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Impact of physicochemical parameters of water on the biodiversity of the invertebrate fauna from Echatt Lake, Northeast Algeria

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Abstract. *Houmani M, Bendali-Saudi F, Soltani N. 2023. Impact of physicochemical parameters of water on the biodiversity of the invertebrate fauna from Echatt Lake (Northeast Algeria). Biodiversitas 24: 258-268.* The coastal area of Algeria is part of the global biodiversity hotspot which is the Mediterranean perimeter and has several regional red spots of biodiversity. Biodiversity provides raw material resources necessary for living beings' survival and maintaining atmospheric quality, climate regulation, water quality, and soil fertility. In addition, macrobenthic fauna is an important provider of aquatic ecosystems. The present study aimed to determine the biodiversity of the invertebrate community from Echatt Lake (Northeast Algeria) located in a protected area classified by Ramsar in 1983, and to evaluate the impact of anthropogenic activities using water physicochemical parameters on their structure and function. Samples were collected monthly over one year (January 2019-December 2019) at four selected stations, and 2,861 specimens were collected. The identified species (16 species) belong to 9 families: Naucoridae, Hydrophilidae, Notonectidae, Pleidae, Corexidae, Eylaidae, Pionidae, Daphniidae, and Copepoda. Seven physicochemical parameters (temperature, hydrogen potential, electrical conductivity, hydrometric title, alkalimetric title, complete alkalimetric titer, and turbidity) of the water were also determined in each station to evaluate their influence on the abundance and distribution of the invertebrate fauna. The pH and the apparent turbidity influence the invertebrate fauna, while the richness was relatively low at stations 2 and 4, located near anthropogenic sources of pollution. The data obtained permitted us to evaluate the possible impact of anthropogenic activities on the biodiversity of invertebrates.

Keywords: Biodiversity, inventory, invertebrates, physicochemical parameter of water

INTRODUCTION

Over the last decades, biodiversity and ecosystem functioning have been the subject of intensive studies (Lam-Gordillo et al. 2020). Biodiversity provides raw material resources necessary for living beings' survival and maintaining atmospheric quality, climate regulation, water quality, and soil fertility. Moreover, macroinvertebrate organisms represent a significant part of the aquatic ecosystem and are of economic and ecological importance (Arimoro and Keke 2016). Indeed, benthic macroinvertebrates are an important link in the food chain of aquatic environments, as they are a primary food source for several species of fish and birds (Karus et al. 2014). Moreover, they actively participate in the transformation of organic matter and constitute good bioindicators (Parmar et al. 2016; Ismail and Adnan 2016; Zinsou et al. 2017; Ameur et al. 2022). Therefore, faunistic and ecological studies are of primary importance in understanding the functioning and management of this natural system (Martinez- Haroetal 2015; Tshijik et al. 2015).

Anthropogenic activities have induced uncontrolled effects on the environment and human health (Hamida et al. 2021; Ekperusi et al. 2022). The physicochemical components of a water can play a pivotal role, not only in the biology of a species but also in the structure and dynamics of the entire biocenosis (Thakur et al. 2013). The analysis of physicochemical parameters is widely used to diagnose problems of water pollution and habitat degradation (Zinsou et al. 2016). Freshwater ecosystems are mostly impacted compared to terrestrial and marine ecosystems (Young et al. 2016). The study on the biodiversity of freshwater invertebrates, both running and stagnant, includes the systematic determination of insects, crustaceans, and mollusks. Recent studies have been made in several aquatic ecosystems in Northeast Algeria, like on the aquatic beetle community living in Tonga Lake (Mahmoudi et al. 2022), morphometry and reproduction of a crustacean species *Atyaephyra desmaresti* Millet 1831 used as a bioindicator species of health quality of hydrosystems (Ameur et al. 2022), or on culicidian fauna in some habitats from Souk-Ahras province (Hafsi et al. 2021; Hamaidia and Soltani 2021). These studies show the importance of ecological factors in the distribution of species. The Generalized Linear Model analysis of data showed that all measured physicochemical parameters of water had an effect on the abundance and species richness of aquatic beetles community (Mahmoudi et al. 2022). Quantification of morphometric parameters and bioenergetic reserves of marine invertebrates from different locations with a wide geographic range is necessary to assess the status of species populations, which can vary across spatial scales (Baldanzi et al. 2018). Thus, morphological variations among shrimps' populations sampled at three different sites in Northeast Algeria: El Battah (in the mouth of the Mafragh River) and Lakes of

Tonga and Oubeira are evidenced (Ameur et al. 2022). The link between climatic factors and mosquito diversity in Souk-Ahras province in northeastern Algeria was also evaluated and the abundance of mosquito's species was found affected by the combination of temperature and rainfall which were negatively correlated (Hafsi et al. 2021; Hamaidia and Soltani 2021).

The objective of this study was to draw up an inventory of the invertebrate fauna in Echatt Lake (Northeast Algeria), located in a protected area classified by Ramsar in 1983. Since the establishment of species in a biotope is governed by a set of factors like physico-chemical, environmental, biological, and ecological (Chaib et al. 2013), the sampling stations retained were characterized by some water physicochemical parameters (temperature, hydrogen potential, electrical conductivity, hydrometric title, alkalimetric title, complete alkalimetric titer, and turbidity), to investigate their impact on the structure of this aquatic invertebrate community. The data obtained permitted us to evaluate the possible impact of anthropogenic activities on the biodiversity of invertebrates.

MATERIALS AND METHODS

Study area

The study was located in the El Tarf region, which covers an area of 3,339 km² with 7 sub-prefectures and 24 communes in the extreme northeast of Algeria. It is located at a latitude of 36°46'0" in the North and 8°19'0" in the East, with an altitude of 16 m. Our study site concerns a small endorheic lake two kilometers from Echatt city (Figure 1). This lake is fed by groundwater and shrinks during the dry season (summer), and the water condenses in its center.

Sample collection

The sampling of the specimens was carried out from January to December 2019. It was carried out in 4 stations, located on the periphery of the lake spaced about 500 m apart and chosen according to water accessibility (Figure 1). The geographical position of these stations are as follows: station 1 (36°49 .6910'N, 7°54 .5310'E), station 2 (36°49 .7370'N, 7°54 .5290'E), station 3 (36°49 .7530'N, 7°54 .5100'E) and station 4 (36°49 .7830'N, 7°54 .5970'E). Stations 2 and 4 are located near anthropogenic sources of pollution. Biomass is influenced by two main factors: human activities and climate. Recurrent droughts and climatic and human aggressiveness such as clearing, pruning, and overgrazing, irrational exploitation of some pastoral species for domestic or industrial purposes materialize the interactions between human activities and climate and their impacts on biodiversity. Furthermore, the increase in these human discharges alters environments, sometimes making them unsuitable for life, which reduces the diversity of animal and plant species (Soulama et al. 2015).

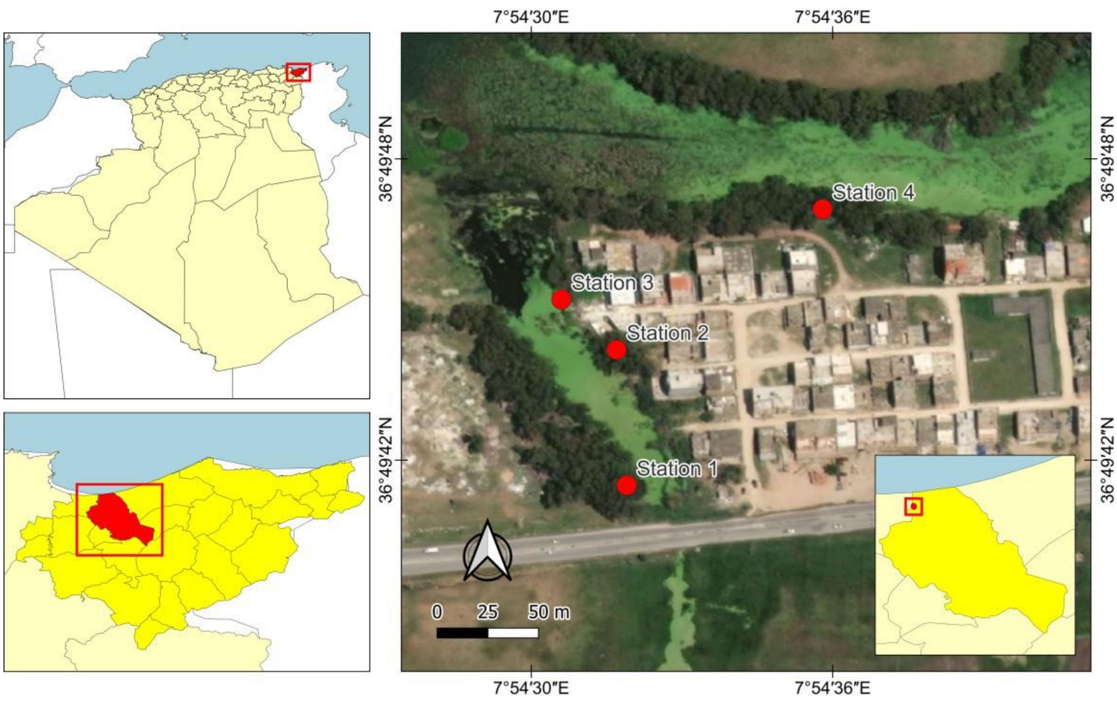

Figure 1. Location of studied stations in Echatt Lake, Northern Algeria

Sampling method

Sampling was carried out using a ladle with a capacity of 500 mL. This last one is plunged into the water and then moved uniformly by avoiding the swirls "dipping" and a strainer whose net is 1mm in diameter. The fauna thus collected (Hydracaria; Heteroptera; Coleoptera) were placed in containers filled with water, hermetically sealed, and labeled (indicating the date of collection and the station) for transport to the laboratory (Bernadet et al. 2013). Crustacean samples (one whole sample =100 mL) were sedimented for 24 h in a cylinder plugged with Parafilm, and then the top 20 mL volume was gently removed. The systematic identification of water bugs was made according to Błędzki and Rybak (2016). Our sampling concerning the crustaceans was carried out using a net with fine meshes of a 1 mm diameter. The numerous collections of zooplankton have allowed us to better understand the fluctuations of its numbers according to the Mensuel method (Loxdale 2016).

Collection and mounting of specimens

The collected samples were transferred to glass containers containing 70% alcohol and labeled with the necessary information. The larvae were identified after clearing the specimens in a 10% NaOH solution for 2 to 3 days. Next, the specimens will be rinsed with distilled water in three baths for 2 to 3 consecutive minutes. Finally, the mounting is done in a drop of glycerin between the slide and coverslip, fixed with nail polish, and subsequently preserved. Cladocerans and Copepods were stained with neutral red and preserved in 75% alcohol (Lamotte and Bourlière 1971).

Systematic identification

The taxa were identified using a binocular magnifying glass and a Leica-type microscope equipped with a camera. The individuals are systematically counted unless the number of individuals of the same taxa exceeds 100 species. This study concerned the benthic crustaceans (Copepods and Cladocerans) from 500 mL of lodging water. After homogenization and agitation, one takes 20 mL of water, and the number of individuals thus present will be determined (Hecq 1976). The systematics of crustaceans was studied according to the dichotomous keys of Perrier (1979) and Amoros (1984), Heteroptera according to Poisson (1957), and Coleoptera according to the keys of Picard (1929) and Rose (1933), respectively. In addition, the Hydracarids were identified following the keys of Smit (2020).

Statistical analysis

According to Southwood (1978) in Louadi (1999), statistical analysis was conducted. In this context, we analyzed the stands by determining the ecological indices of composition and structure, which was done using R software, version 4.0.1 (R Core Team 2019), and MINITAB16 software. Like most factorial methods, the CFA (Correspondent Factor Analysys) uses the singular value decomposition (or eigenvalue and eigenvector decomposition) of a particular matrix and allows the visualization of words and documents in a reduced dimensional space, having a projected point cloud (words and/or documents) of maximum inertia. Furthermore, CFA provides relevant indicators for interpreting the axes (Morin et al. 2004). Principal Component Analysis (PCA) is a factor analysis that produces factors (or principal axes) that are linear combinations of the original variables, hierarchical and independent of each other. These factors are sometimes referred to as "latent dimensions" because they are "expressions of general processes directing the distribution of several phenomena that are thus correlated with each other" (Bourque et al. 2006).

RESULTS AND DISCUSSION

Inventory and systematic study of the invertebrate fauna

Benthic macroinvertebrates are an important link in the food chain of aquatic environments, as they are a primary food source for several species of fish and birds (Karus et al. 2014). Moreover, they actively participate in the transformation of organic matter and constitute good bioindicators (Parmar et al. 2016; Ismail and Adnan 2016; Zinsou et al. 2017; Ameur et al. 2022). Therefore, faunistic and ecological studies are of primary importance in understanding the functioning and management of this natural system (Martinez-Haroetal 2015; Tshijik et al. 2015).

The results showed that the collection of 2,861 individuals was found distributed in 9 families: Naucoridae (Nau: 6.2%), Hydrophilidae (Hyd: 18.8%), Notonectidae (Not: 6.2%), Pleidae (Ple: 6.2%), Corexidae (Cor: 6.2%), Eylaidae (Eyl: 6.2%), Pionidae (Pio: 12.5%), Daphniidae (Dap: 25.5%) and Copepoda (Cop: 12.2%). Cladocerans were the most abundant, with 2,465 individuals, followed by Hemiptera (167 individuals), then Coleoptera (130 individuals), and finally Hydracaria (99 individuals) (Table 1 and Figure 1).

In Algeria, aquatic invertebrates are severely affected by various natural or anthropogenic perturbations. Early work on the hydro systems of northern Algeria was mainly devoted to describing species, but little attention was paid to their ecology or biogeography. More recently, work has been done on the Chironomids of northeastern Algeria 65 species have been recorded (Chaib et al. 2013). Zerguine et al. 2018 collected 7,615 specimens belonging to 75 species in four subfamilies of the Chironomidae fauna in the Oued Charef basin, northeastern Algeria. Hamaidia and Berchi (2018) studied the Culicidae of northeastern Algeria in the region of Souk-ahras and revealed the presence of 14 species belonging to the two subfamilies (Culicinae and Anophelinae). The study of beetles populating the continental waters of Algeria has been carried out by some researchers: Lamine et al. (2019); 51 beetles divided into 2 sub-orders, 34 genera, and 10 families have been identified. The family Hydrachnidae was presented with 6 species reported by Bendali-Saoudi et al. (2014), and 5 families of Heteroptera were identified by Khedimallah and Tadjine (2016) at Lake Tonga.

Table 1. Total species richness of the invertebrate fauna in the Echatt Lake (January-December 2019)

Groups	Families	Species	N	Stations			
				S1	S2	S3	S4
Coleoptera	Naucoridae Leach 1815	*Naucoris maculates* Fabricius 1798	24	15	03	06	/
Linnaeus 1775	Hydrophilidae Latreille 1802	*Berosus luridus* Linnaeus1761	08	05	/	03	/
		Berosus affinis Brullé 1835	81	52	07	18	04
		Hydroporus palustris Linnaeus1761	17	14	/	01	02
Hemiptera	Notonectidae Latreille 1802	*Notonecta glauca* Latreille 1802	95	75	07	02	11
Linnaeus 1775	Pleidae Fieber 1851	*Plea minutissima* Leach 1817	59	41	03	07	08
	Corexidae Leach 1815	*Corixa punctata* Illiger 1807	13	02	01	10	/
AcariLeach1817	Eylaidae Leach1815	*Eylais hamate* Koenike 1897	26	11	12	/	03
(Hydrachnidia)	Pionidae Thor1900	*Piona nodata* Müller 1781	07	02	/	01	04
		Piona uncata Koenike 1888	66	25	23	06	12
Cladocera	Daphniidae Straus1820	*Daphnia magna* Straus 1820	532	231	162	86	53
Latreille1829		*Daphnia similis* Claus 1876	273	188	48	20	17
		Simocephalus vetulus Müller 1776	76	53	12	08	03
		Simocephalus expinosus koch 1841	692	301	168	147	76
	Copepoda Milne-Edwards1840	*Cyclops fuscus* Jurine 1820	434	188	86	115	45
		Canalis gracilis Gurney 1927	458	131	113	121	93

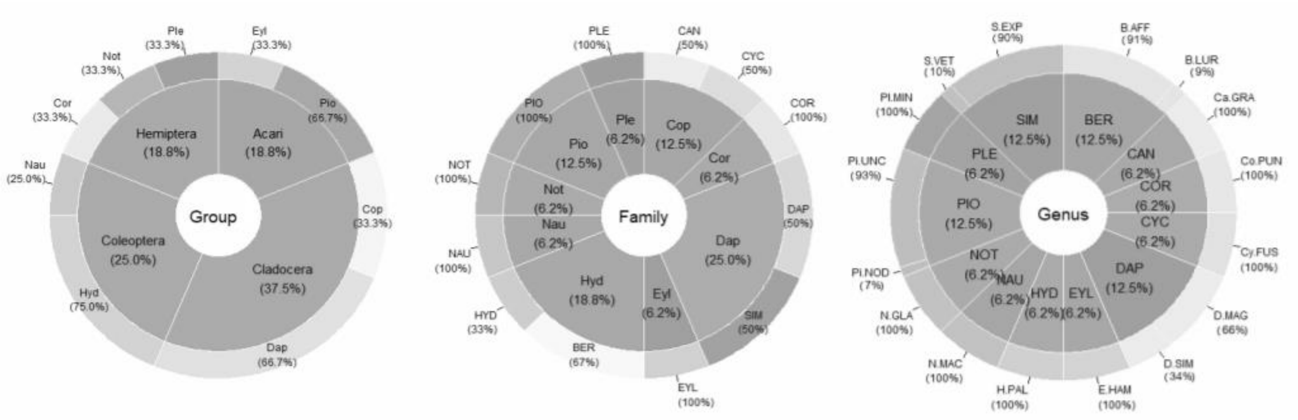

Figure 2. Distribution of identified fauna by the group, family, genus, and species

Ecological composition indices

Spatial composition

Specific richness provides information on the quality of the environment; the richer the stand, the more complex and stable the environment. However, it is not statically interpretable in the case of a comparison between several stands. This parameter gives a very important place to rare species (Tavanayan et al. 2021). The total richness is important at station 1 with 16 species but less important at stations 2 and 4. Regarding the total number of individuals and the average richness, station 1 marks higher values with a total number of 1,334 and a richness of 111.16, respectively. However, minimum values were recorded at station 4 with a total number of 331 and a richness of 27.58, respectively. The diversity index reveals values ranging from 2.50 for station 3 to 2.97 for station 1, which is rich in species (16 species). The equitability, which allows us to compare the structures of the populations, shows values between 0.63 and 0.74 in station 4; these values indicate that the populations are not balanced. Table 2 shows the total richness, which varies by station. It is important that stations 1, with 16 species, and lower at stations 2 and 4, with 13 species. Regarding the total number of individuals and the average richness, station 1 also marks a higher value with 1,334 individuals and 111.16, respectively. However, a minimum value was recorded at station 4.

Relative abundance

Concerning the relative abundance in the lake, the species *Simocephalus expinosus* is in the first position with 692 individuals, which is 24.18%. In second place is *Daphnia magna*, with 532 individuals, which is 18.59%, and in the third position is *C. gracilis*, with 458 individuals, or 16%. As for the other species, relative abundance varies from one species to another and is between 0.24-15.16%.

All species collected belong to the same category (Accidental) except for the species *Simocephalus expinosus*, which is of a different category (Accessory). This variability in species distribution concerning the different sampling stations may be related to the physicochemical parameters of the water (Figure 3).

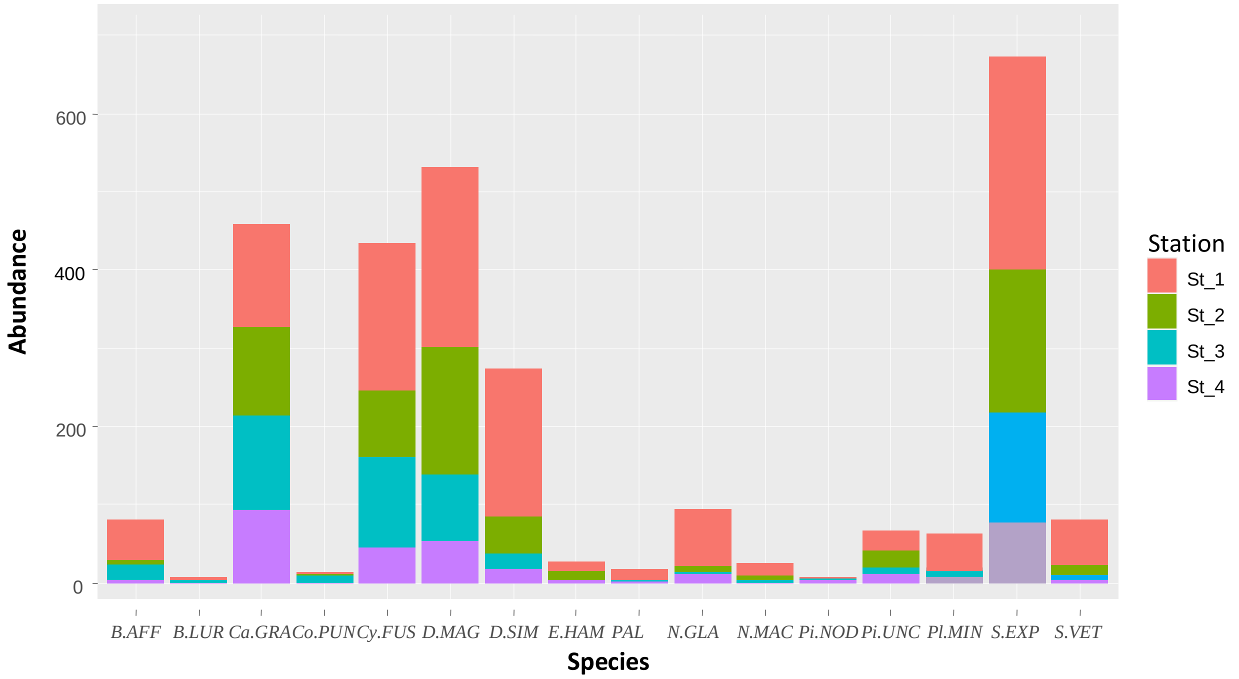

Figure 3. Relative abundance of species per station of macrobenthic fauna inventoried during the sampling year (January 2019 - December 2019). *Daphnia similis (D.sim), Canalis gracilis (C.gra), Simocephalus expinosus (S.exp) , Simocephalus vetulus (S .vet), Cyclops fuscus (Cy.fus), Berosus luridus (B.lur), Piona nodata (Pi.nod), Piona uncata (Pi.unc), Corixa punctata (Co .pun), Naucoris maculates (N.mac) , Eylais hamata (E .ham), Hydroporus palustris (H .pal), Berosus affinis (B.aff), Notonecta glauca (Nt.glau), Berosus luridus (B.lur), Plea minutissima (Pl.min)*

Table 2. 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
St_1	16	2.196	0.861	0.311
St_2	13	1.904	0.814	0.317
St_3	15	1.878	0.807	0.298
St_4	13	1.957	0.818	0.319

Structure indices

Diversity index and equitability

Monthly sampling for one year allowed us to collect 2,861 individuals from the established stations. The total richness was important with 16 species. The results mentioned in Table (1) present the values of Shanon & Weaver diversity index (H'), maximum diversity (H' max), and equirepartition (E). The diversity index shows values ranging from 1.878 for station 3 to 2.196 for station 1, which is rich in species (16 species). In contrast, the Simpson index calculated at station 4 ranged from 0.80 - 0.86. The diversity calculated according to Simpson at different stations can therefore be considered high in station 4. The equitability allows us to compare the structures of the stands, and it shows values between 0.298 and 0.319 in station 4; these values indicate that the populations are not balanced. Shannon and equitability indexes remain dependent on sample size and habitat type, even when not disturbed. Therefore, it isn't easy to use them as a descriptor of an environmental state unless threshold values are first determined for each habitat type and a given sampled area (Tavanayan et al. 2021).

Relative abundance

Concerning the relative abundance in the lake, the species *Simocephalus expinosus* is the first, with 692 individuals, or 24.18%. In second place is Daphnia magna, with 532 individuals, or 18.59%, and in the third position is *C. gracilis*, with 458 individuals, or 16%. As for the other species, relative abundance varies from one species to another and is between 0.24 - 15.16%. All species collected belong to the same category (Accidental) except for the species *Simocephalus expinosus*, which is of a different category (Accessory). This variability in species distribution concerning the different seasons of the sampling year may be related to hydrobiological quality parameters, environmental conditions, or sediments (Figure 4).

We applied analysis factor correspondences (AFC) to summarize and visualize the information in the contingency table [Density of 16 species of macrobenthic fauna (columns) X stations (row)] and [Density of 16 species of macrobenthic fauna (columns) X seasons (row)]. The results expressed by the factorial design Dim1 vs. Dim2 for the two factors "station" and "season" (Figures 5, 6).

Seasonal distribution

Dimensions 1 and 2 explain about 41.8% and 58.4% of the total inertia, respectively, corresponding to a cumulative total of 99.4% of the total inertia retained by these 2 dimensions.

Indeed, Figure 5 indicates that: *Daphnia similis*, *C. gracilis*, *Simocephalus expinosus*, and *Cyclops fuscus* species significantly contribute to the first axis; thus, axis 1 is mainly defined by these species. While the species: *C. gracilis*, *Simocephalus vetulus*, and *Daphnia magna* have a strong contribution of axis 2; thus, axis 2 is mainly defined by these species (Figure 5). All species have a good quality of representation.

Berosus luridus, *D. similis*, *Piona nodata*, *Corixa punctata*, *Naucoris maculates*, and *Eylais hamata* species are most associated with Spring. However, the species *Hydroporus palustris*, *Simocephalus vetulus*, *C. gracilis*, and *Piona uncata* are most associated with the Summer and Spring seasons.

Whereas the species: *Daphnia magna*, *Berosus affinis*, *Notonecta glauca*, and *Plea minutissima* are associated with the Fall and Spring seasons.

Then, the species *Simocephalus expinosus* and *Cyclops fuscus* are associated with the fall and summer seasons (Figure 5).

Spatial distribution

Dimensions 1 and 2 explain 64% and 21.8% of the total inertia, respectively, corresponding to a cumulative total of 85.8% of the total inertia retained by these 2 dimensions. Indeed, the graph in Figure 6 shows that: The species: *B. affinis*, *Corixa punctata*, *Cyclops fuscus*, *Daphnia magna*, *Eylais hamata*, and *Piona uncata* have an important contribution to the first axis. Thus, axis 1 is mainly defined by these species. While the genera *Notonecta glauca*, axis 2 is mainly defined by these species.

The species *Piona nodata* has a poor representation quality (cos2<40%). However, the rest of the species have good representation quality (Figure 6).

The species: *P. minutissima*, *H. palustris*, *Notonecta glauca*, *B. affinis*, *B. luridus*, *N. maculates*, *S. vetulus*, *D. similis* are mostly associated with station 1.

Corixa punctata and *C. gracilis* species are mostly associated with station 3, while *P. nodata* is associated with station 4. The species: *S. expinosus*, *D. magna*, *E. hamata*, and *P. uncata* are associated with stations 1 and 2. Lastly, the species *C. fuscus* is associated with stations 1 and 3.

Hierarchical ascending classification

Seasonal classification. It can be seen that the dendrogram of the ascending hierarchical classification by season indicates that the 16 taxa are divided into 4 main groupings, of which the first grouping consists of six species: *B. luridus*, *D. similis*, *P. nodata*, *C. punctata*, *N. maculates*, *E. hamata*. Group 2 consists of four taxa; *H. palustris*, *S. vetulus*, *C. gracilis*, and *P. uncata.* However, group 3 comprises four taxa; *D. magna*, *B. affinis*, *N. glauca, and P. minutissima;* group 4 includes two taxa; *S. expinosus* and *C. fuscus* (Figure 7).

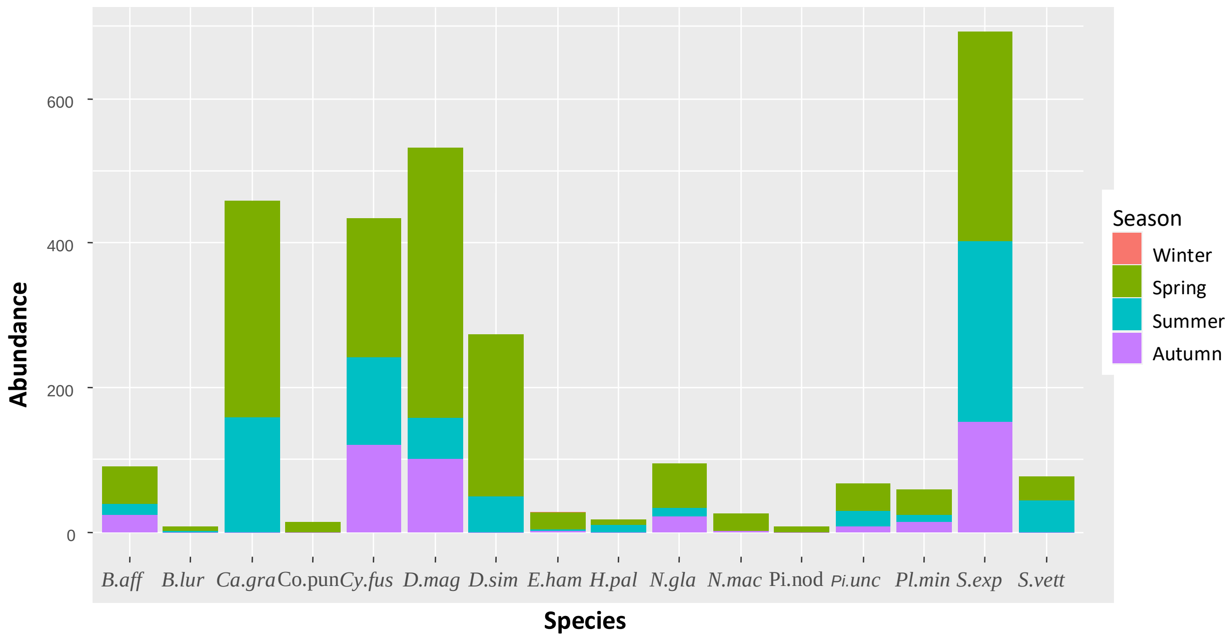

Figure 4. Factor analysis of correspondences

Spatial classification. The dendrogram resulting from the CAH applied to the taxa by station allowed us to obtain three groups with unequal distribution of taxa. Group 1 includes eight taxa (*P. minutissima, H. palustris, N. glauca, B. affinis, B. luridus, N. maculates, S. vetulus* and *D. similis*), Group 2 includes three taxa *(C. punctata, C. gracilis,* and *P. nodata)*, Group 3 includes five taxa (*S. expinosus, C. fuscus, D. magna, E. hamata,* and *P. uncata*) (Figure 8).

Physicochemical parameters of water and principal component analysis

Algeria has 1,451 wetlands, of which 762 are natural, and 689 are artificial. Among the 1,451 sites, 50 are classified on the Ramsar Convention list of wetlands of international importance, with an area of nearly 3 million hectares, or 50% of the total estimated wetlands in Algeria. Currently, Algeria knows the serious problems of degradation of these natural areas. The study of physicochemical parameters is widely used to diagnose problems of water pollution and habitat degradation. Still, it has limitations because it only gives a picture of the environment at the sampling time (Zinsou et al. 2016). The physicochemical components of water can play a pivotal role in the biology of a species and the structure and dynamics of the entire biocenosis (Thakur et al. 2013; Enkhnasan and Boldgiv 2020). Therefore, it is necessary to understand the requirements of the living being in terms of temperature, salinity, transparency, dissolved oxygen, and different xenobiotics present in the environment as they intervene essentially as explanatory factors of the biological conditions. The influence of the environment on species diversity is significant (Enkhnasan and Boldgiv 2020). According to Loucif et al. (2020), the lake studied is currently in eutrophication.

Further severe ecosystem degradation may occur if appropriate management actions are not taken in the short term. This study also underlines that the studied lake is rich from a taxonomic point of view, with 9 families and 16 species. Therefore, the conservation and protection of the lake are necessary. Mahmoudi et al. (2022) reported that aquatic beetle abundance varied among sites on a seasonal basis, and physicochemical water parameters affected the abundance and species richness of the beetle community. Estimating the physicochemical quality of water cannot be done by measuring only one, but of a whole of the parameters of various natures. For example, pH values vary from 7.27 to 7.77, showing alkaline water, and Station 1 is the most alkaline. These pH values can be influenced by photosynthesis and mainly by the physical environment of a lake (the geochemical nature of the rocks), which are mostly limestone and also depends on the nature of the discharges that are flown into it (urban, industrial) (Dimane et al. 2017). On the other hand, the electrical conductivity values vary from 510 to 1984; station 2 reveals the maximum value; electrical conductivity increases with ion concentration in solution and temperature (Haddad et al. 2014). Thus, the Alkalimetric title is between 30.50 and 101.53, with stations 3 and 4 marking the highest values.

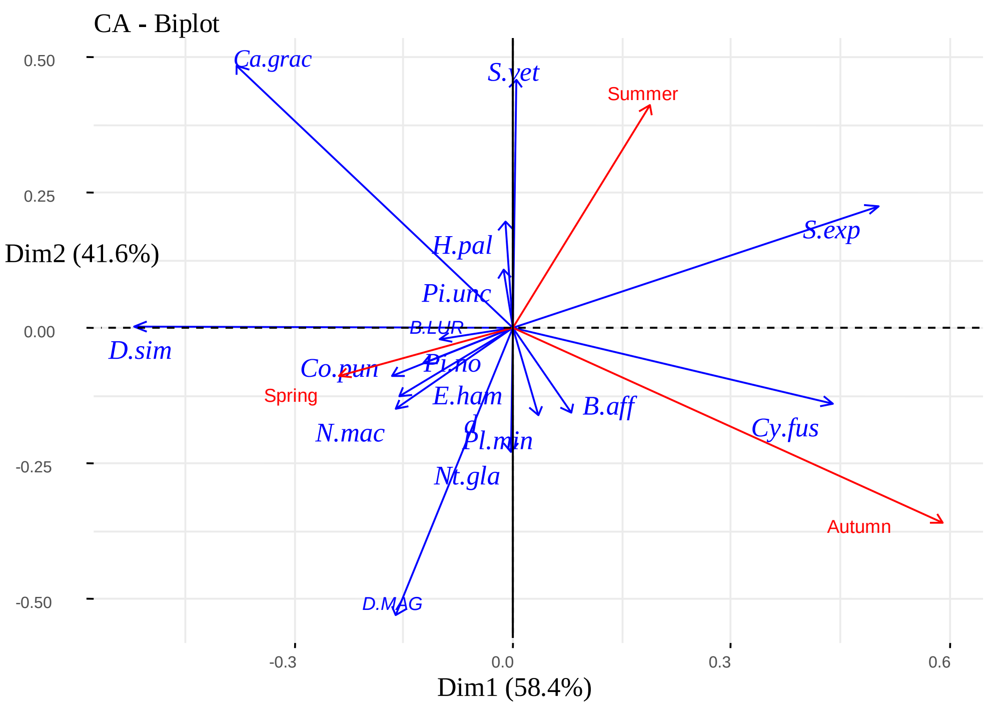

Figure 5. Correspondence factor analysis on the abundance data of the species of the macrobenthic fauna inventoried during four study seasons

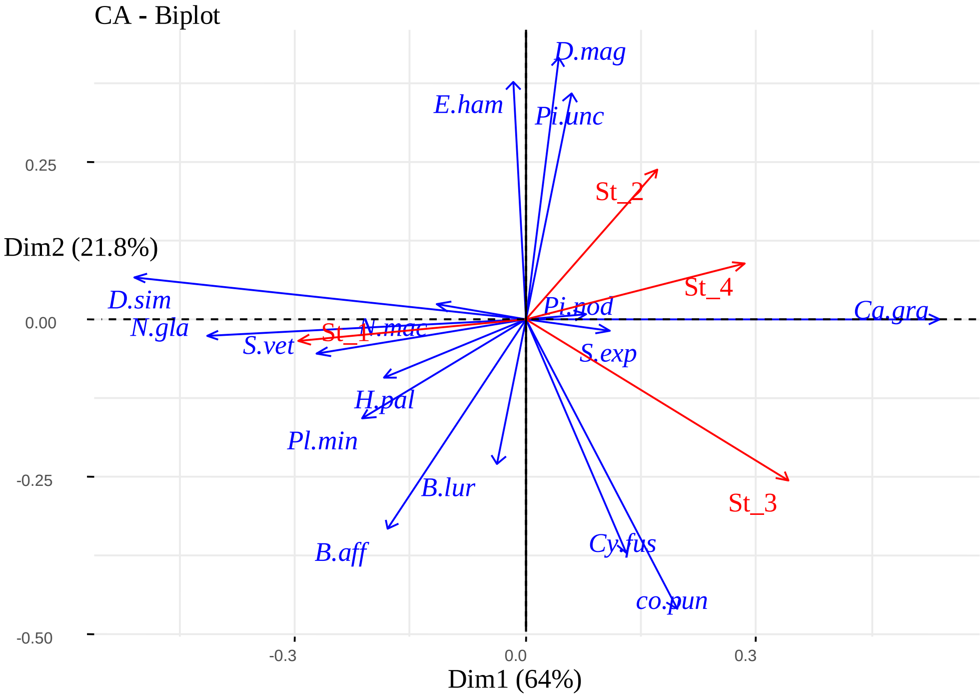

Figure 6. Correspondence factor analysis (CFA) on the abundance data of the species of the macrobenthic fauna inventoried at the four study stations

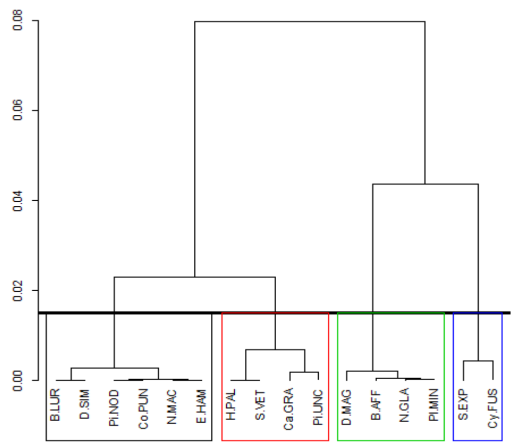

Figure 7. Dendrogram from the bottom-up hierarchical classification of species harvested in the four seasons

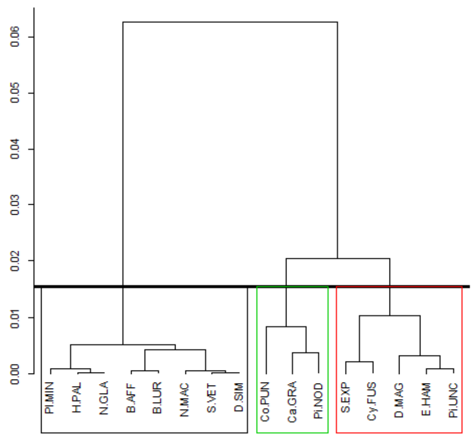

Figure 8. Dendrogram from the bottom-up hierarchical classification of species collected at the four study sites

Regarding the complete alkalimetric Title (FAT), which ranges from 43.00 to 221.28, station 4 shows the maximum value; the complete alkalimetric title or FAT corresponds to the content of free alkalis, carbonates and hydrogen carbonates in the water (Soro et al. 2019). However, the temperature is maximum at stations 1 and 4 (25.6°), which plays a very important role in the solubility of salts and especially gases; it also acts as a physiological factor acting on the metabolism of growth of microorganisms living in the water (El Yemli 2020). While turbidity varies between 7.79 to 13.20, station 2 shows the highest value. The increase in turbidity affects the water's transparency, which reduces aquatic organisms' biological productivity (Ezzat et al. 2012). Thus the hydrometric title studied ranges from 20.5 to 379.00, with a maximum value at station 4. The total hardness of water is the total concentration of Ca^{++} and Mg^{++} ions; waters are acceptable up to 500°F. But if they exceed 600°F, their use is extremely difficult, and the softening should be considered (Sanyal et al. 2019).

Principal component analysis (PCA) was applied to the correlation matrix obtained from the 7 physiological characteristics of the water, measured at the 4 stations of the present study, and to examine the influence of the physicochemical parameters of the water on the distribution of the macrobenthic fauna. The abiotic parameters (Temperature, Hydrogen Potential, Electrical

Conductivity, Hydrometric Title, Alkalimetric Title, Complete Alkalimetric Title, and Turbidity) are used as quantitative variables, while the average density of the macrobenthic fauna is treated as an explained variable (additional). The statistical analysis also provides a graph of the eigenvalues as a function of the ranks of all the components (Figure 9). This graph shows the decreasing importance of the different principal components.

However, the interpretation of these components required the calculation of correlations between each of the selected principal components, that 77.8% of the total variability of our matrix of abiotic variables and explained by the first two principal components.

The 1st PCA axis alone explained 50.4% of the total variability; it is positively correlated with Electrical Conductivity (EC) (r =+0.75; cos2=+0.57), Alkalimetric Title (AT) (r =+82; cos2=+0. On the other hand, this axis is negatively correlated with Hydrogen Potential (pH) (r= -0.45; cos2=-0.20) and Apparent Turbidity (TUR) (r=-0.20; cos2= -0.04). In addition, the 2nd axis alone explained 27.4% of the total variability; it is characterized by a strong positive correlation with temperature (T) (r=-0.89; cos2= -0.79) and a strong negative correlation with the complete alkalimetric title (FAT) (r = -0.34; cos2= -0.11).

The principal component analysis revealed a positive correlation between the average density of benthic fauna with the hydrometric title (HT), the alkalimetric title (AT), and the electrical conductivity (EC), and negatively with the hydrogen potential (pH) and the apparent turbidity (TUR). This observation could express that the distribution of benthic fauna is influenced by nutrients, pH, and apparent turbidity (TUR).

Analysis of the variable point cloud

The correlation circles are graphs aimed at geometrically representing the initial variables in the new coordinate system. Thus, the representation of the seven initial variables (Physicochemical characteristics of water) in the plane formed by axes 1 and 2 and called the first factorial plane is useful, given the importance of these two axes in the reconstruction of the initial variables (77.8% of the total variation) (Figure 10). Table 3 shows the correlations between the initial variables, the first three selected components, and the corresponding square correlations.

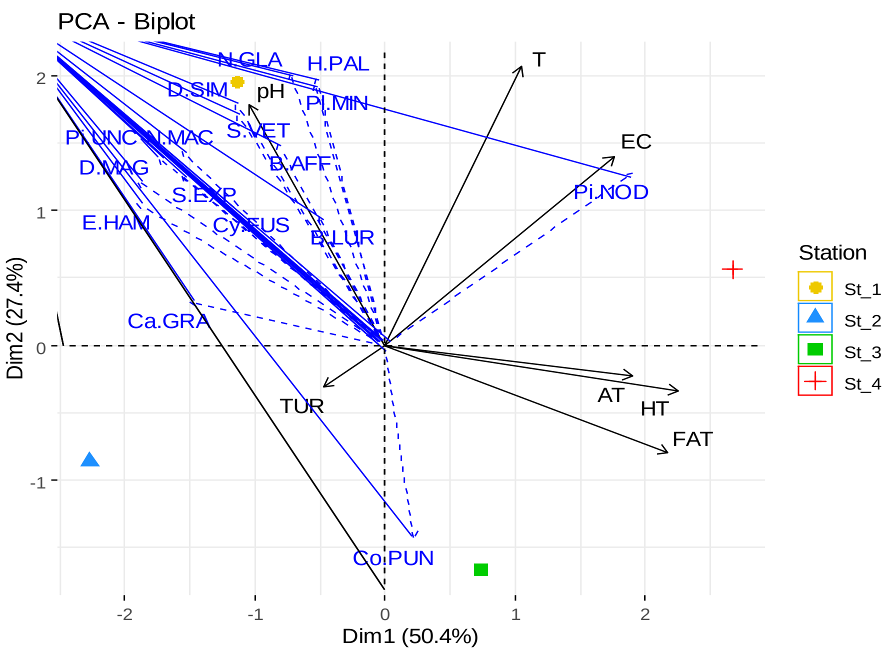

Figure 9. Principal component analysis showing the relationship between the physicochemical parameters of the water and the macrobenthic fauna surveyed at the four study stations

Table 3. Values of correlations and squared correlations of the initial variables with the first 3 principal components and information are taken into account by the 1st factorial design represented by axes1 and 2

Variable	CP1		CP2		CP3	
	Corr	Corr2(%)	Corr	Corr2(%)	Corr	Corr2(%)
Ph	-0.451	5.772	0.770	30.86	0.451	13.137
EC	0 .759	16.347	0.605	19.089	-0.238	3.653
AT	0.821	19.091	-0.097	0.492	0.563	20.425
FAT	0.938	24.918	-0.344	6.160	-0.050	0.158
T	0.454	5.836	0.891	41.35	-0.011	0.008
TUR	-0.206	1.197	-0.134	0.934	0.969	65.75
HT	0.973	26.887	-0.146	1.110	0.178	2.043

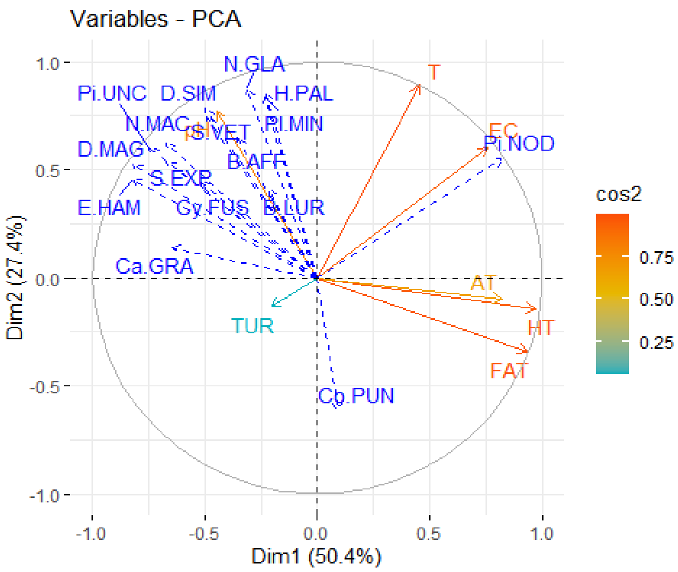

Figure 10. Graphical of the 7 variables (temperature, hydrogen potential, electrical conductivity, hydrometric title, alkalimetric title, complete alkalimetric title, and turbidity) within the correlation circle of factorial design 1-2 obtained from the data of the 4 study site stations

In conclusion, our research was devoted to the inventory of the fauna of freshwater invertebrates in a region located in the North-East of Algeria during a period that extends from January 2019 to December 2019 and allowed us to inventory 9 families: Naucoridae, Hydrophilidae, Notonectidae, Pleidae, Corexidae, Eylaidae, Pionidae, Daphniidae, and Copepoda; Cladocerans are the best represented and most abundant with 16 species. They also show that the physicochemical water parameters were found to impact the abundance and distribution of this aquatic invertebrate community. The pH and the apparent turbidity influence the invertebrate fauna, while the richness was relatively low at stations 2 and 4, located near anthropogenic sources of pollution.

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