RESEARCH ARTICLE

Wetland diversity and Water Quality Dynamics: A Comparative Study of Three Wetlands in Paschim Medinipur District

Susanta Jana[1*], Bingshati Singha Mahapatra[1], Subrata Das[2]

DOI: 10.18811/ijpen.v11i03.13

Abstract

Urbanization, agricultural pollution, siltation, and the invasion of alien species are consistently degrading the water quality of various water bodies in Paschim Medinipur. Sustainable policies can maintain the ecological balance of these valuable water bodies, which in turn enhance the social health, environmental health, and economic reliability of Paschim Medinipur in the future. Therefore, studying the macrophyte diversity and water characteristics of various wetlands is highly relevant. The primary objective was to compare the physico-chemical characteristics of water, and explore the macrophyte diversity in these three noteworthy water bodies. The names of three wetlands, Sarsanka Dighi, Bidhyadhar, and Samlia Dighi, are situated in the Paschim Medinipur district of West Bengal, India. During the present investigation total of macrophyte species were identified to be 17 species in the Sarasanka Dighi wetland site, 15 species in the Bidhyadhar and 12 macrophyte species in Samlia Dighi were recorded from three distinct water bodies. Total aquatic macrophytes species density, concentration of dominance value, the macrophyte species diversity, and similarity index were calculated. Total species density and concentration of the Dominance value is higher in the Bidhyadhar pond wetland, but species diversity is higher in the Sarsanka Jhil wetland.

Highlights

Macrophyte Diversity: The study quantitatively analyzes aquatic macrophyte communities across three ecologically distinct wetlands in Paschim Medinipur.

Distinct Water Quality Profiles: Each wetland exhibits unique physicochemical characteristics reflecting varied environmental conditions.

Ecological Implications: Variations in DO, BOD, and turbidity indicate differences in biological activity and pollution levels affecting biodiversity.

Integrated Monitoring Need: The research emphasizes combining water, macrophyte, and avian data for effective, site-specific wetland conservation.

Keywords: Diversity Macrophyte, IVI, Wetlands, Water quality.

International Journal of Plant and Environment (2025); **ISSN:** 2454-1117 (Print), 2455-202X (Online)

Introduction

Wetlands are among the most productive and ecologically significant aquatic ecosystems on Earth, which are called nature's kidney, providing critical services such as water purification, flood control, carbon sequestration, and habitat for a diverse array of flora and fauna (Mitsch & Gosselink, 2015). Wetlands are ecotones, transitioning between terrestrial and aquatic environments. Macrophytes are vital components of aquatic ecosystems, providing structural and functional support of water bodies Mahato and Ghosh, 2025). Biodiversity refers to the range of different species that inhabit a specific region, shaped over millions of years through the process of evolution (Ramchander and Rahul, 2021). Wetland covers approximately six percent of the Earth's land surface, spanning a wide range of climate and regions tropical to tundra zones (Ricklefs and Miller, 2000). Effective management of the world's diverse wetlands, encompassing various types such as marshes, swamps peatlands, hinges on a deep understanding of the ecological principles that govern their functioning at the ecosystem services they provide (Chakraborty *et al.,* 2023). Aquatic macrophytes act as a primary producer; they drive ecosystem processes. It regulates water quality by assimilating dissolved nutrients and maintaining ecosystem balance and macrophytes are sensitive to environmental changes; they are often used as bioindicators of water quality and ecosystem health (Rai & Munshi, 1979). Wetlands provide critical services such as groundwater recharge, flood control, nutrient retention, carbon sequestration, and habitat provision for a wide array of species, including fish, amphibians, invertebrates, birds, and aquatic plants Among the key floristic components of wetlands, aquatic macrophytes play a crucial role in maintaining ecological balance by stabilizing sediments, regulating nutrient cycling, and offering food

[1]Department of Botany, Bankura University, Bankura, West Bengal-722102, India.

[2]Department of Forestry, PRMS Mahavidyalaya, Bankura, West Bengal-722150, India.

***Corresponding author:** Susanta Jana, Department of Botany, Bankura University, Bankura, West Bengal-722102, India, Email: susantajana@bankurauniv.ac.in

How to cite this article: Jana, S., Mahapatra, B. S., Das, S. (2025). Wetland diversity and Water Quality Dynamics: A Comparative Study of Three Wetlands in Paschim Medinipur District. International Journal of Plant and Environment. 11(3), 557-565.

Submitted: 18/11/2024 **Accepted:** 09/09/2025 **Published:** 30/09/2025

and shelter to aquatic organisms (Chambers *et al.,* 2008). The structure and composition of aquatic macrophyte communities are influenced by different types of environmental factors, particularly water quality parameters such as pH, turbidity, dissolved oxygen, and nutrient content (Wetzel, 2001). However, numerous pollutants, siltation, urbanization, agricultural runoff, and industrial effluents deteriorate wetland water quality and adversely affect macrophyte diversity (Mukherjee and Mandal, 2023). In recent years, the degradation of wetland habitats due to anthropogenic activities has led to a decline in macrophyte diversity and associated wildlife, including avifauna, whose distribution is closely linked to aquatic vegetation (Gopal, 2016). Wetland biodiversity supports sustainable environments and species conservation. Thus, assessing both the physicochemical characteristics of wetlands and the phytosociological attributes of aquatic macrophytes is essential for understanding wetland health and informing conservation strategies. Although numerous researchers have investigated wetland diversity and water quality globally like Foote *et al.,* (1996); Bedford *et al.,* (1999); Ibekwe *et al*., (2007); Kao *et al.,* (2010); Neiff *et al.,* (2011); Pott *et al*., (2011); Dutta *et al., (*2014); Goswami *et al*., (2010); Han *et al.,* (2012);; Sahu *et al., (*2019); Arliyani *et al*., (2021); Bala and Mukherjee, (2010); Badra *et al.* (2022). but there is no evidence of any phytosociological studies conducted on the wetlands in this region. The present study is designed to bridge the knowledge gap by conducting an exploratory ecological investigation on the wetlands of Paschim Medinipur, focusing on their ecological characteristics with the following objectives:

- To study the macrophyte diversity, three distinct wetlands of the Paschim Medinipur district.
- To compare the physicochemical structure of water among three distinct wetlands.

Materials and Methods

Study Sites

Three wetlands were selected for the study, namely Sarsanka Dighi, Bidhyadhar Pond, and Samlia Jhil under Dantan-1 block in Paschim Medinipur district. Three waterbodies are situated 75 km away from Medinipur town at 21°56'18.74"N latitude and 87°16'35.04"E longitude. The morphometric features of the three waterbodies are presented in the Table. 1, and the location map of the study area is illustrated in Fig. 1. Around 20,000 people live in the town of Dantan in the Indian state of West Bengal. With its undulating rivers Subranarekha, the surrounding area is renowned for its natural beauty. Agriculture is the primary industry in this region. It is an avian habitat and a wetland in the district. Sarasanka Dighi, located in the Dantan block of Paschim Medinipur district, is the largest wetland in terms of area. According to local legend, this Dighi was constructed by King Shashanka, a renowned ruler in history. Alongside Sarasanka Dighi, two other significant wetlands, Vidyadhar and Angua Samalia Jhil, play a key role in Odisha and Bengal's cultural integration, symbolizing the bond between the two regions. These three waterbodies are not only significant for migratory birds but also serve as good habitats for various plant and animal species. These wetlands facilitate both farming and fishing. The surrounding villages celebrate several festivals and traditions throughout the year, which is a part of their rich heritage and culture within these wetlands.

Sampling Method

This study focused on three prominent wetlands in the Paschim Medinipur district. Within each selected wetland (Lying 0.001% of the total area of each 0 1 m × 01m of each study site), quadrates were randomly established to sample aquatic macrophytes. After the field sampling, vegetational data were analyzed for the determination of frequency, density, following Mishra (1968). Then the relative frequency and relative density were calculated according to Phillip (1959). Photographs were taken to document species presence, and representative specimens were collected in plastic bags for herbarium preparation and identification. Species diversity (H') of aquatic macrophytes of these three water bodies was calculated following Shannon and Weaver (1963). The concentration of dominance (Cd) value was estimated following Simpson (1949):

- H' = – Σ pi log pi
- Cd = (ni/N)2

Where,
(H') = Diversity index
Cd = Analysis for Concentration of dominance
ni = Important value Index (IVI) of individual species
N = Important value Index (IVI) of total species in the area

The distribution of individuals among the species, called species equitability or (E') species evenness Index was calculated as:

$$E' = \bar{H} / H_{max}$$

Where,
[$\bar{H}$ = Observed diversity] (Shannon and Weaver 1963). [H_{max} = Maximum possible diversity] which was calculated by log K (K = total number of macrophyte species following Pielou (1975).

Collection and Analysis of a Water Sample

In the Paschim Medinipur district, three distinct wetlands that the local people heavily utilize as a socioeconomic resource and for their living were chosen in order to examine the physicochemical properties of a sample of surface water for drinking taken during the pre-monsoon season. Water samples were collected and analyzed using standardized protocols as per APHA-AWWA-WPCF (1995 for sampling and Merck (1974) guidelines for various water quality parameters, and quantitative assessments were conducted subsequently.

Table 1: Morphometric features of three wetlands

Name of the wetland	*Latitude*	*Longitude*	*Types of wetlands*	*Block*
Sarasanka Dighi	21°56'18.74"N	87°16'35.04"E	Freshwater,	Dantan-1
Bidyadhar Pond	87°19'2.06"E	21°56'5.47"N	Freshwater	Dantan-1
Samlia Jhil- Angua	21°53'47.13"N	87°15'39.87"E	Freshwater	Dantan-1

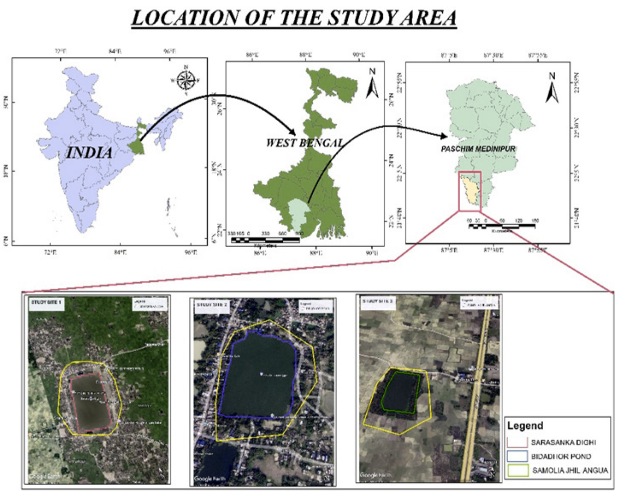

Fig. 1: Location map of the study sites

Results and Discussion

A survey of Paschim Medinipur district's three significant wetlands documented 44 macrophyte species from 17 families, depicted in the Table. 4. The species diversity, like Relative frequency, Relative density, Relative abundance and Importance Value Index (IVI) of aquatic macrophytes of the three water bodies are presented in the Table. 2. The present study assessed the Importance Value Index (IVI) of aquatic macrophytes in three ecologically distinct wetlands of Paschim Medinipur district, Sarasanka Dighi, Bidyadhar Pukur, and Samlia Jhil (Angua). IVI (Importance Value Index) is a critical ecological metric that combines relative frequency, relative density and relative abundance, providing a comprehensive measure of the ecological significance and dominance of each species within a given natural habitat. The IVI (Importance Value Index) values observed in this study revealed important insights into floristic composition, dominance patterns and species community, each shaped by unique environmental conditions and biological interactions in the respective wetlands.

In Sarashanka Dighi**,** the aquatic vegetation was dominated by *Nelumbo nucifera* Gaertn, which recorded the highest IVI of 60.27. This dominance is reflected by its high relative density and frequency, indicating that the species is not only abundant but also well-distributed across the wetland. *Nelumbo nucifera* Gaertn., is a large, emergent aquatic plant known for its ecological importance in nutrient cycling, providing habitat for aquatic fauna such as especially migratory birds, and stabilizing sediment. Its high IVI suggests that it plays a foundational role in shaping the structure and function of this wetland ecosystem. The second most dominant species in Sarasanka was *Nymphoides hydrophylla* with an IVI of 49.52, followed by *Hygrophila auriculata* (Schumach.) Heine (36.79), a common emergent plant found along wetland margins. Other species like *Sporobolus indicus* (L.) R. Br., *Ludwigia adscendens* (L.) H. Hara, and *Eclipta prostrate* (L.)L.showed moderate IVI values, indicating their supportive role in the overall plant community. Several species, such as *Centella asiatica* (L.) Urb, *Aeschynomene aspera* L., and *Polygonium berbatum* L. recorded low IVI (Importance Value Index) values, suggesting a more limited distribution and lesser ecological impact in this site. The diversity and IVI distribution in Sarasanka Dighi indicate a relatively balanced macrophyte community, with a few dominant and several co-occurring species contributing to community stability.

In Bidhyadhar pukur, *Pistia stratiotes* L. emerged as the most dominant species, with an IVI (Importance Value Index) of 66.01 reflecting its aggressive colonization behavior and high adaptability in nutrient-rich water. Its rapid vegetative propagation and ability to form dense mats often give it a competitive advantage, sometimes leading to the suppression of native species. The dominance of *Pistia stratiotes* L could also be an indicator of moderate eutrophication or organic enrichment in the pond. The next highest IVI (Importance Value Index) was recorded for *Nelumbo nucifera* Gaertn (45.68), confirming its wide adaptability across different aquatic systems in the region. Other notable species included *Enydra fluctuans* Lour (38.55), a common semi-aquatic herb, and *Polygonum barbatum* L. (32.46), both indicating a heterogeneous habitat structure with a mix of floating, emergent, and marginal species. Interestingly, while *Nymphoides hydrophylla* (Lour.) Kuntze had a strong presence in Sarasanka; its IVI was significantly lower in Bidyadhar (15.65), suggesting varying environmental preferences or interspecies competition. Species such as *Ipomoea aquatic* Forssk., Centella asiatica (L.) Urb., *Commelina diffuse* Burm.f, and *Eclipta prostrate* (L.)L.had low IVI values but were still present, contributing to the biological diversity and ecological function of the pond. The macrophyte community in Bidyadhar Pond appears to be more unevenly distributed, with a few species showing marked dominance, possibly influenced by human disturbance or nutrient load.

In Samlia jhil (Angua) *Urticularia aurea* Lour. was found to be overwhelmingly dominant, with an exceptionally high IVI (Importance value Index) of 123.10 far surpassing the leading species in the other two wetlands. This free-floating carnivorous plant thrives in oligotrophic to mesotrophic waters and is known for its efficient nutrient uptake mechanisms, including insectivory. The extraordinarily high IVI suggests *Urticularia aurea* Lour. has not only colonized the wetland extensively but also faces minimal competition from other macrophytes. This could be due to specific physico-chemical water conditions such as lower nutrient levels, higher transparency, or acidic pH, as observed in the earlier water quality analysis. Following *Utricularia*, species like *Nymphoides hydrophylla* (Lour.) Kuntze (32.44), *Marsilea quadrifolia* L. (24.01), and *Hydrilla verticillata* (L.f.) Royle (20.27) also contributed to the aquatic vegetation but to a much lesser extent. The pronounced dominance of a single species in this wetland may indicate a specialized ecological niche or early successional stage, where *Urticularia aurea* Lour. has established itself before other species could compete effectively. Nevertheless, the presence of several other low-IVI species suggests some degree of macrophyte diversity is still maintained.

Across all three wetlands, several species such as *Nelumbo nucifera* Gaertn, *Hygrophila auriculata* (Schumach.) Heine, and *Pistia stratiotes* L. were found in more than one site, indicating their wide ecological tolerance and adaptability. However, their IVI values differed significantly, reflecting the influence of site-specific environmental variables such as water chemistry, depth, light availability, and anthropogenic disturbance. For instance,

Table 2: Importance Value Index of the most important aquatic species in different wetlands of Paschim Medinipur district.

Species	*Relative Frequency*	*Relative Density*	*Relative Abundance*	*IVI*
		Sarasanka Dighi		
Nelumbo nucifera Gaertn	11.42857	30.55556	18.28863	60.27275
Nymphoides hydrophylla (Lour.) Kuntze	8.571429	22.77778	18.17779	49.52699
Hygrophila auriculata (Schumach.) Heine	2.857143	10	23.94148	36.79862
Sporobolus indicus (L.) R. Br.	14.28571	10	4.788295	29.07401
Ludwigia adscendens (L.) H. Hara	11.42857	7.777778	4.655287	23.86164
Eclipta prostrate (L.) L.	8.571429	2.777778	2.216803	13.56601
Urticularia aurea Lour.	5.714286	3.333333	3.990246	13.03787
Hydrilla verticillata (L.f.) Royle	5.714286	2.222222	2.660164	10.59667
Commelina diffuse Burm.f.	5.714286	1.666667	1.995123	9.376075
Trapa bispinosa Roxb.	5.714286	1.666667	1.995123	9.376075
Acmella uliginosa (Sw.) Cass.	2.857143	1.666667	3.990246	8.514056
Cyperus esculentus L.	2.857143	1.666667	3.990246	8.514056
Ipomoea aquatic Forssk.	2.857143	1.666667	3.990246	8.514056
Centella asiatica (L.) Urb.	2.857143	0.555556	1.330082	4.74278
Aeschynomene aspera L.	2.857143	0.555556	1.330082	4.74278
Pistia stratiotes L.	2.857143	0.555556	1.330082	4.74278
Polygonium berbatum L.	2.857143	0.555556	1.330082	4.74278
		Bidyadhar Pond		
Pistia stratiotes L.	11.11111	28.57143	26.32541	66.00795
Nelumbo nucifera Gaertn	14.81481	18.25397	12.61426	45.68304
Enydra fluctuans Lour.	11.11111	14.28571	13.16271	38.55953
Polygonium berbatum L.	11.11111	11.11111	10.23766	32.45988
Marsilea quadrifolia L.	14.81481	9.52381	6.581353	30.91998
Hygrophila auriculata (Schumach.) Heine	11.11111	8.730159	8.043876	27.88515
Nymphoides hydrophylla (Lour.) Kuntze	3.703704	3.174603	8.775137	15.65344
Acmella uliginosa (Sw.) Cass.	7.407407	2.380952	3.290676	13.07904
Ipomoea aquatic Forssk.	3.703704	1.587302	4.387569	9.678574
Centella asiatica (L.) Urb.	3.703704	0.793651	2.193784	6.691139
Commelina diffuse Burm.f.	3.703704	0.793651	2.193784	6.691139
Eclipta prostrate (L.) L.	3.703704	0.793651	2.193784	6.691139
		Samlia Jhil		
Urticularia aurea Lour.	21.62162	64.61126	36.86894	123.1018
Nymphoides hydrophylla (Lour.) Kuntze	8.108108	9.651475	14.68638	32.44597
Marsilea quadrifolia L.	10.81081	6.16622	7.037226	24.01426
Hydrilla verticillata (L.f.) Royle	8.108108	4.825737	7.343192	20.27704
Ludwigia adscendens (L.) H. Hara	10.81081	3.217158	3.671596	17.69957
Pistia stratiotes L.	8.108108	3.753351	5.711372	17.57283

Hygrophila auriculata (Schumach.) Heine	8.108108	2.949062	4.487506	15.54468
Sporobolus indicus (L.) R. Br.	2.702703	1.340483	6.119327	10.16251
Nelumbo nucifera Gaertn	2.702703	1.072386	4.895461	8.67055
Cyperus esculentus L.	5.405405	0.80429	1.835798	8.045493
Ipomoea aquatic Forssk.	2.702703	0.536193	2.447731	5.686626
Centella asiatica (L.) Urb.	2.702703	0.268097	1.223865	4.194665
Eclipta prostrate (L.) L.	2.702703	0.268097	1.223865	4.194665
Enydra fluctuans Lour.	2.702703	0.268097	1.223865	4.194665
Polygonium berbatum L.	2.702703	0.268097	1.223865	4.194665

Pistia stratiotes was dominant in Bidyadhar but had low IVI in Sarasanka and a moderate presence in Samlia Jhil, possibly influenced by nutrient availability and competition. Similarly, *Nymphoides hydrophylla* (Lour.) Kuntze. showed a relatively consistent presence across all sites but with differing degrees of dominance, again pointing to habitat-specific interactions.

Overall, the IVI analysis underscores the ecological uniqueness and species dynamics of each wetland. While Sarasanka Dighi harbors a moderately diverse and evenly distributed plant community, Bidyadhar Pond shows signs of species dominance and potential eutrophication. Samlia Jhil, on the other hand, presents a case of extreme species dominance by a single carnivorous macrophyte, likely shaped by distinct environmental conditions. These findings highlight the importance of IVI as a tool for understanding macrophyte community structure and its role in wetland function. Moreover, the dominance of certain indicator species can provide valuable clues about water quality, habitat health, and ecological succession stages.

The present study of macrophyte diversity across three distinct wetlands in Paschim Medinipur Sarasanka Dighi, Bidyadhar Pond, and Samlia Jhil (Angua) revealed quite varied variations in community structure based on key ecological indices depicted in the Table. 3. The Shannon-Wiener Diversity Index (H′) was highest in Bidyadhar Pond (2.48), indicating greater species richness, followed by Samlia Jhil (2.23) and Sarasanka Dighi (2.10). In contrast, the Concentration of Dominance (Cd) was lowest in Bidyadhar Pond (0.10), suggesting a more balanced community with no single species dominating, while Sarasanka Dighi had the highest dominance (0.20), pointing to a community dominated by fewer species. Interestingly, the Evenness Index (E′) was highest in Sarasanka Dighi (0.430), showing a more uniform distribution of species, despite its lower diversity, whereas Bidyadhar Pond had the lowest evenness (0.270). These results indicate that while Bidyadhar Pond supports higher species richness, the species are not evenly distributed, unlike Sarasanka Dighi, which, though less diverse, maintains a more balanced species presence. Samlia Jhil showed intermediate values for all indices, reflecting moderate diversity and community balance. Overall, the findings highlight the ecological uniqueness of each wetland and emphasize the importance of considering multiple diversity metrics, richness, dominance, and evenness, for understanding community dynamics.

The comparative analysis of physico-chemical parameters across Sarasanka Dighi, Bidyadhar Pond, and Samlia Jhil (Angua) reveals variations that reflect the distinct ecological conditions of each waterbody, summarized in the Table 5. The physico-chemical analysis of water samples from the three wetlands yielded the following results: pH: Sarasanka Dighi (7.39), Bidyadhar Pond (7.75), and Samlia Jhil (7.0). TDS: Sarasanka Dighi (482.4 mg/L), Bidyadhar Pond (506 mg/L), Samlia Jhil (485 mg/L), Electrical Conductivity: Sarasanka Dighi (1015 µS/cm), Bidyadhar Pond (984 µS/cm), and Samlia Jhil (1002 µS/cm). Turbidity was highest in Samlia Jhil (mean 3 cm), followed by Bidyadhar Pukur and Sarasanka Dighi. pH values ranged from slightly acidic to neutral, with Sarasanka showing the most stable range (7.21–7.56) and Samlia Jhil indicating possible acidic tendencies (mean 7). Transparency shows the highest in Samlia Jhil (mean 70 cm), suggesting clearer water, whereas Bidyadhar Pond had the lowest (mean 28 cm), likely due to higher suspended matter, which aligns with turbidity values. Samlia Jhil exhibited the highest dissolved oxygen (14.32 mg/l indicating good oxygenation and water quality favorable conditions for aquatic life. But also showed the highest Biochemical Oxygen Demand (BOD), which reflects organic pollution, was also highest in Samlia Jhil (mean 5.045 mg/l), suggesting organic load despite high DO levels. Acidity was notably high in Samlia Jhil (mean 49 mg/l), while alkalinity was highest in Bidyadhar (mean 31 mg/l), indicating better buffering capacity. Total Dissolved Solids (TDS) and electrical conductivity were highest in Bidyadhar, indicating more mineral content, while total hardness was lowest in Samlia

Table 3: Different diversity indices of aquatic plant species in three water bodies.

Study sites	*Diversity index (H′)*	*Concentration of dominance (Cd)*	*evenness(E′)*
Sarasanka Dighi	2.10	0.20	0.430
Bidyadhar Pond	2.48	0.10	0.270
Samlia Jhil- Angua	2.23	0.12	0.282

Table 4: Macrophytes associated with three wetlands in Paschim Medinipur District

Sl. No.	*Scientific Name of Plants*	*Family*	*Group*	*Sarasanka dighi*	*Bidyadhar Pond*	*Samlia Jhil- Angua*
1	*Acmella uliginosa (Sw.) Cass.*	Asteraceae	Emergent	-	+	+
2	*Aeschynomene aspera L.*	Fabaceae	Floating	-	+	-
3	*Centella asiatica*	Apiaceae	Emergent	+	+	+
4	*Commelina diffuse Burm.f.*	Commelinaceae	Floating	-	+	+
5	*Cyperus esculentus L.*	Cyperaceae	Emergent	+	+	-
6	*Eclipta prostrate (L.)L.*	Asteraceae	Floating	+	+	+
7	*Enydra fluctuans Lour.*	Asteraceae	Floating	+	-	+
8	*Hydrilla verticillata* (L.f.) Royle	Hydrocharitaceae	Floating	+	+	-
9	*Hygrophila auriculata* (Schumach.) Heine	Acanthaceae	Emergent	+	+	+
10	*Ipomoea aquatic* Forssk.	Convolvulaceae	Floating	+	+	+
11	*Ludwigia adscendens* (L.) H. Hara	Onagraceae	Floating	+	+	-
12	*Marsilea quadrifolia* L.	Marsileaceae	Emergent	+	-	+
13	*Nelumbo nucifera*	Nymph	Emergent	+	+	+
14	*Nymphoides hydrophylla* (Lour.) Kuntze	Menyanthaceae	Floating	+	+	+
15	*Pistia stratiotes* L.	Araceae	Floating	+	+	+

Table 5: Physico-chemical characteristics of water samples from three wetlands of Paschim Medinipur district

Name of the water bodies	*Sarasanka Dighi*			*Bidyadhar Pond*			*Samlia Jhil- Angua*		
Parameter	*Min*	*Max*	*Mean (±SE)*	*Min*	*Max*	*Mean (±SE)*	*Min*	*Max*	*Mean (±SE)*
pH	7.21	7.56	7.39 ± 0.10	7.4	8.1	7.75 ± 0.20	7.8	6.2	7 ± 0.46
Transparency (cm)	53	51	54 ± -0.58	30	26	28 ± -0.15	68	72	70 ± 1.15
Turbidity (cm)	2.3	1.8	2.05 ± -0.14	3	2.5	2.75 ± 0.14	3.2	2.8	3 ± -0.12
Acidity (mg/l)	32	43	37.5 ± 3.18	48	30	39 ± 2.60	52	46	49 ± - 1.73
Alkalinity (mg/l)	21	24	22.5 ± 0.87	30	32	31 ± -0.29	28	22	25 ± -1.73
DO (mg/l)	8.45	10.43	9.44 ± 0.57	8.23	9.24	8.735 ± 0.29	9.2	10.24	14.32 ± 0.60
BOD (mg/l)	4.11	5.32	4.715 ± 0.35	4.2	3.2	3.7 ± 0.14	3.67	6.42	5.045 ± 0.41
TDS (mg/l)	462.8	502	482.4 ±11.3	490	522	506 ± 9.24	510	460	485 ± 1.15
Electrical conductivity (µmho/cm)	990	1040	1015 ±14.43	980	988	984 ± 0.00	980	1024	1002± 12.70
Total hardness (mg/l)	204	210	207 ± 1.73	200	218	209 ± 2.60	140	148	144 ± 2.31

Jhil angua (mean 144 mg/l). Sarasanka Dighi showed relatively balanced conditions across most parameters, with moderate pH, DO, and turbidity, indicating a stable aquatic environment. Overall, the findings highlight the ecological diversity of the wetlands and the need for site-specific monitoring and management. Table 6 presents the Bureau of Indian Standards (BIS) guidelines for inland surface water quality assessment, outlining the recommended parameters and limits.

The heatmap correlation analysis is presented in Table 7 and Fig. 2 provides a detailed understanding of how macrophyte diversity indices such as Shannon Index, Simpson Index, Evenness and Richness are influenced by water physicochemical parameters. The Shannon Index(Ȟ), which reflects both species richness and evenness(E¢), shows a very strong correlation with alkalinity (r=0.9986) and TDS(r=0.9707), indicating that macrophyte diversity tends to increase in alkaline mineral-rich environments. Similarly, macrophytes richness is positively associated with pH(r=0.6144) and total hardness r=0.9066), suggesting that a higher number of aquatic species prefer slightly basic and hard water conditions, which may enhance nutrient availability and support macrophyte plant growth. On the other hand, species diversity indices reflect strong negative correlations with environmental stress indicators. For instance, Evenness(E¢) is highly negatively correlated with

Table 6: Water quality parameters with recommended BIS standards of inland surface water (BIS: 2296-1982)

Parameters	*Recommended standard for Drinking*	*Outdoor bathing*	*Irrigation*
pH	6.5-8.5	6.5-8.5	6-8.5
Turbidity (NTU)	5	-	-
TDS (mg/l)	500	-	2100
Electrical conductivity (µmho/cm)	400	-	2,250
Alkalinity (mg/l)	200	-	-
Total hardness (mg/l	300	-	-
DO (mg/l)	5	5	-
BOD (mg/l)	5	3	-

Table 7: Correlation map of Pearson correlation coefficient values among different water physico-chemical parameters and the Diversity index, species richness in three different wetlands.

	Shannon Index	*Simpson Index*	*Evenness Index*	*Richness*	*pH*	*Transparency (cm)*	*Turbidity (cm)*	*Acidity (mg/l)*	*Alkalinity mg/l*	*DOmg/l*	*BOD mg/l*	*TDS mg/l*	*Electrical conductivity (µmho/cm)*	*Total hardness (mg/l*
Shannon Index	1													
Simpson Index	-0.87088	1												
Eveness Index	-0.79617	0.990759	1											
Richness	-0.22632	0.675845	0.769567	1										
pH	0.629453	-0.16626	-0.03098	0.614419	1									
Transparency (cm)	-0.74501	0.320951	0.189529	-0.48114	-0.98728	1								
Turbidity (cm)	0.573042	-0.90185	-0.95211	-0.92795	-0.2761	0.119748	1							
Acidity (mg/l)	-0.06005	-0.43832	-0.55618	-0.95871	-0.81343	0.710587	0.783638	1						
Alkalinity (mg/l)	0.998593	-0.84358	-0.76295	-0.17434	0.669777	-0.77934	0.528772	-0.1129	1					
DO (mg/l)	-0.29217	-0.21561	-0.34606	-0.86543	-0.92704	0.85562	0.616339	0.972184	-0.34248	1				
BOD (mg/l)	-0.83598	0.458322	0.333539	-0.34532	-0.95262	0.988865	-0.02933	0.597964	-0.86391	0.769064	1			
TDS (mg/l)	0.97071	-0.72728	-0.62747	0.01433	0.797703	-0.88345	0.359362	-0.29811	0.982086	-0.51339	-0.94334	1		
Electrical conductivity (µmho/cm)	-0.99618	0.910491	0.845989	0.310562	-0.55915	0.683875	-0.64246	-0.0274	-0.99014	0.207493	0.784837	-0.94601	1	
Total hardness (mg/l	0.205913	0.301644	0.428171	0.906577	0.89	-0.80617	-0.68397	-0.98917	0.257522	-0.99603	-0.70914	0.434988	-0.11962	1

turbidity(r=-0.9521) and acidity (r=-0.5562), implying that increased water parameters such as turbidity and acidity may lead to the dominance of a few tolerant macrophyte species, reducing overall balance within the macrophyte community. Water turbidity also negatively affects macrophytes richness (r=-0.9280), highlighting the detrimental impact of suspended solid pollutants on species count. Furthermore, Dissolved Oxygen (DO) of wetlands, although essential for aquatic organisms, is negatively correlated with all diversity indices, especially Species richness (r=-0.8654), which might be because clearer, richer water conditions sometimes favor only few fast-growing dominant aquatic macrophytes. Water Biological Oxygen Demand (BOD), a water quality indicator of organic pollution, is also negatively correlated with Shannon Index (r=-08360) and richness (r=-0.3453), reinforcing the idea that polluted water bodies with high organic matter can suppress plant diversity. Surprisingly, Electrical conductivity data, which indicates the presence of dissolved salts in water bodies, shows a very strong very strong negative correlation with the Shannon Index ($\bar{H}$) (r = -0.9961), further suggesting that high ionic concentrations might stress for macrophyte communities. In the present study correlation correlation-coefficient data revealed that macrophyte diversity is highest in waters with moderate alkalinity, higher pH, and low levels of turbidity, acidity, BOD and conductivity, while extreme polluted water conditions are associated with decreased diversity, evenness, and richness across macrophyte vegetation.

Conservation Efforts

Wetlands are a very important part of a region, which enhances natural balance to control river flows and replenish groundwater. There are initiatives taken to conserve and protect the wetland

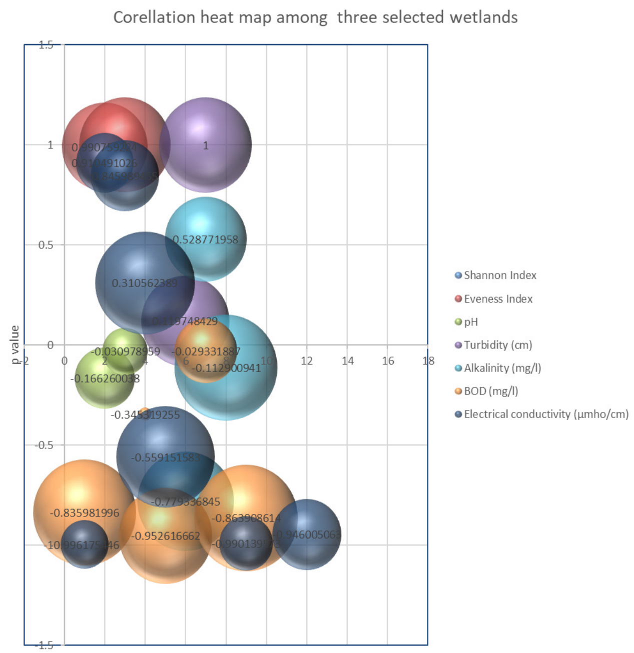

Fig. 2: Correlation Heat Map of water physico-chemical parameters with macrophyte diversity among three selected wetlands

that regulate pollution, stop encroachment and support sustainable livelihoods. This analysis reveals that the water quality and physicochemical parameters of the three wetlands are conducive to supporting diverse macrophyte communities. Nevertheless, these ecosystems face significant threats from anthropogenic activities, including: Municipal drainage pollution, Automobile washing and Domestic animal bathing. To mitigate these risks and preserve the ecological integrity of these wetlands, concerted conservation efforts are imperative, necessitating prompt administrative intervention and proactive measures to safeguard these vital ecosystems.

Conclusion

The present study on macrophyte diversity in three wetlands of Paschim Medinipur provides valuable insights into ecological health and water quality. Macrophytes play a crucial role in maintaining nutrient dynamics and influencing water quality. However, a holistic understanding requires assessing ecological parameters beyond macrophytes. The water report of three selected wetlands shows variation in water quality parameters reflecting differences in ecological conditions and anthropogenic influences. Angua Samlia Jhil exhibited the highest DO (Dissolved Oxygen) but also highest BOD, indicating rich biological activity but potential organic loading. Bidyadhar Pukur shows signs of mineral enrichment and lower water clarity, possibly from urban or agricultural runoff. Sarasanka Dighi remained relatively stable in most parameters. The data emphasize the importance of continuous water quality monitoring and adopting location-specific conservation strategies. Further research on avian diversity is essential, as birds are sensitive to habitat changes and can serve as indicators of ecological integrity. Correlating avian diversity with macrophyte distribution can provide an integrated perspective on ecosystem function, helping identify habitat preferences, detect ecological imbalances, and inform targeted conservation strategies. An integrated approach, encompassing both floral and faunal components, will enrich ecological knowledge and contribute to sustainable management and conservation of wetland ecosystems. Future studies should prioritize combined biodiversity assessments to raise awareness among local communities and authorities about the importance of conserving wildlife and protecting natural habitats. By doing so, we can promote the conservation of these vital ecosystems and support biodiversity in the region.

Acknowledgements

I am also grateful to my teacher Dr. Shyamal Kanti Mallick, Associate Professor, Bishnupur Ramananda College and also thankful to Dr. Tripti Bouri, Assistant Professor Bankura Sammilani College, West Bengal, for their valuable support and facilities to carry out the work.

Authors' Contributions

Susanta Jana played the roles of data curation, Investigation, Methodology, writing the original draft, and editing all the matter. Bingshati Singha Mahaptara contributed highly to Conceptualization, Formal analysis, supervision, and writing. Subrata Das contributed to formal analysis, Methodology, and writing.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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