



Study of Ichthyofaunal Diversity with Reference to Water Quality in Lower Lake of Bhopal, India

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Background: Biodiversity is the concept of variety and variability of living organisms. Biodiversity includes not only the variety of species but also include genetic diversity, habitats, and ecological communities. Preserving biodiversity is crucial for protecting nature and ensuring a future for generations. Advancements in technologies as like remote sensing; robotic equipment improved our understanding of biodiversity on levels from genes to ecosystems.

Aim: The present study examined the ichthyofaunal diversity and several ecological influencers of the diversity in the Lower Lake, Bhopal, during 2023-2024.

Materials and Method: A total of 19 species of fish were recorded across 6 orders, and 9 families, all indication a taxonomically diverse assemblage. For water quality parameters, water was collected from the sampling station in the mornings between 7 am and 11 am of each month. Air

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temperature, water temperature, pH, DO, CO₂, total alkalinity, and total hardness were recorded. The Shannon–Wiener Diversity Index, Margalef's Richness Index and Simpson's Diversity Index was measured for estimation of biodiversity of fish species in various habitats of the lake.

Results and Discussion: The fish community is primarily dominated by Cypriniformes (65%) and followed by Ophiocephaliformes (15%) and Perciformes (10%), with the others being negligible. The prominent species were *Labeo rohita*, *Labeo catla*, and *Cyprinus carpio*, all which have economic significance. Most of the species present in the study area were Least Concern (LC) by IUCN, except for *Cyprinus carpio* (VU) and *Mystus vittatus* (NT). Diversity analysis indicated that the fish diversity was strongest in the winter due to substantial species richness and evenness, as observed with higher Shannon ($H = 2.835$) and Simpson ($1-D = 0.9357$) diversity indices and less dominance in the fish communities. Correlation analysis of the data found that physicochemical variables like temperature and pH, and dissolved oxygen are closely co-distributed with key species distribution. Generalist trophic levels, such as the Siluriformes and Cypriniformes eating and feeding simplicity likely increased their presence due to high ecological flexibility than the other orders of fish which likely occupied similar space but had less representation due to habitat selection, or low tolerance to fluctuations in environmental conditions.

Conclusion: The research emphasizes the effects of seasonal variation and human-induced management, and stresses fish community composition in urban wetlands, thus accenting the need for habitat preservation and water quality management to support aquatics biodiversity. The study will help to understand the present status of fish diversity in Lower Lake (Ramsar Site), one of the twine lake of Bhoj Wetland.

Keywords: Abundant; biodiversity; correlation; water quality; wetland.

1. INTRODUCTION

Conservation correlation to protecting and restoring habitats, establishing wildlife corridors to reconnect fragmented landscapes, and implementing land-use planning strategies that prioritize biodiversity conservation along with human development. Freshwater fish are among the most threatened taxonomic groups by globally. Several factors contribute to the declining of freshwater fish populations and the degradation of their habitat (Bhakta & Saxena, 2024, Bhakta & Saxena, 2025). It is believed that life began in water and grew into a magical world filled with a wide variety of plants and animals (Kar, 2013). India is home to 2,500 fish species; 930 of these are freshwater species, while 1,570 are marine (Kar et al., 2003). Madhya Pradesh is endowed with diverse aquatic ecosystems, including about 3.0 lakh hectares of water bodies in the form of reservoirs and ponds. These ecosystems disturb a rich variety of aquatic flora and organisms. In "Lake City" Bhopal, many lakes and reservoirs exist; However, many of them are subject to pollution arising out of various anthropological activities in their rapidly their catchment areas, causing ecological erosion of these important wetlands (Tamot and Awasthi 2012). Many limnological studies have been conducted over numerous important wetlands of the state and most wetlands have been polluted due to various anthropogenic

reasons. The work on fish fauna of Madhya Pradesh started with the first survey of Fish Fauna of river system of central India by Hora et al. (1941). Thereafter, various ichthyologist have made only limited contribution related with fish biodiversity as per the available literature. Tamot and Bhatanagar (1989) studied raw water quality of Upper Lake and its variation during different stages of treatment. Johri (1990) studied limnological and water quality status of two lakes of Bhopal. Saxena (1990) worked on limnological and water quality status of Lower Lake of Bhopal, and Shrivastava (2003) studied limnology of Kerwan Lake for conservation and management of Mahseer fish. Zoological Survey of India (2000) published 172 fish species reported in the state. Menon had published some work on game fishes in year 1988. Tamot & Awasthi (2010) in Upper Lake studied biodiversity and conservation of indigenous fish species.

2. MATERIALS AND METHODS

2.1 Study Area

The Lower Lake is an acclaimed freshwater water body situated in the heart of Bhopal, the capital of Madhya Pradesh, India. In terms of geographic location, it lies between latitudes 23°15'N and 23°16'N and longitudes 77°23'E and 77°25'E, having an average surface elevation of 500 meters above sea level. This lake is the very

soul of Bhoj Wetland: a Ramsar site of international ecological importance, consisting of both the Upper and Lower Lakes. For the present study we have selected 3 sampling site Site1- Neelam Park (23°15'09.6"N 77°24'46.5"E), Site2- Bhoipura (23°15'05.0"N 77°24'21.2"E) and Site3- Khatlapura (23°15'00.8"N 77°24'36.7"E).

2.2 Collection and Identification of Fish Species

For the study fishes were collected with the help of local fisherman using several mesh sizes of nets (gill net, drug net, hooks and lines) that segmented for 24 hrs. Fish were identified using standard taxonomic keys (Jayaram, 2010; Talwar & Jhingran, 1991), and classification of the fish was performed up to the species level. Those Fishes were not identified on the spot, were collected and preserved immediately in 10% formalin solution and transportation to the laboratory for further study.

2.3 Water Quality Parameters

For water quality parameters water was collected from the sampling station in the mornings between 7 am and 11 am of each month of the year 2023-2024. During this study, air temperature, water temperature, pH, DO, CO₂, total alkalinity, and total hardness were recorded. Temperature was recorded with the help of a

thermometer, and other parameters were analysed in the Laboratory of Department of Aquaculture with the help of methods specified in the "WORK BOOK ON LIMNOLOGY" written by A. D. Adoni (1985).

2.4 Statistical Analysis

In order to measure the biodiversity of fish species in various habitats of the lake, two commonly known diversity indices were applied: the Shannon–Wiener Diversity Index, Margalef's Richness Index and Simpson's Diversity Index.

2.4.1 Shannon–wiener diversity index (H')

Shannon–Wiener Diversity Index (Shannon & Wiener, 1949) was utilized to measure species diversity using both species richness and evenness.

$$H' = \sum_{i=1}^S pi(\ln(pi))$$

Where,

S= number of species

ln= natural log

pi= proportion of individuals in the sample belonging to the *i*th species of the total number of individual species

H' = diversity index



Fig. 1. Location Map of the study station

Margalef's Richness Index (Margalef, 1968) was employed to calculate species richness using the number of species and the total number of individuals in the sample.

$$D_{mg} = (s-1)/\ln N$$

Where:

S = Number of species recorded

N = Total number of individuals in the sample

ln = Natural logarithm

2.4.2 Simpson's diversity index (1 - D)

Simpson's Diversity Index (Simpson, 1949) was used to quantify the likelihood that two randomly chosen individuals from a sample represent different species. The index considers both richness of species and relative abundance of each species, placing stronger emphasis on dominant species.

$$D = \sum_{i=1}^s \left(\frac{n_i}{N} \right)^2$$

Where:

D = Simpson's Dominance Index

n_i = Number of individuals of species i

N = Total number of individuals of all species

S = Total number of species

3. RESULT AND DISCUSSION

During study period 2023–2024, the ichthyofaunal diversity of Lower Lake, Bhopal, showed a very heterogeneous composition at various taxonomic levels. A total of 19 fish species were recorded, belonging to 6 different orders and 9 families. The fish community is dominated by the Cypriniformes, making up 65% of the total species, with Ophiocephaliformes coming next, and making up 15% of the fish population, followed by the Perciformes at 10%, with both Cichliformes and Osteoglossiformes making up 5%. Among these, the order Cypriniformes (family Cyprinidae) was found dominant with important representatives being *Labeo rohita*, *Labeo catla*, *Cyprinus carpio*, *Puntius ticto*, *Puntius sarana*, and *Cirrhinus mrigala*. Most of these species are herbivorous or omnivorous and have important economic values as sources of food. Since *Cyprinus carpio* has been listed as Vulnerable (VU) by the IUCN, it must be popularly stocked by human activities. Carnivorous species of the order Siluriformes included *Heteropneustes fossilis* and species of

Mystus, including *Pangasius pangasius* and *Clarias garipinus*, the last of which was abundantly present. Other important species were *Channa* spp. (order Ophiocephaliformes), *Oreochromis mossambicus* (order Cichliformes), and *Parambassis* spp. (order Perciformes). Most species had their IUCN status registered as Least Concern (LC), except for *Mystus vittatus* (Near Threatened) and *Cyprinus carpio* (Vulnerable).

The seasonal diversity indices of fish species in Lower Lake revealed noticeable temporal variation. During the winter season, the fish community exhibited the highest biodiversity, as indicated by the lowest dominance index ($D = 0.06431$) and the highest Simpson index ($1-D = 0.9357$), implying a more evenly distributed species structure with reduced dominance by any single species. This trend was further supported by the highest Shannon diversity index ($H = 2.835$) and Evenness ($e^H/S = 0.8961$), reflecting a well-balanced and diverse fish community. In summer, the diversity remained relatively high, with Simpson index at 0.9225 and Shannon index at 2.709, while dominance was moderate ($D = 0.0775$). Evenness was also substantial (0.8344), indicating a fairly even spread of species abundances. However, during the monsoon season, diversity was comparatively lower. The dominance index increased to 0.1363, suggesting a few species dominated the assemblage. Correspondingly, the Simpson index dropped to 0.8637, Shannon index decreased to 2.287, and Evenness was the lowest (0.7576) among the three seasons. This reduction may be attributed to environmental disturbances such as increased runoff and turbidity during the monsoon, impacting habitat quality and species distribution.

The seasonal water quality parameters showed a wide range of variation across the three sites (S1, S2, and S3) in Lower Lake. Summer air and water temperatures ranged from 30 to 34°C and 28 to 32°C, respectively, and acidity (pH) varied between 6.9 and 7.5. Dissolved oxygen (DO) levels fluctuated between 4.1 and 7.4 mg/L, with the highest DO prevailing during summer, in the year 2024. Following the monsoons, there were lower temperatures (25–28°C chilliness), a slightly acidic to neutral pH (6.1–7.0), and total hardness (TH) ranging from 194 to 245 mg/L. Winters were characterized by low temperatures (20–25°C), whereas during these days, DO ranged between 5 and 6.9 mg/L in concentration, and TH values were from 172 to 212 mg/L.

Table 1. List of fish species reported in Lower Lake and their Abundance

Order	Family	Local Name	Name of the Species	Availability Status	IUCN Status	Food Habit	Economical Value
Cypriniformes	Cyprinidae	Rohu	<i>Labeo rohita</i>	+	LC	Herbivorous (Young Age) Omnivorous (Adult)	Food Source, Commercially important
		Catla	<i>Labeo catla</i>	+	LC	Herbivorous	Food Source, Commercially important
		Chela	<i>Cyprinus cachius</i>	+	LC	Omnivorous	Food Source
		Common Carp	<i>Cyprinus carpio</i>	+	VU	Omnivorous	Food Source, Commercially important
		Puntius	<i>Puntius ticto</i>	+	LC	Herbivorous	Food Source
		Puntius	<i>Puntius sarana</i>	+	LC	Herbivorous	Food Source
		Mrigal	<i>Cirrhinus mrigala</i>	+	LC	Carnivorous	Food Source, Commercially important
Siluriformes	Heteropneustidae	Singhi	<i>Heteropneustes fossilis</i>	+	LC	Carnivorous	Food Source
	Bagridae	Singara	<i>Mystus singhala</i>	+	LC	Carnivorous	Food Source
		Tangra	<i>Mystus vittatus</i>	++	NT	Carnivorous	Food Source
			<i>Mystus bleekeri</i>	+	LC	Carnivorous	Food Source, Commercially important
	Pangasidae	Pangus	<i>Pangasius pangasius</i>	+	LC	Carnivorous	Food Source, Commercially important
	Claridae	Magur	<i>Clarias garipinus</i>	++	LC	Carnivorous	Food Source
Ophiocephaliformes	Ophiocheilidae	Samhal	<i>Channa marulius</i>	+	LC	Carnivorous	Food Source
		Mathia	<i>Channa gachua</i>	+	LC	Carnivorous	Food Source, Commercially important
		Samhal	<i>Channa straitus</i>	++	LC	Omnivorous	Food Source, Commercially important
Cichliformes	Cichlidae	Tilapia	<i>Oreochromis mossambicus</i>	+++	LC	Omnivorous	Food Source Commercially important
Perciformes	Chandidea	Khasua	<i>Parambassis ranga</i>	++	LC	Omnivorous	Food Source
		Khasua	<i>Parambassis nama</i>	++	LC	Omnivorous	Food Source

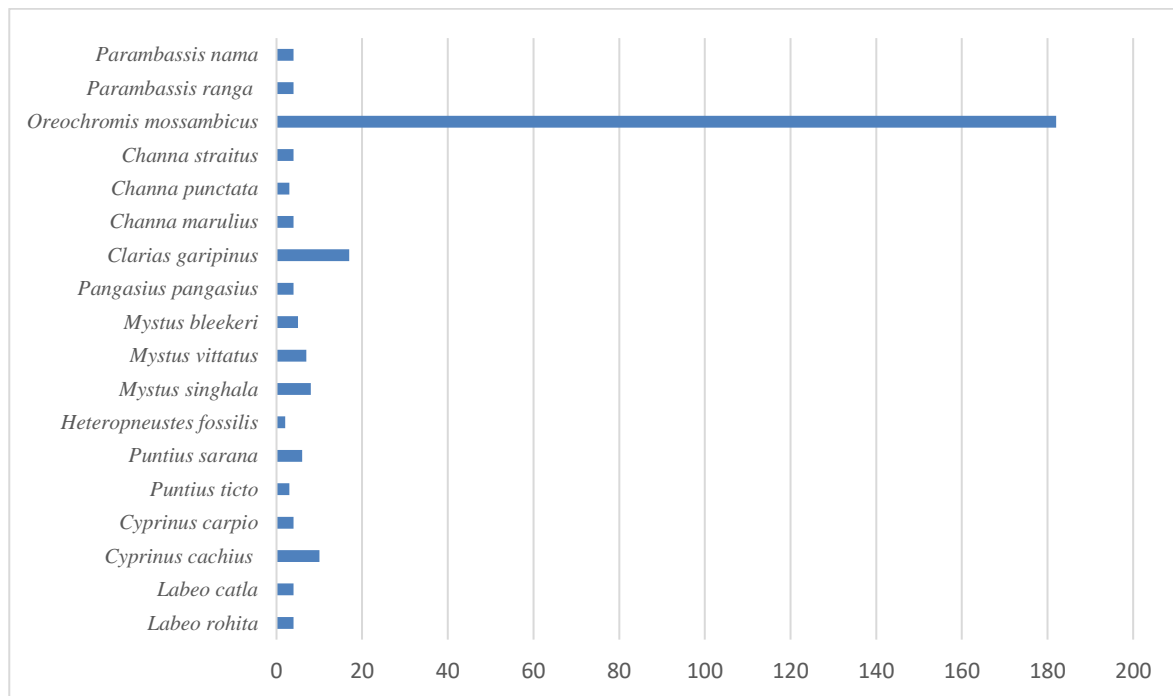


Fig. 2. Showing the composition of individual fish species in Lower Lake

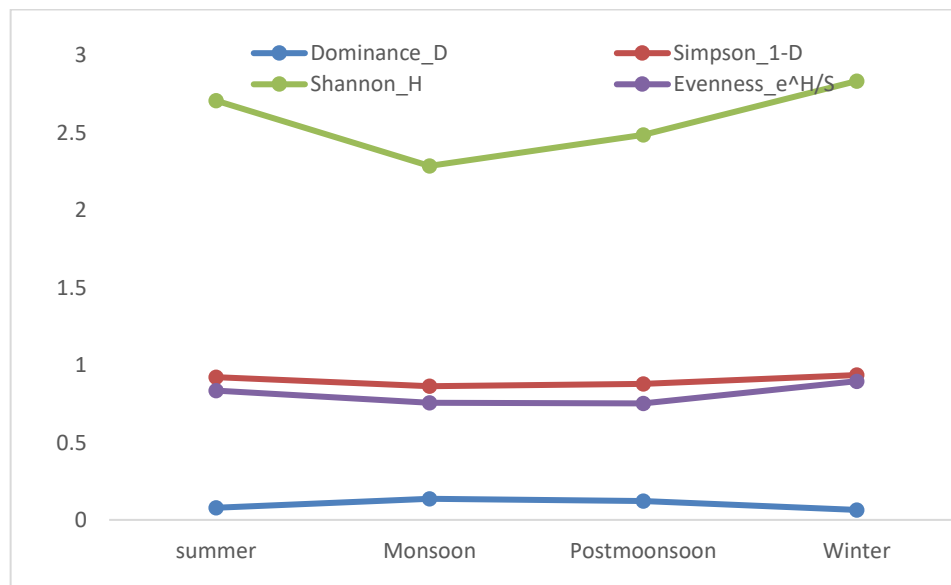


Fig. 3. Showing the seasonal variation in biodiversity indices of Bhoj Wetland (Lower Lake)

Table 2. Showing ichthyofaunal diversity across the three sampling sites (S1, S2, and S3) In Lower Lake

	S1	S2	S3
Taxa_S	10	12	16
Individuals	69	96	85
Dominance_D	0.1970	0.135	0.146
Simpson_1-D	0.803	0.865	0.855
Shannon_H	2.139	2.339	2.228
Evenness_e^H/S	0.472	0.576	0.581

Table 3. Showing temporal variation in water quality of Lower Lake Bhopal during study period (Mean \pm SD)

Season/ Sites			AT	WT	pH	CO ₂	TA	DO	TH
2023	Summer	S1	31	29	7.2	14	154	5.5	190
			± 0.577	± 0.577	± 0.153	± 1.154	± 2.309	± 0.057	± 5.686
		S2	30	28	7.3	11	151	4.8	182
			± 0.577	± 0.577	± 0.153	± 0.577	± 4.509	± 1.479	± 5.132
		S3	32	30	7.5	10	150	4.1	176
			± 0.577	± 0.577	± 0.352	± 1	± 0.577	± 1.572	± 2.082
	Monsoon	S1	25	24	6.5	12	160	4.2	230
			± 1.527	± 1	± 0.568	± 1.5275	± 2.645	± 0.850	± 12.583
		S2	26	24	6.7	9	152	4.5	210
			± 1.155	± 1.527	± 0.404	± 0.577	± 3.512	± 1.250	± 6.028
		S3	27	25	6.8	8	157	5.1	194
			± 0.578	± 0.576	± 0.264	± 1	± 2.516	± 0.208	± 8.386
2024	Summer	S1	23	21	7.1	10	155	5	204
			± 0.577	± 0.577	± 0.058	± 1.527	± 2	± 0.305	± 3.055
		S2	21	19	7.2	8	154	5.4	191
			± 2.309	± 1.732	± 0.208	± 2	± 2.887	± 0.896	± 1.155
		S3	22	21	7.4	7	155	6.2	172
			± 1.527	± 1	± 0.208	± 1.527	± 19.157	± 0.493	± 9.451
	Monsoon	S1	33	31	6.9	11	150	7.4	198
			± 0.577	± 0.577	± 0.153	± 1	± 3.215	± 0.321	± 2.517
		S2	31	29	7.1	10	158	6.9	190
			± 2.082	± 1.527	± 0.321	± 1.527	± 9.609	± 0.231	± 6.429
		S3	34	32	7.2	12	157	7.4	179
			± 1	± 0.577	± 0.1	± 2.082	± 3.512	± 0.351	± 5.507
	Winter	S1	26	25	6.1	11	168	7.3	245
			± 1.527	± 1.527	± 0.529	± 1	± 5.132	± 0.2	± 15.716
		S2	28	26	6.4	9	156	6.9	218
			± 0.577	± 1	± 0.321	± 1.155	± 5.507	± 0.1527	± 9.504
		S3	27	25	7	7	154	7.1	201
			± 1.527	± 2	± 0.251	± 0.577	± 10.263	± 0.321	± 5.686
	Winter	S1	22	20	7.1	10	150	6.8	210
			± 0.577	± 2.517	± 0.1	± 0.577	± 3.215	± 0.360	± 11.846
		S2	25	21	6.4	9	146	6.9	202
			± 1.527	± 0.577	± 0.306	± 1	± 4.510	± 0.058	± 3.055
		S3	25	23	7	7	154	6.1	212
			± 0.577	± 1	± 0.152	± 1.528	± 4	± 0.173	± 6.557

Table 4. Showing the correlation analysis between physicochemical parameters and fish species distribution in Lower Lake

Species	AT	WT	pH	CO ₂	TA	DO	TH
<i>Labeo rohita</i>	-0.855	-0.702	0.275	-0.654	-0.802	-0.236	-0.204
<i>Labeo catla</i>	-0.628	-0.565	0.444	-0.5	-0.456	-0.402	-0.376
<i>Cyprinus cachius</i>	-0.629	-0.554	0.444	-0.5	-0.565	0.540	-0.381
<i>Cyprinus carpio</i>	0.786	0.832	0.907	-0.867	-0.968	-0.783	-0.927
<i>Puntius ticto</i>	-0.243	-0.065	0.840	-0.257	-0.840	0.635	-0.789
<i>Puntius sarana</i>	0.786	0.832	0.907	-0.870	-0.889	0.297	-0.932
<i>Cirrhinus mrigala</i>	-0.142	-0.064	0.833	-0.867	-0.840	0.909	-0.788
<i>Heteropneustes fossilis</i>	-0.143	-0.064	0.833	-0.705	-0.842	0.209	-0.889
<i>Mystus singhala</i>	-0.460	-0.387	0.605	-0.330	-0.618	0.497	-0.545
<i>Mystus vittatus</i>	-0.620	-0.554	0.545	-0.5	-0.458	0.542	-0.377
<i>Mystus bleekeri</i>	-0.142	-0.064	0.930	-0.586	-0.840	0.599	-0.788
<i>Pangasius pangasius</i>	-0.519	-0.554	0.445	-0.5	-0.546	0.696	-0.375
<i>Clarias garipinus</i>	-0.981	-0.976	-0.302	-0.960	-0.287	0.650	0.371
<i>Channa marulius</i>	-0.765	-0.702	0.267	-0.654	-0.280	0.459	-0.193
<i>Channa gachua</i>	-0.628	-0.555	0.454	-0.5	-0.456	0.695	-0.377
<i>Channa straitus</i>	-0.618	-0.554	0.443	-0.5	-0.457	0.996	-0.377
<i>Oreochromis mossambicus</i>	0.189	0.266	0.969	-0.327	-0.971	0.724	-0.946
<i>Parambassis ranga</i>	-0.813	-0.764	0.180	-0.720	-0.192	0.929	-0.102
<i>Parambassis nama</i>	-0.381	-0.304	0.680	-0.240	-0.658	0.989	-0.618

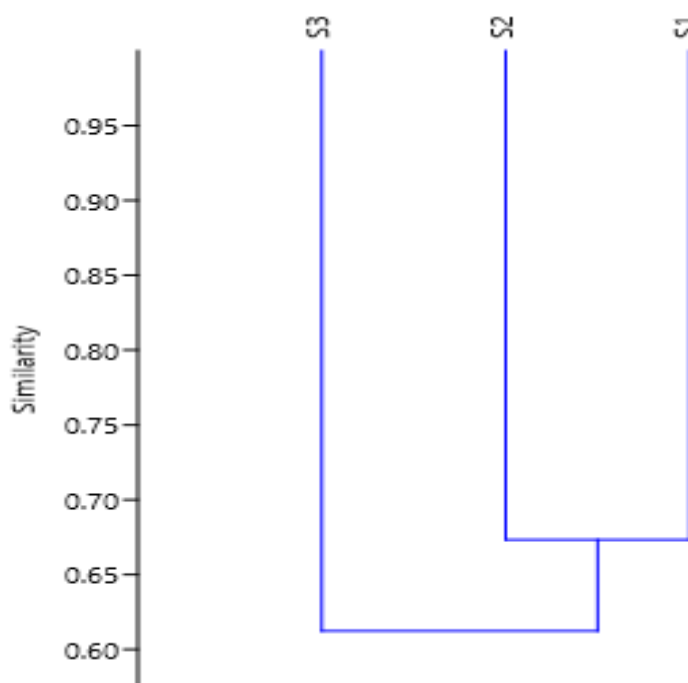


Fig. 4. Showing the upper lake, hierarchical cluster analysis using Bray-Curtis similarity index

Correlation analysis between fish species distribution and physicochemical parameters showed that *Cyprinus carpio* and *Puntius sarana* had strong positive links with water temperature, air temperature, and pH. They also had negative links with CO₂ and total alkalinity. *Oreochromis*

mossambicus had a strong positive correlation with pH (0.969) and dissolved oxygen (0.724). It also showed a negative correlation with total hardness (−0.946). *Clarias garipinus* demonstrated a strong negative correlation with both air and water temperatures (−0.981 and −

0.976) and a moderate positive correlation with dissolved oxygen (0.650). Most Channa and Mystus species showed positive correlations with dissolved oxygen and pH, but negative relationships with temperature and CO₂, suggesting they are sensitive to thermal and acidic stress. Overall, fish distribution in the Lower Lake appears closely tied to seasonal changes in water quality, especially temperature, pH, and dissolved oxygen. These are crucial factors that influence fish metabolism, feeding, and habitat preference.

Fish diversity reached its apex during the winter season, concurrent with generally suitable environmental conditions such as adequate water availability and food resources. The high diversity of Siluriformes and Cypriniformes corresponds to observations made for other freshwater ecosystems across India, where these assemblages predominantly occur due to generalist ecological requirements, broad categories of food, and at least less-evolved forms of reproductive strategies (Jayaram, 2010). On the other hand, the diminutive numbers of Ophiocephaliformes, Perciformes, Cichliformes, and Osteoglossiformes, each recording merely one to three species, may have implications that these orders require more specialized habitats or are less resilient to environmental alterations, including climate variations (Vass et al., 2009). Anthropogenic pressures, habitat modification, and interspecific interactions mostly contribute to shaping the structuring of fish communities in urban wetlands, thus explaining the unevenness recorded in the Lower Lake (Bhatt et al., 2013).

The high dominance value during the monsoon envoys that under disturbed conditions a very few species thrived and the community thus was skewed in their favour, potentially because of the consequences of flooding, sediment influx, and altered water chemistry upon the presence of sensitive taxa (Bhatt et al., 2012; Magurran, 2004).

4. CONCLUSION

The research shows that Lower Lake, Bhopal sustains a moderate diversity of fish fauna with ecological depth, which fluctuates with seasonal changes due to environmental factors and anthropogenic influences. Winter provided the highest level of fish diversity, suggesting the importance of favourable ecological conditions

that allow community equilibrium. The predominance of generalist taxa, particularly Cypriniformes and Siluriformes, indicates their opportunistic flexibility, while the lack of other groups reinforces the notion of the need for habitat.

On the other side the proliferation of Tilapia (*Oreochromis mossambicus*) in Lower Lake has serious ecological implications because it is a highly invasive and adaptable species. Unlike many native species, Tilapia is a highly adaptable and fast reproducing species with the ability to aggressively compete for food and habitat. The proliferation of Tilapia typically involves competition for resources with native species such as Labeo rohita, Puntius spp. and Channa spp., potentially reducing the native species biodiversity. Furthermore, apoptosis of Tilapia, which consumes high levels of material sources, could affect the transportation of nutrients, disrupt typical nutrient cycling, and create ecological disorganization of the lakes ecosystem. As it replaces other species to be the most dominant fish community, it is reducing the abundance of commercially and ecologically important native fishes that could threaten traditional edible fishery sustainability and the long-term ecological stability in Lower Lake.

As well, the study indicates the importance of monitoring water quality and managing anthropogenic impacts to conserve urban wetland ecosystems. Conservation strategies must protect habitat heterogeneity, enhance water quality, and reduce anthropogenic influences so that Lower Lake and other freshwater ecosystems in India may retain ecological integrity and biodiversity.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc have been used during writing or editing of this manuscript. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology.

Details of the AI usage are given below:

1. Canva for Map
2. Grammarly for grammatical mistake

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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