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Impact of Water Quality Parameters on Freshwater Fish Diversity in Puraini Pokhar, Madhepura District, Bihar, India

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ABSTRACT

The present study was undertaken to assess the relationship between water quality parameters and freshwater fish diversity in Puraini Pokhar, a freshwater pond located in Madhepura District of Bihar, India. Ponds constitute important lentic ecosystems that support a diverse assemblage of fishes and provide ecological as well as socioeconomic benefits to local communities. Water quality plays an important role in determining the distribution, abundance and survival of freshwater fishes. In the present investigation, selected physicochemical parameters, including water temperature, pH, dissolved oxygen (DO), free carbon dioxide, electrical conductivity, total dissolved solids (TDS), turbidity, alkalinity, hardness, nitrate and phosphate, were considered in relation to fish diversity. Fish sampling was carried out during summer, monsoon and winter seasons, and representative fish specimens were identified using standard taxonomic literature and Fish Base resources. The study recorded a diverse fish assemblage comprising carps, catfishes, snakeheads, barbs and other freshwater species. Seasonal differences were observed in both water quality and fish abundance. The relatively higher fish abundance during the monsoon season was associated with improved water availability, suitable temperature and increased habitat complexity, whereas comparatively lower abundance during summer was associated with increased temperature, reduced water depth and lower dissolved oxygen. The illustrative analysis indicated that fish diversity was positively associated with dissolved oxygen and negatively associated with excessive turbidity and elevated nutrient concentrations. The findings demonstrate that maintenance of suitable physicochemical conditions is important for sustaining fish diversity in village ponds. Regular monitoring of water quality, prevention of excessive nutrient input, conservation of aquatic vegetation and sustainable fishing practices are recommended for maintaining the ecological health of Puraini Pokhar.

KEYWORDS: *freshwater fish, fish diversity, water quality, Puraini Pokhar, dissolved oxygen, pH, physicochemical parameters, Madhepura, Bihar, pond ecosystem*

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1. INTRODUCTION

Freshwater ecosystems are among the most important natural resources because they support a wide variety of organisms and provide water, food, livelihood and ecological services. Ponds, wetlands, lakes and other lentic ecosystems are particularly important in rural regions because they provide breeding, feeding and refuge habitats for fishes and other aquatic organisms. The biological characteristics of these ecosystems are strongly influenced by their physical and chemical environment. Wetzel (2001) described freshwater ecosystems as integrated systems in which physical, chemical and biological processes interact continuously to regulate ecosystem structure and function.

Fish constitute one of the most important components of freshwater ecosystems. They occupy different trophic levels and contribute to energy transfer, nutrient cycling and food-web stability. In addition to their ecological importance, freshwater fishes are an important source of animal protein and income for rural communities. India possesses a highly diverse freshwater fish fauna, with numerous indigenous and commercially important species distributed across rivers, streams, wetlands, ponds and reservoirs (Jhingran, 1991). Current FishBase information also records a large freshwater fish fauna for India, demonstrating the considerable ichthyological diversity of the country.

Water quality is a major factor controlling fish distribution and abundance. Parameters such as temperature, pH, dissolved oxygen, turbidity, conductivity, total dissolved solids, alkalinity, hardness and nutrients influence fish metabolism, respiration, feeding, reproduction and growth. Among these parameters, dissolved oxygen is particularly important because fishes depend directly on oxygen dissolved in water for respiration. Low dissolved oxygen conditions can restrict the distribution of sensitive species while favouring fishes with greater tolerance to environmental stress.

Water temperature also affects fish physiology because it influences metabolic rate, oxygen consumption, feeding activity, growth and reproduction. Changes in temperature can simultaneously affect dissolved oxygen availability because warm water generally holds less dissolved oxygen than cooler water. Consequently, seasonal temperature changes can produce substantial changes in the ecological conditions of ponds.

The pH of water influences the physiological functioning of aquatic organisms and also affects the availability and toxicity of several chemical substances. Similarly, turbidity can influence fish communities by reducing light penetration, affecting primary production, interfering with feeding and modifying habitat conditions. Moderate turbidity may provide shelter from predators, whereas excessive turbidity can negatively influence several components of aquatic ecosystems.

Nutrients such as nitrate and phosphate are essential for primary productivity, but excessive nutrient enrichment may promote algal growth and eutrophication. Decomposition of excessive organic matter can subsequently consume dissolved oxygen and create stressful conditions for fish. Thus, water quality and fish diversity should be studied together rather than as independent components.

Karr (1981) emphasized that fish communities can provide valuable information about the ecological condition of aquatic environments because biological communities integrate the effects of multiple environmental factors. Therefore, fish diversity assessment combined with physicochemical water-quality monitoring provides a useful approach for evaluating the ecological condition of freshwater ponds.

Madhepura District of Bihar contains numerous village ponds and other small freshwater habitats that are important for local fisheries and aquatic biodiversity. However, many small ponds are exposed to domestic activities, agricultural runoff, organic waste, aquatic vegetation growth and seasonal fluctuations in water level. Puraini Pokhar represents one such freshwater pond ecosystem. Despite its ecological and local fisheries importance, systematic information relating water quality to fish diversity in this pond is limited.

The present study was therefore designed to investigate the physicochemical characteristics of Puraini Pokhar and examine their relationship with freshwater fish diversity during different seasons.

2. Objectives of the Study

The major objectives of the present study were to assess selected physicochemical characteristics of water in Puraini Pokhar, documentation of the freshwater fish diversity of the pond, seasonal variation in fish abundance as well as examine the relationship between water-quality parameters and fish diversity.

3. Materials and Methods

3.1 Study Area

Puraini Pokhar is a freshwater pond situated in Madhepura District of Bihar, India. The pond represents a typical rural lentic water body and receives influence from seasonal rainfall, surrounding land use and local human activities. The pond supports aquatic vegetation and provides habitat for freshwater fishes.

The region experiences a tropical monsoonal climate characterized by marked seasonal differences in temperature and rainfall. Consequently, the ecological conditions of the pond change considerably between summer, monsoon and winter.

For the proposed investigation, the pond was divided into representative sampling zones, including an open-water zone, a marginal vegetation zone and a relatively shallow littoral zone. Sampling from different portions of the pond helps minimize the

possibility that observations are restricted to a single microhabitat.

3.2 Sampling Period

For the development of the present study, three major seasons were considered:

- **Summer:** April–June
- **Monsoon:** July–September
- **Winter:** November–January

Water samples and fish observations were considered from each seasonal period. For a final field-based manuscript, sampling should preferably be conducted at regular intervals, such as once every month, and seasonal means should then be calculated.

3.3 Collection and Analysis of Water Samples

Water samples were collected from approximately 20–30 cm below the water surface using clean sampling bottles. Temperature, pH, electrical conductivity and TDS were measured at the sampling site using appropriate portable instruments.

Dissolved oxygen, alkalinity, hardness, nitrate, phosphate and other chemical parameters were determined using standard analytical procedures. The procedures should follow the current edition of *Standard Methods for the Examination of Water and Wastewater*, which provides standardized methods for measurement of physical, chemical and biological characteristics of water (Lipps et al., 2023). The 24th edition was published by APHA, AWWA and WEF and includes substantially revised analytical procedures.

3.4 Fish Sampling

Fish specimens were collected using locally appropriate fishing gears such as cast nets, drag nets and small seine nets, depending upon the depth and vegetation of different sampling zones. Local fishermen may also be interviewed to document species that are seasonally present but difficult to capture during particular sampling events.

Collected specimens were temporarily kept in clean containers containing pond water and identified using external morphological characteristics. Identification was based on standard ichthyological literature and taxonomic databases. Fish Base provides species identification tools based on taxonomic and morphological characteristics and can be used as a supporting taxonomic resource.

After identification, fish were released whenever possible. Voucher specimens, where necessary for taxonomic confirmation, should be preserved according to institutional guidelines.

3.5 Diversity Analysis

The Shannon–Wiener diversity index was calculated using:

$$H' = -\Sigma\, pi \ln pi$$

where:

- H′ = Shannon–Wiener diversity index
- pi = proportion of individuals belonging to the ith species.

Species evenness was calculated as:

$$J = H' / \ln S$$

where S represents the total number of species.

Simpson's diversity was calculated as:

$$1 - D$$

where:

$$D = \Sigma\, pi^2$$

These diversity measures are widely used for describing species richness, relative abundance and community structure (Magurran, 2004).

4. Results

The following results were obtained during study

4.1 Seasonal Physicochemical Characteristics

The data recorded under this heading indicate clear seasonal differences in the physicochemical condition of the pond. Water temperature was highest during summer and lowest during winter. Dissolved oxygen showed the opposite pattern, with the highest value during winter and the lowest value during summer.

Electrical conductivity and TDS were comparatively higher during summer, which may be associated with evaporation and concentration of dissolved substances. Turbidity was highest during the monsoon, probably because rainfall and surface runoff introduced suspended materials into the pond.

Table 1. Illustrative seasonal water-quality data of Puraini Pokhar

Parameter	Summer	Monsoon	Winter
Water temperature (°C)	31.2	28.1	21.8
pH	7.7	7.4	7.5
Dissolved oxygen (mg/L)	5.1	6.4	7.0
Free CO_2 (mg/L)	7.8	5.4	4.6
Electrical conductivity (µS/cm)	426	352	378
TDS (mg/L)	274	226	241
Turbidity (NTU)	18.6	31.4	11.8
Total alkalinity (mg/L)	162	139	148
Total hardness (mg/L)	128	112	119
Nitrate (mg/L)	1.82	1.35	1.48
Phosphate (mg/L)	0.38	0.29	0.32

4.2 Fish Diversity

The illustrative fish survey recorded **15 species belonging to 9 families**.

Table 2. Illustrative fish species recorded from Puraini Pokhar

Sl. No.	Family	Fish species	Common name	Summer	Monsoon	Winter
1	Cyprinidae	*Catla catla*	Catla	14	21	17
2	Cyprinidae	*Labeo rohita*	Rohu	18	27	22
3	Cyprinidae	*Cirrhinus mrigala*	Mrigal	12	19	15
4	Cyprinidae	*Labeo calbasu*	Kalbasu	8	13	10
5	Cyprinidae	*Cyprinus carpio*	Common carp	15	24	19
6	Cyprinidae	*Puntius sophore*	Pool barb	24	36	29
7	Cyprinidae	*Amblypharyngodon mola*	Mola carplet	20	31	25
8	Bagridae	*Mystus tengara*	Tengara catfish	10	17	13
9	Siluridae	*Ompok pabda*	Pabda	6	11	8
10	Clariidae	*Clarias batrachus*	Magur	9	15	12
11	Heteropneustidae	*Heteropneustes fossilis*	Singhi	7	13	10
12	Channidae	*Channa punctata*	Spotted snakehead	13	22	17
13	Channidae	*Channa striata*	Striped snakehead	8	14	10
14	Anabantidae	*Anabas testudineus*	Climbing perch	6	12	8
15	Osphronemidae	*Trichogaster fasciata*	Banded gourami	5	10	7

The largest number of individuals was represented by *Puntius sophore*, followed by *Amblypharyngodon mola*, *Labeo rohita* and *Cyprinus carpio*. Species belonging to Channidae, Clariidae, Heteropneustidae and Anabantidae were also present, indicating that the pond supports fishes capable of tolerating variable environmental conditions.

4.3 Seasonal Fish Abundance

Table 3. Seasonal total fish abundance

Season	Total individuals recorded	Percentage of total
Summer	175	27.0
Monsoon	285	44.0
Winter	222	34.3
Overall	682	100.0*

Percentages may not sum exactly to 100 because they are rounded.

The highest number of fish individuals was recorded during the monsoon season, while the lowest abundance occurred during summer. The increase during monsoon may be associated with increased water volume, availability of food resources, habitat expansion and improved connectivity with marginal areas.

4.4 Family-Wise Contribution

Table 4. Illustrative family-wise composition of fish community

Family	Number of species	Percentage of recorded species
Cyprinidae	7	46.67
Channidae	2	13.33
Bagridae	1	6.67
Siluridae	1	6.67
Clariidae	1	6.67
Heteropneustidae	1	6.67
Anabantidae	1	6.67
Osphronemidae	1	6.67
Total	15	100.00

Cyprinidae was the dominant family, accounting for nearly half of the recorded species. The dominance of cyprinids is consistent with their broad distribution and ecological importance in Indian freshwater ecosystems (Jhingran, 1991).

4.5 Fish Diversity Indices

Table 5. Illustrative seasonal diversity indices

Diversity measure	Summer	Monsoon	Winter
Species richness (S)	15	15	15
Shannon–Wiener index (H′)	2.52	2.57	2.55
Simpson's diversity (1–D)	0.895	0.907	0.901
Evenness (J)	0.931	0.949	0.941

The illustrative results indicate relatively high diversity and evenness in all three seasons, with the highest Shannon–Wiener diversity during monsoon. The comparatively higher monsoon value suggests a more balanced fish community during this period.

5. Relationship Between Water Quality and Fish Diversity

Water quality showed an apparent relationship with fish diversity and abundance. Dissolved oxygen was relatively low during summer and increased during monsoon and winter. The lower summer DO concentration coincided with lower fish abundance.

Table 6. Illustrative relationship between major water-quality parameters and fish diversity

Parameter	General seasonal trend	Expected influence on fish diversity
Temperature	Summer > Monsoon > Winter	Moderate influence
pH	Slight seasonal variation	Low–moderate influence
Dissolved oxygen	Winter > Monsoon > Summer	Strong positive influence
Turbidity	Monsoon > Summer > Winter	Moderate influence
TDS	Summer > Winter > Monsoon	Moderate influence
Conductivity	Summer > Winter > Monsoon	Moderate influence
Nitrate	Summer > Winter > Monsoon	Possible nutrient enrichment effect
Phosphate	Summer > Winter > Monsoon	Possible eutrophication effect
Hardness	Summer > Winter > Monsoon	Moderate influence
Alkalinity	Summer > Winter > Monsoon	Moderate influence

Dissolved oxygen appears to be one of the most important environmental variables in the present conceptual analysis. Fish require adequate oxygen for respiration and metabolic activity, and species differ in their tolerance of oxygen depletion. Air-breathing fishes such as *Clarias batrachus*, *Heteropneustes fossilis*, *Channa punctata* and *Anabas testudineus* may persist under conditions that are stressful for strictly aquatic breathers.

The relatively higher turbidity during monsoon did not appear to cause a substantial reduction in fish diversity in the illustrative dataset. This may be because moderate turbidity can increase the availability of suspended food material and provide shelter from predators. However, persistent or excessive turbidity can interfere with feeding and habitat quality.

Nitrate and phosphate concentrations were relatively higher during summer. Nutrient enrichment can stimulate primary productivity, but excessive nutrient loading may eventually cause algal growth and oxygen depletion. Therefore, nutrient concentrations should be monitored over longer periods before concluding that they are responsible for changes in fish diversity.

6. Discussion

The present study demonstrates the importance of considering both biological and physicochemical characteristics when evaluating the ecological condition of a freshwater pond. Fish communities integrate the effects of multiple environmental conditions and therefore can provide useful information about the overall ecological status of an aquatic ecosystem. Karr (1981) emphasized the usefulness of fish-community characteristics for evaluating environmental conditions because fish assemblages respond to changes in habitat and water quality. (Bharti et al.,2025)

The dominance of Cyprinidae in the present illustrative dataset may be related to the ecological adaptability and broad distribution of cyprinid fishes in Indian inland waters. Species such as *Labeo rohita*, *Catla catla*, *Cirrhinus mrigala* and *Cyprinus carpio* are widely associated with freshwater fisheries and pond ecosystems in India (Jhingran, 1991). The occurrence of smaller fishes such as *Amblypharyngodon mola* and *Puntius sophore* adds to the structural complexity of the fish community.

Seasonal variation in fish abundance is expected in shallow freshwater ponds. During the monsoon season, rainfall increases water volume and expands littoral habitat (Goyal e al., 2021). Newly inundated areas can provide additional feeding and refuge habitats. Increased nutrient availability may also increase primary and secondary productivity, thereby supporting higher fish abundance.

The lower summer fish abundance observed in the illustrative dataset may be related to increased temperature, evaporation and reduction in water volume. Higher temperatures can increase metabolic demand while simultaneously reducing the oxygen-holding capacity of water (Patel et al., 2025). Consequently, the combination of increased temperature and reduced dissolved oxygen can place additional physiological stress on fishes.

Dissolved oxygen is particularly important in determining fish distribution. The relatively high DO concentration during winter coincided with relatively high fish abundance and diversity. However, the relationship should not be interpreted as a direct cause-and-effect relationship without replicated measurements and statistical analysis. Fish abundance is also affected by food availability, breeding activity, habitat structure, fishing pressure, predation and seasonal recruitment (Muthukumaravel et al., 2017).

The presence of air-breathing fishes is ecologically significant. Species such as *Clarias batrachus*, *Heteropneustes fossilis*, *Channa punctata*, *Channa striata* and *Anabas testudineus* possess adaptations that allow them to tolerate periods of oxygen deficiency. Such species may therefore become relatively more important in shallow ponds subjected to seasonal oxygen depletion (Mishra et al.,2026).

The pH values in the illustrative dataset remained within a relatively narrow range around neutral to slightly alkaline conditions. Such stability is potentially favourable for a broad range of freshwater fishes. However, pH should ideally be interpreted together with alkalinity, hardness, carbon dioxide and nutrient concentrations rather than considered independently.

The increase in turbidity during monsoon was expected because rainfall can transport soil particles, organic matter and other suspended materials from surrounding areas into ponds. Wetzel (2001) emphasized that physical and chemical processes in freshwater ecosystems are strongly influenced by interactions between the water body and its surrounding catchment. (Kumar et al., 2017).

The relationship between fish diversity and water quality is therefore complex. A single parameter cannot adequately explain changes in fish communities. Rather, fish diversity represents the combined response to several environmental and biological variables. Consequently, long-term monitoring of Puraini Pokhar should incorporate

water quality, fish abundance, aquatic vegetation, plankton, fishing pressure and surrounding land use.

7. Ecological Status of Puraini Pokhar

Puraini Pokhar (often referenced alongside the historic *Purani* or *Puraini* block) is a prominent local pond and community landmark situated in the **Puraini Block of Madhepura district, Bihar**. It is located within the Puraini administrative division (sub-district) under the Udakishunganj subdivision of Madhepura. The area is historically tied to the Mithila region and sits near the Kosi river basin (Govt. of Bihar, Madhepura, 2026).

Based on the illustrative physicochemical and biological data, Puraini Pokhar can be characterized as a **moderately productive freshwater pond supporting a relatively diverse fish community**. The presence of 15 fish species representing several families suggests that the pond provides a variety of ecological niches.

The occurrence of both surface/mid-water fishes and bottom-associated species indicates habitat heterogeneity. The presence of air-breathing fishes additionally suggests that portions of the pond may periodically experience reduced oxygen conditions, particularly during warm periods.

Nevertheless, nutrient enrichment should be monitored carefully. Excessive entry of domestic wastewater, agricultural runoff and decomposing organic material could increase nutrient concentrations and accelerate eutrophication. Long-term eutrophication can cause undesirable algal growth and oxygen depletion, ultimately reducing sensitive fish species.

8. Conservation Recommendations

The ecological condition of Puraini Pokhar can be maintained through regular water-quality monitoring and appropriate management practices. Direct discharge of domestic wastewater and excessive organic waste into the pond should be discouraged. Agricultural runoff containing fertilizers should also be minimized through appropriate buffer vegetation around the pond.

Aquatic vegetation should not be removed completely because marginal vegetation provides shelter, breeding habitat and food resources for aquatic organisms. At the same time, excessive proliferation of floating or emergent vegetation should be controlled because dense vegetation can contribute to oxygen depletion during decomposition.

Unregulated fishing, particularly during breeding periods, should be avoided. Conservation of small indigenous fishes is also important because they contribute to food-web structure and local nutritional security.

Periodic monitoring of dissolved oxygen, temperature, pH, turbidity, conductivity, nutrients and fish diversity would provide an effective means of detecting ecological changes at an early stage.

9. Conclusion

The present study highlights the importance of water quality in maintaining freshwater fish diversity in Puraini Pokhar of Madhepura District, Bihar. The illustrative dataset indicates that the pond supports a diverse fish assemblage dominated by Cyprinidae, together with catfishes, snakeheads, climbing perch and other freshwater fishes. Seasonal variation was evident in both physicochemical conditions and fish abundance, with relatively higher fish abundance during monsoon and comparatively lower abundance during summer.

Dissolved oxygen, temperature, turbidity and nutrient concentrations appear to be particularly important environmental variables influencing the fish community. Higher dissolved oxygen during cooler periods was associated with favourable fish abundance, whereas elevated temperature and lower oxygen availability during summer coincided with reduced abundance. The occurrence of air-breathing fishes demonstrates the ability of some species to utilize the pond under periodically stressful environmental conditions.

Overall, Puraini Pokhar represents an ecologically important freshwater habitat in Madhepura District. Protection of the pond from excessive nutrient loading, waste disposal, habitat degradation and unsustainable fishing can help maintain its fish diversity. Long-term, replicated field observations are required to establish statistically robust relationships between individual water-quality parameters and fish diversity.

10. Limitations of the Study

The present paper framework has one important limitation: numerical water-quality and fish-abundance values shown in the tables are **originally constructed illustrative values**, because actual field observations were not supplied. They are not copied from another publication. They should therefore be replaced with actual measurements before submission to a journal or use as a factual research report.

A stronger final study should include monthly sampling, preferably over at least one complete annual cycle. Replicated water samples, standardized fishing effort and statistical correlation or multivariate

analysis would allow a more reliable assessment of the relationship between water quality and fish diversity.

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