

# Diversity and Distribution of Aquatic Macrophytes in Pond Ecosystem

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**Abstract-** A comprehensive seasonal study of the flora and fauna diversity in the freshwater pond ecosystem at Bhimsen, Kanpur, Uttar Pradesh, India was conducted from January 2021 to December 2022. Water samples were collected from four fixed stations and analysed for physico-chemical and biological parameters at Dayanand Girls Post Graduate College, Kanpur. A total of 53 species were recorded across four biological groups: 14 phytoplankton species (Chlorophyceae, Bacillariophyceae, Cyanophyceae, and Euglenophyceae), 15 aquatic macrophyte species (free-floating, floating-leaved, emergent and submerged forms), 14 zooplankton species (Rotifera, Cladocera, Copepoda, Ostracoda and Protozoa), and 10 fish species from six families. Physico-chemical parameters revealed pronounced seasonal variation, with dissolved oxygen declining to  $4.2 \pm 0.8$  mg/L during the monsoon and BOD peaking at  $6.2 \pm 1.1$  mg/L, indicative of organic enrichment. Shannon–Wiener diversity indices ranged from  $H' = 2.19$  (fish) to  $H' = 2.61$  (aquatic macrophytes), indicating a moderately diverse but anthropogenically stressed ecosystem. Chromium was detected at levels approaching concern thresholds during winter months. The study underscores the urgent need for sustained monitoring and management of urban pond ecosystems in industrial cities such as Kanpur.

**Keywords:** Pond Water Ecosystem; Phytoplankton; Aquatic Macrophytes; Zooplankton; Fish Diversity; Bhimsen Kanpur; Water Quality; Biodiversity Indices

## I. INTRODUCTION

Freshwater ponds are among the most ecologically significant and yet most threatened components of the aquatic biosphere. Despite covering a small proportion of the earth's surface, these lentic water bodies contribute disproportionately to regional biodiversity, serve as breeding grounds for amphibians and aquatic invertebrates, support fisheries, and perform essential ecosystem services including nutrient cycling, carbon sequestration and water purification (Arya, 2024). In semi-urban and industrial settings, freshwater ponds

are subjected to mounting anthropogenic pressure from domestic sewage, agricultural runoff, solid waste dumping, and industrial discharge, which cumulatively degrade water quality and reduce biological diversity (Chaudhary *et al.*, 2021; Arya *et al.*, 2021).

Kanpur, situated on the right bank of the River Ganga in Uttar Pradesh, is one of India's most industrialised cities and a focal point for research on aquatic pollution. Studies by Madhulekha and Arya (2016) demonstrated the severe impact of tannery effluents on the fish communities of the Ganga at Kanpur, while Shukla *et al.* (2017) documented heavy metal contamination and deteriorating physico-chemical conditions in Ganga water at the same site. Arya and Shukla (2018) specifically reviewed the toxic effects of hexavalent chromium on freshwater fish, a concern directly relevant to the Bhimsen area given its proximity to tannery-affected drainage networks. Shukla and Arya (2017) further demonstrated cadmium-induced morphological changes in the indigenous catfish *Heteropneustes fossilis*, highlighting the vulnerability of local fish fauna to industrial metal contamination. Chromium in pond water at Kanpur was quantified spectrophotometrically by Tewari and Shukla (2007), providing a methodological baseline adopted in the present study.

Biological communities, phytoplankton, aquatic macrophytes, zooplankton, and fish are recognized as sensitive indicators of aquatic ecosystem health (Dubey and Arya, 2022; Rani and Arya, 2021; Goel *et al.*, 2023). Phytoplankton forms the primary productive base of the aquatic food web, with their community composition directly reflecting trophic status and pollution load (Singh *et al.*, 2022; Kumar *et al.*, 2022). Zooplankton, particularly Rotifera, serves as reliable bioindicators of water quality due to their short generation times and differential sensitivity

to organic enrichment (Mishra, 2020; Singh *et al.*, 2021a). Aquatic macrophytes regulate nutrient dynamics, stabilise sediments, and support invertebrate diversity; their species composition and growth form distribution change predictably with increasing eutrophication (Dubey *et al.*, 2022; Rasal *et al.*, 2020). Fish species assemblages reflect the cumulative health of the ecosystem across multiple trophic levels and are affected by both chronic pollution and pesticide exposure (Goel *et al.*, 2022; Arya, 2024).

Despite the ecological importance of pond ecosystems in the Kanpur region, systematic documentation of flora and fauna diversity in these water bodies remains sparse. The Bhimsen Pond, located in the densely populated Bhimsen area of Kanpur, receives surface runoff and partial domestic wastewater from the surrounding area and has not previously been the subject of a comprehensive limnological survey. The present investigation was therefore undertaken to document the seasonal diversity of phytoplankton, aquatic macrophytes, zooplankton and fish fauna of the Bhimsen pond; to assess physico-chemical water quality parameters using standard methods; and to compute biodiversity indices to evaluate the ecological integrity of this urban freshwater pond. All analytical work was conducted at Dayanand Girls Post Graduate College, Kanpur.

## II. STUDY AREA

The study site, Bhimsen Pond, is in the Bhimsen locality of Kanpur district, Uttar Pradesh, India (approximately 26.44° N, 80.33° E). The pond is a semi-perennial lentic water body with an approximate surface area of 0.8 hectares. Maximum depth reaches 2.5 meters during the monsoon and declines to approximately 0.9 meters in the summer months. The pond receives surface runoff from the surrounding residential and semi-agricultural catchment, as well as periodic discharge of partially treated domestic wastewater. The margins support dense stands of emergent and floating macrophytes. Nearby areas are subject to small-scale industrial and leather processing activities, resulting in trace metal inputs into the drainage that ultimately reach the pond.

Kanpur experiences a sub-tropical semi-arid climate, with a mean summer temperature exceeding 40°C and winter temperatures falling as low as 5°C. Mean

annual rainfall is approximately 800 mm, with over 80% occurring during the monsoon months of July to September. The climatic conditions impose marked seasonal cycles on both physico-chemical water quality and biological community composition, as documented in Ganga River studies from Kanpur (Arya and Dubey, 2017; Shukla *et al.*, 2017; Shukla and Arya, 2018).

## III. MATERIALS AND METHODS

### 3.1 Sample Collection and Field Stations

Sampling was carried out at four permanent stations: S1 (inlet/surface runoff area), S2 (open centre of pond), S3 (littoral zone near aquatic vegetation), and S4 (outlet/drainage area). Samples were collected seasonally in summer (April–June), monsoon (July–September), post-monsoon (October–December) and winter (January–March) from January 2021 to December 2022. Water samples for physico-chemical analysis were collected in acid-washed polyethylene bottles (1 L), transported on ice and processed within 24 hours at Dayanand Girls Post Graduate College, Kanpur. Plankton samples were obtained by filtering 100 L of surface water through bolting silk plankton nets (64 µm mesh) and preserved in 4% formalin. Aquatic macrophytes were surveyed using 1 m × 1 m quadrats along transects at each station. Fish were sampled using cast nets, drag nets and local fishermen catch records.

### 3.2 Physico-Chemical Analysis

Temperature, pH, dissolved oxygen (DO) and turbidity were measured in situ using calibrated digital instruments. Biological oxygen demand (BOD) was determined by the standard five-day incubation method. Total dissolved solids (TDS), total hardness (by EDTA titration), total alkalinity (by acid titration), chloride (by Mohr method as described by Shukla and Arya, 2018), nitrate and phosphate were determined following the methods of APHA (American Public Health Association). Hexavalent chromium (Cr<sup>6+</sup>) was quantified spectrophotometrically using 1,5-diphenylcarbazide reagent according to the procedure validated for Ganga water at Kanpur by Arya (2018a). Statistical analysis including mean and standard deviation (SD) was performed for all parameters across seasons (n = 12 per season per station).

### 3.3 Biological Surveys and Diversity Indices

Phytoplankton were identified to species level under compound microscopy and a Sedgwick-Rafter counting chamber using standard keys. Relative abundance was scored semi-quantitatively (++++ = very abundant, +++ = abundant, ++ = common, + = rare, - = absent). Zooplankton were identified and counted using 1 mL aliquots in Sedgwick-Rafter chambers. Aquatic macrophytes were classified by growth form (free-floating, floating-leaved, emergent, submerged) and identified using regional flora. Fish were identified using published taxonomic keys and through records of local fishermen. Diversity was quantified using the Shannon-Wiener diversity index ( $H' = -\sum p_i \ln p_i$ ), Simpson's dominance index ( $D = 1 / \sum p_i^2$ ), Margalef species richness ( $d = (S-1)/\ln N$ ), and Pielou's evenness index ( $J = H'/\ln S$ ).

## IV. RESULTS AND DISCUSSION

### 4.1 Physico-Chemical Parameters of Bhimsen Pond Water

The seasonal physico-chemical parameters are presented in Table 1. Water temperature ranged from  $18.7 \pm 0.9^\circ\text{C}$  in winter to a maximum of  $31.6 \pm 1.8^\circ\text{C}$  during the monsoon, reflecting the sub-tropical climate of Kanpur. These values are consistent with the temperature regimes reported for Ganga water at Kanpur by Arya and Dubey (2017) and Shukla *et al.* (2017). The pH remained slightly alkaline throughout the study period (7.2–8.1), with peak alkalinity in winter, consistent with reduced biological activity and lower CO<sub>2</sub> consumption. A comparable pH range was documented in the Khanwari pond of Kaushambi

district, Uttar Pradesh, during 2018–2019 (Mishra, 2020).

Dissolved oxygen was lowest during the monsoon ( $4.2 \pm 0.8$  mg/L), coinciding with maximum BOD values ( $6.2 \pm 1.1$  mg/L), elevated turbidity ( $24.8 \pm 4.2$  NTU) and highest temperature. This seasonal depression of DO is characteristic of eutrophic urban ponds and reflects enhanced microbial decomposition of organic matter entering from surface runoff (Dubey *et al.*, 2022; Kumar *et al.*, 2022). BOD values during the monsoon exceeded the CPCB desirable limit of 5 mg/L, indicating organic pollution attributable to domestic sewage and agricultural drainage. Shukla and Arya (2018) similarly documented chloride enrichment in the Ganga at Kanpur linked to drainage from residential areas, and the chloride levels in the Bhimsen pond (38–56 mg/L) reflect comparable inputs.

Total dissolved solids (278–385 mg/L) and total hardness (142–210 mg/L) were highest in winter, reflecting reduced dilution and evaporative concentration. Phosphate levels (0.38–0.52 mg/L) consistently exceeded the oligotrophic threshold of 0.1 mg/L established for Indian freshwater bodies (Dubey *et al.*, 2022), confirming eutrophic conditions. Chromium (Cr<sup>6+</sup>) was detected at concentrations of 0.012–0.024 mg/L across seasons, with the highest values in winter. While these values are below the WHO permissible limit of 0.05 mg/L for drinking water, the presence of hexavalent chromium in the pond likely derived from tannery-influenced drainage is a concern given its demonstrated toxicity to freshwater fish at sub-lethal concentrations (Arya and Shukla, 2018; Shukla and Arya, 2017).

Table 1: Seasonal physico-chemical parameters of Bhimsen Pond, Kanpur (Mean  $\pm$  SD; n = 12 per season per station)

Parameter	Summer (Apr–Jun)	Monsoon (Jul–Sep)	Post-Monsoon (Oct–Dec)	Winter (Jan–Mar)
Water Temperature (°C)	28.4 $\pm$ 1.2	31.6 $\pm$ 1.8	24.2 $\pm$ 1.1	18.7 $\pm$ 0.9
pH	7.8 $\pm$ 0.3	7.2 $\pm$ 0.4	7.9 $\pm$ 0.2	8.1 $\pm$ 0.2
Dissolved Oxygen (mg/L)	5.4 $\pm$ 0.6	4.2 $\pm$ 0.8	6.8 $\pm$ 0.5	8.1 $\pm$ 0.4
BOD (mg/L)	4.6 $\pm$ 0.7	6.2 $\pm$ 1.1	3.8 $\pm$ 0.5	2.9 $\pm$ 0.4
Total Hardness (mg/L)	186 $\pm$ 12	142 $\pm$ 18	198 $\pm$ 14	210 $\pm$ 10

Total Alkalinity (mg/L)	142 ± 10	118 ± 14	156 ± 11	164 ± 8
TDS (mg/L)	342 ± 22	278 ± 30	360 ± 18	385 ± 20
Chloride (mg/L)	48 ± 4	38 ± 6	52 ± 5	56 ± 4
Nitrate (mg/L)	2.4 ± 0.4	1.8 ± 0.5	2.8 ± 0.3	3.1 ± 0.3
Phosphate (mg/L)	0.46 ± 0.06	0.38 ± 0.08	0.52 ± 0.05	0.44 ± 0.04
Turbidity (NTU)	12.4 ± 2.1	24.8 ± 4.2	8.6 ± 1.4	6.2 ± 0.9
Chromium Cr <sup>6+</sup> (mg/L)	0.018 ± 0.003	0.012 ± 0.002	0.021 ± 0.004	0.024 ± 0.003

BOD: Biological Oxygen Demand; TDS: Total Dissolved Solids; Cr<sup>6+</sup>: Hexavalent Chromium

#### 4.2 Phytoplankton Diversity

A total of 14 species of phytoplankton representing four classes were recorded from the Bhimsen pond (Table 2). Class-wise, Chlorophyceae contributed five species, Bacillariophyceae four species, Cyanophyceae three species and Euglenophyceae two species. Seasonal presence/absence and relative abundance of each species are indicated in Table 2. This composition is broadly consistent with phytoplankton assemblages reported from lentic water bodies of eastern Uttar Pradesh (Kumar *et al.*, 2021) and comparable ponds of western Uttar Pradesh (Mishra, 2020).

Chlorophyceae, particularly *Chlorella vulgaris*, dominated during summer and monsoon seasons when nutrient loading was highest a pattern also observed in eutrophic ponds of the Central Ganga Plain by Dubey *et al.* (2022). Bacillariophyceae (diatoms), especially *Navicula sp.* and *Nitzschia sp.*, were most abundant in

post-monsoon and winter months when water clarity improved and temperature moderated. The dominance of diatoms in cooler, cleaner water periods is well established for Indian freshwater ponds (Singh *et al.*, 2022). Cyanophyceae, notably *Microcystis aeruginosa*, *Anabaena sp.*, and *Oscillatoria sp.*, showed their peak abundance in summer, reflecting elevated temperatures and phosphate availability. The bloom-forming tendency of *Microcystis aeruginosa* in eutrophic ponds is well documented and represents a concern for water quality and aquatic animal health (Kumar *et al.*, 2022). *Oscillatoria sp.* is commonly recorded as an indicator of organic pollution in freshwater ponds of Uttar Pradesh, consistent with its presence as a monsoon-season dominant in the Bhimsen pond. Euglenophyceae (*Euglena viridis* and *Phacus sp.*) were primarily recorded during the monsoon when organic enrichment was greatest, reinforcing their status as pollution-tolerant taxa. The Shannon–Wiener diversity index for phytoplankton was  $H' = 2.42$ , with species evenness  $J = 0.92$  and species richness  $S = 14$ , indicating moderate and uniform diversity.

Table 2: Phytoplankton species diversity and seasonal relative abundance in Bhimsen Pond, Kanpur (S = Summer; M = Monsoon; PM = Post-Monsoon; W = Winter; +++++ Very abundant; +++ Abundant; ++ Common; + Rare; - Absent)

S.No.	Species	Class	S	M	PM	W
1	<i>Chlorella vulgaris</i>	Chlorophyceae	++++	++++	+++	++
2	<i>Spirogyra sp.</i>	Chlorophyceae	+++	++	+++	++
3	<i>Chlamydomonas sp.</i>	Chlorophyceae	+++	++	++	+
4	<i>Pediastrum boryanum</i>	Chlorophyceae	++	++	+	+
5	<i>Closterium sp.</i>	Chlorophyceae	++	++	+	+

6	<i>Navicula sp.</i>	Bacillariophyceae	+++	++	++++	++++
7	<i>Nitzschia sp.</i>	Bacillariophyceae	++	+	+++	+++
8	<i>Cyclotella sp.</i>	Bacillariophyceae	+	+	++	++
9	<i>Synedra ulna</i>	Bacillariophyceae	+	+	++	++
10	<i>Microcystis aeruginosa</i>	Cyanophyceae	++++	+++	++	+
11	<i>Anabaena sp.</i>	Cyanophyceae	+++	++	+	+
12	<i>Oscillatoria sp.</i>	Cyanophyceae	+++	+++	++	+
13	<i>Euglena viridis</i>	Euglenophyceae	+	++	+	+
14	<i>Phacus sp.</i>	Euglenophyceae	+	++	+	-

#### 4.3 Aquatic Macrophyte Diversity

Fifteen species of aquatic macrophytes were recorded from the Bhimsen pond distributed across four growth form categories: five free-floating, two floating-leaved, six emergent and three submerged species (Table 3). Free-floating macrophytes dominate the pond surface, especially during summer and monsoon. *Eichhornia crassipes* (Water Hyacinth) formed extensive mats covering over 60% of the surface during peak summer months, significantly reducing light penetration to submerged vegetation and contributing to surface oxygen supersaturation by day and sub-surface hypoxia at night. Rasal *et al.* (2020) similarly documented *Ipomoea aquatica* and *Typha* spp. as dominant emergent macrophytes in reservoir ecosystems of Madhya Pradesh, India, emphasising their role in structuring aquatic habitats. Free-floating macrophytes such as *Pistia stratiotes*, *Lemna minor* and *Spirodela polyrrhiza* were recorded throughout the open water margins.

Among floating-leaved macrophytes, *Nymphaea pubescens* and *Nymphaea nouchali* were recorded at

the relatively undisturbed station S3 adjacent to the littoral vegetation belt. Emergent macrophytes, including *Nelumbo nucifera*, *Typha angustata*, *Phragmites australis*, *Ipomoea aquatica* and *Marsilea quadrifolia*, colonised the pond margins throughout the study period. Submerged macrophytes like *Hydrilla verticillata*, *Ceratophyllum demersum* and *Vallisneria spiralis* were restricted to the post-monsoon and winter months when turbidity declined and light penetration improved. The decline in submerged macrophyte cover under high phosphate and turbidity conditions is consistent with the findings of Dubey *et al.* (2022) for eutrophic lakes of the Central Ganga Plain and reflects the global pattern of submerged vegetation loss under nutrient enrichment (Dubey and Dutta, 2020). The proliferation of free-floating macrophytes (particularly *Eichhornia crassipes*) at the expense of submerged forms confirms the eutrophic to hypereutrophic status of the Bhimsen pond during summer months. Shannon-Wiener diversity for aquatic macrophytes was the highest among all groups studied ( $H' = 2.61$ ,  $J = 0.96$ ).

Table 3: Aquatic macrophyte diversity in Bhimsen Pond, Kanpur, with growth form classification

S.No.	Scientific Name	Family	Growth Form / Local Name
1	<i>Eichhornia crassipes</i>	Pontederiaceae	Free-floating / Water Hyacinth
2	<i>Pistia stratiotes</i>	Araceae	Free-floating / Water Cabbage
3	<i>Lemna minor</i>	Araceae	Free-floating / Duckweed

4	<i>Spirodela polyrrhiza</i>	Araceae	Free-floating / Giant Duckweed
5	<i>Azolla pinnata</i>	Salviniaceae	Free-floating / Mosquito Fern
6	<i>Nymphaea pubescens</i>	Nymphaeaceae	Floating-leaved / Pink Lotus
7	<i>Nymphaea nouchali</i>	Nymphaeaceae	Floating-leaved / Blue Lotus
8	<i>Nelumbo nucifera</i>	Nelumbonaceae	Emergent / Sacred Lotus
9	<i>Typha angustata</i>	Typhaceae	Emergent / Cattail
10	<i>Phragmites australis</i>	Poaceae	Emergent / Common Reed
11	<i>Ipomoea aquatica</i>	Convolvulaceae	Emergent / Water Spinach
12	<i>Marsilea quadrifolia</i>	Marsileaceae	Emergent / Water Clover
13	<i>Hydrilla verticillata</i>	Hydrocharitaceae	Submerged / Hydrilla
14	<i>Ceratophyllum demersum</i>	Ceratophyllaceae	Submerged / Hornwort
15	<i>Vallisneria spiralis</i>	Hydrocharitaceae	Submerged / Eelgrass

#### 4.4 Zooplankton Diversity

Fourteen species of zooplankton belonging to five taxonomic groups i.e. Rotifera, Cladocera, Copepoda, Ostracoda and Protozoa were recorded from the Bhimsen pond (Table 4). Rotifera was the most species-rich group, represented by four species: *Brachionus calyciflorus*, *Brachionus urceolaris*, *Philodina roseola* and *Keratella cochlearis*. *Brachionus calyciflorus* showed the highest density during summer ( $48 \pm 6$  org/L), consistent with its recognised status as an indicator of eutrophic, organically enriched freshwater bodies (Singh *et al.*, 2021a; Singh *et al.*, 2021b). The dominance of Rotifera in the Bhimsen pond is comparable to findings from the Guthia Taal wetland of Bahraich district, Uttar Pradesh, where Rotifera constituted 30% of total zooplankton density (Prakash and Ansari, 2000; Prakash, 2001; Bassi, *et al.* 2014; Prakash *et al.*, 2015; Prakash and Singh, 2019; Prakash, 2020a,b; Verma and Prakash, 2020; Prakash *et al.*, 2002; Singh and Prakash, 2024), and from ponds of Jharkhand (Singh *et al.*, 2021a; Singh *et al.*, 2021b; Biggs, 2025).

Cladocera were represented by three species: *Daphnia pulex*, *Ceriodaphnia cornuta* and *Bosmina longirostris*. *Daphnia pulex* showed maximum abundance during post-monsoon ( $30 \pm 5$  org/L), consistent with improved water clarity and declining organic enrichment. *Brachionus urceolaris* and *Brachionus calyciflorus* are known to be abundant in waters with elevated BOD and reduced DO conditions documented here during the monsoon (Mishra, 2020). Copepoda (three species), Ostracoda (two species, restricted to post-monsoon and winter) and Protozoa (two species recorded in all seasons) complemented the zooplankton community. The restriction of Ostracoda to cooler, less turbid seasons reflects the sensitivity of this group to organic enrichment and confirms comparable observations from freshwater ponds of Jharkhand (Singh *et al.*, 2021b). The Shannon–Wiener diversity index for zooplankton was  $H' = 2.38$ , suggesting moderate diversity consistent with mesotrophic to eutrophic conditions. The dominance of pollution-tolerant *Brachionus* species alongside the presence of Copepoda and Ostracoda indicates that while the pond is organically enriched, conditions are not severely degraded.

Table 4: Zooplankton species diversity, seasonal occurrence, and density (org/L) in Bhimsen Pond, Kanpur (+ = Present; - = Absent; Density: Mean ± SD; n = 8 per season)

S.No.	Species	Group	S	M	PM	W	Density (org/L) Mean ± SD
1	<i>Brachionus calyciflorus</i>	Rotifera	+	+	+	-	48 ± 6
2	<i>Brachionus urceolaris</i>	Rotifera	+	+	+	-	36 ± 5
3	<i>Philodina roseola</i>	Rotifera	-	-	+	+	22 ± 4
4	<i>Keratella cochlearis</i>	Rotifera	-	-	+	+	18 ± 3
5	<i>Daphnia pulex</i>	Cladocera	+	-	+	-	30 ± 5
6	<i>Ceriodaphnia cornuta</i>	Cladocera	+	-	+	-	26 ± 4
7	<i>Bosmina longirostris</i>	Cladocera	-	-	+	+	14 ± 3
8	<i>Cyclops viridis</i>	Copepoda	+	-	+	+	20 ± 4
9	<i>Diaptomus sp.</i>	Copepoda	-	-	+	+	12 ± 2
10	<i>Nauplius larvae</i>	Copepoda	+	+	+	+	24 ± 5
11	<i>Cypria sp.</i>	Ostracoda	-	-	+	+	8 ± 2
12	<i>Candona sp.</i>	Ostracoda	-	-	+	+	6 ± 1
13	<i>Amoeba proteus</i>	Protozoa	+	+	+	+	16 ± 3
14	<i>Paramecium caudatum</i>	Protozoa	+	+	-	-	28 ± 5

#### 4.5 Fish Diversity

Ten fish species from six families were recorded from the Bhimsen pond (Table 5). The family Cyprinidae was most diverse, comprising four species. Indian Major Carps *Labeo rohita* (Rohu), *Catla catla* (Catla) and *Cirrhinus mrigala* (Mrigal) were the most abundant species, reflecting their importance in aquaculture and wild fisheries throughout Uttar Pradesh. These three species occupy distinct feeding zones (column, surface and bottom, respectively) enabling their coexistence in the pond ecosystem, a well-established polyculture principle documented for freshwater ponds across India (Singh *et al.*, 2022a). *Puntius sophore* was also recorded as a native Cyprinid from marginal vegetated habitats.

*Heteropneustes fossilis* (Singhi) and *Clarias batrachus* (Magur) are obligate air-breathing catfishes tolerant of low dissolved oxygen and organically enriched conditions, explaining their consistent presence even during the monsoon when DO decline below 5 mg/L.

The susceptibility of *H. fossilis* to cadmium toxicity at the morphological level has been documented for Kanpur region fish populations by Shukla and Arya (2017), and sublethal chromium concentrations recorded in the Bhimsen pond may similarly affect this species. *Channa striata* and *Channa punctata* (Snakeheads) were recorded as top predators; the haematological impacts of pyrethroid insecticides on *C. punctata* have been documented by Goel *et al.* (2022), Das *et al.*, (2025), and the presence of insecticide residues in urban pond runoff of Kanpur is a plausible stressor for this species. *Oreochromis niloticus* (Nile Tilapia) was recorded as an introduced aquaculture species and *Anabas testudineus* (Climbing Perch) occupied the shallow vegetated margins. The Shannon–Wiener diversity index for fish was  $H' = 2.19$ . The dominance of pollution-tolerant air-breathing species (*Heteropneustes*, *Clarias*) and the absence of sensitive rheophilic species are consistent with moderate organic enrichment and intermittent periods of low dissolved oxygen.

Table 5: Fish species diversity of Bhimsen Pond, Kanpur (N = Native; I = Introduced)

S.No.	Common Name	Scientific Name	Family	Status	Feeding Zone
1	Rohu	<i>Labeo rohita</i>	Cyprinidae	N	Column
2	Catla	<i>Catla catla</i>	Cyprinidae	N	Surface
3	Mrigal Carp	<i>Cirrhinus mrigala</i>	Cyprinidae	N	Bottom
4	Punti Barb	<i>Puntius sophore</i>	Cyprinidae	N	Column
5	Singhi / Stinging Catfish	<i>Heteropneustes fossilis</i>	Heteropneustidae	N	Bottom
6	Magur / Walking Catfish	<i>Clarias batrachus</i>	Clariidae	N	Bottom
7	Snakehead Murrel	<i>Channa striata</i>	Channidae	N	Predator
8	Spotted Snakehead	<i>Channa punctata</i>	Channidae	N	Predator
9	Nile Tilapia	<i>Oreochromis niloticus</i>	Cichlidae	I	Column
10	Climbing Perch	<i>Anabas testudineus</i>	Anabantidae	N	Column

#### 4.6 Biodiversity Indices

Biodiversity indices for all four organism groups are summarised in Table 6. Aquatic macrophytes exhibited the highest Shannon–Wiener diversity ( $H' = 2.61$ ) and evenness ( $J = 0.96$ ), reflecting the diverse growth forms present across the littoral, limnetic and sublittoral zones of the pond. Phytoplankton ( $H' = 2.42$ ) and zooplankton ( $H' = 2.38$ ) showed comparable levels of moderate diversity, while fish recorded the lowest  $H'$  value (2.19). The overall range of  $H'$  values

(2.19–2.61) is consistent with mesotrophic to eutrophic freshwater pond ecosystems across India (Singh *et al.*, 2021a; Mishra, 2020) and suggests a moderately biodiverse but anthropogenically stressed ecosystem. Species evenness ( $J > 0.90$  for all groups) indicates no extreme dominance by single species, though the seasonal preponderance of *Microcystis aeruginosa* (phytoplankton) and *Brachionus calyciflorus* (zooplankton) during summer months signals periodic stress-mediated community simplification.

Table 6: Summary of biodiversity indices for all organism groups in Bhimsen Pond, Kanpur

Organism Group	Shannon $H'$	Simpson D	Species Richness (S)	Evenness J
Phytoplankton	2.42	0.84	14	0.92
Aquatic Macrophytes	2.61	0.88	15	0.96
Zooplankton	2.38	0.82	14	0.90
Fish Fauna	2.19	0.89	10	0.95

#### V. CONCLUSION

The present investigation provides the first comprehensive documentation of flora and fauna diversity from the Bhimsen pond ecosystem, Kanpur. A total of 53 species across four major biological groups were recorded: 14 phytoplankton, 15 aquatic

macrophytes, 14 zooplankton and 10 fish species. The ecosystem exhibits characteristics of a mesotrophic to eutrophic freshwater pond, with clear indicators of seasonal organic enrichment, nutrient loading and trace metal contamination including hexavalent chromium, consistent with the industrial and residential land use of the Bhimsen area.

Phytoplankton communities are dominated by Chlorophyceae and Cyanophyceae during summer, shifting to Bacillariophyceae during cooler, clearer post-monsoon and winter months. Free-floating macrophytes, especially *Eichhornia crassipes*, dominate the pond surface during summer and monsoon. Zooplankton communities are characterised by pollution-tolerant Rotifera, particularly *Brachionus calyciflorus*, and fish fauna includes a significant proportion of air-breathing, low-oxygen tolerant species.

The following management interventions are recommended: (i) regular monitoring of chromium, cadmium and other heavy metals derived from tannery-influenced drainage (Madhulekha and Arya, 2016; Arya and Shukla, 2018); (ii) biological control or mechanical removal of invasive *Eichhornia crassipes* to restore light penetration and submerged macrophyte diversity; (iii) regulation of sewage and agricultural runoff entering the pond; (iv) adoption of green technology practices for sustainable pond management (Arya, 2018b); and (v) periodic assessment of pesticide contamination given the proximity of agricultural land to the pond catchment (Chaudhary *et al.*, 2021; Rani *et al.*, 2024). The application of metagenomics (Arya and Hemprabha, 2025) in future studies would provide a more detailed picture of microbial biodiversity and pollutant transformation dynamics in this ecosystem. The Bhimsen Pond supports a still-moderate level of aquatic biodiversity and merits conservation attention as an urban ecological resource in Kanpur.

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