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SPATIO-TEMPORAL CHANGES OF WATER QUALITY AND ZOOPLANKTON DYNAMICS OF THE SHIVNA RIVER AT MANDSAUR, INDIA

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ABSTRACT
Rivers are an important source of fresh water, but because of increasing human activity, it is challenging to examine their ecological health. This paper had studied the seasonal change in the water quality and zooplankton population in the river Shivna around Mandsaur in India to establish the influence of physical and chemical conditions of the water on the living organisms. A total of twelve parameters such as pH, temperature, dissolved oxygen, biological oxygen demand, electrical conductivity, total dissolved solids, hardness, alkalinity, nitrates and phosphates were analyzed and evaluated in the water samples of the various river sites. They were used to calculate the Water Quality Index (WQI). Two tailed Pearson correlation was used to perform the statistical test to establish the impact of water chemistry on plankton density. The results indicated that the values of number of water quality parameters were higher than the BIS/WHO standard limits. The living community is comprised of three major groups: Rotifera (49), Copepoda (33), and Cladocera (13). The values of the WQI differed greatly in different seasons with a range of 32.13 (good) in the monsoon to 166 (inappropriate) in the summer. This shows a critical issue of organic waste. The high density of planktons, high BOD (12.8 mg/L) and low dissolved oxygen (5.1 mg/L) were all significantly correlated, and it was concluded that sudden increase in rotifers also known as Rotifer Surge is one of the main indicators that the water is enriched with nutrients. The results indicate that zooplanktons are beneficial in semi-arid river systems to determine the health of the aquatic system. The study offers useful information for creating sustainable management plans to deal with urban waste and protect the river's natural habitat.

KEYWORDS: Shivna River, Zooplankton, Bioindicators, Eutrophication, Mandsaur.

INTRODUCTION
A wide variety of aquatic life and high-water quality are essential to river ecosystems. The most important parameters of river health are pH, temperature, dissolved oxygen, biological oxygen demand, electrical conductivity, hardness, alkalinity, total dissolved solids, total nitrogen, total phosphorus, and plankton density (Verma et al., 2025; Das, A., 2025). Lakes and rivers play a significant role in the ecosystem of the world since they link the land and the sea (Mitra and Reddy, 2015, 2016). Water has to be monitored by lakes and rivers in case of the influence of climate and environmental changes (Parida et al 2025, Pant et al 2025). These water bodies have significant domestic, commercial, and agricultural purposes, such as irrigation (Rana et al., 2026). Consequently, they play a crucial role in defending the world's chemical cycle and human life. 2026). Due to human activity, poor water quality is a common occurrence in most parts of the world. Although river water should be assessed especially, the Water Quality Index (WQI) and its lowest possible level are frequently used as a measure of water quality (Islam et al., 2025). Previous studies suggest that the bottom part of a river (Station S3/III) is generally the most impacted by agricultural and urban runoffs. Nevertheless, some scientists, such as Reddy (2025) and Mitra and Reddy (2016) speculate that these downstream sites can sometimes serve as havens or even productive

ecosystems of pollution-tolerant species due to the abundance of nutrients. The same simplification that has befallen the diatoms has befallen the zooplankton, which are the primary consumers, according to a recent study, which also shows that the rotifers (49 percent of the sample) have been affected. Pannales dominance is also consistent with long-term stress resulting in an increase in the Rotifera pollution-tolerant population (Mitra and Reddy 2016). Zooplankton on the other hand may be employed as useful bioindicators to monitor human influences.

One of the alterations, which occur when the water quality is degraded, is a decrease in the species diversity (Gołdziejewska et al., 2024). None of the published studies have so far used multivariate statistical analysis to assess both biological (zooplankton) and abiotic (water chemistry) parameters concurrently over the Shivna River at Mandsuar. The study can give an in-depth ecosystem perspective to make solid conclusions (Wander et al. 2026). The literature currently available in print disregards the idea of integrated multivariate ecological analysis instead of addressing each of these elements separately. Our work bridges this gap by mapping 12 months (June 2024 May 2025) water quality (pH, temperature, DO, BOD, COD, EC, TDS, hardness, alkalinity, nitrogen, chloride, sulfate, and phosphorus), calculating water quality indicators and finding environmental problems. The authorities will utilize this information to enhance health in rivers and help maintain the existence of sustainable ecosystems.

MATERIALS AND METHODS

***Description of Study Stations*: Study Area**. Mandsaur, a city in Madhya Pradesh, India was selected as a site of study and three particular locations along the river Shivna were selected. They were chosen due to the characteristics of the land, the sources of water, land utilization as well as the way in which people influence the environment. The places indicate the various environmental variants and anthropogenic effects with the river passing across Mandsaur.

Station 1 (Upstream): Station one is the first one that is found in the southwest. It can be used as an upstream reference point. It is located in a rural farming region before the river flows to a major municipality of Mandsaur. It is predominantly an area with natural vegetation and is low lying with proximity to farmlands.

Station 2 (Urban Center): This station is located in the central part of the city, close to the Shree Pashupatinath Temple. There is a high amount of human traffic, religious practices, and runoff of the city water in the area.

Station 3 (Downstream): This area is the final one which is situated in the northeast. It is also located below the city, and it is close to the College of Horticulture. It probably gets a blend of trash from various sources, both within the city and within the farms.

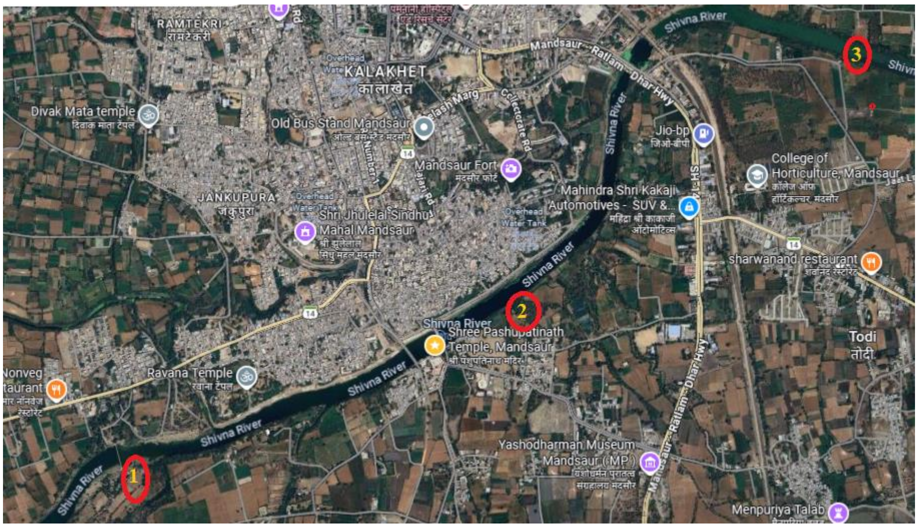

Fig. 1: Study location map of present investigation.

2.2. Fig. 2-5. Sampling stations and processing

Fig. 2: Study area. (a) SI- Upstream, (b) S2, Pashupatinath temple, (c) S3 (Downstream) (d) S3- Downstream) Horticulture college.

2.2.1. Water Quality Sampling and Experiments. The present paper sampled various parts of the Shivna river at three sites. Some of the physical and chemical properties that we analyzed included water pH, temperature, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, electrical conductivity, hardness, alkalinity, total dissolved solids, total nitrogen, total sulphates, and total phosphorus. A digital pH meter and a calibrated mercury thermometer were used to measure pH and temperature. A Hanna Instruments DiST series water analyzer was used to measure dissolved oxygen, electrical conductivity and total dissolved solids. The standard methods were used to test biochemical oxygen demand as per the American Public Health Association (APHA, 2012; Midya et al., 2022). Sulphate, nitrogen, and phosphorus were determined by means of portable Hanna instruments (HI83399). To be able to achieve accurate and reliable results, all of the instruments were checked and calibrated before use.

2.2.2. Zooplankton Collection and Counting: The zooplankton feeds on phytoplankton and has access to it. In order to examine the living communities at each of the sample locations, 25 liters of river water were filtered using a plankton net with a 52-micrometer mesh. Then the sample obtained was put in the 1-liter containers and treated with 5% formalin as soon as possible to store the sample to be analyzed in the laboratory in accordance with the approach outlined by Sharma (2017). With large samples of over 250ml, the water was left to settle in covered containers within a 48-hour period to ensure that all the particles settled to the bottom. Once this settling period was finished the excess water was then carefully removed as per the standard procedures to isolate the organisms in order to count them. Quantitative analysis was done by scooping three portions of 1 ml each of a sample and putting them in Sledgewick Rafter counting chamber. The study of each of them was performed using a Nikon E200 binocular microscope. The identification and enumeration of organisms of a specific species were carried out based on established scientific sources like Edmondson (1959), Battish (1992), Todd (1991), Ranga Reddy (1994), and Dussart and Defaye (2001).

2.5. Statistical Analysis The combination data on the environmental variables was subjected to descriptive statistics using Microsoft Excel to compute the mean, standard deviation, maximum and minimum values of the environmental variables. The paired-group (UPGMA) algorithm of cluster analysis of Bray Curtis distance was applied to the website www.alyoung.com/labs/biodiversity calculator. Correlation matrices were then used to determine relationships between water parameters and plankton density and multivariate analysis was done.

3. RESULT AND DISCUSSION

3.1. Analysis of physical and chemical indexes of water quality

Table 1 indicates the physical and chemical measurements of the Shivna River per year during the study. According to the measurements of the surface water at three locations S1, S2 and S3, the temperature is significantly different according to the seasons. The values are mostly above the guidelines by BIS and WHO. The analysis reveals large variations about areas and seasons. This is because the water quality tends to decrease as the river moves upstream to station S1 to the urban stations S2 and S3. The ecological pressure is the most significant in summer in all the stations. At Station 3, temperatures are approximately 33.6 0 C and dissolved oxygen is as low as 5.1mg/L. This is the definite seasonal loss in quality. There is also a drastic growth of organic pollution in summer; BOD grows to approximately 12.8 mg/L, four times less than in winter.

Table 1: Seasonal changes physical and chemical measurements of surface waters of the Shivna River.

Parameters	**Monsoon**			**Winter**			**Summer**			**BIS Acceptable Limit**
	S1	S2	S3	S1	S2	S3	S1	S2	S3	
Temp (0C)	19.5± 0.2	19.1± 0.3	19.4 ± 0.2	19.3 ± 0.2	18.6.7±0.3	18.8±0.2	29.1 ± 0.5	30.3 ± 0.4	33.6 ± 0.7	
EC (µmhos/cm)	885.92±9.84	894.1± 11.3	842.82±9.28	742.82±9.28	786.1±10.6	830.2± 11.1	880.6 ± 14.5	830.4 ± 15.6	930.7 ± 14.8	100–500
pH	7.3±0.14	7.4±0.17	7.14±0.19	6.5-8.5	7.6±0.3	8.1±0.4	8.5±0.8	8.6±0.5	8.4±0.4	6.5 – 8.5
Total Alkalinity (mg/l)	46.86 ±5.92	52.4±6.2	48.5±5.14	42.4±3.3	44.4±3.2	43.4±3.6	39.4±3.2	41.5±3.1	43.5±3.6	200
DO	7.28 ± 0.2	7.3 ± 0.5	7.5±0.24	7.2 ±0.32	7.9±0.30	7.4±0.4	5.5±0.4	5.8±0.6	5.1±0.3	6
TDS (mg/l)	205.4±4.1	212.3 ± 4.2	199.6±3.76	127.5±2.26	109.4±1.5	97.5± 2.1	113.3± 3.6	127.5±4.6	119.5±5.5	500
BOD (mg/L)	8.2.2 ± 0.4	9.2.5 ± 0.6	10.4 ± 0.5	4.5 ± 0.3	4.4 ± 0.6	5.7 ± 0.7	12.3±0.3	12.2 ± 0.3	12.8 ± 0.4	2-3 (WHO)
COD (mg/L)	26.4±3.2	26.5±2.1	26.4±2.14	36.5±3.1	37.5±3.8	36.9±4.2	34.4±4.1	33.2±3.8	35.5±3.7	10
TH (mg/l)	142.32±2.8	146.6 ± 3.3	154.8±4.8	144.1±4.2	146.8±5.2	151.4±5.3	152.3±5.6	157.9±5.7	164.1±5.3	200
Nitrate (NO3), mg/l	107.4±3.88	104.1 ± 3.8	103.4±3.06	87.4±2.8	83..2 ± 4.2	78.4±4.6	77.4±2.1	73.3 ± 3.3	74.4±4.2	45
Chloride (Cl) mg/l	27.4 ±0.88	21.3.1 ± 0.8	22.34± .7	17.3± 0.6	18.2± 0.5	18.8± 0.8	19.3± 0.7	18.9± 0.5	19.6± 0.4	250
Phosphate (ppm)	1.08±0.01	1.1 ± 0.01	1.07 ± 0.001	0.07-1.0	0.2 ± 0.01	0.6 ± 0.01	0.7 ± 0.01	0.8 ± 0.01	0.8 ± 0.01	0.1
Sulphate (SO_4) mg/l	133.4±3.64	138.1 ± 3.7	128.4 ±3.9	250	289.6 ± 4.8	292.8± 7.1				250

The river continues to be loaded with large quantities of nutrients, although the monsoon increases dilution, with the maximum nitrate concentration of 107.4 mg/L at Station 1. The comparison of the sites shows that Station 1 (upstream) is typically characterized by superior water, particularly during the monsoon and winter seasons, low electrical conductivity (EC), and phosphate. However, towards the urban regions of Station 2 (Pashupatinath Temple) and Station 3, the pollution increases four-fold on nearly all indicators. Station 3 is the most contaminated in COD, total hardness, and EC, with EC of 1630 -1 cm/summer. These findings indicate that seasonal conditions such as summer heat and monsoon rain influence timing, yet the release of pollutants at the stations 2 and 3 remains constant, which is fatally leading the river to the long-term eutrophication that is mostly above the safety threshold.

3.2. Zooplankton Community in Mandsaur River Shivna 2024-2025. The taxonomic analysis indicates that the community of the river is dominated by species that are tolerant to pollution. It is changing greatly in terms of population and diversity, which demonstrates the deteriorating water quality. The biological evaluation reveals a community primarily comprised of species that are able to withstand the pollution, and the involvement of massive fluctuations in the population and diversity that are in line with the deteriorating environmental conditions. The most popular were rotifer, approximately 49% of all known organisms throughout the year. During summer, their population increased significantly nearly twice during the winter, and was approximately 1,012 +- 245 organisms per liter. This difference was quite high (ANOVA $F = 89.4$, $p < 0.001$). The same was not true in other groups such as Cladocera and Ostracoda where seasonal stress was observed. Cladocera fell to a summer minimum of 112 38 (which was equivalent to 189 +-54 organisms/liter) out of a peak of about 189 +-54 organisms per liter of a monsoon. During the same period, Ostracoda reduced to the lowest level of about 12 / -8 organisms per liter.

Table 2: Dynamics of zooplankton in Shivna River.

Taxon	**Monsoon**	**Winter**	**Summer**	**Annual %**	**ANOVA F (p)**
Rotifera	342±98	489±112	1,012±245	49	89.4 (<0.001)
Copepoda	298±76	456±89	482±134	33	21.3 (<0.001)
Cladocera	189±54	167±43	112±38	13	14.7 (<0.01)
Ostracoda	28±12	41±15	12±8	3	8.2 (<0.05)
Protozoa	19±7	24±9	28±11	2	1.9 (0.15)
Total	876±167	1,177±238	1,646±392	-	24.3 (<0.001)

The change in the zooplankton community in the Shivna River varied significantly with increased ecological stress with summer. The diversity (Shannon index) during winter was high with a value of 1.8 + 0.2 but in summer it was 1.1 + 0.1 ($F = 32.6$, $p = 0.001$), which indicates strong pressure. Such loss of diversity was associated with a decrease in Water Quality Index (WQI) and there was a strong negative correlation (r 0.82, p 0.001). Evenness (Pielou index) reduced too, 0.72 to 0.48 and the count of species (Margalef richness) reduced as rotifers dominated. In general, the summer "Rotifer Surge is an immediate consequence of the high level of organic matter and low oxygen that already existed in the water of the river. 4. Discussion The analysis indicates that the Shivna River has entered the late phase of eutrophy, that is, physical and chemical properties of the water, as well as the biosphere, are closely interrelated in time and space. Water quality is the poorest in summer when the BOD (12.8 mg/L) is high, dissolved oxygen (5.1mg/L) is low, and WQI scores are unsuitable. This shows a massive disproportion in the metabolism of the river due to excess organic matter. These circumstances are a breaking point that transforms rivers into productive systems with a limited energy supply and stressed ones (He et al., 2023; Singh and Saxena, 2025). One of the most prominent conclusions is that changes in the water stress are accompanied by the changes in the zooplankton. Rotifers constitute 49 0 -percent of the population and increased rapidly in summer, the typical response to eutrophy. These low oxygen tolerant, fast reproducing species outsmart more delicate species, e.g., cladocerans and ostracods. It has also occurred with polluted tropical rivers (Dubey and Pathak, 2025; Manjunath et al., 2025), where a small number of robust species replace very many others. The rotifer surge does not only involve the species that are present, but it also alters the flow of the energy in the ecosystem. Most of the algal energy is usually passed to fish, commonly 7080 percent, by zooplankton. Rotifer domination is less effective than it is when rotifers form the dominant species since they are small, less fat, and reproduce rapidly. The disappearance of the cladocerans which are good food and which eat well, implies that the quality of the energy is lost, not its quantity. This has a direct impact on the fish population and ecosystem productivity, just as the fish farms where the type of zooplankton defines the larval survival (Ashaari et al., 2024). In the landscape perspective, instead of improving as water moves down, the water quality deteriorates as water flows upstream (S1) to the downstream (S3) due to various sources of pollution such as cities, religious sites and farms. There is long-term pollution of water in Downstream, which is the worst, highly conductive, hard, and nutrient. This is equivalent to the metacommunity concept that land use alters the characteristics of the zooplankton, as well as the entire ecosystem (Goździejewska et al., 2024). The system in the Shivna River is overstressed and thus the system is dominated by the stress-tolerant species. Seasons also matter. Hot weather, reduced oxygen, and increased rate of organic matter breakdown increase hypoxia and nutrient cycling in summer. This is beneficial to rotifers and reduces biodiversity, as evidenced by the reduction in Shannon diversity (1.8 to 1.1) and evenness. Essentially the same happens in bad conditions where rotifers have been observed to dominate and cladocerans identified to re-occur when conditions improve in both fish farms and natural waters (Sharpe et al., 2024). Thus, the River Shivna will be able to regenerate, particularly during monsoon seasons when the water level increases and purifies the pollutants. The negative relationships of WQI and zooplankton diversity (r = -0.82) prove that biological and physical indicators can help to see the picture of the health of the river better. WQI depicts the physical and chemical status of the water, whereas the zooplankton indices reflect the ecological effect. This includes recent suggestions to apply both types of indicators to determine the health of rivers (Islam et al., 2026). According to the previous researchers (Mitra and Reddy, 2015, 2016; Reddy, 2025), the Shivna River has shifted to sustained eutrophication over the past decade as compared to moderate pollution. The diatoms signals have been replaced by zooplankton signals, which exhibit worse trophic depletion. This typically occurs in low-flow and chronically nutrient polluted waters. In terms of the management, the study indicates that merely resolving the water quality is not enough. We have to consider the ecosystem organization and energy circulation. It is important to reduce nutrient pollution particularly the nitrates and phosphates in major cities such as Pashupatinath. Vitality of zooplankton (with recovery of cladocerans) is important in enhancing energy transfer and fish productivity. The timed activities during the monsoon will help in restoration.

In brief, the Shivna River displays how human stress causes the ecosystem to undergo physical and chemical changes that reduce its functionality and simplify it. In semi-arid tropical regions, the Water Quality Index and zooplankton data are reliable sources of evidence about the health of the river and help with sustainable management planning.

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