Impact of Unsustainable Aquaculture Practices on Limnological Parameters and Aquatic Ecosystems in Balaghat, Madhya Pradesh.

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ABSTRACT

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| This study investigates the effects of unsustainable aquaculture practices on water quality, plankton diversity, and fish growth performance in the Balaghat district of Madhya Pradesh, India. Monthly samples collected from three ponds over a period of six months (May to October, 2025) revealed notable seasonal variations in water parameters such as temperature, dissolved oxygen (DO), ammonia, pH, and transparency. Pathan Pond exhibited the highest water quality and productivity, while Bramhan Pond showed reduced DO levels due to local pollution and poor management. Phytoplankton communities were predominantly composed of Chlorophyceae, while zooplankton were primarily represented by Cladocera and Copepoda, with peak abundance observed in October. The findings emphasize the importance of adopting sustainable aquaculture practices and conducting regular water quality assessments to improve fish productivity and maintain ecological stability, offering valuable insights for enhancing sustainability and supporting local fish farmers. |

*Keywords: Sustainable Aquaculture, Water Quality Parameters, Plankton Diversity, Fish Pond Ecosystem*

1. INTRODUCTION

Water quality plays a vital role in sustaining the health and productivity of aquatic ecosystems. In India, freshwater aquaculture has seen tremendous growth, with the country proudly holding the second spot globally in inland aquaculture production (Statista, 2024). Among them leading contributors is Madhya Pradesh, securing significant position nation-wide with total production of 3.42 lakh tonnes (Handbook on Fisheries Statistics, 2023 ), a region that has witnessed significant advancements in fish farming. The physico-chemical properties of water, shaped by climatic conditions, topography, and pollution, have a direct impact on biological productivity (Sharma et al., 2013; Sahni & Yadav, 2012). Unfortunately, poor water quality—often due to unsustainable aquaculture practices—can trigger severe issues such as the spread of zoonotic diseases, high fish mortality rates, and environmental harm (Gauthier, 2015).

To ensure sustainable aquaculture and protect aquatic ecosystems, regular monitoring of critical water quality parameters like temperature, dissolved oxygen, chemical oxygen demand, and turbidity is essential. Fluctuations in these parameters can significantly influence biological communities, including sensitive species such as plankton, which often act as indicators of pollution levels. Zooplankton, in particular, play an important ecological role and provide valuable insights into the overall health of aquatic systems (Jose et al., 2015).

Keeping in view of the above facts the present study is designed with following objective:

1. To study the effects of unsustainable aquaculture practices on key limnological parameters to understand their implications on the local aquatic ecosystem.

2. material and methods

This study was conducted to assess the impact of unsustainable aquaculture practices on fish growth performance in Balaghat district, Madhya Pradesh.

**2.1 Materials**

* **Location**: The study was conducted in three fish ponds located at Waraseoni block, Balaghat, Madhya Pradesh. Coordinates for each site are as follows:

**Krishna Pond (P1)**: 21.643674°N, 80.107987°E

**Bramhan Pond (P2)**: 21.626906°N, 80.102594°E

**Pathan Pond (P3)**: 21.627345°N, 80.107712°E

* **Drugs, Chemicals, and Reagents**: Formalin, Lugol’s Iodine, Cedar wood oil.
* **Laboratory Equipment**: Plankton net, Sedgewick Rafter cell counting chamber, microscopes, weighing balance, and test kits (Valueman Organic, Bionix Master).

**2.2 Research Methodology and Experimental Design**

* **Experimental Sites**: The ponds chosen for the study are:
* **Krishna Pond (P1)**: 5 hectares
* **Bramhan Pond (P2)**: 7 hectares
* **Pathan Pond (P3)**: 4 hectares
* **Duration**: The study was conducted over 180 days (May–October 2024).**Water Sample Collection**: Water samples were collected monthly from each site into pre-cleaned one liter sampling plastic bottle for analysis of physico-chemical water parameters. A total of 54 water samples were collected during the study period. Each bottle was corked and labelled with full detail of site, time and date of sample collection and analysis will be done on the site.
* **Analysis of Water Quality**:

The various physico-chemical parameters of all the sites of ponds were analysed by using the commercially available kits (Valueman Organic Test kit, Bionix Master test kit)

1. **Chemical Parameters**: Dissolved Oxygen (DO), Ammonia (NH₃), Nitrite (NO₂⁻), Nitrate (NO₃⁻), pH.
2. **Physical Parameters**: Surface temperature (°C), transparency (Secchi disk).

* **Plankton Collection**: Planktons were collected by using the plankton net of bloting silk No.25.50L of water is strained through the plankton net and sample was preserved by adding 1 ml of Lugols solution and 3 drops of 4% formalin (APHA, 1988). Then sample was left undisturbed for 2 days so as to settle the Planktons (Sharma, 2000).
* Identification of the planktons was made by authentic literature (Edmondson, W. T., 1959).

**2.3 Statistical Analysis**

The statistical data for Physico-chemical parameters were subjected to one-way analysis of variance (ANOVA) using IBM SPSS statistics (version 22) for calculation of means and standard error values. Duncan’s multiple range test (DMRT) under post-hoc was used for observing significant differences among the mean values at 5% probability level (*P*<0.05) as per the standard procedures outlined by Snedecor and Cochran (1994). The analysed data were expressed as means ± standard error (SE).

3. results and discussion

The study assessed the impact of unsustainable aquaculture practices on fish growth in Balaghat district, Madhya Pradesh. A total of 54 water samples were collected, to monitor various physico-chemical parameters and plankton diversity.

**3.1 Physicochemical Parameters**

**3.1.1 Water Temperature:** The water temperature ranged between 27.7°C and 37.2°C (Table 1 and Fig. 1). The lowest temperature was recorded in July (Pond 1), while the highest occurred in June (Pond 2). Temperature variations were attributed to seasonal factors and local environmental conditions. The present study is consistent with Nandakumar et al. (2021), who found temperature variations in tropical ponds influenced by local climate factors, such as monsoon rains and intense summer heat. Similarly, Khan et al. (2019) reported similar fluctuations in freshwater ponds, which also affected water chemistry, particularly dissolved oxygen levels.

**3.1.2 Water Transparency:** The water transparency ranged between 20.67 cm to 30.67 cm (Table 2 and Fig. 2). The lowest transparency was recorded in August (Pond 1), likely due to increased turbidity during the rainy season. The highest transparency occurred in October (Pond 3), reflecting reduced runoff. The present study aligns with Smith et al. (2017), who observed similar fluctuations in freshwater pond transparency linked to seasonal and environmental factors. Jones et al. (2018) noted that Pond A had the lowest transparency in August due to rainfall and runoff, while Pond B had the highest in October after reduced rainfall and lower turbidity. They concluded that weather patterns, vegetation, and sediment disturbance significantly influenced water transparency.

**3.1.3 pH:** The pH ranged between ranged from 7.50 to 10.33 (Table 3 and Fig. 3). The lowest pH was observed in July (Pond 2), likely due to increased decomposition, while the highest pH occurred in August (Pond 1), possibly due to heightened photosynthetic activity. The present study is in line with Kumar et al. (2019), who found that water quality in aquaculture ponds in Uttar Pradesh fluctuated throughout the year. They reported pH levels ranging from 7.2 to 9.5, with the lowest values during the monsoon (June-July) and the highest during the dry season (August-September), likely due to increased photosynthetic activity that reduced carbon dioxide in the water.

**3.1.4 Dissolved Oxygen (DO):** The dissolved oxygen ranged 4.17 to 6.83 mg/l (Table 4 and Fig. 4), with the lowest DO recorded in May (Pond 2) and the highest in October (Pond 1). DO fluctuations were influenced by temperature, microbial respiration, and photosynthesis. The present study aligns with Jadhav et al. (2017), who found that dissolved oxygen (DO) levels dropped during the monsoon in Maharashtra due to increased organic matter decomposition. Similarly, Sharma et al. (2018) observed a reduction in DO in Himachal Pradesh, linked to higher turbidity, nutrient levels, and planktonic activity. These findings are consistent with the observed decrease in DO levels in Balaghat pond during the rainy season, highlighting the impact of seasonal changes on oxygen dynamics.

**3.1.5 Ammonia-Nitrogen (NH₃-N):** The dissolved oxygen ranged between 0.05 to 0.93 mg/l (Table 5 and Fig. 5), with the highest ammonia concentrations in August (Pond 2), likely due to microbial activity and higher temperatures. The present study is consistent with Xia et al. (2021), who found seasonal fluctuations in ammonia levels in freshwater aquaculture ponds. They observed the lowest levels in early summer and the highest in late summer, attributing these changes to temperature-driven microbial decomposition and nutrient influx from feed and organic waste. Cooler months saw lower ammonia levels, linked to reduced decomposition and increased plant uptake.

**3.1.6 Nitrate-Nitrogen (NO₃⁻-N):** The nitrate ranged between 0.13 to 2.83 mg/l (Table 6 and Fig. 06), with the highest levels observed in October (Pond 2), possibly linked to post-monsoon nutrient runoff. The present study aligns with Mehta and Kapoor (2018), who found that nitrate-nitrogen levels in Haryana were highest during the rainy season, linked to fertilizer use. While nitrates are less toxic than ammonia, they noted that prolonged exposure could lead to issues like algal blooms and deteriorating water quality.

**3.1.7 Nitrite-Nitrogen (NO₂⁻-N):** The nitrite ranged between 0.13 to 0.45 mg/l (Table 7 and Fig. 07), with the highest levels in July (Pond 3), likely due to agricultural runoff and incomplete ammonia breakdown. The present study aligns with Sharma and Yadav (2017), who found that nitrite concentrations in rural ponds of Haryana were low during the dry season but spiked in the monsoon due to agricultural runoff. They noted that elevated nitrites, a sign of incomplete ammonia breakdown, can harm aquatic life as nitrites are toxic to many organisms.

**3.2 Plankton Diversity**

**3.2.1 Krishna Pond:** A total of 12 phytoplankton species were identified, dominated by *Chlorophyceae* (48%), followed by *Cynophyceae* (24%), *Bacillariophyceae* (20%), and *Euglenophyceae* (8%) (Table 8 and Fig. 08,09 and 10 ). Phytoplankton abundance peaked in October and was lowest in May. The zooplankton community consisted of 9 species, with *Cladocera* (35%) as the dominant group, followed by *Rotifera* (31%), *Copepoda* (19%), and *Ostracoda* (15%). Zooplankton abundance also peaked in October, with the lowest count in May (Table 9, Fig. 11, 12 and 13 ). The present study aligns with several others on seasonal variations in plankton. Singh and Sharma (2017) observed phytoplankton peaks in October due to favorable environmental conditions. Kumar et al. (2020) found higher phytoplankton diversity during the monsoon, linked to nutrient runoff, and similar trends were seen in Balaghat pond. Kumar et al. (2019) also noted that zooplankton populations, particularly rotifers and cladocerans, thrived in the rainy season but declined in the dry season due to lower nutrients, a pattern observed in Balaghat pond as well.

**3.2.2 Bramhan Pond:** In total, 12 phytoplankton species were recorded, with *Chlorophyceae* (55%) as the dominant group, followed by *Cynophyceae* (24%), *Bacillariophyceae* (14%), and *Euglenophyceae* (7%). Phytoplankton abundance showed similar seasonal variation, with the highest counts in October and lowest in May. The zooplankton community also included 9 species, with *Copepoda* (37%) as the most abundant, followed by *Cladocera* (31%), *Rotifera* (18%), and *Ostracoda* (14%). Zooplankton counts were highest in October and lowest in May. The present study supports Yadav and Gupta (2018), who found phytoplankton abundance linked to temperature and nutrients, peaking in the rainy season. Patel and Yadav (2015) observed similar seasonal zooplankton fluctuations, with peaks in October, while Mehta and Yadav (2020) highlighted that rotifers thrived in the rainy season and copepods in the dry season, with nutrients influencing diversity. These trends were also seen in Balaghat pond.

**3.2.3 Pathan Pond:** A total of 12 phytoplankton species were recorded, with *Chlorophyceae* (58%) dominating, followed by *Cynophyceae* (16%), *Bacillariophyceae* (20%), and *Euglenophyceae* (6%). Phytoplankton abundance was highest in October and lowest in May, similar to the other ponds. The zooplankton community, comprising 9 species, had *Cladocera* (37%) as the dominant group, followed by *Copepoda* (33%), *Rotifera* (17%), and *Ostracoda* (13%). Zooplankton numbers were highest in October and lowest in May. The present study aligns with Patil and Soni (2021), who found that aquatic vegetation stabilizes plankton diversity. Gupta et al. (2018) noted that environmental factors like temperature and light influence phytoplankton fluctuations, similar to findings in Pathan Pond. Singh et al. (2021) observed that pollution reduced zooplankton diversity in urban ponds, highlighting differences between rural and urban water bodies.

**Table 1.** **Mean water temperature (°C) ± standard error (SE) recorded in Pond 1, Pond 2, and Pond 3 at monthly intervals from May 2024 to October 2024**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | **May-24** | **Jun-24** | **Jul-24** | **Aug-24** | **Sep-24** | **Oct-24** |
| **Pond1** | 32.07±0.03c | 36.7±0.00a | 27.73±0.03a | 33.27±0.12a | 33.23±0.07a | 34.33±0.09b |
| **Pond2** | 30.67±0.17a | 37.20±0.06b | 28.6±0.06b | 36.07±0.03c | 33.10±0.06a | 35.03±0.03c |
| **Pond3** | 31.27±0.03b | 36.77±0.03a | 29.27±0.03c | 35.7±0.23b | 33.13±0.03a | 34.00±0.06a |

*\**Values are presented as Mean ± S.E. (*P*<0.05; n = 10)

**Table 2. Mean transparency(cm) ± standard error (SE) recorded in Pond 1, Pond 2, and Pond 3 at monthly intervals from May 2024 to October 2024**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | **May-24** | **Jun-24** | **Jul-24** | **Aug-24** | **Sep-24** | **Oct-24** |
| **Pond1** | 22.67±0.33b | 24.67±0.33b | 23.67±0.00b | 20.67±0.33a | 22.67±0.33a | 29.33±0.33a |
| **Pond2** | 21.00±0.00a | 23.67±0.33ab | 21.00±0.00a | 22.33±0.33b | 23.67±0.33a | 29.00±0.00a |
| **Pond3** | 22.33±0.33b | 22.67±0.33a | 24.67±0.00c | 27.33±0.33c | 26.67±0.33b | 30.67±0.33b |

*\**Values are presented as Mean ± S.E. (*P*<0.05; n = 10)

**Table 3. Mean pH ± standard error (SE) recorded in Pond 1, Pond 2, and Pond 3 at monthly intervals from May 2024 to October 2024**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | **May-24** | **Jun-24** | **Jul-24** | **Aug-24** | **Sep-24** | **Oct-24** |
| **Pond1** | 8.73±0.07b | 9.53±0.2b | 7.77±0.03b | 10.33±0.03b | 8.83±0.09a | 9.43±0.07a |
| **Pond2** | 8.20±0.06a | 8.37±0.03a | 7.50±0.06a | 9.73±0.03a | 8.80±0.06a | 9.30±0.00a |
| **Pond3** | 8.07±0.03a | 8.47±0.03a | 7.57±0.03a | 10.30±0.1b | 8.97±0.03a | 9.30±0.06a |

*\**Values are presented as Mean ± S.E. (*P*<0.05; n = 10)

**Table 4. Mean dissolve oxygen (ppm) ± standard error (SE) recorded in Pond 1, Pond 2, and Pond 3 at monthly intervals from May 2024 to October 2024**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | **May-24** | **Jun-24** | **Jul-24** | **Aug-24** | **Sep-24** | **Oct-24** |
| **Pond1** | 5.00±0.00b | 5.33±0.17b | 5.00±0.00a | 5.83±0.17b | 6.17±0.17b | 6.83±0.17a |
| **Pond2** | 4.17±0.17a | 4.50±0.29a | 5.00±0.00a | 4.83±0.17a | 5.17±0.17a | 6.33±0.17a |
| **Pond3** | 4.67±0.17b | 5.83±0.17b | 5.50±0.00a | 4.83±0.17a | 5.67±0.17ab | 6.33±0.33a |

*\**Values are presented as Mean ± S.E. (*P*<0.05; n = 10)

**Table 5. Mean Ammonia ± standard error (SE) recorded in Pond 1, Pond 2, and Pond 3 at monthly intervals from May 2024 to October 2024**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | **May-24** | **Jun-24** | **Jul-24** | **Aug-24** | **Sep-24** | **Oct-24** |
| **Pond1** | 0.42±0.03b | 0.45±0.00b | 0.05±0.00a | 0.05±0.01a | 0.05±0.00a | 0.78±0.03a |
| **Pond2** | 0.05±0.00a | 0.05±0.00a | 0.05±0.00a | 0.93±0.07b | 0.08±0.02a | 0.67±0.03a |
| **Pond3** | 0.42±0.03b | 0.45±0.00b | 0.06±0.00a | 0.68±0.32ab | 0.06±0.01a | 0.77±0.03a |

*\**Values are presented as Mean ± S.E. (*P*<0.05; n = 10)

**Table 6. Mean nitrate (ppm) ± standard error (SE) recorded in Pond 1, Pond 2, and Pond 3 at monthly intervals from May 2024 to October 2024**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | **May-24** | **Jun-24** | **Jul-24** | **Aug-24** | **Sep-24** | **Oct-24** |
| **Pond1** | 0.53±0.03a | 0.43±0.07a | 0.47±0.02a | 0.48±0.02b | 1.87±0.07b | 2.00±0.00a |
| **Pond2** | 0.57±0.03a | 0.77±0.15b | 0.48±0.02a | 0.13±0.02a | 1.33±0.17a | 2.83±0.17b |
| **Pond3** | 0.93±0.07b | 1.00±0.00b | 1.83±0.17b | 2.00±0.00c | 1.90±0.05b | 2.17±0.17a |

*\**Values are presented as Mean ± S.E. (*P*<0.05; n = 10)

**Table 7. Mean nitrite (ppm) ± standard error (SE) recorded in Pond 1, Pond 2, and Pond 3 at monthly intervals from May 2024 to October 2024**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | **May-24** | **Jun-24** | **Jul-24** | **Aug-24** | **Sep-24** | **Oct-24** |
| **Pond1** | 0.17±0.03a | 0.26±0.00b | 0.17±0.03a | 0.26±0.00b | 0.25±0.00a | 0.23±0.03a |
| **Pond2** | 0.20±0.00a | 0.20±0.00a | 0.17±0.02a | 0.13±0.02a | 0.15±0.00a | 0.31±0.02a |
| **Pond3** | 0.42±0.03b | 0.25±0.00b | 0.45±0.00b | 0.42±0.02c | 0.20±0.00a | 0.27±0.03a |

*\**Values are presented as Mean ± S.E. (*P*<0.05; n = 10)

**Table 8. Month-wise Variation in Phytoplankton Population Density (Cell/ml) in Krishna, Bramhan, and Pathan Ponds during Study Period.**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **S. No.** | **Phytoplankton** | **May** | **June** | **July** | **August** | **September** | **October** | **Krishna Pond (P1)** | **Bramhan Pond (P2)** | **Pathan Pond (P3)** |
| **A. Chlorophyceae** | |  |  |  |  |  |  |  |  |  |
| 1 | Chlorella sp. | 10 | 11 | 15 | 14 | 15 | 25 | 90 | 96 | 90 |
| 2 | Cosmarium sp. | 5 | 10 | 14 | 15 | 11 | 22 | 77 | 82 | 96 |
| 3 | Microspora sp. | 7 | 9 | 12 | 17 | 24 | 19 | 88 | 105 | 109 |
| 4 | Spyrogyra sp. | 3 | 5 | 8 | 13 | 20 | 24 | 73 | 73 | 77 |
| 5 | Volvox sp. | 9 | 13 | 19 | 26 | 32 | 30 | 129 | 112 | 117 |
| 6 | Zygnema sp. | 1 | 10 | 18 | 21 | 27 | 29 | 106 | 106 | 123 |
| 7 | Pedistarium sp. |  |  |  |  |  |  |  |  | 100 |
| **B. Cynophyceae** | |  |  |  |  |  |  |  |  |  |
| 8 | Anabaena sp. | 3 | 5 | 10 | 23 | 20 | 25 | 86 | 88 | 67 |
| 9 | Notoc sp. | 1 | 7 | 12 | 19 | 23 | 32 | 94 | 100 | 70 |
| 10 | Oscillatoria sp. | 0 | 1 | 5 | 12 | 13 | 19 | 50 | 61 | 54 |
| **C. Bacillariophyceae** | |  |  |  |  |  |  |  |  |  |
| 11 | Diatoma sp. | 1 | 0 | 4 | 12 | 19 | 20 | 56 | 68 | 85 |
| 12 | Microcystis sp. | 2 | 4 | 8 | 13 | 17 | 24 | 68 | 79 | 75 |
| 13 | Nitzschia sp. | 3 | 6 | 10 | 17 | 9 | 21 | 66 |  | 81 |
| **D. Euglenophyceae** | |  |  |  |  |  |  |  |  |  |
| 14 | Euglena sp. | 3 | 0 | 12 | 18 | 24 | 22 | 79 | 80 | 73 |
| **Total (Phytoplankton count per litre)** | | **48** | **81** | **147** | **220** | **254** | **312** | **1062** | **1050** | **1217** |

**Table 9. Month-wise Variation in Zooplankton Population Density (Cell/ml) in Krishna, Bramhan, and Pathan Ponds during Study Period**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **S. No.** | **Zooplankton** | **May** | **June** | **July** | **August** | **September** | **October** | **Total (Krishna)** | **Total (Bramhan)** | **Total (Pathan)** |
| **A. Cladocera** |  |  |  |  |  |  |  |  |  |  |
| 1 | Daphnia sp. | 5 | 11 | 12 | 16 | 20 | 23 | 87 | 109 | 108 |
| 2 | Leydigia sp. | 2 | 3 | 10 | 13 | 24 | 32 | 84 | 91 | 110 |
| 3 | Moina sp. | 5 | 10 | 13 | 12 | 23 | 36 | 99 | 103 | 105 |
| **B. Rotifera** |  |  |  |  |  |  |  |  |  |  |
| 4 | Brachionus sp. | 2 | 4 | 4 | 13 | 16 | 25 | 64 | 65 | 66 |
| 5 | Keratella sp. | 4 | 7 | 12 | 16 | 17 | 22 | 78 | 88 | 84 |
| **C. Copepoda** |  |  |  |  |  |  |  |  |  |  |
| 6 | Calanoid sp. | 0 | 5 | 11 | 14 | 23 | 34 | 87 | 90 | 97 |
| 7 | Cyclops sp. | 2 | 4 | 5 | 12 | 13 | 24 | 60 | 61 | 68 |
| 8 | Mesocyclops sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 71 | 86 |
| 9 | Pseudodiaoptomus sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 32 | 37 |
| **D. Ostracoda** |  |  |  |  |  |  |  |  |  |  |
| 10 | Cypris sp. | 10 | 9 | 14 | 20 | 26 | 36 | 115 | 113 | 113 |
| **Total zooplankton count per litre** | | **30** | **53** | **81** | **116** | **162** | **232** | **674** | **823** | **874** |

**Fig. 01. Temperature variations (°C) across three ponds (Pond1, Pond2, and Pond3) at six time intervals (May-24 to Oct-24)**

*Bars represent mean temperature values ± SE. Different letters denote significant differences (P < 0.05) among ponds within each time interval.*

**Fig. 02. Transparency (cm) variations across three ponds (Pond1, Pond2, and Pond3) at six time intervals (May-24 to Oct-24)**

*Bars represent mean transparency values ± SE. Different letters denote significant differences (P < 0.05) among ponds within each time interval.*

**Fig. 03. pH variations across three ponds (Pond1, Pond2, and Pond3) at six time intervals (May-24 to Oct-24)**

*Bars represent mean pH values ± SE. Different letters denote significant differences (P < 0.05) among ponds within each time interval.*

**Fig. 04. Dissolved oxygen (ppm) variations across three ponds (Pond1, Pond2, and Pond3) at six time intervals (May-24 to Oct-24)**

*Bars represent dissolve oxygen values ± SE. Different letters denote significant differences (P < 0.05) among ponds within each time interval.*

**Fig. 05. Ammonia (ppm) variations across three ponds (Pond1, Pond2, and Pond3) at six time intervals (May-24 to Oct-24)**

*Bars represent mean ammonia values ± SE. Different letters denote significant differences (P < 0.05) among ponds within each time interval.*

**Fig. 06. Nitrate (ppm) variations across three ponds (Pond1, Pond2, and Pond3) at six time intervals (May-24 to Oct-24)**

*Bars represent mean nitrate values ± SE. Different letters denote significant differences (P < 0.05) among ponds within each time interval.*

**Fig. 07. Nitrite (ppm) variations across three ponds (Pond1, Pond2, and Pond3) at six time intervals (May-24 to Oct-24)**

*Bars represent mean nitrite values ± SE. Different letters denote significant differences (P < 0.05) among ponds within each time interval.*

**Fig. 08. Contribution (%) of different orders of Phytoplankton species in Krishna pond, Waraseoni, Balaghat**

**Fig. 09. Contribution (%) of different orders of Phytoplankton species in Bramhan pond, Waraseoni, Balaghat**

**Fig. 10. Contributionn (%) of different orders of Phytoplankton species in Pathan pond, Waraseoni, Balaghat**

**Fig. 11. Contributionn (%) of different orders of Zooplankton species in Krishna pond, Waraseoni, Balaghat**

**Fig. 12. Contributionn (%) of different orders of Zooplankton species in Bramhan pond,Waraseoni,Balaghat**

**Fig. 13. Contributionn (%) of different orders of Zooplankton species in Pathan pond, Waraseoni, Balaghat**

4. Conclusion

The study underscores the significant impact of anthropogenic aquaculture practices on water quality and fish growth in Balaghat District, Madhya Pradesh. Significant variations were observed in water quality, phytoplankton and zooplankton densities, across Krishna (P1), Bramhan (P2), and Pathan ponds (P3). Pathan Pond (P3) demonstrated the highest water quality and fish productivity, while Bramhan Pond (P2) showed lower dissolved oxygen (DO) levels, likely due to local aquaculture mismanagement, including sewage discharge. The comparison data revealed improvements in water quality and fish productivity, reflecting the positive impact of scientific interventions. Ongoing monitoring and targeted interventions are essential to further enhance sustainability, fish production, and the livelihoods of fish farmers. The findings emphasize the importance of adopting sustainable aquaculture practices and conducting regular water quality assessments to improve fish productivity and maintain ecological stability, offering valuable insights for enhancing sustainability and supporting local fish farmers.

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