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Monitoring Tropical Urban Wetlands through Biotic Indices

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ABSTRACT Integrity of urban wetlands depends on biological aspects, which is dependent on physical and chemical aspects. Biological assessment focuses on biotic components of an ecosystem. Among many known bioindicators, benthic diatoms and macroinvertebrates are commonly used. This study investigates the water quality for 11 urban wetlands in a tropical region (Bangalore, India) using bioindicators. Diatom and macroinvertebrate community structure, diversity and indices were calculated to understand the appropriateness of a particular biotic indicator group for routine and long term monitoring of wetlands. Principal component analysis bi-plot separates most polluted sites influenced by phosphate, electrical conductivity, hardness and chloride in axis 1 from the least polluted sites in axis 3. The species assemblages and distribution pattern also confirm the level of pollutants. A correlation of biological oxygen demand, chemical oxygen demand and electric conductivity with trophic diatom index (TDI) was significant than with biotic index (BI). The TDI indices clustered eutrophic sites in class V, while oligotrophic, clean water sites in class I reflecting the measured water quality. The BI index grouped sampling sites into Class I, II and III, indicating water quality to meso - eutrophic status. The insufficient data of tolerance values for several insects and mollusc species indicate the inability of BI indices for the present eco-regions. The analysis using TDI indices, with BI and FBI indices, highlight the appropriateness of implementing diatom indices for biomonitoring. In this context, developing long term monitoring programme focusing on diatom as bioindicators would help in understanding the drivers of ecosystem changes.

INTRODUCTION

The rapid urbanization involving the large scale changes in the catchment area and the inflow of pollutants are known to influence the water quality and thereby threatening the aquatic life and its ecosystems severely in the last decade. This has reached the critical levels by influencing the water quality furthermore on the ecosystem integrity. The significance of the role of regional impacts in determining the biological assemblages has been focused in recent years (Soininen et al. 2004), emphasizing the need for investigations on the biological components such as algae and macroinvertebrates as indicators of pollution (Alves et al. 2008; Smith et al. 2007).

Diatoms are the most diverse and dominant group of algae in rivers, streams, lakes and wetlands forming the important component of the aquatic ecosystem (Stoermer and Smol 1999). Shift in diatom community structure, in particular is used to detect change in water quality in a more integrated manner to assess the ecosystem integrity rather than traditional water monitoring. Thus, benthic diatoms have been used to monitor environmental changes because of their immediate response to physical and chemical conditions such as pH, conductivity and organic nutrients (Bennion et al. 2000; Potapova and Charles 2003), eutrophication (Kitner and Poulícková 2003) and global warming problems (Leelahakriengkrai and Peerapornpisal 2010). The impact on distributional pattern of benthic diatom assemblages in relation to varying environmental characteristics are evident in streams (Soininen et al. 2004), ponds (Poulíèková et al. 2008) and lakes (Reid and Ogden 2009) and leads to the potential use of diatom indices such as trophic diatom indices (TDI), Pollution sensitivity indices (IPS), Generic diatom indices (GDI) and Trophic diatom indices (TDIL) for lakes (Taylor et al. 2007a; Blanco et al. 2004).

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Owing to its ubiquity, diatom assemblages and pollution indices are an integral part of many stream assessment programs worldwide (Simkhada et al. 2006).

Benthic macroinvertebrates are common inhabitants of freshwater systems and are also sensitive elements of aquatic biota (Alves et al. 2008). Macroinvertebrate communities play a decisive role in many ecological and eco-toxicological processes in lakes and rivers (Downing 1991). The changes in its taxonomic richness and composition are considered sensitive tools for perceiving alterations in aquatic ecosystems (Mance 1987). Biotic indices such as Trent Biotic index (Woodiwiss 1964); BMWP score (Armitage et al. 1983), ASPT score (Armitage et al. 1983), Wisconsin Biotic Index (BI) and Family Biotic Index (FBI) for macro-invertebrates are used to detect and monitor water quality and human perturbations in varying ecosystems like rivers (Chessman 1999), streams (Lenat 1994) and lakes (Schartau et al. 2008). Macroinvertebrates in general explain changes in sediment composition and grain size (Robbins et al. 1989), lake trophy and depth (Rasmussen 1988), macrophyte (Downing 1991), periphyton and other food resources (Lamberti et al. 1996) predation by fish and other invertebrates (Power 1990) and, metals and organic contaminants (Rosenberg and Resh 1993).

Diatoms and macroinvertebrates responses to environmental variables have been investigated in rivers and streams (Beyene et al. 2009), focusing on organic pollution (Kucuk 2008) and anthropogenic degradation of wetlands (Lougheed et al. 2008). Niemi et al. (2009) studied diatoms and macroinvertebrates along with breeding birds, fish and wetland plant communities to develop indicators to estimate ecological conditions and suggest plausible causes of ecosystem degradation. A compiled biotic data of several indicator groups of species has been mandated under Water Framework directive program defining ecological status (CEC 2000). However, the compiled study of several biotas and their use in wetland assessment in tropical India has been scarce. With an increase in anthropogenic activities and improper water management, urban wetlands are subjected to a variety of hydrological alterations more noticeably in arid and semi-arid regions (Pan et al. 2004). The pollution sources such as sewage, effluents from industries, agricultural wastes runoff, soil erosion, etc. has deteriorated the ecosystem's health (Kucuk 2008; Ramachandra and Uttam 2008). Government committee was constituted in 1986 to record the water quality of several lakes which was followed by a series of studies (Ramachandra et al. 2002; Ramachandra 2008) explaining the physical and chemical variables of wetlands. These studies recommend the need for conserving biological diversity in an urban region and biological monitoring to assess the ecological integrity of wetlands.

The main objective of this study is to examine the response of benthic diatoms and macro invertebrate distribution in relation to water quality variables. This study is a part of an exploratory multidisciplinary research conducted in 11 urban wetlands of Bangalore, to establish the biotic integrity with biological indicators for monitoring the environmental quality of wetlands and to classify sampling sites based on their ecological status.

Study Area

Bangalore is the principal administrative, cultural, commercial, industrial, and knowledge capital of the state of Karnataka, India (Fig. 1). Bangalore is one of the fastest growing cities in India, and is also known as the 'Silicon Valley of India' for heralding and spearheading the growth of Information Technology (IT) based industries in the region. With the advent and growth of the IT industry, as well as numerous industries in other sectors and the onset of economic liberalization since the early 1990s, Bangalore has taken the lead in service-based industries, which have fuelled the growth of the city both economically and spatially. Bangalore has become a cosmopolitan city attracting people and business alike, within and across nations (Ramachandra and Uttam Kumar 2008).

Wetlands of Bangalore occupy about 1.48% of the geographical area (741 sq km) covering urban and non- urban areas. Bangalore is situated in the semi-arid climatic zone of the tropics. Due to its high elevation, Bangalore usually enjoys healthy climate throughout the year. Bangalore City had more than 400 interconnected lakes that followed the natural gradient of flow from one lake to the next lake/tank, thereby preventing flooding. However in recent years, the lake number has been decreased to 93 due to improper sewage treatment system and

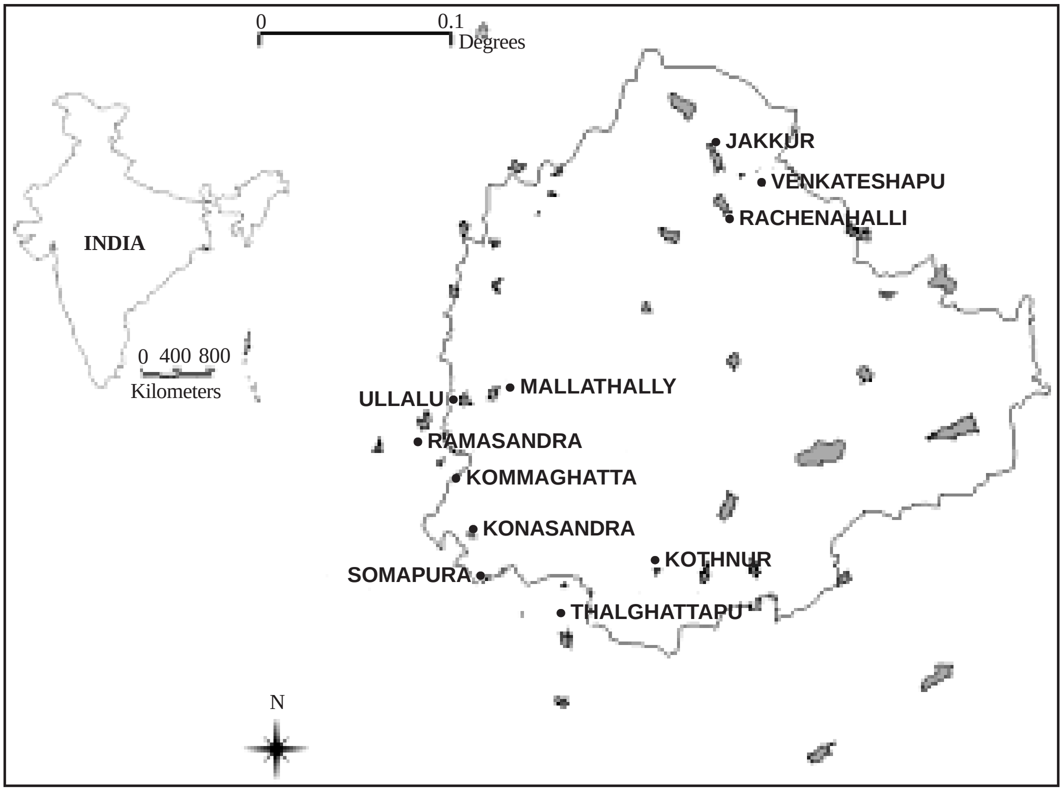

Fig. 1. Bangalore map with study sites

unplanned growth of the city (Ramachandra and Kumar 2008). The city earlier harbored many wetlands to meet the domestic and agricultural needs. Ramachandra and Kiran (2000) showed the decline of 35% in the number and loss in the interconnectivity among wetlands which has been disturbing the drainage network and the hydrological regime. 11 wetlands are selected to investigate the water quality and the influence of shifts in water quality on the aquatic biota (Fig. 1).

The undulating terrain in the region facilitated the creation of a large number of tanks in the past, providing for the traditional uses of irrigation, drinking, fishing and washing. This led to Bangalore having hundreds of such water bodies through the centuries. In 1961, the number of lakes and tanks in the city stood at 262. A large number of water bodies (locally called lakes or tanks) in the city had ameliorated the local climate, and maintained a good water balance in the neighborhood. Temporal analysis of wetlands, however, indicates a decline of 58% in Greater Bangalore which can be attributed to intense urbanization processes. This is evident from a 466% increase in built-up area from 1973 to 2007 (Ramachandra and Uttam Kumar 2008). The undulating topography, featured by a series of valleys radiating from a ridge, forms three major watersheds namely the Hebbal Valley, Vrishabhavathi Valley and the Koramangala and Challaghatta Valleys. These form important drainage courses for the interconnected lake system which carries storm water beyond the city limits. Bangalore, being a part of peninsular India, had the tradition of storing this water in these man-made water bodies which were used in dry periods. Today, untreated sewage is also let into these storm water streams which progressively converge into these water bodies. Varthur is one such wetland at the end of a chain of lakes. Figure 2 illustrates the interconnectivity among lakes (digitized from the Survey of India topo-sheets of 1:50000 scale. Jakkur, Rachenahalli, Yelahanka and Allalasandra wetlands are interconnected in the water-

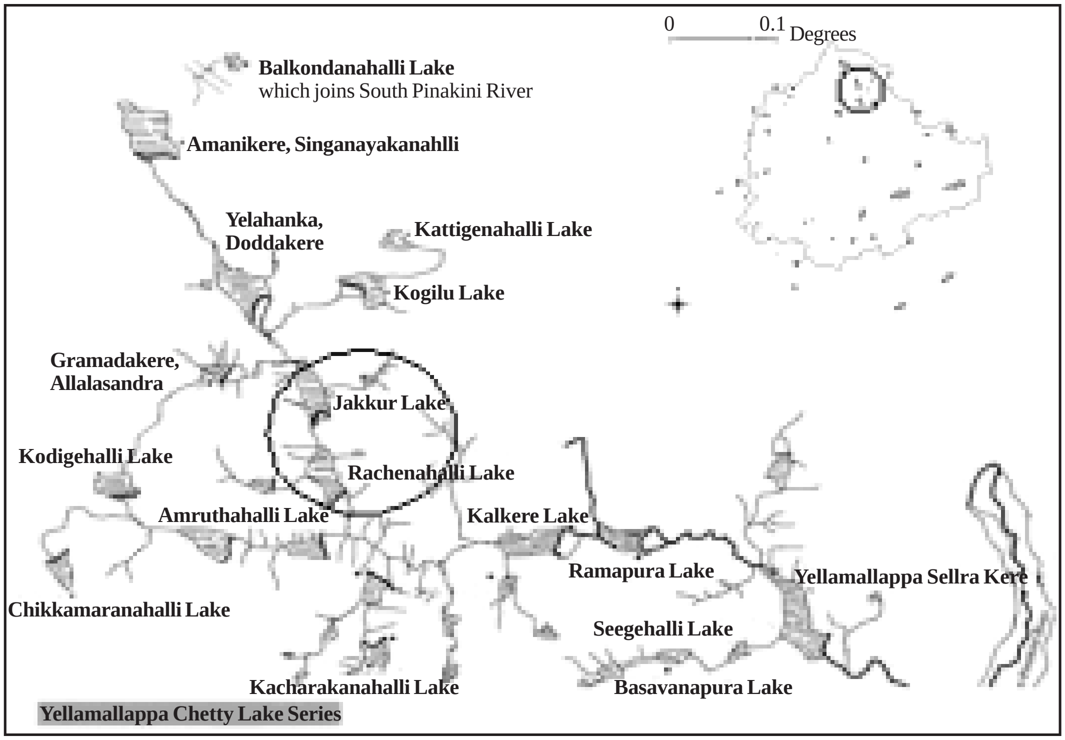

Fig. 2. Interconnected lakes in Yellamallappa chetty lake series (In circle, Jakkur, and Rachenahalli lakes under this study)

shed and overflow of Jakkur drains to the Rachenahalli wetlands. The objective of this study is to examine the influence of water quality on benthic diatoms and macroinvertebrates especially to pollution loads. The study also evaluates the applicability of benthic diatoms and macroinvertebrate indices to monitor wetlands of tropics, which were developed and validated to temperate and other regions. The similarity in water quality and also indices in the interconnected wetlands highlight the transport of water in the chain. Table 1 lists the spatial extent (area), catchment, lake system surrounding the lake (as per Bangalore Development Authority, BDA) and the pollution status (as per Bruhat Bengaluru Mahanagara Palike, BBMP). Table 2 lists the acronyms used for the study sites.

METHODS

Water Sampling

Eleven lakes were monitored during February and April 2009 corresponding to lean monsoon season with only sewage inflow and higher evaporation. Three replicates of water samples were collected from inlets, outlets and other sites (such as centre) to observe the effect of sewage and effluents as well as to understand the quality variations at the regional scale. Onsite variables like pH, electric conductivity (EC), salinity (SAL), total dissolved solids (TDS), water temperature (WT) (Extech pH/conductivity EC500) and dissolved oxygen (DO) were measured. The samples were stored at 4^0C in laboratory and analyzed for nitrates (N), inorganic phosphates/or phosphorous (P), total hardness (TH), calcium hardness (CaH), magnesium hardness (MgH), chlorides (CHL), alkalinity (ALK), chemical oxygen demand (COD) and biological oxygen demand (BOD) following standard protocols (Trivedy and Goel 1986; APHA 1998).

Diatom Sampling, Identification and Analysis

Diatoms samples were collected along with the water samples from the microhabitats (that

Table 1: Details of lakes selected for the study. (*Data compiled by BDA. ** data compiled by BBMP)

Wetland	*Geographic co-ordinates(Lat/long)*	*Depth (m)* **	*Size of the lake in Ha (Weed cover in Ha)***	*Catch-ment area in Ha* **	*Lake system**	*Remarks***
Jakkur	13^0 04’ N/ 77^0 36’ E	1.25	59 (5.1)	806	Jakkur, Yelahanka, Allalsandra	Domestic sewage run-off of Jakkur village, urbanization, fields, plantations
Rachenahalli	13^o03' N/ 77^0 37’E	1.7	44.35 (2.1)	850	Yelahanka, Jakkur, Venkateshpura	Runoff of surrounding village, urbanized area, fields, plantations
Venkateshpura	13^o03' N/ 77^0 37’E	2.33	4.4 (0.1)	109.5	Venkateshpura	Runoff of Jakkur village, urbanized area, fields, plantations, quarry
Ullalu	-	2.91	12.64	342.8	Ullalu, Mallathally	Vacant land, less human density, less vegetation, more road sediment near inflow and soil erosion
Mallathally	-	1.54	23.516	618	Mallathally Hirohalli	Discharge of surrounding sewage, defecation, Layout run-off
Ramasandra	12^0 55’ N/ $77^0$27’ E	3.2	54.77 (1)	1629	Kanneli lake,	Inflow from fields and plantations, undeveloped areas
Konasandra	12^0 53’N/ 77^0 29’ E	1.4	15.11 (5.5)	128	Kenchanapura, Ramasandra	Upper reaches include forest area and urbanized at other parts
Kommaghatta	-	2.51		553	Vrishahavathi river Kommaghatta	Sewage discharge, Plantations, road run-offs
Somapura	12^0 52’N/ 77^0 30’ E	1	7.49(1.29)	93	Vrishahavathi river	Urban developments, road run-offs
Thalghattapura	12^0 59’N/ 77^0 32’ E	2.5	7.85 (1)	217.45	Thalghattapura	Open fields, rugged terrain in forest, Layout run-off
Kothnur	12^0 52’N/ 77^0 34’ E	1.75	7.375(0.5)	89.9	Kothnur	Developed area, layout run- offs

is, Epilithic sample: 5-15 cm cobbles and pebbles) following the standard collection techniques (Taylor et al. 2007b; Karthick et al. 2010). Epiphytic samples were collected from water hyacinth (*Eichornia* sp.) by crushing the submerged roots of plant in a polythene cover. Epilithic samples were collected by brushing the stones thoroughly with tooth brush. Episammic sample was collected from upper layer of sediment (0.5 cm) using a pippete. All samples were transferred to polythene bottle and carried to laboratory for immediate observation in order to record live diatoms and later preserved in ethanol. Diatom samples were cleaned by $KMnO_4$-acid method following standard protocols (Taylor et al. 2007b; Karthick et al. 2010) for further enumeration. 350-400 frustules in each slide were counted using DIC microscopy (Olympus). Diatoms were identified following taxonomic literatures (Krammer and Lange-Bertalot 1986, 1988, 1991; Lange-Bertalot 2001; Taylor et al. 2007c; Karthick et al. 2008).

Table 2: List of sampling sites with codes

Codes	*Sampling site*	*Codes*	*Sampling site*	*Codes*	*Sampling site*
JK	Jakkur	KMO1	Kommaghatta outlet 1	KT	Kothanur
JKI1	Jakkur inlet 1	ML	Mallathally	KTI1	Kothanur inlet 1
JKI2	Jakkur inlet 2	MLI1	Mallathally inlet 1	KTO1	Kothanur outlet 1
JKO1	Jakkur outlet 1	MLO1	Mallathally outlet 1	KN	Konasandra
RC	Rachenahalli	UL	Ullalu	KNFN	Konasandra fencing
RCI1	Rachenahalli inlet 1	ULI1	Ullalu inlet 1	KNL1	Konasandra layout
RCI2	Rachenahalli inlet 2	ULO1	Ullalu outlet 1	KNI1	Konasandra inlet 1
RCO1	Rachenahlalli outlet 1	TA	Thalghattapura	KNO1	Konasandra outlet 1
VN	Venkateshapura	TAI1	Thalghattapura inlet 1	RM	Ramasandra
VNI1	Venkateshapura inlet 1	TAI2	Thalghattapura inlet 2	RMI1	Ramasandra inlet 1
VNO1	Venkateshapura outlet 1	TAO1	Thalghattapura outlet 1	RMA1	Ramasandra animal grazing 1
KM	Kommaghatta	SM	Somapura	RMO1	Ramasandra outlet 1
KMI1	Kommaghatta inlet 1	SMI1	Somapura inlet 1	RML1	Ramasandra layout 1
KMI2	Kommaghatta inlet 2	SMO1	Somapura outlet 1	RMB1	Ramasandra boat 1

Diatom taxa occurring at least in one sample with a relative abundance of 5 % were included in the analysis. Trophic diatom index (TDI) indicating the nutrient load in the sample was calculated in OMNIDIA 7.0 software.

Macroinvertebrate Sampling and Identification

Insects and mollusk communities as macroinvertebrates were collected during the summer (April-May 2009). Aquatic insects were sampled using a D-net sampler holding against water current and dragged along the shore of the lakes up to a distance of 1m. Contents of the net were pooled and preserved in 70% ethanol. At each lake, mollusks in the littoral zone were collected by employing quadrat and time constrained methods. In time constrained method, mollusks were sampled by search and handpick along the littoral zone for five minutes. While in quadrat collection, aquatic vegetation and other objects were collected in an area of 25 × 25 cm from littoral zone and were kept in a bucket and half of the bucket was filled with water and all the materials were washed thoroughly. Then the bucket water were passed through 0.5 mm sieve, mollusks retained were collected. The samples collected from both methods were kept in separate glass/plastic bottles and preserved with 70 % alcohol. Collected samples were examined under a stereo zoom microscope (10X) and identified using standard taxonomic literatures (Fraser 1933-36; Morse et al. 1994; Subramanian and Sivaramakrishnan 2007) for Insects (Ramakrishna and Dey 2007) and for mollusk (Subba Rao 1989).

Statistical Analysis

Percentage relative abundance of species was derived along with the number of taxa, dominance (D), evenness (E) and Shannon and weaver diversity index as quantitative structural attributes. Principal component analysis (PCA) was performed to assess significant environmental variables. Spearman correlation between diatom indices (TDI, GDI) and macroinvertebrate indices (FBI, BI) with EC, DO, N, P and alkalinity was calculated to observe the significant correlations. All the statistical analysis was carried out in PAST version 2.06.

RESULTS

Water Quality Analysis

Table 3 lists the physical and chemical parameters, which indicate significant variations across wetlands. pH, EC, BOD and COD values indicated marked difference among as well as within wetlands. pH was lowest at Jakkur (JK) outlet (7.89), highest at Mallathally (ML) inlet (10.30) and beyond the permissible limits at Kommaghatta (KM), Kothanur (KT) and Rachenahalli (RC) sites. JK (1267.44μScm^{-1}) comprised high electric conductivity followed by Somapura (SM) (1022.67μScm^{-1}) and the least EC was observed at Venkateshpura (VN, 351.75 μScm^{-1}) followed by Ramasandra (RM, 494.4 μScm^{-1}). Sampling sites such as RC, VN, KM, RM and SM reflected low organic matter in terms of BOD whereas high at JK, ML, Thalghattapura (TH), Ullau (UL), Kothanur (KT) and Konasandra (KN). The consistent high organic pollution in terms of COD was recorded at all wetlands with exception at few sites such as RCI1, KMI1, SMO1, KNO1, RMA1 and RMB1 (refer table 2 for codes and respective sampling sites). Nitrates and phosphates were within the permissible limits ranging between 0.015 to 0.092 mgL^{-1} and 0.001 to 0.064 mgL^{-1} respectively. Total hardness ranged between 67.5 mgL^{-1} (KTO1) to 346.67 mgL^{-1} (JKI2) and increased at MLO1 and JKI1. Chlorides level reflected impacts on KNI1 (41.75 mgL^{-1}), JK, RCI2, MLI1 and JKI2 (295.36 mgL^{-1}) where inflow of sewage and urbanization was intensely noticed. PCA biplot (Fig. 3) explains 44.799% and 12.453 % variance from 1st and 3rd components respectively, and separates most polluted sites from least polluted sites. The PC1 explained influence of P at RC, KTI1, TAO1 and KMI1 sites. EC, TH, CaH, MgH and CHL were significantly high at right side of PC1 influencing ML, UL, JK and TH inlet sites where inflow of sewage with high ionic concentrations was apparent. The high alkalinity was evident through PC3 at RM and KN sites.

Species Richness, Diversity and Distribution

40 diatom genera comprising 91 species were found on 33 sampled habitats, with 10 species occurring at ≥10% relative abundances in at

Table 3: Variation in water physical and chemical analysis across lakes. (Sampling codes are mentioned in Table 2)

Sampling Site	*pH*	*WT °C*	*ECμS cm^{-1}*	*TDS mgL^{-1}*	*DO mgL^{-1}*	*BOD mgL^{-1}*	*COD mgL^{-1}*	*N mgL^{-1}*	*P mgL^{-1}*	*TH mgL^{-1}*	*CaH mgL^{-1}*	*MgH mgL^{-1}*	*CHL mgL^{-1}*	*ALK mgL^{-1}*
JKI1	8.02	27.8	1240.33	870.67	4.67	14.2	79.31	0.016	0.026	326.67	193.33	56.93	286.84	163.33
JKI2	8.07	28.77	1325.67	947	6.91	13.6	48.72	0.015	0.03	346.67	100	60.19	295.36	163.33
JKO1	7.89	28.6	1236.33	869.33	4.76	8.2	65.08	0.016	0.027	325.33	185.33	58.56	267.91	160
RCI1	9.22	30.33	871.33	625	6.12	2.9	11.71	0.018	0.026	221.33	184.67	33.35	195.96	126.67
RCI2	9.1	30.07	885.67	620	7.75	4.05	77.55	0.018	0.023	221.33	172.67	36.27	208.27	120
RCO1	9.05	31.33	854.33	609.33	7.32	3.22	35.91	0.02	0.023	222.67	180	34.81	191.23	120
VNI1	8.54	28.15	342	239	8.13	3.11	26.88	0.02	0.022	122	63.33	14.31	45.44	100
VNO1	8.21	24.95	361.5	247.5	6.18	5.22	83.45	0.02	0.027	152	56	23.42	44.02	95
KMI1	9.32	28.05	812	594	5.98	2.96	24	0.049	0.038	264	124.05	58.55	121.41	276
KMI2	9.01	29.05	782	558	4.55	5.3	84	0.056	0.02	298	150.23	69	109.48	248
KMO1	8.98	28.7	764.5	548.5	6.14	3.71	48	0.066	0.022	286	132.87	61.76	119.42	170
MLI1	10.3	26.65	1160	807	9.39	25.8	110	0.072	0.064	278	132.87	59.81	214.42	252
MLO1	9.28	31.45	1105	803	7.44	18	69	0.062	0.046	302	124.05	67.82	106.5	301
ULI1	8.8	28.75	747.5	514	7.03	6.5	106	0.092	0.037	298	123.25	67.04	80.94	315
ULO1	8.97	26.05	587	416.5	6.59	4.91	82	0.078	0.041	224	120.04	49.77	80.94	210
TAI1	8.98	30.1	779	536	11.54	14.35	70	0.048	0.045	178	136.87	34.43	185.31	252
TAI2	8.92	29.2	788.5	548	11.18	13.26	34	0.058	0.054	190	129.66	39.12	187.44	293
TAO1	8.45	29.55	790.5	670	5.61	2.67	30	0.043	0.049	180	136.87	34.92	184.6	163
SMI1	8.77	29.47	1020.67	708.67	6.69	2.88	36	0.078	0.044	112.67	81	19.93	120.7	265.33
SMO1	8.72	30.2	1024.67	709.67	6.29	2.31	26.67	0.075	0.046	109.33	33.67	18.46	82.36	286.67
KTI1	9.13	30.05	681	472	6.91	20.58	31	0.068	0.056	82.5	55.05	14.02	142	194
KTO1	9.12	29.15	653	467	7.56	23.5	12	0.079	0.056	67.5	23.05	10.85	139.16	192
KNFN	8.8	33.43	792	551.33	6.37	2.63	38.67	0.067	0.015	88.67	22.98	16.03	69.2	406
KNL1	8.8	31.47	718	548	6.41	2.35	30.67	0.067	0.006	86	22.98	15.38	57.46	334.67
KNI1	8.97	32.43	766	537.67	7.28	13.44	49.33	0.058	0.005	80	23.99	13.67	41.75	327.33
KNO1	8.69	31.67	825.67	582	6.11	13.75	26.67	0.07	0.007	85.33	24.9	14.74	71.95	398
RMI1	8.85	31	490	343	6.67	2.88	44.89	0.051	0.001	113.33	80.73	20.16	59.92	1088.67
RMA1	8.96	31.1	466	369.33	6.05	1.92	19.11	0.067	0.004	129.33	33.13	23.47	61.53	788.67
RMO1	8.6	31.1	496	356	7.06	3.33	58.67	0.039	0.02	164	121.28	29.94	100.82	744
RML1	8.88	28.97	516.67	357.67	6.21	2.68	36.44	0.047	0.014	112.67	34.2	19.15	65.13	974
RMB1	8.86	30.07	503.33	353.67	6.37	4.59	17.79	0.027	0.006	107.33	93.67	17.97	64.94	1100.67
PL * (BIS)	6.5-9	-	<1200	<500	>5	<3	<30	<45	-	<300	<80	-	<200	<600

*Permissible limits

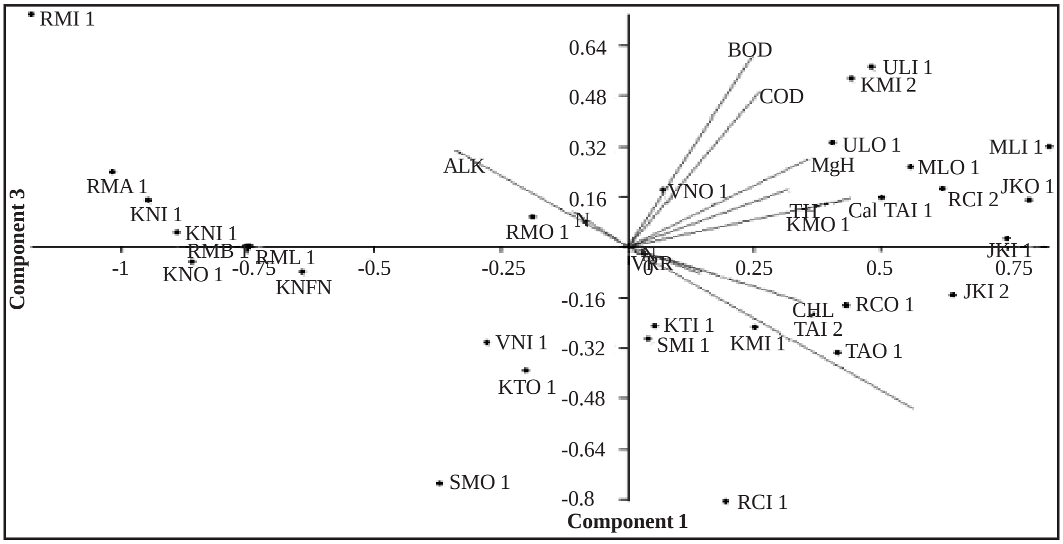

Fig. 3. PCA bi-plot showing water physico chemical variation across sampling sites. (Sampling codes are mentioned in Table 2)

least one sample (Annexure I). The most common and abundant species were *Achnanthidium* Kützing, *Cyclotella meneghiniana* Kützing, *Diadesmis confervaceae* Kützing, *Gomphonema* Ehrenberg, *Nitzschia palea* (Kutzing) W. Smith, *Amphora veneta* Kützing, *Gyrosigma rautenbachiae* Cholnoky and *Cymbella kappi* (Cholnoky) Cholnoky, The species belonging to genera *Achnanthidium* was not further identified due to complexity in the species and its wide range of occurrence. Two *Gomphonema* sp. could not be identified to species level. More number of taxa (24) was recorded at UL and lowest at VN (9.50).

A total of 16 macroinvertebrates samples were identified from 27 sites up to family level and 2 till order level. The macroinvertebrates were represented by 19 families of aquatic insects, among them, the dominant were Belostomatidae, Corixidae, Diptera, Gerridae, Damsel fly, Odonata, and Pleidae and, 8 Mollusca family such as Viviparidae, Lymnaeidae, Physidae, Planorbidae and Thiaridae were dominant (Annexure II and III). The contribution of the most common and abundant families to the total of macroinvertebrates were Corixidae (22.69 %; JKO1 and 44.27 %; MLI), Nepidae (7.80%; JKI1), Notonectidae (58.40%; JKO1), Physidae (37.16; MLI1) and Planorbidae (9.87%; MLI1). Family Corixidae and Physidae at site MLI1 showed highest abundance of 305 and 256 respectively. The species such as *Lamellidens consobrinus*, *Physa acuta*, *Segmentina* (Polypylis) *taia*, and *Thiara* (*Thiara*) *scabra*, and genus *Gabbia*, *Pisidium* and *Tarebia* are first time recorded from this region.

The diatom and macroinvertebrate assemblage were compared for its dominance, evenness and species richness (Fig. 4). Shannon diversity index for diatoms was highest at JK (2.27) and lowest at ML (1.10), while macroinvertebrate diversity index was highest at ML (1.40) and lowest was recorded as 0.49 at KM. Dominance ranged between 0.18 to 0.58 (diatoms) and 0.30 to 0.72 (macroinvertebrates). ML (0.58) had highest diatom dominance of *C. meneghiniana* whereas macroinvertebrate species *Physa acuta* was highest dominant at TH. None of the sampling sites except VN (0.58) had evenness index more than 50%. VN being the least polluted site with low ionic concentrations, inhabit pollution sensitive species such as *Achnanthidium* sp., and *Cymbella* sp. Evenness ranged from 0.54 (JK) to 1 (TH), and the distribution of macroinvertebrates was observed with the changing levels of pollution (Table 3).

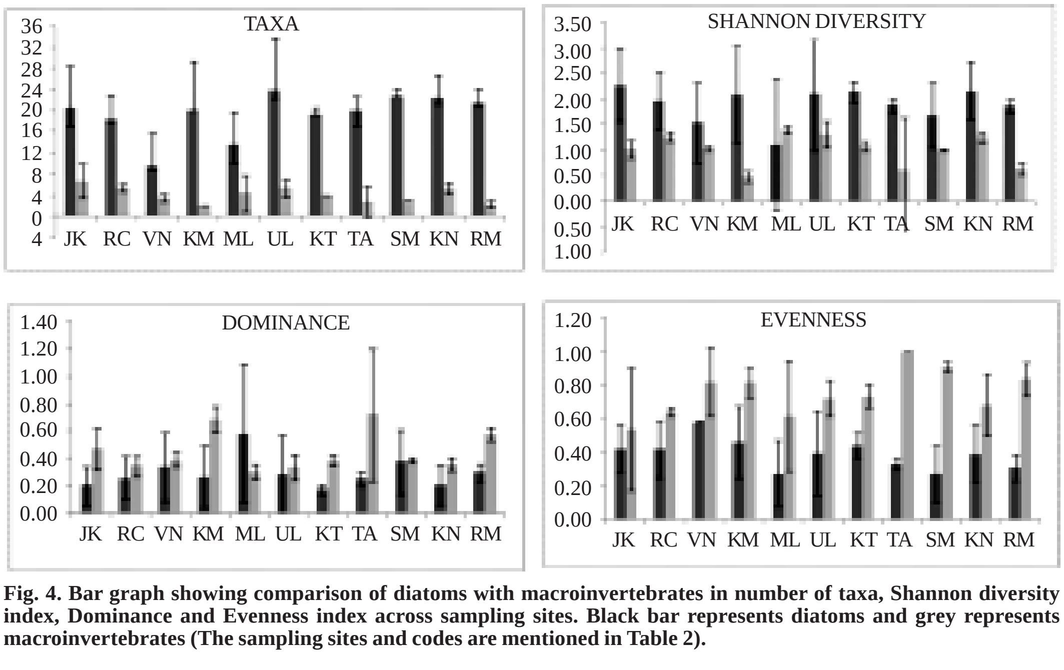

Fig. 4. Bar graph showing comparison of diatoms with macroinvertebrates in number of taxa, Shannon diversity index, Dominance and Evenness index across sampling sites. Black bar represents diatoms and grey represents macroinvertebrates (The sampling sites and codes are mentioned in Table 2).

Table 4: Spearman correlation between major environmental variables and indices derived from diatoms and macroinvertebrates. (n= 27, p<0.05) (Codes are mentioned in Table 2)

	pH	*EC*	*DO*	*BOD*	*COD*	*N*	*P*	*CHL*	*ALK*	*TDI*	*%PT*	*GDI*	*BI*	*FBI*
pH	0													
EC	0.051	0												
DO	**0.493**	0.113	0											
BOD	0.370	0.352	0.377	0										
COD	0.117	0.203	0.115	0.176	0									
N	**0.525**	0.077	0.145	0.221	0.040	0								
P	0.385	0.275	0.386	**0.492**	0.099	0.355	0							
CHL	0.177	**0.739**	0.058	0.346	0.202	**0.448**	0.338	0						
ALK	0.082	0.352	0.056	0.233	0.117	0.163	**0.456**	**0.404**	0					
TDI	0.070	**0.554**	0.192	**0.636**	**0.529**	0.235	0.188	**0.675**	0.054	0				
%PT	0.012	0.309	0.035	0.067	0.004	0.038	0.299	0.173	**0.650**	0.282	0			
GDI	0.212	0.213	0.147	0.269	0.088	0.135	0.056	0.023	0.321	**-0.640**	**-0.712**	0		
BI	0.203	**0.481**	0.228	0.234	0.152	0.366	0.288	0.191	0.091	0.159	0.100	0.292	0	
FBI	0.262	0.246	0.192	0.256	0.149	**0.424**	0.318	0.139	0.138	0.106	0.130	0.324	**0.975**	0

Relationship between Water Chemistry and Indices

The correlation among environmental variables with the diatom and macro invertebrate indices is listed in Table 4. Among water chemistry variables, pH correlated with DO and N whereas, CHL correlated well with EC and N. BOD with P correlated significantly indicating the profuse growth of algae (algal blooms) with high P concentration leading to high BOD. The alkalinity also showed correlation with CHL and P which attributes to pollution. %PT significantly correlated with ALK and GDI index showed a significant, but negative correlation with TDI and %PT. The strong correlation was also observed, BI with EC (0.481) while FBI with N (0.424) signifying trophic status. The comparison of the indices resulted in a very good negative correlation between TDI and GDI (-0.64), %PT and GDI (-0.712) and a positive correlation between FBI and BI (0.975).

Variation in Indices

There was not much difference found in the indices scores between TDI and GDI, and between FBI and BI. The overall dissimilarity was observed to be 14.57% and 38.6% in diatom and macroinvertebrate indices respectively. However, TDI and BI indices were used in further clustering of sites because of the accuracy and these comprise score for most of the taxa recorded in this study and have been represented as modified index table in Table 5. TDI value ranged from 0 to 20 revealing high trophic level as score increases to 20 and clean water as the score decreases. TDI with much variation ranged between 3.3- 17.28 and sites were grouped based on the classes mentioned in table 5. BI indices ranged from 0 to 10, the increasing score indicated increasing levels of pollution. BI ranged between 0-6.5 and follows 6 classes as mentioned in Table 5.

Variation in Water Quality and Species Composition among Interconnected Wetlands

Data analysis reveals of a marked difference between Jakkur and Rachenahalli in terms of water quality. pH of Jakkur was ranging from 7.89-8.02 and Rachenahalli had high alkaline range (9.05-9.22). There was no difference in

Table 5: Modified index table of Diatom (TDI) and Macroinvertebrate (BI) indices reflecting water quality and respective trophic status.

S. No.	*TDI*	*Trophy*	*BI*	*Status*	*Degree of organic pollution*	*Class*
1	<9	Oligotrophy	0-3.5	Excellent	No apparent organic pollution	Class I
2	9-12	Oligo-mesotrophy	3.51-4.50	Very good	Possible slight organic pollution	Class II
3	12-15	Mesotrophy	4.51-5.50	Good	Some organic pollution	Class III
			5.51-6.5	Fair	fairly significant organic pollution	
4	15-17	Meso-eutrophy	6.51-7.5	Fairly poor	Significant organic pollution	Class IV
5	>17	Eutrophy	7.51-8.5	Poor	Very Significant organic pollution	
			8.51-10	Very poor	Severe organic pollution	Class V

Source: Kelly et al. 1998 and Bode et al. 2002.

the nutrient load but higher values for BOD, COD, total hardness and chlorides concentration was observed at Jakkur compared to Rachenahalli. The Shannon diversity index was 2.27 and 1.03 at Jakkur and, 1.97 and 1.26 at Rachenahalli representing diatom and macroinvertebrate diversity respectively. However, there was a significant dissimilarity in species composition. The dominant diatom taxa at Jakkur were CMEN, DCOF and macroinvertebrate were Belostomatidae and Gerride groups. The dominant diatom taxa at Rachenahalli were ACHD, CMEN, FBCP and NAMP, and Lymnaeidae, Planorbidae and Diptera groups.

Clustering of Wetlands

Figures 5 and 6 explain the pair-wise clustering of sampling sites based on the macro-invertebrate community and diatom indices respectively and are grouped into 5 classes (Table 5). The variation in classification of sites was significant in both the indices. Macroinvertebrate index tended to have slightly lower variation in index values characteristic of lack of species data. According to TDI, 2 sampling sites were clustered under class I, SM and VN as oligotrophic status or clean water and, outlets of UL, KN and inlets of SM and VN sites with slightly higher values under class II. Class III includes sites such as TA, RM, RC, KM and ULI1 indicating oligo-mesotrophic conditions. Class IV and V mainly comprised sampling sites of JK, ML, TA and KT with heavy pollution. BI grouped 6 sites as oligotrophic and 13 sites as oligo-mesotrophic condition. Whilst the inlets of JK, KN, ML and outlets of TA, KN, RM and RC were in mesotrophic condition (C III). In the BI clustering, none of the sites were grouped under class IV and V.

DISCUSSION

Water Quality Analysis

The higher values of ionic concentrations at JK, ML, RC, KM, SM, TH and KN and in contrast, low values at VN, RM and UL explained variation in water chemistry and sewage as the sole source of increased cations and anions inflow to wetlands. The EC was found to be conservative surrogate with strong correlation with aquatic biota such as diatom communities (Soininen 2004). The accumulation of more ions has also lead to increased demand for oxygen (COD and BOD) which was evident at JK, ML,

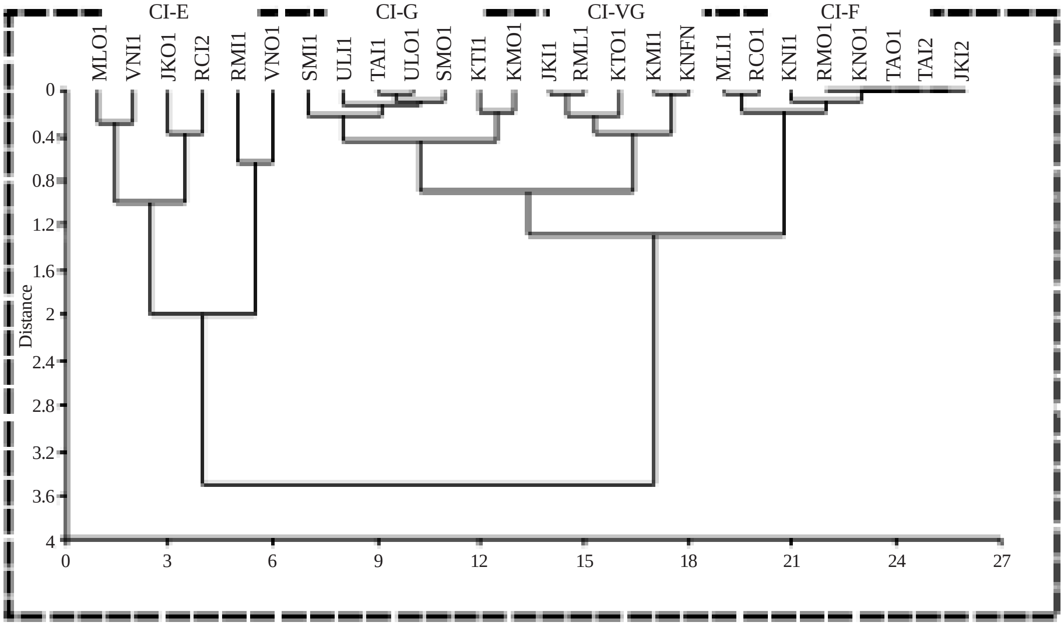

Fig. 5. Pair wise cluster analysis of (a) biotic indices (BI) across sampling sites with class- I Excellent (CI-E), class-I very good (CI-G), class-I very good (CI-VG) and class- I fair (CI-F)

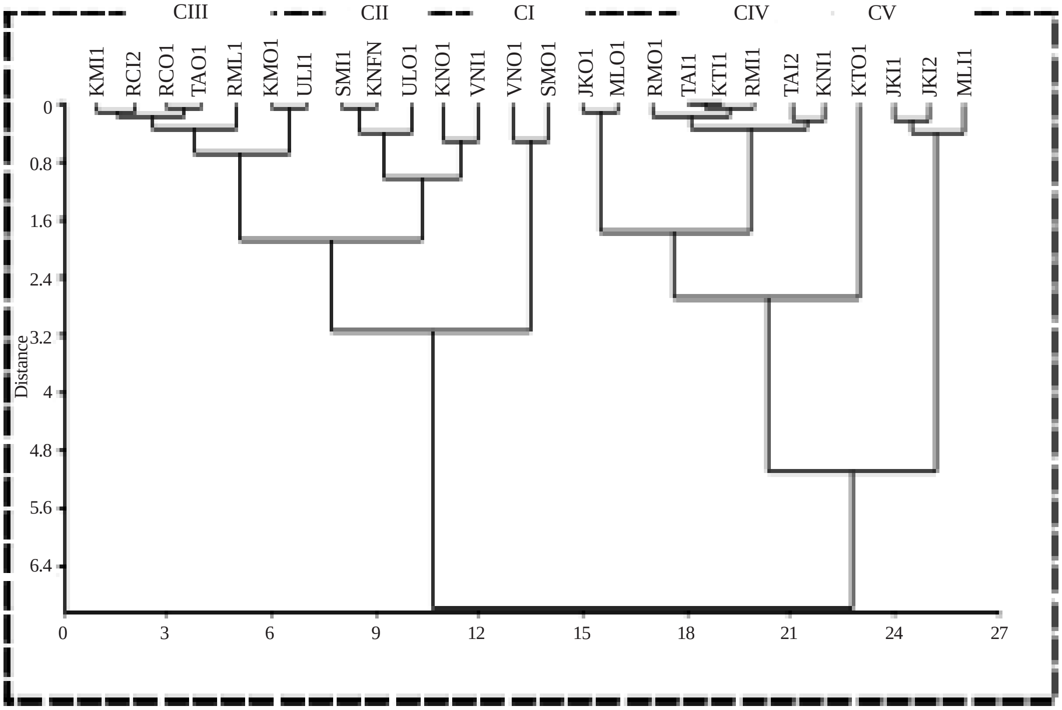

Fig. 6. Trophic diatom indices (TDI) across lakes with class-I oligotrophic (C-I), class-II oligo- mesotrophic, class-III mesotrophic (C-III), class-IV meso- eutrophic (C-IV) and class-V eutrophic conditions.

TH and KT. Poor management in discharging of untreated domestic, industrial and commercial waste in to the water bodies and land use pattern in catchment area were the observed major environmental stressors that affected the water quality (Beyene and Legesse 2005). Furthermore in PCA analysis, PC3 revealed high BOD and COD concentrations at sewage fed, polluted wetlands such as ML, TH inlets and UL. VN, SM and KN were separated from rest of the sites indicating no influence of any of the variables as explained in PCA plot.

Diatom and Macroinvertebrate Distribution

Species distribution, richness and evenness reflected significant changes across sites and gradients in water chemistry. Diatoms comprised species indicating pollution levels such as *N. palea, D. confervaceae and C. meneghiniana* which are known to be tolerant species with high saprobic number (van Dam et al. 1994) and hence reflected pollution at JK and ML. Corixidae, pollution indicator group among macroinvertebrates was also evident of increasing degradation in water quality at JK and ML. The biota is found to have been influenced by both the primary (physical and chemical water variables) and secondary (human disturbances and land use in catchment) factors (Nautiyal and Verma 2009). Species richness was less in case of macroinvertebrates when compared to diatoms (Fig. 4) because of the response of former to poor habitat quality. It has been reported that less habitat-dependency of diatoms when compared with macroinvertebrates consents to more occupancy of diatoms on several habitats (McCormick and Cairns 1994; and Reid et al. 1995).

Diatom and Macroinvertebrate Indices

Most of the water quality variables (BOD, COD, EC, ALK and chlorides) revealed significant positive correlation with %PT and TDI indices indicating pollution level. The increasing TDI with increasing BOD, COD and EC, the representative of ionic concentrations, gave evidence for the relationship between physical and chemical variables with the biological variables (Atazadeh et al. 2007). Implementing GDI indices could not be useful for urban wetlands though the genus level identification explains pollution, it may cover up species contribution, its tolerance and sensitivity in indices calculation. The resolution of this index is considerably lower than the TDI indices which rely on species level identification. However, this index may be useful for the purposes of providing an initial indication that an aquatic system is polluted but not its severity.

The low correlation coefficients between macroinvertebrate metrics and environmental parameters is caused by the fact that benthic communities are not always affected by this kind of pollution and considerable diversity can be present in places with heavy chemical loads (De Pauw and Heylen 2001; Beyene and Legesse 2005). On the other hand several report scores for macroinvertebrate metrics correlating strongly with a wide variety of water quality parameters, including toxicants. The families such as Belostomatidae, Diptera, Gerridae, Hydrometridae, Notonectidae, Gerridae, Pleidae, Hydrophiloidea, Thiaridae and damsel fly lacks tolerance scores in both FBI and BI (Mandaville 2002) which are documented as pollution sensitive groups (Crane et al. 2000). Though Thiaridae was dominant, VK outlet site had 0 indices score because the tolerance value of Thiaridae is not specified in either of the indices. Similar problem was recorded with families such as Belostomatidae and Gerridae at Jakkur, Pleidae at Mallathally and Diptera at Rachenahalli. However, the BI index includes most of the families than the FBI index and can be further modified to use as indicators.

The interconnected wetlands explain the significance of environmental conditions for species occupancy. High ionic level is attributable for 56% of CMEN taxa at Jakkur, while it was 35%, at Rachenahalli with less ionic level compared to former. The species composition reflected not just the water chemistry but physical habitat quality such as substrate composition, turbulence and land use patterns as factors that influence diatom macroinvertebrate assemblages (Giller and Malmqvist 1998).

The clustering of sampling sites based on the relative abundance of diatoms and macroinvertebrate revealed the trophic status and scale of organic pollution across Bangalore. The sites categorized under class I and II were relatively clean waters with fewer nutrients and less disturbed wetlands. The sites which are grouped in the class III to IV are inflow sites with sewage and industrial effluents while, class I and II include most of the outlet sites. The oligotrophic status of outlet sites explains the role of ecosystem in uptake of nutrients by macrophytes and other organisms. According to TDI, most of the sites come under mesotrophic classification, while inlets of ML and JK were clustered as Meso-eutrophic to eutrophic (Class IV-V) with high constituents of EC, CHL, hardness and organic nutrients, which were also evident from water quality and dominance indices.

In macroinvertebrates, the family viz., Nepidae and Belostomatidae, being dominant at JKO1 and Thiaridae at JKI1, are underprovided with tolerance values and though with elevated ionic values, grouped as good water quality as per BI index. The tolerance values for these macroinvertebrates are not defined in BI and FBI, hence indices fail to distinguish the appropriate trophic status and subsequently a slight difference between diatom and macroinvertebrate indices classification was recorded. JK and ML wetlands, where high EC, BOD and COD influencing water quality was considerable due to intense human disturbances, these sites trophic status was not reflected through BI indices. The autecological values of individuals explaining trophic status has to be standardized to support the development of macroinvertebrates as bioindicators in Indian condition. The application of a number of biotic indices and scores leads often to conflicted results (Iliopoulou-Georgudaki et al. 2003). Several studies as well, Triest et al. (2001), Gonçalves et al. (2008), pointed out in their comparative study that primary producers - diatoms are more indicative for water quality and trophic status than macroinvertebrates. Lack of species ecological data could be the reason for less prevalence of macroinvertebrates as indicators.

It has been reported earlier that macroinvertebrates as poor water quality bioindicators while diatoms as better in response to pollution load. Nevertheless, the species composition and environmental variables vary among temperate and tropical regions, and leaves an unknown margin of uncertainty as differences in environmental conditions and species sensitivity are not taken into account in the latter case (Rico et al. 2011). The diatom indices developed based on taxa of temperate regions was successful in reflecting pollution in tropical ecosystems as diatoms are cosmopolitan (with few exceptions) compared to macroinvertebrates due to lack of species data and are specific to tropical region (Mandaville 2002). Diatoms and macroinvertebrates provided consistent information on water quality assessment and were suggested for use of combination of indices as biological indicators of the water quality of temperate regions (European Parliament and European Counseling, 2000; Soininen and Könönen 2004; Schletterer et al. 2011). On the other hand, the studies on tropical ecosystems explained macroinvertebrate composition as liable to severe physical habitat and chemical water quality degradation. Thus, macroinvertebrates are less diverse and are not found in tropical, severely polluted sites with low dissolved oxygen levels and diatoms are more reliable and indicate a gradient of pollution than macroinvertebrates (Samways 2005; Beyene et al. 2009). This suggests the implementation of indices and integrating region specific taxa and methods for improved biomonitoring.

CONCLUSION

Maintaining the balance among different taxonomic groups is vital for any aquatic ecosystem integrity. This study highlights the research required in the field of aquatic sciences particularly for tropical regions and the use of bioindicators such as diatom and macroinvertebrate communities. The bioindicators used differentiated the sampling sites based on the pollution level and substantiates of their wide applicability to monitor the environmental perturbations associated with human activities.

The BI and FBI indices lack tolerance values for few families/species which inhabit in high organic pollution. The addition of indicator value of many such species would enhance the efficacy of macroinvertebrate indices to highlight the ecosystem conditions in Indian region. In this regard, diatom community provided interpretable indications of specific changes in water quality, while macroinvertebrate assemblages could reflect only certain chemical changes. The case study on the urban wetlands exhibited a wide range of local impacts such as high nutrient loads due to common purpose water use, sewage inflows and agricultural run offs. These indices together showed the impacts due to chemical variations such as BOD and COD. The modification is required in BI and TDI indices with integration of locally dominant species; specific to eco-region to monitor trophic status is an obligatory. The current results which include TDI indices support the use of diatom indices for the biomonitoring wetlands. However, spatial and temporal variations, along with effects of catchment variations and human impacts needs to be accounted and this would aid in compiling data describing present situation and developing eco-region specific indicators. These indicators would be useful in the ecosystem's monitoring and also in restoration and management measures.

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ANNEXURE

Annexure I: List of diatoms recorded and its code name during analysis

Species name	*CODES*
Achnanthidium exiguum (Grunow) Czarnnecki	*AEHE*
Achnanthidium Kützing Sp. 1	*ACHD*
Achnanthidium Kützing Sp. 2	*AEUT*
Amphora coffeaeformis(Agardh) Kützing	*ACAC*
Amphora copulata (Kütz) Schoeman & Archibald	*ACOP*
Amphora veneta Kützing	*AVCA*
Anomeoneis sphaerophora (Ehr.) Pfitzer	*ASAN*
Aulocoseira granulata (Ehr.) Simonsen	*AGCU*
Brachysira Kützing	*BRAC*
Brachysira wygaschii Lange-Bertalot	*BWYG*
Caloneis (Grunow) Cleve	*CALO*
Caloneis aequatorialis Hustedt	*CRAE*
Cocconeis placentula Ehrenberg var. *placentula*	*CPLA*
Craticula accomodiformis Lange-Bertalot	*CRAC*
Craticula Grunow	*CRAT*
Craticula vixnegligenda Lange-Bertalot	*CVIX*
Cyclotella meneghiniana Kützing	*CMEN*
Cymbella C Agardh	*CYMB*
Cymbella cymbiformis Agardh	*CCYM*
Cymbella tumida (Brebisson)Van Heurck	*CTUM*
Diadesmis confervaceae Kützing	*DCOF*
Diploneis oblongella (Naegeli) Cleve-Euler	*DOBL*
Diploneis subovalis Cleve	*DSUB*
Discotella stelligera (Hustedt) Houk & Klee	*DISC*
Encyonema mesianum (Cholnoky) D.G. Mann	*ENME*
Encyonopsis K Krammer	*ENCP*
Eolimna sumbmiscula (Manguin) Moser Lange-Bertalot & Metzeltin	*ESBM*
Eolinma Lange-Bertalot & W.Schiller in W. Schiller & H. Lange-Bertalot	*EOLI*
Epithemia sorex Kützing	*ESOR*
Eunotia Ehrenberg.	*EUNO*
Eunotia minor (Kützing) Grunow	*EMIN*
Fallacia pygmea (Kützing) Stickle & Mann	*FPYG*
Fragilaria biceps (Kützing) Lange-Bertalot	*FBCP*
Fragilaria Kützing.	*FRAG*
Fragilaria tenera (WM Smith) Lange-Bertalot	*FTEN*
Fragilaria ulna (Nitzsch.) Lange-Bertalot var. *ulna*	*FUAC*
Fragilaria ulna v. acus (Kutz.)Lange-Bertalot	*FAUT*
Gomphonema affine Kützing	*GAFF*
Gomphonema Ehrenberg	*GOMP*
Gomphonema gracile Ehrenberg	*GGRA*

Annexure I: Contd.....

Species name	*CODES*
Gomphonema parvulum Kutzing var. *parvulum*	*GPAR*
Gomphonema pseudoaugur Lange-Bertalot	*GPSA*
Gyrosigma rautenbachiae Cholnoky	*GRAU*
Hantzschia amphioxys (Ehrenberg) Grunow *v. gracilis*	*HAMP*
Lemnicola hungarica (Grunow) Round & Basson	*LHUN*
Mastagloia smithii Thwaites	*MSMI*
Mastogloia elliptica (Agardh) Cleve	*MELL*
Navicula antonii Lange-Bertalot	*NANT*
Navicula cryptotenella Lange- Bertalot	*NCTE*
Navicula gregaria Donkin	*NGRE1*
Navicula Kützing	*NAVI*
Navicula rostellata Kützing	*NROS*
Navicula symmetrica Patrick	*NSYM*
Navicula viridula (Kützing) Ehrenberg	*NVIR*
Nedium productum (W Smith) Cleve	*NEPR*
Nitzschia acicularis (Kützing) W Smith	*NSUA*
Nitzschia amphibia Grunow *f.amphibia*	*NAAC*
Nitzschia capitellata Hustedt	*NCPL*
Nitzschia etoshensis Cholnoky	*NETO*
Nitzschia frustulum Hustedt	*NFTU*
Nitzschia gracilis Hantzsch	*NGLS*
Nitzschia Hassall	*NITZ*
Nitzschia intermedia Hantzsch	*NINT*
Nitzschia lancettula O Müller	*NLTL*
Nitzschia obtusa W M Smith	*NOBT*
Nitzschia palea (Kutzing) W.Smith	*NPAL*
Nitzschia reversa W. Smith	*NREV*
Nitzschia umbonata (Ehrenberg)Lange-Bertalot	*NUMB*
NitzschIia clausii Hantzsch	*NCLA*
Nizschia pura Hustedt	*NIPR*
Pinnularia acrospheria Rabenhorst	*PACR*
Pinnularia borealis Ehrenberg senso lato	*PBOR*
Pinnularia Ehrenberg	*PINU*
Placoneis Mereschkowsky	*PLAC*
Planothidium frequentissimum (Lange-Bertalot) Round & Bukhityarova	*PLER*
Pleurosigma elongatum W Smith	*PELO*
Pleurosigma W Smith	*PLSG*
Rophalodia gibba (Ehr.) O.Muller var.*gibba*	*RGIB*
Sellaphora laevissima (Kützing) D G Mann	*SELA*
Sellaphora pupula (Kützing) Mereschkowksy	*SPUP*
Sellaphora stroemii (Hustedt) DG Mann	*SSTM*
Seminavis D.G Mann	*SMNA*
Staphanodiscus Ehrenberg	*STEP*
Staphanodiscus hantzschii Grunow	*SHAN*
Surirella angusta Kützing	*SANG*
Surirella brebissonii Krammer & Lange-Bertalot	*SBKU*
Surirella ovalis Brébisson	*SOVI*
Surirella Turpin	*SURI*
Tabularia (F.T.Kützing) D.M.Williams et Round	*TABU*
Thalosiosira duostra Pienaar	*THAL*
Tryblionella calida (grunow in Cl. & Grun.) D.G. Mann	*TRYB*

Annexure- II: List of aquatic insects recorded and its code names during analysis

Order	*Family*	*Genus*	*CODES*
Coleoptera	Hydrophiloidae	*Hydrophilus* Leach	HYDR
	Curculionidae	*Bagous*	BAGO
	Dytiscidae		DYTI
Diptera	Chironomidae	*Chironomous* Meigen	CHIR
	Chironomidae		CHI1
	Chironomidae		CHI2
Ephemeroptera	Baetidae	*Cloeon* Leach	CLOE
Hemiptera	Gerridae	*Gerris* Fabricius	GERR
	Corixidae		CORI
	Pleidae	*Plea* Leach	PLEA
	Corixidae	*Micronecta* Kirkaldy	MICR
	Belostomatidae	*Diplonychus* Laporte	DIPL
	Notonectidae	*Notonecta* Linnaeus	NOTO
	Gerridae		GER1
	Hydrometridae		HYDR
	Nepidae	*Ranatra* Fabricius	RANA
	Gerridae		GER2
	Nepidae	*Laccotrephes* Stal	LACC
Odonata	Coenagrionidae		COE1
	Libellulidae		LIB1
	Coenagrionidae		COE2
	Libellulidae		LIB2
	Aeshnidae		AESH
	Libellulidae		LIB3
	Libellulidae		LIB4

Annexure III: List of Molluscs recorded and its code names during analysis

Classification	*Taxa*	*CODES*
	Class : Gastropoda	
Species	*Bellamya bengalensis* Lamarck	BEBN
Genus	*Bellamya* Jousseaume	BEJU
Genus	*Gabbia* Tryon	GABB
Genus	*Gyraulus* Charpentier	GYCA
Species	*Indoplanorbis exustus* Deshayes	INEU
Genus	*Lymnaea* Lamarck	LYMN
Genus	*Melanoides* Olivier	MELA
Species	*Melanoides tuberculata* Mueller	MELA
Species	*Physa acuta* Draparnaud	PHYS
Tribe	Segmentinieae	SEGM
Species	*Segmentina (Polypylis) taia* Annandale	SETI
Genus	*Tarebia* H. and A. Adams	TARE
Species	*Thiara (Thiara) scabra* Mueller	THSA
	Class : Bivalvia	
Species	*Lamellidens consobrinus* Lea	LACN
Genus	*Pisidium* Pfeiffer	PISI