

Macroinvertebrate diversity as an indicator of ecological health and water quality in Northern Algeria

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This study aims to investigate the spatial and temporal variation of macroinvertebrate communities and their relationship with environmental factors in the rivers of Chrea National Park, northern Algeria. Analysis of the spatio-temporal variation of physico-chemical parameters revealed no significant differences in temperature between stations. However, highly significant differences were observed for pH, conductivity and dissolved oxygen. Over a four-month period, a total of 19,737 individuals were sampled at four stations. Macroinvertebrate diversity was highest in the Djir and Merdja Rivers, with Diptera dominating the community composition at most stations. However, species richness and evenness were significantly lower in the Tamesguida River, suggesting greater environmental degradation in this region. The logarithmic curve of the rank frequency diagrams shows that the Merdja and Djir Rivers have higher initial abundances than the Mouzaia. Index results diversity indices show a high biodiversity in the Djir, Merdja and Mouzaia Rivers, while the Tamesguida River has much lower values, indicating a lower diversity and a more marked dominance of certain species. The Shannon-Wiener index reaches its maximum in the Djir (2.75) and its minimum in the Tamesguida (0.87). The Standardized global biological index, the Pielou evenness index and the Simpson index follow a similar trend, showing a more balanced species distribution in the Djir and Merdja and a less balanced distribution in the Tamesguida. The Margalef index confirms a much lower species richness in Tamesguida compared to the other stations. The results indicate that the Tamesguida River has a significantly lower diversity and species richness than the other stations, with a more pronounced dominance of certain species.

Keywords: macroinvertebrates; physico-chemical parameters; species richness; rank frequency diagrams; diversity indices.

Introduction

Freshwater ecosystems, particularly rivers, are among the most biodiverse and ecologically significant habitats globally, providing essential services, such as water purification, nutrient cycling, and habitat for numerous species (Castello et al., 2013; Bunn, 2016; Namayandeh & Beresford, 2022; Baguma et al., 2024). However, these ecosystems are increasingly threatened by various anthropogenic activities, including habitat modification, pollution, and climate change (Berton, 2001; Oberdorff, 2022; Markert et al., 2024).

In Algeria, river systems are crucial for sustaining both biodiversity and human livelihoods, yet they are highly vulnerable to environmental degradation caused by both natural and human-induced stressors (Rouibi et al., 2021). Macroinvertebrates are widely recognized as valuable bioindicators for assessing the health of freshwater ecosystems given their sensitivity to changes in water quality and habitat conditions (Boulahbal et al., 2022; Baaloudj et al., 2024). In Algerian rivers, macroinvertebrate communities display considerable spatial and temporal variability, influenced by bioclimatic regions, altitudinal gradients, and water quality parameters (Arab et al., 2004; Gharbi et al., 2024). Studies conducted across various watersheds have demonstrated that taxon richness tends to be higher in semi-arid temperate regions than in arid zones, with key environmental factors such as water velocity, conductivity, and pH, which play critical roles in shaping community structure (Chaib et al., 2023).

The Chiffa River, located in northern Algeria, is an important watercourse flowing through Chréa National Park, an ecologically sensitive area that encompasses a range of habitats, from mountainous regions to

plains. Rivers face increasing anthropogenic pressures, including urbanization, agricultural runoff, and climate change, which have the potential to alter natural flow regimes and degrade water quality, thereby threatening the integrity of macroinvertebrate communities in rivers (Markovic et al., 2017; Baaloudj et al., 2024). Understanding how these communities respond to environmental stressors is crucial for the development of effective conservation and management strategies (Castello et al., 2013; Angeler et al., 2014; Markert et al., 2022). This study aimed to explore the spatial and temporal variations in macroinvertebrate communities within the Chiffa River and examine how environmental factors such as altitude and water quality influence their structure and diversity. By investigating the response of these communities to both natural and anthropogenic influences, this study seeks to identify key bioindicators that can inform future water quality assessments and ecological management efforts in Algerian rivers. These findings will contribute to a broader understanding of freshwater biodiversity in North Africa, offering insights into the role of macroinvertebrates in maintaining ecological integrity under varying environmental conditions.

Materials and methods

The Chiffa region, located 4 km west of Blida and 50 km southeast of Algiers in Chrea National Park, covers an area of 48.11 km², consists of 64% plains (Mitidja), 8% foothills, and 28% mountains. The Chiffa River originates in the Médéa Mountains and flows through the Chiffa gorges within Chréa National Park. It is formed by the confluence of the Mouzaia and Sidi Bahloul Rivers, traversing the Mitidja plain before joining the

Mazafran River and eventually discharging into the sea. The Chiffa River's banks are characterized by Eocene limestone to the northeast and Maastrichtian limestone formations to the southwest. Four sampling stations were selected along the Chiffa River based on parameters such as altitude, biotope diversity, and proximity to urban areas to assess anthropogenic pollution (Fig. 1). The first station, the Tamesguida River (36°19'27" N 2°41'22" E), is situated in a mountainous area in the vicinity of a waste water treatment plant at an altitude of 527.2 m. The second

station, the Mouzaia River (36°20'02" N 2°45'42" E), is located in the southern part of Chréa National Park at an altitude of 396.20 m. The third station, the Djir River (36°20'29" N 2°46'10" E), lies near El Hamdania, at an altitude of 377.1 m. The fourth station, the Merdja River (36°22'35" N 2°46'25" E), is located in the western part of Chréa National Park at an altitude of 321.3 m. These sites were chosen to represent different environmental conditions and human impacts in order to ensure a comprehensive assessment of the ecological state of the Chiffa River.

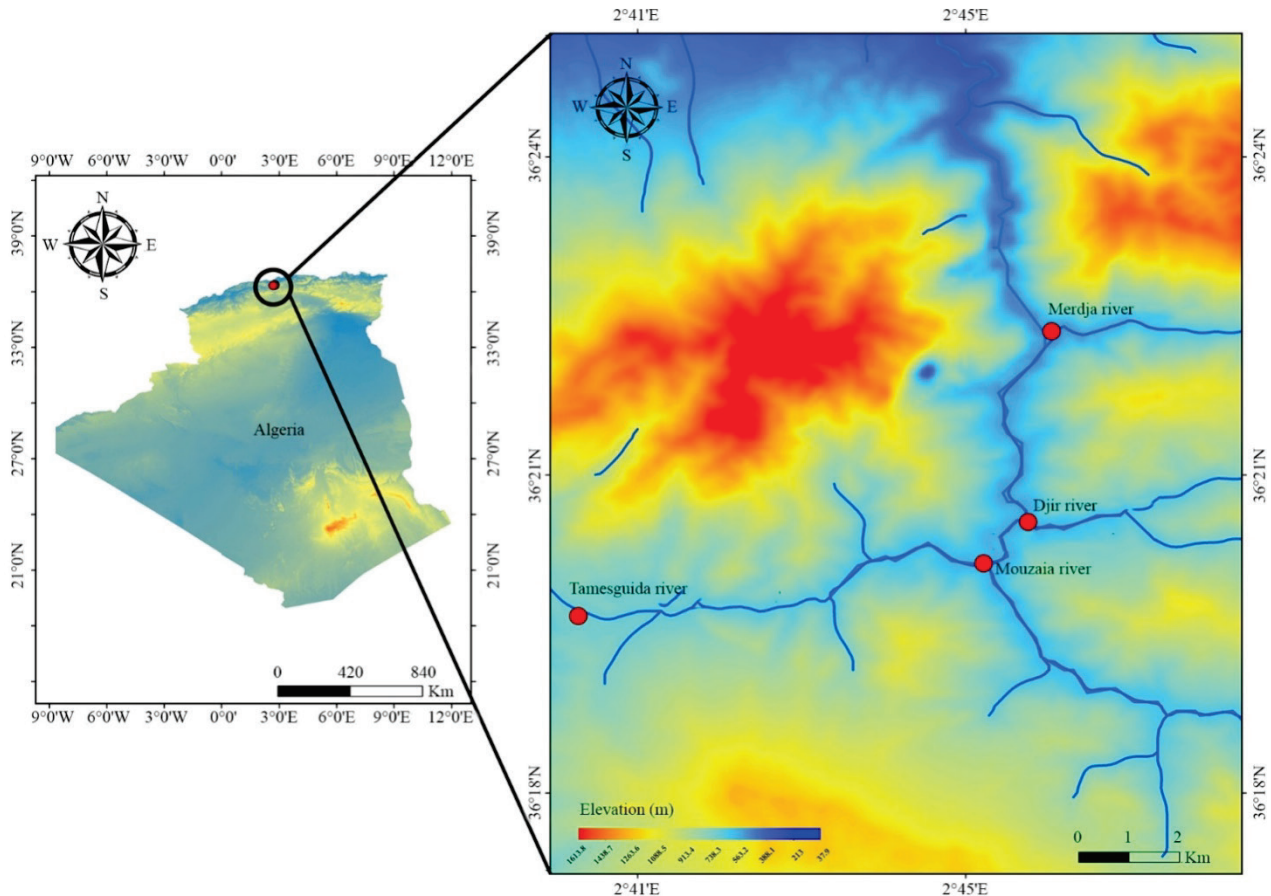


Fig. 1. Geographical projection of sampling stations (Merdja River, Djir River, Mouzaia River, and Tamesguida River) along the Chiffa River

From February to May 2024, benthic macroinvertebrates were sampled from four quantitative replicates using a Surber sampler (30 × 30 cm, 500 μm), covering a defined sampling area of 0.09 m² within a 100-meter reach at each station. The net was deployed in representative microhabitats with its opening oriented upstream to capture organisms dislodged by substrate agitation. The substrate was systematically disturbed to dislodge fauna, which were then collected in the net. Specimens were carefully removed with forceps, passed through a 0.5 mm sieve, and preserved in 70% ethanol. Identification was performed using a stereo microscope. The four replicate samples per station were pooled for statistical analysis.

Environmental measurements for temperature (Temp) °C, pH, conductivity (Cond), and dissolved oxygen (DO) were taken at each station (Merdja River, Djir River, Mouzaia River, and Tamesguida River) using a multiparameter analyzer (3420-SET-G).

To evaluate the spatial and temporal variations in the physicochemical parameters of water across the study stations (Merdja, Djir, Mouzaia, and Tamesguida Rivers), a one-way ANOVA was performed. Tukey's HSD test was employed for post-hoc comparisons to determine significant differences between the stations. Biodiversity was assessed using a range of diversity indices, including the Shannon-Wiener index (Shannon & Weaver, 1949), Pielou's evenness index (J) (Pielou, 1966), Simpson's index (Simpson, 1949), and Margalef's index (Margalef, 1968), to analyze species diversity, evenness, dominance, and richness. All statistical analyses were conducted using R (version 4.2.3; R Core Team, 2023) and RStudio (RStudio Team, 2024).

Results

Table 1 summarizes the variations in the physicochemical parameters of water across the four study stations. The analysis of spatiotemporal variation did not reveal any significant differences in temperature between the stations ($P > 0.05$). The mean temperature values for the Merdja, Djir, Mouzaia, and Tamesguida Rivers were, 18.25 ± 1.85 , 17.15 ± 0.75 , 15.05 ± 2.95 and 15.46 ± 2.74 °C, respectively. However, there were highly significant differences in pH, conductivity, and dissolved oxygen (DO) between the stations ($P < 0.001$ for all parameters). The pH values for the Merdja, Djir, Mouzaia, and Tamesguida Rivers were 8.34 ± 0.01 , 9.37 ± 0.07 , 13.97 ± 0.00 and 14.00 ± 0.01 , respectively, showing significant variation between stations. The conductivity values for the same stations were 187.5 ± 0.5 , 189.5 ± 0.5 , 181.0 ± 1.0 and 185.3 ± 1.5 , respectively, also exhibiting significant differences. Dissolved oxygen levels varied significantly between stations, with values of 8.76 ± 0.73 mg/L for the Merdja, 8.27 ± 0.45 mg/L for the Djir, 5.48 ± 0.99 mg/L for the Mouzaia, and 3.52 ± 1.03 mg/L for the Tamesguida.

Macroinvertebrate richness is a measure used to assess the distribution and abundance of different species in an aquatic ecosystem and can provide information on the health and quality of the aquatic environment and any anthropogenic or natural pressures. Macroinvertebrates are sensitive to changes in water quality, with some species tolerating pollution better than others. Therefore, very abundant and dominant taxa may indicate a change in the ecosystem, especially if less pollution-tolerant species are rare or absent. The dominant species in Merdja and Djir River are Chiro-

nomidae (929 and 785) and Simuliidae (826 and 779) respectively, while the dominant species in Mouzaia River are Gyrinidae (516). Chironomids are often tolerant of pollution and can tolerate low levels of dissolved oxygen, although they are also found in healthy environments. Simuliidae, on the other hand, often prefer fast, well-oxygenated currents, which corresponds to the sampling area the Merdja and Djir Rivers. Culicidae (758 and 454) and Perlidae (795 and 735) are also very common. Perlidae, a group of plecopterans, are sensitive to pollution and require well-oxygenated water, which is a good indicator of water quality. They are very rare in the Mouzaia River and even absent from the Tamezguida River. On the other hand, moderately abundant species were observed: such as Glossosomatidae (621 Merdja River, 514 Djir River), Brachycentridae (413 Merdja, 352 Djir Rivers) and Baetidae (381) were present in significant numbers. Glossosomatidae and Brachycentridae belong to the order Trichoptera, which is often sensitive to pollution. Their abundance supports the idea that the water is well oxygenated and of good quality. The Ephemeroidea (341) and Caenidae (534 Merdja, 325 Djir Rivers), two families of Ephemeroidea, are also well represented. These families vary in their tolerance to pollution, but most mayflies prefer clean water. Families such as Leptophlebiidae, Ephemereliidae, Planorbidae and Lymnaeidae have very low or even rare abundances. Leptophlebiidae and Ephemereliidae, which are sensitive to pollution, may have lower frequencies, either because they are outside their optimum period of presence or because of certain environmental pressures. Gastropods such as Lymnaeidae and Physidae are rare, which may indicate that the water conditions are less favourable for these families, probably due to the rapid current or the nature of the rocky substrate. A notable absence of certain families such as Stratiomyidae and Corydalinae. This could be linked to ecological preferences that do not correspond to the characteristics of the site, in particular the rapid current or the low organic matter content. The results for Tamezguida River, show a very low distribution of different macroinvertebrate families, such a distribution indicates low diversity, with dominance of one or two families, which could indicate specific habitat conditions or environmental constraints limiting macroinvertebrate diversity.

Table 1
Variations in water physicochemical parameters at the different study stations during the study period (n = 4)

River	Temperature, °C	pH	Conductivity	Dissolved oxygen
Merdja River	18.25 ± 1.85 ^a	8.34 ± 0.01 ^c	187.5 ± 0.5 ^{ac}	8.76 ± 0.73 ^b
Djir River	17.15 ± 0.75 ^a	9.37 ± 0.07 ^b	189.5 ± 0.5 ^c	8.27 ± 0.45 ^b
Mouzaia River	15.05 ± 2.95 ^a	13.97 ± 0.00 ^a	181.0 ± 1.0 ^b	5.48 ± 0.99 ^a
Tamesguida River	15.46 ± 2.74 ^a	14.00 ± 0.01 ^a	185.3 ± 1.5 ^a	3.52 ± 1.03 ^a

Note: different letters (^{a-c}) indicate the differences between the stations (Tukey test, P < 0.05).

Figure 2 presents the relative abundance of macroinvertebrate orders and families across the four river stations, namely Merdja, Djir, Mouzaia, and Tamesguida Rivers. A grand total of 19,737 individuals were sampled across these stations, distributed among various families and orders, highlighting significant spatial variations in macroinvertebrate community composition (Table 2). Diptera emerged as the dominant order, particularly in the Merdja River, where 2,616 individuals were recorded (Table 2), representing 30.0% of the total abundance (Fig. 2a). In the Tamesguida River, Diptera also dominated, with a notable presence of Simuliidae, accounting for 61.9% of the total abundance, despite the overall lower macroinvertebrate diversity in this station.

In contrast, Trichoptera were more abundant in the Djir and Mouzaia Rivers, where Glossosomatidae constituted a significant proportion of the community, with 514 and 218 individuals, respectively (Table 2). Ephemeroptera reached its highest prevalence in the Mouzaia River, with 1,043 individuals across five families, particularly Leptophlebiidae (329 individuals, representing 10.80% of the station's total).

Coleoptera exhibited a more consistent distribution across stations, with Gyrinidae and Haliplidae being particularly well-represented in Merdja and Djir.

Plecoptera, while less abundant overall, showed a similar distribution pattern, with Pternarcyidae being the most prominent family in all sites.

Table 2
Distribution of macroinvertebrate taxonomic groups at four riverine locations in the Chiffa River Basin

Orders	Families	Stations			
		Merdja River	Djir River	Mouzaia River	Tamesguida River
Diptera	Simuliidae	826	779	185	13
	Culicidae	758	454	323	0
	Tipulidae	103	110	3	0
	Stratiomyidae	0	3	0	0
	Chironomidae	929	785	130	0
Trichoptera	Glossosomatidae	621	514	218	0
	Brachycentridae	413	352	150	0
Coleoptera	Gyrinidae	716	695	516	0
	Haliplidae	702	630	114	0
	Elmidae	530	416	97	0
Ephemeroptera	Leptophlebiidae	7	312	329	0
	Ephemereliidae	6	216	0	6
	Baetidae	381	325	219	0
	Ephemeridae	341	317	195	0
Plecoptera	Caenidae	534	414	385	0
	Pternarcyidae	695	634	130	2
	Taeniopterygidae	319	240	15	0
	Perlidae	795	735	30	0
Mollusca	Planorbidae	15	12	3	0
	Lymnaeidae	1	7	1	0
	Physidae	4	2	1	0
Megaloptera	Lorydalinae	0	1	0	0
Odonata	Lestidae	12	8	2	0
Nematoda	Bratylenchidae	1	0	0	0
Total station		8709	7961	3046	21

Mollusca were sparsely distributed, with very low relative abundances observed across all stations. Notably, Planorbidae and Physidae were only marginally present, indicating a significant spatial heterogeneity in macroinvertebrate communities. Other less abundant orders, such as Megaloptera, Odonata, and Nematoda, were either absent or present in minimal numbers, primarily confined to specific stations.

The logarithmic curve shows a rapid decrease in macroinvertebrate abundance with increasing rank for each wadi, which is typical of many ecosystems. The most abundant species occupy the top ranks, followed by the least abundant species. The Merdja and Djir rivers have higher initial abundances than the Mouzaia (Fig 3). This could indicate differences in environmental conditions or habitat quality that influence macroinvertebrate diversity and abundance. The Mouzaia River, on the other hand, has a steeper slope, indicating greater dominance by a smaller number of species, a possible sign of environmental stress or a less diverse habitat. A smoother slope in the graph (as for Merdja and Djir) reflects a better distribution of frequencies, which is often associated with greater species richness. Rivers with more uniform abundances, indicated by a less steep slope, could support more diverse and stable habitats. Conversely, a steep gradient, as in the case of the Mouzaia River, could indicate low species richness and high dominance by a few species, often associated with ecological disturbance. A balanced ecosystem has a frequency rank in which several taxa are represented, without any single group being too dominant, as in the case of the Merdja and Djir wadis. A marked dominance of certain taxa, especially those tolerant to pollutants, as in the case of Wadi Mouzaia, may indicate habitat degradation. The rank of the Tamezguida wadi could not be determined due to the low number of macroinvertebrates in this station.

The diversity indices for the various stations are listed in Table 3. The analysis revealed significant variations across stations. The Shannon-Wiener index, which measures overall diversity by accounting for both species richness and evenness, showed high values across most of the studied stations: the Djir River exhibited the highest value at 2.75, followed by the Merdja River at 2.65, and Mouzaia River at 2.51, whereas the Tamesguida River had a markedly lower value of 0.87. These findings suggest a greater level of biodiversity in the communities of the Djir and Merdja Rivers than in the Tamesguida River. The Pielou evenness index, which assesses the relative uniformity of species distribution, was highest in the Djir River (0.87), followed by the Merdja River (0.85), and Mouzaia River (0.83). The Tamesguida River demonstrated a slightly less even speci-

es distribution with a value of 0.79, indicating the potential dominance of certain species in this area. The Simpson index, reflecting species dominance, showed similar values at the Djir River (0.93) and Merdja River (0.92), slightly lower at the Mouzaia River (0.90), and substantially lower at the Tamesguida River (0.52), indicating a less balanced diversity at this latter station. Lastly, the Margalef index, which measures species richness,

displayed comparable values for the Merdja River (2.31), Djir River (2.44), and Mouzaia River (2.36), while a significantly lower value was observed for the Tamesguida River (0.65). These results suggest that the Tamesguida River station has considerably lower species richness than the other studied stations.

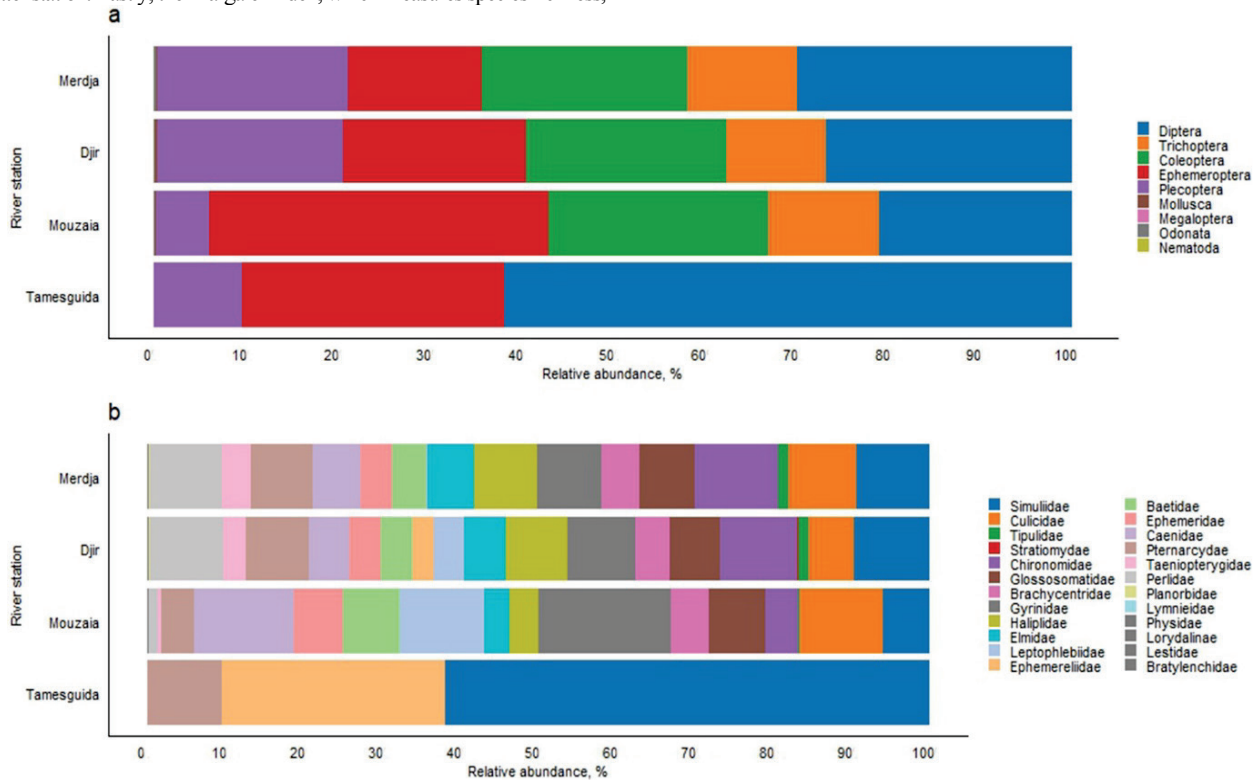


Fig. 2. Relative abundance of zoological orders and families across four river stations during the study period: *a* – distribution of zoological orders (%) in the Merdja, Djir, Mouzaia, and Tamesguida rivers; *b* – distribution of families (%) in the Merdja, Djir, Mouzaia, and Tamesguida rivers

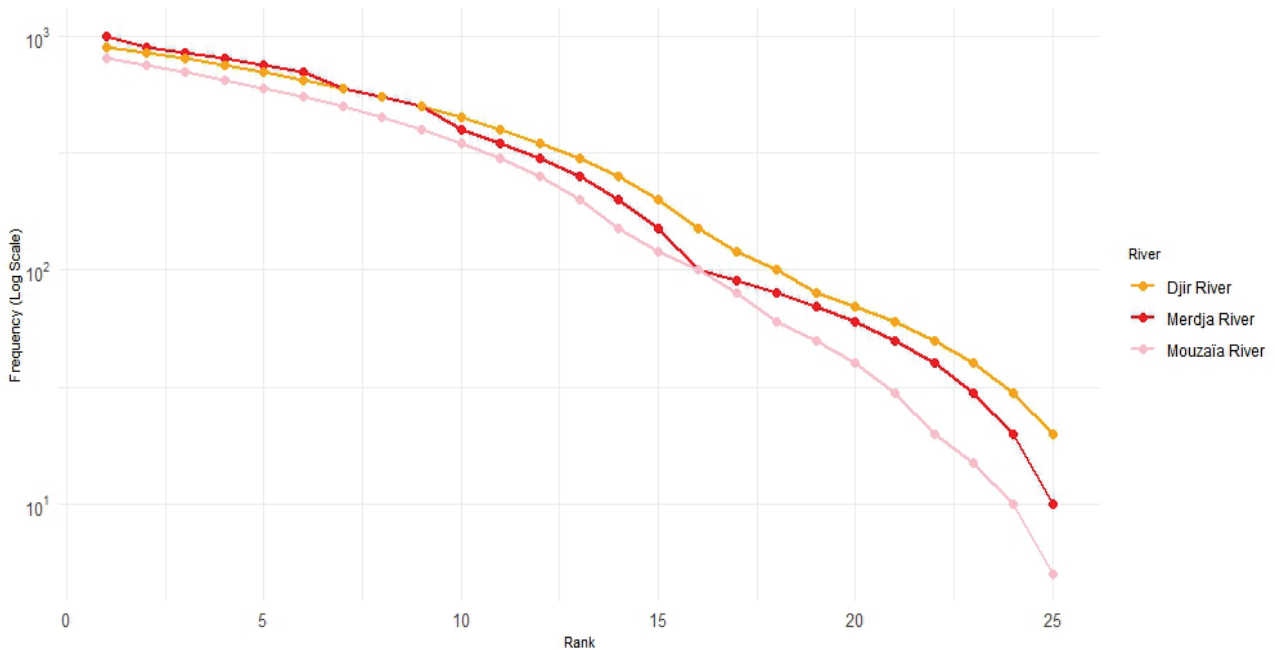


Fig. 3. Rank-frequency distribution of macroinvertebrates in the Merdja, Djir and Mouzaia rivers

The watercourse diagnostic tool based on macroinvertebrates is IBGN, some species are more or less resistant to pollutants than others. The presence or absence of these pollution indicator species reflects the quality of the ecosystem. IBGN values range from 1 to 20, depending on the taxonomic diversity of the station and the presence or absence of indi-

cator taxa, and in our case its ranged from 9 to 18 (Fig. 4). The overall assessment of hydrobiological quality is based on an examination of the benthic macroinvertebrate fauna. In the AFNOR standard the taxonomic unit used is the family, except for a few faunal groups for which it is the phylum or the class. The results of the analyses are obtained by integrating

two determining factors: faunal diversity, which reflects the carrying capacity of the environment and the potential of the fauna to occupy the habitats present, and the nature of the highest indicator group, which reflects the quality of the water. Table 3 summarises the results of the hydrobiological analyses, including the indicator group, the IBGN value and the hydrobiological water quality class. In this way, the IBGN value is given by the point where the faunal diversity within the surveyed station intersects with the nature of the highest indicator group. The repertoire of organisms used to calculate the IBGN contains 19,737 taxa likely to contribute to the total diversity, spread over a range of 3 to 23 taxa, constituting 3 to 5 faunal indicator groups (IFG).

Table 3
Variations in biodiversity indices at different study stations in 2024

Diversity indices	Stations			
	Merdja River	Djir River	Mouzaia River	Tamesguida River
Families Taxa	22	23	20	3
Sample variety class (VC)	14	14	14	7
Indicator fauna group (IFG)	5	5	5	3
The standardized global biological index (IBGN)	18	18	18	9
Individuals	8709	7961	3046	21
Shannon-Wiener	2.65	2.75	2.51	0.87
Equitability	0.85	0.87	0.83	0.79
Simpson	0.92	0.93	0.90	0.52
Margalef	2.31	2.44	2.36	0.65

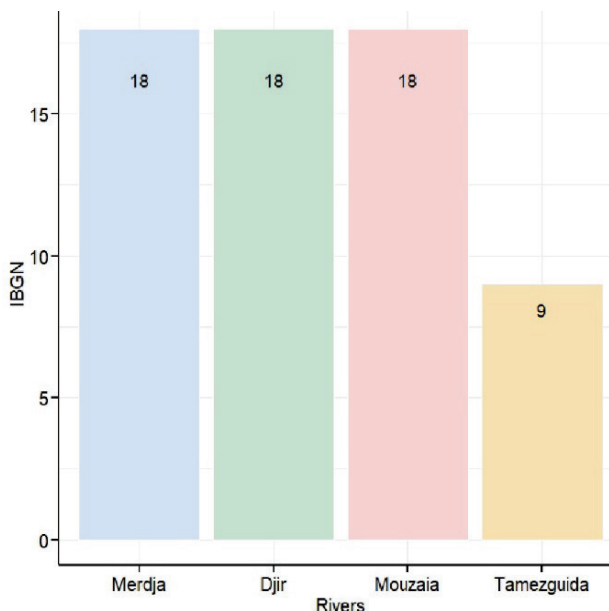


Fig. 4. Standardized global biological index of the Merdja, Djir, Mouzaia and Tamezguida Rivers

Discussion

Assessment of spatial variation in physicochemical parameters and macroinvertebrate communities across the four rivers yields valuable insights into the environmental health of these aquatic ecosystems. This study builds upon the extensive literature linking environmental conditions, anthropogenic influences, and biological responses, highlighting key findings across parameters, such as water temperature, pH, conductivity, and dissolved oxygen (DO).

Water temperature, despite showing no significant variation among the four rivers, remains a critical factor in determining the overall health of aquatic ecosystems. This uniformity can likely be attributed to the homogeneous regional climate and buffering effects of riparian vegetation and water inflows. Similar observations were made by Leach et al. (2023), where temperature was recognized as a major influence on both chemical and biological processes in aquatic systems. Temperature affects the solubility of salts and gases and, consequently, the concentration of dissolved

oxygen. Although the lack of significant differences suggests regional climatic uniformity, the potential impact of climate change cannot be ignored because rising temperatures could pose a threat to aquatic ecosystems, as suggested by Danladi Bello et al. (2017).

A notable variation was observed in pH levels ($P < 0.001$), with the Mouzaia and Tamesguida rivers exhibiting highly alkaline water (13.97 and 14.00, respectively). This alkalinity could be attributed to the proximity of landfills, which release substances that increase the pH, which is consistent with the findings of Gwisai et al. (2019) and Cerar et al. (2023). Elevated pH can create ecological stress, particularly by disrupting the biological cycles of aquatic species and reducing biodiversity. In contrast, the pH levels in the Merdja (8.34) and Djir (9.37) rivers were closer to neutral, creating more favorable conditions for aquatic life. Variations in pH across rivers may also be influenced by local geology, human activities, and groundwater inflows, all of which contribute to the chemical composition of water.

Conductivity, an indicator of the concentration of dissolved ions in water, displayed significant variation across the rivers ($P < 0.001$). The Djir River exhibited the highest conductivity (189.5 $\mu\text{S}/\text{cm}$), suggesting greater mineralization, possibly due to salt inputs or rock erosion. Conversely, the Mouzaia River had the lowest conductivity (181.0 $\mu\text{S}/\text{cm}$), indicating fewer dissolved ions. These conductivity differences are often linked to environmental factors such as geology, precipitation, or anthropogenic activities, as reported by Arciszewski & Roberts (2022). However, the moderate conductivity values across all rivers suggest a consistent chemical composition, indicative of relatively stable ionic compositions across the study area. This stability is essential for maintaining ecological balance, with similar findings reported by Brent et al. (2022), who associated moderate conductivity with natural mineral interactions and potential anthropogenic inputs, such as agricultural runoff.

Dissolved oxygen (DO), a key indicator of water quality, exhibited substantial variation ($P < 0.001$) between the rivers. The Tamesguida River, with a low DO concentration (3.52 mg/L), suggests potential hypoxic conditions that could be detrimental to aquatic life, especially fish, as levels below 4 mg/L can induce stress (Wang et al., 2023). In contrast, the Djir (8.27 mg/L) and Merdja (8.76 mg/L) Rivers exhibited higher DO concentrations, indicative of healthier, well-oxygenated environments. These higher DO levels are typically associated with colder flowing waters, which create optimal conditions for aquatic species. The DO level (5.48 mg/L) was marginally acceptable for most aquatic organisms, suggesting less ideal but viable conditions. These findings align with those of Chapman et al. (2004), who emphasized the importance of dissolved oxygen in habitat selection by aquatic species, particularly benthic macroinvertebrates, which thrive in cool oxygen-rich environments.

The analysis of macroinvertebrate communities and their diversity provides further insight into the ecological conditions of the rivers. In the literature, work on the assessment of spatial variation in physicochemical parameters and macroinvertebrate communities has developed considerably, highlighting the complex interactions between environmental factors, anthropogenic influences and biological responses (Eume et al., 2022). In their seminal work, (Davy-Bowker et al., 2005) found that environmental conditions and historical events are critical in shaping macroinvertebrate community structures over large geographical areas. Their research showed that while a wide range of environmental variables can predict macroinvertebrate fauna, a more refined selection of eleven key variables is sufficient for accurate prediction, particularly at unpolluted sites where stream velocity and depth emerged as key predictors, as is the case in our study at the Tamezguida and Mouzaia rivers. This study highlights the need to understand the spatial structuring of macroinvertebrate communities, and suggests that unexplained spatial elements may reflect unmeasured abiotic variables or historical biogeographical constraints. Similarly, Arman et al. (2019) directly addresses the assessment of spatial variation in physicochemical parameters and macroinvertebrate communities.

In our study we note that the presence of Simuliidae in large numbers could indicate that the river has favourable conditions for this particular family, possibly due to a high concentration of organic matter or a moderate to fast current (Dusabe et al., 2022), which is true in the case in the Tamesguida River. The Ephemerelidae are Ephemeroptera that are sensitive to

water quality. Their presence often indicates well oxygenated water, but their low numbers (compared to Simuliidae) may indicate conditions that are not optimal for greater diversity in this family. The low diversity in the Tamezguida River (many families present at 0) could reflect an environment under ecological stress or a homogeneous habitat that does not allow the colonisation of diverse macroinvertebrates (Markert et al., 2022). This could be due to a number of factors, such as pollution and the physical quality of the habitat (substrate with low diversity). Overall, the high abundance of Perlidae, Glossomatidae, Brachycentridae and some Ephemeroptera suggests that the water is of good quality, well oxygenated and with low organic pollution (Banegas et al., 2020). The dominance of Simuliidae is consistent with a fast-flowing environment, and the high abundance of Chironomidae could indicate a certain tolerance to variations in water quality, although this is still compatible with a healthy ecosystem, as in the case of Merdja and Djir rivers. The Tamezguida River shows an abundance concentrated in a few families, suggesting specific conditions limiting diversity. The analysis of the physico-chemical parameters of the water mentioned above confirms the hypotheses on the quality and environmental conditions of this river. In addition, the Diagram Rank-Frequency (Fig.3) obtained provides important clues about the ecology of macroinvertebrates in these different wadis (Kemka et al., 2004).

In aquatic ecology, rank-frequency distributions of macroinvertebrates are often used to assess habitat quality and diversity, as these organisms respond rapidly to variations in environmental conditions, including pollution, food availability and physical characteristics of the habitat (Wallace & Webster, 1996). The presence of different rank-frequency curves could reflect habitats of different complexity and stability. In a more stable and less polluted river we would generally expect greater diversity with a more even distribution of species (Richards et al., 1996). Habitats that are more disturbed or subject to anthropogenic pressures often show a more asymmetric frequency distribution, with tolerant species in high abundance and loss of sensitive species, as in the case of the Mouzaia River. This pattern is often a sign of eutrophication, organic pollution or habitat homogenisation (Rosenberg & Resh, 1993). These results suggest that conservation efforts could be better targeted to restore habitat diversity, especially for rivers showing signs of high dominance (Mouzaia River). Management practices focused on improving water quality and maintaining local biodiversity could help to restore more balanced distributions (Vinson & Hawkins, 1998). By combining the frequency rank with the specific tolerances of the taxa, we can calculate a biotic index. This index is used to assign a quality rating to the aquatic environment. Rank values are therefore useful for calculating indices such as the IBGN, which assesses the health of rivers Hilsenhoff (1988); Tachet et al. (2010).

The standardized global biological index (IBGN) values range from 1 to 20 depending on the taxonomic diversity of the station and the presence or absence of indicator taxa. Moreover, the overall assessment of hydrobiological quality is based on an examination of the benthic macroinvertebrate fauna, and all within the AFNOR standard (Arman et al., 2019). The taxonomic unit used is the family with the exception of a few faunal groups for which it is the phylum or the class (Worku et al., 2023). The Merdja, Djir and Mouzaia rivers show high diversity and significant abundance, with very good biological quality (IBGN = 18). In the other hand, the last river mentioned, the Tamezguida, shows lower diversity and much lower abundance, but the standardized global biological index was 9. The indicator group for the first three stations is excellent, indicating a stable state of the environment with good water quality. Nevertheless, the taxonomic richness of these stations is not significant. It is around 23 in Djir, 22 in Merdja and 20 in Mouzaia rivers. The Tamezguida River reflects an average hydrobiological quality, with an IBGN of 9, likewise, the indicator fauna group is represented by a low value of 3 (Table 3), indicating a slight degradation of the environment and the water. These observations could be used to make informed decisions on the management and conservation of natural resources in these specific environments (Arman et al., 2019). The tool diagnostic for watercourses based on macroinvertebrates shows that some species are more or less resistant to pollutants than others, and the presence or absence of these pollution indicator species will reflect the quality of the ecosystem (Barus et al., 2021).

Table 3 showed that the Shannon-Wiener indices in the Djir and Merdja rivers (2.75 and 2.65, respectively) indicate high species diversity,

consistent with other studies conducted in relatively undisturbed environments, as noted by Cabrera et al. (2021) and Ben Moussa et al. (2014). However, the much lower Shannon index (0.87) in the Tamezguida River suggests significant ecological stress, likely due to pollution and habitat degradation, as reflected in previous studies by Masese et al. (2023). In terms of species distribution, the Simpson index results further reinforced these findings, with high values in the Djir, Merdja, and Mouzaia rivers (0.93, 0.92, and 0.90, respectively), indicating balanced and diverse species communities. In contrast, the low Simpson index (0.52) for the Tamezguida River reflects dominance by pollution-tolerant species, as observed in similar studies of degraded environments (Ertaş & Yorulmaz, 2021).

Conclusion

This study provides a comprehensive assessment of the spatial variations in physicochemical parameters and macroinvertebrate communities in the Chiffa River basin, highlighting the influence of both natural and anthropogenic factors on freshwater ecosystems. Significant differences in pH, conductivity, and dissolved oxygen across the studied stations reflected varying degrees of environmental stress, with notable degradation observed in the Tamezguida River. On the other hand, and according to the results of the physico-chemical parameters and the benthic fauna, we can say that there has been a natural self-depollution from Tamezguida to the Merdja River. The variation in macroinvertebrate diversity, particularly the dominance of Diptera and reduced species richness at certain stations, underscores the importance of biodiversity as a key indicator of river health. These findings emphasize the need for targeted conservation efforts, especially in areas experiencing increased anthropogenic pressure, to preserve biodiversity and maintain ecosystem function. These insights contribute to a broader understanding of freshwater ecosystems in Chrea National Park, Northern Algeria, North Africa, and underscore the role of macroinvertebrates as valuable bioindicators for ecological monitoring and management.

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