D.sim), (B.aff), (Ur.ung), (C .bis), (L.for),* [pH], [COND], [T], [TH], [$Ca^{2+}$],[TA], [TAC], [$Cl^{-}$],[DCO], [$Mg^{2+}$].

In contrast, the principal component analysis revealed that from axis 1:

-TH, Ca, COND and Mg positively influence the distribution of: *Cyclops fuscus, Simocephalus vetulus, Simocephalus expinosus, Lithobius forficatus, Micronecta poweri* and *Cypris bispinosa*, on the other hand they influence negatively the distribution of*: Eucyprisvirens, Anacaena globulus, Chironomus plumosus, Culiseta longiareolata* and *Culex laticinctus.*

**Table 4.** Mean water physical and chemical variables (± standard deviation) recorded across five stations of Roman Ruins

| water physical and chemical parameters | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Stat-ions** | **Hydro-gen poten-tial [pH]** | **Conducti-vity [COND] (µS cm-1)** | **Tempe-rature [T] (C°)** | **Total Hardness [TH] (F°)** | **Calcuim [$Ca^{2+}$] (mg/l)** | **Alkalime-tric Title [TA] (F°)** | **Complete Alkalime-tric Title [TAC] (F°)** | **Chloride [$Cl^-$] (mg/l)** | **Chemical Oxygen Demand [DCO] (mg/l)** | **Magne-sium [$Mg^{2+}$] (mg/l)** |
| **1** | 6.8 ±0.49 | 2500 ±110 | 23 ±2 | 44± 3.63 | 33 ±2.6 | 0 | 46 ±6.8 | 227.2 ±48.53 | 27 ±5.5 | 11 ±0.65 |
| **2** | 7.63 ±0.08 | 2320 ±40 | 23 ±2 | 39.7± 0.33 | 30 ±1.66 | 0 | 56 ±4.5 | 310.6 ±13.56 | 40 ±0.33 | 9.7 ±0.3 |
| **3** | 7.46 ±0.33 | 2290 ±60 | 23 ±2 | 37.4± 3.53 | 28 ±2.33 | 0 | 56.4 ±4.7 | 291 ±23.37 | 6 ±3 | 9.4 ±0.8 |
| **4** | 7.66 ±0.31 | 2320 ±70 | 23 ±2 | 41± 2.13 | 30 ±1.86 | 0 | 56.8 ±5.8 | 319.5 ±18 | 40 ±0.6 | 11 ±0.4 |
| **5** | 7.63 ±0.35 | 2210 ±90 | 23 ±2 | 44.4± 1.7 | 32.2 ±2.8 | 0 | 47 ±2.6 | 333.7 ±7.1 | 38 ±1.55 | 12.2 ±0.6 |

-pH, Cl and COND positively influence the distribution of*: Eucypris virens, Anacaena globulus, Chironomus plumosus, Culiseta longiareolata* and *Culex laticinctus,* but they negatively influence the distribution of: *Cyclops fuscus, Simocephalus vetulus, Simocephalus expinosus, Lithobius forficatus, Micronecta poweri* and *Cypris bispinosa.*

However, axis 2 showed that COND positively influences the distribution of *Piona uncata, Eucypris virens and Berosus affinis* While Mg, pH and Cl negatively influence the distribution of *Piona uncata* and *Berosus affinis.*

The further analysis of the PCA for the factor "station" showed that from the first axis two groups were found: the first group includes station 1 and station 5, they are characterised by high levels of TH, Ca, Mg and COD, with a high abundance of *Cyclops fuscus, Simocephalus vetulus, Simocephalus expinosus, Lithobius forficatus, Micronecta poweriand Cyprisbispinosa.* While the second group includes stations 2, 3 and 4, they are characterised by high levels of pH, Cl and TAC, with a high abundance of *Eucypris virens, Anacaena globulus, Chironomus plumosus, Culiseta longiareolata* and *Culex laticinctus.* However, the 2nd axis revealed that stations 1 and 3 are rich in *Piona uncata* and *Berosus affinis* compared to the other stations (Fig.7).

## Discussion

The bioindicators revealed change in environmental conditions and can be used to identify and/or quantify these changes. Benthic macroinvertebrates are good indicators for biomonitoring the health of aquatic ecosystems (Parmar*et al*. 2016, Odountan*et al.* 2019, Djitli*et al.* 2020, Nahli *et al.* 2022). Our results identified 8 groups belonging to 11 families composed of 18 taxa. Cladocera were the dominant group followed by Diptera. Similarly, Baaloudj *et al* (2022) showed that Crustaceans were dominant followed by Insects at Oued Seybouse. Other work in the region of Oum El Bouaghi where the inventory recorded 11 orders, 31 families and 47 species where Coleoptera were the dominant and numerically important ecological group, followed by Odonata (Lounis *et al*. 2019). In Lake Tonga 20 families belonging to six orders were collected; Hemiptera and Coleoptera are dominant (Djamai*et al.* 2019) in contrast to our results where Beetles mark the low presence.

The species richness gives us information on the state of the environment, this parameter gives a very important place to rare species (Tavanayan*et al*.2021).Varying with the stations, the highest value of total richness is marked at the second station with 14 species. While station 1 has the highest value for total number of individuals and average richness. For the relative abundance, the first and second positions occuped by *Simocephalus expinosus* and *Culiseta longiareolata* respectively, both belonging to the Accessory category, followed by *Simocephalus vetelus*, which belongs to the Accidental category, and the rest of the taxa are in the Rare category.

Simpson's index indicates that diversity can be considered high, as it is strong at two stations and degrades at the rest of stations; however the equitability that compares the structures of the stands allowed us to consider that the populations are not balanced at the different stations. Differences in the distribution of the macrobenthic fauna could be attributed to spatial heterogeneity, geographical position (longitude & depth) (Baalouj*et al*. 2020) the stations knowing that the whole study area is globally homogeneous in terms of temperature, the difference in sedimentary texture (influence of granulometry, porosity and the quantity of agglomerates) (Labrune*et al.* 2006, Cosentino & Giocobbe 2008). Moreover, the abundance, biomass and diversity index of macrobenthiccommunities vary with the season and the depth (Farshchi *et al.* 2017), Water temperature (Farshchi *et al.* 2020), the duration of water permanence in Mediterranean wetlands (Djamai*et al.* 2019)and environmental changes, particularly the physicochemical parameters of the water (Loucif*et al.* 2020, Mahmoudi*et al.* 2022, Raphahlelo *et al.* 2022,Bendary*et al*. 2022, Houmani*et al.* 2023).The physicochemical parameters of the water show that the temperature is generally around 23°C and is modified by the climatic conditions and particularly by the air temperature (Ezzat 2012).However, pH values between 6.8 and 7.66 qualify water of good quality for aquatic life. This parameter is responsible for a large part of the physico-chemical balance and depends on several factors including the origin of the water (Haddad *et al*. 2014). The pH is lower than 8 and consequently the alkalimetric titer obtained for the samples are zero, which means that these waters do not contain strong bases; Therefore, the alkalimetric titers are within the standards for all the stations. On the other hand, the electrical conductivity which electrical conductivity, which is used to assess the overall mineralization of the water to a very rough approximation, varies between 2210 and 2500 µS $cm^{-1}$ and the maximum value is recorded at the first station, a high mineralization exceeding 1000 µs $cm^{-1}$ (Rodier, 2005). Thus, values of the electrical conductivity exceeding the standards recommended by the WHO (300 µS $cm^{-1}$), this may be due to the low quantity of water, the short duration of permanence of the water, almost present in only one season, the texture of the rocks that form the walls of the vestiges and the texture of the ground. Furthermore, the Total Hardness (TH), which is the sum of the calcium (CA) and magnesium (Mg) contents, vary between 37 F° at station 3 and 44 F°, 44.4 F°at stations 1 and 5, respectively. The high TH values can be explained by the hydrogeology, geochemistry and soil conditions (calcium bicarbonate) of the study area (Ayad & Kahoul 2016). Concerning the Chemical Oxygen Demand (COD) which is the quantity consumed by the oxidisable matters present in the water whatever their origin, our results show that the minimal value recorded at station 3 with 0 mg/l and a maximum of 40 mg/l reached at station 4, the values of CODin the standard of WHO (40 mg/l).However, chloride is important in water, due to its high solubility, and is naturally present in all types of water bodies (Brraich & Saini 2015).The observed chloride levels indicate a minimum value of 227.2 mg/l (Station 1) and a maximum of around 333.7 mg/l (Station 5). It can be seen that all the stations are within the standards.The Total Alkalinity Content (TAC) is the sum of the hydroxyl ion ($OH^-$), carbonate ion ($CO3^{-2}$) and bicarbonate ion contents of the water (Soro *et al*. 2019) with values between 46-56.8 at station 1 and 4. The PCA showed that the most influential physical and chemical parameters seems the electrical conductivity, correlated with the results of a previous study in region of Oum El Bouaghi northeast of Algeria (Lounis *et al*. 2019).

## Conclusions

The inventory of freshwater macroinvertebrates at the Ruines Romaines archaeological site in north-east Algeria and the analysis of physical and chemical parameters during the rainy period recorded 18 species dominated by the Crustacae class, followed by insects. Ecological indices reveal that diversity can be considered significant in certain remains (stations), but populations are not balanced and electrical conductivity is the factor that seems to govern spatial distribution through its positive correlation with the majority of species at the different stations. More in-depth ecological studies would be essential for a better understanding of the structure and function of this ecosystem.

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