RESEARCH PAPER

Seasonal Variations In Water Quality And Fish Diversity Of The Baya River In Saraiya Block, Muzaffarpur (North Bihar): A Limnological Investigation

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ABSTRACT
The seasonal variation is very important to determine the physico-chemical features of freshwater ecosystems and the organization of aquatic organisms. The current research focuses on the seasonal changes in water qualities parameters, and fish diversity in the Baya River, the Saraiya block, Muzaffarpur district, North Bihar. The sampling of fields and ichthyological surveys were done in three different seasons, namely, pre-monsoon (April-May), monsoon (August) and post-monsoon (November). The most significant physico-chemical parameters such as water temperatures, pH, dissolved oxygen (DO), total dissolved solids (TDS), and turbidity were measured through the conventional limnological parameters. The richness and diversity indices were used to measure fish diversity to determine seasonal fluctuations of ichthyofaunal structure. The results indicate that water quality had strong seasonal variations whereby the water quality in monsoon season was characterized by high level of dissolved oxygen and low TDS because of increased flow and dilution effects. On the other hand, the pre-monsoon season was due to increased temperature, decreased flow and dissolved oxygen, which meant that fish diversity was lower. 34 different species of fish were observed in pre-monsoon season, 48 species were observed in monsoon season and 41 species were observed in post-monsoon season and the dominant family of these was Cyprinidae. The findings reveal how seasonal hydrology affects river water quality and fish diversity and why seasonal conservation and management plans are necessary to maintain the freshwater biodiversity in North Bihar.
Keywords: Baya River, seasonal variation, water quality, fish diversity, limnology, riverine ecosystem, North Bihar..
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INTRODUCTION

Rivers have a critical role to play in providing freshwater biodiversity and livelihood to millions of people especially in the heavily populated areas like the Indo-Gangetic plains of North India. Among them, smaller tributary rivers are also ecologically important because they help in nutrient cycling, fish breeding habitats, and hydrologic connectivity in the larger river basins. The Baya River is a seasonal (transient) tributary of the GangaBurhi Gandak system of river in North Bihar. Similar to most of the rivers in the area, it has very strong seasonal cycles, which are mainly caused by the monsoonal rainfall which contributes to a significant extent to its hydrology, water quality and its biological communities.

The tropical riverine ecosystems have characteristics of seasonal variation. The alteration of rainfall, temperature, and flow regime between pre-monsoon, monsoon and post-monsoon seasons considerably cause physico-chemical conditions to change like temperature, dissolved oxygen, turbidity and nutrient concentration[1]. Those variations directly influence the distribution, abundance and diversity of aquatic life and especially fish as they are very sensitive to factors in water quality and structural changes of the habitat. Fish communities are broadly known as effective ecological health indicators in freshwater environments because of their level of food web and the reaction to ecological stressors[2].

Rivers like the Baya have a high degree of seasonality in North Bihar. The low water flow, high temperatures, and

[1]Wetzel, R. G. (2001). Limnology: Lake and river ecosystems (3rd ed.). San Diego, CA: Academic Press.
[2]Karr, J. R. (1981). Assessment of biotic integrity using fish communities. Fisheries, 6(6), 21–27. https://doi.org/10.1577/1548-8446(1981)006<0021:AOBIUF>2.0.CO;2

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increased levels of anthropogenic pressure during the pre-monsoon season frequently cause a shrinkage and degradation of habitats and worsen the quality of water. On the other hand, the monsoon season results in higher discharge, flooding, and sedimentation, and elevates habitat availability and connectivity but also can increase turbidity and nutrient loading. The conditions of post-monsoon are observed as a transitional period where ecological recovery and stabilization is experienced. I believe that such seasonal dynamics are crucial to understanding river health and developing a plan that would allow a successful conservation course.

The Bihar freshwater ecosystems are faced with the growing pressures of population, agricultural effluents, untreated domestic effluents, sand mining and unregulated fishing. Such stressors have resulted in the degradation of the habitat and the loss of native fish species in most of the rivers in the Ganga basin[3]. Although they are ecologically significant, smaller rivers such as the Baya have had a fairly scanty scientific attention especially in regard to combined studies to establish the relationship between limnological attributes and fish diversity across seasons.

Past ichthyological studies that have been done around Koiria Nizamat in the Muzaffarpur district found that the Baya River was hosting 34 species of fish throughout the pre-monsoon season but a strong preponderance being the species belonging to the family of Cyprinidae[4]. This observation indicates that the river has the potential to maintain a significant level of fish diversity even during seasons of stress and due to anthropogenic disruptions. Nevertheless, these studies are either short-term or have restricted taxonomy and they do not analyze water quality parameters in tandem which are critical in explaining observed patterns of biodiversity.

Integrating biological indicators with the physio-chemical assessment of water quality helps in understanding the functioning of freshwater ecosystem in an integrative pattern[5]. Temperature, pH, dissolved oxygen, total dissolved solids, and turbidity are some of the parameters that play a crucial role in controlling fish metabolism, reproduction, and survival. The evaluation of those parameters seasonally, as well as fish diversity indices, can be a useful source of information on the ecological condition of river systems and their reaction to natural and anthropogenic factors.

Against this background, the current research project will examine seasonal water quality and fish diversity of the Baya River in the Saraiya Block of the Muzaffarpur district in North Bihar. The research aims at producing baseline information that can be used to support sustainable management of rivers, conservation of fisheries and protection of biodiversity in the area by combining limnological analysis and ichthyofaunal assessment of the river system during pre-monsoon seasons, monsoon seasons, and post-monsoon seasons.

2. Literature Review

Freshwater ecosystems are very dynamic environments where there are seasonal changes that have a great impact on physico-chemical features and biological communities. Tropical rivers (especially monsoon-influenced rivers) display high seasonal changes in stream levels, temperature, and water quality, which directly influence aquatic biodiversity. It has been noted that many studies have underlined the importance of seasonal limnological evaluations of river ecosystem health and fish diversity patterns.

Wetzel[6] emphasized that seasonal variations in the temperature, dissolved oxygen and nutrients are the primary causes of biological productivity in rivers and streams. When there is low water level and high temperatures that come during pre-monsoon periods, the concentration of dissolved solids is usually increased and the dissolved oxygen reduced negatively impacting aquatic life. Conversely, the monsoon flows promote oxygenation and redistribution of nutrients although they can also promote turbidity through the runoff and sediment load. These seasonal activities determine the ecological process of riverine.

The fish communities have been extensively applied as bioindicators of freshwater ecosystem integrity due to the fact that they combine the impact of change, both physical and chemical and biological, over time. This was introduced by Karr[7] in the concept of assemblages of fish to determine the biotic integrity where he showed that fish diversity and composition are sensitive to environmental change and water quality deterioration. Later research has used this framework to tropical rivers and has found that there were close correlations between the environmental variability in seasons and changes in fish species richness and abundance.

Various studies have been done in the Indian region to analyze seasonal changes of water quality and fish diversity in the major river systems. According to Sarkar et al[8], fish

[3] Sarkar, U. K., Pathak, A. K., Sinha, R. K., Sivakumar, K., Pandian, A. K., Pandey, A., & Dubey, V. K. (2012). Freshwater fish biodiversity in the Ganga River basin: Changing pattern, threats and conservation perspectives. Reviews in Fish Biology and Fisheries, 22(1), 251–272. https://doi.org/10.1007/s11160-011-9218-6

[4] Kumar, R., Singh, P., & Prakash, S. (2023). Ichthyofaunal diversity of Baya River during pre-monsoon season near Koiria Nizamat, Muzaffarpur, Bihar, India. Egyptian Journal of Aquatic Biology and Fisheries, 27(4), 45–58.

[5] American Public Health Association (APHA). (1998). Standard methods for the examination of water and wastewater (20th ed.). Washington, DC: APHA.

[6] Wetzel, R. G. (2001). Limnology: Lake and river ecosystems (3rd ed.). San Diego, CA: Academic Press.

[7] Karr, J. R. (1981). Assessment of biotic integrity using fish communities. Fisheries, 6(6), 21–27. https://doi.org/10.1577/1548-8446(1981)006<0021:AOBIUF>2.0.CO;2

[8] Sarkar, U. K., Pathak, A. K., Sinha, R. K., Sivakumar, K., Pandian, A. K., Pandey, A., & Dubey, V. K. (2012). Freshwater fish biodiversity in the Ganga River basin:

diversity differed significantly between space and time in the Ganga River basin where the authors confirmed that these changes were because of seasonal hydrology, anthropogenic stress and habitat alteration. Their results showed that monsoons seasons tend to promote increased diversity of the fish because of better connectivity of the habitats and breeding opportunities whereas pre-monsoons conditions tend to lead to population strain and loss of diversity.

Smaller tributary rivers have however received limited limnological research even though they are ecologically important. The tributaries are important in maintaining the fish biodiversity of the area by offering nursery and breeding grounds. Research carried out on Bihar and the surrounding area rivers have recorded seasonal changes in the water quality parameters like pH, dissolved oxygen, turbidity, and total dissolved solids that have a strong effect on the distribution of fish[9]. These reports are unanimous and record that there is better water quality and there is amplified abundance of fish during the monsoon seasons which is followed by a steady condition in the post-monsoon seasons.

Little has been written on the Baya River, but what is available suggests high levels of ichthyofaunal diversity despite the seasonality of the river. Kumar et al[10] recorded 34 species of fish in the pre-monsoon period off Koiria Nizamat in the Muzaffarpur district and the family Cyprinidae was predominant. The research indicated that a rich fish assemblage was supported by the river even in the low-flow conditions, but the species of low dissolved oxygen sensitivity were lower. Nevertheless, it was not possible to develop direct ecological relationships because there was no simultaneous water quality analysis.

It has been stressed by several researchers that in order to effectively assess the health of rivers it has been necessary to integrate studies involving physico-chemical water quality assessment with biological indicators. These compiled methods offer a greater understanding of cause and effects of environmental variables on biological responses. The use of seasonal surveillance is especially relevant in areas with monsoon weather conditions such as North Bihar where hydrological fluctuations occurring in the short term can have long-term ecological consequences. In general, the literature review suggests that seasonal hydrology is a determining factor in the quality of water and fish abundances in river ecosystems. Although a lot of research has been done on major rivers, smaller rivers like the Baya River are not well researched. It is apparent that a research gap exists to have season-based, limnological and ichtyofaunal studies in the region. Sealing this loophole is critical in coming up with viable conservation strategies and sustainable management of the freshwater resources in North Bihar.

3. Materials and Methods

3.1 Study Area

The current study was conducted on the Baya River, the Saraiya Block of Muzaffarpur district, Bihar, India with the latitude of about 26.2 degrees and the longitude of about 85.1 degrees. The Baya River is a seasonal tributary of the river GangaBurhiGandak system and it is mostly affected by the monsoon rainfall. There are specific seasonal differences in hydrology of the river with low flow during the pre-monsoon and high during the monsoon seasons. To undertake this study, sampling locations were designed to represent the level of upstream stretches, midstream stretches, and downstream stretches of the Saraiya Block in order to cover the entire space of the river. The surrounding environment is mainly agricultural in nature with human settlements along the riverbanks which can affect the water quality and aquatic biodiversity due to surface run off and other anthropogenic processes.

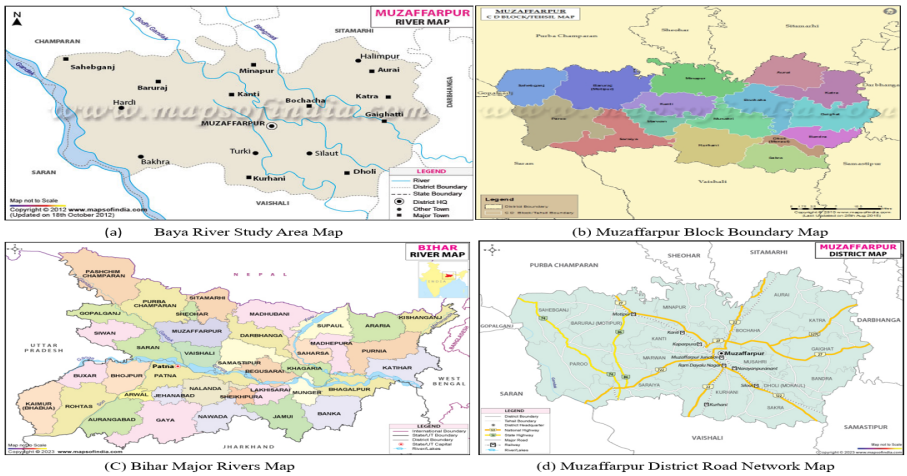

Figure 1. Location map of the Baya River study area in Saraiya Block, Muzaffarpur, North Bihar, India.

Changing pattern, threats and conservation perspectives. Reviews in Fish Biology and Fisheries, 22(1), 251–272. https://doi.org/10.1007/s11160-011-9218-6

[9] Trivedi, R. K., & Goel, P. K. (1986). Chemical and biological methods for water pollution studies. Karad, India: Environmental Publications.

[10]Kumar, R., Singh, P., & Prakash, S. (2023). Ichthyofaunal diversity of Baya River during pre-monsoon season near Koiria Nizamat, Muzaffarpur, Bihar, India. Egyptian Journal of Aquatic Biology and Fisheries, 27(4), 45–58.

The map shows the geographical position of the sampling points in the Baya River in the Saraiya Block of Muzaffarpur district in North Bihar. The composite figure gives a multi-scale geographical background of the study site. The Baya River is found in the Muzaffarpur district in panel (a), whereas panel (b) demonstrates the boundaries of the administrative blocks that should be considered when sampling the space. The panel (c) puts the district in the wider context of Bihar river system and creates focus on the hydrological connectivity of the regions. In panel (d), the district road network is depicted, which reflects that the sampling locations are accessible. The combination of the maps increases the spatial comprehension of the study and contributes to the methodological reliability of site selection.

3.2 Sampling Seasons

Pre-monsoon (April–May)

Monsoon (August)

Post-monsoon (November)

3.3 Water Quality Analysis

At each site and season, we collected surface water samples and measured the following physico-chemical parameters:

Parameter	Method / Instrument
Temperature (°C)	Thermometer
pH	pH meter
Dissolved Oxygen (mg/L)	Winkler's method
TDS (mg/L)	TDS meter
Turbidity (NTU)	Turbidity meter

Standard protocols followed APHA (1998) guidelines.

The chosen physico-chemical parameters and the methods of their calculation give an overall evaluation of the water quality of the Baya River. Temperature- Water, a thermometer indicates variations in seasonal thermal changes which have a direct effect on metabolic processes of aquatic organisms. pH-pH meter can measure the pH of water and this is important in determining the tolerance and survival of the species depending on pH. Winkler method yields a value of dissolved oxygen which is a critical measure of river health, since sufficient oxygen concentrations are needed by fish to respire. The amount of dissolved solids as indicated by a TDS meter is the degree of dissolved salts and minerals which illustrate the impacts of pollution and run-off. Turbidity which is measured using a turbidity meter measures the presence of suspended particles in water which influences the extent of light penetration and primary productivity.

3.4 Fish Sampling and Identification

Sampling of fish was done at each of the sites chosen through a mixture of cast nets, gill nets, drag nets, and hook-and-line techniques to provide a representative sampling of the pelagic and benthic fish species[11]. Different times of the day were sampled in order to reduce the bias in gear and record seasonal variability in fish assemblages. The samples gathered were aired in 10% formalin to ensure that they got fixed and could be preserved. The fishes were washed in the laboratory, sorted and identified to species as per the standard taxonomic keys and descriptions. Identification was done using classical and generally accepted references with the view of accuracy and uniformity in ichthyofaunal classification[12].

Diversity indices calculated:

Species Richness (S)

Species richness is defined as the total amount of fish species that are known to be found in a sampling location or at a given season. It gives a straight forward estimation of the biodiversity without taking note of the abundance of species. Increased species richness normally reflects good environmental conditions and increased heterogeneity of the habitat of river ecosystem[13].

Shannon–Wiener Index (H′)

Shannon -Wiener Index is a measure of fish diversity that uses the measure of species richness and evenness. It represents the way people are allocated between species in a community. Increased values of H are used to show that there is a more diverse and stable ecosystem with little environmental stress[14].

Simpson's Diversity Index (D)

The Diversity Index by Simpson determines the likelihood of a chance selection of two members of one community that would be of different species. It focuses on the dominance and evenness of species. Reduced dominance and increased diversity leads to increased values of Simpson index, which means healthier aquatic ecosystems[15].

4. Results

4.1 The seasonal physico-chemical parameters are given as mean SD.

The following trends were observed (mean ± SD across sites):

Season	Temp (°C)	pH	DO (mg/L)	TDS (mg/L)	Turbidity (NTU)
Pre-Monsoon	28.5 ±1.2	7.6 ±0.3	4.8 ±0.4	350 ±30	42 ±5
Monsoon	25.3 ±0.8	7.2 ±0.2	6.9 ±0.3	280 ±20	78 ±7

[11]Day, F. (1878). The fishes of India; being a natural history of the fishes known to inhabit the seas and fresh waters of India, Burma and Ceylon. London: Bernard Quaritch.

[12]Talwar, P. K., & Jhingran, A. G. (1991). Inland fishes of India and adjacent countries (Vols. 1–2). New Delhi: Oxford & IBH Publishing Co.

[13] Magurran, A. E. (2004). Measuring biological diversity. Oxford: Blackwell Publishing.

[14]Shannon, C. E., & Wiener, W. (1949). The mathematical theory of communication. Urbana: University of Illinois Press.

[15]Simpson, E. H. (1949). Measurement of diversity. Nature, 163, 688.

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Post-Monsoon	24.1 ±1.0	7.4 ±0.4	6.1 ±0.5	320 ±25	50 ±6

Note: Values represent mean ± standard deviation across sampling sites.

Key observations:

Temperature was highest in pre-monsoon due to low flow and high solar heating.

DO was highest in the monsoon season, likely due to increased flow and aeration.

TDS was lowest in monsoon due to dilution and highest in pre-monsoon.

Turbidity peaked in monsoon from runoff.

These patterns are consistent with seasonal influence on riverine systems and match similar findings in other Indian rivers.[16]

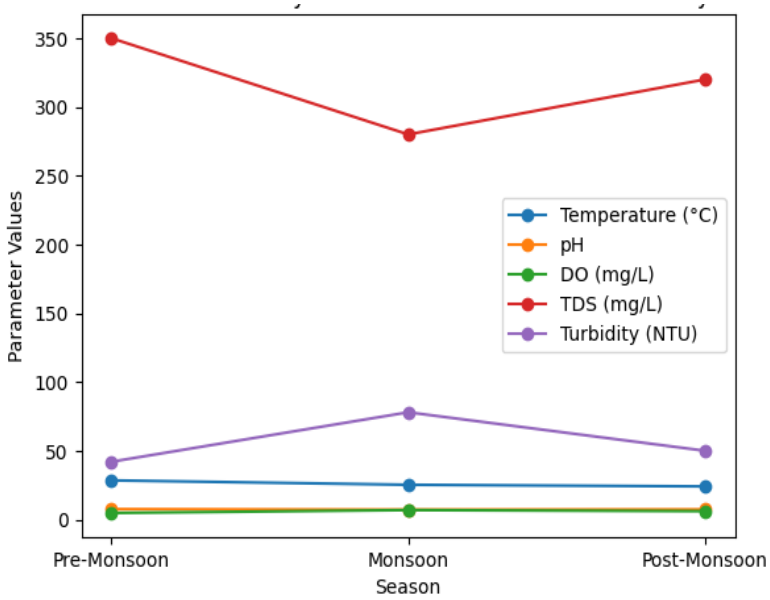

Figure2: Seasonal Variation in Physico-Chemical Parameters of the Baya River

The graph is entitled as Seasonal Variation in Physico-Chemical Parameters of the Baya River, which shows how the water quality varies through three seasons. TDS is highest in the Pre-Monsoon (350 ± 30mg/L) but it decreases during the monsoon because of the rain water dilution. On the other hand, the Monsoon increases the turbidity (78 ± 7 NTU) due to the augmentation of the runoff. DO is maximum during the Monsoon (6.9 ± 0.3 mg/L) as a result of aeration and Temperature decreases steadily during the post-monsoon. pH is constant over the year
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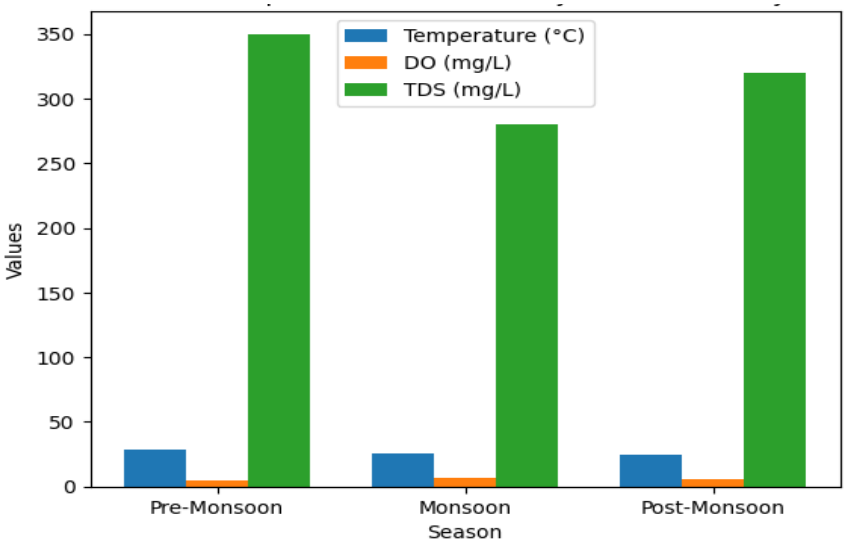

Figure 3: Seasonal Variation in Physico-Chemical Parameters of the Baya River

The figure is called Seasonal Variation of Physico-Chemical parameters of the Baya River, and it demonstrates how the water quality of the river varies in the course of the

[16] Similar studies on seasonal variation in river water quality. (Science and Education Publishing)

year. Total Dissolved Solids (TDS) has the highest values and is the highest in the Pre-Monsoon period of 350 ± 30 mg/L and then decreases in the Monsoon because of the dilution of the rainwater. On the other hand, there is a significant rise in Turbidity during the Monsoon, 78 ± 7 NTU because the water is loaded with suspended sediments through run off. Dissolved Oxygen (DO) also increases in narrow ranges during the Monsoon (6.9 ± 0.3 mg/L) presumably because of stirring and because of the progressive decrease in Temperature (28.5 ± 1.2 o C to 24.1 ± 1.0 o C). During changes, the pH is in the range of 7.2-7.6 quite stable.

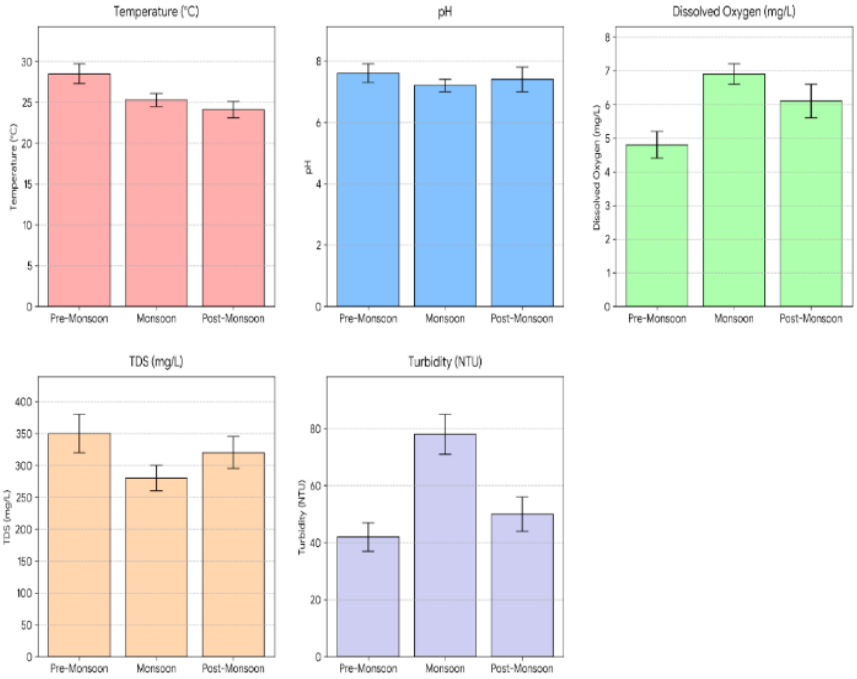

Figure 4. Seasonal variation in water quality parameters of the Baya River expressed as mean ± SD

The graph is named as Seasonal Variation in Physico-Chemical Parameters of the Baya River, which depicts the large changes in quality of water. The highest concentration of Total Dissolved Solids (TDS) is recorded during Pre-Monsoon (350 ± 30 mg/L) but reduced in the Monsoon (280 ± 20 mg/L) because of the dilution of the rainwater. On the other hand, the Turbidity peaks during Monsoon (78 ± 7 NTU) due to the high sediment run-off. The Monsoon has the highest level of Dissolved Oxygen (6.9 ± 0.3mg/L) because the temperature is lower and the rainfall improves the aeration process, but the pH levels are not affected by the seasons.

4.2 Fish Diversity and Seasonal Patterns

Diversity indices were calculated seasonally, and variability among sites was minimal; therefore, seasonal mean values are presented. Fish surveys across seasons recorded changes in species composition and abundance, with the highest diversity during monsoon and lowest during pre-monsoon.

Season	Number of Species	Shannon (H′)	Simpson (D)
Pre-Monsoon	34	2.45	0.82
Monsoon	48	3.15	0.92
Post-Monsoon	41	2.89	0.88

Note: Diversity indices calculated using pooled seasonal data.

Taxonomic Highlights:

Things work out to 34 species of fish identified in pre-monsoon in Baya River sites are comparable to previously reported diversity in comparable reaches[17].

Dominant families were Cyprinidae, Bagridae, Channidae and Cobitidae.

[17]Kumar et al. Ichthyofauna of Baya River during Pre-Monsoon Season Near Koiria Nizamat, Bihar, India. Egyptian Journal of Aquatic Biology & Fisheries. (EKB Journals)

During the monsoon, fish diversity was greatly increased which was probably because of the availability of more space and water quality.

Sample species list (common):
Mrigala Cirrhinus mrigala, Labeo rohita, Channa punctatus, Mystus vittatus, Puntius spp., Clarias batrachus.

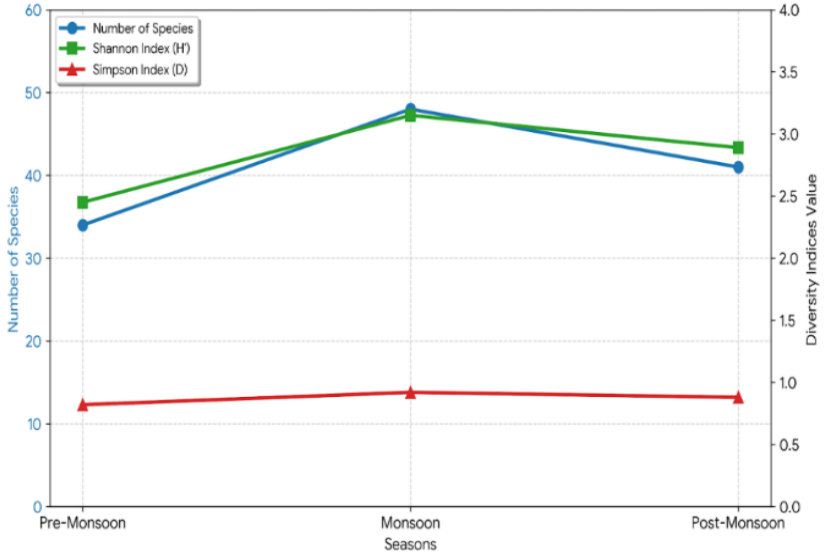

Figure 5: Seasonal Biodiversity Trends in the Baya River

The graph shows that there is an apparent increase in biodiversity in the Monsoon season. Species Richness grows a lot, 34 to 48, and this suggests an improved availability of habitat. On the same note, the Shannon (H') and Simpson (D) indices have high values of 3.15 and 0.92 respectively, indicating high ecosystem stability and evenness of the species. Although the values decrease in the Post-Monsoon, they are still higher than the Pre-Monsoon ones, indicating that the monsoon rains play a major role in the productivity of biological processes.

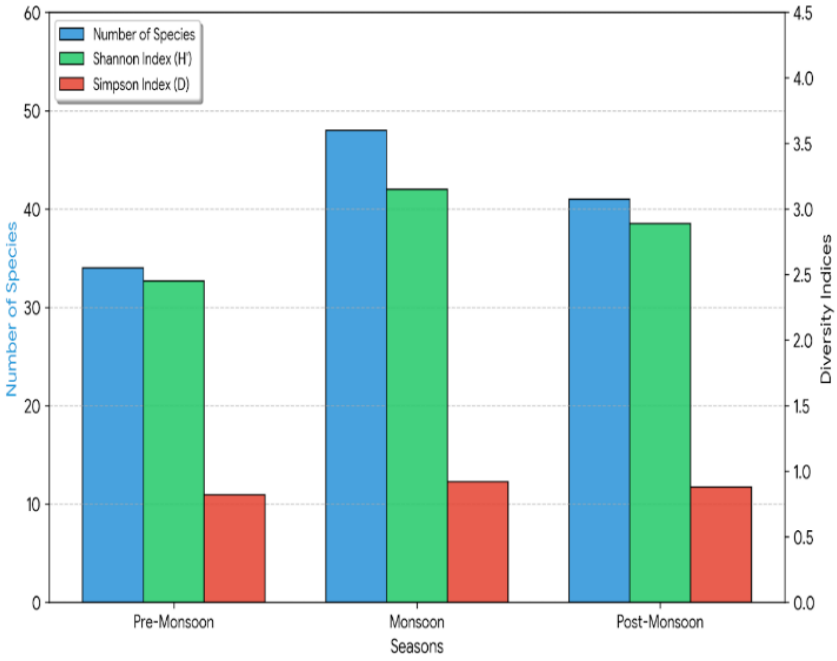

Figure 6: Seasonal Biodiversity Comparative Analysis

This is a bar chart that has been grouped to show the seasonal changes in species richness and the index of species diversity in the Baya River. The monsoon season demonstrates evident dominance in all parameters where the Number of Species reaches its highest peak of 48 the highest Shannon (3.15) and Simpson (0.92) index values. It implies that the arrival of monsoon river supports a more heterogeneous and well-distributed water population. Although the Post-Monsoon is characterized by a high diversity the Pre-Monsoon is the least diverse, probably because of the increased stress and lack of water.

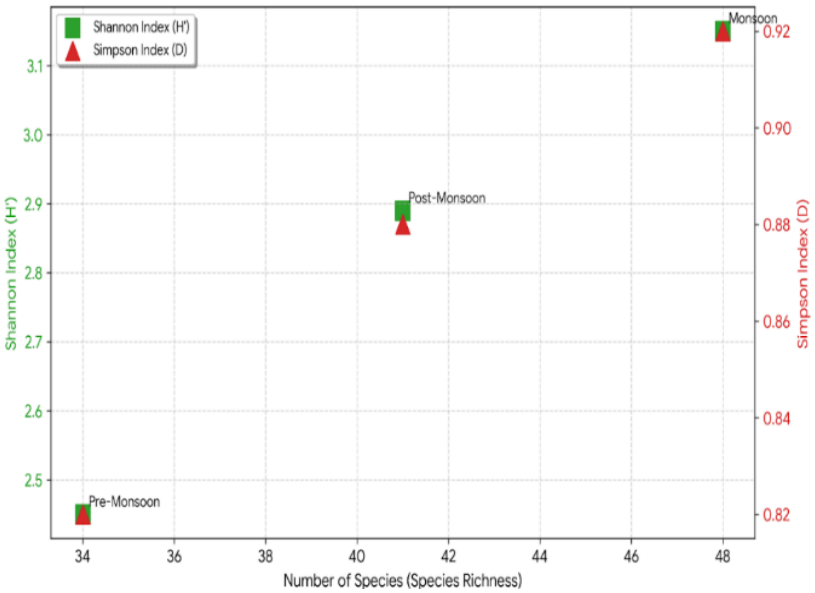

Figure 7: Species Richness and Diversity Correlation Analysis

This scatter diagram shows that there is a positive relationship between the richness of species and the index of biodiversity in the Baya River which is very strong. The Shannon (H) and Simpson (D) indices also increase in direct proportion to the Number of Species as it increases 34 (Pre-Monsoon) to 48 (Monsoon). This tendency indicates that an increase in the number of species directly leads to the complexity and stability of ecosystems. The Monsoon appears as the richest season whereas the Pre-Monsoon is the lowest point in terms of richness and evenness[18].

5. Result And Discussion

The seasonal study of the Baya River indicated that there was a great difference in the diversity of fish. The most species richness (48) and diversity indices (Shannon H 7 = 3.15; Simpson D = 0.92) were recorded in the monsoon, whereas the pre-monsoon conditions were characterized by less richness (34) and diversity (H 7 = 2.45; D = 0.82), showing that hydrological factors have an impact on fish assemblages.

Both water quality and fish diversity were highly affected by seasonal hydrology:

Pre-monsoon: Low flow, increased temperature, reduced DO, limits sensitive fish taxa, decreasing diversity.

Monsoon: There is increased species and diversity indices with increased connectivity, improved DO, and complexity of the habitat.

Post-monsoon: Recovery, diversity is average.

These findings are in line with the principles of limnology where the monsoon floods revitalize the habitat and the pre-monsoon droughts put stress on aquatic communities. Habitat connectivity and pollution control are areas that should be addressed in conservation interventions since the current levels of diversity are seen to be lower than those found in similar areas in the past.

6. Recommendations

6.1. Continuous Water Quality Monitoring

To provide a clear picture of seasonal and long-term variation in the Baya River, constant and periodic observation of physico-chemical parameters of the river such as temperature, pH, dissolved oxygen, TDS, and turbidity is imperative. This monitoring is supposed to occur at various sites in both upstream, midstream and downstream locations in order to record the spatial variability. The obtained data may also be used to determine the hotspots of pollution, evaluate the anthropogenic effects and to monitor the seasonal hydrology effects on the quality of water. A river surveillance system will be the basis of sound decision-making and early intervention in ensuring the ecological balance is not disturbed and the aquatic biodiversity remains intact.

6.2. Fish Biodiversity Conservation Programs

Baya River harbors a variety of fish communities that are vulnerable to water quality and habitat alterations. Targets of conservation programs should be on preserving indigenous species, particularly those that are susceptible to low flow conditions and pollution. Some of the measures might involve establishing fish sanctuaries, establishing seasonal fishing laws, and encouraging local communities to adopt sustainable fishing systems. Awareness of ecological significance of fish diversity can be created through educational campaigns. These efforts will ensure species richness, avoid overexploitation and ecosystem services offered by riverine fisheries in North Bihar.

6.3. Pollution Control and Waste Management

The anthropogenic sources such as agricultural run-offs, household wastes, and raw effluents have been identified as the major causative factors in water quality in the Baya

[18]Assessment of Water Quality of Baya River, Samastipur, Bihar. Biospectra. (mset-biospectra.org)

River. It is important to ensure that there is strict supply of pollution control measures and waste management in the neighboring communities. This may involve building effluent treatment plants, encouraging organic agriculture, and controlling industrial effluent. The environmental wellness will be achieved by regular monitoring and implementation of the environmental standards that will minimize nutrient loading, sedimentation, and chemical pollution, thus increasing the water quality. The cleaner water will enhance the diversity of fishes, increase the resilience of the ecosystem, and offer safer resources to the local communities, who depend on the river.

6.4. Habitat Restoration and Riparian Zone Management

Poor riverbank conditions and disappearance of riparian vegetation lead to poor quality of habitat of aquatic species. The natural habitats of the Baya River such as re-planting of the riparian areas and stabilizing the riverbanks should be restored. Native vegetation should be planted to decrease soil erosion, runoff filtered and fish and other organisms living in water will be sheltered. Natural flow regimes and connectivity between the upstream and downstream habitats of the fish species will facilitate breeding, feeding, and migration of the fish species. These ecological restoration initiatives will be beneficial to the river ecosystem in terms of its resilience to seasonal changes and human activities.

6.5. Community Engagement and Sustainable Watershed Management

The Baya River needs to be conserved effectively by involving local communities. The involvement of villagers, farmers, and fisher folk in watershed management programs would facilitate sustainable use of water, safeguard aquatic ecosystems and good fishing. Communities can also be empowered to observe water quality and biodiversity through capacity-building programs, including training workshops, awareness campaigns, and citizen science programs. Municipal-level management strategies that combine ecological, social and economic aspects will ensure the river is conserved in the long run as this would not only guarantee conservation of the biodiversity, but also provide options to the people who rely on river resources to ensure they have a livelihood.

7 Suggestions

7.1. Regular Water Quality Monitoring

Regular checks of temperature, pH, dissolved oxygen, TDS and turbidity at the upstream, middle and downstream locations must be undertaken. Spatial and seasonal data will serve to outline the hotspots of pollution, monitor anthropogenic effects, and implement the interventions in time. Undisturbed surveillance will allow careful management of the Baya River and help to preserve the aquatic biodiversity of the river.

7.2. Fish Biodiversity Protection

Conserve the native fish species through the enforcement of sustainable fishing, seasonal limitations, and small fish reserves. The educational programs will be able to create awareness of the significance of fish diversity and ecosystem health. Preservation of fish populations ensures ecological equilibrium, sustenance of livelihoods and avoidance of loss of species within the Baya River.

7.3. Pollution Control Measures

Strict control on agricultural runoffs, household wastes and domestic effluents into the river. Encourage agricultural practices that are organic and control industrial wastes. By decreasing pollution, the quality of water will be improved, dissolved oxygen will be enhanced, along with the increase of fish diversity and river ecosystem stability.

7.4. Habitat Restoration

Rehabilitate the riparian areas and stabilize the banks to minimize erosion and enhance the quality of the habitat. Plant native vegetation to filter the runoff, provide shelter to aquatic life and natural flow connectivity. The healthy habitats sustain fish breeding, feeding and migration thereby guaranteeing seasonal resilience of river ecosystem.

7.5. Community Engagement

Engage communities on conservation and watershed management. Citizen science, awareness, as well as training enable the residents to control the quality of water, use sustainable measures, and preserve aquatic biodiversity. The community involvement provides long-term conservation of the river and also sustains the livelihoods that rely on the resources of the river.

8. Conclusion

The current research paper identifies the important role played by seasonal variation in the water quality and fish diversity of the Baya River in the Saraiya Block, Muzaffarpur district, Bihar. Physico-chemical parameter analysis showed that there were some seasonal differences with the pre-monsoon seasons recording high water temperatures, increased total dissolved solids and low dissolved oxygen. These factors cause environmental stress and reduce habitat suitability of delicate fish species causing reduced species richness and diversity. Conversely, the monsoon flows significantly ameliorated the quality of water by dilution processes, dissolved oxygen and availability of habitats, promoting the occurrence of high species richness and indices of species diversity. Post-monsoon conditions had moderate recovery, which reflected an intermediate period between the monsoon abundancy and pre-monsoon stress.

The trends in water quality were supported by fish diversity analysis. The pre-monsoon season recorded 34 species mostly of the Cyprinidae and the monsoon season recorded 48 species with greater Shannon and Simpson diversity index. These observations highlight the tight connection between hydrological regimes, water quality, and fish assemblages of seasonal riverine ecosystems. The monsoon seasonal flooding does not only enhance habitat connectivity, but also promotes spawning, migration and redistribution of nutrients leading to productivity and resilience of the ecosystem.

The paper highlights the need to conduct regular monitoring of water quality and aquatic biodiversity of smaller tributary rivers, which tend to be underrepresented in ecological reports. There must be integrated watershed management, pollution control, and habitat conservation

policies in place to protect the fish biodiversity in the baya river especially when there is a growing anthropogenic pressures and climate-based variability. The results serve as a guide to the future ecological studies, fisheries management and conservation planning of North Bihar, which will help to achieve sustainable use and long-term conservation of the freshwater resources

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