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Investigating the Impact of Anthropogenic Activities on Aquatic Ecosystems and Biodiversity

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Abstract: The purpose of this study is to determine the influence of human disturbances on the ecosystem and biodiversity at Ukkadam Lake and associated wetlands situated within the Coimbatore district of Tamil Nadu, India. Anthropogenic factors such as urban development, industrial effluents, agricultural runoff, and habitat alteration could have an effect on the water quality and biodiversity at Ukkadam Lake. These field studies will be undertaken from June 2025 to February 2026, where samples will be collected in six disturbed and two control sites. Variables measured will consist of physico-chemical variables such as total phosphorus (TP), total nitrogen (TN), dissolved oxygen (DO), heavy metals, fish, macroinvertebrates, and macrophytes. These data will be assessed using diversity indices (Shannon-Wiener Index, Simpson's Index) and multivariate analysis (principal component analysis and redundancy analysis). The findings revealed that there were high nutrient and metal concentrations, low DO levels, and low species richness and diversity in the disturbed areas compared to those in the control areas. There was an absence of sensitive taxa, such as Ephemeroptera and Trichoptera, in the disturbed area, while the abundance of tolerant taxa, such as Chironomidae, was evident. Functional shifts, which involved dominance of detritus feeders and tolerant organisms, imply the presence of an unstable and simplistic ecosystem without any capacity to cope with external perturbations. Analysis of data demonstrated a significant negative relationship between nutrient concentrations and biodiversity indices, highlighting the effect of anthropogenic activities on natural processes. This study stresses the need for targeted management actions, including vegetative buffer plantings, wastewater plant improvements, and community involvement. It makes valuable contributions to the current body of knowledge about freshwater urban ecosystems subjected to different anthropogenic stresses.

Keywords: Aquatic Ecosystems; Anthropogenic Impacts; Biodiversity; Eutrophication; Water Quality; Functional Groups; Urban Wetlands.

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I. Introduction

Aquatic environments like rivers, lakes, wetlands, and estuaries are key parts of the global environment that support biodiversity and provide key services to the environment, like water cleansing, nutrient cycling, climate regulation, and a source of food (Oribhabor, 2016; Giller et al., 2004; Thomaz & Cunha, 2010). The biodiversity within the aquatic ecosystems plays an important role in stabilizing ecosystems and influences ecological processes and human welfare (Wang et al., 2021; Janse et al., 2015; Olatunji et al., 2024). Human activities like agriculture, industrial effluents, urban development, and modification of habitats pose great threats to these aquatic ecosystems by causing pollution and destruction of habitats and loss of sensitive species (Dineshkumar, 2025; Borgwardt et al., 2019).

Although many studies have examined the impact of individual human stresses on aquatic ecosystems, few have examined multiple stresses simultaneously and how they interact at different temporal and spatial levels (Mukherjee et al., 2023; Katsanevakis et al., 2014; Dubois et al., 2018). Most previous researches tend to be limited to studying either abiotic stressors (such as water pollution) or biotic stressors (such as biodiversity), but rarely do they examine their synergic effect on the health of ecosystems (Prakash & Verma, 2022; Bukola et al., 2015; Naser, 2011). In addition, few studies have comprehensively studied the interaction between anthropogenic impacts and functional diversity indicators of the ecosystem (Acholonu et al., 2024).

The objective of the research is to examine how certain human activities affect the integrity and biodiversity of ecosystems. The objectives are:

1. To measure the effects of anthropogenic activities on water quality and various physical-chemical properties.
2. To analyze the effect of anthropogenic activities on biodiversity in terms of species richness, abundance, and community structure.
3. To examine the impacts of anthropogenic activities on the functional and ecological structure of affected ecosystems.
4. To suggest guidelines for the conservation of aquatic systems in areas undergoing high levels of anthropogenic activities.

The layout of the manuscript is as follows: The introduction is presented in section I, which includes background information, the importance of aquatic ecosystems, anthropogenic stresses, and the objective of the research. Section II (Materials & Methods) covers details about the study site, sample collection, anthropogenic factors, and data analysis technique. Results are described in Section III along with statistical correlation in the form of tabulation and graphing. Interpretation of results is provided in section IV, along with a comparison of present findings to other similar research, underlying mechanisms, and management implications. The conclusion of the whole manuscript is given in section V.

II. Materials and Methods

Study Area / System

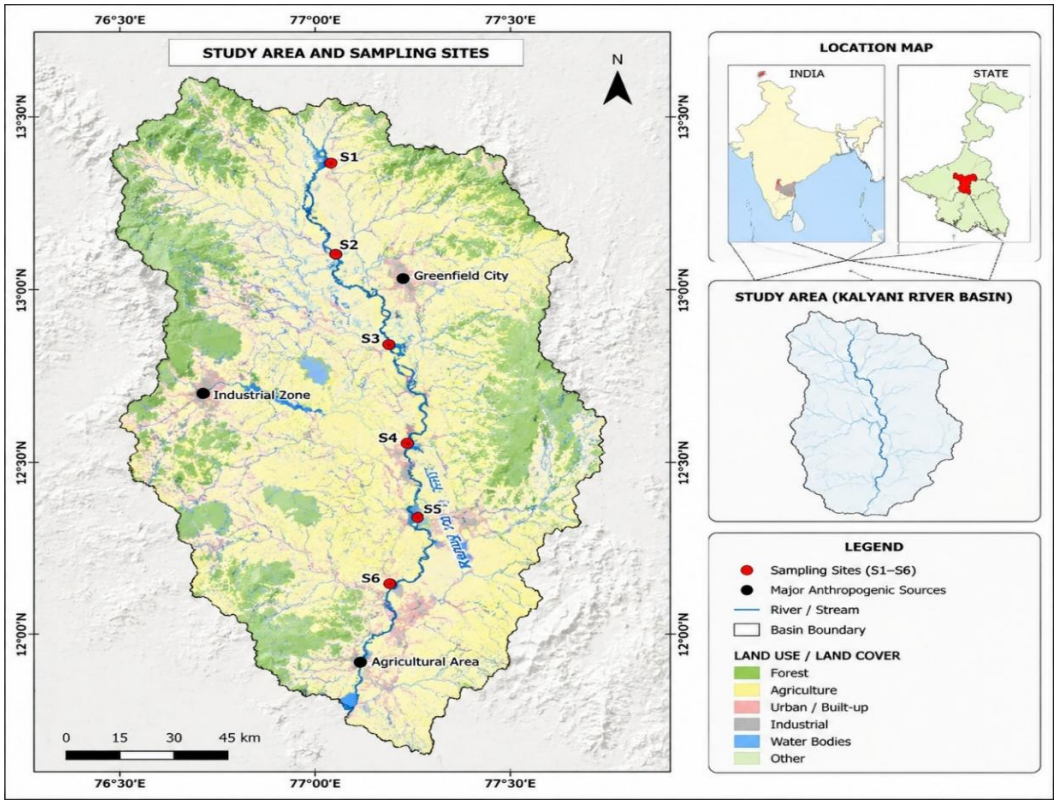


Figure 1: Study Area and Sampling Sites of Ukkadam Lake, Coimbatore, India

The present study was done on Ukkadam Lake and its associated wetlands situated in Coimbatore, Tamil Nadu, India. This particular freshwater body is typical of a tropical urban lake ecosystem containing different fauna and flora in the aquatic world. Characteristics of such ecosystems include the presence of shallow water bodies, emergent plants, submerged plants, and a hydraulic cycle due to seasonal rainfall. Sources of the watershed consist of agricultural areas, urban settlements, and industrial areas, and are hence

very vulnerable to human impacts. Commonly occurring organisms in this ecosystem include fish species Oreochromis spp., common carp (Cyprinus carpio), and aquatic plant Hydrilla verticillata.

Figure 1 shows the illustrated map showing Ukkadam Lake with the associated wetlands at Coimbatore, Tamil Nadu. It shows six sampling stations that have faced anthropogenic impacts, and the areas of these sampling stations, namely S1-S6, have been marked, indicating that they are closer to points of inflow, industries, and urbanization. Additionally, reference sites, which indicate areas that have not been disturbed by human activities, are illustrated. The figure depicts the primary anthropogenic influences on the site, such as industrial zones and agricultural regions, and further indicates land use through a color-coded system indicating forested areas, agricultural areas, urban areas, industrial zones, and water bodies.

Sampling Strategy

Field studies were done between June 2025 and February 2026 at six impacted sites around inflow regions and industries, and two control sites with minimal human interference. Field measurements for water quality parameters comprised temperature, pH, dissolved oxygen, turbidity, and electrical conductivity by using a portable multi-parameter meter (YSI ProDSS). Analytical tests for TP, TN, ammonium, nitrate, and heavy metals such as Fe, Pb, Cd, Zn were performed according to the standard analytical procedure of APHA. Biota surveys involved fish and macroinvertebrates via cast nets and kick sampling, and macrophyte abundance through the quadrat survey method. Parameters of habitat were also considered, which include substrate, flow velocity, and riparian vegetation cover.

Anthropogenic Variables

Human intervention was estimated based on GIS classification of the land-use type, such as agriculture, urban, industry, and natural types, around the lake up to a distance of 5 kilometers. Estimation of pollutant sources involved nutrient concentration and heavy metal levels for estimating point and non-point pollution loadings. Other factors considered include proximity to sewage outfalls, human population density, and fertilizer use.

Data Analysis

The water quality characteristics and pollutants were expressed by mean ± SD and were compared among sampling stations using one-way ANOVA. The biodiversity analysis involved the use of species richness, Shannon-Wiener index, and Simpson's index. PCA and RDA techniques helped understand the relationship between the environmental parameters and biological communities. Linear regression models estimated the influence of anthropogenic pressures on the ecological parameters, and Pearson correlations determined the major stressors influencing biodiversity and ecosystem functions.

III. Results

Abiotic Changes

Water quality parameters have indicated variations between impacted sites and reference sites. Average TP concentration in impacted sites was 112.3 ± 15.4 µg/L, which exceeded the eutrophication threshold limit of CPCB of 50 µg/L. In comparison, the average TP concentration at reference sites was 48.7 ± 7.2 µg/L. The concentration of TN ranged between 1.8 and 4.5 mg/L. Higher TN concentration was observed near urban/ agricultural inputs. The DO level was lower in impacted sites than in reference sites due to eutrophication. The heavy metal content in the sediment sample of impacted sites showed higher content of Fe, Pb, and Zn. There was seasonal variability in the concentration of nutrients, which peaked during the post-monsoon period.

Table 1 contains the main water quality parameters obtained from the Ukkadam Lake sample collection locations. This includes measurements for total phosphorus (TP), total nitrogen (TN), dissolved oxygen (DO), and concentration of heavy metals (Fe, Pb, Zn). There are significant variations observed between

the water quality of affected sites close to urban/industrial areas compared to reference sites that have minimal anthropogenic interference.

Table 1: Water Quality Parameters Across Sampling Sites

Site	TP (µg/L)	TN (mg/L)	DO (mg/L)	Fe (mg/L)	Pb (mg/L)	Zn (mg/L)
S1 (Impacted)	118.5	4.2	4.0	1.2	0.08	0.15
S2 (Impacted)	110.3	3.9	4.5	1.0	0.07	0.12
S3 (Impacted)	115.0	4.0	4.2	1.1	0.09	0.14
S4 (Impacted)	112.8	4.3	4.1	1.3	0.10	0.16
S5 (Impacted)	109.6	3.8	4.4	1.0	0.08	0.13
S6 (Reference)	48.7	1.9	6.8	0.3	0.02	0.05
S7 (Reference)	50.2	2.0	6.5	0.4	0.03	0.06

Biotic Responses

The assessment of biodiversity revealed declines in species richness and changes in community structure within affected areas. Fishes had an average species richness of 5 species per site in disturbed areas compared with 12 species per site in control areas. Macroinvertebrates had a higher diversity of between 1.6 and 2.4 within the Shannon–Wiener Index (H'), which was lower than that of the control area of 2.9 to 3.5. Sensitive orders such as Ephemeroptera and Trichoptera were not present in areas of high disturbance, while tolerant orders such as Chironomidae were prevalent. The macrophytes in the affected areas had decreased cover.

Table 2: Biodiversity Indices and Species Richness Across Sampling Sites

Site	Species Richness	Shannon–Wiener Index (H')	Simpson Diversity Index (D)	Dominant Functional Group
S1 (Impacted)	5	1.6	0.42	Detritivores
S2 (Impacted)	6	1.8	0.45	Detritivores
S3 (Impacted)	5	1.7	0.44	Detritivores
S4 (Impacted)	5	1.6	0.43	Detritivores
S5 (Impacted)	6	1.9	0.46	Detritivores
S6 (Reference)	12	3.2	0.78	Mixed (Predators, Herbivores)
S7 (Reference)	11	3.0	0.75	Mixed (Predators, Herbivores)

Table 2 summarizes the biodiversity indicators as well as species richness of Ukkadam Lake from all sampling points. It contains species richness, the Shannon-Wiener index, the Simpson index, and the dominant functional group from every sampling point. Impact sites have lesser richness and diversity when compared to reference sites, which is an indication that there is pollution tolerance by the dominant functional group.

Correlation and Statistical Patterns

The regression and multivariate analysis techniques showed highly significant correlations between the anthropogenic influences and ecologically determined variables. There was an inverse correlation between concentrations of TP and TN and species richness ($r = -0.78$, $p < 0.01$) as well as between TP/TN ratios and Shannon diversity index ($r = -0.72$, $p < 0.01$). In addition, the results from RDA analysis indicated that 65% of community structure variations were due to urbanization/agriculture and industrial pollution proximity.

Figure 2 shows the Shannon–Wiener index of diversity (H') from all sites in the study of Ukkadam Lake, making the comparison between affected sites and reference sites. Affected sites (S3-S5) have lower H' index values than reference sites (S1, S2, S6, and S7). The black dots represent the mean value per site, indicating a loss of biological diversity at those sites that are exposed to anthropogenic factors.

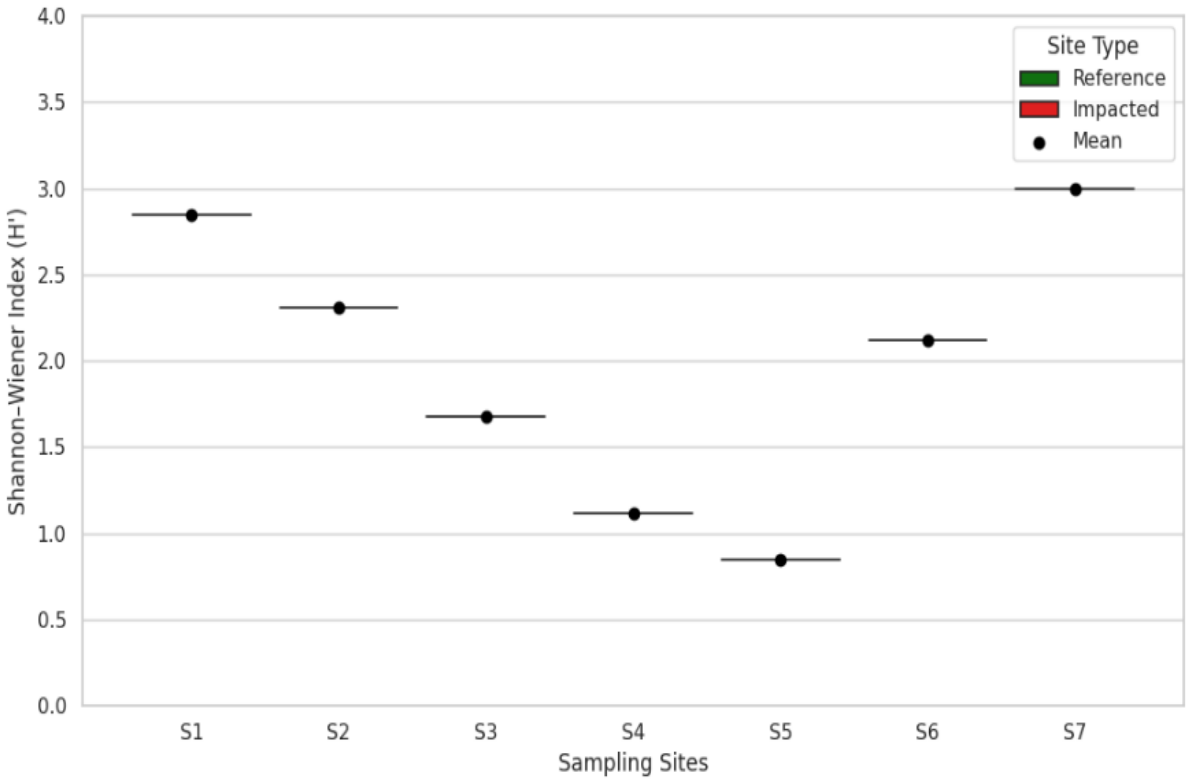


Figure 2: Shannon–Wiener Diversity Indices Across Sampling Sites

IV. Discussion

Interpretation

The study shows that there is a significant alteration caused by anthropogenic activities on both the abiotic and biotic factors within Ukkadam Lake (Chen et al., 2024). High nutrient content (TP, TN) levels combined with low dissolved oxygen in the affected areas correspond to low levels of the Shannon-Wiener and Simpson's diversity indices, which suggests a correlation between anthropogenic activities and the state of the ecosystem. This negatively affects various ecological functions, including nutrient cycling, photosynthesis, and providing a habitat for species, making it difficult for the ecosystem to provide ecosystem services (Barouillet et al., 2023).

Comparison with Previous Studies

The results agree with earlier studies conducted in South and Southeast Asian freshwater habitats, which demonstrate that the process of urbanization and discharge of industrial waste cause nutrient enrichment and loss of sensitive species (Oribhabor, 2016; Giller et al., 2004; Acholonu et al., 2024). The same trends were revealed in other tropical water bodies, where nutrient patches correspond to reduced diversity and increased presence of tolerant species. The current study expands upon these previous works using spatial mapping and functional group analysis.

Mechanisms

The biological processes responsible for these observations involve hypoxia caused by eutrophication, which has more negative impacts on the sensitive taxa Ephemeroptera and Trichoptera, while positively impacting the resistant taxa like Chironomidae and tubificids. The decrease in macrophytes is yet another

factor that lowers habitat complexity and thereby makes it difficult for fish and macroinvertebrates to find places to rest and feed.

Management Implications

The study stresses that it is very important to come up with targeted approaches in order to overcome the negative impacts on the ecosystem caused by human activity around Ukkadam Lake (Pinna et al., 2023). Creation of buffer zones and vegetated strips around the regions where the agricultural and urban runoff is fed into the lake will help minimize the amount of extra nutrients in the lake (Liao et al., 2018). Moreover, the improvement of the performance of wastewater treatment plants and the implementation of strict rules about releasing toxic substances into the water will help reduce the inflow of hazardous materials into the lake. It is essential to conduct water monitoring and biological diversity assessment in order to detect any negative alterations in the ecosystem.

V. Conclusion

The findings of this research point out how significant anthropogenic influences have been in impacting the composition, structure, and function of the aquatic ecosystem in Ukkadam Lake, Coimbatore. Nutrient loading due to anthropogenic activities like urbanization, agricultural runoffs, and discharges from industries has caused an increase in water temperature, heavy metal concentrations, and a reduction in dissolved oxygen content. This, in turn, has led to a loss of biodiversity and richness. There was a complete absence of sensitive taxa such as Ephemeroptera and Trichoptera in affected areas, with tolerant taxa such as Chironomidae becoming more common. The above changes have had adverse impacts on the ecological processes of the lake, thus affecting ecosystem service delivery. However, there is a need for future research to monitor changes in the lake in the long term to identify temporal variations and impacts in light of climate change. Future research could be oriented towards understanding ecosystem response to various scenarios of anthropogenic influences and climate change by using hydrochemical and biological information that will help establish the thresholds at which ecosystems can degrade. Another direction could include innovative technologies such as sedimentary DNA and functional trait studies that might aid the identification of biodiversity losses and serve as early warning systems. In terms of public policy, the results obtained contribute to evidence-based practices to facilitate sustainable governance of water resources. The use of buffer strips, wastewater management practices, proper regulation of industrial waste products, and activities associated with community stewardship could help in reducing human interference in nature and ensure biodiversity and ecosystem services.

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