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Fish Diversity and Habitat Complexity: The Role of Macrophytes and Physicochemical Parameters in Urban and Rural Tropical Lakes

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ABSTRACT

This study highlights the impact of urbanization, agricultural runoff, and invasive species on freshwater ecosystems and aquatic biodiversity. It presents a comparative ecological assessment of two freshwater lakes in Vellore District, Tamil Nadu, India: Katpadi Lake (urban) and Saina Palayam Lake (rural). A total of 15 fish species were documented across both lakes, with *Oreochromis niloticus* identified as an exotic invasive species. The fish community was dominated by Cypriniformes (60%), demonstrating ecological adaptability. Diversity indices such as Shannon (H′) and Simpson (1–D) showed slight variations between the lakes. Katpadi Lake had higher total dissolved solids and conductivity, indicating greater anthropogenic influence. Ten macrophyte species, including submerged, floating-leaved, and emergent types, were observed, with their distribution differing between urban and rural sites, reflecting habitat and water-quality differences. Macrophyte diversity was greater in Saina Palayam Lake, linking habitat complexity to higher fish diversity. Submerged species such as *Najas marina* and *Myriophyllum spicatum* likely enhance habitat quality for native species. The rural wetland recorded nitrate and phosphate concentrations of 3 mg L^{-1} and 0.13 mg L^{-1}, respectively, indicating measurable nutrient enrichment, while higher hardness, chloride, and ammonia levels in Katpadi Lake point to urban pollution. The findings underscore the importance of integrated monitoring of fish, macrophytes, and water quality to conserve and manage freshwater biodiversity across different environmental contexts.

1. INTRODUCTION

Freshwater ecosystems are among the most biodiverse and ecologically vital habitats, playing a key role in maintaining ecological balance. They face increasing threats from human activities in both urban and rural settings (Dudgeon et al. 2006). Investigating freshwater fish diversity across these areas offers important insights into how urbanization, industrialization, and agriculture impact aquatic life (Paul & Meyer 2001, Walsh et al. 2005). Urban environments often contend with issues like sewage disposal, industrial waste, and habitat alteration, while rural regions are affected by pesticide and fertilizer runoff from farming, which can cause eutrophication and toxic contamination (Carpenter et al. 1998, Allan 2004). Each setting contributes uniquely yet significantly to stress in freshwater habitats, potentially leading to changes in fish diversity and community composition. A major biological threat in both environments is the introduction of invasive fish species, which can threaten native populations through competition, predation, and hybridization (Moyle & Light 1996). These invasive species tend to thrive in disturbed habitats and can worsen biodiversity declines, especially when ecosystems are already compromised by poor water quality or habitat loss (Gido & Brown 1999).

Aquatic macrophytes are vital components of freshwater ecosystems, closely linked to fish diversity. They enhance habitat complexity, provide refuge from predators, serve as spawning grounds, and support diverse invertebrate communities that constitute a food source for numerous fish species (Diehl & Kornijów 1998, Thomaz et al. 2025). Nevertheless, macrophyte abundance and diversity are often threatened by pollutants, siltation, and nutrient overloads common in urban drainage and agricultural runoff (Lacoul & Freedman 2006). Physicochemical water parameters, such as pH, temperature, conductivity, and nutrient levels, are crucial in shaping fish communities by affecting habitat suitability and biological processes. Low oxygen or extreme pH can limit the survival and reproduction of sensitive species, while elevated nutrient concentrations may lead to algal blooms that disrupt food webs (Gilvear et al. 1999, Wetzel 2001).

This study aims to conduct a comprehensive ecological assessment of two contrasting freshwater ecosystems: Katpadi Lake (KAL), also known as Dharapadavedu Lake, located within an urban area, and Saina Palayam Lake (SPL), situated in a rural setting in Vellore. Despite numerous studies on freshwater fish diversity in Tamil Nadu, there remains a lack of integrated comparative assessments of fish assemblages, macrophyte communities, and physicochemical parameters across urban and rural lakes in the Vellore District. This research offers a thorough urban–rural comparison of freshwater lake ecosystems by jointly analyzing fish diversity, macrophyte structure, and water quality variables. The selected study areas enable a comprehensive evaluation of ecosystem health and facilitate the identification of multiple drivers influencing biodiversity changes in freshwater systems. Such holistic studies are particularly valuable for informing conservation strategies and supporting the sustainable management of water resources in both urban and rural contexts.

2. MATERIALS AND METHODS

2.1. Study Area

The study was carried out in two freshwater lakes located in Vellore District, Tamil Nadu, India. KAL, with a catchment area of 17.09 km^2, is situated in the urban zone of Katpadi, while SPL, commonly known as S.N. Palayam Lake, with a catchment area of 12.96 km^2, lies in the rural region of Ponnai (TNWRD 2020). The geographical coordinates of KAL (Lat: 12.963766°, Long: 79.128653°) and SPL (Lat: 13.141206°, Long: 79.267942°) were mapped and georeferenced using ArcMap GIS software version 10.8 (Fig. 1). Fish sampling,

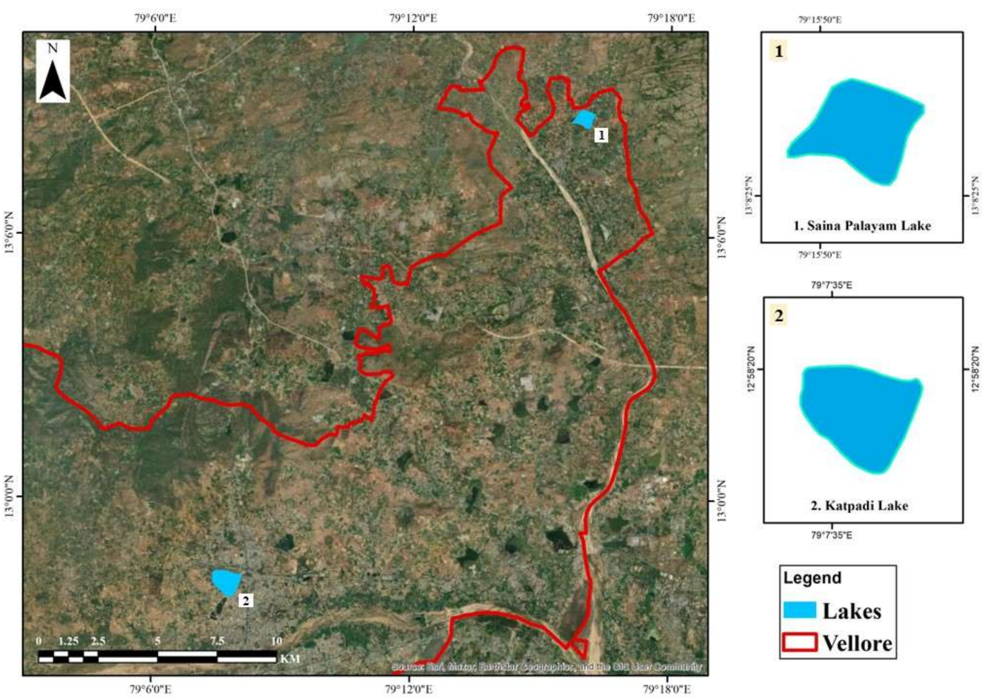

Fig. 1: Geographical location of the study areas.

macrophyte recording, and physicochemical parameters were measured. In KAL, sampling occurred in December 2024, whereas in SPL, it was conducted in April 2025.

2.2. Fish Sampling and Identification

Fish samples were obtained from both lakes using three different sizes of cast nets (radius 1.2–2.4 m, mesh size 1.3–5.1 cm), allowing the capture of small and large-bodied species. Each net was equipped with sinkers weighing 7–14 g to ensure proper spread and descent in shallow waters. Sampling occurred between 07:00 and 13:00 hours, aligning with the peak activity period of shallow-water fish. The process was carried out independently in each lake following a standardized protocol. In each location, nine representative sites along the lake margins were selected based on habitat features such as macrophyte coverage, water depth, flow variation, human disturbance, and accessibility. At each site, six to nine hauls were performed across different microhabitats, including open water, vegetated zones, and shallow marginal areas. Multiple net types and mesh sizes, as previously described, targeted a wide range of fish sizes. Specimens caught were photographed on-site for initial documentation and subsequently preserved in 10% formalin for detailed identification. Species identification relied on standard taxonomic keys (Talwar & Jhingran 1991, Jayaram 2010) and was cross-verified with online databases such as FishBase (Froese & Pauly 2024).

2.3. Analysis of Fish Diversity

Table 1 displays the relative abundance of each fish species in Katpadi Lake and Saina Palayam Lake. To evaluate species diversity and community structure, several diversity metrics, including Dominance (D), Simpson's index (1–D), Shannon-Wiener index (H), Menhinick's richness index, Margalef's richness index, Fisher's alpha, and the Berger-Parker dominance index, were calculated using PAST software version 4.03 (Hammer et al. 2001).

In addition to diversity indices, which primarily describe the diversity, richness, and evenness within individual communities, similarity indices such as Jaccard and Sørensen offer valuable insights into beta diversity. While alpha diversity emphasizes the internal structure of each site, these similarity indices measure the extent of species overlap and turnover between sites, thereby complementing diversity

Table 1: Fish species recorded in Katpadi Lake (KAL) and Saina Palayam Lake (SPL).

S. No..	Scientific name	Order	Family	Relative abundance in KAL (%)	Relative abundance in SPL (%)	KAL	SPL	Common name	Exotic/ invasive	IUCN
1	*Oreochromis niloticus*	Cichliformes	Cichlidae	50.34	52.86	✓	✓	Nile tilapia	Exotic/ invasive	LC
2	Anabas testudineus	Anabantiformes	Anabantidae	5.03	0	✓	–	Climbing perch	Native	LC
3	*Pethia conchonius*	Cypriniformes	Cyprinidae	16.78	0	✓	–	Rosy barb	Native	LC
4	*Glossogobius giuris*	Gobiiformes	Gobiidae	3.36	0	✓	–	Tank goby	Native	LC
5	*Parambassis ranga*	Mugiliformes	Ambassidae	2.68	5.29	✓	✓	Indian glassy fish	Native	LC
6	*Puntius sophore*	Cypriniformes	Cyprinidae	6.71	8.81	✓	✓	Pool barb	Native	LC
7	*Channa striata*	Anabantiformes	Channidae	3.36	0	✓	–	Striped snakehead	Native	LC
8	*Esomus danrica*	Cypriniformes	Danionidae	10.07	0	✓	–	Indian flying barb	Native	LC
9	*Chanda nama*	Mugiliformes	Ambassidae	1.68	0	✓	–	Elongated glassy perchlet	Native	LC
10	*Rasbora daniconius*	Cypriniformes	Danionidae	0	6.61	–	✓	Scissortail rasbora	Native	LC
11	*Amblypharyngodon mola*	Cypriniformes	Danionidae	0	10.57	–	✓	Mola carplet	Native	LC
12	*Amblypharyngodon microlepis*	Cypriniformes	Danionidae	0	7.93	–	✓	Indian carplet	Native	LC
13	*Salmostoma phulo*	Cypriniformes	Danionidae	0	2.2	–	✓	Finescale razorbelly minnow	Native	LC
14	*Pethia ticto*	Cypriniformes	Cyprinidae	0	3.52	–	✓	Ticto barb	Native	LC
15	*Rasbora* spp.	Cypriniformes	Danionidae	*0*	*2.2*	–	✓	*Rasbora* species	Native	-

Note: ✓ = Present; – = Absent; LC = Least Concern measures. This distinction is essential, as communities may have similar levels of species richness but differ significantly in composition. The species similarity between KAL and SPL was evaluated using the Sørensen and Jaccard similarity indices, where 'a' indicates the number of shared species, 'b' the species unique to KAL, and 'c' the species unique to SPL. The Sørensen similarity coefficient was calculated as:

$$S_s = \frac{2a}{2a + b + c}$$

and the Jaccard index as:

$$J = \frac{a}{a + b + c}$$

Both indices were employed to assess beta diversity and compare fish community composition between the two sites. To enhance visualization of similarity patterns, a hierarchical cluster analysis was conducted using the unweighted pair-group method with arithmetic mean (UPGMA). The Jaccard similarity coefficient (J) was calculated from presence-absence data, and the corresponding Jaccard-derived dissimilarity (1 − J) was used as the distance matrix for UPGMA clustering. The resulting dendrogram illustrates the clustering of fish species across the sites.

2.4. Macrophyte Identification

Macrophyte assessment involved visual, qualitative observations conducted during field surveys. The presence, general abundance, and dominant growth forms of macrophytes were documented to characterize habitat conditions, although quantitative measures such as percent cover, biomass, or spatial extent were not assessed. Consequently, macrophyte data offered descriptive insights into habitat structure. Specimens were identified to the species level using standard macrophyte identification keys (Subramanyam 1962, Cook 1996).

2.5. Physicochemical Water Analysis

Physicochemical parameters were analyzed from water samples collected at each study site following BIS 10500:2012 and APHA (2017) protocols. pH and electrical conductivity were measured in situ using a portable multiparameter probe (Eutech Instruments, Singapore), turbidity with a nephelometric turbidity meter (APHA 2130B), and total dissolved solids (TDS) with a digital TDS meter. Nutrients (nitrate, nitrite, phosphate, and ammonia) were quantified by UV–visible spectrophotometry (APHA 4500 series), while major and trace metals (iron, manganese, calcium, and magnesium) were determined using atomic absorption spectrophotometry (AAS; PerkinElmer). Alkalinity, total hardness, and chloride were measured by titrimetric methods, while oxygen absorbed in 4 h was determined according to IS 3025 (Part 63):2007 (Oxygen Absorbed in 4 h), commonly referred to as Tidy's test. Sensory characteristics (color, odor, and appearance) were recorded visually and organoleptically.

3. RESULTS AND DISCUSSION

3.1. Fish Diversity

A total of 15 fish species were recorded across KAL and SPL. The species identified in KAL included *Oreochromis niloticus*, *Anabas testudineus*, *Pethia conchonius*, *Glossogobius giuris*, *Chanda nama*, *Parambassis ranga*, *Puntius sophore*, *Channa striata*, and *Esomus danrica* (Fig. 2 and Table 1). In SPL, the species included *Rasbora daniconius*, *Oreochromis niloticus*, *Amblypharyngodon mola*, *Amblypharyngodon microlepis*, *Salmostoma phulo*, *Puntius sophore*, *Parambassis ranga*, *Pethia ticto*, and *Rasbora* spp. *(Fig. 2* and Table 1). Notably, *Oreochromis niloticus*, an exotic and invasive species, was present in both lakes. Its ability to tolerate a wide range of environmental conditions and reproduce rapidly can displace native species and disrupt local food webs (Canonico et al. 2005).

Cypriniformes dominated the fish community, accounting for 60% of the total species diversity. Mugiliformes and Anabantiformes each contributed 13%, while Cichliformes and Gobiiformes each represented 7% (Fig. 3). The dominance of Cypriniformes may be attributed to their ecological adaptability, versatile feeding habits, and reproductive strategies in diverse aquatic habitats (Nelson et al. 2016, Chakraborty 2021).

Small indigenous freshwater fish species (SIFs), including *Amblypharyngodon mola*, *Amblypharyngodon microlepis*, *Pethia ticto*, and *Rasbora* spp., were documented in the current study area. These SIFs are crucial to both the ecological balance and the socioeconomic fabric of Indian freshwater ecosystems, exhibiting high adaptability to the fluctuating environmental conditions typical of tropical lakes and wetlands (Sarkar & Lakra 2010). Sarkar & Lakra (2010) also emphasize that, despite their resilience, these species

Table 2: Diversity analysis in KAL and SPL.

	KAL	SPL
Dominance (D)	0.2996	0.311
Simpson (1–D)	0.7004	0.689
Shannon (H′)	1.615	1.628
Menhinick	0.5214	0.5974
Margalef	1.404	1.475
Fisher's alpha	1.75	1.873
Berger-Parker	0.5034	0.5286

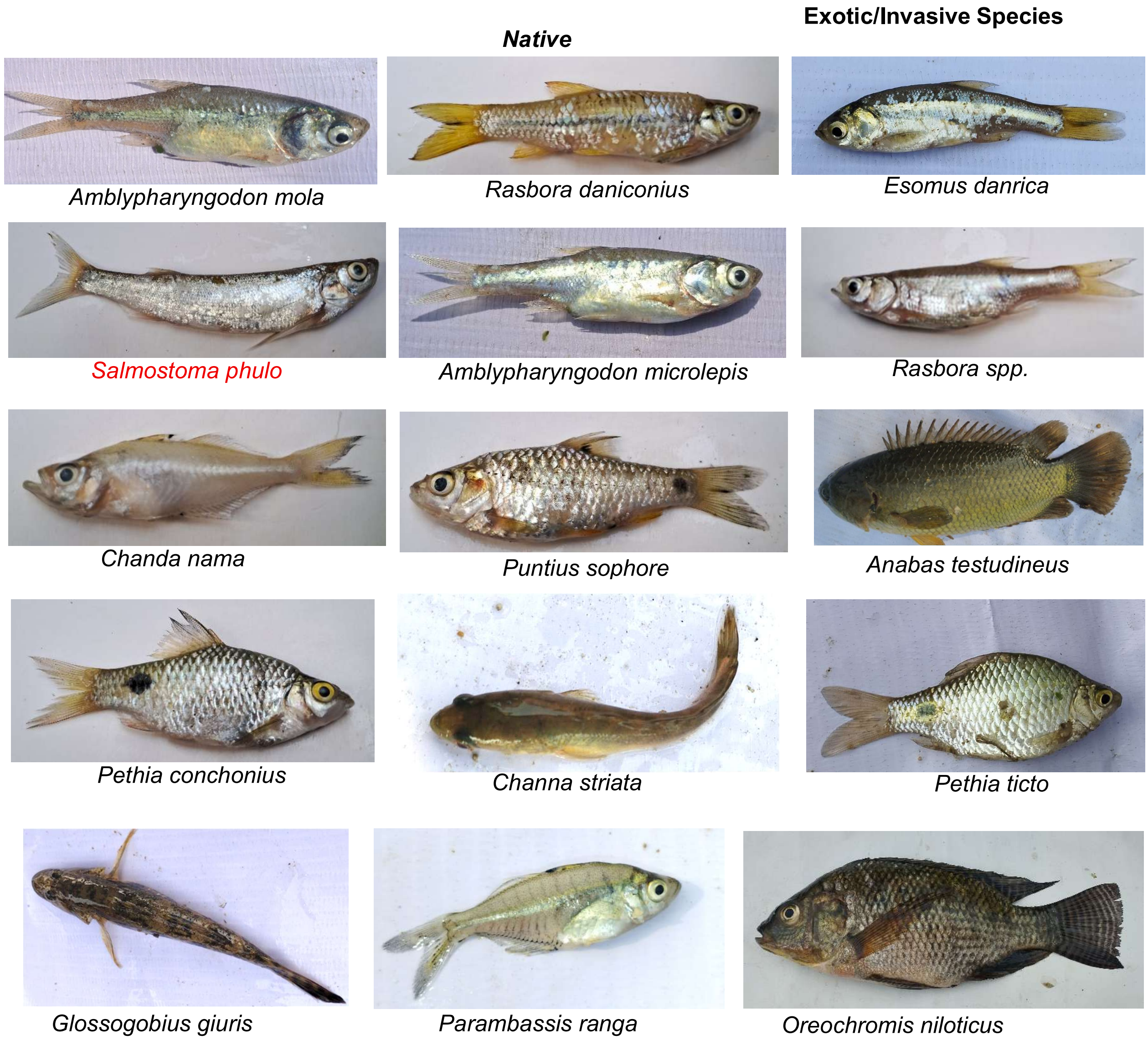

Fig. 2: Fish species recorded in Katpadi Lake (KAL) and Saina Palayam Lake (SPL).

remain vulnerable to habitat degradation, overfishing, and competition from invasive species. Therefore, implementing targeted conservation efforts and sustainable management strategies is vital to safeguard these SIF populations and preserve ecosystem health in the region.

3.1.1. IUCN Conservation Status

All fish species identified to species level were classified as Least Concern (LC) in the IUCN Red List (IUCN 2025), while *Rasbora* spp. was not assigned a species-level category (Table 1). Lewis (2002) highlights that tropical lakes are particularly vulnerable to eutrophication and deep-water oxygen depletion, making them more sensitive to nutrient loading and hydrological changes than temperate lakes. When subjected to even moderate nutrient enrichment, tropical systems can experience amplified alterations in water quality and biotic communities.

3.1.2. Diversity Analysis

Diversity indices showed comparable species richness across both sites. The Shannon diversity index (H′) was marginally higher in SPL (1.628) compared to KAL (1.615) (Table 2). Magurran (2004) reported a slightly more even distribution of individuals among species in rural sites. The Margalef and Menhinick indices were also higher in SPL, suggesting greater richness relative to sample size.

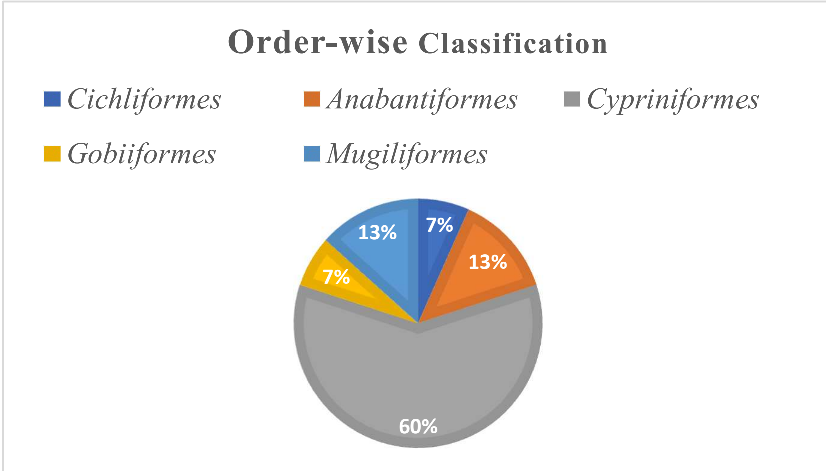

Fig. 3: Percentage composition of fish species across different taxonomic orders in KAL and SPL.

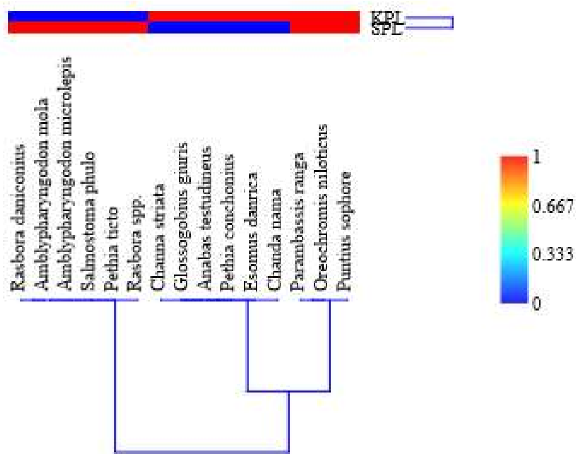

Fig. 4: Cluster dendrogram illustrating similarity in fish species composition between KAL and SPL based on hierarchical cluster analysis.

Meanwhile, Berger–Parker and dominance (D) indices were elevated in SPL, suggesting the presence of dominant species (*Oreochromis niloticus*) (Table 1). The observed variation in Shannon, Margalef, and Menhinick indices may partly reflect differences in macrophyte heterogeneity and associated habitat complexity. Structurally diverse macrophyte assemblages can enhance habitat availability by providing shelter and feeding opportunities, thereby supporting higher fish richness and evenness, whereas sparse or monospecific vegetation may favor a limited number of tolerant species (Thomaz et al. 2025). Accordingly, the diversity indices represent not only species richness but also habitat structure mediated by macrophyte composition.

Dominance-sensitive indices, particularly Simpson and Berger–Parker, revealed a skewed community structure in both lakes, characterized by a few species contributing disproportionately to overall abundance. This pattern was primarily driven by the overwhelming dominance of the invasive cichlid *Oreochromis niloticus*, which made up about half of the total fish population. The species' ecological traits, such as high reproductive capacity, trophic versatility, and resilience to environmental stressors, likely foster numerical dominance and diminish community evenness through competitive exclusion and habitat monopolization (Johnson et al. 2022). Similar patterns have been observed elsewhere; for example, in the hydrologically fragmented Vaigai River-Estuary, *Oreochromis* spp. comprised over a third of the total catch, significantly reducing community evenness despite moderate to high diversity levels (Mogalekar et al. 2025). Such dominance patterns are common in disturbed freshwater systems and underscore the importance of interpreting richness- and dominance-based indices together, since higher species richness can coexist with strong numerical dominance. The consistent dominance patterns across lakes

Table 3: Species distribution and similarity indices between KAL and SPL.

Species distribution	Count
Shared species (a)	3
Unique to Katpadi (b)	6
Unique to Palayam (c)	6
Similarity indices	
Jaccard	0.2
Sørensen	0.333

further suggest that invasive species pressure may partially override spatial differences, shaping the overall community structure.

3.1.3. Similarity Analysis

In this study, the relatively low similarity values, Jaccard = 0.20 and Sørensen = 0.33, highlight the distinctiveness of fish communities between the urban (KAL) and rural (SPL) systems (Table 3). This dissimilarity reflects the combined effects of varying environmental conditions, macrophyte composition, and physicochemical parameters, which influence species distributions differently across sites. Incorporating both Jaccard and Sørensen indices places the findings within the broader context of alpha, beta, and gamma diversity, aligning with standard community ecology practices that consider both within-site diversity and between-site similarity to gain a comprehensive understanding of biodiversity patterns. The hierarchical cluster analysis based on Jaccard-derived dissimilarity further supported this observation, grouping the two lakes together and highlighting species restricted to individual sites (Fig. 4).

These findings align with previous research emphasizing the ecological factors behind low similarity in fish communities. Koleff et al. (2003) highlighted the importance of employing multiple similarity measures to capture various aspects of community structure, while Johnson & Angeler (2014) and Gebrekiros (2016) noted that environmental heterogeneity and land-use pressures lead to significant

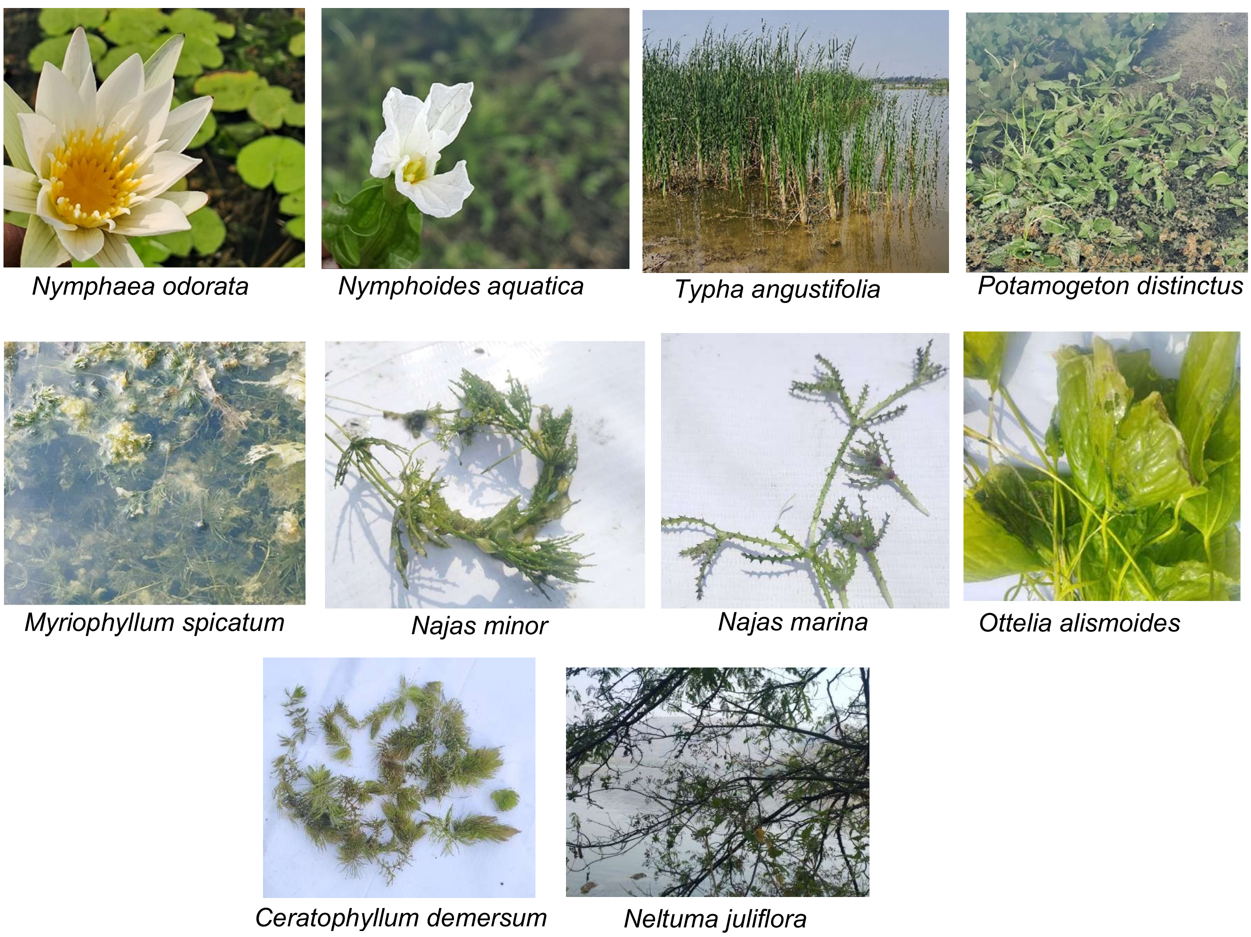

Fig. 5: Macrophytes recorded in KAL and SPL.

Table 4: Macrophytes recorded in KAL and SPL.

S. No.	Species	Order	Family	KAL	SPL	Common Name	Exotic/ Invasive	IUCN
1	*Neltuma juliflora*	Fabales	Fabaceae	✓	–	Mesquite	Invasive	LC
2	*Ceratophyllum demersum*	Ceratophyllales	Ceratophyllaceae	✓	–	Hornwort	Native	LC
3	Ottelia alismoides	Alismatales	Hydrocharitaceae	✓	✓	Duck lettuce	Native	LC
4	*Najas marina*	Alismatales	Hydrocharitaceae	✓	✓	Spiny water nymph	Native	LC
5	*Nymphoides aquatica*	Asterales	Menyanthaceae	–	✓	Banana lily	Native	NE
6	*Nymphaea odorata*	Nymphaeales	Nymphaeaceae	–	✓	White water lily	Native	LC
7	*Potamogeton distinctus*	Alismatales	Potamogetonaceae	–	✓	Pondweed	Native	LC
8	*Najas minor*	Alismatales	Hydrocharitaceae	–	✓	Lesser naiad	Native	LC
9	*Myriophyllum spicatum*	Saxifragales	Haloragaceae	–	✓	Eurasian watermilfoil	Native	LC
10	*Typha angustifolia*	Poales	Typhaceae	–	✓	Narrowleaf cattail	Invasive	LC

Note: ✓ = Present; – = Absent; LC = Least Concern; NE = Not Evaluated.

Table 5: Physico-chemical parameters of water samples collected in KAL and SPL

Observations	Acceptable limit	Maximum permissible limit in the absence of an alternative source	KAL	SPL
I. PHYSICAL EXAMINATIONS				
1. Appearance			slightly turbid	slightly turbid
2. Color	-	-	slightly yellow	slightly yellow
3. Odor	Agreeable	Agreeable	Odorous	odorous
4. Turbidity (NTU)	1	5	4	0
5. Total dissolved solids (mg L^{-1})	500	2000	894	337
6. Electrical conductivity (µS cm^{-1})	-	-	1277	481
II. CHEMICAL EXAMINATIONS				
7. pH	6.5–8.5	6.5–8.5	7.32	7.62
8. Alkalinity pH as $CaCO_3$ (mg L^{-1})	-	-	0	0
9. Total alkalinity as $CaCO_3$ (mg L^{-1})	200	600	244	112
10. Total hardness as $CaCO_3$ (mg L^{-1})	200	600	296	206
11. Calcium as Ca (mg L^{-1})	75	200	61	41
12. Magnesium (mg L^{-1})	30	100	35	25
13. Free ammonia as NH_3 (mg L^{-1})	0.5	0.5	1.04	0.53
14. Nitrite as NO_2 (mg L^{-1})	0.5	0.5	0.14	0.05
15. Nitrate as NO_3 (mg L^{-1})	45	45	10	3
16. Chloride as Cl (mg L^{-1})	250	1000	204	69
17. Fluoride as F (mg L^{-1})	1	1.5	0.4	0.4
18. Sulfate as SO_4 (mg L^{-1})	200	400	111	23
19. Phosphate as PO_4 (mg L^{-1})	-	-	0.14	0.13
20. Tidy's test, 4 h, as O_2 (mg L^{-1})	-	-	0.1	0.1

Note: The acceptable limits and maximum permissible limits are as per BIS (2012). BIS 10500:2012.

compositional differences across freshwater systems. Likewise, Schlosser (1984) underscored the influence of local habitat features on fish community organization, and Baselga (2007) showed that beta diversity often results from species turnover along environmental gradients. Supporting this perspective, Yang et al. (2008) found that spatial environmental variability predominantly shapes freshwater fish assemblages, often indicated by low Jaccard and

Sørensen indices across different habitats. The observed low similarity values suggest that species turnover between the two lakes exceeds mere differences in species richness. This variation is likely driven by a combination of environmental and biotic factors identified in this study. Variations in physicochemical conditions, water depth, and differences in macrophyte composition and structural complexity may affect habitat suitability for various fish species, resulting in species replacement across lakes.

Furthermore, the prominent numerical dominance of the invasive cichlid *Oreochromis niloticus* in both systems likely alters community composition by suppressing subordinate native species, leading to distinct assemblages dominated by different sets of non-dominant species. Macrophyte structure may also influence these patterns by selectively favoring species adapted to either vegetated or open habitats. Collectively, these factors indicate that beta diversity patterns in the study lakes are driven by invasion and habitat-mediated community restructuring rather than random species variation.

3.2. Macrophyte Diversity

Macrophyte diversity in KAL included *Neltuma juliflora, Ceratophyllum demersum, Ottelia alismoides*, and *Najas marina* (Fig. 5 and Table 4). The abundance of *Neltuma juliflora* likely contributes minimally to aquatic biodiversity and may adversely impact shoreline habitats by increasing water loss and modifying habitat structure. Conversely, *Ceratophyllum demersum*, a submerged macrophyte, creates dense underwater meadows that offer cover and spawning grounds for small fish and invertebrates (Lacoul & Freedman 2006). *Najas marina*, another submerged species, performs a similar function and aids in sediment stabilization, which reduces turbidity and maintains clearer waters (Chambers et al. 2008).

SPL displayed higher macrophyte diversity, with species such as *Nymphoides aquatica*, *Nymphaea odorata*, *Najas marina*, *Potamogeton distinctus*, *Ottelia alismoides*, *Najas minor*, *Typha angustifolia, and Myriophyllum spicatum* (Fig. 5 and Table 4). The abundance of submerged and floating-leaved macrophytes in water bodies not only enhances habitat complexity but also contributes to nutrient cycling, oxygenation, and protection of juvenile fish from predation (Wetzel 2001, Lacoul & Freedman 2006). Previous studies have demonstrated that dense *Myriophyllum spicatum* stands can impact trophic interactions by boosting invertebrate populations, which may then be kept in check by fish predation, ultimately promoting macrophyte growth (Ward & Newman 2006). In this study, the presence of dense *Myriophyllum in SPL* was associated with higher dominance index values. Although direct causal links were not tested, this pattern aligns with established macrophyte–fish interaction frameworks and provides a plausible ecological explanation for the dominance structure observed in SPL.

Similarly, species of Potamogeton and Najas serve as indicators of moderately nutrient-rich waters, which can promote fish diversity (Chambers et al. 2008). The increased structural heterogeneity in SPL may help explain the slightly higher evenness and richness indices observed there, despite the rural setting. Overall, the presence and diversity of aquatic macrophytes significantly influence the spatial distribution, shelter availability, breeding potential, and foraging opportunities of fish communities in both lakes.

3.3. Physicochemical Parameters

Physicochemical analysis showed that both lakes were slightly turbid and yellowish in color, with odors indicative of organic matter or algal presence (APHA 2017) (Table 5). The KAL exhibited elevated total dissolved solids (894 mg L^{-1}), conductivity (1277 µS cm^{-1}), and chloride concentration (204 mg L^{-1}), suggesting increased anthropogenic pollution (Table 5). According to Allan (2004), such pollution likely originates from urban effluents, sewage discharge, and road runoff. Elevated conductivity values reflect a higher ion concentration, often due to domestic wastewater and industrial discharges in urban lakes. In fact, electrical conductivity is a reliable indirect marker of pollution in shallow lakes, as it shows linear correlations with total dissolved solids, sulfates, and other dissolved ions (Das et al. 2006).

SPL exhibited lower levels of dissolved ions and turbidity. SPL recorded nitrate and phosphate concentrations of 3 mg L^{-1} and 0.13 mg L^{-1}, respectively, indicating measurable nutrient enrichment in the freshwater system (Table 5). As suggested by Carpenter et al. (1998), nutrient enrichment may be attributed to agricultural runoff and fertilizer application in nearby fields. Such runoff is a common cause of nutrient enrichment in freshwater systems, especially in the absence of buffer vegetation. The marginally higher pH of 7.62 in SPL also supports the presence of biogenic activity, whereby photosynthetic organisms such as macrophytes and algae remove CO_2, shifting the carbonate equilibrium and increasing pH. Diurnal and seasonal pH fluctuations driven by biological metabolism are well documented in freshwater habitats, particularly wetlands, where photosynthesis reduces dissolved CO_2 and elevates pH (Gupta et al. 2021).

Higher levels of free ammonia (1.04 mg L^{-1}) were detected in KAL (Table 5). Elevated ammonia concentrations can adversely affect fish health by damaging gills and hindering growth (Randall & Tsui 2002). An integrated assessment of fish species, macrophyte composition, and water quality highlights the impact of surrounding environmental conditions on freshwater biodiversity. Although both lakes support similar fish diversity levels, the presence of invasive species, differences in macrophyte richness, and varying physicochemical parameters emphasize the importance of comprehensive freshwater ecosystem monitoring.

4. LIMITATIONS

Although the primary goal of this study was to investigate spatial differences between the lakes, variations in sampling periods may have influenced some of the results. KAL was sampled post-monsoon, while SPL was sampled during peak summer, and seasonal shifts in hydrological conditions can affect water quality, macrophyte abundance, and fish communities. Therefore, these findings should be interpreted with the understanding that both spatial factors and seasonal changes may have contributed, and future synchronized sampling across multiple seasons could improve spatial comparisons.

5. CONCLUSIONS

The present study emphasizes the complex relationships between fish diversity, macrophyte composition, and physicochemical conditions in the two examined freshwater lakes. Diversity indices indicate that SPL supported slightly higher fish diversity than KAL, likely owing to greater macrophyte richness and structural complexity, which offer a variety of niches for feeding, breeding, and shelter. This habitat heterogeneity, along with favorable water quality, seems to promote more balanced species assemblages despite the dominance of *Oreochromis niloticus*. The diversity of macrophytes, ranging from submerged to emergent forms, plays a crucial role in maintaining biodiversity. Additionally, physicochemical analyses revealed site-specific differences in parameters such as pH, conductivity, nutrient levels, and ionic composition, reflecting both natural processes and human activities. These findings highlight the importance of integrated lake management strategies that focus on habitat diversity, control of invasive species, and pollution reduction to preserve ecological integrity.

6. REFERENCES

Allan, J.D., 2004. Landscapes and riverscapes: the influence of land use on stream ecosystems. *Annual Review of Ecology, Evolution, and Systematics*, 35, pp.257–284. [DOI]

APHA, 2017. *Standard Methods for the Examination of Water and Wastewater*. Twenty-Third Edition. American Public Health Association.

Baselga, A., 2007. Disentangling distance decay of similarity from richness gradients: response to Soininen et al. *Ecography*, 30, pp.838–841. [DOI]

Bureau of Indian Standards, 2007. *Methods of sampling and test (physical and chemical) for water and wastewater: Part 63—Oxygen absorbed in 4 h (IS 3025 (Part 63):2007)*. Bureau of Indian Standards.

Bureau of Indian Standards, 2012. *Drinking water—Specification (IS 10500:2012) (Second revision)*. Bureau of Indian Standards.

Canonico, G.C., Arthington, A., McCrary, J.K. and Thieme, M.L., 2005. The effects of introduced tilapias on native biodiversity. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 15(5), pp.463–483. [DOI]

Carpenter, S.R., Caraco, N.F., Correll, D.L., Howarth, R.W., Sharpley, A.N. and Smith, V.H., 1998. Nonpoint pollution of surface waters with phosphorus and nitrogen. *Ecological Applications*, 8(3), pp.559–568. [DOI]

Chakraborty, S.K., 2021. Ecology of fishes of rivers: functional roles. In: Babu, C. and Sivaperuman, C. (eds.) *Riverine Ecology, Vol. 2*. Cham: Springer, pp.187–286. [DOI]

Chambers, P., Lacoul, P., Murphy, K. and Thomaz, S., 2008. Global diversity of aquatic macrophytes in freshwater. In: *Abstracts of the 5th International Weed Science Congress*. Vancouver, Canada, p.323.

Cook, C.D.K., 1996. *Aquatic and Wetland Plants of India*. Oxford University Press.

Das, S., Mandal, R. and Bandyopadhyay, S., 2006. Role of electrical conductivity as an indicator of pollution in shallow lakes. *Asian Journal of Water, Environment and Pollution*, 3(1), pp.153–156.

Diehl, S. and Kornijów, R., 1998. *The Structuring Role of Submerged Macrophytes in Lakes*. Springer, pp.24–46.

Dudgeon, D., Arthington, A.H., Gessner, M.O., Kawabata, Z.I., Knowler, D.J., Lévêque, C. and Sullivan, C.A., 2006. Freshwater biodiversity: importance, threats, status and conservation challenges. *Biological Reviews*, 81(2), pp.163–182. [DOI]

Froese, R. and Pauly, D., 2024. *FishBase*. Retrieved August 13, 2026, from https://www.fishbase.org/.

Gebrekiros, S.T., 2016. Factors affecting stream fish community composition and habitat suitability. *Journal of Aquaculture & Marine Biology*, 4(2), 00076. [DOI]

Gido, K.B. and Brown, J.H., 1999. Invasion of North American drainages by alien fish species. *Freshwater Biology*, 42(2), pp.387–399. [DOI]

Gilvear, D.J., Karr, J.R. and Chu, E.W., 1999. Restoring life in running waters: better biological monitoring. *Water, Air, and Soil Pollution*, 116, pp.666–667.

Gupta, D., Ranjan, R.K., Parthasarathy, P. and Ansari, A.M.S., 2021. Spatial and seasonal variability in the water chemistry of Kabar Tal wetland (Ramsar site), Bihar, India: multivariate statistical techniques and GIS approach. *Water Science and Technology*, 83(9), pp.2100–2117. [DOI]

Hammer, O., Harper, D.A.T. and Ryan, P.D., 2001. PAST: paleontological statistics software package for education and data analysis. *Palaeontologia Electronica*, 4(1), pp.1–9.

IUCN, 2025. *The IUCN Red List of Threatened Species, Version 2025-1*. Retrieved August 13, 2026, from https://www.iucnredlist.org.

Jayaram, K.C., 2010. *The Freshwater Fishes of the Indian Region*. Delhi: Narendra Publishing House.

Johnson, C., Sarkar, U.K., Koushlesh, S.K., Das, A.K., Das, B.K. and Naskar, B.K., 2022. Fish assemblage, ecosystem status and potential impact of Nile tilapia in Halali Reservoir of Central India. *Environment, Development and Sustainability*, 24(6), pp.7753–7775. [DOI]

Johnson, R.K. and Angeler, D.G., 2014. Effects of agricultural land use on stream assemblages: taxonspecific responses of alpha and beta diversity. *Ecological Indicators*, 45, pp.386–393. [DOI]

Koleff, P., Gaston, K.J. and Lennon, J.J., 2003. Measuring beta diversity for presence–absence data. *Journal of Animal Ecology*, 72(3), pp.367–382. [DOI]

Lacoul, P. and Freedman, B., 2006. Environmental influences on aquatic plants in freshwater ecosystems. *Environmental Reviews*, 14(2), pp.89–136. [DOI]

Lewis, W.M. Jr., 2002. Basis for the protection and management of tropical lakes. *Freshwater Biology*, 47(5), pp.957–970.

Magurran, A.E., 2004. *Measuring Biological Diversity*. Blackwell Publishing.

Mogalekar, H.S., Sudhan, C., Katare, M.B. and Swami, A.M., 2025. Fish assemblage dynamics, Tilapia invasion, trophic guilds, and conservation priorities in the hydrologically fragmented Vaigai River–Estuary continuum, India. *Thalassas: An International Journal of Marine Sciences*, 41, p.153. [DOI]

Moyle, P.B. and Light, T., 1996. Biological invasions of fresh water: empirical rules and assembly theory. *Biological Conservation*, 78(1–2), pp.149–161. [DOI]

Nelson, J.S., Grande, T.C. and Wilson, M.V.H., 2016. *Fishes of the World*. 5th edn. John Wiley & Sons. [DOI]

Paul, M.J. and Meyer, J.L., 2001. Streams in the urban landscape. *Annual Review of Ecology and Systematics*, 32, pp.333–365. [DOI]

Randall, D.J. and Tsui, T.K., 2002. Ammonia toxicity in fish. *Marine Pollution Bulletin*, 45(1–12), pp.17–23. [DOI]

Sarkar, U.K. and Lakra, W.S., 2010. Small indigenous freshwater fish species of India: significance, conservation and utilization. *Aquaculture Asia Magazine*, 15(3), pp.34–35.

Schlosser, I.J., 1984. Fish community structure and function along two habitat gradients in a headwater stream. *Ecological Monographs*, 52(4), pp.395–414.

Subramanyam, K., 1962. *Aquatic Angiosperms*. CSIR.

Talwar, P.K. and Jhingran, A.G., 1991. *Inland Fishes of India and Adjacent Countries*. Vols. 1–2. New Delhi: Oxford & IBH Publishing Co. Pvt. Ltd.

Thomaz, S.M., Cardozo, A.L.P., Quirino, B.A., Yofukuji, K.Y., Aleixo, M.H.F. and Fugi, R., 2025. A review of the ecological role of aquatic macrophytes on freshwater fish. *Hydrobiologia*, 852, pp.3257–3290. [DOI]

TNWRD, 2020. *Catchment Area Statistics*. Government of Tamil Nadu.

Walsh, C.J., Roy, A.H., Feminella, J.W., Cottingham, P.D., Groffman, P.M. and Morgan, R.P. II, 2005. The urban stream syndrome: current knowledge and the search for a cure. *Journal of the North American Benthological Society*, 24(3), pp.706–723. [DOI]

Ward, D.M. and Newman, R.M., 2006. Fish predation on Eurasian watermilfoil (*Myriophyllum spicatum*) herbivores and indirect effects on macrophytes. *Canadian Journal of Fisheries and Aquatic Sciences*, 63(5), pp.1049–1057. [DOI]

Wetzel, R.G., 2001. *Limnology: Lake and River Ecosystems*. Academic Press. [DOI]

Yang, Y.C., Cai, X. and Herricks, E.E., 2008. Identification of hydrologic indicators related to fish diversity and abundance: a data mining approach for fish community analysis. *Water Resources Research*, 44(4), W04401. [DOI]