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# Aquatic macroinvertebrate diversity and water quality assessment in Vembannur Wetland, Tamil Nadu, India

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## ABSTRACT

Wetlands are vital components of the ecosystem, offering both ecological and economic benefits. This study was conducted in the Vambannur wetland, located in Rajakkamangalam block, Kanyakumari, Tamil Nadu, to assess the diversity of aquatic macroinvertebrates and water quality across three sites in September 2024. A total of 237 individuals, 15 genera, 11 families and 8 orders were identified, with Gastropods being the most dominant order. Key biodiversity indices, including Shannon, Simpson, Menhinick, Margalef and Berger-Parker, were calculated, revealing diversity in sites 2 and 3 compared to site 1. The results highlight the significance of macroinvertebrate diversity in determining wetland quality. Principal Component Analysis (PCA) is used to explore the relationship between physicochemical parameters and macroinvertebrate communities, providing insights into wetland health.

**Keywords**: Aquatic macroinvertebrates, Water quality, Diversity indices, Biodiversity, Vembannur wetland

## Introduction

Wetlands are among the most vital ecosystems on Earth, acting as transitional zones between terrestrial and aquatic habitats (Xu et al., 2019). These ecosystems are crucial for preserving biodiversity, regulating water cycles, and providing numerous other ecological services, including water purification, flood regulation, and carbon storage (Singh et al., 2006). The significance of wetlands in maintaining ecological balance is further underscored by their role in supporting a diverse range of species, enhancing local economies through fishing and water resource management, and mitigating environmental damage caused by human activities (McLaughlin & Cohen, 2013). In India, the country's varied topography and climatic conditions have fostered the development of a diverse range of wetland ecosystems. These wetlands are home to approximately 20% of the nation's biodiversity, playing an indispensable role in maintaining ecological stability (Deepa & Ramachandra, 1999).

The global importance of wetlands has become increasingly apparent as human activities continue to threaten their existence (Junk et al., 2013). Over the past century, wetlands have faced widespread degradation, with 64% of the world's wetland areas impacted by urbanisation, agricultural expansion, and industrial development (Ballut-Dajud et al., 2022). This degradation often results in the contamination of wetland water, loss of biodiversity, and a decrease in the vital services they provide to both nature and society. Despite these threats, awareness of the ecological and economic values of wetlands has grown, with many nations, including India, taking steps toward their protection and conservation. India currently recognises the importance of wetlands through the establishment of 85 Ramsar sites, which highlights the country's commitment to conserving these critical ecosystems for biodiversity preservation (Prasad et al., 2002). In the context of this growing concern, aquatic macroinvertebrates have emerged as effective bioindicators of wetland health. These organisms are susceptible to environmental changes, making them invaluable for monitoring water quality and ecosystem stability. Previous studies have demonstrated that macroinvertebrates respond rapidly to both chemical pollutants and habitat alterations, with their diversity and abundance providing valuable insights into the ecological condition of a wetland (Dodson et al., 2001; Sharma et al., 2009). By examining these organisms, researchers can assess the degree of environmental stress and identify potential areas for conservation efforts. The presence of diverse macroinvertebrate communities, for instance, often correlates with higher water quality and a more balanced ecosystem. In contrast, a decline in their diversity may signal pollution or habitat degradation.

The purpose of the current study is to investigate the diversity of macroinvertebrates and evaluate the water quality in the Vembannur wetland, a crucial wetland located in southern India. This wetland, like many others, faces the dual pressures of natural and anthropogenic changes, including urban encroachment and agricultural runoff. The central question driving this study is: What is the current status of macroinvertebrate diversity and water quality in the Vembannur wetland, and how do these factors reflect the overall ecological health of the ecosystem? By addressing this question, the study aims to provide a comprehensive assessment of the wetland's ecological condition, offering valuable data to inform future conservation strategies. The rationale for this research stems from the need to enhance our understanding of wetland ecosystems, particularly in regions like India, where rapid development poses significant threats to ecological integrity. Although considerable research has been conducted on the general importance of wetlands and macroinvertebrates as bioindicators, studies focusing on specific wetlands in India, such as Vembannur, remain limited. The findings of this study will not only contribute to the body of knowledge about the ecological health of this particular wetland. However, they will also offer insights into the broader issues of wetland conservation in the region. Through a detailed analysis of macroinvertebrate diversity and water quality, this research will help identify potential environmental stressors and provide a baseline for future monitoring efforts.

## Materials and Methods

### *Study Area*

The Vembannur Wetland is a freshwater urban pond located in Rajakkamangalam Block of Kanyakumari District, Tamil Nadu, India. This artificial wetland spans approximately 19.75 hectares, with an average depth of 7 feet, and was developed through human intervention. The surrounding area includes residential settlements, railway quarters, and roadways, with some sewage inflow impacting the water quality. Vembannur Wetland is recognized for its biodiversity, particularly in bird and fauna species. Since April 8, 2022, it has been listed by UNESCO for its ecological importance.

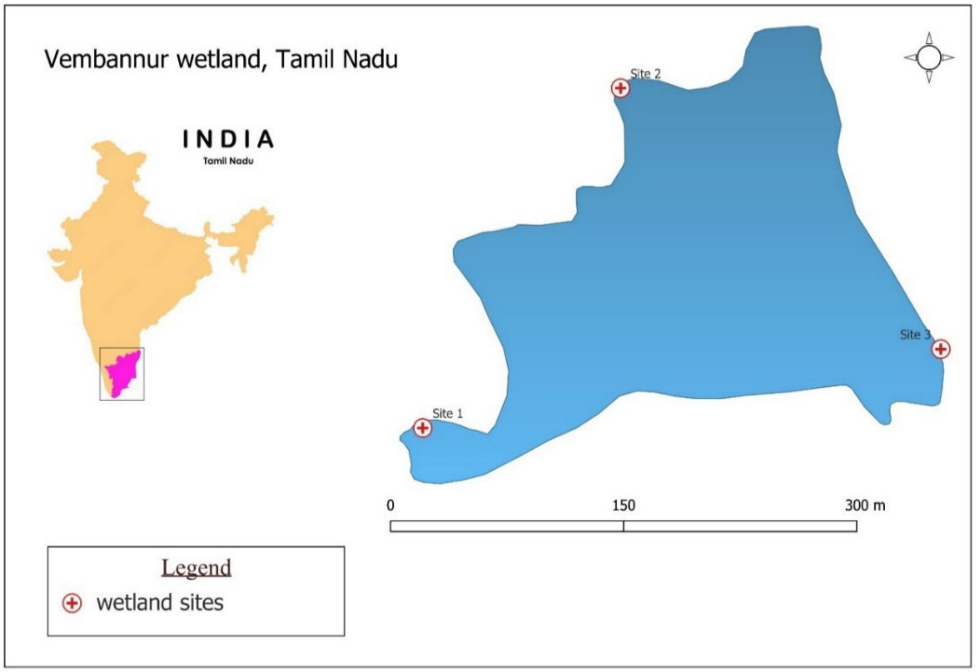


**Figure 1.** Geographical locations of sampling sites for macroinvertebrate and physicochemical water quality assessments

A field survey was conducted in September 2024, focusing on macroinvertebrate sampling and physicochemical analyses across three sites selected based on bird activity, accessibility, and environmental conditions. The latitude and longitude of each sampling site are detailed in Figure 1. The general land use patterns in the basin range from large-scale agriculture near the wetland to small-scale farming on elevated land. These patterns reflect the district's topography and highlight the importance of agriculture for local livelihoods.

### *Sampling Design*

During the autumn season, macroinvertebrate samples and physicochemical parameters were collected from three distinct sites within the Vembannur Wetland to assess water quality and biodiversity. Site 1 is located near a roadside, Site 2 is adjacent to cultivated farmland, and Site 3 is situated in an area with moderate human influence. These sites were selected to represent different levels of anthropogenic impact on the wetland ecosystem. The latitude and longitude coordinates for the sites are as follows: Site 1 is at 8°10'47.8"N, 77°22'23.7"E, Site 2 is at 8°10'48.6"N, 77°22'42.9"E, and Site 3 is at 8°11'02.5"N, 77°22'39.8"E.

Water samples (1 litre each) were collected in pre-cleaned plastic containers for the analysis of environmental factors. On-site measurements were taken for parameters such as water temperature, surface temperature, dissolved oxygen (DO), electrical conductivity (EC), total dissolved solids (TDS), and pH using a multi-parameter digital meter. The samples were then transported to the laboratory, where they underwent further analysis for chlorides, phosphates, water hardness, total alkalinity, ammonia, calcium, nitrate, nitrite, and magnesium, following the methods outlined by the American Public Health Association (APHA, 2005).

### *Macroinvertebrate Sampling*

Aquatic macroinvertebrate samples were collected using a multi-habitat sampling technique as recommended by the United States Environmental Protection Agency (US-EPA) (Rico-Sánchez et al., 2021). Sampling was carried out for 5 minutes at each site using a 500 µm mesh kick net. Specimens were preserved in 70% ethanol for laboratory identification, following the methods described by Andrew et al. (2008) and Thorp et al. (2009).

### *Diversity Indices*

The diversity and community composition of macroinvertebrates were assessed using diversity indices, including Taxa

Richness, Shannon Diversity Index, Simpson Diversity Index, Evenness Index, Menhinick's Richness Index, Margalef Diversity Index, and Berger-Parker Dominance Index.

### *Statistical Analysis*

Physicochemical parameters and taxonomic richness data were analysed to assess site-wise relationships. Cluster analysis was employed to assess the similarity among sites based on environmental factors. At the same time, Principal Component Analysis (PCA) was applied to reduce the dataset's dimensionality, facilitating a more straightforward interpretation of macroinvertebrate diversity and environmental parameters. Multivariate relationship analysis and correlation analysis were performed using PAST software (Shrestha & Kazama, 2007).

## Results and Discussion

### *Physicochemical Parameters of the Water*

The physicochemical parameters of the water from Vembannur Wetland were measured across three sampling sites. Water temperature at site 1 is 26.40 °C, at site 2, 270 °C, and at site 3, 26.70 °C. The pH values remained consistent across all sites, with slight variations ranging from 7.1 to 7.2. Electrical conductivity exhibited minor fluctuations at sites 290µS/cm, 274µS/cm and 278 µS/cm, respectively. Total dissolved solids (TDS) were highest at Site 1 (174 mg/L) and recorded the same values at Sites 2 and 3 (137 mg/L). The chi-square test revealed no significant differences in the physicochemical parameters in sites ($p>0.05$).

Total hardness showed a minor difference between sites, with Sites 1 and 2 measuring 75 mg/L and Site 3 showing a slightly higher value at 100 mg/L. Other parameters, such as depth, Total alkalinity, calcium, magnesium, chloride, phosphate, nitrate, nitrite, and ammonia, were consistent across all three sites, showing no notable spatial variation. Depth was constant at 7 meters across all sites, while total alkalinity, calcium, and magnesium were recorded at 100 mg/L, 50 mg/L, and 75 mg/L, respectively. Chloride levels were uniform at 35.46 mg/L, phosphate at 0.612 mg /L, nitrate at 0.2744 mg /L, nitrite at 25 mg /L, and Ammonia at 2.44 mg /L.

### *Principal Component Analysis*

Principal Component Analysis (PCA) revealed a clear spatial separation of sites based on factors of electrical conductivity, depth, total dissolved solids, total hardness, total alkalinity, calcium, magnesium, chloride, phosphate, nitrate, nitrite and ammonia (Figure 2). The total variance explained by PCA analysis is 80%. The analysis also revealed a significant relationship ($p < 0.05$) in the physicochemical parameters across the sites, highlighting the influence of these factors on the environmental dynamics of the Vembannur wetland.

### *Phylogenetic Tree*

The phylogenetic tree (dendrogram) represents the hierarchical clustering of the study sites (site 1, site 2, and site 3) based on their physicochemical parameters using Ward's linkage method, which minimises variance within clusters (Figure 3). The tree reveals that sites 2 and 3 are closely clustered, indicating a high degre of similarity in their physicochemical characteristics, while site 1 stands apart, reflecting distinct environmental conditions. Parameters such as aerial temperature, total dissolved solids, and electrical conductivity contribute significantly to this differentiation, with total hardness playing a key role in the clustering of Site 3. This clustering highlights spatial variations in water quality across the Vembannur Wetland, with site 1 potentially being influenced by unique natural or anthropogenic factors. Such analyses are essential for identifying patterns in water quality and prioritising targeted conservation and management strategies for these wetland ecosystems.

### *Taxonomic Composition of Macroinvertebrates*

The taxonomic composition of aquatic macroinvertebrates across the three sample sites in Vembannur Wetland is presented in Table 2. A total of 237 individuals were recorded, representing 3 classes, 8 orders, 11 families, and 15 taxa. Among these, gastropods were dominant, particularly within the family Viviparidae, which were abundant in all environmental conditions. These organisms thrive on organic debris, contributing to the wetland's ecosystem function (Madomguia et al., 2016). Site 1, which features sparse trees and minimal vegetation, had a relatively lower abundance, while site 2, with more intact vegetation, exhibited greater biodiversity and better water quality. Site 3, which had minimal vegetation and a small stream, also showed moderate biodiversity but indicated fair environmental conditions. Several key macroinvertebrate groups were recorded, including gastropods, malacostraca, and insecta. Mollusca showed notable diversity with four taxa present, and decapods were also observed in the wetland. Orders such as Ephemeroptera, Hemiptera, Odonata, and Diptera were well-represented. Meanwhile, orders such as Plecoptera, Tricoptera, and Oligochaeta were less dominant but are crucial for understanding macroinvertebrate diversity in the wetland (Fındık & Aras, 2024).

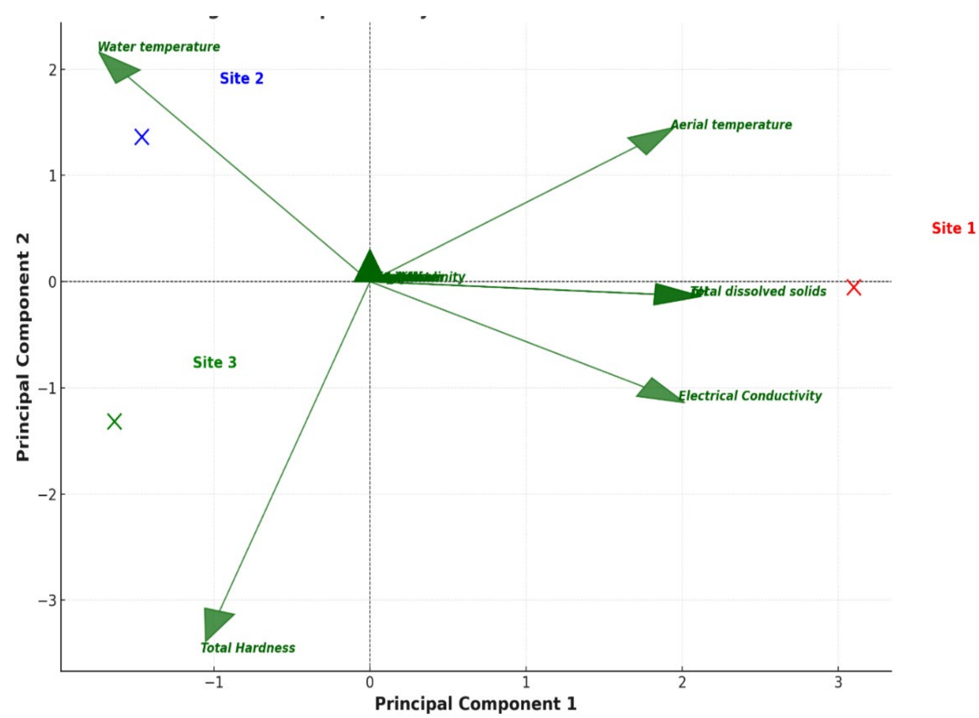


**Figure 2.** Principal Component Analysis showing the differentiation among sampling sites and their relationships based on physicochemical data

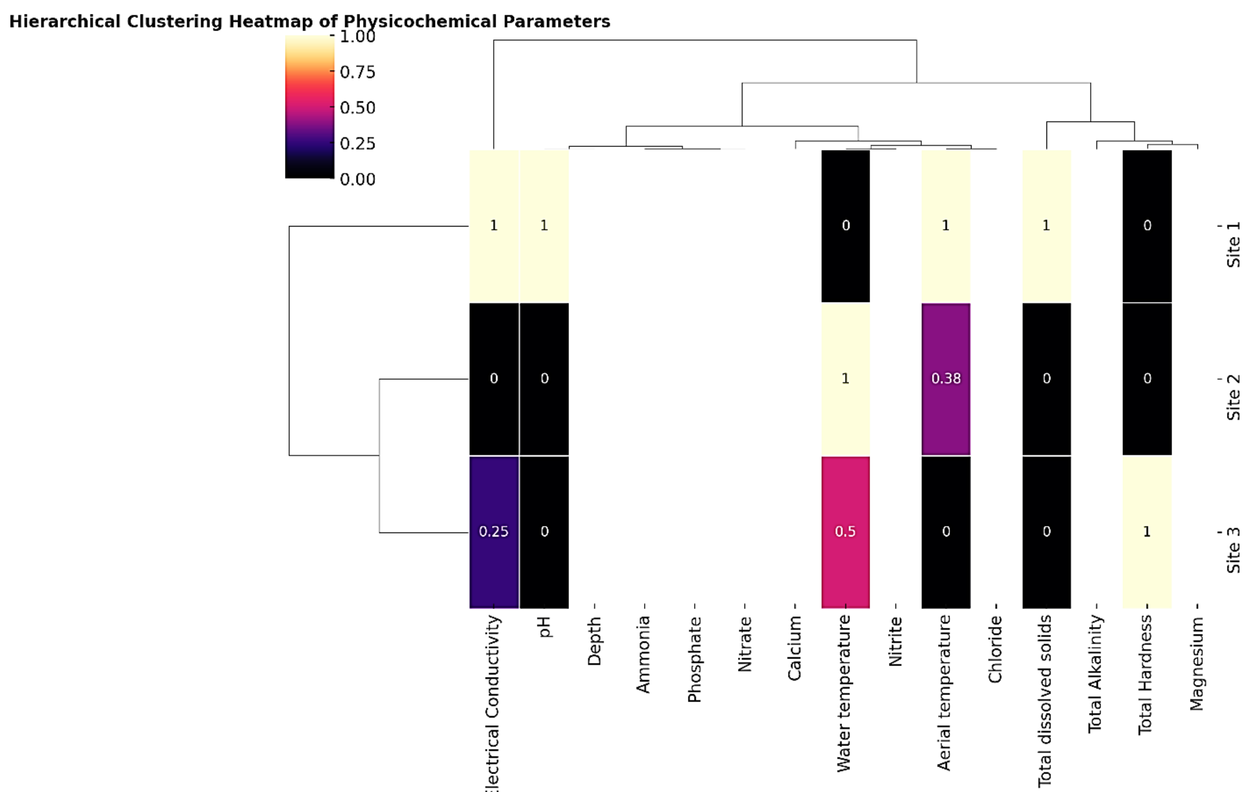


**Figure 3.** Phylogenetic tree constructed using physicochemical data, illustrating the similarity among the sampling sites

***Diversity Indices***

The diversity indices calculated for the macroinvertebrate communities show the diversity in comparing two site 2, with a Shannon-Wiener index (H) of 2.069 and Simpson's dominance index (1-D) of 0.8567, is showing balance diversity evenness was also moderate at this site (e^H/S = 0.7438), indicating a more even distribution of species. In contrast, Site 1 showed the lowest status, with an H value of 1.806 and a dominance index of 0.7917. Site 3 had the lowest status diversity (H = 1.905; D-1 = 0.8172), with the evenness index suggesting better species distribution (Table 3).

All three sites show a decreasing trend in diversity as the correlation of macroinvertebrates increases. Site 1 exhibits the steepest decline, suggesting a more sensitive decrease in diversity with increased correlation. Site 2 follows, with a more gradual decline, while Site 3 experiences the least significant drop in diversity. This suggests that as the correlation between macroinvertebrates strengthens, the overall diversity tends to decrease, but the rate of change varies across the sites (Figure 4). The data indicate that site 2 is unpolluted, while sites 1 and 3 exhibit moderate pollution. The proximity of these latter sites to agricultural land suggests that runoff during rain events may introduce pollutants, affecting water quality and biodiversity.

This study examined Physical-chemical characteristics such as temperature, DO, and pH, which varied significantly across the three sites. Site 2 exhibited a neutral pH (7.1), which contributed to greater macroinvertebrate diversity. In contrast, sites with higher TDS levels (Site 1 at 174 mg/L and Sites 2 and 3 at 134 mg/L) supported more diverse communities good TDS level in acceptable in drinking and insect survival in TDS level is 300 above this danger for insect survival, and this good condition as well as sites biological normal condition (Jiang et al., 2010; Zeybek et al., 2012). Higher temperatures (26.4–27°C) also correlated positively with macroinvertebrate abundance, suggesting that these conditions are conducive to their survival (Hauer & Hill, 2007). Identifying 237 individuals across 15 taxa of macroinvertebrates, indicating moderate biodiversity in Vembannur wetland (Andem et al., 2013). The presence of various taxa suggests that human activity, birds, and aquatic insects have a significant impact on diversity and abundance. Although the wetlands are moderately polluted, the community structure and functional diversity of the macroinvertebrates remain relatively intact. Hydrological factors such as water depth and habitat structure play a central role in influencing the distribution of insects. Chironomidae, for example, were found to be indicators of organic pollution, corroborating findings from previous studies (Basu et al., 2013; Koumba et al., 2017). The important elements of a biological community are measured by the community structure index, richness, and evenness, according to Barbour & Michael (1999), as well as the availability of equal to habit to diversity indices. A diversity index site 2 and 3 are good, and site one is polluted in water, as described in the diversity index. A comparison of diversity between site 1, site 3, and site 2 reveals moderate pollution in the water sources. The presence of pollution-sensitive taxa, such as Ephemeroptera, at specific sites further supports this conclusion. The population structure is primarily influenced by water depth, habitat type, and wetland features, as well as comparisons of water quality and aquatic macroinvertebrates, indicating good and moderate richness and abundance.

**Table 2.** Taxonomic composition of aquatic macroinvertebrates at the sampling sites

| Classes | Orders | Families | Taxons | S1 | S2 | S3 |
|---|---|---|---|---|---|---|
| Gastropoda | Architaenioglossa | Viviparidae | *Idiopoma* sp. | - | + | ++ |
| | | | *Viviparus* sp. | ++ | + | - |
| | Basommatophora | Planorbidae | *Gryalus* sp. | - | + | + |
| | | | *Indoplanorbis* sp. | + | + | ++ |
| Malacostraca | Decapoda | Palaemonidae | *Palaemonetes* sp. | - | ++ | - |
| | | Penaeidae | *Litopenaeus* sp. | - | + | - |
| Insecta | Ephemeroptera | Tricorythidae | *Madecassorythus* sp. | + | - | ++ |
| | Hemiptera | Belostomatidae | *Diplonychus* sp. | + | - | ++ |
| | Odonata | Gomphidae | *Gomphidia* sp. | - | + | - |
| | | Libellulidae | *Brachymesia* sp. | + | + | - |
| | | Coenagrionidae | *Ischura* sp. | - | ++ | - |
| | | | *Argia* sp. | + | ++ | + |
| | Diptera | Chironomidae | *Chironomus* sp. | + | - | - |
| | | | *Parochlus* sp. | - | - | + |
| | | Culicidae | *Culex* sp. | + | ++ | + |

**Table 3.** Diversity index of aquatic macroinvertebrates in Vembannur Wetland

| Index | S1 | S2 | S3 |
|---|---|---|---|
| Taxa | 8 | 10 | 8 |
| Shannon_ H | 0.753 | 0.875 | 0.811 |
| Simpson_ D | 0.208 | 0.143 | 0.183 |
| Evenness e^H/S | 0.7114 | 0.7438 | 0.8397 |
| Menhinick's | 1.099 | 1.054 | 0.8251 |
| Margalef's | 1.763 | 2 | 1.541 |
| Berger-Parker | 0.3774 | 0.2333 | 0.3511 |

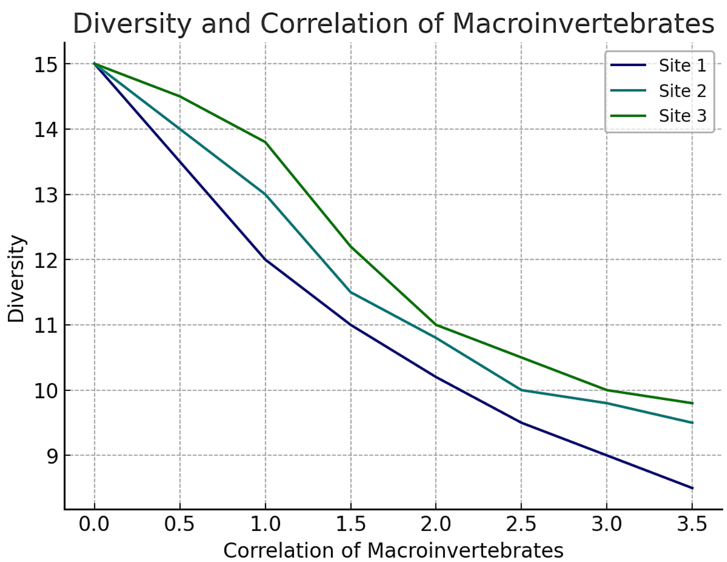


**Figure 4.** Correlation between macroinvertebrate diversity in Vembannur Wetland

## Conclusion

This study highlights the significance of macroinvertebrates as bioindicators for assessing the health of wetlands and water quality. By documenting diversity indices and conducting water quality assessments, it becomes evident that sites 2 and 3 are relatively unpolluted, while Site 1 exhibits moderate pollution due to agricultural runoff. Macroinvertebrate assemblages offer valuable insights into the ecological condition of wetlands, and future research should explore their potential for long-term ecosystem monitoring.

**Compliance with Ethical Standards**

**Conflict of interest:** The author declares no actual, potential, or perceived conflict of interest for this article.

**Ethics committee approval:** Ethics committee approval is not required for this study.

**Data availability:** Data will be made available on request from the author.

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**Disclosure**

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