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Macrophytes of two sacred wetlands, Shibnagar Beel and Sonamati Beel of Islampur, North Dinajpur District, West Bengal: An approach to phytosociological analysis

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Abstract
The present ecological investigation was conducted for detailed study of phytosociology and diversity analysis of macrophytes inhabiting Shibnagar beel and Sonamati beel of Islampur, North Dinajpur district. A total of 12 macrophyte species belonging to 11 families were reported. Hierarchial cluster analysis represented the relationship among all the species along with the vegetational distinguishes among the different sites. Simpson Dominance index, Shannon and Weiner diversity index and Pielous evenness index were also computed to understand the overall diversity status of the concerned wetlands. The present research revealed that Sonamati beel possess higher species diversity and richness with dynamic ecosystem.

Keywords: Phytosociology, diversity, macrophytes, shannon-weiner index, evenness index

Introduction
Biodiversity conservation is the most important global concern nowadays, as it already reached alarming situation due to loss of overexploitation of nature and natural resources, invasiveness of exotic species, loss and fragmentation of habitat, pollution and climatic change. Wetlands which are the most economically valuable ecosystem and regulators of global climate losing its diversity many times faster than any other ecosystem (Agbogidi *et al*. 2022; Bhanja *et al.* 2023; Mukherjee and Mandal, 2023a) [1-3]. Hydrophytes are the backbone of any aquatic ecosystems which constitute the wide range of vegetational diversity from macroalgae to angiosperms. Besides that they also maintain substrate composition, improve water quality, accumulate heavy metals, and being primary producers these provide the basement of food chain for proper cycling of nutrients (Sharma and Singh, 2017; Sheikh and Slathia, 2021) [4-5]. By reciprocating to the change in water quality it also recognized as overall bioindicator of wetland ecosystem. Due to indispensable contribution of macrophytes into the aquatic ecosystem, they received high attention over the last more than a decade to conserve them in their natural habitat for the sake of protection and prevention the loss of biodiversity (Mandal and Mukherjee, 2017; Shelekar *et al.* 2022; Radhanpuri, 2023; Troia, 2023) [6-9]. Though so many research on macrophytes have been done previously but there are no such study has been done earlier specially on sacred wetlands of this district (Mandal and Mukherjee, 2016; Hegde *et al.* 2018; Chanda and Ramachandra, 2019; Sen and Bhakat, 2021; Mukherjee and Mandal, 2023b) [10-14]. The present research aimed to document the current status of macrophytes with their detailed floristic and phytosociological studies as the macrophytes diversity and quantity will be the direct indicator for the urge of conservation and proper management of sacred wetlands, source of spiritual and religious significance.

Materials and Method
Study site
North Dinajpur district lies between 25.11° N to 26.49° N latitude and between 87.49° E to 90.00° E longitude. The total area of the district is about 3142 sq. km. The main rivers of this district are Kulik, Mahananda, Nagar etc. The district is rich in alluvial soil and mostly

sandy to sandy-loam in texture and porous along with thick forest. The district is divided into two subdivision i.e. Raiganj and Islampur. The two selected wetlands, Shibnagar beel and Sonamati beel belonging from Kultahar mouza of Islampur block and Doshu mouza of Islampur block.

Specimen collection and identification

Vigorous field survey was conducted from November 2021 to September 2023, for the collection of macrophytes specimen to make the detail analysis of floristic composition, vegetation richness and diversity. Macrophytes specimen were dried properly and worked out have been done in the laboratory for the identification. Authentic identification have been done with the help of some standard taxonomic literatures (Cook, 1996; Verma, 2022; Mishra and Singh, 2022; Kol and Kumhar, 2022; Maitry *et al.* 2023; Mjelde *et al.* 2023; Mandal and Mukherjee, 2023a, 2023b, 2023c; Mukherjee and Mandal, 2023c, 2023d; Syed and Sonule, 2023; Tamang, *et al.* 2023; Tian *et al.* 2023) [15-28]. For comparing morphological characteristics and checking the valid scientific name POWO (Plants of the World Online, 2023) [29], WFO (World Flora Online, 2023) [30] and GBIF (Global Biodiversity Information Facility) [31] were used**.** Herbarium sheets of the identified specimen were kept at Taxonomy of Angiosperms and Biosystematics laboratory of SKBU, Purulia. Macrophytes were classified after Raunkiaer's life forms (1934) [33] and growth forms also classified according to Cook (1996) [15].

Specimen sampling and statistical analysis

Quantitative analysis of some ecological parameters are the most important and helpful method to prepare the diversity index with comparing the two different wetland communities which are facing tremendous anthropogenic pressure. Specimen sampling were done by laying random quadrats which consist four different sites in each of the wetland. Different diversity index such as Shannon Weiner diversity index, Simpson Dominance index and Pielou's evenness index were computed to make the comparative analysis of species richness and diversity in between two wetland communities.

Cluster analysis

This is a technique for grouping similar observations into a series of clusters based on the observed values of multiple variables. Cluster analysis is similar in concept to discriminant analysis. Here the dendrogram is constructed using the paired group (UPGMA) algorithm and Braye-Curtis similarity method, the most efficient clustering algorithm with the help of PAST (Paleontological Statistics) 4.14 software.

Rarefaction analysis

This analysis is used to obtain species accumulation curves in order to find out the species diversity and richness of the plant communities using the PAST (Paleontological Statistics) 4.14 software.

Principal coordinate analysis (PCoA)

Principal coordinates analysis, also known as multidimensional scaling was developed by John Gower (1966). It is a statistical method that converts data on distances between items into map-based visualization of those items. Generated mappings are used to determine which items are close to each other and which are different. Here PCoA analysis was carried out on the data using Euclidean distances, using the PAST (Paleontological Statistics) 4.14 software in order to observe the distribution of plant species according to the different sites of the wetland.

Measurement of diversity indices

Species diversity of aquatic macrophytes was calculated by using following formula:

a. Shannon and Weiner diversity index (H)

Calculated using the Shannon and Weiner formula (1949)

$H' = -\sum$ pi In pi.

H'= Index of species diversity

Where, pi = the proportion of the important value of the i^{th} species (pi = ni / N, ni is the important value index of i^{th} species and N is the important value index of all the species)

b. Simpson's Diversity Index (D)

It provides the measure of diversity, taking into account the dominant species as well as its abundance.

$D=1-\sum_{i=1}^{s}(\text{pi})2$

Where, "pi" is the proportion of individuals in the "ith" taxon of the community and "s" is the total number of taxa in the community (Simpson, 1949).

c. Pielou's evenness index (J)

This index measure diversity along with species richness and ranges from 0 (no evenness) to 1 (complete evenness).

Evenness = H'/Hmax = H'/lnS

Results and Discussion

A total of 12 different macrophytes belonging to 11 families have been documented from these two studied wetlands. Among these Amaranthaceae showed highest dominance than others comprising of two species whereas rest of all each contain only one specis.

Table 1: Documentation of macrophytes inhabiting Shibnagar Beel and Sonamati Beel, sacred wetlands of North Dinajpur District:

Sl. No.	Scientific Name	Family	Life form (LF)	Growth form (GF)	W_1	W_2
1	*Alternanthera philoxeroides* (Mart.) Griseb.	Amaranthaceae	TH	Hyp	+	+
2	*Alternanthera sessilis* (L.) DC.	Amaranthaceae	TH	Hel		+
3	*Cyperus compressus* L.	Cyperaceae	TH	Hel	+	
4	*Eclipta prostrata* (L.) L.	Asteraceae	CH	Hel	+	+
5	*Ipomoea aquatica* Forssk.	Convolvulaceae	HCP	Hyp		+
6	*Ludwigia perennis* L.	Onagraceae	TH	Hel	+	+
7	*Marsilea quadrifolia* L.	Marsileaceae	TH	Ple	+	+
8	*Persicaria hydropiper* (L.) Delarbre	Polygonaceae	TH	Hel	+	

9	*Pistia stratiotes* L.	Araceae	TH	Ple	+	+
10	*Poa pratensis* L.	Poaceae	TH	Ple		+
11	*Potamogeton crispus* L.	Potamogetonaceae	CP	Vit		+
12	*Torenia crustacea* (L.) Cham. & Schltdl.	Linderniaceae	TH	Hel	+	+

W1: Shibnagar beel; W2: Sonamati beel; LF: CH = Chamaephytes, CP = Cryptophytes, HCP = Hemicryptophytes, TH = Therophytes.; GF: Hel = Helophyte, Hyp = Hyperhydrate, Ple = Pleustophyte, Vit = Vittate

Table 2: Morphometric features of two wetlands in Islampur

Features of the wetlands	Shibnagar Beel (W1)	Sonamati Beel (W2)
Location	88.25° E, 26.28° N	88.25° E, 26.30° N
Altitude	9.37 m	9.39 m
Nature of the wetland	Perennial	Perennial
Area (acres)	7.42	9.90
Water source	Rainwater	Rainwater
Ownership pattern	Public ownership	Government ownership
Water type	Freshwater	Saline
Anthropogenic pressure	Overexploitation of natural resources and invasiveness of alien species.	Habitat loss and fragmentation.
Rituals/Worship	Worship at Shivmandir and local people believe that to take bath in this wetland is sacred.	Crematory work, and fair at sankranti.

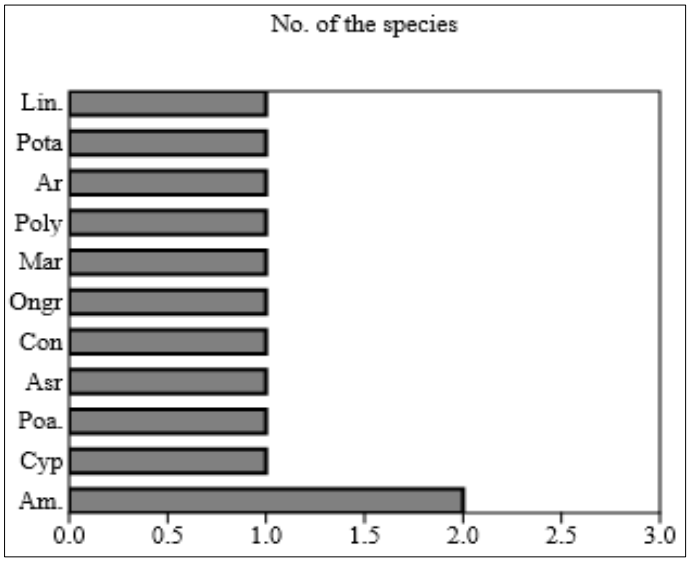


Fig 1: Familywise distribution of macrophytes

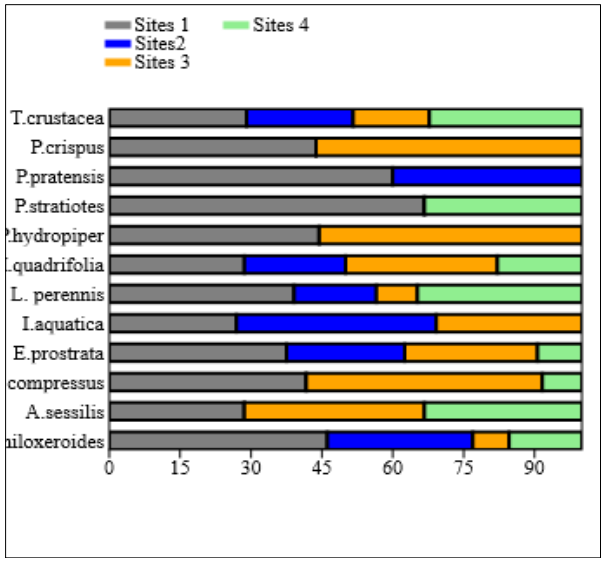


Fig 2: Distribution of macrophytes according to the four study sites

Classification and categorization of collected macrophytes were done on the basis of life forms (Raunkiaer, 1934) and growth forms (Cook, 1996). Pie chart of life forms (Fig 3) showed the highest distribution of Therophytes (9), followed by HCP, CP and CH (each contain 1 species). Whereas pie chart on the basis of growth forms (Fig 4) of macrophytes showed there were highest distribution of Helophytes(6) followed by pleustophytes (3), hyperhydrates(2) and Vittate (1).

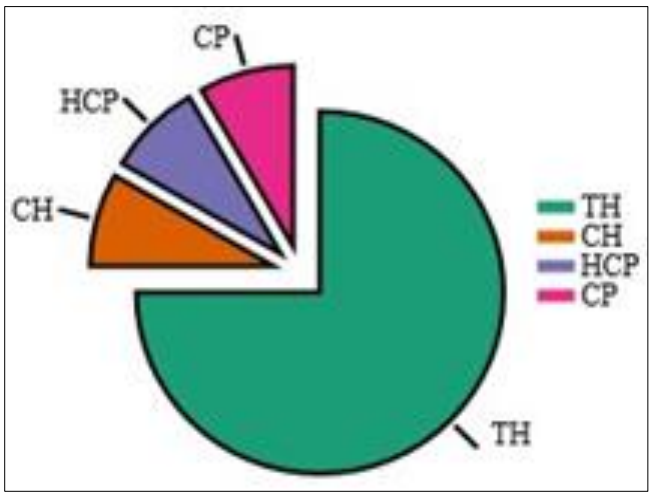


Fig 3: Distribution of life forms (Raunkiaer, 1934)

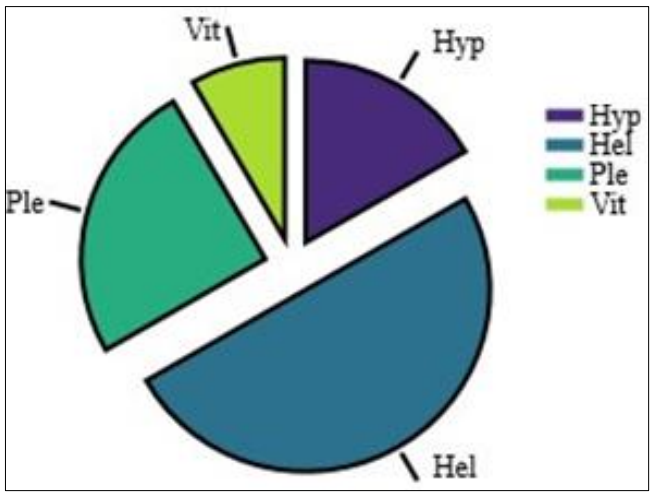


Fig 4: Distribution of growth forms (Cook, 1996)

Individual rarefaction curve of W1 showed highest species richness and diversity in S1 of W1 followed by S2, S3 and S4 of W1. Whereas in W2 rarefaction curve showed highest species richness and diversity in S1 of W2 followed by S4, S3 and lowest in S2 of W2. Rarefaction analysis of the species richness of all four sites (after standardizing the sampling effort across the sites) also showed almost similar trends in plant species richness except S4 in both of the wetlands (Fig 5 and Fig 6).

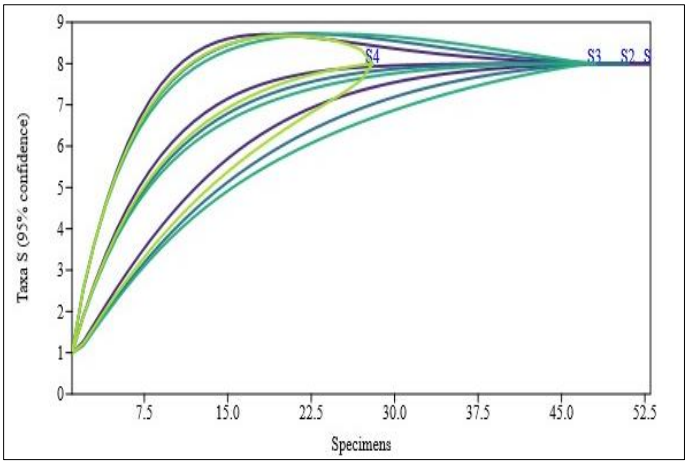


Fig 5: W1 individual rarefaction curve

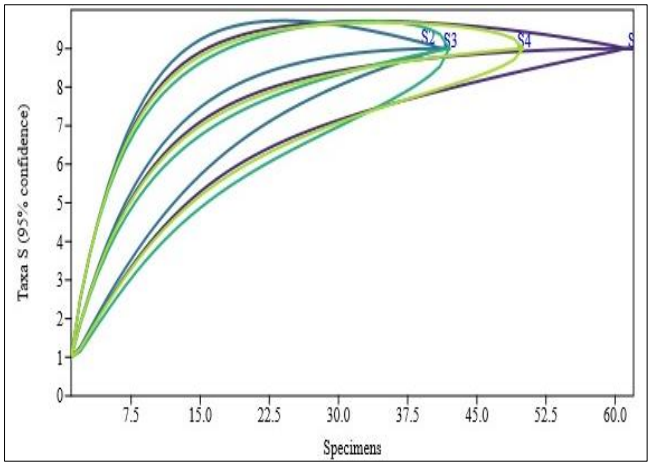


Fig 6: W2 individual rarefaction curve

Principal coordinate analysis (PCoA) analysis showed that although the plant species lived in the same area, significant differences in the numbers were observed among the species. Species composition and proportion were also different at four different sites (Fig 7 and Fig 8).

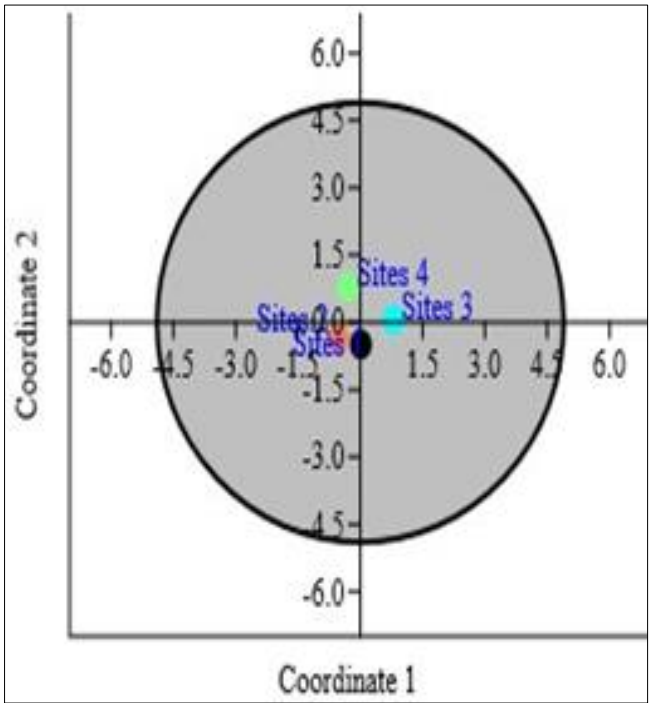


Fig 7: W1 Prinicipal coordinate analysis

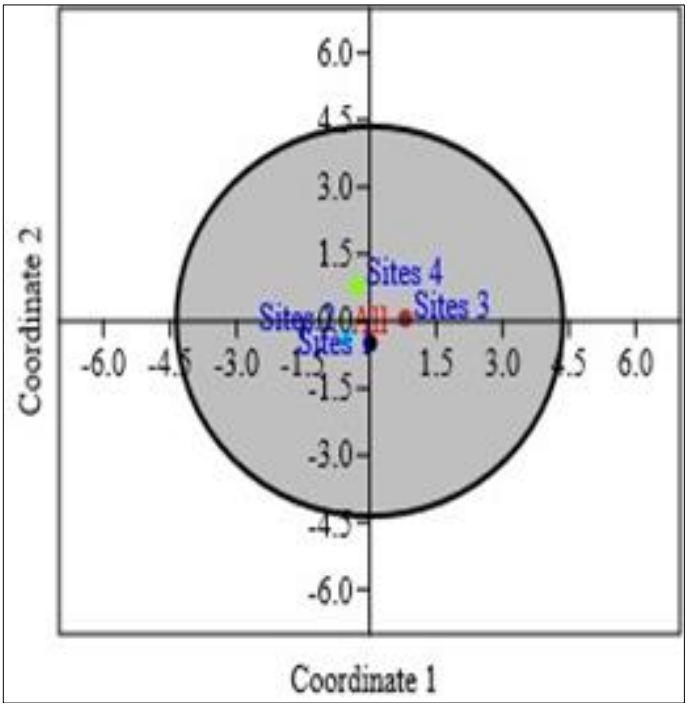


Fig 8: W2 Principal coordinate analysis

Dendrogram (Fig 9) was constructed comparing with 8 different sites (4 each) of both the wetlands based on Bray-Curtis similarity index, showing which sites have similarity in their relation and which have not or distant relationship.

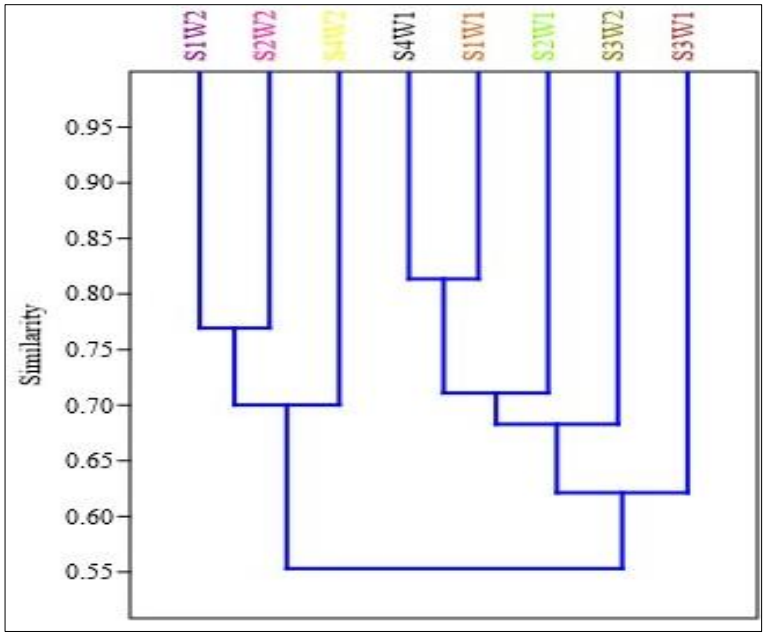
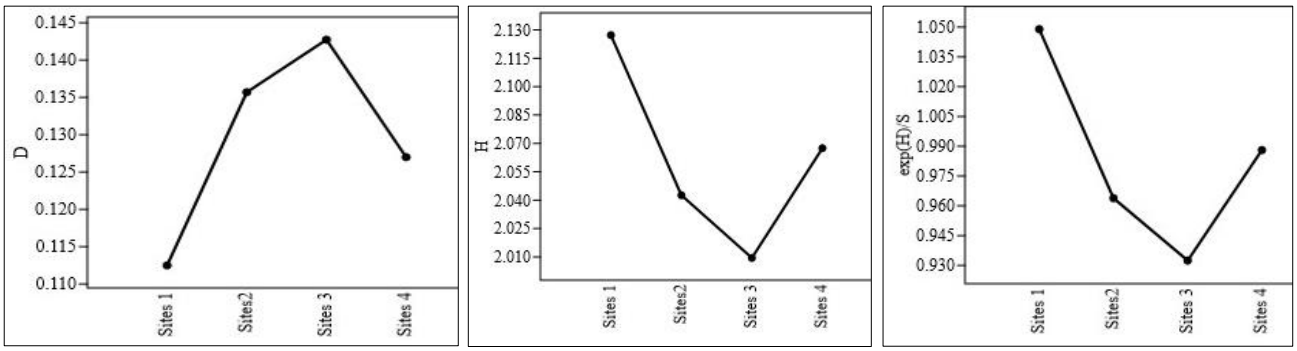


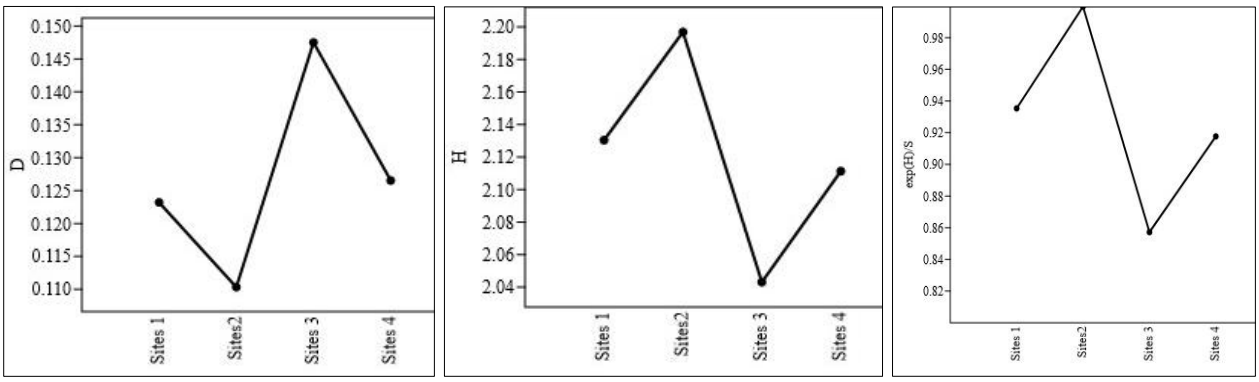
Fig 9: Hierarchial cluster analysis based on sitewise species richness processed for Bray-Curtis similarity index using PAST version 4.14.

Overall diversity indices of macrophytes showed that S3 contain highest diversity value and lowest shown by S4 according to Simpsom dominance index in case of both W1 and W2. Shannon and Weiner diversity index showed highest value for S1 of W1 and lowest for S3 of W1. Whereas in case of W2, it showed highest value for S2 and lowest for S3. Pielous Evenness index showed highest species richness for S1 and lowest for S3 of W1. But in case of W2 it showed highest value for S2 and lowest for S3. So overall diversity indices showed that S3 of both the wetlands contain poor species richness and diversity (Fig 10 and Fig 11).



W1 Simpson Dominance index W1 Shannon and Weiner diversity index W1 Pielou's Evenness index

Fig 10: Different diversity indices curve on the basis of sitewise species vegetation of W1 using PAST version 4.14



W2 Dominance index curve W2 Shannon index curve W2 Evenness index curve

Fig 11: Different diversity indices curve on the basis of sitewise species vegetation of W2 using PAST version 4.14.

Conclusion

Comparative phytosociological analysis in between two sacred wetlands reveal the dynamic nature of ecosystem in case of Sonamati beel(W2) due to profuse growth and diversity of macrophytes. But the species richness and dominance in particular sites of the wetland clearly indicates that both the wetlands are under

the pressure of various anthropogenic activities and continuously facing challenge to sustain their natural biodiversity. So this kind of quantitative investigation will be helpful and impactful to raise the public awareness as well as authority for overall conservation and sustainable management of these sacred wetlands to prevent the loss of biodiversity and water quality. Regular monitaring and every essential steps should be taken immediately to maintain the water quality of this spiritual and religious water resources.

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