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Assessment of Water Quality by Identification of the Faunal Biodiversity of Oum Errabia River in Morocco

Hicham Bouasria[1, 2*], El -Houssaine Bahouar[1, 2], Youssef S'hih[2, 4], Loubna Mrabet[2, 3], Abdechahid Loukili[2], El Hassan Abba[1]

[1]Laboratory of Biotechnology, Bio-resources and Bioinformatics, Khénifra Higher School of Technology Sultane Moulay Slimane University, Morocco

[2]Laboratory of "Scientific Research and Educational Innovation", Regional Center for Education and Training Professions, (CRMEF Rabat-Salé-Kénitra), Morocco

[3]Laboratory of Multidisciplinary Research in Science, Technology and Society, Khénifra Higher School of Technology; Sultane Moulay Slimane University, Morocco

[4]Laboratory Biology and Health, Department of Life Sciences, Faculty of Sciences, Kenitra, Ibn Tofail University, Morocco

[*]Corresponding Author: hicham.bouasria@usms.ma

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ABSTRACT

The Oum Errabia River is a vital aquatic ecosystem that supports both biodiversity and human activities in the region. However, it is increasingly threatened by pollution, habitat degradation, and the effects of climate change. One of the primary contributors to this degradation is the discharge of domestic wastewater, which significantly impacts aquatic fauna. This study focused on benthic communities to assess water quality through faunal analysis at three sampling stations, ranging from upstream to downstream, including the urban area of Khénifra. A total of 52 different taxa were identified, with insects being the most dominant group, followed by crustaceans, mollusks, and annelids. The upstream station (S1) exhibited high species diversity (H' > 2) and a strong biological quality index for macroinvertebrates (IBGN), indicating good water quality. In contrast, station S2—located in the area receiving untreated domestic wastewater—showed low diversity (H' < 2) and a poor IBGN score (< 5). This station was dominated by Chironomidae, a group known for its tolerance to pollution, and showed a marked absence of sensitive taxa such as Ephemeroptera, Plecoptera, and Trichoptera, indicating degraded water quality. Downstream at station S3, water quality was classified as moderate, suggesting some degree of natural self-purification despite the upstream pollution. Although biodiversity at S3 was higher than at S2, it remained lower than that recorded at the upstream station (S1). These results underscore the significant impact of human activities—particularly wastewater discharge—on the ecological integrity of the Oum Errabia River. The findings provide valuable data to support conservation and restoration efforts aimed at preserving this critical ecosystem.

INTRODUCTION

Morocco is in an area that serves as a point of contact between southern Europe and Africa. It is particularly relevant for faunistic, ecological and biogeographic research as it serves as a necessary transit zone for much of the fauna travelling between the Palaearctic and Afrotropical zones **(Lamri *et al.*, 2016; Abba *et al*., 2023)**. Although the invertebrate fauna of aquatic habitats in Europe is well-documented, significant knowledge gaps remain in Morocco, where studies on this fauna have been limited in both temporal and spatial scope. Moreover, Morocco's aquatic invertebrate fauna is remarkably diverse in terms of species richness and taxonomic composition. Moroccan scientists and naturalists are currently interested in understanding the benthic macroinvertebrates of rivers **(Amrani *et al*., 2006)**.

Biodiversity research will provide crucial data for assessing the ecological health of hydro-systems in the region and guiding conservation and environmental management policies **(Mrabet *et al*., 2025)**. By contributing to the documentation of the Moroccan benthic fauna, this research will also strengthen the overall understanding of biodiversity in this rich and diverse region. The degradation of water quality and its impact on aquatic ecosystems is a major concern, particularly in the Khenifra region where Oued Oum Errabia is affected. This degradation of water alters the environmental conditions of watercourses, jeopardizing the distribution and diversity of benthic macroinvertebrates.

These organisms play a crucial role in the trophic chain and material cycle of river ecosystems and are also used as biological indicators to assess water quality **(Vaidya, 2019; Zuedzang Abessolo *et al*., 2021)**. However, the biological richness of these ecosystems, particularly that of benthic macroinvertebrates, remains little studied in Morocco **(Souilmi *et al*., 2019; Qalmoun *et al*., 2022)**.

Understanding the composition and distribution of benthic macroinvertebrates is essential for the sustainable management of aquatic ecosystems, particularly in pollution-sensitive areas such as Khénifra. This study investigated the aquatic biodiversity in Morocco’s Oum Errabia River by analyzing benthic macroinvertebrate communities-key bioindicators of ecosystem health, focusing on the distribution and diversity of benthic macroinvertebrates to assess the quality of the water.

MATERIALS AND METHODS

The study area

The town of Khénifra is part of the Béni Mellal-Khénifra region. It is in the center of the Middle Atlas Mountains, at an altitude of over 1200 metres. The climate is continental, with hot, dry summers and freezing winters. The Oum Errabia river basin, located in the central-western region of Morocco between latitudes 31°19.330 ~ 33°22.2100N and longitudes 5°8.550 ~8°22.530W, receives an average of 400 to 700 millimeter of rainfall per year. Compared with the entire water basin, the upstream region, where Khénifra is located, benefits from adequate irrigation **(Abba *et al*., 2023)**.

The stations were selected according to various criteria that meet the objectives of our study, such as the representativeness of the stations in relation to the section studied, their position upstream and downstream of potential sources of pollution affecting the ecological integrity of the river studied, and ease of access and sampling at the stations. Based on these criteria, three sampling stations were chosen (Fig. 1) along the Oum Errabia stream. The 1st is located upstream of Khénifra S1, the 2nd at Chellal (S2) near the source of the domestic wastewater discharge and the last downstream of Khénifra (S3).

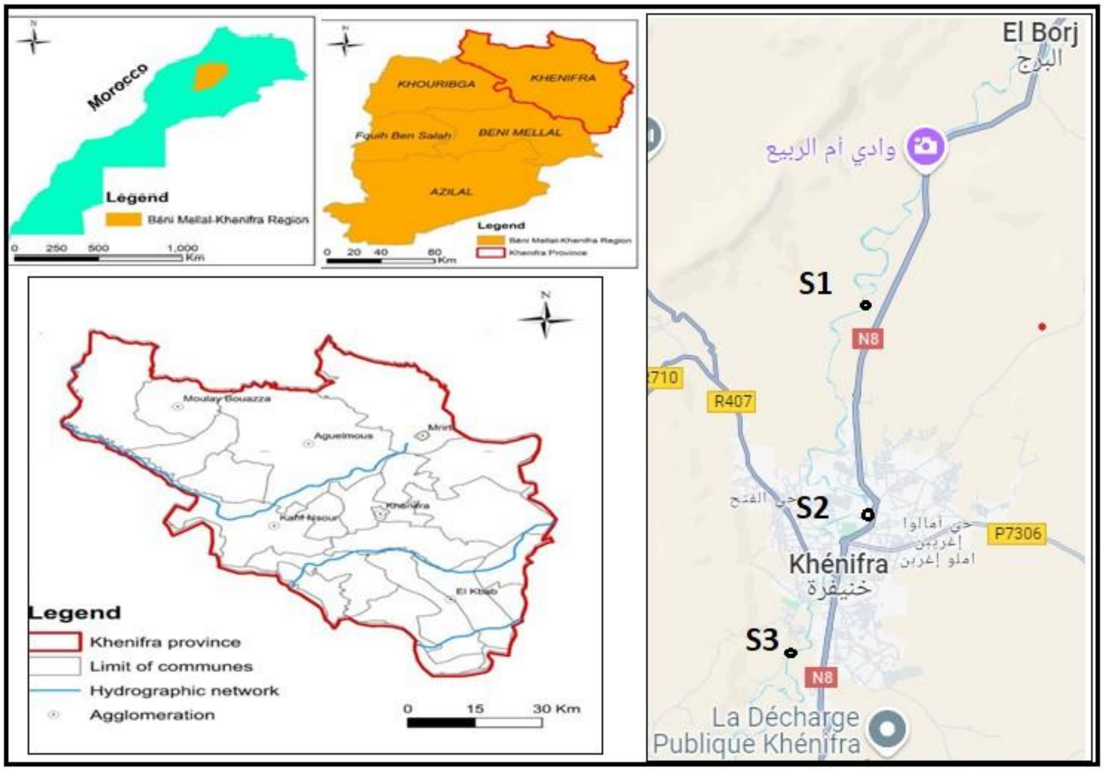

Fig. 1. Map of the study area and location of sampling stations

Sampling and analysis of macroinvertebrates

From March 2022 to February 2023, surveys were carried out for 8 sampling series to the order of one sample per month, in addition to the 8 microhabitats in accordance with the IBGN sampling protocol AFNOR NF T90-350 **(AFNOR, 2004)**. Another qualitative collection of substrates, using speed-depth pairs, was carried out to obtain an optimum variety of taxa. Surber and Troubleau Net samplers were used to collect the fauna. Samples were immediately placed in marked plastic containers and fixed with 10% formalin. The species to be identified were preserved in 70% alcohol **(Foto *et al*., 2010; Zuedzang Abessolo *et al*., 2021)**. In the laboratory, the macroinvertebrates taken were washed with water, filtered through a binocular magnifying glass and identified using reference books and benthic macroinvertebrate identification keys **(Hawking & Smith, 1997; Moisan, 2010; Tachet *et al*., 2010; Martin & Boughrous, 2012)**.

Shannon index (H')

This indicator makes it possible to assess diversity by considering the number of species and the abundance of individuals in each of them. Consequently, a community controlled by a single species will have a lower coefficient than a community where all species are dominant **(Kakundika *et al*., 2022)**. It is represented by the formula below **(Hyangya *et al*., 2014; Koumba *et al*., 2017; Swana *et al*., 2022)**:

$$H' = -\sum(pi \cdot ln(pi)) \qquad (1)$$

Where, pi = relative abundance of a taxon of rank i. with Pi=Ni/N, Ni: number of individuals of a given species and N: total number of individuals.

Normalized global biological index (IBGN)

The biological index global (IBGN), based on macroinvertebrate bioindicators, is a valuable tool for assessing water quality. By using the macroinvertebrate fauna as an essential component of the environment **(AFNOR, 2004)**, it provides an overall quantitative overview of the environment. This measurement has been used to establish the biological quality of water **(Karim *et al*., 2020)**. The AFNOR method is used to carry out the calculation, with the following form:

$$\text{IBGN} = \text{IG} + \text{VC} - 1 \qquad (2)$$

This formula means that IG is the indicator group, which groups together only those taxa present in an appropriate quantity, and VC is the variety class, which groups together all the species identified in the sample. There are five quality levels for the IBGN, which can fluctuate between 0 and 20: very poor quality (less than 5), poor quality (5 to 8), average (9 to 12), good (13 to 16) and very good (17 or more). In the absence of indicator taxa, a score of 0 is assigned **(Compagnat *et al*., 2000)**.

Data analysis

To assess variability in macroinvertebrate diversity and species richness, a standardized statistical analysis was applied using non-metric multidimensional ordination (nMDS). This approach allowed us to compare differences between sampling sites based on the ecological parameters measured **(Budka *et al*., 2024)**. In addition, nMDS facilitated the visualisation of ecological relationships, providing an in-depth understanding of the dynamics of the aquatic ecosystems studied and the factors influencing macroinvertebrate community composition **(Zhou *et al*., 2020)**.

RESULTS

Biodiversity of benthic macrofauna

Analysis of the faunistic and taxonomic data, enhanced by our own observations, provided significant information on the composition of this fauna. The results of the census of the benthic fauna in the study area enabled us to draw up a precise inventory of current biodiversity. A total of 52 different taxa were identified which were classified into 4 classes and 37 distinct families (Fig. 2).

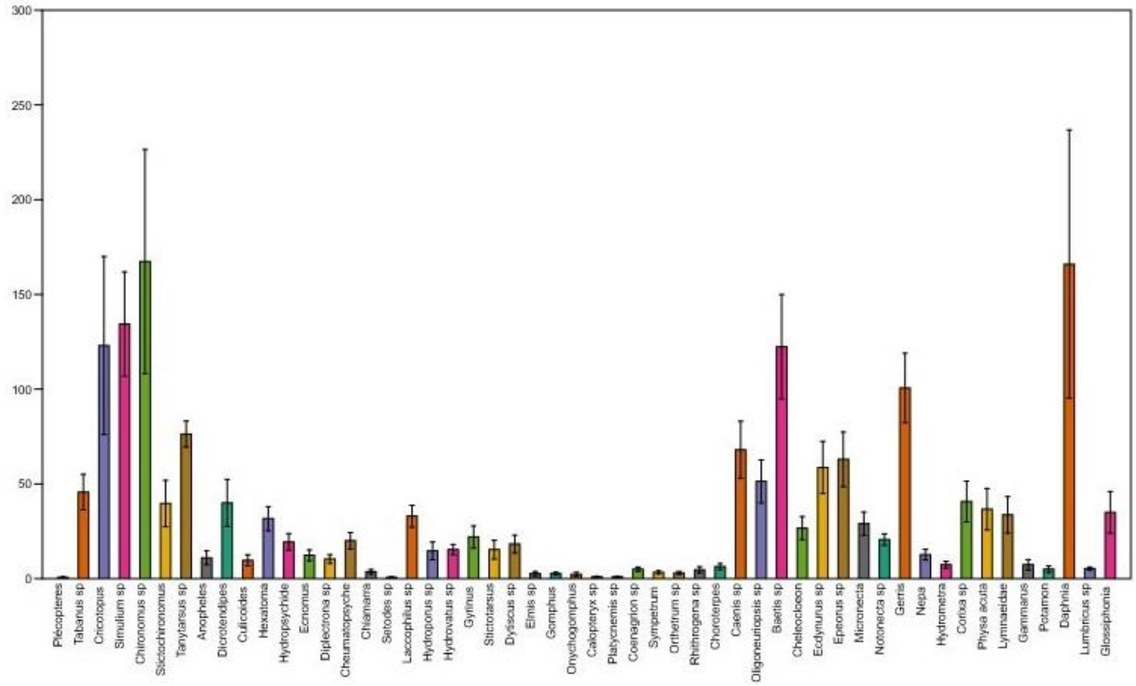

Fig. 2. Benthic composition of macroinvertebrates in the Oum Errabia River

The collected fauna was categorized into four major classes (Fig. 3). Insects were the most abundant, accounting for 86.54% of the total. These were further divided into seven orders: Ephemeroptera, Coleoptera, Trichoptera, Hemiptera, Odonata, Diptera, and Plecoptera. Mollusks were represented by a single order, Gastropoda, comprising 3.85% of the total fauna. Crustaceans made up 5.77% and included three orders: Potamonidae, Amphipoda, and Cladocera. Annelids accounted for 3.85% and were represented by two orders: Oligochaeta and Achaeta.

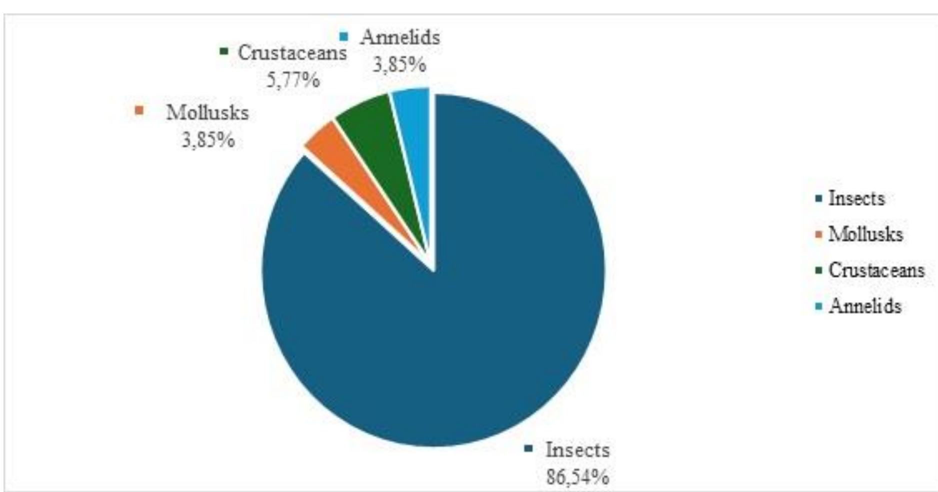

Fig. 3. Relative abundance of the main fauna groups

In this zone, the insect class is the most diverse, represented by 7 orders. Diptera and Ephemeroptera are the most abundant orders, with 45.33 and 26.78%, respectively (Fig. 4).

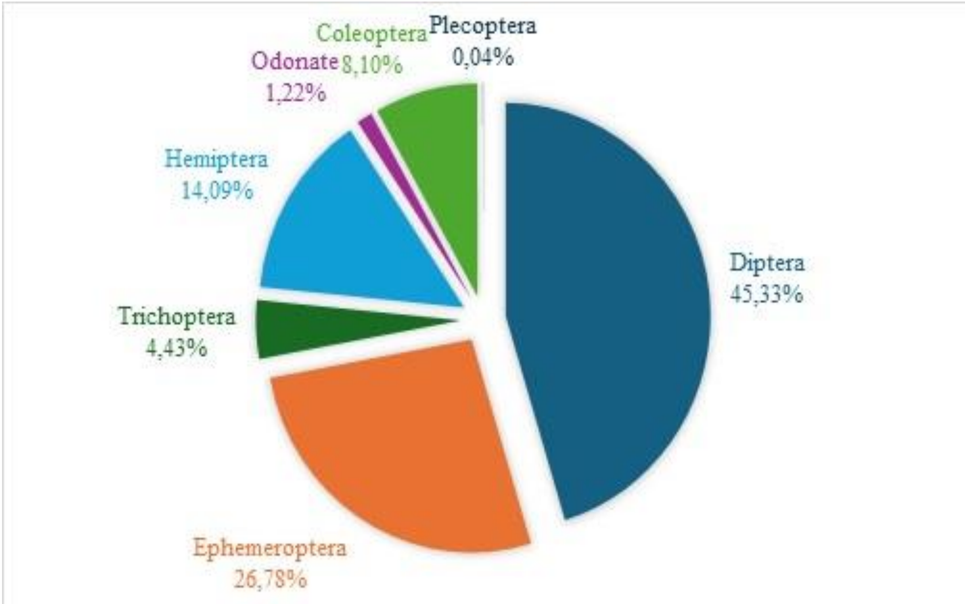

Fig. 4. Relative percentages of different orders of aquatic insects

The species belonging to the Diptera and Ephemeroptera group are represented by *Tabanus* sp., *Cricotopus*, *Simulium*, *Chironomus* sp., *Stictochironomus*, *Tanytarsus*, *Anopheles*, *Dicrotendipes*, *Culicoide*, *Hexatoma*, *Rhithrogena*, *Choroterpes*, *Caenis*, *Oligoneuriopsis*, *Baetis*, *Cheleocloeon*, *Ecdynurus*, *Epeorus*. The taxon *Hexatoma* is a Diptera taxon inventoried for the first time in the Oum Errbia catchment area (Table 1).

Table 1. Inventory of families surveyed

Order	Families	Taxa
Diptera	Tabanidae, Limoniidae, Simullidae, Chironomidae, Culicidae, Ephydridae, Ceratopogonidae.	*Tabanus, Cricotopus, Simulium, Chironomus, Stictochironomus, Tanytarsus, Anopheles, Dicrotendipes, Culicoide, Hexatoma*
Trichoptera	Hydropsychidae, Ecnomidae, Philopotamidae, Leptoceridae.	*Hydropsychide, Ecnomus, Diplectrona, Cheumatopsyche, Chiamarra, Setodes.*
Hemiptera	Gerridae, Notonectidae, Micronectidae, Nepidae, Hydrometridae, Corixidae.	*Micronect, Notonecta, Gerris, Nepa, Hydrometra, Corixa.*
Odonata	Gomphidae, Libellulidae, Coenagrionidae, Calopterygidae, Platycnemididae	*Gomphus simillinus, Onychogomphus, Calopteryx, Platycnemis, Coenagrion, Sympetrum, Orthetrum.*
Coleoptera	Dytiscidae, Gyrinidae, Noteridae, Elmidae.	*Laccophilus, Hydroporus, Hydrovatus, Gyrinus, Stictotarsus, Dytiscus, Elmis.*
Ephemeroptera	Baetidae, Heptageniidae, Caenidae, Oligoneuriidae, Leptophlebiidae.	*Rhithrogena, Choroterpes, Caenis, Oligoneuriopsis, Baetis, Cheleocloeon, Ecdynurus, Epeorus.*
Plecoptera		
Molluscs	Physidae, Lymnaeidae.	*Physa acuta, lymnaea.*
Crustaceans	Potamonidae, Gammaridae, Daphniidae.	*Potamon, Daphnia, Gammarus.*
Annelids	Lumbricidae, Glossiphoniidae.	*Lumbricus, Glossiphonia.*

In contrast, the remaining insect orders collectively accounted for 27.89% of the total insect population recorded. The order Hemiptera comprised 14.09%, represented by genera such as *Micronecta*, *Notonecta*, *Gerris*, *Nepa*, *Hydrometra*, and *Corixa*. Coleoptera made up 8.10% and included genera viz. *Laccophilus*, *Hydroporus*, *Hydrovatus*, *Gyrinus*, *Stictotarsus*, *Dytiscus*, and *Elmis*. Trichoptera represented 4.43%, with the presence of *Hydropsychidae*, *Ecnomus*, *Diplectrona*, *Cheumatopsyche*, *Chimarra*, and *Setodes*.

Odonata constituted 1.22% of the insect fauna and were represented by species such as *Gomphus simillimus*, *Onychogomphus*, *Calopteryx*, *Platycnemis*, *Coenagrion*, *Sympetrum*, and *Orthetrum*. These taxa are recognized as valuable bioindicators for identifying aquatic areas that should be prioritized for conservation. On the other hand, Plecoptera formed the least represented insect order, making up only 0.04% of the population. Their low abundance and diversity suggest they are rare or in decline in the study area.

Species richness and variation in pollutant-sensitive species

Analysis of the species richness along the Oum Errabia River (Fig. 5) reveals significant variations from upstream to downstream depending on the impact of domestic pollution, with trends observed for pollutant sensitives species. At station S1, taxonomic richness is high (52 taxa). This station has a high diversity, with a notable presence of pollutant sensitives species. These species thrive in high-quality environments.

Downstream toward station S2, domestic wastewater discharges directly threaten water quality and the integrity of aquatic ecosystems. A significant reduction in taxonomic richness is observed, with 31 taxa. This station is marked by the disappearance of species sensitive to pollution due to habitat degradation and domestic pollution. Ephemeroptera, Trichoptera and Odonata have almost disappeared from site S2 due to the deterioration in the quality of the biotope compared with other sites on the river. This situation could be linked to natural and/or anthropogenic factors influencing this watercourse. Indeed, the discharge of untreated domestic wastewater at station S2 probably contributes significantly to the creation of unfavorable conditions for benthic populations.

Downstream of Khénifra (Station 3), the taxonomic richness is higher than that observed at Station 2, but lower than at Station 1. This station is characterized by average diversity (47 taxa), with a relatively significant presence of pollutant-sensitive species.

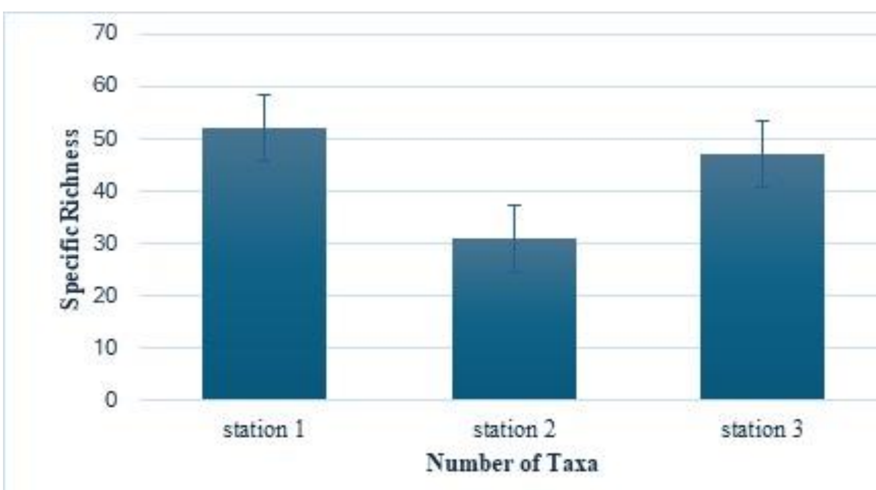

Fig. 5. Variation in species richness at different stations

Assessment of the biological quality of the water by IBGN and of biological diversity

Biological diversity

The evolution of the Shannon-Weaver index in the waters of the Oum Errabia River illustrates a diversity of benthic macroinvertebrates, and this Shannon-Wiener diversity (H') makes it possible to appreciate the diversity of a population (Fig. 6).

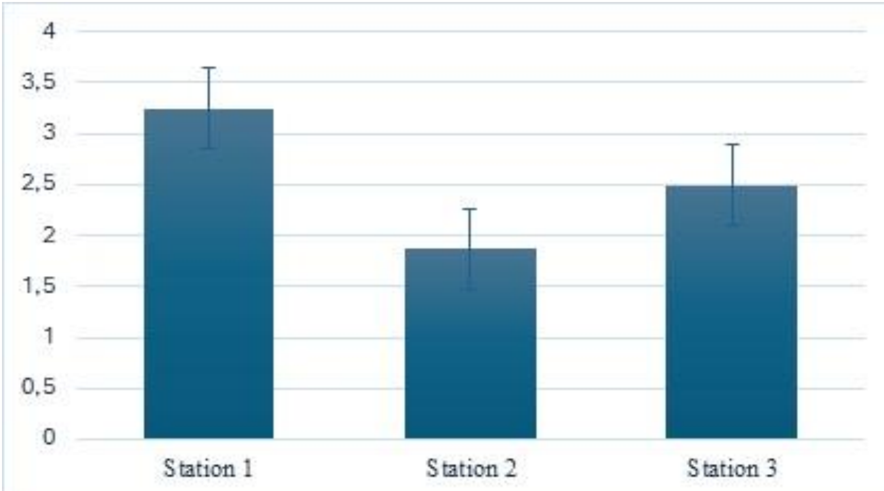

Fig. 6. Variation in Shannon diversity at the sampling stations

According to the results obtained in Fig. (6), the value of the Shannon index H' differs from one station to another. Station S1 has a high diversity of species sensitive to pollution, such as Ephemeroptera, Plecoptera and Odonata, with an H' value greater than 3 and IBGN 17. These indices confirm good water quality at this station. Station S2 is polluted, and is characterized by low biotic and diversity indices, with the Shannon H' index equals to 1.86 and the IBGN below 5.5. This indicates poor water quality, often dominated by pollution-resistant taxa such as Chironomidae. The loss of indicator faunal groups, such as Plecoptera and Trichoptera and Odonata, explains the low IBGN values at this station. The downstream station S3 shows average diversity with a value of H=2.49, and IBGN is equal to 13, these results confirm average water quality at this station.

Table 2. IBGN values for the various stations in Oued Oum Errabia

Station	Taxonomic richness (N. of families)	Indicator group	Index score	Quality of Station
Station 1	32	8	16/20	Good
Station 2	14	2	6/20	Wrong
Station 3	30	5	13/20	Average

Table 3. IBGN values according to macrofaunal taxonomy and variety **(AFNOR, 1992)**

Variety class		**14**	**13**	**12**	**11**	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
Indicator taxa	∑t GI	>50	49 45	44 41	40 37	36 33	32 29	28 25	24 21	20 17	16 13	12 10	9 7	6 4	3 1
Chloroperlidae Perlidae Perlodidae Taeniopterygidae	9	20	20	20	19	18	17	16	15	14	13	12	11	10	9
Capniidae Brachycentridae Odontoceridae Philopotamidae	8	20	20	19	18	17	16	15	14	13	12	11	10	9	8
Leuctridae Glossosomatidae Beraeidae Goeridae Leptophlebiidae	7	20	19	18	17	16	15	14	13	12	11	10	9	8	7
Nemouridae Lepidostomatidae Sericostomatidae Ephemeridae	6	19	18	17	16	15	14	13	12	11	10	9	8	7	6
Hydroptilidae Heptageniidae Polymitarcidae Potamanthidae	5	18	17	16	15	14	13	12	11	10	9	8	7	6	5
Leptoceridae Polycentropodidae Psychomyidae Rhyacophilidae	4	17	16	15	14	13	12	11	10	9	8	7	6	5	4
Limnephilidae * Hydropsychidae Ephemerellidae * Aphelocheiridae	3	16	15	14	13	12	11	10	9	8	7	6	5	4	3
Baetidae * Caenidae * Elmidae * Gammaridae * Mollusca	2	15	14	13	12	11	10	9	8	7	6	5	4	3	2
Chironomidae * Asellidae * Achete Oligochaete *	1	14	13	12	11	10	9	8	7	6	5	4	3	2	1
* Taxa represented by a minimum of 10 individuals; the remaining taxa by a minimum of 3 individuals.															

Indicator species for each sampling station

At station 1, which is upstream, water quality is good according to the IBGN index and is also characterized by high biodiversity according to the Shannon index (H'), which reaches a high value of 3.25. The aquatic fauna at this station is dominated by poluosensitive species such as Trichoptera (*Chiamarra*, *Setodes*), Ephemeroptera (*Rhithrogena. Baetis*) and Odonata such as (*Gomphus simillinus, Onychogomphus*), Plecoptera. Other species such as *Gammarus*, *Potamon*, *Daphnia*, and *Physa acuta* (a gastropod) are also common in this station, indicating a richness in microfauna and a good ecological condition of the aquatic environment.

Station 2, located in an area that receives domestic wastewater, is characterized by pollution-tolerant species such as the Chironomidae (*Chironomus* sp., *Cricotopus*, *Stictochironomus*, *Dicrotendipes*, *Tanytarsus Culicoides).*

An Station 3, located downstream of Khenifra, the biological indicators show that the aquatic fauna is still made up of Chironomidae, with several more sensitive species, such as Ephemeroptera, Trichoptera, and odonata.

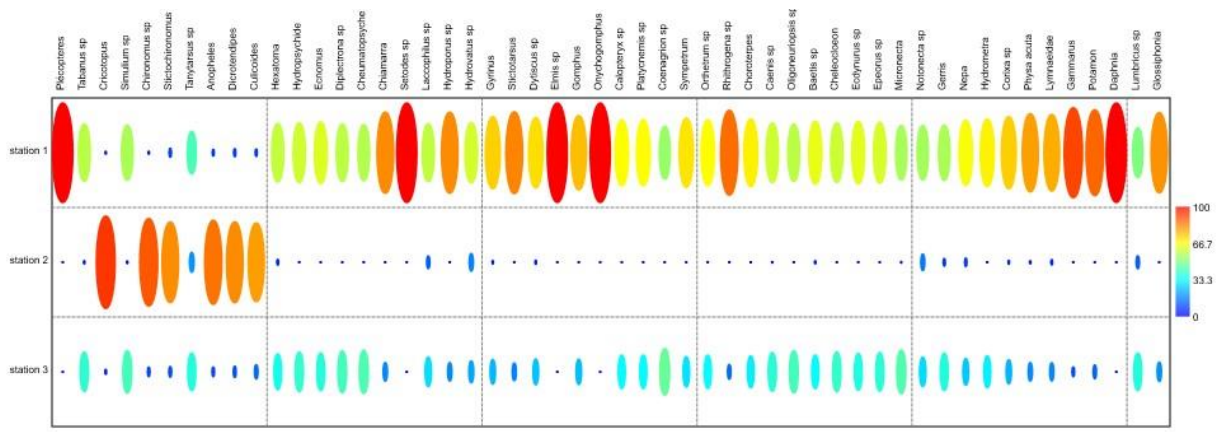

Fig. 7. Indicator species for each sampling station

DISCUSSION

The aim of this study was to assess the ecological health of the Oum Errabia River through the distribution and composition of the benthic macrofaunal community along a section of the river, from upstream to the downstream of Khénifra. The faunal analysis revealed significant variations in community structure and water quality across the three sampling stations.

Station S1, located upstream of Khénifra in an area minimally impacted by human activity, exhibited relatively high water quality. This site stood out for its exceptional biological diversity, surpassing that of the other stations. Species sensitive to pollution, including Plecoptera, were recorded here—taxa considered rare in the Oum Errabia River. Their presence indicates clean, well-oxygenated water, likely due to the absence of direct pollution sources **(Belala & Saheb, 2022)**.

The scarcity or absence of Plecoptera in other North African rivers has been linked to high summer temperatures **(Berrahou *et al.,* 2001)**. Other studies **(Bouzidi, 1989; Lamri *et al.,* 2016; Zuedzang Abessolo *et al.,* 2021)** have noted that these insects are typically confined to high-altitude, well-oxygenated streams due to their sensitivity to thermal and water quality fluctuations.

Station S1 also hosted a wide variety of Ephemeroptera, including *Baetis*, a known environmental indicator species, as well as Trichoptera, Diptera, and Odonata. Odonata, which are often observed above water but are heavily dependent on aquatic and riparian habitat conditions, serve as strong indicators of ecosystem health. Their assemblages can help prioritize areas for conservation **(Hart, 2014)**. The discovery of Cladocerans such as *Daphnia*—highly sensitive to water quality changes—further confirmed the relatively undisturbed and favorable conditions of this site **(Karpowicz *et al.,* 2020)**.

Station S2, located within the urban zone of Khénifra, was characterized by species tolerant of pollution, notably Chironomidae. This site suffers from significant pollution due to the direct discharge of domestic, agricultural, and industrial wastewater, including effluents from oil mills, phosphate mining, livestock farming, and sugar beet processing **(Barakat *et al.,* 2016; Bhadarka *et al.,* 2024)**. These pressures result in a severely degraded aquatic habitat and reduced biodiversity **(Derradj *et al.,* 2007)**, particularly affecting taxa sensitive to pollutants.

Sensitive groups such as Plecoptera, Odonata, and Crustaceans (notably *Daphnia*) were absent at Station S2, a clear indication of deteriorated water quality. The fauna was dominated by pollution-tolerant Chironomidae, including *Chironomus* sp., *Cricotopus*, *Stictochironomus*, *Dicrotendipes*, and *Tanytarsus*. *Chironomus* sp., in particular, is an environmental indicator of high organic pollution and low dissolved oxygen. Chironomidae play a central role in the resilience of aquatic communities, especially in nutrient-poor environments, and are often seen as pollution-resistant **(Jacobsen, 1998; Serra *et al.,* 2017)**. A benthic community dominated by Chironomidae typically signals poor water quality **(Raunio *et al.,* 2007)**.

Other tolerant taxa observed at this station included certain Coleoptera (e.g., *Hydrophilus*, *Dytiscus*) and Oligochaetes (Tubificidae), which are known to thrive in polluted sediments such as wastewater basins **(Crespo *et al.,* 2020)**. The absence of *Daphnia* further underlines the significant ecological degradation at this site, likely driven by domestic pollution **(Tromas *et al.,* 2025)**.

Station S3, situated downstream of Khénifra, benefited from natural self-purification processes, resulting in moderate water quality. Macroinvertebrate diversity at this site was slightly higher than at Station S2 but still lower than that recorded at Station

S1. Although Chironomidae remained present, more sensitive taxa such as Ephemeroptera, Trichoptera, and some Odonata were also found, indicating partial ecological recovery.

The presence of *Baetis* and a modest number of Odonata taxa—both indicators of improving conditions—suggests the ecosystem is showing signs of resilience. This station is also characterized by the presence of riffles—shallow, fast-flowing sections with gravel and stones—that facilitate aeration and the breakdown of organic matter. Such features contribute significantly to the river's self-purification capacity **(Vervier *et al*., 1993; Namour *et al*., 2012)**.

The diversity index at Station S3 was H' = 2.49, and the IBGN score was 13, both indicating average water quality. Although self-purification processes have helped improve conditions, sensitive taxa such as Plecoptera and Odonata remain rare or absent. The limited presence of *Daphnia* suggests that while the water quality has improved relative to Station S2, it still does not match the ecological integrity of Station S1.

CONCLUSION

The results of this study clearly show that domestic wastewater has a significant impact on both water quality and the biodiversity of aquatic fauna in the Oued Oum Errabia. The various sampling stations (S1, S2, S3) revealed significant variations in the biological indices of ecological quality, illustrating the effects of domestic pollution. Because of its diversity and the presence of pollution-sensitive species, the upstream station S1 was used as a reference point for unpolluted environmental conditions. Station S2 illustrates the negative effects of domestic pollution, while station S3, although showing signs of recovery thanks to the presence of riffles favouring self-purification, continues to feel the residual effects of pollution.

The integration of biological indices such as IBGN and the Shannon index provides a complete picture of the ecological diversity and water quality at the three stations studied.

Effective management of wastewater discharges and rigorous protection of natural habitats are essential to preserve and restore aquatic biodiversity in the Oued Oum Errabia. To improve the situation, it is crucial to strengthen wastewater treatment policies, promote sustainable management practices and implement awareness and monitoring programmes. Implementing ecosystem restoration measures, such as creating buffer zones and rehabilitating natural habitats, could also help mitigate the impact of pollution and promote faster ecological recovery.

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