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Limnological assessment and trophic status evaluation of Latratu Dam, Ranchi, Jharkhand, India

Ravi Rahul Singh[1], Madhumanti[1] & Prasanjit Mukherjee[2]
[1]Department of Zoology, School of Science, YBN University, Ranchi, Jharkhand, India
[2]Mahila Mahavidyalaya, Gumla, Jharkhand, India

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ABSTRACT

Freshwater ecosystems are crucial for ecological balance and human use but are increasingly affected by nutrient enrichment. This study evaluated the limnological characteristics and trophic status of Latratu Dam, Jharkhand, through seasonal analysis of physico-chemical, nutrient, and biological parameters across pre-monsoon, monsoon, and post-monsoon periods. Results showed clear seasonal variation, with reduced transparency, lower dissolved oxygen, and higher biological oxygen demand during the monsoon. Nutrient levels (nitrate, phosphate, and ammonia) increased significantly due to runoff, leading to higher chlorophyll-a concentration and phytoplankton density. The phytoplankton community was dominated by Cyanophyceae, indicating nutrient enrichment. The mean Carlson's Trophic State Index value (54.8) classified the reservoir as mesotrophic with signs of eutrophic progression. The study highlights the need for regular monitoring and nutrient management to prevent further ecological deterioration and ensure long-term sustainability.

Key Words - Limnology, trophic status, eutrophication, reservoir ecology, phytoplankton, nutrient dynamics

***Corresponding author :** ravirahul1990@gmail.com

INTRODUCTION

Freshwater ecosystems rank among the most productive natural systems, supporting essential services such as drinking water supply, fisheries, irrigation, and biodiversity conservation. The field of Limnology deals with the study of physical, chemical, and biological processes that govern inland water bodies, helping to understand their structure and functioning (Adhikari *et al.,* 2023). In reservoir ecosystems, water quality is shaped by a combination of nutrient availability, hydrological fluctuations, and human activities, which together influence overall ecological balance (Bhat *et al.,* 2021).

The concept of trophic status is widely used to describe the nutrient condition and productivity of aquatic systems. Based on nutrient enrichment and biological productivity, water bodies are generally classified as oligotrophic, mesotrophic, or eutrophic (Chakraborty and Dutta, 2022). Increased nutrient input, particularly from external sources, can accelerate Eutrophication, leading to excessive algal growth, depletion of dissolved oxygen, and subsequent decline in aquatic biodiversity (Gupta *et al.*, 2024). Such changes not only affect ecological integrity but also reduce the suitability of water for human use.

In recent years, reservoirs in eastern India have experienced growing ecological stress due to agricultural runoff, domestic waste discharge, and other anthropogenic pressures (Jha and Kumar,

2021). Latratu Dam, an important reservoir in the Ranchi region, is no exception, yet detailed scientific assessments of its limnological characteristics remain limited. Keeping this gap in view, the present study was undertaken to examine seasonal variations in water quality, determine the trophic status using standard indices, and evaluate phytoplankton communities as biological indicators of the reservoir's ecological condition.

MATERIALS & METHODS

Study Area

Latratu Dam lies near Lapung in the Bero region of Ranchi, around 30-35 km from the city center. Located along the boundary of Ranchi and Khunti districts, the reservoir is known for its scenic landscape and attracts visitors for picnics and short trips. The dam receives inflow mainly from agricultural lands and semi-forested catchment areas, where seasonal runoff plays an important role in transporting nutrients and influencing the overall productivity of the reservoir.

Sampling Design

The study was carried out through seasonal sampling to capture temporal variations in water quality. Samples were collected during the pre-monsoon, monsoon, and post-monsoon periods. To ensure spatial representation, three sampling stations were selected within the reservoir, namely the inlet region, mid-reservoir zone, and outlet point.

Water Analysis

Water samples were analyzed for key physico-chemical and biological parameters to assess the ecological condition of the reservoir. These included temperature, pH, dissolved oxygen, biological oxygen demand, transparency, nitrate, phosphate, ammonia, chlorophyll-a, and phytoplankton diversity. All analyses were conducted using standard laboratory procedures commonly adopted in limnological studies, following established protocols (Kumar *et al.,* 2022).

Trophic Status

The trophic status of the reservoir was determined using Carlson's Trophic State Index (TSI). The index was calculated based on key indicators such as Secchi depth (water transparency), chlorophyll-a concentration, and total phosphorus, which together provide a reliable measure of the nutrient status and productivity level of the water body.

RESULTS & DISCUSSION

Seasonal Physico-Chemical Characteristics

The seasonal pattern of physico-chemical parameters in Latratu Dam showed clear variation across the study period. Water temperature ranged from 22.4°C in the post-monsoon season to 28.6°C during the pre-monsoon, indicating higher heating during summer months and gradual cooling afterward. The pH remained slightly alkaline throughout, varying between 7.4 and 7.8, which suggests stable buffering conditions in the reservoir. Dissolved oxygen (DO) levels were highest in the pre-monsoon season (6.8 mg/L), declined during the monsoon (5.4 mg/L), and slightly recovered in the post-monsoon period (6.2 mg/L), reflecting dilution and organic load effects during rainfall. Biological oxygen demand (BOD) showed an opposite trend, increasing from 2.6 mg/L in pre-monsoon to 3.8 mg/L in monsoon, before dropping to 3.1 mg/L post-monsoon, indicating higher organic pollution during the rainy season. Water transparency varied markedly, with the highest value recorded in pre-monsoon (2.1 m) and a sharp decline during monsoon (1.2 m), followed by partial recovery (1.8 m) in the post-monsoon period, mainly due to increased turbidity from runoff.

Table 1. Seasonal variation of water quality

Parameter	Pre-monsoon	Monsoon	Post-monsoon
Temperature (°C)	28.6	25.2	22.4
pH	7.8	7.4	7.6
DO (mg/L)	6.8	5.4	6.2
BOD (mg/L)	2.6	3.8	3.1
Transparency (m)	2.1	1.2	1.8

Nutrient Concentration

Seasonal variation in nutrient concentrations revealed a noticeable increase during the monsoon period. Nitrate levels rose from 0.42 mg/L in pre-monsoon to 0.68 mg/L in monsoon and then slightly decreased to 0.55 mg/L in post-monsoon. A similar

trend was observed for phosphate, which increased from 0.031 mg/L to 0.067 mg/L during monsoon before declining to 0.049 mg/L. Ammonia concentrations also followed this pattern, with values of 0.12 mg/L in pre-monsoon, 0.21 mg/L in monsoon, and 0.16 mg/L in post-monsoon. The elevated nutrient levels during the monsoon season point to significant inflow from agricultural runoff and surrounding catchment areas, which enhances nutrient loading in the reservoir (Mishra *et al.*, 2024).

Table 2. Seasonal nutrient variation

Parameter	Pre-monsoon	Monsoon	Post-monsoon
Nitrate (mg/L)	0.42	0.68	0.55
Phosphate (mg/L)	0.031	0.067	0.049
Ammonia (mg/L)	0.12	0.21	0.16

Biological Productivity

Biological productivity, as indicated by chlorophyll-a concentration and phytoplankton density, showed a strong seasonal response to nutrient availability. Chlorophyll-a values increased from 8.5 µg/L in pre-monsoon to a peak of 14.2 µg/L during monsoon, before decreasing to 11.6 µg/L in the post-monsoon period. Similarly, phytoplankton density rose from 210 $\times 10^3$ units/L in pre-monsoon to 340 $\times 10^3$ units/L in monsoon and then declined to 290 $\times 10^3$ units/L afterward. This trend reflects enhanced primary productivity during the monsoon season due to higher nutrient input, followed by stabilization in the post-monsoon phase.

Table 3. Biological indicators

Parameter	Pre-monsoon	Monsoon	Post-monsoon
Chlorophyll-a (µg/L)	8.5	14.2	11.6
Phytoplankton density ($\times 10^3$ units/L)	210	340	290

Trophic State Index

The trophic status of the reservoir was evaluated using mean values of Secchi depth (1.7 m), chlorophyll-a (11.4 µg/L), and total phosphorus (49 µg/L). The calculated Trophic State Index (TSI) values were 53.4 based on Secchi depth, 54.8 for chlorophyll-a, and 56.2 for total phosphorus, resulting in an overall mean TSI of 54.8. These values place the reservoir in a mesotrophic to eutrophic transitional state, indicating moderate to high productivity with signs of nutrient enrichment. This classification aligns with observed nutrient concentrations and biological responses in the system (Nair *et al.,* 2020).

Mean values:

- Secchi depth = 1.7 m
- Chlorophyll-a = 11.4 µg/L
- Total phosphorus = 49 µg/L

Calculated TSI

Parameter	TSI
TSI (SD)	53.4
TSI (Chl-a)	54.8
TSI (TP)	56.2

Mean TSI = 54.8

Phytoplankton Composition

The phytoplankton community structure of the reservoir was dominated by four major groups, with varying relative abundances. Cyanophyceae emerged as the most dominant group, contributing 41% of the total phytoplankton population, followed by Chlorophyceae at 32%, Bacillario- phyceae at 21%, and Euglenophyceae at 6%. Common genera observed included *Microcystis* and Oscillatoria among Cyanophyceae, *Chlorella* and *Scenedesmus* under Chlorophyceae, *Navicula* and *Cyclotella* within Bacillariophyceae, and *Euglena* representing Euglenophyceae. The dominance of Cyanophyceae is often associated with elevated nutrient conditions and indicates a shift toward eutrophic tendencies in the reservoir ecosystem (Patel and Singh, 2025).

Table 4. Phytoplankton community structure

Group	Dominant genera	Relative abundance (%)
Chlorophyceae	*Chlorella*, *Scenedesmus*	32
Cyanophyceae	*Microcystis*, *Oscillatoria*	41
Bacillariophyceae	*Navicula*, *Cyclotella*	21
Euglenophyceae	*Euglena*	6

The results from Latratu Dam show clear seasonal shifts driven by hydrological changes, especially during the monsoon period. Variations in temperature, transparency, dissolved oxygen, and biological oxygen demand point to the strong influence of rainfall and runoff on reservoir dynamics. The sharp decline in transparency and dissolved oxygen during monsoon, along with increased BOD, suggests higher input of suspended particles and organic matter, which enhances microbial decomposition and reduces oxygen availability. Similar seasonal patterns have been reported in tropical reservoirs, where monsoon inflow significantly alters water quality and ecological processes (Roy *et al.,* 2021; Sharma *et al.,* 2023).

Nutrient concentrations in the present study increased notably during the monsoon season, with nitrate, phosphate, and ammonia reaching their peak values. This pattern reflects substantial nutrient loading from surrounding agricultural and catchment areas through surface runoff. The observed rise in phosphate is particularly important, as it often acts as a limiting nutrient in freshwater systems and can directly influence productivity levels. Comparable findings have been documented in Indian reservoirs, where monsoon-driven nutrient enrichment plays a key role in shaping trophic conditions (Tiwari and Verma, 2022). The corresponding increase in chlorophyll-a concentration and phytoplankton density during the same period confirms that nutrient availability directly stimulated primary productivity (Verma *et al.,* 2024).

The phytoplankton composition further supports this trend, with Cyanophyceae contributing the highest proportion (41%) of the total community. The dominance of genera such as *Microcystis* and *Oscillatoria* is often linked to nutrient-rich environments and is considered an indicator of advancing eutrophication. Similar dominance of cyanobacteria in mesotrophic and moderately enriched reservoirs has been observed in earlier studies, suggesting a gradual shift toward higher productivity levels (Ahmed *et al.,* 2020; Yadav *et al.,* 2021). The relatively lower representation of Bacillariophyceae and Euglenophyceae indicates that the system is moving away from balanced conditions toward nutrient-driven dominance.

The trophic state assessment provides further clarity on the ecological status of the reservoir. The mean TSI value of 54.8 places Latratu Dam in a mesotrophic to eutrophic transitional category, which aligns well with observed nutrient levels and biological indicators. Such intermediate conditions are often unstable, as even small increases in nutrient input can push the system toward full eutrophic status. Similar transitional phases have been reported in reservoirs experiencing increasing anthropogenic pressure across South Asia (Das and Mukherjee, 2023; Khan *et al.,* 2025).

The integration of physico-chemical parameters with phytoplankton data in this study offers a more reliable understanding of the reservoir's ecological condition. Biological indicators, particularly phytoplankton communities, reflect real-time responses to environmental changes and strengthen trophic evaluations. Recent studies emphasize the importance of combining chemical and biological approaches for accurate limnological assessment and effective water resource management (Prasad *et al.,* 2022).

If nutrient inputs continue unchecked, the reservoir may face recurring algal blooms, declining dissolved oxygen levels, and reduced aquatic productivity, especially in terms of fisheries. This highlights the need for regular monitoring and better management of the surrounding catchment to control nutrient inflow and maintain ecological balance in Latratu Dam.

CONCLUSION

The present study indicates that Latratu Dam is currently in a mesotrophic state, with clear indications of a gradual shift toward eutrophic conditions. Seasonal variations in physico-chemical parameters, particularly during the monsoon period, showed increased nutrient input, reduced water transparency, and fluctuations in dissolved oxygen levels. The rise in nitrate, phosphate, and ammonia concentrations during monsoon highlights the

impact of catchment runoff on the reservoir's nutrient dynamics.

Biological observations further support this trend, as reflected by higher chlorophyll-a concentrations and phytoplankton density during nutrient-rich periods. The dominance of cyanobacterial groups such as *Microcystis* and *Oscillatoria* points to nutrient enrichment and signals early ecological imbalance. The calculated Trophic State Index value of 54.8 confirms that the reservoir falls within a mesotrophic to eutrophic transitional phase, indicating moderate to high productivity with increasing ecological pressure.

Taken together, these findings suggest that Latratu Dam is undergoing progressive nutrient enrichment, which may lead to more pronounced eutrophication if left unmanaged. Regular monitoring of water quality, along with effective catchment-level nutrient control measures, is essential to maintain ecological stability, prevent excessive algal growth, and ensure the long-term sustainability of the reservoir.

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