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Research Article

SEASONAL CHANGES IN LIMNOLOGICAL PARAMETERS AND MACROPHYTE DIVERSITY ASSOCIATED WITH WETLANDS IN BIRBHUM DISTRICT, WEST BENGAL, INDIA

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ABSTRACT
An inventory of 40 wetlands could be prepared eventual to survey of water bodies occupying 19 Blocks of Birbhum district, West Bengal. These wetlands were described and classified using 11 parameters. Macrophyte specimens and water samples were collected from these wetlands in different seasons during 2005 to 2011 to study the influence of physico-chemical attributes of water on macrophyte diversity. It was revealed that DO, $N\text{-}NO_3$ and $P\text{-}PO_3$ contents of water play a significant role in determining the macrophyte diversity in wetlands of this ecoregion. Some of the macrophytes prevalent throughout the year include *Nymphoides hydrophylla, Marsilea minuta, Trapa bispinosa, Cyperus amabilis, Cucumis sativus, Commelina bengalensis, Croton bonplandianum, Heliotropium indicum, Limnophila pulcherrima, Wolffia globosa, Hygrophila schulli, Ranunculus sceleratus, Alternanthera philoxeroides, Aponogeton natans,Potamogeton crispus, Hydrilla verticillata, Limnophila heterophylla, Ottelia alismoides, Vallisneria spiralis var. denseserrulata, Salvinia cuculata, Phragmites karka, Typha domingensis, Utricularia stellaris, Azolla pinnata, Eichhornia crassipes, Lemna acquinoctialis, Pistia stratiotes.* This study aims to work out the strategy to optimize sustainability of concerned wetlands in ensuring rural water supply, augment success in pisciculture and promote livelihood diversification, economic development and recreation.

Key Words: *Wetlands, Macrophyte Diversity, Seasonal Water Quality and Birbhum*

INTRODUCTION

Wetland Perspectives

Wetlands are perhaps the most interesting landscapes in the world to have earned global importance during the last few decades. They are being discussed all round the world in matters of environmental protection, pollution control, eco-restoration, biodiversity conservation etc. Wetlands have been drawing considerable attention of agriculturists, natural and social scientists, urban planners, land managers, landscape designers and many others. Wetlands representing an ecotone between terrestrial uplands and true aquatic bodies cover about 6% of total earth surface (Williams, 1990). Interestingly these are ubiquitous being found in almost every climatic realm from tundra mires of the pole to the tropical mangroves of the equator, and in every continent except Antarctica. As per Ramsar Convention (1971) wetlands identified to be internationally important as per the norms laid down by Ramsar Bureau, are designated as 'Ramsar sites´. Up till 2012, no less than 1,994 wetlands of 160 countries covering a total area of 191,860,656 hectares are known to be Ramsar sites.

Physicochemical Perspectives

Physicochemical characteristics of a wetland, viz. pH, specific conductance, total hardness, DO,BOD, Nitrate nitrogen, phosphates etc. are the products of complex interactions among biotic, abiotic components of its water and soil and ambient climatic factors like temperature, humidity, wind, radiations intercepted with concomitant light, heat etc. The physico-chemical attributes of wetlands depend to a great extent on the activities of primary producers (micro- and macrophytes), consumers (micro- and macro fauna), decomposers (bacteria, fungi and actinomycetes) and their physical environment, which are likely to vary in the rhythm of seasonal variation of climate of the concerned place (Boyacioglu, 2006).

Macrophyte Perspective

Macrophytes form the bulk of the wetland flora. They include floating plants as well as those rooted with free floating leaves, the submerged, and amphibious and hygrophilous plants. Researches on wetland macrophyte have started gaining importance not only because systematic stock taking of biodiversity is presently given top most priority but also because these plants have implications with functional values of wetlands. In addition to stocktaking and assessment of ecological functions of different forms of wetlands, biodiversity pattern is studied emphatically. Vegetation patterns are likely to control major aspects of wetland-biogeochemistry and trophic dynamics and wetlands should be viewed as complex mosaics of habitats with distinct structural and functional characteristics (Rose and Crompton, 1996). In a review Brix (1997) has brought into light the role of macrophytes with reference to constructed treatment wetlands.The root system of many macrophytes impedes the formation of erosion channels and thus stabilizes the soil surface. In vertical flow system, the presence of macrophytes together with an intermittent loading regime helps to prevent clogging of the medium (Bahlo and Wach, 1990). The movement of plants due to wind etc. keeps the surface open and the growth within filter medium of treatment wetlands help decomposition of organic matter and prevent clogging. Another important effect of the plants is the insulation that the cover provides during winter especially in temperate areas (Smith *et al*., 1997). This keeps the soil free of frost. The litter layer also helps to protect the soil from freezing during winter, but on the other hand also keeps the soil cooler during spring (Brix, 1994).Because of the ability of wetland plants to absorb large amounts of nutrients and a variety of toxic substances, the wetlands are considered useful in waste water treatment. Since nutrient enrichment (eutrophication) accelerated by agricultural run-off, industrial effluents, domestic sewage has been posing serious threat to the existence of many wetlands, environmental scientists have been designing restorative strategies based on appropriate removal of nutrients by binding them within the biomass of wetland plants. Thus the metabolism of macrophytes (nutrient uptake, oxygen release etc.) is very useful in wastewater treatment and wetland restoration. The nutrient uptake by wetland plants and impact of landfil leachate on them as studied by Bernard and Lauve (1995) and physiological responses of the denitrification process in wetlands as observed by Whitaker *et al.,* (1995) are noteworthy. The uptake capacity of emergent macrophytes and thus the amount that can be removed if the biomass is harvested is roughly in the range of 30 to 150 Kg P ha^{-1} $year^{-1}$ and 200 to 2500 Kg N ha^{-1} $year^{-1}$ (Gumbricht, 1993 and Brix, 1994). The highly productive water hyacinths (*Eichhornia crassipes*) have higher uptake capacities (approx. 350 Kg P and 2000 Kg N ha^{-1} $year^{-1}$). The capacity of submerged macrophytes is lower (<100 Kg P and 700 Kg N ha^{-1} $year^{-1}$). The narrow leaved cat tails (*Typha angustifolia*) in constructed wetland unit having the plant harvesting interval of 8 weeks are capable of yielding the N plant uptake of 7.1-7.5 Kg ha^{-1} day^{-1} amounting to 66%-71% of the total Nitrogen input (Kottatep and Polprasert, 1997). Furthermore, some of the wetlands plants viz. *Scirpus americanus, Scirpus cyperius, Scirpus validus, Juncus effuses, Spanganium americanum, Typha angustifolia* and *Typha latifolia* have the capacity to remove more nitrate N according to dentrification enzyme activity determinations (Hunt *et al.*, 2002). Capability of uptaking nutrients by wetland plants like *Ceratophyllum* sp., *Monochoria cyanea*, *Nymphoides indica, Ipomoea diamantinensis, Ipomoea aquatica, Ludwigia peploids, Eleocharis sphacelata* etc. was studied by Greenway (1997). Phosphorous concentration in wetland plants like *Lythrum salicaria* and *Typha* sp. (Emery and Perry, 1996), sedimentation rate and nutrient concentration in *Zizania palustris* (Meeker, 1996) are noteworthy. The use of subsurface flow constructed wetlands planted with *Phragmites australis* (the common reed) for the sewage treatment is now widespread in the UK (Griffin and Upton, 1999). The wetland macrophyte *Phragmites australis* play a critical role in achieving low residual iron concentrations (<0.5 mg/l) in mine water treatment wetlands was studied by Batty and Younger (2001). Macrophytes also releases a wide range of organic substances through their roots (Rovira, 1965 and Barber and Martin, 1976), the reported values of which are generally in the range of 5%-25% of the photosynthetically fixed

Carbon. This organic Carbon is capable of acting as a carbon source for denitrifier and thus can augment nitrate removal (Platzer, 1996).The major objective of this investigation is to prepare an inventory of wetlands in Birbhum district and assess associated macrophyte diversity, density and water quality of wetlands selected from them.

MATERIALS AND METHODS

Study Site

Birbhum District lying within $23^0$32´30´´ and $24^0$35´0´´ N latitude and $88^0$01´40´´ and $87^0$05´25´´ E longitude covers an area of 454.00 sq km it is traditionally a very important district in relation to agriculture, education and culture. The district has a triangular tract of country bisected longitudinally by the loop line of East Indian Railway. The district is under the regime of dry tropical monsoon type of climate. Wetlands herein are of both natural and man-made origin. In view of their enormous importance and multifarious implications it was felt necessary to locate and study them with special emphasis on their macrophyte diversity as well as water quality trends.

Survey of Wetlands

Almost all parts of Birbhum District were surveyed following the district map procured from the Office of the District Magistrate and Birbhum Zilla Parishad and observations on 40 wetlands, thus identified, were recorded. Their names, wherever available, place of occurrence (town/village, Block) were recorded in the field note book and presented in Table1. Periodic visits to these wetlands were paid in different seasons from 2005 to 2011 for multiparametric observations covering hydrology, biodiversity (mainly macrophytes) stress factors, use pattern, existing mode of management etc. For studying certain hydrological features, biodiversity, stress factors, use and management of each of 40 representative wetlands an information collecting sheet was prepared for use in the field more or less adopting Zalidis and Mantzavelas (1996) so that it gathered information about location, area, the uses, the pressures threatening the wetlands, the legal status and the positive actions.

Physico-Chemical Characterization of Water

Sampling: Water samples were collected from representative sites of each subdivision (Siuri, Bolpur, Rampurhat) during pre-monsoon (middle of April each year), monsoon (middle of August each year) and post-monsoon (middle of December each year) seasons during 2005-2011.

Analysis of water sample: The sensitive water parameters like temperature, pH, Dissolved Oxygen were analysed on the spot with the help of a portable water testing kit containing essential reagents and glasswares, whereas samples for estimation of specific conductance, total hardness, nitrate-nitrogen, phosphate-phosphorous and Biological Oxygen Demand, which allow time period of about 24-72 hours after collection, were brought to the laboratory for analysis following APHA (2005). Water was filled in 500 ml plastic bottle from each wetland. From each sampling point three sets of collections were made and mixed to form a composite sample. The plastic bottles were washed with source water before filling them up. The value of each parameter was expressed as mean with Standard deviations (Table 3).

Taxonomic study: During periodic visit to the study sites (40 wetlands as shown in Table -1) from time to time in different parts of the year since 2010 adequate plant specimens of vascular macrophytes (pteridophytes and angiosperms) were collected and relevant observations on them were recorded in field note book. The plant specimens were then properly dried and processed for herbarium preservation. After the plants samples were collected, the macroscopic and microscopic characters of each species were observed with minute details in the laboratory. For correct identification of each species, they were referred to pertinent literature and author's specimens were matched with the authentic specimens preserved in the Central National Herbarium, Shibpur and Howrah (CAL) and in the Herbarium of Burdwan University (BURD). Nomenclature of each species was checked with that given in the latest Floras and Monographs. Help was also taken from the work of Bennett (1989). Standard herbarium sheets measuring 41.5 – 42.0 x 28.0 cm were used for mounting specimens after proper pressing, drying and poisoning. Labels with all relevant information such as name of the plant, family, place and altitude, date

Table 1: An inventory of wetlands in Birbhum District

	Name of the Wetlands	Latitude	Longitude	Block	Nearest village/town
1.	Baidhara barrage	24^{0}16´00´´ N	87^{0}49´ 00´´ E	Nalhati I	Nalhati
2.	Ballabpur bandh	23^{0}41´00´´ N	87^{0}39´45´´ E	Bolpur- Sriniketan	Bolpur
3.	Barabandh	23^{0}40´ 05´´ N	87^{0}40´50´´ E	Bolpur-Sriniketan	Bolpur
4.	Baradighi	24^{0}25´ 57´´ N	87^{0}54´21´´ E	Murarai I	Murarai
5.	Barrobandh	23^{0}38´22.9´´ N	87^{0}31´7.7´´ E	Illambazar	Payer
6.	Biswas pukur	23^{0}38´17.4´´ N	87^{0}31´30.9´´ E	Illambazar	Illambazar
7.	Boro pukur	24^{0}06´15´´N	87^{0}46´30´´E	Bolpur-Sriniketan	Bolpur
8.	Borobandh	23^{0}46´20.5´´N	87^{0}17´28.9´´E	Khoyrasol	Moynadal
9.	Chamna dighi	23^{0}59´ 40´´ N	87^{0}43´15´´ E	Sainthia	Sainthia
10.	Chandrakumar pukur	23^{0}37´42´´N	87^{0}33´20.3´´E	Illambazar	Illambazar
11.	Datin dighi	23^{0}48´ 11´´ N	87^{0}21´10´´ E	Dubrajpur	Dubrajpur
12.	Gopalnagar bandh	24^{0}04´ 10´´ N	87^{0}39´15´´ E	Muhammad Bazar	Gonpur (near Muhammad Bazar)
13.	Joysagar dighi	23^{0}59´ 34´´ N	87^{0}34´55´´ E	Muhammad. Bazar	Muhammad Bazar
14.	Jugadamai dighi	24^{0}12´ 55´´ N	87^{0}52´32´´ E	Rampurhat I	Rampurhat
15.	Kalisayer	23^{0}41´57´´N	87^{0}40´74.9´´E	Suri I	Suri
16.	Lakshmi sayer	23^{0}38´03.0´´N	87^{0}36´48.2´´E	Ilambazar	Daranda
17.	Lalbandh	23^{0}41´ 15´´ N	87^{0}40´50´´ E	Bolpur- Sriniketan	Bolpur
18.	Lambadharpur Sayer	23^{0}55´ 30´´ N	87^{0}31´ 05” E	Suri I	Suri
19.	Lohabandh dighi	23^{0}42´ 45´´ N	87^{0}42´25´´ E	Bolpur-Sriniketan	Uttarnarayanpur (near Bolpur)
20.	Mahindrapur dighi	24^{0}11´ 30´´ N	87^{0}49´10´´ E	Rampurhat I	Rampurhat
21.	Mahulah dighi	24^{0}06´ 15´´ N	87^{0}46´30´´ E	Mayureswar I	Mallarpur
22.	Mayureswar dighi	23^{0}55´ 49´´ N	87^{0}49´26´´ E	Mayureswar II	Mayureswar
23.	Paboipara dighi	24^{0}13´ 13´´ N	87^{0}53´07´´ E	Rampurhat II	Rampurhat II
24.	Paikar dighi	24^{0}26´ 08´´ N	87^{0}55´15´´ E	Muraroi II	Muraroi
25.	Panchpara dighi	23^{0}51´ 38´´ N	87^{0}51´40´´ E	Sainthia	Sainthia
26.	Pansiuri Bandh	23^{0}46´52.1´´N	87^{0}16´28.5´´E	Khoyrashole	Khuyrashole
27.	Poddar bandh	23^{0}47´17.5´´N	87^{0}22´17.6´´E	Dubrajpur	Dubrajpur
28.	Ragur Bandh	23^{0}46´30.0´´N	87^{0}17´28.1´´E	Khoyrashole	Moynadal
29.	Rajarpukur	23^{0}37´44.7´´N	87^{0}31´54.4´´E	Ilambazar	Ilambazar
30.	Rampurhat dighi	24^{0}10´ 15´´ N	87^{0}47´10´´ E	Rampurhat I	Rampurhat
	Ramsayer	23^{0}59´ 13´´ N	87^{0}44´12´´ E	Labhpur	Ramkrishnapur
31.	Salkhana Pond	23^{0}52´14.4´´N	87^{0}33´48.4"E	Suri II	Suri
32.	Sankari Bandh	23°46'38.89"N	87°17'23.97"E	Khoyrashole	Moynadal
33.	Santhla/Manthla dighi	23^{0}42´ 35´´ N	87^{0}51´28´´ E	Nanoor	Nanoor
34.	Sarbasundari dighi	24^{0}11´ 42´´ N	87^{0}48´35´´ E	Rampurhat I	Mahindrapur
35.	Saroda sagar	23^{0}55´49´´N	87^{0}49´26´´E	Bolpur-Sriniketan	Bolpur
36.	Sayer	23^{0}48´ 25´´ N	87^{0}21´25´´ E	Dubrajpur	Dubrajpur
37.	Sayor bithi park	23^{0}55´49´´N	87^{0}49´26´´E	Bolpur-Sriniketan	Bolpur
38.	Shib pukur	23^{0}42´27.1´´N	87^{0}41´231´´E	Bolpur-Sriniketan	Bolpur
39.	Tilpara barrage	23^{0}56´ 35´´ N	87^{0}31´30´´ E	Suri I	Suri

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of collection, collector's name and field numbers were affixed on the bottom right hand corner of the mounted sheets.

Statistical Treatment of Data

Paleontological Statistics (PAST), Statistical Package for Social Sciences (SPSS version 17) and XLSTAT 2010 were used to analyze data obtained during this work.

RESUT AND DISSCUSION

Inventory of Wetlands

Of the several water bodies observed in this district during field survey as many as 40 wetlands each with an area more than 5 acres could be recorded which occur in 19 Blocks of the district. (Table 1)

Geneal characteristics

The wetlands thus enumerated are characterized on the basis of as many as 11 parameters (Table 2) scored during field survey.

Table 2: An enumeration of wetlands in Birbhum District and their general characteristics

Name of the Wetland	Size (acres)	Water regime	Origin	Source of water	Mean depth (ft)	Use pattern	Major problem associated with the wetland	Pollution mainly from	Scientific management/ optimization programme, if any	Plant diversity (qualitative)	Animal diversity (qualitative)
1. Baidhara barrage	750	P	Mm	RC	15	I,P,D	Sh	Ar	Ny	R	R
2. Ballabpur bandh	450	P	Mm	RC	10	I,P,D	E	Ar	Ny TAR,FAF&M	R	R
3. Barabandh	50	P	Mm	RW	8	P,D	Sh	Ds	Ny	P	MR
4. Baradighi	16.45	P	Na	RW	7	I,P,D	Sh	Ds	Ny	R	MR
5. Barrobandh	16	P	Mm	RW	17.5	I,P,D	NS	Ar	Ny	MR	MR
6. Biswas pukur	34	P	Na	RW	15	I,P,D	NS	Ar	Ny	R	R
7. Boro pukur	6	P	Mm	RW	7	I,P,D	NS	Ar	Ny	MR	MR
8. Borobandh	33	P	Mm	RC	8	I,P,D	Sh	Ar	TAR,FAF&M	R	R
9. Chamna dighi	13.98	P	Mm	RW	7	P,D	Sh	Ar	Ny	MR	MR
10. Chandrakumar pukur	17	P	Mm	RW	9	P,D	E	Ds	Ny	P	MR
11. Datin dighi	19.73	P	Mm	RW	12	I,P	NS	Ns	Ny	R	R
12. Gopalnagar bandh	82.32	P	Mm	RW	7	I,P,D	Sh	Ar	FAF &M	R	R
13. Joysagar dighi	21	P	Mm	RW	9	I,P,D	E	Ds	Ny	MR	MR
14. Jugadamai dighi	14.82	P	Mm	RW	7	I,P,D	NS	Ds	Ny	MR	MR
15. Kalisayar	12	P	Mm	RW	7	I,P,D	NS	Ds	Ny	MR	MR
16. Lakshmi sayar	100	P	Na	RW	22.33	I,P,D	Sh	Ar	FAF&M	MR	MR
17. Lalbandh	18.92	P	Mm	RW	8	P,D	Sh & E	Ds	TAR	R	R
18. Lambadharpur sayer	28.8	P	Na	RW	8	P,D	E	Ds	FAF &M	R	MR
19. Lohabandh dighi	17.11	P	Mm	RW	7	I,P,D	Sh, E	Ar	Ny	MR	MR
20. Mahindrapur dighi	12.35	NP	Mm	RW	7	I,P,D	NS	Ds	Ny	MR	MR

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Table 2: An enumeration of wetlands in Birbhum District and their general characteristics

Name of the Wetland	Size (acres)	Water regime	Origin	Source of water	Mean depth (ft)	Use pattern	Major problem associated with the wetland	Pollution mainly from	Scientific management/ optimization programme, if any	Plant diversity (qualitative)	Animal diversity (qualitative)
21. Mahulah dighi	17.17	P	Mm	RW	7	I,P	NS	Ar	FAF & M	P	MR
22. Mayureswar dighi	19.48	P	Mm	RW	11	I,P,D	NS	Ar	Ny	MR	MR
23. Paboipara dighi	19.76	P	Mm	RW	7	I,P,D	Sh	Ar	Ny	MR	MR
24. Paikar dighi	48	NP	Na	RC	5	I	Sh	Ds	Ny	P	P
25. Panchpara dighi	18.1	NP	Mm	RW	9	I	NS	Ds	TAR	MR	MR
26. Pansiuri bandh	22	P	Mm	RW	6.5	I,P,D	NS	Ar	Ny	R	R
27. Poddar bandh	3	P	Na	RW	3	I,P,D	E	Ar,Ds	Ny	MR	MR
28. Raghur bandh	35	P	Mm	RW	6.5	I,P,D	NS	Ar	Ny	R	R
29. Rajarpukur	17	P	Na	RW	22.5	I,P,D	NS	Ar	TAR	MR	MR
30. Rampurhat dighi	14.82	P	Mm	RW	7	P,D	E	Ds	Ny	MR	P
31. Ramsayer	18.92	P	Mm	RW	8	I,P,D	NS	Ds	Ny	MR	R
32. Salkhana Pond	8	P	Mm	RC	15	I,P,D	Sh	Ar	E	R	R
33. Sankari bandh	15	P	Na	RC	8	I,D	E	Ar	Ny	MR	P
34. Santhla/Manthla dighi	12.35	P	Mm	RW	8	I	NS	Ds	E	MR	MR
35. Sarbasundari dighi	15.63	P	Na	RW	9	I,P	NS	Ds	Ny	MR	MR
36. Saroda sagar	6	P	Na	RW	9	I,P,D	Sh	Ar,Ds	Ny	MR	MR
37. Sayer	12.5	P	Mm	RW	7	I,P	Sh	Ns	Ny	MR	MR
38. Sayor bithi park	15	P	Mm	RW	25	I,P,D	NS	Ns	TAR	P	R
39. Shib pukur	10	P	Mm	RW	9	I,P,D	NS	Ar	Ny	R	MR
40. Tilpara barrage	2964	P	Mm	RC	35	I,P,D	Sh, E	Ar	FAF &M	R	R

Legend of abbreviations	P = Perennial	Mm = Man-made	Rc = Riverine canal	I= Irrigation	NS = Non specific	Ar = Agricultural run-off	TAR = Technical assistance for restoration	R = Rich; MR = Moderate; P = poor
	NP = Nonperennial	Na = Natural	RW = Rain water	P= Pisciculture	Sh = Shrinkage	Ds = Domestic sewage	FAF&M = Financial assistance for fishery management	
				D = Domestic use	E= Eutrophication	Ns= Nonspecific	E = Excavation	
							NY = Not yet implemented	

PHYSICO CHEMICAL CHARACTERISTICS OF WATER

Assessment of water quality in wetlands of Birbhum District (Subdivisions) in different seasons is represented in Table 3.

Table 3: Physicochemical properties of water (subdivision wise)

		PRMS	MONS	POMS	PRMB	MONB	POMB	PRMR	MONR	POMR
Temparature($^{\circ}$centigrade)	MEAN	27.773	27.440	20.777	30.330	29.330	23.443	29.050	28.377	22.107
	SD	2.693	0.697	0.693	0.330	0.330	0.510	1.300	0.402	0.582
pH	MEAN	7.473	7.573	7.450	7.607	7.497	7.640	7.537	7.530	7.543
	SD	0.051	0.268	0.344	0.133	0.217	0.203	0.050	0.242	0.257
Specific Conductance(μ mhocm^2)	MEAN	126.997	132.663	119.107	58.773	73.773	50.773	93.000	101.667	85.000
	SD	0.665	1.665	1.072	3.151	5.602	2.987	1.000	2.082	1.732
Total Hardness(mg/lt)	MEAN	55.440	82.883	95.550	80.843	77.317	90.687	68.577	80.097	93.117
	SD	0.840	1.345	1.645	1.362	2.925	1.497	1.054	2.137	0.375
Dissolved Oxygen(D.O)(mg/lt)	MEAN	8.262	7.079	6.200	3.493	7.583	5.433	5.877	7.327	5.813
	SD	0.337	0.060	0.030	0.325	0.333	0.338	0.289	0.163	0.162
Bioloical Oxygen Demand[B.O.D](mg/lt)	MEAN	5.687	6.127	4.740	2.053	2.637	3.320	3.850	4.380	4.027
	SD	0.546	0.012	0.080	0.365	0.278	0.167	0.121	0.132	0.110
Nitrate Nitrogen(No_3-N)(mg/lt)	MEAN	3.630	5.463	4.590	3.357	4.607	3.527	3.743	5.033	4.053
	SD	0.031	0.035	0.053	0.144	0.037	0.085	0.033	0.009	0.042
Phosphate Phohphorus PO_4-P(mg/lt)	MEAN	3.093	4.193	3.870	3.067	4.327	3.517	3.077	4.043	3.690
	SD	0.155	0.049	0.053	0.217	0.179	0.306	0.183	0.326	0.154

List of Abbreviations: PRMS = PRE MONSOON (SURI) , MONS = MONSOON (SURI) , POMS =POST MONSOON (RAMPURHAT), PRMB = PRE MONSOON (BOLPUR) MONB = MONSOON (BOLPUR), POMB = POST MONSOON (BOLPUR), PRMR = PRE MONSOON (RAMPURHAT), MONR = MONSOON (RAMPURHAT)POMR = POST MONSOON (RAMPURHAT), MEAN = MEAN DATA, SD = STANDARD DEVIATIO

Table 4-6: Correlation between physico chemical parameters of wetlands in Birbhum District (subdivision wise) [Bold correlation are significant at p<0.05]

	TEMP	Ph	SC	TH	DO	BOD	N-NO3
Ph	**0.613**						
SC	**0.891**	**0.905**					
TH	-0.771	0.031	-0.397				
DO	**0.844**	0.094	**0.508**	-0.992			
BOD	**0.937**	**0.851**	**0.994**	-0.499	**0.603**		
N-NO3	-0.069	**0.745**	0.391	**0.689**	-0.594	0.284	
P-PO4	-0.272	**0.593**	0.194	**0.823**	-0.746	0.082	**0.979**

	TEMP	Ph	SC	TH	DO	BOD	N-NO3
Ph	-0.575						
SC	**0.673**	-0.992					
TH	-0.924	**0.844**	-0.905				
DO	-0.105	-0.753	**0.665**	-0.283			
BOD	-0.942	0.266	-0.385	**0.742**	0.434		
N-NO3	0.260	-0.939	**0.889**	-0.609	**0.933**	0.080	
P-PO4	0.029	-0.834	**0.759**	-0.408	**0.991**	0.309	**0.973**

<u>**List of abbreviations**</u>
TEMP- Temperature
Ph- Ph
SC-Specific Conductivity
TH- Total Hardness
DO- Dissolve Oxygen
BOD- Biological Oxygen Demand
N-N03- Nitrate Nitrogen
P-PO4- Phosphate Phosphorous

	TEMP	Ph	SC	TH	DO	BOD	N-NO3
Ph	-0.819						
SC	**0.805**	-1.000					
TH	-0.921	**0.530**	-0.511				
DO	0.455	-0.884	**0.894**	-0.072			
BOD	0.102	-0.655	**0.672**	0.294	**0.932**		
N-NO3	0.202	-0.728	**0.743**	0.196	**0.964**	**0.995**	
P-PO4	-0.240	-0.361	0.383	**0.599**	**0.755**	**0.941**	**0.902**

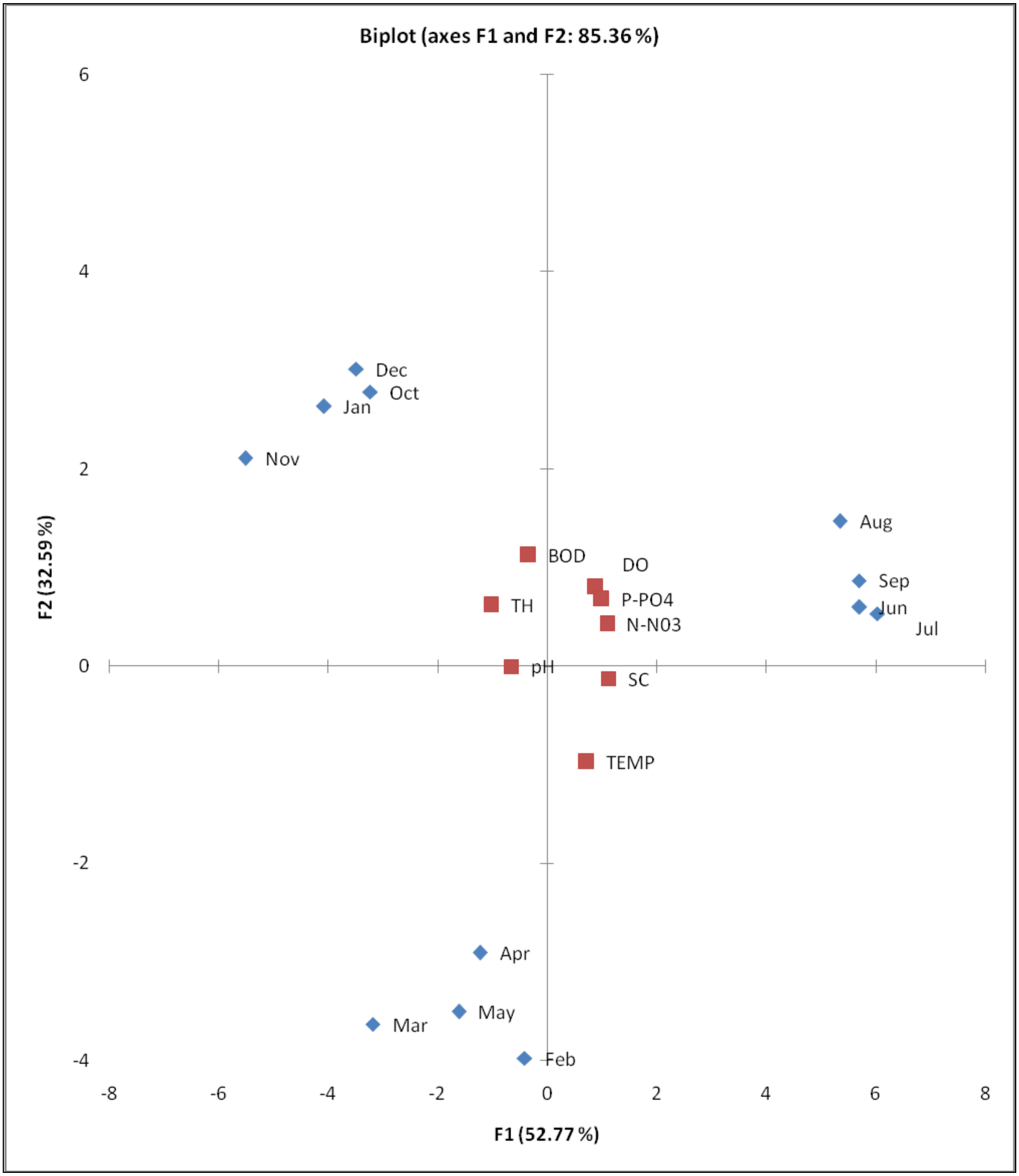

Figure 1: Principle component analysis of physicochemical parameters observed during the study

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TAXONOMIC STUDY

Table: 7 A systematic accounts of macrophyte species, which were found, associated with different wetlands throughout the Birbhum District

1.	*Nymphaea nouchali*
2.	*Nymphaea pubescens*
3.	***Nymphoides hydrophylla***
4.	*N. indica*
5.	**Marsilea minuta**
6.	***Trapa bispinosa***
7.	*Aristida adscenscionis*
8.	*Brachiaria ramose*
9.	*Brachiaria reptans*
10.	*Bulbostylis barbata*
11.	*Coix lachryma-jobi*
12.	*Cynodon dactylon*
13.	***Cyperus amabilis***
14.	*Echinochloa colona*
15.	*Echinochloa crusgalli*
16.	*Eragrostis coarctata*
17.	*Eragrostis gangetica*
18.	***Eragrostis nutans***
19.	*Eragrostis tenella*
20.	*Fimbristylis aestivalis*
21.	*Mariscus aristatus*
22.	*Panicum paludosum*
23.	*Panicum repens*
24.	*Panicum trypheron*
25.	*Paspalum conjugatum*
26.	*Perotis indica*
27.	*Saccharum spontaneum*
28.	***Vetiveria zizanioides***
29.	*Alternanthera paronychioides*
30.	***Alternanthera pungens***
31.	*Alternanthera sessilis*
32.	*Alysicarpus monilifer*
33.	***Amaranthus spinosus***
34.	*Amaranthus tenuifolius*
35.	*Ampelocissus latifolia*
36.	*Boerhavia diffusa*
37.	*Canscora decussate*
38.	***Cassia sophera***
39.	*Cayratia triflora* var. *cinerea*
40.	*Centaurium centaurioides*
41.	*Centella asiatica*
42.	*Citrulus lanatus*
43.	*Cucumis callosus*
44.	***Cucumis sativus***
45.	*Coldenia procumbens*
46.	***Commelina bengalensis***
47.	*Commelina paludosa*
48.	***Croton bonplandianum***
49.	*Dentella repens*
50.	*Desmodium gangeticum*
51.	*Desmodium triflorum*
52.	*Eclipta alba*
53.	*Euphorbia dracanculoides*
54.	*E. hypercifolia*
55.	*E. thymifolia*
56.	*Evolvulus alsinoides*
57.	*E. nummularius*
58.	*Flacourtia indica*
59.	*Glinus lotoides*
60.	*Glinus oppositifolius*
61.	*Gnaphalium polycaulon*
62.	*Gomphrena celosioides*
63.	*Grangea maderaspatana*
64.	***Heliotropium indicum***
65.	*H. ovalifolium*
66.	***Heliotropium strigosum***
67.	*Hemiadelphis polysperma*
68.	*Hemigraphis hirta*
69.	*Hibiscus cannabinus*
70.	*Hoppea dichotoma*
71.	*Hybanthus enneaspermus*
72.	*Hydrolea zeylanica*
73.	*Indigofera linifolia*
74.	***Jatropa gossypifolia***
75.	*Juncus minticola*
76.	*Justicia simplex*
77.	*Leucas lavandulifolia*
78.	***Limnophila pulcherrima***
79.	*Lindernia ciliata*
80.	*Lindernia crustacea*
81.	*Lindernia oppositifolia*
82.	*Lindernia pusilla*
83.	*Lippia alba*
84.	*Lobelia alsinoides*
85.	*Melochia corchorifolia*
86.	*Merremia emarginata*
87.	*Murdania nudiflora*
88.	*Nicotiana plumbaginifolia*
89.	*Phyla nodiflora*
90.	*Phyllanthus fraternus*

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91.	*Phyllanthus virgatus*
92.	*Polygala chinensis*
93.	***Polygonum hydropiper***
94.	*Polygonum plebeium*
95.	*Portulaca oleracea*
96.	*Pupalia lappacea*
97.	*Rumex dentatus* ssp. *klotzschianus*
98.	*Rumex trisetifer*
99.	*Sesamum indicum*
100.	***Sida cordata***
101.	*Sida rhombifolia*
102.	*Sphaeranthus indicus*
103.	*Spilanthes paniculata*
104.	*Staurogyne glutinosa*
105.	*Trianthema portulacastrum*
106.	*Vernonia cinerea*
107.	***Xanthium indicum***
108.	***Ipomoea aquatic***
109.	*Ipomoea carnea* ssp. *fistula*
110.	*Ipomoea obscura*
111.	*Ludwigia adscendens*
112.	*Ludwigia perennis*
113.	*Aeschynomene aspera*
114.	*A. indica*
115.	*Neptunia oleracea*
116.	*Monochoria hastate*
117.	*Monochoria vaginalis*
118.	*Sagittaria guyanensis*
119.	***Sagittaria sagitifolia***
120.	***Nelumbo nucifera***
121.	***Mimosa rubicaulis***
122.	*Polycarpon prostratum*

123.	*Cyperus articulates*
124.	*Eleocharis artopurpurea*
125.	***Phragmites karka***
126.	***Typha domingensis***
127.	***Utricularia stellaris.***
128.	***Azolla pinnata***
129.	***Eichhornia crassipes***
130.	***Lemna acquinoctialis***
131.	***Pistia stratiotes***
132.	*Spirodela polyrhiza*
133.	***Salvinia cuculata.***
134.	***Vallisneria spiralis* var. *denseserrulata***
135.	***Ottelia alismoides***
136.	***Limnophila heterophylla***
137.	*Rotala indica*
138.	***Hydrilla verticillata***
139.	*Najas graminea*
140.	***Potamogeton crispus.***
141.	*Ammania multiflora*
142.	*Cyperus castaneus*
143.	*C. compressus*
144.	*C. cuspidatus*
145.	*C. distans*
146.	*C. exaltatus*
147.	*C. iria*
148.	*C. pilosus*
149.	*C. rotundus*
150.	*Fimbristylis bisumbellata*
151.	*F. dichotoma*
152.	*F. miliacea.*
153.	*Enydra fluctuans*
154.	*Polygonum orientale*

155.	*Digitaria bicornis*
156.	*Digitaria ciliaris*
157.	*Digitaria longiflora*
158.	*Kyllinga brevifolia*
159.	*Kyllinga triceps*
160.	*Lasia spinosa*
161.	*Setaria pumila*
162.	*Setaria verticillata*
163.	*Sporobolus diander.*
164.	*Leersia hexandra*
165.	*Paspalidium flavidum.*
166.	*Polygonum barbatum*
167.	*Leptochloa chinensis.*
168.	*Bacopa monnieri*
169.	*Cyperus difformis.*
170.	*Veronica anagalis- aquatica*
171.	*Oryza rufipogon*
172.	*Utricularia gibbosa*
173.	*Ceratophyllum demersum*
174.	***Wolffia globosa***
175.	***Hygrophila schulli***
176.	*H. difformis*
177.	*Eleocharis dulcis*
178.	*Schoenoplectus articulatus.*
179.	*Cyperus platystylis*
180.	*Limnophila indica*
181.	*Hygrophila polysperma*
182.	***Ranunculus sceleratus***
183.	***Alternanthera philoxeroides***
184.	***Aponogeton natans***
185.	*Potamogeton nodosus*

MACROPHYTE ABUNDANCE AND DIVERSITY

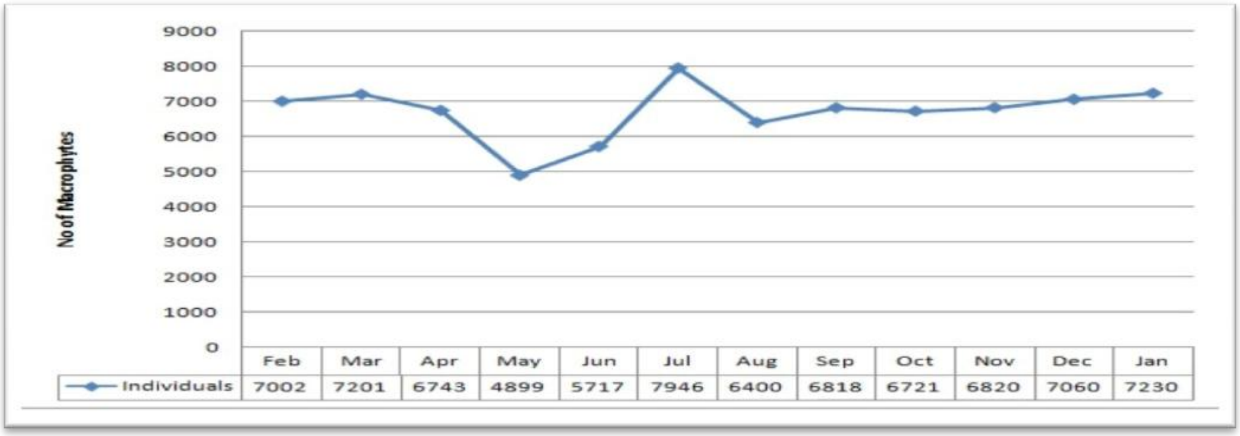

Figure 2: Seasonal variation of total number of Macro Invertebrates observed during the study period

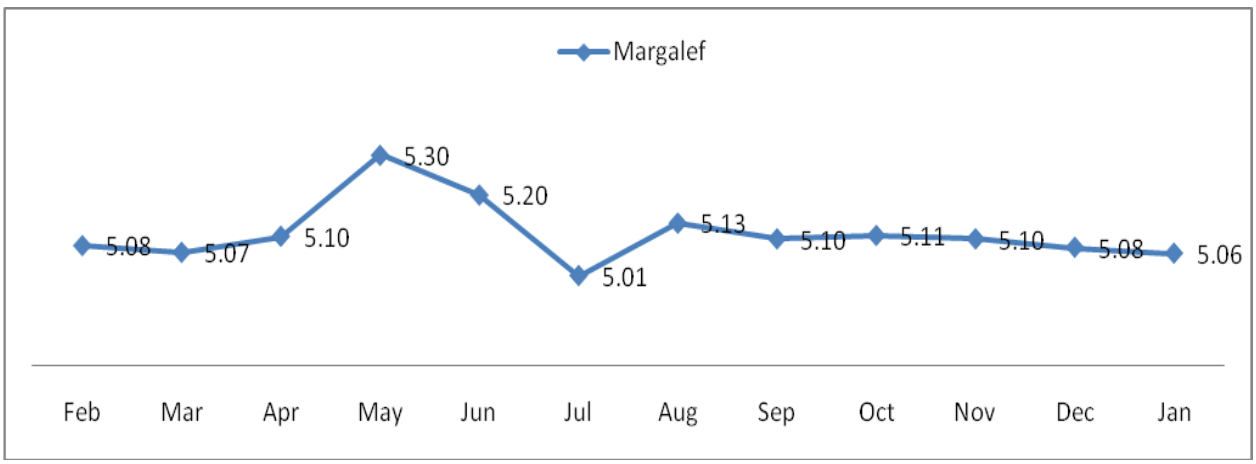

Figure 3: Variation in the Margalef's index

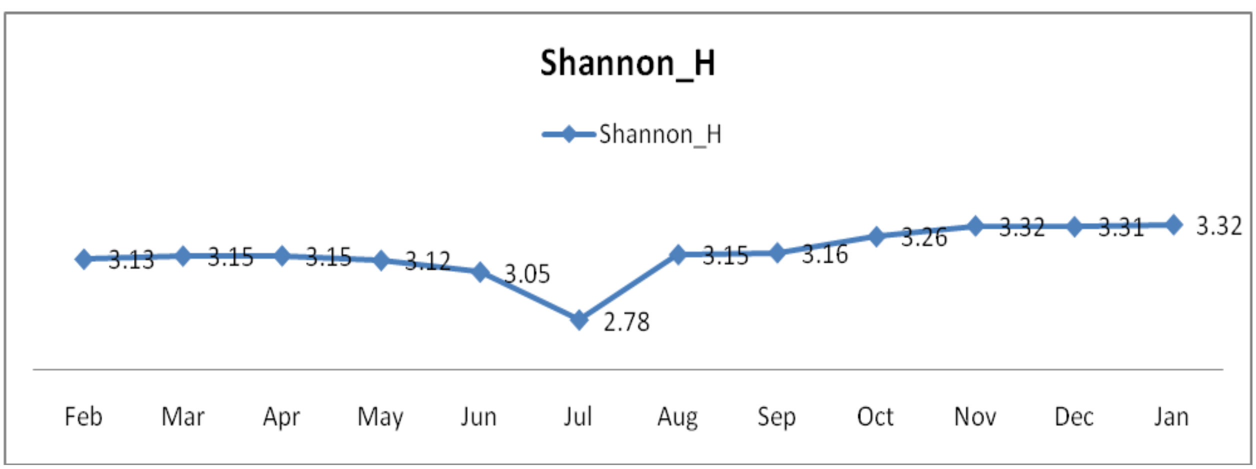

Figure 4: Variation in the Shanon's Index of Diversity

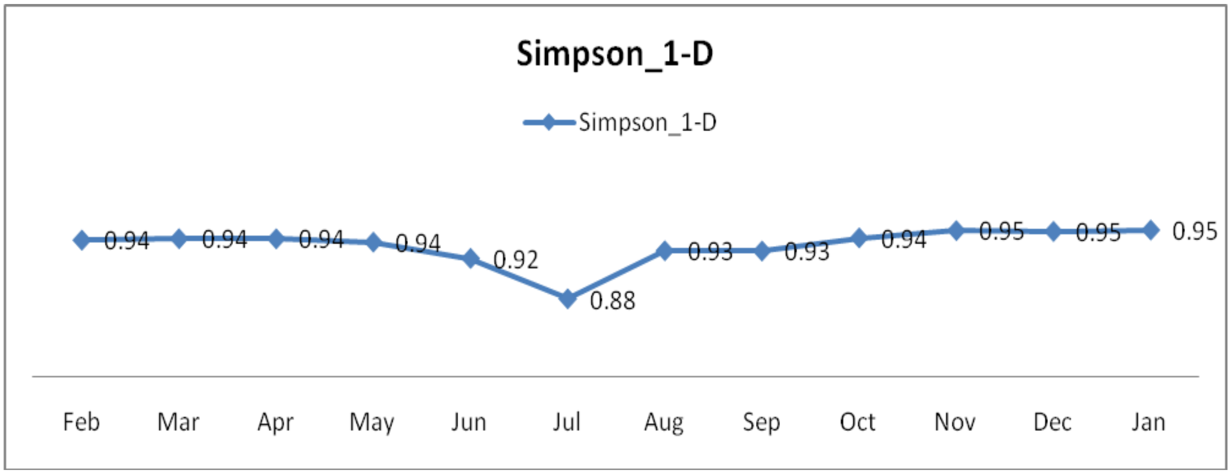

Figure 5: Variation in the Simpsons Index

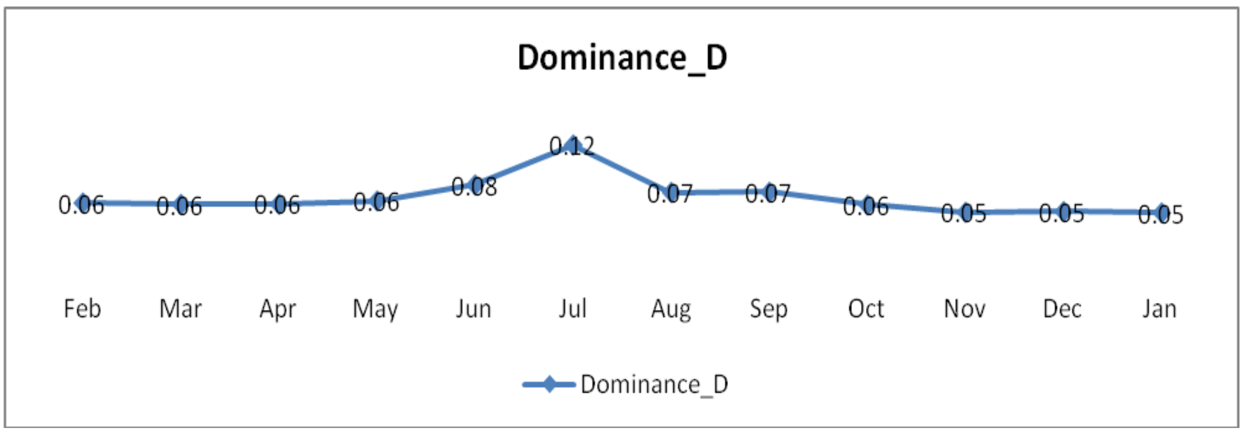

Figure 6: Seasonal Variation in the Index of Dominance

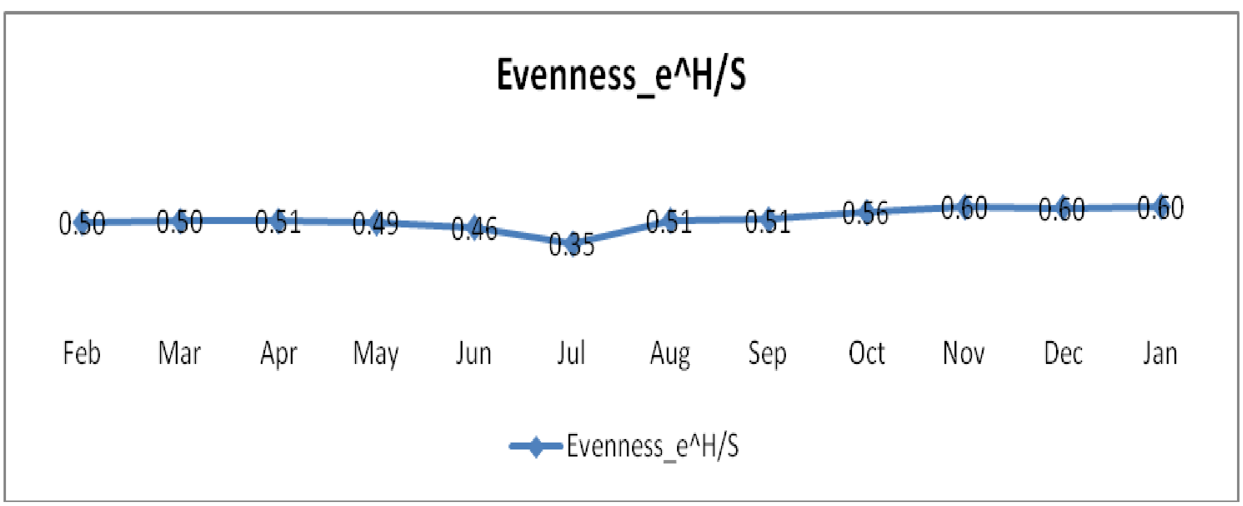

Figure 7: Variation in the Index of Evenness

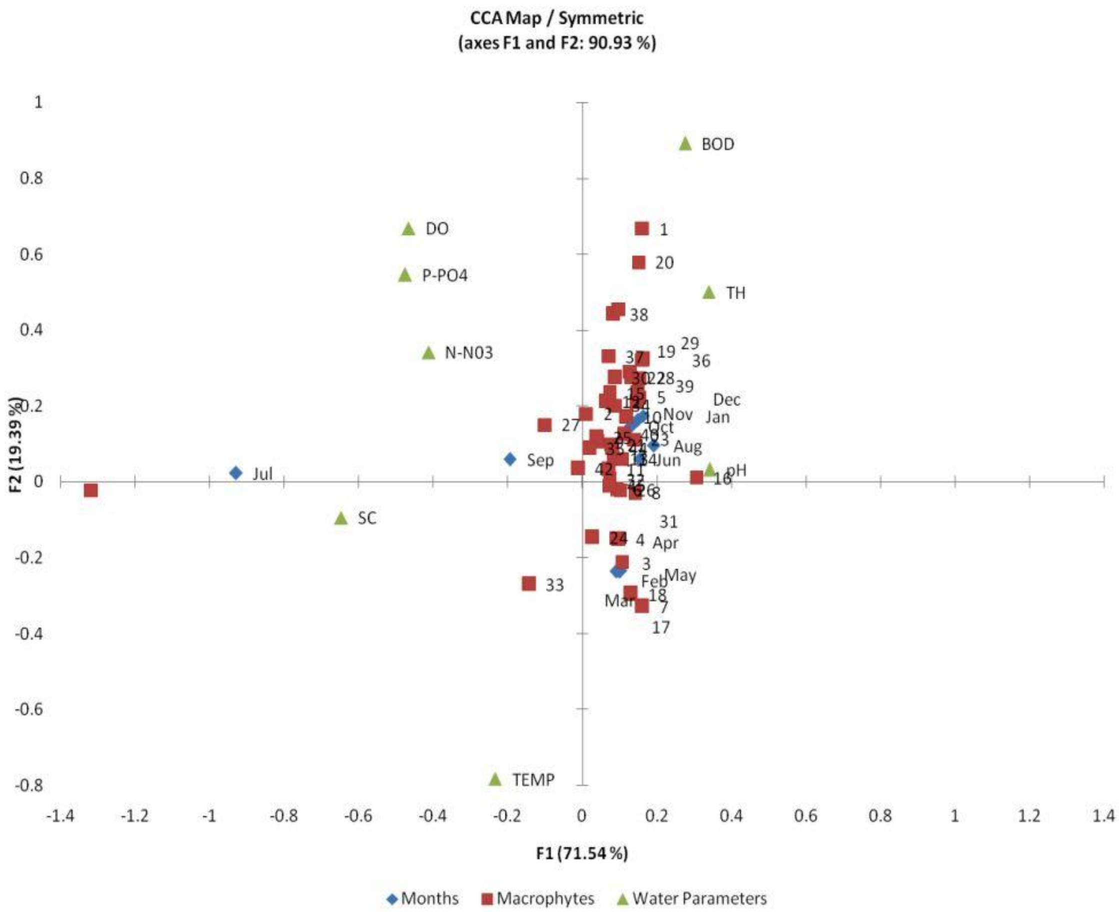

Figure 8: CCA of Macrophyte density and physicochemical parameters of water in wetlands of Birbhum District (species (1-40) BOLD names in table7)

INVENTORY OF WETLANDS

Preparation of an inventory of a country's resources is an important prerequisite for judicious planning for sustainable development and prosperity. Wetlands being as valuable as a distinct natural resource deserve consideration in such a work. Of the several water bodies observed during field survey conducted in different parts of the district as many as 40 were distinguishable as wetlands, each having an area exceeding 5 acres. These water bodies are in possession of important wetland characteristics as laid down by United States Fish and Wildlife Services through their Circular 39, viz. (i) presence of water for at least seven successive days during growing season, (ii) the habitat supports aquatic macrophytes growing in water, soil and some other substrate that is periodically deficient in oxygen due to water logging in some parts of the year and (iii) the substrate is predominantly of hydric soils that are saturated or flooded for a sufficiently long period to become anaerobic in their upper layers. Cook's (1996) consideration of wetland as a place where inundation must occur for about 14 days and saturation for at least about 60 consecutive days has also been considered as a basis for identification of these wetlands.

These wetlands occur in 19 Blocks of the District. Bolpur-Sriniketan, Muhammad Bazar, Rampurhat-1 have high frequencies of wetlands. Dubrajpur, Murarai-I, Murarai-II, Sainthia have medium and Labhpur, Mayureswar-I, Mayureswar-II, Nalhati-I, Nanoor, Rampurhat-II, Suri-I, Suri-II have low frequencies of wetland. The quota of wetlands per sq Km. is thus very low, the value being 0.0055 or conversely there is a single wetland per 18180 sq Km. of the district. These wetlands contribute, as a natural resource, in terms of covered area to an extent of 9.74 per cent of the contribution of forests which cover about 4.33 per cent (196.7 sq Km.) of the total district area. However, the importance of wetland to global carbon cycle, water balance, wildlife biodiversity and human food production is much greater than their proportional surface area on Earth would suggest (Neue *et al.,* 1997).

Figure 1-9 (horizontally): Study sites in Birbhum District
1.Pansiuri 2. Salkhana 3. Kalisayer 4. Barobandh 5. Lakhsmisayer 6. Ballabhpur Bandh 7. Biswas Pukur 8.Lalbandh 9.Chandrakumar

Classification of the wetlands on the basis of ownership pattern reveals majority of these to be privately owned (Table 2). All the rest are owned by the State Government and none of them is under the Panchayat (Local Self Government of the village) and Co-operative Society. Each of the wetlands studied is spread over an area greater than 5 (approx) acres. These wetlands belong to five size categories, the smallest category (10-15 acres) includes wetlands such as Chamna dighi, Jugadamai dighi, Mahindrapur dighi, Rampurhat dighi, Santha/Manthla dighi, Sayer and to the largest category (greater than 100 acres) belong wetlands such as Baidhara barrage, Ballabpur bandh, Tilpara barrage.. From these values, an idea can be built up about the general size-range of the wetlands in the district on which sustainable utilization strategies can be based.

Interestingly 88 per cent of the wetlands studied are perennials which ensure water availability from them throughout the year. Similar trends were found work done earlier in this region (Palit and Mukherjee, 2007, 2010). It is worthwhile to mention that management strategies to ensure uninterrupted supply of the water and biotic resources and sustainable developmental work based on them can promise a lot of benevolence.

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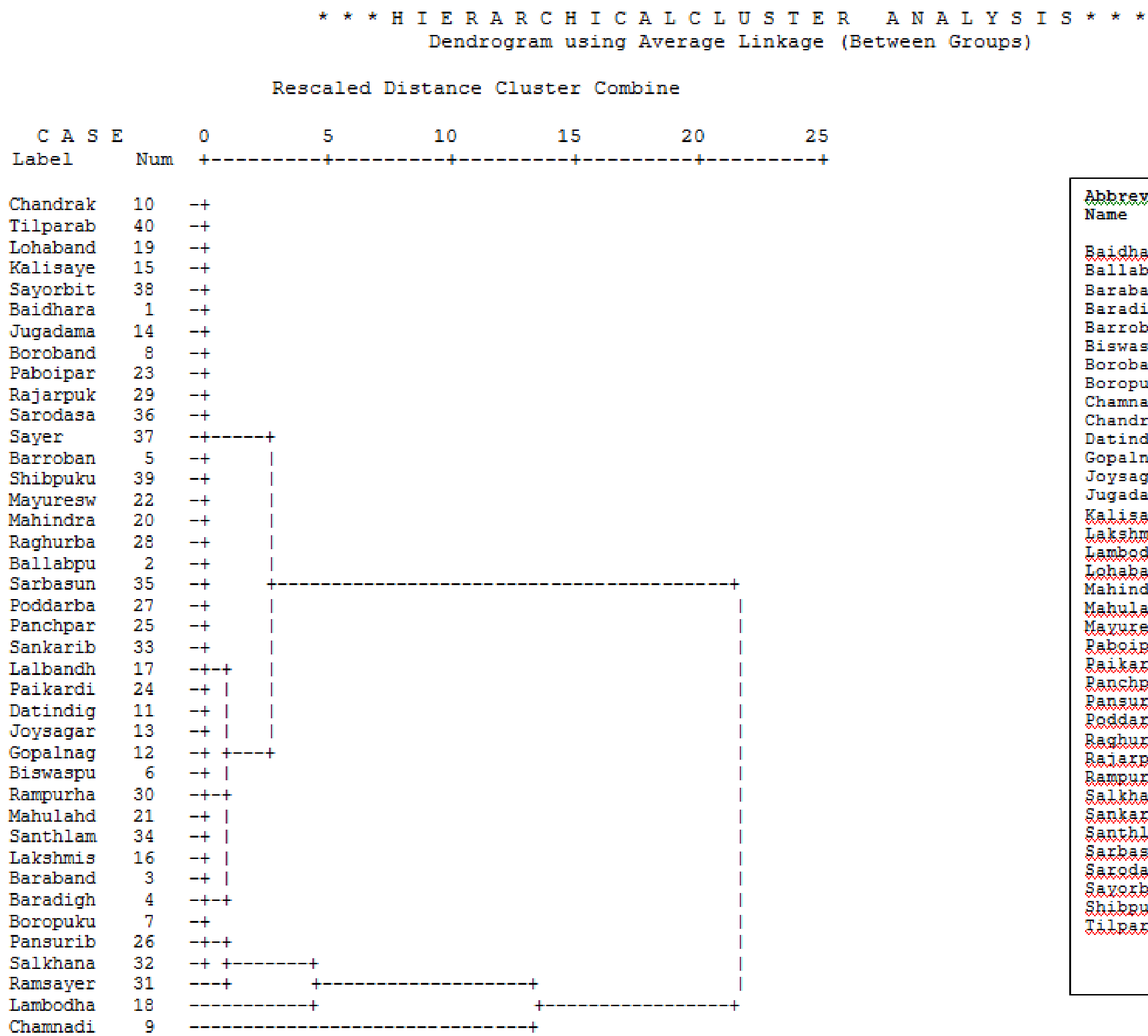

Abbreviated Name	Extended Name
Baidhara	Baidharabarrage
Ballabpu	Ballabpurbandh
Baraband	Barabandh
Baradigh	Baradighi
Barroban	Barrobandh
Biswaspu	Biswaspukur
Boroband	Borobandh
Boropuku	Boropukur
Chamnadi	Chamnadighi
Chandrak	Chandrakumarpukur
Datindig	Datindighi
Gopalnag	Gopalnagarbandh
Joysagar	Joysagardighi
Jugadama	Jugadamaidighi
Kalisaye	Kalisayer
Lakshmis	Lakshmisayer
Lambodha	Lambodharpursayer
Lohaband	Lohabandhdighi
Mahindra	Mahindrapurdighi
Mahulahd	Mahulahdighi
Mayuresw	Mayureswardighi
Paboipar	Paboiparadighi
Paikardi	Paikardighi
Panchpar	Panchparadighi
Pansurib	Pansuribandh
Poddarba	Poddarbandh
Raghurba	Raghurbandh
Rajarpuk	Rajarpukur
Rampurha	Rampurhatdighi
Salkhana	Salkhanapond
Sankarib	Sankaribandh
Santhlam	Santhlamanthladighi
Sarbasun	Sarbasundaridighi
Sarodasa	Sarodasagar
Sayorbit	Sayorbithipark
Shibpuku	Shibpukur
Tilparab	Tilparabarrage

Figure 9: Cluster analysis of the study sites (based on Macrophyte Diversity)

So far the use patterns of these wetlands are concerned as many as 13 wetlands have multifarious uses e.g. in pisciculture, irrigation and different domestic purposes. As many as 5 wetlands of pond type are used by the village people for pisciculture and domestic purposes. While 3 wetlands, viz. Paikar dighi, Panchpara dighi and Santhla/Manthla dighi are used exclusively for irrigation, no less than 4, viz. Datin dighi, Mahulah dighi, Sarbasundari dighi and Sayer are used for pisciculture in addition. On the whole as many as 30 out of 40 wetlands are used in irrigation. Thus it is clearly revealed that most of the wetlands for being used for irrigation are likely to be in distress

LIMNOLOGICAL CHARACTERISTICS

The limnological investigations on the selected wetlands of the subdivisions of Birbhum district revealed significant variations in the parameters studied in relation to the three seasons.

Temperature

In pre-monsoon, temperature variation throughout the three subdivisions of Birbhum district ranges from 27.77 to 30.33^{0}c, in monsoon 27.44 to 29.33^{0}c and in post monsoon between 20.77 to 23.44^{0}c respectively. Similar trend in water temperature is also reported (Palit *et al.,* 2009).

pH

There was very little season induced variations in pH, in the three subdivisions of the Birbhum district. In pre-monsoon maximum pH was recorded in Bolpur subdivision (7.6) and minimum in Siuri subdivision (7.47). Maximum pH (7.64) was recorded in Bolpur subdivision in postmonsoon and minimum in Siuri (7.45). Similar trend in water temperature wass also reported earlier (Palit *et al.,* 2009).

Specific Conductance

The seasonal impact on the specific conductance is dissimilar. Whereas in premonsoon maximum specific conductance noted in Suri subdivision (126.99) and minimum in Bolpur subdivision (58.77). In monsoon season maximum specific conductance was recorded in Siuri (132.66) division and minimum in Bolpur subdivision (73.77) was recorded and the same trend occurred in post-monsoon i.e maximum value of 119.1 in case of Siuri subdivision and minimum (50.77) in Bolpur subdivision. Similar trend in Specific conductance was also reported earlier (Palit *et al*., 2009).

Dissolved Oxygen (DO)

In pre-monsoon, dissolved oxygen variation throughout the three subdivisions of Birbhum district ranged between 3.49 and 8.26, in monsoon from 7.07 to 7.58 and in postmonsoon between 5.43 and 7.32. Similar trend in DO was also reported earlier (Palit *et al.,* 2009).

Biological Oxygen Demand (BOD)

BOD was recorded to be maximum in Siuri subdivision (5.68), minimum in Bolpur (2.05) in premonsoon. In case of monsoon maximum and minimum values of BOD were observed in Siuri and Bolpur subdivisions as 6.12 and 2.05 respectively. Maximum and minimum values of BOD were observed in Siuri and Bolpur subdivisions as 4.74 and 3.32 respectively in post monsoon. Similar trend in BOD was also reported earlier (Palit *et al.,* 2009).

Total Hardness

The seasonal impact on the specific total hardness is dissimilar. Whereas in premonsoon maximum total hardness was noted in Bolpur subdivision (80.84) the minimum in Siuri subdivision (55.44). In monsoon maximum total hardness was recorded in case of Siuri subdivision (82.88) and minimum in case of Bolpur subdivision (77.31) and same trend occurred in post-monsoon i.e maximum in Siuri subdivision (95.5) and minimum in Bolpur subdivision (90.68). Similar trend in Total hardness was also reported earlier (Palit *et al.,* 2009).

Nitrate Nitrogen

Nitrate nitrogen recorded was maximum in Rampurhat subdivision (3.74) and minimum in case of Bolpur subdivision (3.35) in pre-monsoon. In case of monsoon maximum and minimum BOD were recorded in case of Siuri and Bolpur subdivisions as 5.46 and 4.60 respectively. Maximum and minimum values were observed in Siuri and Bolpur subdivisions as 4.59 and 3.52 respectively in post monsoon season. Similar trend in Nitrate nitrogen was also reported earlier (Palit *et al.,* 2009).

Phosphate Phosphorus

The seasonal impact on the specific phosphate phosphorous is dissimilar. Whereas in pre-monsoon maximum value was noted in Siuri subdivision (3.09) and minimum (3.06) in Bolpur subdivision. In monsoon maximum phosphate phosphorous was in Bolpur subdivision (4.32) and minimum in Rampurhat subdivision (4.04) and the same trend occurred in postmonsoon being maximum in Siuri subdivision(3.87) and minimum in Bolpur subdivision(3.51).Similar trend in Phosphate phosphorus was also reported earlier (Palit *et al.*,2009).

The correlation studies revealed that in Siuri subdivision pH and specific conductance are positively correlated with temperature (Table 4). Temperature correlated positively with specific conductance in Bolpur and Ramprhat subdivisions (Table 5, 6). Values of pH were found to be positively correlated with specific conductance of water samples of siuri subdivision and total hardness for Bolpur and Rampurhat subdivisions. Specific conductance is positively correlated with Dissolve Oxygen contents for all the three subdivisions. Dissolve oxygen is positively correlated with nitrate nitrogen and phosphate phosphorus for Bolpur and Rampurhat subdivisions. Nitrate nitrogen could be positively correlated with phosphate phosphorus in all subdivisions.

Principal component analysis revealed that for all the three subdivisions during monsoon season dissolve oxygen, nitrate nitrogen and phosphate phosphorus are the crucial factors (Figure 1) which may have significant influence over the water quality of the wetland ecosystem. During post monsoon period BOD, total hardness and pH are the significant parameters which may have the significant role in the wetlands of the eco region.

MAOCROPHYTE DIVERSITY

In the present study 185 species could be recorded from the all the studied sites (table7). Among these following are the dominant species viz. *Nymphoides hydrophylla, Marsilea minuta, Trapa bispinosa, Cyperus amabilis, Eragrostis nutans, Vetiveria zizanioides, Alternanthera pungens, Amaranthus spinosus, Cassia sophera, Cucumis sativus, Commelina bengalensis, Croton bonplandianum, Heliotropium indicum, Jatropa gossypifolia, Limnophila pulcherrima, Wolffia globosa, Hygrophila schulli, Ranunculus sceleratus, Alternanthera philoxeroides, Aponogeton natans,Potamogeton crispus, Hydrilla verticillata, Limnophila heterophylla, Ottelia alismoides, Vallisneria spiralis var. denseserrulata, Salvinia cuculata, Phragmites karka, Typha domingensis, Utricularia stellaris, Azolla pinnata, Eichhornia crassipes, Lemna acquinoctialis, Pistia stratiotes, Sagittaria sagitifolia, Nelumbo nucifera, Mimosa rubicaulis, Polygonum hydropiper, Sida cordata, Xanthium indicum, Ipomoea aquatic.*

Seasonal variation in total number of macrophytes observed during the study period was found to be an average of 6500 per month (Figure 2). The variation of the species diversity is very well demarcated in fig 3 to 7. There is a decreasing trend in the Shannon (2.78), Simpson (0.88) and Evenness (0.35) indices in the monsoon season where as the index of dominance (0.12) increased during this period. Margelf's index increased in the late pre-monsoon (May 5.3) and showed similar decrease in the monsoon season (Jul 5.0). This type trend in all the wetlands suggest that during monsoon local dominance of the major macrophyte taxa in the studied site is strong rather than the diversity of the macrophytes as observed in other studies previously made in this region. (Mukherjee and Palit, 2002 and Palit and Mukherjee, 2008).

The canonical correspondence (Figure 8) demonstrates the trend of the association of dominant macrophyte species and physicochemical parameters measured in the studied sites. 1-40 are the dominant species encountered and tabulated in table 7 (bold). Most of the species revealed their preferences to monsoon period where as some of the species revealed higher affinity towards pre-monsoon season. All the macrophytes showed their affinity towards moderate pH and total hardness. From the above discussion it is established that the macrophyte and limnological parameters are strongly associated with each other and are interdependent (F1 and F2 CCA axis together explain 90.93% of variability, Figure 8). Regarding the future management and sustainable use programmes this will be useful a valuable criterion in site specific wetlands. The hierarchical cluster analysis was used to classify sampling sites. By

comparing the limnochemical data with the diversity of macrophytes, the sampling sites could be classified into 3 groups (Figure 9). The results of cluster analysis were also supported by PCA results.
Future studies will deals with the management, conservation and sustainable use of wetlands in the Birbhum District, West Bengal, India.

ACKNOWLEDGEMENT
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