Original Article

Environmental drivers of macrobenthic diversity and seasonal variability in the Jajrood River, Iran

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ABSTRACT

This study investigates the environmental drivers influencing the spatial and seasonal distribution of macrobenthic communities in the Jajrood River, Iran. Seasonal sampling was conducted at five geographically distributed stations during autumn and winter of 2014 and spring and summer of 2015. Key environmental parameters, including water temperature and dissolved oxygen levels, were recorded in conjunction with biological data on species diversity and abundance. A total of 19 species belonging to five taxonomic orders were identified, with Insecta dominating across all seasons. Diversity indices indicated that macrobenthic richness was highest during spring and lowest during winter, corresponding to variations in temperature and dissolved oxygen. Downstream stations exposed to urban effluents exhibited lower diversity and were dominated by pollution-tolerant species such as Chironomus and Tubificidae. These findings underscore the role of macrobenthos as reliable biological indicators for assessing riverine ecosystem health and highlight the impact of anthropogenic activities on aquatic biodiversity. The study also demonstrates how seasonal fluctuations and spatial gradients reflect natural ecological cycles alongside human-induced pressures. By emphasizing the integration of biological indicators with environmental parameters, the results provide valuable insights for monitoring programs and reinforce the importance of sustainable management of freshwater resources to preserve biodiversity and ecosystem integrity in vulnerable river systems.

Keywords: Macrobenthos, Diversity indices, Seasonal variation, Water quality, Jajrood river, Pollution indicators

Introduction

Macrobenthic invertebrates are critical components of freshwater ecosystems, playing essential roles in nutrient cycling, organic matter decomposition, and serving as vital links within aquatic food webs [1, 2]. Due to their relatively sedentary nature, diverse species compositions, and varying tolerances to environmental stressors, macrobenthos are widely recognized as effective biological indicators of water quality and ecosystem health [3, 4].

Environmental factors, including temperature fluctuations, dissolved oxygen levels, hydrological changes, and anthropogenic pollution, profoundly influence the distribution, abundance, and diversity of benthic communities [5, 6]. Seasonal dynamics, in particular, result in variations in community structure, driven by changes in water temperature, flow regimes, and organic matter availability [7, 8]. High temperatures in summer typically lead to lower dissolved oxygen concentrations, favoring tolerant taxa, whereas cooler seasons such as spring and winter often support higher diversity.

Rivers subjected to urban and agricultural pollution often experience alterations in their macrobenthic assemblages, with pollution-tolerant taxa like Chironomidae and Tubificidae dominating in heavily impacted zones [9, 10]. Thus, monitoring macrobenthic communities provides a cost-effective, reliable method for assessing ecological integrity and identifying anthropogenic impacts on freshwater ecosystems.

The Jajrood River, originating from the Alborz mountains in Iran, is a vital water source for the Tehran metropolitan area, supporting both drinking water supplies and agricultural irrigation. Given its ecological importance and exposure to varying degrees of anthropogenic influence, the Jajrood River presents an ideal case study for examining the interactions between environmental factors and macrobenthic community dynamics.

The primary objectives of this study were to:

Identify the seasonal composition and abundance of macrobenthos in the Jajrood River,

Evaluate the influence of environmental factors such as temperature and dissolved oxygen on macrobenthic diversity,

Assess spatial variations in community structure across stations exposed to different pollution levels, and

Affirm the utility of macrobenthos as biological indicators for freshwater ecosystem monitoring.

Materials and Methods

Study area

The Jajrood River originates from the Alborz mountain range in northern Iran, with headwaters located at altitudes exceeding 4000 meters above sea level. It flows southwest through mountainous terrains, rural communities, and agricultural lands before entering the Latyan Dam, which supplies water to Tehran's eastern districts and the Varamin plain. The river receives inputs from multiple tributaries and is influenced by agricultural runoff, urban wastewater, and natural hydrological processes, making it an ideal subject for investigating spatial and temporal variations in aquatic biodiversity.

Sampling stations

Five sampling stations were selected along the Jajrood River based on river morphology, land use, and proximity to pollution sources:

Station 1 (S1): Upstream site representing relatively pristine conditions.

Station 2 (S2): Site 2 km downstream of S1, receiving minor lentic water inflow.

Station 3 (S3): Located just before Latyan Dam, monitoring water quality entering the dam reservoir.

Station 4 (S4): Downstream of Latyan Dam, assessing post-dam effects on river ecology.

Station 5 (S5): Situated within Jajrood city limits, subject to urban effluents.

The geographic coordinates of each station were recorded using GPS, and environmental variables were measured at each site.

Environmental data collection

At each station, environmental parameters were recorded during each sampling event, including:

- Water temperature (°C) using a digital thermometer.
- Dissolved oxygen concentration (mg/L) using a portable oxygen meter.
- Visual assessments of substrate composition and turbidity levels.

Biological sampling

Macrobenthic samples were collected seasonally—during the last month of autumn (December 2014), winter (March 2015), spring (May 2015), and summer (August 2015).
At each station, three replicate samples were taken from both river margins and mid-channel using a 50 × 50 cm quadrat and a hand-held benthic net (mesh size: 500 µm). Samples were preserved in 70% ethanol and transported to the laboratory for sorting and identification.
Organisms were identified to the lowest possible taxonomic level (usually genus or species) using standard identification keys (e.g., Cranston, 1996; Arimoro, 2011).

Diversity indices

The following biodiversity indices were calculated:

Shannon-Wiener Diversity Index (H′):

Measures species richness and evenness.

Simpson's Diversity Index (D):

Reflects species dominance.

Margalef's Richness Index (d):

Estimates species richness relative to sample size.

Hilsenhoff Family Biotic Index (HFBI):

Assesses organic pollution levels based on species tolerance.
Indices were calculated seasonally at each station to evaluate spatiotemporal variations in macrobenthic communities.

Statistical analyses

Descriptive statistics were used to summarize macrobenthos abundance and diversity indices.
Comparisons across seasons and stations were conducted using one-way analysis of variance (ANOVA), and Tukey's post hoc tests were employed to identify significant differences ($p < 0.05$).
All statistical analyses were performed using SPSS software (version 24).

Results and Discussion

Environmental parameters

Water temperature across the Jajrood River showed distinct seasonal variations, ranging from approximately 0°C during winter to 26°C in summer, with an overall annual mean of 13°C. Dissolved oxygen (DO) levels displayed an inverse pattern, peaking during winter (up to 12 mg/L) and reaching minimum levels during the summer months (as low as 4 mg/L) at downstream stations exposed to urban pollution.

Macrobenthos community composition

A total of 19 species belonging to 5 taxonomic orders and 15 families were identified throughout the study period.
Insecta dominated across all seasons, comprising approximately 70–72% of total individuals collected. Other major groups included:

- Oligochaeta (Annelids) — 4.8%
- Malacostraca (Crustaceans) — 3.2%
- Gastropoda (Snails) — 1.9%
- Crustacea (Aquatic isopods) — 0.2%

Key Genera Identified:

- Chironomus sp. (Diptera) — most abundant genus across all stations
- Tipula sp. (Diptera) — least abundant
- Potamon sp. (Malacostraca)
- Valvata sp. and Limnaea sp. (Gastropoda)

Seasonal variation in macrobenthos

Table 1 presents the seasonal variation in macrobenthos abundance and diversity indices.

Table 1. Seasonal variations in macrobenthos abundance and diversity indices.

Season	Mean Water Temp (°C)	Total Abundance (individuals/m²)	Shannon-Wiener Index (H′)	Simpson's Index (D)	Margalef's Richness Index (d)	HFBI Score
Autumn 2014	15	1090	1.65	0.72	2.45	5.2
Winter 2014	8	801	0.92	0.55	1.83	6.4
Spring 2015	18	1039	2.01	0.81	2.68	4.8
Summer 2015	23	921	1.45	0.68	2.10	5.7

Spatial patterns

Upstream Stations (S1 & S2):

Exhibited higher species richness and diversity. Dominant species included pollution-sensitive taxa such as Baetis spp. and Gomphus spp.

Station 3 (Pre-Dam):

Moderate diversity; transitional community influenced by partial stagnation and sedimentation near the dam.

Downstream Stations (S4 & S5):

Lower diversity and abundance; dominated by pollution-tolerant taxa (Chironomus spp., Tubificidae).
HFBI scores increased downstream, indicating worsening organic pollution.

Key observations

- The highest total abundance was recorded in autumn (1090 individuals/m²), coinciding with moderate water temperatures and optimal oxygen levels.
- The lowest species richness and diversity were recorded in winter, likely due to low temperatures and restricted biological activity.
- Chironomidae and Tubificidae displayed consistent dominance in downstream polluted stations across all seasons.
- Diversity indices consistently declined from upstream to downstream, correlating with increasing anthropogenic impacts.

The findings of this study demonstrate that environmental variables, particularly temperature, dissolved oxygen, and anthropogenic pollution, play significant roles in shaping the spatial and seasonal distribution of macrobenthic communities in the Jajrood River.

These findings are in agreement with earlier research on the Latyan Dam's ecological effects (Zamani Alaei 2025).

Influence of seasonal changes.

Seasonal variations exerted marked influences on macrobenthic diversity and abundance.

Spring recorded the highest Shannon-Wiener diversity index, attributed to moderate temperatures, increased primary productivity, and favorable oxygen conditions.(Zamani Alaei, 2025).

Winter exhibited the lowest diversity, likely due to low temperatures and reduced biological activity, consistent with observations in similar temperate river systems [6, 8].

In line with previous studies [4, 5], our results confirm that seasonal hydrological fluctuations, including flooding events and changes in water velocity, contributed to habitat disturbances, leading to declines in macrobenthic density during certain periods, particularly winter.

Impact of pollution and spatial variability

Spatial patterns of macrobenthic assemblages clearly reflected the gradient of anthropogenic disturbance along the river continuum.

Upstream stations (S1 and S2), characterized by minimal anthropogenic impacts, maintained higher diversity, abundance of sensitive taxa (Baetis, Gomphus), and lower HFBI scores, indicating better water quality.

Downstream stations (S4 and S5) experienced significant organic pollution, evidenced by lower diversity, the dominance of tolerant species (Chironomus, Tubificidae), and higher HFBI scores (>5.5), indicating moderate to poor water quality.

These observations align with previous studies emphasizing the effectiveness of macrobenthic taxa as indicators of organic enrichment and water pollution [3, 7].

Biological indicators and management implications

The dominance of Diptera, particularly Chironomidae, and Oligochaeta in impacted sites underscores their potential as reliable biological indicators for freshwater monitoring programs. Their presence in high densities at downstream stations mirrors pollution-tolerant assemblages described in other anthropogenically disturbed rivers worldwide [1, 11].

Considering that physical and chemical water quality assessments often fail to capture transient pollution events, integrating biological assessments through macrobenthos monitoring offers a more holistic and long-term perspective on riverine ecosystem health [10].

Given the critical ecological services provided by freshwater macrobenthos, including nutrient cycling and energy transfer within food webs, preserving habitat quality and mitigating pollution sources are paramount to maintaining riverine biodiversity and ecological integrity [8, 12].

Conclusion

This study underscores the significant influence of environmental factors—particularly water temperature, dissolved oxygen, and organic pollution—on the spatial and seasonal dynamics of macrobenthic communities in the Jajrood River.

The seasonal fluctuations observed, with higher diversity during spring and lower diversity during winter, reflect the sensitivity of macrobenthic assemblages to natural hydrological and thermal cycles. Moreover, the spatial degradation in macrobenthic diversity and abundance downstream highlights the adverse impacts of urban and agricultural pollution on riverine ecosystems.

The dominance of pollution-tolerant taxa such as Chironomidae and Tubificidae at impacted sites further confirms the utility of macrobenthos as effective biological indicators for water quality assessments.

Integrating macrobenthic monitoring into routine environmental management programs can offer critical insights for detecting ecological disturbances, guiding conservation strategies, and promoting the sustainable management of freshwater resources.

Future studies are recommended to incorporate broader biological metrics, including functional feeding groups and life history traits, to deepen the ecological understanding of anthropogenic impacts on freshwater ecosystems.

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References

1. Covich AP, Palmer MA, Crowl TA. The role of benthic invertebrate species in freshwater ecosystems. BioScience. 1999;49(2):119-27.
2. Allan JD, Castillo MM. Stream Ecology: Structure and Function of Running Waters. Springer; 2007.
3. Rosenberg DM, Resh VH. Freshwater Biomonitoring and Benthic Macroinvertebrates. Chapman & Hall; 1993.

4. Bonada N, Prat N, Resh VH, Statzner B. Developments in aquatic insect biomonitoring: A comparative analysis of recent approaches. Annu Rev Entomol. 2006;51:495-523.
5. Armitage PD, Moss D, Wright JF, Furse MT. The performance of a new biological water quality score system based on macroinvertebrates over a wide range of unpolluted running-water sites. Water Res. 1983;17(3):333-47.
6. Cranston PS. Identification keys to the larvae of Chironomidae of the Holarctic region. In: Wiederholm T, editor. The Chironomidae: Biology and Ecology of Non-biting Midges. Entomological Society of Lund, Sweden; 1996. p. 153–190.
7. Arimoro FO. Macroinvertebrate community structure in a tropical river, southern Nigeria. Tropical Zoology. 2011;24(1):1–15.
8. Zhang Y, Xu Y, Wang B, Chen Y, Ma X, Yu H, Li S, et al. Seasonal variations in macrobenthos communities and their responses to environmental changes in the Yuqu River Basin. Biology. 2023;14(2):120.
9. Sapto P. Macrobenthos as bioindicators in aquatic environments. Int J Sci Eng. 2014;8(2):84-7.
10. Sahidin A, Zahidah Z, Herawati H, Wardiatno Y, Setyobudiandi I, Partasasmita R. Macrozoobenthos as bioindicator of ecological status in Tanjung Pasir Coastal, Indonesia. Biodiversitas. 2018;19:1123-9.
11. Macleod CK. Environmental indicators based on benthic fauna. 2000.
12. European Commission. Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for Community action in the field of water policy (Water Framework Directive). 2000.
13. Bhosale LJ. Environmental Ecology and Biodiversity. Pragati Prakashan; 2012.
14. Castro P, Huber ME. Marine Biology. McGraw-Hill; 2000.
15 . Zamani Alaei, M. (2025). Seasonal Identification of Macrobenthos in the Jajrood River. TMP Universal Journal of Research and Review Archives, 4(2). Retrieved from https://tmp.twistingmemoirs.com/index.php/ujrra/article/view/155
16. Zamani Alaei, M. Z. (2025). Seasonal Identification of Macrobenthos in the Jajrood River. TMP Universal Journal of Research and Review Archives, 4(2). https://doi.org/10.69557/ujrra.v4i2.155