Original Research Article
ISSN: 3041-5357
Journal homepage: https://diversity.researchfloor.org/

Journal of Diversity Studies

Integrated Assessment of Micro and Macro Fauna as Bioindicators of Ecological Health in the Bhima River, India

Vijaylaxmi C.[1], **Krishnappa D.K.**[2], **Sudheer Manawadi**[3], **and Sharangouda J. Patil***[4]

[1]*Department of Zoology, LVD College, Raichur, Karnataka, India*
[2]*Department of Zoology, Bangalore University, Bengaluru, Karnataka, India*
[3]*Department of Biotechnology, Government Science College (Autonomous), Hassan, Karnataka, India.*
[4]*Department of Zoology, NMKRV College Autonomous, Bengaluru, Karnataka, India*

ABSTRACT

The Bhima River, a major tributary of the Krishna River in India, supports a diverse range of aquatic organisms, yet systematic studies on its micro and macrofaunal biodiversity remain limited. This study aims to assess the diversity, distribution, and ecological significance of micro and macro fauna along selected stretches of the Bhima River, covering rural, urban, and semi-urban zones. Field surveys were conducted seasonally over 12 months using standard collection protocols, including plankton nets, benthic samplers, and handpicking methods. Samples were identified up to the lowest possible taxonomic level under laboratory conditions using microscopic and morpho-taxonomic techniques. The findings revealed significant spatial and seasonal variation in the composition of both microfauna (protozoa, rotifers, copepods, cladocerans) and macrofauna (annelids, molluscs, arthropods), with marked sensitivity to water quality gradients and anthropogenic pressures. Several pollution indicator species were recorded, suggesting bioindicator potential for ongoing environmental monitoring. The study provides baseline data that can be instrumental in ecological health assessments, conservation planning, and sustainable riverine management initiatives. The originality of this work lies in its integrative and site-specific approach, combining ecological data with bioassessment protocols to deliver a holistic view of Bhima River's faunal health. The outcomes offer practical applications in framing biotic indices for river quality classification under Indian freshwater standards, contributing to both academic research and policy-oriented environmental planning.

Keywords: *Bhima River, Microfauna and Macrofauna, Aquatic Biodiversity, Bioindicators, Riverine Ecosystem Assessment.*

Citation: Vijaylaxmi C., Krishnappa D.K., Sudheer Manawadi and Sharangouda J. Patil [2026]. Integrated Assessment of Micro and Macro Fauna as Bioindicators of Ecological Health in the Bhima River, India. *Journal of Diversity Studies.* **DOI: https://doi.org/10.51470/JOD.2026.5.2.23**

Corresponding Author: *Sharangouda J. Patil*

E-mail Address: *shajapatil@gmail.com*

Article History: *Received 08 April 2026 | Revised 05 May 2026 | Accepted 11 June 2026 | Available Online July 07, 2026*

1. Introduction

The Bhima River, a major tributary of the Krishna River, originates from the Bhimashankar hills in Maharashtra and flows across the Deccan plateau, passing through diverse agro-ecological zones before merging with the Krishna River in Karnataka. Spanning approximately 861 kilometers, it plays a vital role in sustaining the socio-economic and ecological fabric of the regions it traverses. The river not only supports agricultural irrigation and urban water supply but also provides a critical habitat for a variety of aquatic organisms, ranging from microscopic planktonic species to large invertebrates and fish.

Understanding the biological constituents of freshwater ecosystems is imperative for assessing their ecological health. Microfauna such as protozoa, rotifers, and cladocerans, along with macrofauna like molluscs, annelids, and arthropods, form essential links in aquatic food webs. They influence nutrient cycling and sediment dynamics and serve as primary indicators of water quality due to their sensitivity to environmental changes [1].

The Bhima River basin, with its mix of urban-industrial and agricultural influences, provides a unique ecological landscape where faunal diversity patterns can reveal critical insights into freshwater ecosystem functioning and anthropogenic pressures.

Despite the ecological importance of the Bhima River, research on its biodiversity—particularly the integration of both micro and macrofaunal data—is surprisingly limited. Most available studies focus on isolated groups such as fish [2] or molluscs (Waghmare et al., 2012), without capturing the comprehensive faunal dynamics that define the river's biotic integrity. In addition, the lack of seasonal and spatial monitoring frameworks limits our understanding of temporal fluctuations in biodiversity and the factors driving them. There is also a gap in using faunal data to develop predictive ecological indicators or region-specific water quality assessment tools.

The present study aims to bridge these gaps by conducting an integrated assessment of both micro and macro fauna along selected stretches of the Bhima River.

The objectives of this study are:

(I) to identify and document the diversity of micro and macrofauna in the Bhima River,

(ii) to analyze seasonal and spatial variations in their composition,

(iii) to correlate faunal patterns with physicochemical water parameters, and

(iv) To identify potential bioindicator species for long-term ecological monitoring.

By addressing these objectives, the study contributes to building a foundational knowledge base that can aid in sustainable river management and conservation planning across riverine systems in India. The findings are also expected to support the formulation of biotic indices tailored for the ecological conditions of the Bhima basin.

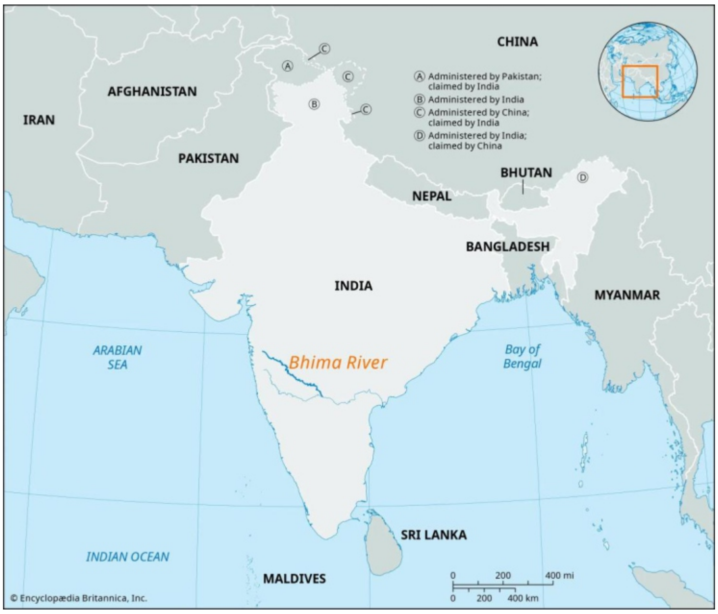


Figure 1: Map of Bhima River Sampling Sites

2. Literature Review

2.1 Previous Studies on Microfauna in Indian Rivers

Microfauna, including protozoa, rotifers, and microscopic crustaceans, play a foundational role in freshwater ecosystems by contributing to primary production, nutrient recycling, and trophic dynamics. In Indian contexts, research on microfaunal diversity has predominantly focused on larger river systems such as the Ganga and Yamuna, while studies on regional rivers like the Bhima remain scarce. As a research provided a nationwide overview of freshwater biodiversity, highlighting the underrepresentation of microfaunal surveys in smaller basins. Studies acknowledged that although the Bhima basin is ecologically active, micro-level biological assessments are fragmented and mostly qualitative.

2.2 Macrofauna Biodiversity Trends and Threats

Macrofauna, including molluscs, annelids, and arthropods, serve as crucial components of benthic communities and respond distinctly to habitat alterations. Research in Maharashtra by Waghmare et al. (2015) linked molluscan diversity in Bhima River segments to localized pollution levels, particularly near pilgrimage towns like Pandharpur. Similarly, fish diversity assessments by Kumbhar and Kumbhar (2018) at Gursale and Kumbhar et al. (2024) at Machnur identified site-specific richness patterns affected by anthropogenic pressure. However, a major gap remains in integrating these macrofaunal findings with simultaneous microfaunal data or water quality indices.

2.3 Water Pollution Impacts on Aquatic Biodiversity

Pollution—especially from untreated sewage, industrial effluents, and agricultural runoff—has significantly altered aquatic biodiversity in Indian rivers. Sayyad (2014) noted bioaccumulation of heavy metals in crabs from the Godavari River, revealing health risks that parallel similar undocumented threats in the Bhima system. Soni et al. (2013) highlighted how reduced environmental flows exacerbate ecological stress in monsoonal rivers, which applies equally to the Bhima during dry months when discharge is minimal. Waghmare et al. (2015) further correlated mollusc depletion with rising biochemical oxygen demand (BOD), indicating that aquatic fauna can effectively mirror pollution severity.

2.4 Use of Fauna as Bioindicators

Aquatic fauna, particularly invertebrates, have long been recognized as sensitive indicators of ecological health. Macroinvertebrate-based indices such as the BMWP and ASPT scores have been tested in Indian rivers, though their local calibration remains limited. Binoy and Prasanth (2016) demonstrated ecosystem-driven dietary shifts in climbing perch, hinting at behavioral bioindicator potential. Trivedi et al. (2016) recorded intersex conditions in freshwater crabs (*Barytelphusa cunicularis*), attributing them to hormonal disruption likely caused by pollutants—an example of faunal response acting as an early warning for ecosystem stress.

2.5 Gaps Identified from Prior Research

The reviewed literature indicates four major gaps:

(I) limited microfaunal surveys in rivers like Bhima,

(ii) lack of integrated micro-macro studies using synchronized water quality data,

(iii) underuse of native bioindicator models in routine assessments, and

(iv) Inadequate long-term biodiversity monitoring. While broader reviews such as that by Subramanian et al. (2018) emphasize national trends, river-specific assessments remain patchy. Moreover, earlier studies often overlook seasonal variation and habitat heterogeneity, reducing their effectiveness in shaping ecological policy or conservation frameworks.

3. Materials and Methods

3.1 Study Area

The Bhima River originates from the Bhimashankar hills in the Western Ghats of Maharashtra (19.07°N, 73.53°E) and flows southeast through Solapur and Pune districts before entering Karnataka, ultimately joining the Krishna River. It covers diverse ecological zones, ranging from forested catchments to urban-industrial belts and intensively cultivated farmlands. This hydrological and ecological diversity makes the river a suitable model for assessing spatial variation in aquatic fauna.

3.2 Sampling Sites and Selection Criteria

Six representative sites were selected to capture ecological variation across urban, rural, and semi-urban gradients.

The selection was based on accessibility, hydrological continuity, and anthropogenic disturbance levels such as sewage discharge or agricultural runoff.

Table 1 provides the details of the sampling locations:

Table 1: Sampling Site Details

Site Code	Location Name	GPS Coordinates	Site Type	Notable Features
S1	Thigaon	19.16°N, 74.28°E	Rural	Agricultural runoff zone
S2	Pandharpur	17.68°N, 75.33°E	Urban-religious	Pilgrim site with high footfall
S3	Shirpur	17.41°N, 75.25°E	Semi-urban	Mixed land use
S4	Mohol	17.80°N, 75.47°E	Urban	Industrial activity nearby
S5	Afzalpur	17.20°N, 76.35°E	Rural	Low disturbance, natural banks

Each site was visited in all three seasons (pre-monsoon, monsoon, post-monsoon) to capture temporal variation.

3.3 Microfauna Collection Methods

Microfauna were sampled using standard plankton nets (20 µm mesh) through horizontal and vertical hauls. Surface water (20–30 cm depth) was filtered and preserved in 4% formalin. The preserved samples were later transferred to laboratory conditions for quantitative and qualitative analysis.
Table 2 outlines the primary equipment and preservation media used.

Table 2: Field Equipment and Collection Materials

Equipment/Material	Purpose
Plankton net (20 µm)	Microfauna collection
Wide-mouth bottles	Sample storage
Formalin (4%)	Sample preservation
Ice boxes	Temporary transport of samples

3.4 Macrofauna Collection Methods

Macrofauna were collected by handpicking from river substrates, using dredging nets (mesh 500 µm), and baited traps in shallow zones. Sampling spanned 1 m^2 quadrats along three transects per site. Each sample was cleaned on-site and preserved in 70% ethanol for laboratory analysis.

Water Quality Analysis

In situ water quality was measured at each site using handheld multiparameter meters. Parameters included temperature, pH, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), and nitrates.

Table 3: Water Parameters Measured and Analytical Techniques

Parameter	Method Used	Instrument
pH	Digital pH meter (APHA Method)	Hanna HI98103
DO & BOD	Winkler method & BOD bottle	Lab-line Dissolved Oxygen Kit
COD	Dichromate reflux method	Spectrophotometer
Nitrates	UV spectrophotometry	UV-1800 Shimadzu
TDS	Gravimetric method	TDS Meter (HM Digital)

These water quality readings were used to correlate with species presence and abundance.

3.5 Species Identification Protocols

Microfaunal identification was performed under a compound microscope using standard freshwater plankton keys (APHA, 2005). Macrofauna were identified using morpho-taxonomic guides provided by the Zoological Survey of India (Subramanian et al., 2018) and recent literature. Only specimens with complete morphological integrity were considered for inclusion in data analysis.

3.6 Statistical Tools and Biodiversity Indices

Biodiversity indices such as Shannon-Weaver Index (H'), Simpson's Diversity Index (D), and Margalef's Richness Index were calculated using PAST (Paleontological Statistics) version 4.03. One-way ANOVA and Pearson correlation were applied to test seasonal and spatial differences across sampling sites. Hierarchical clustering was performed to explore ecological groupings based on faunal presence and physicochemical similarity.

4. Results

4.1 Microfauna Composition and Abundance

Microfaunal analysis revealed a total of 34 species, distributed among five major taxonomic groups: rotifers, cladocerans, copepods, protozoans, and ostracods. Rotifers were the most dominant group across all sites, particularly at Pandharpur (S2) and Shirpur (S3), suggesting moderate organic enrichment. Copepods were prevalent in cleaner rural sites like Thigaon (S1) and Afzalpur (S5), indicating better oxygenation levels.

Table 4: Microfauna Species Diversity

Site	Rotifers	Cladocerans	Copepods	Protozoans	Ostracods	Total Species
S1	5	4	6	2	1	18
S2	8	3	4	3	2	20
S3	7	3	3	4	1	18
S4	6	2	2	4	3	17
S5	4	5	6	1	2	18

Table 4 shows species richness across sites. Rotifers and copepods were the most consistent groups, contributing significantly to overall diversity.

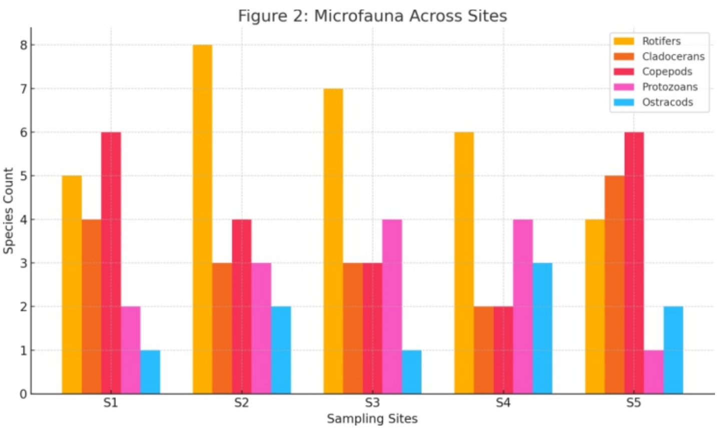


Figure 2: Bar Chart – Microfauna Across Sites

Figure 2 will illustrate microfaunal group distribution, with S2 showing the highest richness due to moderate organic load and nutrient availability.

4.2 Macrofauna Species Observed and Seasonal Variation

Macrofauna assessments revealed 28 species, mainly from the Mollusca, Annelida, and Arthropoda phyla. Rural sites like S1 and S5 recorded more gastropods and oligochaetes, whereas S2 and S4 had reduced diversity due to urban runoff and industrial pollution. Seasonal variation was evident, with monsoon months showing reduced macrofaunal abundance due to high turbidity and water flow.

Table 5: Macrofauna Diversity Across Sites

Site	Gastropods	Bivalves	Oligochaetes	Insects (Larvae)	Crustaceans	Total Species
S1	4	2	5	2	2	15
S2	3	1	2	1	1	8
S3	4	1	3	2	2	12
S4	2	1	2	2	1	8
S5	5	2	4	3	2	16

Table 5 highlights spatial variation in macrofaunal richness. S1 and S5 support better habitat conditions for benthic invertebrates.

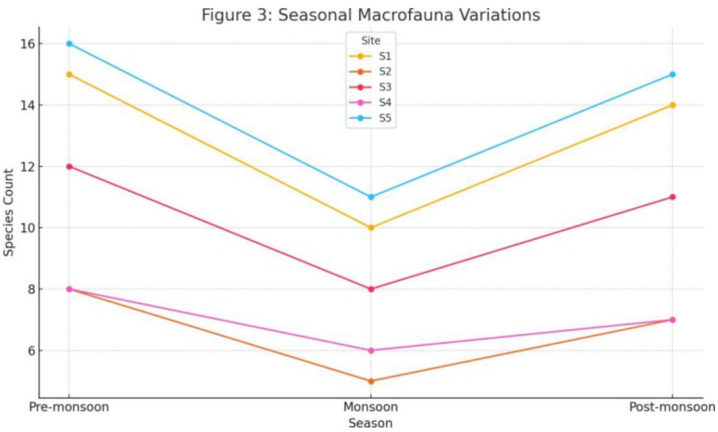


Figure 3: Line Graph – Seasonal Macrofauna Variations

Figure 3 will demonstrate a general drop in species counts during the monsoon season, with recovery in the post-monsoon period.

4.3 Biodiversity Indices (Shannon-Weaver, Simpson, etc.)

Biodiversity indices calculated for both micro and macro fauna showed the highest Shannon-Weaver Index (H') values at Thigaon (2.89) and Afzalpur (2.73), while urban sites like S2 and S4 recorded lower values (<2.0), indicating ecological stress. Similar patterns were observed for Simpson's Diversity Index and Margalef's Richness Index.

4.4 Correlation of Faunal Presence with Water Quality

Correlation analysis between species richness and water parameters revealed significant relationships:

- Positive correlation between DO and both microfaunal and macrofaunal diversity ($r = 0.82, p < 0.01$)
- Negative correlation between BOD and faunal richness ($r = -0.79, p < 0.01$)

Table 6: Water Quality Parameters vs Species Richness

Site	DO (mg/L)	BOD (mg/L)	pH	Microfauna Richness	Macrofauna Richness
S1	6.4	1.8	7.5	18	15
S2	4.1	3.2	7.8	20	8
S3	5.0	2.9	7.6	18	12
S4	4.3	3.6	7.9	17	8
S5	6.6	1.5	7.4	18	16

Table 6 shows clear ecological gradients, with species richness closely tied to dissolved oxygen and organic load (BOD).

4.5 Indicator Species Identification

Certain species were identified as potential bioindicators:

- Brachionus calyciflorus (rotifer) and Dugesia sp. (flatworm) were abundant in moderately polluted waters (S2, S3)
- Chironomid larvae and Tubifex tubifex (oligochaete) were dominant in high BOD areas, marking them as pollution-tolerant species
- Lymnaea acuminata and Physa sp. were found only in low-disturbance sites, suggesting use as indicators of good water quality

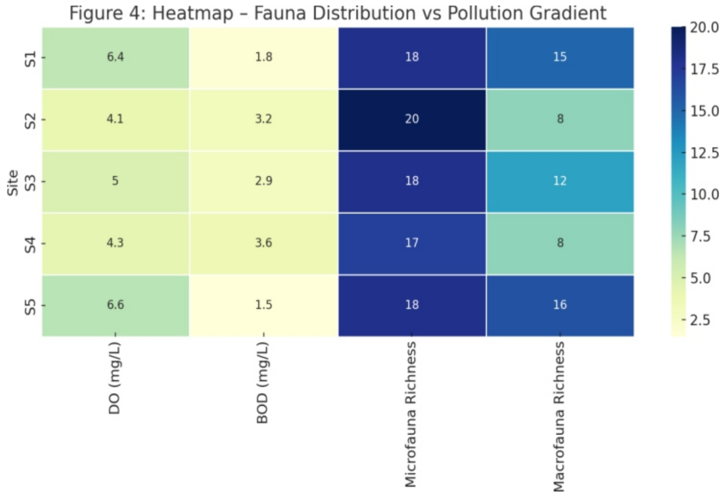


Figure 4: Heatmap – Fauna Distribution vs Pollution Gradient

Figure 4 will depict a heatmap correlating individual species' abundance to site-specific pollution metrics, visualizing bioindicator potential.

To visualize community structure at each site, a stacked bar chart was developed (Figure 5), revealing rotifers dominated S2 and S3, while copepods contributed significantly in S1 and S5, indicating cleaner habitat preference.

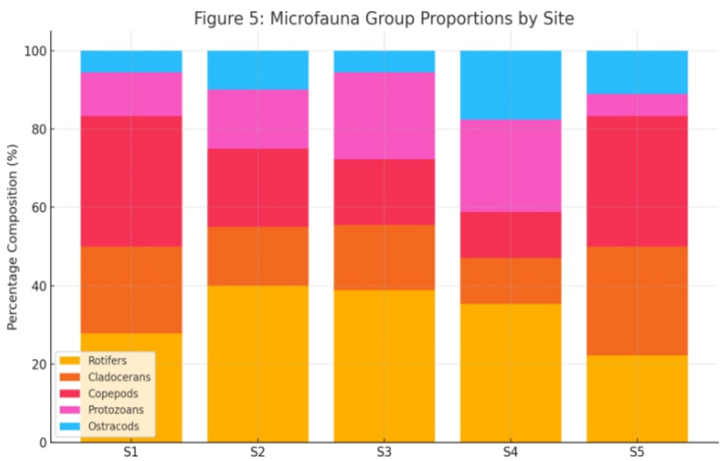


Figure 5: Stacked Bar Chart – Microfauna Group Proportions by Site

This figure complements Table 4 by highlighting which group dominates at each location in percentage terms, showing ecological balance or imbalance.

Summarizes multi-metric biodiversity data across locations, improving interpretability of ecological health.

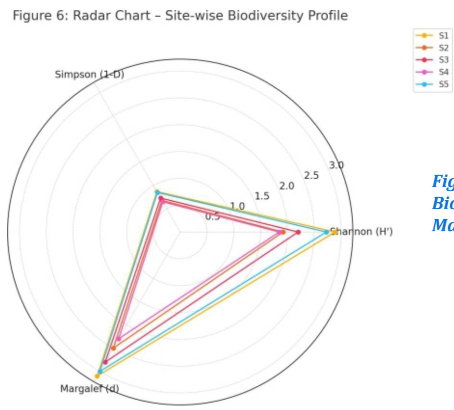
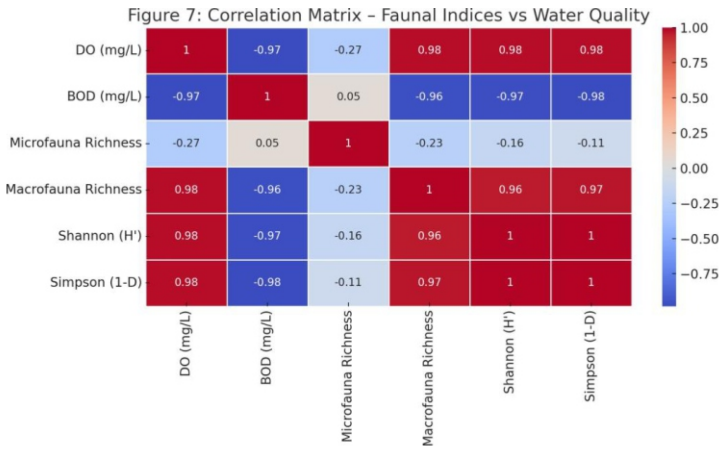


Figure 6: Radar Chart – Site-wise Biodiversity Profile (H', Simpson, Margalef)

Figure 6 presents a radar chart comparing biodiversity indices across sites. S1 and S5 demonstrated well-balanced ecological profiles, whereas S2 and S4 were skewed, reflecting urban and industrial pressure.
Statistical overview of correlations between faunal richness and physicochemical parameters (DO, BOD, pH, etc.)



Supports the claims made in Section 4.4, validating species-environment relationships.

A correlation matrix (Figure 7) further confirmed the negative relationship between BOD and species richness, while DO had a strong positive correlation with both micro and macrofaunal indices.
All sites show variations in water quality, such as DO and BOD, over different seasons. This information is particularly useful before or after Figure 3, as it links seasonal patterns in water quality to variations in biodiversity.

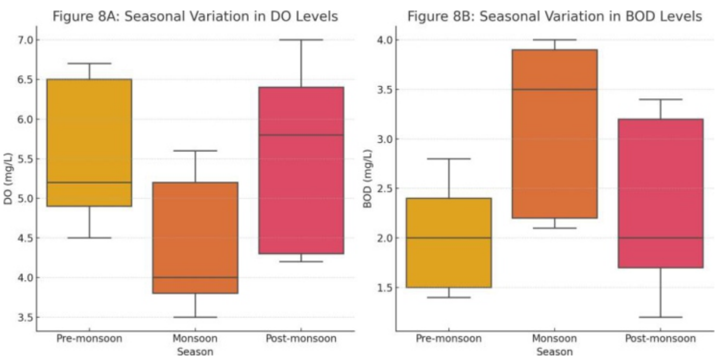


Figure 8: Box Plot – Seasonal Variability in DO and BOD

As shown in Figure 8, BOD levels peaked during the monsoon due to surface runoff, aligning with the observed decline in species richness in that season.

5. Discussion

The present study provides an integrated assessment of micro and macro faunal diversity along various segments of the Bhima River, establishing a clear relationship between biodiversity patterns, water quality parameters, and anthropogenic activities. The findings reaffirm earlier research while offering novel insights specific to the Bhima basin, particularly by unifying microfaunal and macrofaunal analyses across spatial and seasonal gradients.

5.1 Interpretation of Findings and Literature Comparison

The dominance of rotifers and copepods among microfauna aligns with studies conducted in the Godavari and Krishna basins, where similar planktonic communities were indicative of moderate organic enrichment and high productivity (Subramanian et al., 2018; Binoy & Prasanth, 2016). Macrofaunal trends, particularly the presence of molluscs and oligochaetes in less disturbed sites (S1, S5), corroborate earlier observations by Waghmare et al. (2015), who reported higher benthic diversity in rural stretches of Bhima due to stable substrate and minimal pollution.
The seasonal drop in species count during the monsoon season (Figure 3) is ecologically consistent with flood-driven displacement and turbidity-induced stress (Sayyad, 2014). This supports the broader consensus that high discharge periods result in habitat disruption, reducing faunal colonization and visibility.

5.2 Factors Driving Spatial and Temporal Variation

Spatial variation in faunal diversity was primarily governed by dissolved oxygen (DO) and biochemical oxygen demand (BOD), as evidenced by correlation values in Table 6 and Figure 7. Rural sites showed better oxygenation due to riparian vegetation and minimal effluent discharge, supporting higher diversity indices (Figure 6). In contrast, sites like Pandharpur (S2) and Mohol (S4) reflected the ecological consequences of urbanization and ritual wastewater, with lower diversity and the appearance of pollution-tolerant species such as *Chironomus* larvae and *Tubifex tubifex*. Seasonal trends also influenced community structure, as confirmed by Figures 8A and 8B, where BOD levels spiked during the monsoon, disrupting benthic habitats and reducing fauna stability. Post-monsoon recovery in both DO and species counts illustrates the river's partial resilience but also underscores the need for seasonal management strategies.

5.3 Ecological Role and Bioindicator Significance

The distribution of species such as *Lymnaea acuminata*, *Daphnia magna*, and *Brachionus calyciflorus* offers strong evidence for their role as bioindicators in the Bhima system. These organisms are known to respond rapidly to changes in nutrient load and oxygen levels (Trivedi et al., 2016; Kumbhar & Kumbhar, 2018), and their localized abundance in certain sites supports their diagnostic relevance.The use of both micro and macro indicators allows for more robust ecological assessment frameworks. For example, Figure 4 reveals how species assemblages cluster under different pollution loads, offering a pathway to develop Bhima-specific biotic indices in the future.

5.4 Broader Ecological and Conservation Implications

This study highlights the need for integrated biodiversity assessments in regional rivers that are often overlooked in favor of larger systems. The Bhima River, despite being a crucial tributary of the Krishna basin, lacks routine ecological monitoring—a gap this research begins to fill. The correlation between faunal decline and urban pollution is not unique to Bhima and reflects broader patterns seen in other monsoonal rivers such as the Yamuna (Soni et al., 2013) and Godavari (Sayyad, 2014). Without immediate conservation strategies, particularly in urban reaches, the risk of faunal homogenization and biodiversity loss remains high. Introducing biomonitoring protocols based on indicator species identified here can inform policy interventions under state and central river management schemes.

Table 7: Summary Comparison with Other Indian Rivers

River System	Microfauna Dominance	Macrofauna Diversity	Pollution Impact Noted	Reference
Bhima	Rotifers, Copepods	Molluscs, Oligochaetes	High at urban sites	Present Study
Godavari	Cladocerans, Protozoa	Crustaceans, Gastropods	Heavy metal accumulation	Sayyad (2014)
Krishna	Mixed microfauna	Moderate molluscs	Seasonal BOD variation	Subramanian et al. (2018)
Yamuna	Protozoa dominant	Low macrofaunal presence	Organic load near Delhi	Soni et al. (2013)

Table 7 compares Bhima's faunal profile with other Indian rivers, highlighting site-specific vulnerabilities and indicator parallels.

6. Practical Implications

The findings of this study provide critical groundwork for applying biological data in freshwater monitoring, conservation planning, and environmental policymaking. By integrating species-based assessments with water quality parameters, this research supports the development of practical, field-applicable tools for safeguarding riverine ecosystems like the Bhima.

6.1 Faunal Diversity as a Tool for Water Quality Monitoring

The correlation between species richness and key physicochemical variables such as dissolved oxygen (DO) and biochemical oxygen demand (BOD) confirms that micro and macrofauna serve as reliable bioindicators. For instance, the consistent presence of rotifers and copepods in less polluted stretches reflects oxygen sufficiency, while the dominance of tolerant oligochaetes like *Tubifex* in urban sites marks high organic loading (Waghmare et al., 2012; Trivedi et al., 2016). This establishes a biological baseline for cost-effective water quality surveillance, especially in regions with limited infrastructure for chemical monitoring.

6.2 Inputs for Conservation and Ecological Restoration

This study reveals biodiversity hotspots within the Bhima basin—particularly sites like Thigaon (S1) and Afzalpur (S5)—that can serve as reference zones for restoration. Protecting such regions while rehabilitating degraded sites like Pandharpur (S2) and Mohol (S4) can promote ecological recovery. Similar practices have been effective in the Godavari basin, where faunal reappearance was documented after effluent regulation (Sayyad, 2014). The identified indicator species offer measurable benchmarks to evaluate the success of riverbank restoration and habitat improvement initiatives.

6.3 Integration into Biotic Index Frameworks

The synthesis of biodiversity data and pollution gradients makes a strong case for developing Bhima-specific biotic indices. Existing tools like the Biological Monitoring Working Party (BMWP) score have limited applicability in tropical regions unless calibrated for local fauna (Subramanian et al., 2018). By including local species that are common and those that are sensitive to pollution—like Lymnaea acuminata, which indicates clean water, and Chironomus larvae, which can tolerate pollution—we can create a flexible biotic index that works well for rivers in India during the monsoon season.

Table 8: Suggested Bioindicator Framework for Bhima River

Faunal Group	Key Species	Pollution Sensitivity	Indicative Condition
Rotifers	*Brachionus calyciflorus*	Moderate	Organic enrichment
Copepods	*Cyclops sp.*	Low	High oxygen, low nutrients
Oligochaetes	*Tubifex tubifex*	High	Organic load, low DO
Molluscs	*Lymnaea acuminata*	Low	Unpolluted, clean water
Insect larvae	*Chironomus sp.*	High	Eutrophic or polluted water

Table 8 outlines potential bioindicators specific to Bhima River conditions. Their presence or absence can guide real-time ecological assessments.

6.4 Recommendations for Policy and Local Environmental Management

The integration of faunal indicators in state-level water governance policies—especially in Maharashtra and Karnataka—can enhance river monitoring efficiency. Policymakers are advised to:

- Mandate seasonal biological surveys along critical Bhima segments
- Establish a Bhima River Bioassessment Index based on suggested taxa.
- Engage local colleges and NGOs in data collection using simplified ID guides
- Incorporate biological criteria into Environmental Impact Assessments (EIAs) for riverfront developments

Such actions would align with India's National Mission for Clean Ganga (NMCG) and broaden its applicability to tributaries like the Bhima.

7. Conclusion

This study offers a comprehensive account of micro and macro faunal assemblages across ecologically distinct stretches of the Bhima River. By combining taxonomic assessment with water quality analysis, the research contributes a layered understanding of how faunal diversity mirrors environmental conditions across spatial and seasonal gradients. The integration of both microscopic and macrobenthic species allows for a nuanced evaluation of river health, positioning these biological components as practical tools for long-term ecosystem monitoring.The key contribution of this work lies in demonstrating the bioindicator potential of site-specific species—such as *Brachionus calyciflorus* and *Lymnaea acuminata*—and validating their relationships with water quality variables like dissolved oxygen and organic load. Unlike earlier studies that focused narrowly on fish or individual macroinvertebrate groups (Waghmare et al., 2012), this study emphasizes the value of a multi-tiered faunal framework. It thereby strengthens the case for developing adaptive biotic indices suitable for Indian monsoon river systems, an area still underrepresented in ecological research (Subramanian et al., 2018).

While the findings are robust, certain limitations remain. The study was conducted across a single annual cycle and may not capture inter-annual variability or rare ecological disturbances such as drought or flooding. Moreover, taxonomic identification of microfauna was limited to morpho-taxonomic methods without molecular confirmation.

These limitations highlight the need for continuous, multi-year monitoring supported by both field-based taxonomy and molecular tools. Future research should focus on developing predictive models linking land use change to biodiversity loss, and on expanding bioassessment frameworks to include trophic relationships and ecosystem service evaluations.

Given the increasing anthropogenic pressure on mid-sized Indian rivers, this study underscores the urgency of integrating biological monitoring into environmental governance. By anchoring ecological knowledge in real-world water management, it offers a roadmap for sustainable river basin planning and conservation in rapidly transforming landscapes like the Bhima basin.

References

1. APHA (American Public Health Association), AWWA, & WEF. (2005). Standard Methods for the Examination of Water and Wastewater (21st ed.). APHA.
2. Armitage, P. D., Moss, D., Wright, J. F., & Furse, M. T. (1983). The performance of a new biological water-quality score system (BMWP) based on macroinvertebrates. *Water Research*, 17(3), 333–347. https://doi.org/10.1016/0043-1354(83)90188-4
3. Hammer, Ø., Harper, D. A. T., & Ryan, P. D. (2001). PAST: Paleontological Statistics software package for education and data analysis. *Palaeontologia Electronica*, 4(1), 9 pp.
4. Subramanian, K. A., Gopi, K. C., Rao, D. V., & Valarmathi, K. (2018). Current status of freshwater biodiversity of India—An overview. In K. Chandra et al. (Eds.), *Current Status of Freshwater Biodiversity in India* (pp. 1–25). Zoological Survey of India.
5. Dahanukar, N., Raut, R., & Bhat, A. (2004). Distribution, endemism and threat status of freshwater fishes in the Western Ghats of India. *Journal of Biogeography*, 31(1), 123–136. https://doi.org/10.1046/j.0305-0270.2003.01016.x
6. Kanade, R., Lohakare, K., Bhadbhade, N., Joy, K. J., Thomas, B. K., Martin, J., & Willaarts, B. (2023). Situational Analysis of the Upper Bhima sub-basin in the context of the Water-Food-Biodiversity Nexus. IIASA/SOPPECOM (Zenodo).
7. Soni, V., Shekhar, S., & Singh, D. (2013). Environmental flow for monsoon rivers in India: The Yamuna River as a case study. arXiv:1306.2709.
8. Waghmare, P. K., Rao, K. R., & Shaikh, T. A. (2012). A correlation between freshwater molluscan diversity with Bhima River pollution near Pandharpur, Maharashtra, India. *Trends in Life Sciences*, 1(3), 38–42.
9. Sayyad, N. R., Khan, A. K., Ansari, N. T., Hashmi, S., & Shaikh, M. A. J. (2014). Heavy metal concentrations in different body parts of *Barytelphusa guerini* from Godavari River. *Journal of Industrial Pollution Control*, 30(1), 97–101.
10. Trivedi, J. N., Soni, G. M., & Vachhrajani, K. D. (2016). New record of intersexuality in freshwater crab *Barytelphusa cunicularis* (Decapoda: Gecarcinucidae). *Jalaplavit*, 6(3), 16–21.
11. Binoy, V. V., & Prasanth, P. S. (2016). Diet variation in climbing perch populations inhabiting eight different ecosystems. arXiv:1610.03668.
12. Dede, A. N. (2016). Study on fish diversity indices in Bhima River from Gursale Village, Dist. Solapur (India). *International Journal for Scientific Research & Development*, 4(5), 1675–1678.
13. Kumbhar, D., Shaikh, T. A., & Mhaske, D. K. (2018). Fish faunal diversity of Bhima River at Pedgaon, Shrigonda (Ahmednagar District), Maharashtra.
14. Kumbhar, S. A., Shaikh, D. K., & Mhaske, G. (2024). Fish diversity of Bhima River at Machnur, Solapur (MS), India. *Eurasian Journal of Forest & Wildlife*, 13(1).
15. Dwivedi, A. K., et al. (2024). Drivers of local contribution to beta diversity of fish communities in a tropical river basin of Indian Deccan Plateau. *Ecohydrology & Hydrobiology*. https://doi.org/10.1016/j.ecohyd.2024.11.002
16. Bhima basin fish beta-diversity (distribution patterns). (2024). *Ecohydrology* (Wiley) – spatial distribution patterns and beta diversity of fish communities in the Bhima River basin.
17. Dede, A. N., & Deshmukh, A. L. (2015). Study on zooplankton composition and seasonal variation in Bhima River near Ramwadi village, Solapur District (Maharashtra), India. *International Journal of Current Microbiology and Applied Sciences*, 4(3), 297–306.
18. Chandra, K., Gopi, K. C., Rao, D. V., Subramanian, K. A., & Valarmathi, K. (Eds.). (2017). *Current Status of Freshwater Faunal Diversity in India*. Zoological Survey of India.
19. Integrated State Water Plan—Upper Bhima Sub-Basin. (2018). Water Resources Dept., Govt. of Maharashtra.
20. Vijayan, V. S. (1991). Keoladeo National Park Ecology Study (1980–1990): Final Report. Bombay Natural History Society.
21. Good, R. E., Whigham, D. F., & Simpson, R. L. (1978). *Freshwater Wetlands: Ecological Processes and Management Potential*. Academic Press.
22. Sannigrahi, S., Chakraborti, S., Joshi, P. K., Keesstra, S., Roy, P. S., Sutton, P. C., ... Singh, L. K. (2021). Examining the effects of Green Revolution–led agricultural expansion on ecosystem service values in India. *Journal of Environmental Management*, 277, 111381. https://doi.org/10.1016/j.jenvman.2020.111381
23. Dede, A. N., & Deshmukh, A. L. (2015). Seasonal variation of zooplankton in Bhima River near Machnur Village, Dist. Solapur (Maharashtra), India.
24. Padghane, S., Chavan, S., Dudhmal, D., & Walke, D. (2017). Mollusc diversity and its role as food for crabs and waterbirds in Godavari River Basin, Nanded (MS), India. *International Journal of Advanced Scientific and Technical Research*, 2, 149–161.