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## Utilization of Abandoned Sand Mining Ponds for Sustainable Indian Major Carp Aquaculture: A Potential Aquaculture Model in Purba Medinipur, West Bengal

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### Abstract

Present study was conducted in abandoned sand pit ponds located in the village Depal, Purba Medinipur, West Bengal for a period of two years June, 2024 to May, 2026. The study focuses on utilization of abandoned sand mining ponds for sustainable Indian Major Carp (IMC) Aquaculture. The investigation demonstrates both water and soil quality remained within the favourable ranges throughout the culture period despite seasonal variations. Water quality maintained near neutral pH, adequate dissolved oxygen and good buffering capacity, while soil exhibited near neutral pH, improved organic carbon and balanced nutrient status, indicating good fertility. The composite fish culture system achieved a 90% survival rate with efficient feed utilization. Among the cultured species, *Catla catla* showed the highest growth performance and feed conversion efficiency, whereas *Labeo rohita* and *Cirrhinus mrigala* also exhibited satisfactory growth under the prevailing culture conditions.

**Keywords:** Indian major carp, composite fish culture, abandoned sand mining ponds, sustainable aquaculture, aquaculture rehabilitation, freshwater aquaculture, pond water quality, soil quality, fish growth performance, feed conversion ratio, survival rate, carp polyculture, sand pit ponds, Purba Medinipur, West Bengal

### Introduction

Aquaculture has emerged as one of the fastest growing food production sectors in India, contributing significantly to fish supply, employment generation, nutritional security, and rural economic development. India is among the leading aquaculture producing countries of the world, with freshwater aquaculture contributing the major share of inland fish production. The expansion of aquaculture has been driven by the adoption of scientific culture practices, improved seed production, feed technology, and better pond management strategies (FAO, 2024) <sup>[12]</sup>. The total global fisheries and aquaculture production is 223.2 million tonnes and the global aquaculture production reached an all-time high of 130.9 million tonnes in 2022, comprising 94.4 million tonnes of aquatic animals and 36.5 million tonnes of algae, with an estimated first sale value of USD 312.8 billion. For the first time history, aquaculture contributed 51% of the world's aquatic animal production, surpassing capture fisheries and highlighting its increasingly important role in ensuring global food security and sustainable aquatic food systems (FAO, 2024) <sup>[12]</sup>.

Indian aquaculture is predominantly based on freshwater pond culture, especially the polyculture of Indian Major Carps (IMC), including *Catla catla*, *Labeo rohita* and *Cirrhinus mrigala*. These species are preferred due to their complementary feeding habits, efficient utilization of pond resources, fast growth, and suitability under Indian climate conditions (Jhingran, 1991) <sup>[16]</sup>. Carp based aquaculture systems have played a key role in increasing fish productivity from small and medium sized water bodies. The India aquaculture sector has experienced remarkable growth due to the availability of improved fish seed, expansion of culture areas, and increasing adoption of intensive and semi-intensive production systems (Ayyappan and Jena, 2003; Katiha *et al.*, 2005; Jayasankar, 2018) <sup>[1, 15, 18]</sup>. Kumar *et al* (2018) <sup>[22, 23]</sup> reported that inland aquaculture, particularly carp culture, has become a major contributor to India's fisheries production and livelihood support systems, sustainable

utilization of unused and degraded water bodies, including abandoned mining pits and sand quarry ponds, has recently gained attention as an alternative approach for increasing aquaculture production. Conversion of such water bodies into scientifically managed fish culture systems can enhance resource utilization, restore degraded landscapes, and provide livelihood opportunities (FAO, 2024) [12]. According to Ayyappan and Jena (2003) [1], scientific management practices such as proper stocking density, balanced fertilization, supplementary feeding, and water quality management can substantially enhanced fish yield from freshwater ponds.

Indian major carp (IMC) fingerlings are in high demand across the Indian subcontinent as stocking materials for table size fish production. Fry rearing is a critical phase in carp aquaculture, aimed at achieving higher survival rates and optimum growth for the production of healthy fingerlings suitable for stocking. The success of fry rearing largely depends on the availability of adequate quantities of suitable natural food organisms, particularly zooplankton, which serve as an essential dietary component during the early growth states of fish (Jhingran and Pullin, 1985; Chakrabarti and Jena, 1998; Rahman *et al.*, 2017 [28]; Sinha *et al.*, 2026) [7, 17, 39]. In any culture systems, the pond preparation is the most important factors because, through the pond preparation time application of organic and inorganic fertilizers is an economical and effective approach for enhancing primary productivity and promoting natural food availability in aquaculture systems (Sinha *et al.*, 2025) [37, 38]. However, excessive fertilization may adversely affect water quality Garg and Bhatnagar (1996) [14] and lead to a reduction in dissolved oxygen levels, creating stressful conditions for cultured fish. In intensive pond farming systems, the benefits of fertilization are often increased nutrient loading and associated ecological imbalances (Steffens, 1990) [40]. Pond fertilization rate varies with temperature, pond nutrient composition and water quality. Fertilization and manuring should be carried out every month to increase the productivity of the pond. The primary considerations for choosing a pond are that the soil should

not be located in an area that is prone to flooding. But here the abandoned ponds after sand mining are converted to cultivable ponds to use them for aquaculture.

Moreover, higher stocking densities may result in increased competition for available natural food resources, leading to a decline in the standing crop of natural fish food organisms. Therefore, the application of supplementary artificial feed becomes necessary to meet the nutritional requirements of cultured fish and enhance aquaculture production. The present investigation was undertaken to evaluate the growth performance of Indian major carps, namely *Catla catla*, *Labeo rohita*, *Cirrhinus mrigala*, fed with locally prepared and commercial feeds, as these species are among the most important commercially cultured fishes with high market demand.

## Materials and Methods

### Study area

The site selection is one of the most important factors that determine the success of the fish farming. Before the selection of the pond, the water holding capacity and fertility of the soil was considered to be the most crucial step in this regard as these factors influence the response to the organic and inorganic fertilization in the farming ponds. As per report by the Telegraph newspaper dated 05.1.2021 in West Bengal there are about 900 sand mines. The sand mines, are locally called as bali khadan. The bali khadan areas in Purba Medinipur district around 100 hectares. The major areas are CD-Block of Ramnagar I (about 25.08 hectare), Ramnagar - II (about 62.71 hectare), Egra - I (about 12.54 hectare) and Haldia (about 12.54 hectare). These Bali khadans are under the clutches private ownership but mining activities are regulated by the State govt. These areas after sand mining the abandoned lands are filled by rainwater and converted into ponds or Dighi. Present investigation was carried out in abandoned sand pit or bali khadan (Lat- 21.728068°N and Long- 87.549863°E) located at Depal under community development block of Ramnagar - II, Purba Medinipur.

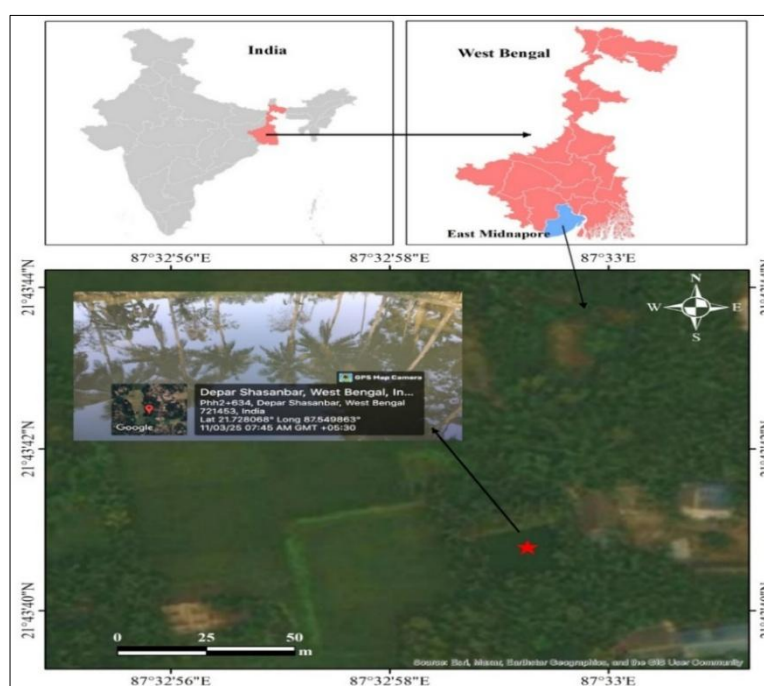


Fig 1: Study site

Experimental designs

The experiment was conducted in a sand pit pond from June, 2024 to May, 2026 covering an area of was 500 m<sup>2</sup>. After pond preparation, pond was stocked with 300 No's *Catla catla* species, 300 No's *Cirrhinus mrigala* species, and 1900 No's *Labeo rohita* species and cultured for one year. The experimental pond was supplemented with feed at the rate of 4% of the fish body weight. The feeding rate was adjusted monthly based on the measurement of the fresh body weight of the fish. Fish growth was measured in terms of increased in body weight by randomly capturing individuals' fish of each species from the pond on every month throughout the experimental period. After recording the growth parameters, the fish were released back into the pond.

Results and Discussion

The present study evaluated growth performances of three cultured fish species in abandoned sand mining pond

converted into aquaculture ponds.

A. *Catla catla*

The initial average body weights of the *Catla catla* were recorded as 72 grams and the final body weight was 685 grams. They gain average weight 613gram in the period of one year.

B. *Labeo rohita*

The initial average body weights of the *Labeo rohita* were recorded as 62 grams and the final body weight was 580 grams. They gain average weighs 518 gram in the period of one year.

C. *Cirrhinus mrigala*

The initial average body weights of the *Labeo rohita* were recorded as 65 grams and the final body weight was 590 grams. They gain average weighs 525 gram in the period of one year.

Table 1: Growth parameters of IMC in sand mining pond from June, 2025 to May 2026

|                               | Fish Species       |                     |                          | Total   |
|-------------------------------|--------------------|---------------------|--------------------------|---------|
|                               | <i>Catla catla</i> | <i>Labeo rohita</i> | <i>Cirrhinus mrigala</i> |         |
| No. of fishes stocked         | 300                | 1900                | 300                      | 2,500   |
| Initial average weight (g)    | 72                 | 62                  | 65                       | 199     |
| Initial Biomass (kg)          | 21.6               | 117.8               | 19.5                     | 158.1   |
| Survival Rate (%)             | 90                 |                     |                          |         |
| Total feed used (kg)          | 2340               |                     |                          |         |
| Final average body weight (g) | 685                | 580                 | 590                      | 1855    |
| Gain average body weight      | 613                | 518                 | 525                      | 1662    |
| Final Biomass (kg)            | 184.95             | 991.8               | 159.3                    | 1336.05 |
| Total SGR (%)                 | 0.62               | 0.61                | 0.60                     |         |
| FCR                           | 1.71               | 1.74                | 1.80                     |         |

Growth performance, survival, and feed utilization of the three cultured fish species - *Catla catla*, *Labo rohita*, and *Cirrhinus mrigala* is presented in Table 1. A total of 2,500 fishes were stocked, comprising 300 *Catla catla*, 1900 *Labeo rohita*, and 300 *Cirrhinus mrigala*. The stocking ratio reflects the common composite fish culture practices performed by the local fish farmers, where *Labeo rohita* is stocked at a higher proportion because of its superior growth and market demand. The initial average body weights were 72g for *Catla catla*, 62 grams for *Labeo rohita*, and 65 grams for *Cirrhinus mrigala*. The overall survival rate was 90% indicating favourable environmental conditions and effective pond management throughout the culture period. The total feed supplied during the culture period was 2,340kg. Adequate feed availability contributed significantly to the observed increase in body weight and biomass across all species.

Among the three species, *Catla catla* attained the highest final average body weight (685g), followed by *Cirrhinus mrigala* (590g) and *Labo rohita* (580g). Correspondingly, the average weight gain was highest in *Catla catla* (613g),

followed by *Cirrhinus mrigala* (525g) and *Labeo rohita* (518g). The superior weight gain of *Catla catla* indicates its faster growth potential under the prevailing culture conditions, which may be attributed to its efficient utilization of available feed and favourable adaptation to the culture environment. The specific growth rate (SGR) was relatively similar among the three species, with values of 0.62% day<sup>-1</sup> for *Catla catla*, 0.61% day<sup>-1</sup> for *Labeo rohita*, and 0.60% day<sup>-1</sup> for *Cirrhinus mrigala*. Feed conversion ratio (FCR) values ranges from 1.71 to 1.80. The lowest FCR was observed in *Catla catla* (1.71), followed by *Labeo rohita* (1.74), while *Cirrhinus mrigala* recorded the highest FCR (1.80). Lower FCR values indicate better feed utilization efficiency; therefore, *Catla catla* converted feed into body mass more efficiently than the other two species.

Study of growth parameter of fish

At the time of the final harvest, the mean weight gain (g), specific growth rate (SGR), feed conversion ratio (FCR), and survival rate were recorded. Growth parameter calculated using the following formula:

Weight gain (g) = Mean final weight (g) - Mean initial weight (g)

Specific growth rate (SGR %) =  $\frac{\ln(\text{final weight}) - \ln(\text{initial weight})}{\text{Final day} - \text{Initial day}} \times 100$

Total Feed Consumed =  $\frac{\text{Initial body weight} \times \text{feed given @ 4\%body weight} \times \text{experimental days}}{100}$

FCR =  $\frac{\text{Amount of fed (dry weight basis)}}{\text{Net weight gain (wet weight basis)}}$

**Table 2:** Physico chemical parameter of water from June 2024- May 2026

| TIME            | pH          | Temp (°C)    | Dissolved Oxygen (mg/lit) | Free CO <sub>2</sub> (mg/lit) | Alkalinity (mg/lit) |
|-----------------|-------------|--------------|---------------------------|-------------------------------|---------------------|
| June, 2024      | 7.89 ± 0.17 | 31.44 ± 1.51 | 6.5 ± 0.07                | 3.9 ± 0.04                    | 100 ± 8.01          |
| July, 2024      | 6.77 ± 0.08 | 30.38 ± 1.50 | 4.6 ± 0.05                | 3.2 ± 0.04                    | 119 ± 8.95          |
| August, 2024    | 6.90 ± 0.09 | 29.89 ± 1.49 | 5.32 ± 0.06               | 2.6 ± 0.03                    | 123 ± 9.05          |
| September, 2024 | 6.99 ± 0.09 | 27.89 ± 1.47 | 5.72 ± 0.06               | 2.7 ± 0.03                    | 126 ± 9.13          |
| October, 2024   | 7.0 ± 0.10  | 26.55 ± 1.45 | 4.90 ± 0.05               | 2.5 ± 0.03                    | 119 ± 8.95          |
| November, 2024  | 7.32 ± 0.13 | 25.01 ± 1.43 | 5.89 ± 0.06               | 2.78 ± 0.03                   | 125 ± 9.08          |
| December, 2024  | 6.72 ± 0.08 | 22.03 ± 1.42 | 5.50 ± 0.06               | 3.88 ± 0.04                   | 119 ± 8.95          |
| January, 2025   | 6.64 ± 0.07 | 22.89 ± 1.42 | 5.21 ± 0.06               | 3.67 ± 0.04                   | 109 ± 8.35          |
| February, 2025  | 6.98 ± 0.10 | 24.77 ± 1.43 | 5.15 ± 0.05               | 3.00 ± 0.04                   | 100 ± 8.01          |
| March, 2025     | 7.15 ± 0.12 | 29.9 ± 1.49  | 5.86 ± 0.06               | 2.32 ± 0.03                   | 90 ± 7.95           |
| April, 2025     | 7.55 ± 0.16 | 26.78 ± 1.45 | 5.63 ± 0.06               | 2.45 ± 0.03                   | 100 ± 8.01          |
| May, 2025       | 6.94 ± 0.10 | 28.77 ± 1.48 | 4.90 ± 0.05               | 2.98 ± 0.03                   | 117 ± 8.91          |
| June, 2025      | 6.71 ± 0.08 | 29.99 ± 1.50 | 5.42 ± 0.06               | 3.65 ± 0.04                   | 116 ± 8.90          |
| July, 2025      | 6.44 ± 0.06 | 30.33 ± 1.50 | 5.33 ± 0.06               | 3.79 ± 0.04                   | 110 ± 8.42          |
| August, 2025    | 6.87 ± 0.08 | 31.55 ± 1.51 | 5.27 ± 0.06               | 3.88 ± 0.04                   | 106 ± 8.30          |
| September, 2025 | 6.83 ± 0.08 | 28.78 ± 1.48 | 5.65 ± 0.06               | 3.99 ± 0.05                   | 114 ± 8.88          |
| October, 2025   | 6.88 ± 0.08 | 27.42 ± 1.47 | 5.87 ± 0.06               | 4.00 ± 0.05                   | 118 ± 8.93          |
| November, 2025  | 6.95 ± 0.09 | 26.43 ± 1.46 | 5.67 ± 0.06               | 3.54 ± 0.04                   | 113 ± 8.88          |
| December, 2025  | 6.90 ± 0.09 | 24.32 ± 1.43 | 4.99 ± 0.05               | 3.32 ± 0.04                   | 108 ± 8.33          |
| January, 2026   | 6.84 ± 0.08 | 23.69 ± 1.42 | 5.11 ± 0.06               | 3.67 ± 0.04                   | 109 ± 8.35          |
| February, 2026  | 6.88 ± 0.09 | 24.69 ± 1.43 | 5.25 ± 0.05               | 3.23 ± 0.04                   | 103 ± 8.01          |
| March, 2026     | 7.11 ± 0.12 | 27.19 ± 1.47 | 5.76 ± 0.06               | 2.82 ± 0.03                   | 98 ± 7.95           |
| April, 2026     | 7.45 ± 0.15 | 26.68 ± 1.45 | 5.83 ± 0.06               | 2.58 ± 0.03                   | 106 ± 8.01          |
| May, 2026       | 6.83 ± 0.09 | 27.65 ± 1.46 | 4.99 ± 0.05               | 2.88 ± 0.03                   | 121 ± 8.91          |

Table 2 represents the seasonal variations in the physico chemical characteristics of water in sand mining pond including pH, temperature, dissolved oxygen (DO), free carbon dioxide (CO<sub>2</sub>) and alkalinity, from June 2024 to May 2026. These parameters are important indicators of water quality and directly influence biological productivity, aquatic metabolism and ecosystem stability.

### Water pH

The pH of the water varied from  $6.38 \pm 0.08$  to  $7.89 \pm 0.17$  during the study period. The highest pH was recorded in June 2024 ( $7.89 \pm 0.17$ ), while the lowest value was observed in September 2025 and May 2026 ( $6.83 \pm 0.08$ ). Throughout the study, the water remained slightly acidic to slightly alkaline, which is considered suitable for most aquatic organisms. Higher pH values during summer months may be attributed to increased photosynthetic activity that removes carbon dioxide from the water, thereby reducing carbonic acid concentration. In contrast, lower pH values observed during the monsoon and post monsoon periods may result from runoff carrying organic matter and increased decomposition processes that release carbon dioxide into the water. Ideal pH of pond water ranges in between 7.5 to 8.5 for the optimal growth of fishes in freshwater composite culture farms of Indian Major carp (Santhosh and Singh, 2007<sup>[33]</sup>; Manjulakshmi *et al.*, 2014)<sup>[25]</sup>. Maintaining water pH 7.0-9.0 is central to breeding, fish health and feed utilization and nutrition, and culture practices of Indian major carps for sustainable aquaculture (Manam & Quraishi, 2024<sup>[24]</sup>; Yusoff *et al.*, 2024<sup>[44]</sup>; Sinha and Banerjee, 2025; Ganesh *et al.*, 2026)<sup>[13, 37, 38]</sup>. Other workers also reported ideal pH values for IMC culture in their investigations, 7 to 8.5 (Bhatanagar and Devi, 2013), 6.24 to 6.68 (Keremah *et al.*, 2014)<sup>[19]</sup>; 7.4-8 (Chibhade *et al.*, 2020)<sup>[8]</sup> and 7.60-8.30 (Ujjania *et al.*, 2026)<sup>[42]</sup>.

### Water temperature

Water temperature showed marked seasonal variation, ranging from  $22.03 \pm 1.42^\circ\text{C}$  in December 2024 to  $31.44 \pm 1.51^\circ\text{C}$  in June 2024. Elevated temperature was generally

recorded during summer months, whereas lower temperature occurred during winter. Temperature is a critical environmental factor affecting metabolic activities, nutrient cycling, and dissolved gas concentrations. The observed seasonal pattern reflects normal climate fluctuations and is consistent with the thermal characteristics of tropical freshwater ecosystem. Increased temperature during summer likely accelerated biological and chemical processes, while lower winter temperature reduced metabolic activity. The required water temperature for IMC culture ranges in between 20- 33 °C (Das *et al.*, 2004; Ramakrishna *et al.*, 2013<sup>[30]</sup>; Chibhade *et al.*, 2020; Roy *et al.*, 2023; Manam & Quraishi, 2024)<sup>[8, 10]</sup>. Other investigations reported quite extreme values in water temperature for IMC culture, 15 °C to 31 °C (Bhatanagar and Devi, 2013), 16 °C to 31 °C (Bhattacharyya and Ghosh, 2018)<sup>[5, 6]</sup> and 30.80 - 39.00 °C (Ujjania *et al.*, 2026)<sup>[42]</sup>.

### Dissolved oxygen

Dissolved oxygen concentration ranged from  $4.90 \pm 0.05$  mg /L in October 2024 to  $6.50 \pm 0.07$  mg/L in June 2024. A general decline in DO was observed during warmer months, while relatively higher concentrations occurred during cooler periods and times of enhanced water mixing. The inverse relationship between temperature and dissolved oxygen is well documented, as oxygen solubility decreased with increasing temperature. Additionally, decomposition of organic matter and microbial respiration may contribute to oxygen depletion during certain periods. Despite seasonal fluctuations the recorded DO levels remained within a range capable of supporting aquatic life. The ideal dissolved oxygen range 5-10 mg/L is central to breeding, fish health, feed utilization and nutrition, and sustainable culture practices of IMC (Dineshkumar *et al.*, 2017<sup>[21]</sup>; Sultana *et al.*, 2017<sup>[41]</sup>; Manam & Quraishi, 2024<sup>[24]</sup>; Yusoff *et al.*, 2024<sup>[44]</sup>; Sinha and Banerjee, 2025<sup>[37, 38]</sup>; Ganesh *et al.*, 2026; Ujjania *et al.*, 2026)<sup>[13, 42]</sup>. Dissolved oxygen concentration should be maintained around 5 mg/L to improve nutrient distribution (Kestemont, 1995<sup>[20]</sup>; De

Oliveira *et al.*, 2019; Yusoff *et al.*, 2024 <sup>[44]</sup>; Sinha and Banerjee 2025) <sup>[11, 37, 38]</sup>. As per report Bhagde *et al.* (2020) <sup>[3]</sup> the dissolved oxygen concentration varied in between 3.6 mg/L to 7.9 mg/L in the freshwater ponds from Sangamner Taluka of Ahmednagar, Maharashtra, India.

**Free carbon dioxide (co2)**

Free carbon dioxide content varied from 2.32 ± 0.03mg/L in March to 4.00 ±0.04 mg/L in June 2024 and October 2025. Higher concentrations of free CO<sub>2</sub> were generally observed during periods of increased decomposition and respiration, whereas lower values corresponded to periods of active photosynthesis. The fluctuations in CO<sub>2</sub> levels indicate dynamic interactions between biological production and respiration within the aquatic ecosystem. The inverse relationship observed between pH and free carbon dioxide further supports the role of carbon dioxide in regulating water acidity. The range of free carbon dioxide was varied in between 4.0 to 8mg/L in the pond environment (Sayeswara, 2011 <sup>[34]</sup>; Shandilya and Patralekh, 2021) <sup>[35]</sup>. The range of free carbon dioxide varied in between 2.8 to 10.2 mg/L of pond water in Purba, Barddhanman, West Bengal, India (Bhattacharyya, 2018) <sup>[5, 6]</sup>. Slight higher values of free carbon dioxide reported by Roy *et al.* (2023) with in the range of 6.40mg/L to 11.75mg/L in fish ponds located in the District of Birbhum, West Bengal.

**Alkalinity**

Total alkalinity ranged from 90±7.95 mg/L in March 2025 to 126±9.13 mg/L in September 2024. The relatively high alkalinity values recorded during the monsoon and post monsoon periods may be attributed to runoff carrying bicarbonates, carbonates, and other dissolved minerals into the water body. Lower alkalinity utilization of bicarbonate ions. The moderate alkalinity levels observed throughout the study indicates good buffering capacity, enabling the water body to resist sudden changes in pH. 50-300 mg/L of water alkalinity is essential for IMC culture (Manam & Quraishi, 2024) <sup>[24]</sup>. While, Chibhade *et al.*, (2020) <sup>[8]</sup> mentioned optimum water alkalinity100-140 mg/L, of freshwater fish farms of Raigad District of Maharashtra. Suitable alkalinity is in between 75- 200 mg/L, but not less than 20 mg/L is ideal in an aquaculture pond (Wurts and Durborow, 1992) <sup>[43]</sup>. The ideal alkalinity range for freshwater aquaculture was 30- 180 mg/L (Santhosh and Singh, 2007) <sup>[33]</sup> and 69. 30 to 100.00 mg/L (Roy *et al.*, 2023). The total alkalinity values reported within the range of 85 - 210 mg/L in ponds of Basudevpur Block, Bhadark District Parida *et al.* (1999) <sup>[26]</sup>. Rana and Jain (2017) <sup>[31]</sup> documented the total alkalinity value 54 to198 mg/L in all ponds of district Bijnor (U.P), India. Bhagde *et al.*, (2020) <sup>[3]</sup> showed that the low alkalinity ranges 140 mg/L and the high range of 330 mg/L in the freshwater ponds of Ahmednagar, Maharashtra, India.

**Table 3:** Physico chemical parameter of soil from June 2024- May 2026

| Time            | pH          | Organic carbon (%) | Nitrogen (mg/100gm) | Phosphorus (mg/100gm) | Potassium (mg/100gm) |
|-----------------|-------------|--------------------|---------------------|-----------------------|----------------------|
| June,2024       | 7.36 ± 0.14 | 0.87 ± 0.01        | 30.24 ± 1.50        | 2.90 ± 0.03           | 10.20 ± 0.21         |
| July,2024       | 7.19 ± 0.13 | 0.99 ± 0.01        | 28.21 ± 1.45        | 3.19 ± 0.04           | 11.89 ± 0.23         |
| August,2024     | 7.02 ± 0.11 | 1.20 ± 0.02        | 27.76 ± 1.41        | 3.88 ± 0.04           | 11.65 ± 0.23         |
| September,2024  | 7.00 ± 0.10 | 1.10 ± 0.02        | 28.89 ± 1.46        | 4.55 ± 0.04           | 12.01 ± 0.24         |
| October,2024    | 6.80 ± 0.09 | 1.50 ± 0.02        | 28.65 ± 1.45        | 4.89 ± 0.04           | 12.87 ± 0.25         |
| November,2024   | 6.70 ± 0.08 | 1.67 ± 0.02        | 29.54 ± 1.47        | 4.90 ± 0.04           | 12.99 ± 0.26         |
| December,2024   | 6.87 ± 0.09 | 1.34 ± 0.02        | 29.89 ± 1.48        | 5.67 ± 0.05           | 11.91 ± 0.24         |
| January,2025    | 6.97 ± 0.10 | 1.09 ± 0.02        | 30.45 ± 1.50        | 5.91 ± 0.05           | 12.89 ± 0.25         |
| February,2025   | 7.08 ± 0.12 | 0.99 ± 0.01        | 30.56 ± 1.50        | 5.34 ± 0.05           | 13.01 ± 0.26         |
| March, 2025     | 7.19 ± 0.13 | 0.89 ± 0.01        | 29.89 ± 1.49        | 5.33 ± 0.05           | 13.44 ± 0.27         |
| April,2025      | 7.43 ± 0.15 | 1.22 ± 0.02        | 30.87 ± 1.51        | 4.92 ± 0.04           | 12.59 ± 0.24         |
| May, 2025       | 7.33 ± 0.14 | 1.45 ± 0.02        | 30.99 ± 1.51        | 4.55 ± 0.04           | 12.98 ± 0.26         |
| June, 2025      | 6.89 ± 0.10 | 1.77 ± 0.02        | 30.78 ± 1.51        | 3.97 ± 0.04           | 12.31 ± 0.25         |
| July, 2025      | 6.59 ± 0.07 | 1.59 ± 0.02        | 29.89 ± 1.49        | 4.81 ± 0.04           | 11.70 ± 0.24         |
| August, 2025    | 6.97 ± 0.10 | 1.63 ± 0.02        | 30.54 ± 1.50        | 5.03 ± 0.05           | 12.39 ± 0.25         |
| September, 2025 | 7.01 ± 0.10 | 1.93 ± 0.02        | 30.45 ± 1.50        | 4.52 ± 0.04           | 12.95 ± 0.26         |
| October, 2025   | 7.02 ± 0.11 | 1.55 ± 0.02        | 30.23 ± 1.50        | 4.21 ± 0.04           | 13.43 ± 0.27         |
| November, 2025  | 6.73 ± 0.09 | 1.63 ± 0.02        | 29.77 ± 1.49        | 4.49 ± 0.04           | 12.77 ± 0.25         |
| December, 2025  | 6.96 ± 0.09 | 1.44 ± 0.02        | 29.75 ± 1.49        | 5.01 ± 0.05           | 12.84 ± 0.25         |
| January,2026    | 7.00 ± 0.10 | 1.10 ± 0.02        | 29.32 ± 1.48        | 5.71 ± 0.05           | 12.69 ± 0.25         |
| February,2026   | 7.05 ± 0.11 | 1.09 ± 0.02        | 29.56 ± 1.49        | 5.84 ± 0.05           | 12.91 ± 0.25         |
| March, 2026     | 7.11 ± 0.12 | 1.07 ± 0.02        | 29.83 ± 1.49        | 5.55 ± 0.05           | 13.04 ± 0.26         |
| April,2026      | 7.38 ± 0.14 | 1.12 ± 0.02        | 30.27 ± 1.51        | 5.02 ± 0.04           | 13.19 ± 0.24         |
| May, 2026       | 7.51 ± 0.16 | 1.35 ± 0.02        | 30.88 ± 1.51        | 4.95 ± 0.04           | 13.08 ± 0.26         |

Table 3 represents the physico chemical properties of soil exhibited clear temporal variations during the study period, indicating seasonal influences on soil fertility and nutrient dynamics. The parameters analysed included pH, organic carbon (OC), nitrogen (N), phosphorus (P), and potassium (K).

**Soil pH**

Soil pH one of the most important factors regulating nutrient availability and microbial activity. The soil pH ranged from

6.59±0.07 to 7.51±0.16, indicating that the soil remained within the slightly acidic to slightly alkaline range throughout the investigation. The lowest pH was recorded in July 2025(6.59±0.07), whereas the highest value was observed in May 2026 (7.51±0.16). Seasonal fluctuations in pH may be attributed to variations in rainfall, decomposition of organic matter, microbial activity, and nutrient transformations. Nevertheless, the pH values remained within the optimum range for nutrient availability and microbial functioning, favouring plant growth and soil

fertility. Parida *et al.* (1999) <sup>[26]</sup> examined that the soil pH ranges 5.71- 7.6 of Basudevpur Block of Bhadark District, Odisha. Investigation carried out in freshwater fish farms of Raigad District, Maharashtra suggests optimum soil pH 6.1-8.0 (Chibhade *et al.*, 2020) <sup>[8]</sup>. The values of soil pH in the aqua ponds of Guntur district, Andhra Pradesh ranged in between 6.80 to 9.04 in monsoon months (Raliengoane, 2021) <sup>[29]</sup>. Banoo *et al.* (2024) <sup>[2]</sup> reported that the pH ranges from 5.7 to 7.4, indicating slightly acidic to near neutral soil conditions in Chandil dam, Jamshedpur with their near neutral pH, are better suited for both aquaculture and agriculture.

### Organic carbon

Organic Carbon content varied between  $0.87 \pm 0.01\%$  and  $1.77 \pm 0.02\%$ . The minimum value was observed in June, 2024 ( $0.87 \pm 0.01\%$ ), while the maximum was recorded in June, 2025 ( $1.77 \pm 0.02\%$ ). An increasing trend in organic carbon was observed during several months of 2025, suggesting enhanced accumulation of organic residues and improved decomposition processes. Higher organic carbon levels generally contribute to improved soil structure, water holding capacity, nutrient retention, and microbial activity. The subsequent decline after June, 2025 may indicate mineralization and utilization of organic matter by soil microorganisms. Parida *et al.* (1999) <sup>[26]</sup> examined that organic carbon ranged 0.52% - 1.68% indicating average productivity in the ponds of Basudevpur Block of Bhadark District, Odisha. The physico chemical properties of soil around aqua ponds in Guntur district of Andhra Pradesh was studied by Raliengoane (2021) <sup>[29]</sup> indicating lowest organic carbon range of 0.26% and the highest range 0.77% in post monsoon season. Roy *et al.* (2023) reported the range of organic carbon from 0.45 to 0.87% in fish ponds located in the District of Birbhum, West Bengal. Banoo *et al.* (2024) <sup>[2]</sup> reported that in Chandil dam, Jamshedpur the organic carbon ranges from 0.851 to 1.032 kg/ ha, values indicating good soil fertility and good microbial activity that supports both aquaculture and agriculture.

### Available nitrogen

Available nitrogen content ranged from  $27.76 \pm 1.41\text{mg}/100\text{ g}$  in August 2024  $30.98 \pm 1.49\text{ mg}/100\text{g}$  July 2025. Although fluctuations were relatively small, nitrogen levels remained consistently moderate throughout the study period. Elevated nitrogen concentration during certain months may be associated with increased microbial mineralization of organic matter, whereas lower values may result from plant uptake, leaching losses, or denitrification processes. The relatively stable nitrogen content indicates a balanced nutrient cycling system within the soil. Roy *et al.* (2023) <sup>[32]</sup> reported similar range of nitrogen content 27.65 to 35.90 mg/100 g in fish ponds located in the District of Birbhum, West Bengal. Investigation carried out by Singh *et al.* (2015) <sup>[36]</sup> reported the available nitrogen of 234 and 248 kg ha<sup>-1</sup> from two different locations at Dhanti- Umbharat

Research Station, Navsari, India. Raliengoane (2021) <sup>[29]</sup> studied the physico chemical properties of soil around aqua ponds in Guntur district of Andhra Pradesh, where they found the lowest range 100kg ha<sup>-1</sup> and highest range of 226 kg ha<sup>-1</sup> in pre monsoon season. The available nitrogen ranges from 460- 565 kg/ha in the Chandil dam, Jamshedpur (Banoo *et al.*, 2024) <sup>[2]</sup>.

### Available phosphorus

Available phosphorus exhibited considerable variation, ranging from  $2.90 \pm 0.03\text{mg}/100\text{ g}$  in June 2024  $5.91 \pm 0.05\text{ mg}/100\text{g}$  in January, 2025. A gradual increase in phosphorus availability was observed from mid-2024 to early 2025, followed by periodic fluctuations thereafter. The increase may be linked to mineralization of organic phosphorus compounds and favourable soil pH conditions that enhance phosphorus compounds and favourable soil pH conditions that enhanced phosphorus solubility. Variations in phosphorus availability could also be influenced by adsorption desorption reactions and seasonal changes in microbial activity. Roy *et al.* (2023) <sup>[32]</sup> reported similar range of phosphorus 1.37 to 2.35 mg/100 g in fish ponds located in the District of Birbhum, West Bengal. Investigation executed by Parida *et al.* (1999) <sup>[26]</sup> examined that available phosphorus ranged between 0.72 - 3.0 mg/L in the pond of Basudevpur Block of Bhadark District, Odisha. The available phosphorus content varied between 34.59 and 51.89 kg ha<sup>-1</sup> in East and West Godavari District of Andhra Pradesh (Penmetsa *et al.*, 2013) <sup>[27]</sup>. Singh *et al.*, (2015) <sup>[36]</sup> reported that the values of available phosphorus content was 26.10 kg ha<sup>-1</sup> in soils collected in the aqua ponds at Dhanti-Umbharat Research Station, Navsari, India. Raliengoane (2021) <sup>[29]</sup> studied the physico chemical properties of soil around aqua ponds in Guntur district of Andhra Pradesh, where low range < 25 kg ha<sup>-1</sup> and highest range of 59 kg ha<sup>-1</sup>.

### Available potassium

Potassium content ranged from  $10.20 \pm 0.21\text{mg}/100\text{ g}$  in June 2024  $13.44 \pm 0.27\text{ mg}/100\text{g}$  in October 2025. A general increase in potassium levels was observed over the study period, particularly during 2025. The higher potassium concentration may be attributed to weathering of potassium bearing minerals, release from organic residues, and reduced crop uptake during specific periods. Potassium is essential for enzyme activation, osmoregulation, and stress tolerance in plants; therefore, the observed levels indicate adequate potassium availability in the soil. Roy *et al.* (2023) <sup>[32]</sup> reported similar range of Potassium 7.70 to 9.65 mg/100 g in fish ponds located in the District of Birbhum, West Bengal. Choubey (1991) <sup>[9]</sup> reported that the available potassium ranging from 160 - 171 kg ha<sup>-1</sup> in Gandhisagar reservoir, Madhya Pradesh. The lower range of potassium was 20 kg ha<sup>-1</sup> and higher range of 126 kg ha<sup>-1</sup> in the soil sample around aqua ponds in Guntur district of Andhra Pradesh (Raliengoane, 2021) <sup>[29]</sup>.

**Table 4:** Feeding habit and niche preference for IMC

| Common name | Feeding habit       | Niche occupied in ponds |
|-------------|---------------------|-------------------------|
| Catla       | Zoo plankton feeder | Surface feeder          |
| Rohu        | Omnivorous          | Column feeder           |
| Mrigal      | Detritivorous       | Bottom feeder           |

*Catla catla* is primarily a zooplankton feeder and occupies the surface zone of the pond, utilizing food resources available in the upper water column. *Labeo rohita* exhibits omnivorous feeding behaviour and mainly inhabits the middle or Colum region of the pond, where it feeds on a variety of plant and animal materials. *Cirrhinus mrigala* is detritivorous in nature and occupies the bottom zone of the pond, feeding mainly on organic detritus and decomposed matter present in the pond sediment. The distinct feeding habits and niche preferences of the species minimize interspecific competition for food and space, thereby promoting efficient utilization of available resources and enhancing overall fish production in composite fish culture systems.

### Conclusion

The physico chemical characteristics of water exhibit clear seasonal patterns among the measured parameters. Water temperature exhibited an inverse relationship with dissolved oxygen; whereby higher temperature corresponded to lower oxygen concentration. Similarly, pH and free carbon dioxide showed a negative association, with elevated CO<sub>2</sub> concentrations resulting in reduced pH values. Alkalinity fluctuations appeared to influence the buffering capacity of the water, helping maintain relatively stable pH conditions despite variations in biological and chemical processes. The results indicate that the water body maintained generally favourable physico chemical conditions throughout the study period. Although seasonal fluctuations were evident, all parameters remained within acceptable ranges for sustaining aquatic life and ecological functions. Overall, the physico chemical analysis demonstrated that the aquatic ecosystem remained ecologically balanced during the study period. Seasonal changes significantly influenced water quality parameters, particularly temperature, dissolved oxygen, and alkalinity. However, the maintenance of near neutral pH, adequate oxygen concentration, and moderate buffering capacity indicates good water quality capable of supporting diverse aquatic biota and sustaining ecosystem productivity.

The physico chemical characteristics of soil demonstrate that the soil maintained favourable condition throughout the study period. The pH remained near neutral, supporting nutrient availability and biological activity. Organic carbon content showed substantial improvement during the study, which likely contributed to enhanced nutrient retention and soil quality. Nitrogen, phosphorus, and potassium levels remained within moderate to adequate ranges, indicating a well-balanced nutrient status. Seasonal fluctuations in all parameters reflect the influence of environmental conditions, organic matter decomposition, microbial processes, and nutrient cycling. Overall, the soil exhibited good fertility status and suitable conditions for sustaining plant growth and productivity during the study period. A positive association was observed between organic carbon and the availability of major nutrients. Periods characterized by higher organic carbon content generally corresponded with elevated nitrogen, phosphorus, and potassium concentration. These findings suggest that the soil possesses sufficient fertility to sustain plant growth and productivity while maintaining ecological stability.

The composite fish culture system achieved a high survival rate (90%) and efficient feed utilization, indicating favourable culture conditions. Among the three species,

*Catla catla* exhibited the best growth performance, recording the highest final body weight, weight gain, and the lowest FCR, demonstrating superior feed conversion efficiency. *Labeo rohita* and *Cirrhinus mrigala* also showed satisfactory growth with comparable SGR values.

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