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DIVERSITY OF FRESHWATER MACRO-INVERTEBRATE COMMUNITIES ASSOCIATED WITH MACROPHYTES

R. A. KHAN

Zoological Survey of India, Nizam Palace, 234/4, A. J. C. Bose Road, Kolkata-700 020

INTRODUCTION

Floating and submerged macrophytes in freshwater lakes, reservoirs and ponds, besides playing important roles in the energy dynamics of the ecosystem, also provide shelter to a large number of invertebrate species. It has been reported that the species diversity of macro-fauna associated with submerged plants is significantly greater than those of benthos. While detailed studies on the diversity and density of such communities have been carried out in different parts of the world (Rosine, 1955; Harrod, 1964; Soszka, 1975; Junk, 1976; Rook, 1984; Scheffer *et al.*, 1984; Chilton *et al.,* 1986; Schramm, *et al.,* 1987; Kornijow, 1989 and Kornijow and Gulati, 1992), and the knowledge so obtained has been employed to formulate management strategies for biomanipulation, in India, practically very little attention has been given to this community specifically, as most of the earlier works on such lines deal with general macrobenthos of freshwaters (Srivastava, 1956; Krishnamurthy, 1966; Dev *et al.*, 1993; Mandal and Moitra, 1975; Raman, *et al.*, 1976; Gupta, 1976; Misra *et al.*, 1981; Gupta and Pant, 1983 and Barbhuiyan and Khan, 1992). The earlier attempt in this direction is mainly confined to the works of Michael (1968) on a fishpond in Bengal, Sarma *et al.,* (1975) on ponds of Vishakhapatnam and Sarma *et al.* (1983) on Dal Lake of Kashmir.

The present report, which is a part of the detailed studies on the structure and dynamics of aquatic fauna in some lakes and ponds of southern West Bengal, deals with the species diversity, community structure, numerical density and biomass of macro-invertebrate fauna associated with submerged and floating vegetation in a large man made lake and a medium sized pond of Calcutta, with the analyses of species diversity and the extent of similarity between the two wetlands.

MATERIAL AND METHOD

1. Description of the study area :

The large man made lake, Rabindra sarovar (lake) situated in the southern part of the city of Calcutta, is meant chiefly for recreational purpose. It was constructed some 70 years ago. The main lake is elongated in shape and covers an approximate area of 72 acres. Its maximum length is about 1776 m and width at broadest point is 286 m. Depth varies between 9.3 and 10.5 m. It is mainly fed

by rain water during monsoon. The lake contains abundant macrophytes belonging to several species. Four sampling stations covering the entire lake on northern side were fixed.

The Manohar Das Pukur (Pond) is a medium sized pond situated in the heart of the city. This is also meant for recreational/aesthetic purposes but due to excessive and undesirable use by surrounding human population of the metropolis, it has become highly polluted. During the period of investigation, the pond was completely filled up by monospecific strand of water hyacinth, *Eichhornia sp.* Two sampling stations one on northern end and the other on southern end were fixed. The detail description of these two water bodies has already been given (Khan, 1979).

Sampling and analyses :

The studies were carried out for three consecutive years, 1994-95, 1995-96 and 1996-97 during different seasons. The seasons were defined as Pre-monsoon (PRM, March to June), Monsoon (MON, July to October) and Postmonsoon (POM, November to February). All data were pooled under these three seasons. The samples were collected from all stations with a hand net of the size of 50 cm x 50 cm from littoral zone only.A wooden frame of this size was attached to a large net made up of fine malmal cloth with mesh size of approximately 200 μ. The net was fixed on a long pole. The design and operation of the net was roughly based on those described by Junk (1977). For collection of fauna, the net was slowly pushed upside down to the bottom of littoral zone and quickly lifted after turning the mouth of the net. After pulling the net near the shore, the vegetation projecting outward from the marginal area of the net frame, were cut off. The distance from the bottom to surface which ranged between 100 and 125 cm, was measured and total area covered by the net was calculated. Three replicate samples from each of the four stations of lake and two of pond were collected.

The macrophyte leaves and roots were then washed thoroughly several times in the net itself, removing all attached faunas manually from each strand with the help of a magnifying glass. The contents of the net as well as macrophytes were again washed on a sieve of 0.5 mm and all fauna retained on the sieve were collected. Animals were first killed or narcotized slowly by putting few drops of 5% formaldehyde solution and then preserved in either in 70% alcohol or 5% formalin. The animals were then sorted out into different taxonomic groups and identified up to lowest possible taxon under low powered stereo binocular microscopes. Enumeration and size measurements were carried out simultaneously. For biomass determination, the wet weight of several individuals of each species were taken after broadly dividing into various size groups and mean individual weight of each species was worked out. For dry weight biomass, the animals were dried for 3 days at 65°C. and weighed. This was done only once in the beginning.

The chemical analysis of water were carried out as per Standard Methods (APHA, 1975). The water samples were collected only from littoral zone. The temperature and pH were determined with electronic probes (HANA, Japan) and light penetration (transparency) by Secchi disc.

Measurement of Diversity :

The number of species, density of individual species and total macrofaunal density were used to compute following diversity indices :

1. **Species Richness** : Total number of species recorded from a water body over the entire period of study.
2. **Menhinick's Index** : S/In (Menhinick, 1964)
3. **Maragalef's Index** : $\frac{S-1}{\log N}$ (Margalef, 1951)
4. **Simpson's Measure of Diversity** : $D = 1 - \frac{Ni(ni-1)}{N(N-1)}$
5. **Shannon-Weiner Index** : $H = -\{ni/N \log 2\, ni/N\}$ (Shannon-Weiner, 1949)
6. **Evenness** : $J = \frac{H}{H_{max}}$ (Pielow, 1969)

S = total number of species, N = total density, ni = density of individual species

Similarity Analysis :

Qualitative : $C \times 100/A + B - C$ (Greig-Smith, 1964)

A and B are number of species in two waterbodies and C is the number of species common to both.

Quantitative : $S = \frac{W}{a+b-c}$ (Romaniszyn, 1970)

W = sum of density minima of each species irrespective of waterbody and a and b are sum of total densities of all taxa in waterbody A and B respectively.

RESULTS

1. Physico-chemical characteristics of water :

The variations in physico-chemical characteristics of the two wetlands are shown in Table 1. The seasonal mean values of water temperature varied very little in the two wetlands and ranged between 22.5 and 32.0°C in lake and between 22.5 and 32.5°C in the pond, lowest during premonsoon and highest in monsoon. Transparency values differed considerably between lake and pond, it was always higher in lake than in pond. Monsoon season was characterized by lowest values in both, lake and pond. While the range of pH was much different in the two systems, it fluctuated very narrowly between seasons. Considerable variations occurred in dissolved oxygen contents of the two wetlands during different seasons. The DO content was lower in pond throughout the year than the lake. Further, the periods of maxima and minima also differed significantly. While the lowest

values were observed during monsoon in lake, premonsoon was the period of minimal DO concentration in pond. While the chlorides were considerably high in pond as compared to lake, its total alkalinity contents were significantly low.

Table 1. : Physicochemical characteristics water in the two wetlands.

Parameters	Lake (Rabindra sarovar)			Pond (Manohar das pond)		
Water Temperature °C	32.0	31.5	23.5	32.5	30.5	22.5
Transparancy (cm)	40.0	22.5	45.0	30.0	25.0	36.5
PH	8.0	7.5	7.8	8.5	7.9	8.3
Dissolved Oxygen (mg/l)	7.0	6.5	7.8	6.5	6.0	6.8
Alkalinity (Total) (mg/l)	210.0	195.0	180.0	310.0	160.0	270.5
Chloride (mg/l)	80.5	70.0	76.4	95.0	60.0	65.0

2. Macrophytes :

The lake harbored a variety of floras (Table 2). Seventeen commonly occurring species were recorded which included 11 species of floating forms and 6 of submerged forms. The free floating forms were represented mainly by *Pistia sp, Lemna sp, Utricularia sp, and Wolffia sp.* The submerged hydrophytic genera like *Chara, Ceratophyllum, Vallisneria, Naja, and Hydrilla* were of common occurrence. *Ceratophyllum sp.* dominated the submerged macrophyte community quantitatively. At several points its monospecific strands were recorded. Among rooted plants, *Typha sp* was recorded at several places. The condition of pond was entirely different. This was completely filled up by monospecific strands of water hyacinth, *Eichhornia sp.*

3. Faunal diversity :

Altogether 49 commonly occurring taxa of macrophyte associated macroinvertebrate fauna were recorded during the period of study from the two wetlands (Table 3). These belonged to Mollusca : Gastropoda (11 species) Oligichaeta (2 species) and Hirudinea (3 species), Hydroacarina (2 species) Crustacea : Decapoda (3 species) Odonata (6 species), Hemiptera (8 species), Coleoptera (10 species) and Diptera (4 species). Gastropods were represented by the largest number of taxa followed closely by Coleoptera and Hemiptera (Fig. 1).

Wetland wise, the faunal diversity was considerably high in lake throughout the period of investigation, where 43 species were recorded, but it was significantly low in pond where only 25 species were noticed. Many of the species were common to both wetlands. Out of 25 species that

Table 2. : List of Macrophyte taxa recorded from Rabindra Sarovar.

FLOATING	SUBMERGED
Rooted floating	**Rooted Submerged**
Family : Nymphaceae	Family : Characeae
Nymphaea sp.	*Chara sp.*
Nymphoides indicum	Family : Hydrochorideae
Family : Scrophularineae	*Hydrilla sp.*
Limnophila sp.	*Vallisneria sp.*
Free Floating	Family : Najadaceae
Family : Aroideae	*Najas sp.*
Pistia sp.	**Free submerged**
Family : Lemnaceae	Family Lentibullariaceae
Lemna sp.	*Utricularia sp.*
Spirodella sp.	Family : Ceratophyllaceae
Wolffia sp.	*Ceratophyllum sp.*
Family : Onagraceae	
Trapa sp.	
Family : Pontederiaceae	
Eichhornia sp.	
Family : Salviniaceae	
Azolla sp.	
Family : Hydrocharidae	
Hydrocharis cellulosa	

occurred in pond, 17 also occurred in the lake. However, lake harboured many more species, which were never recorded from the pond. The Decapoda was totally absent from the pond and Hydroacarina and Hirudinea were recorded in small numbers. The common fauna belonged mainly to gastropoda (4 species), oligochaetea (both species), Diptera (all 4 species), Hemiptera (4 species) and Odonata (3 species). It may be seen that all the species of oligochatea and Diptera (Chironomidae and Culicidae) were represented in both wetlands (Table 3) and except these two groups, significant differences were recorded in the faunal diversity of the two wetlands. In fact all taxa occurring in the pond were the most abundant aquatic fauna of this region, which have fully adapted to all types of freshwaters, including the highly polluted ones.

Highest number of species was recorded during postmonsoon in both wetlands. Marked seasonal variations were recorded in the species richness of the lake, where number of species decreased

considerably during monsoon months (Fig. 1). However, the seasonal impact on the pond fauna was not severe, as the reduction in the number of species was not very significant.

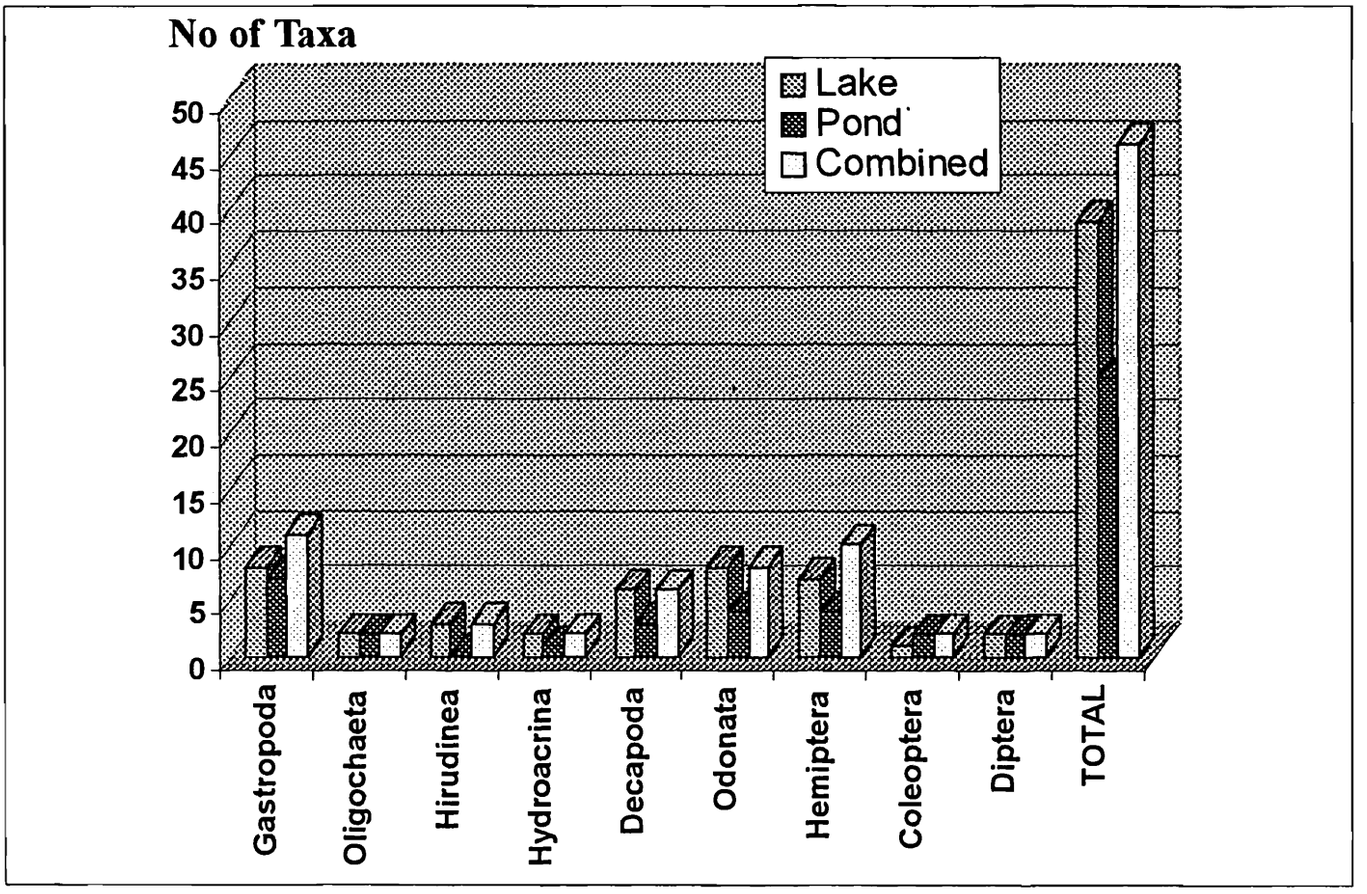

Fig. 1. Number of taxa of each group in the two wetlands and combined.

4. Density :

The total density of macrophyte associated macroinvertebrates varied between 3225/m^2 and 5993/m^2 with a mean of 4644.0 in lake and between 2198/m^2 and 6510/m^2 with a mean of 4344. In pond (Tables 4 and 5). Three groups, Oligochaeta, Gastropoda, and Diptera-Chironomidae formed the bulk of density in both, lake and pond. While total density in the two wetlands did not differ much, the contribution of individual groups varied greatly (Fig. 2). The contribution of oligochaetes was only 29.54% in lake but their share in pond was more than half (52.39%). Contrary to this the contribution of gastropod was considerably higher in lake (33%) than pond (7.5%). The dipteran larvae, especially chironomidae also contributed differently in the two wetlands. Variations were also recorded in other groups too.

Pronounced seasonal variations occurred in the density. In general lowest density in both the systems was observed during monsoon and highest in premonsoon. The high density during

Table 3. Occurrence of differrent species of Macrophyte associated macro-invertebrate during different seasons in the lake and pond. + Present, – Absent.

MACROINVERTEBRATE GROUPS	Lake (Rabindra Sarovar)			Pond (Monohar Das Pond)		
	PRM	MON	POM	PRM	MON	POM
MOLLUSCA- GASTROPODA						
Family : Bellamyidae						
Bellamya bengalensis (Lamarck)	+	+	+	+	+	+
Family : Pilidae						
Pila globosa (Swainson)	–	–	–	–	–	+
Family : Bithyniidae						
Gabbia orcula Frauenfeld	+	+	+	–	–	–
Digoniostoma cerameopoma (Benson)	+	+	+	+	+	+
Family : Thiaridae						
Thiara (Tarebia) granifera (Lamarck)	+	–	+	–	–	–
Thiara (Thiara) lineata (Gray)	–	–	–	+	+	+
Thiara(Melanoides)tuberculata (Muller)	+	+	+			–
Family : Lymnaeidae						
Lymnaea (P.) accuminata Lamarck	+	–	+	–	–	–
Lymnaea (P.) luteola Lamarck	+	+	+	+	+	+
Family : Planorbidae						
Indoplanorbis exustus (Deshayes)	–	–	–	+	+	+
Gyraulus convexiusculus (Hutton)	+	+	+	+	+	+
ANNELIDA : OLIGOCHAETA						
Branchiura sowerbyi Beddart	+	–	+	+	–	+
Limnodrillus hoffmeisteri Claparede	+	+	+	+	+	+
ANNELIDA : HIRUDINEA						
Glassophonia weberi (Blanchard)	–	+	+	–	–	–
Helobdella nociva Harding	–	+	–	–	–	–
Hemiclepsis marginata Muller	–	+	+	–	+	–
HYDROACARINA						
Arrenurus sp.	+	–	+	–	–	–
Hydrachna sp.	+	+	+	+	+	+
CRUSTACEA : DECAPODA						
Sartoriana spinigera Wood-Mason	+	–	+	–	–	–
Macrobrachium lamarrei(H.M.Edwards)	+	+	+	+	–	–
Macrobrachium dyanum (Henderson)	+	–	+	–	–	–
INSECTA						
ODONATA						
Family : Coegrionoidae						
Ceriagrion coromandelianum Fabricius	–	+	+	–	–	–

Pseudagrion microcephalum Rambur		+	+	+	–	+	–
Family : Gomphidae							
Ictinogomphus rapax Rambur)		–	+	+	–	–	–
Family : Libellulidae							
Brachythemis contaminata(Fabricius)		+	+	+	–	+	–
Crocothemis servilla (Drury)		–	+	+	+	–	+
Orthetrum sabina (Drury)		+	+	+	–	–	–
HEMIPTERA							
Family : Corixidae							
Micronecta scutellaris (Stal)		+	–	+	–	–	–
Family : Notonectidae							
Anisops bouvieri Kirkaldy		+	+	+	–	+	+
Family : Nepidae							
Ranatra filiformis Fabricius		+	–	+	–	–	+
Family : Belostomatidae							
Diplonychus annulatum (Fabricius)		+	+	+	+	+	+
Family : Mesoveliidae							
Mesovelia vittigera Horvath		–	–	+	–	–	–
Family : Hydrometridae							
Hydrometra Vittata Stal		+	–	+	–	–	–
Family : Gerridae							
Limnogonus (L.) fossarum (Fabricius)		+	+	+	+	+	+
Limnogonus (L.) nitidus(Mayr)		+	–	+	–	–	–
COLEOPTERA							
Family : Dystiscidae							
Hydrocoptus subvittulus Motschhulsky		–	–	–	+	+	+
Canthydrus laetabilis (Walker)		+	–	+	–	–	–
Laccophilus anticatus Sharp		+	–	+			–
Guignotus flammulatus (Sharp)		–	–	–	+	–	+
Family : Gyrinidae							
Dineutus indicus Aube		+	+	+	–	–	–
Family : Halipidae							
Haliplus angustifrons Regimbart		–	–	+	–	–	–
Family : Hydrophilidae							
Helochares ancholaris Sharp		–	–	–	+	+	+
Hydrophilus rufocinetus (Bedel)		+	–	+	–	–	–
Sternolophus rufipes (Fabricus)		+	–	+	+	–	+
Amphiops pedestris Sharp		+	–	+	–	–	–

DIPTERA : CHIRONOMIDAE							
Chironomus sp.A		+	+	+	+	+	+
Chironomus sp. B		-	-	-	+	+	+
DIPTERA : CULICINAE							
Culex sp		+	+	+	+	+	+
Anophles sp.		+	+	+	+	+	+
TOTAL NO. OF SPECIES	**49**	**33**	**25**	**41**	**22**	**19**	**23**

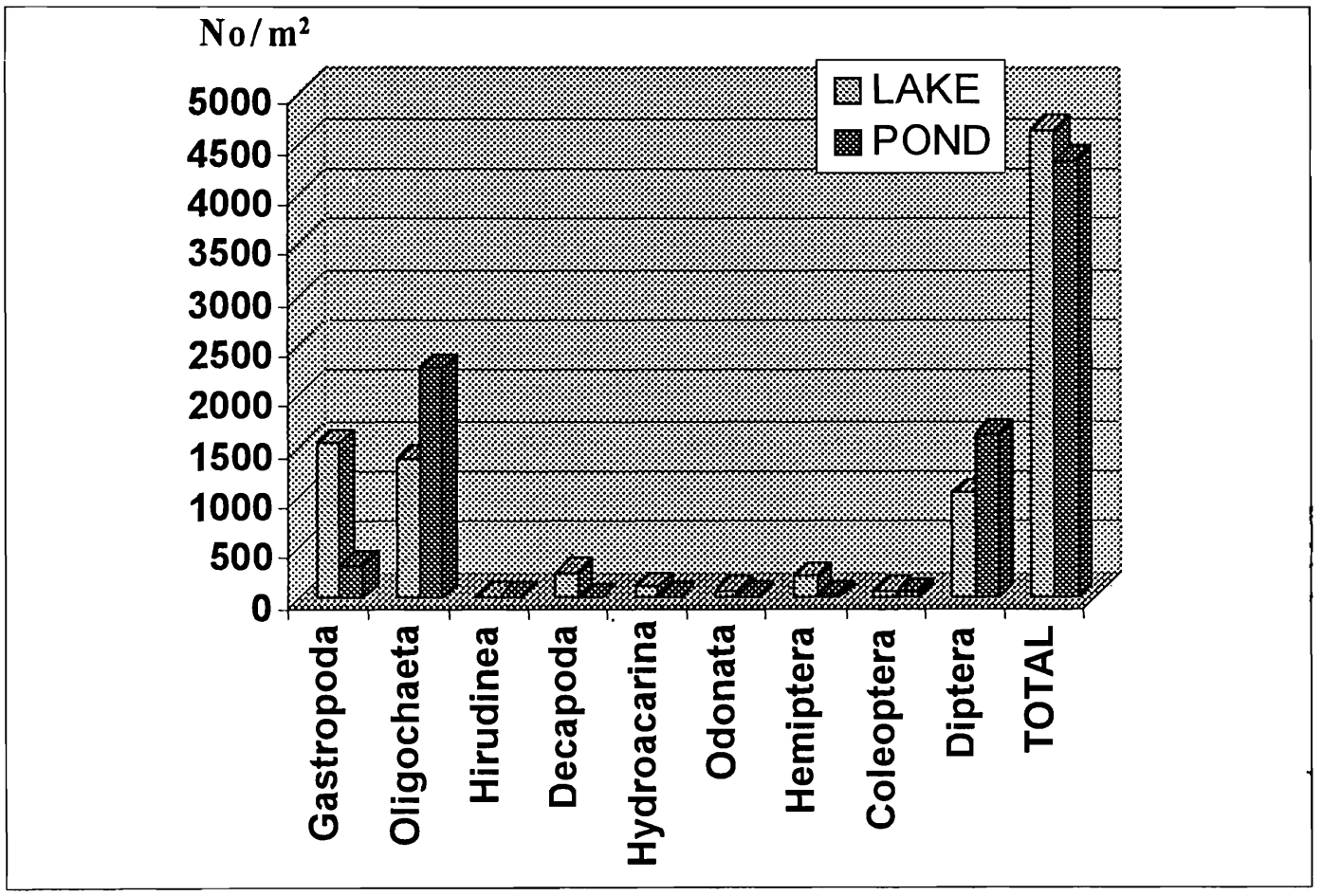

Fig. 2. Mean density of different groups of macrophyte associated macroinvertebrates in the two wetlands.

premonsoon was contributed mainly by extraordinary increase in the population of oligochaetes and chironomids (Tables 4 and 5).

5. Biomass :

The dry weight biomass of the macrophyte associated macroinvertebrates in the two wetlands varied from 174.8 g/m^2 to 244.5 g/m^2 with a mean of 174.8 g/m^2 in lake and from 69.0 g/m^2 to 201 g/m^2 with a mean of 130 g/m^2 in pond (Tables 6 and 7). The contribution of gastropods was highest

Table 4. : Seasonal variations in the density of macrophyte associated macroinvertebrate fauna in lake.

GROUP	PRM	MON	POM	MEAN	PERCENT
	Number per square meter				
Oligochaeta	2080.5	795.5	1240.5	1372.20	29.54
Hirudinea	15.0	23.0	0.0	8.16	0.18
Decapoda	65.0	397.5	276.2	246.20	5.30
Odonata	52.5	60.0	90.0	67.50	1.45
Hemiptera	80.0	420.0	114.5	204.66	4.40
Coleoptera	63.5	99.0	38.5	67.00	1.40
Diptera	1608.5	448.5	1056.0	1037.70	22.40
Hydroacarina	75.0	15.5	235.0	108.33	2.33
Gastropoda	1967.0	966.5	1664.0	1532.00	32.99
TOTAL	5993.5	3225.5	4714.7	4643.70	

Table 5. : Seasonal variations in the density of macrophyte associated macroinvertebrate fauna in pond.

GROUP	PRM	MON	POM	MEAN	PERCENT
	Number per square meter				
Oligochaeta	3420.0	1055.0	2352.5	2276.00	52.39
Hirudinea	2.5	17.5	5.0	8.30	0.19
Odonata	5.0	23.0	10.0	12.70	0.29
Hemiptera	32.5	17.5	41.0	30.40	0.70
Coleoptera	26.7	115.0	23.5	55.06	1.26
Diptera	2641.0	820.0	1410.0	1624.00	37.38
Hydroacarina	17.5	–	12.5	10.00	0.23
Gastropoda	365.0	150.0	468.0	327.70	7.54
TOTAL	6510.2	2198.0	4322.5	4344.50	

in both wetlands (Fig. 3). Their contribution to biomass was markedly higher in comparison to their numerical density. It may be seen that in pond while the share of their numerical density was only 7.54%, the contribution to biomass was 27.47%. In lake they contributed to nearly 65% of total biomass as compared to density contribution of 33%. The oligochates and chironomids, inspite of their considerably high densities, contributed very little to the biomass in both wetlands (Fig. 3).

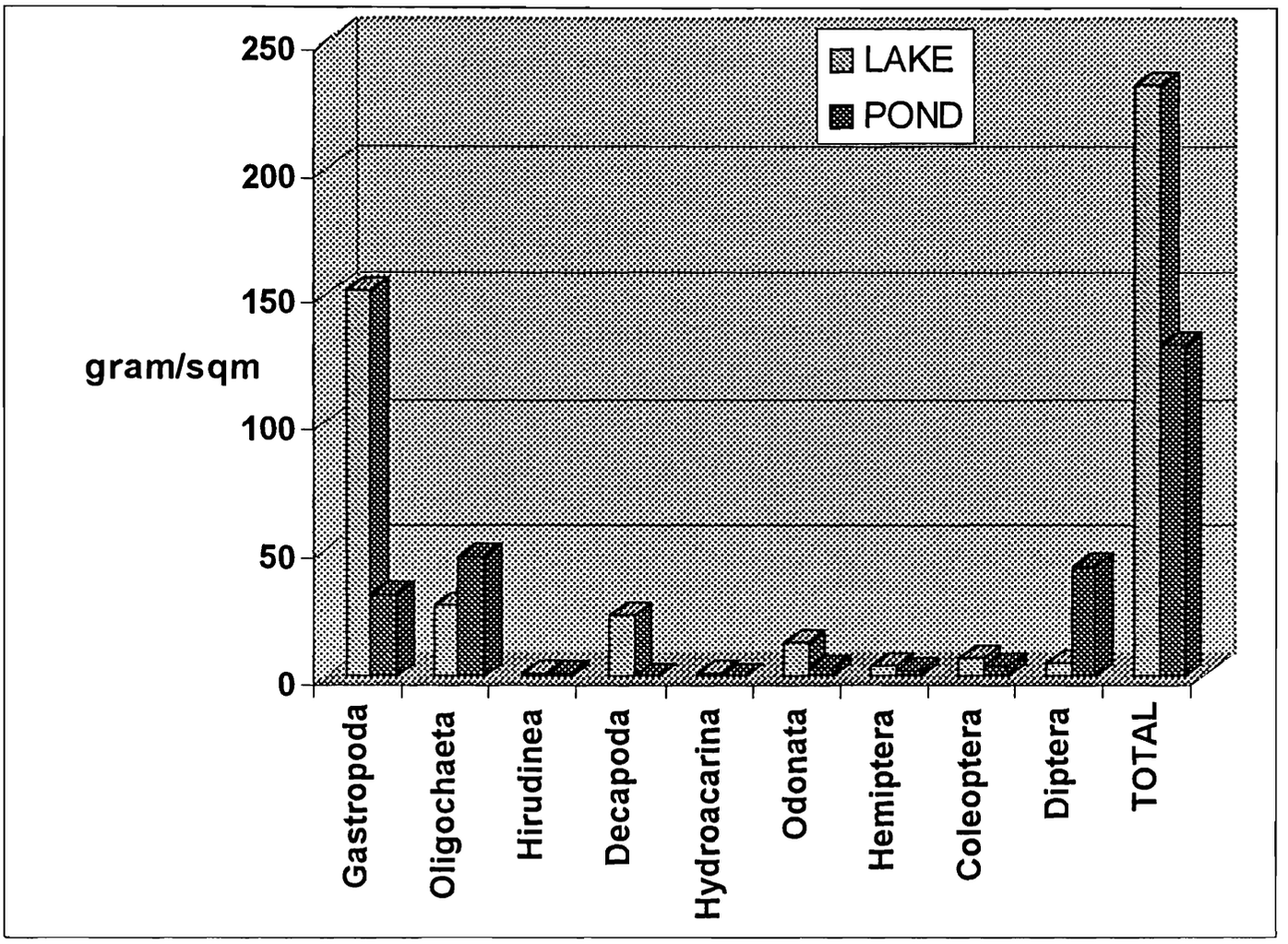

Fig. 3. Mean Biomass of different groups of macrophyte associated macroinvertebrates in the two wetlands.

The seasonal variations in the biomass followed the pattern of density, highest during premonsoon and lowest in monsoon (Tables 6 and 7)

6. Density : Biomass ratio :

Distinct variations were recorded in the density biomass ratio of macrophyte associated macroinvertebrates in the two wetlands. The ratio was considerably higher in lake than in ponds in all seasons. While the values ranged between 0.0469 and 0.5420 with a mean of 0.0502 in lake these were 0.0278 and 0.0314 with a mean of 0.0299 in pond. While highest values were observed during monsoon in both wetlands, the periods of lowest ratio was different, which were premonsoon in lake and postmonsoon in pond (Tables 6 and 7).

7. Diversity and Similarity indices :

Table 8a shows the values of various diversity indices applied. While the values of different indices varied according to their characteristics, it was clearly visible that all of these gave similar

information, excepting a slight deviation noted in case of Menhinick's index. These indices revealed that faunal diversity was considerably higher in lake than pond.

Table 6. : Seasonal variations in the biomass of macrophyte associated macroinvertebrate fauna in lake.

GROUP	PRM	MON	POM	MEAN	PERCENT
	Gram per square meter				
Oligochaeta	43.06	16.46	25.65	28.39	12.16
Hirudinea	0.11	1.80	–	0.64	0.27
Decapoda	16.90	25.63	29.90	24.14	10.34
Odonata	8.82	14.02	16.83	13.22	5.66
Hemiptera	3.36	1.78	4.83	3.32	1.40
Coleoptera	6.64	10.29	3.99	6.97	3.00
Diptera	3.35	8.25	1.92	4.50	1.92
Hydroacarina	0.03	0.65	0.11	0.26	0.11
Gastropoda	198.75	95.93	161.23	151.97	65.10
TOTAL	281.02	174.81	244.46	233.42	
DENSITY : BIOMASS RATIO	0.0469	0.0542	0.5186	0.0502	

Table 7. : Seasonal variations in the biomass of macrophyte associated macroinvertebrate fauna in pond.

GROUP	PRM	MON	POM	MEAN	PERCENT
	Gram per square meter				
Oligochaeta	70.80	21.80	48.70	47.10	38.73
Hirudinea	0.21	1.99	0.42	0.87	0.58
Odonata	0.94	4.30	1.87	2.37	1.94
Hemiptera	1.36	0.73	1.72	1.27	1.04
Coleoptera	2.62	6.82	2.36	3.93	3.23
Diptera	88.10	18.00	22.20	42.80	26.94
Hydroacarina	0.08	0.00	0.05	0.05	0.04
Gastropoda	37.20	15.30	42.70	31.80	27.47
TOTAL	201.34	69.01	120.07	130.14	
DENSITY : BIOMASS RATIO	0.0308	0.0314	0.0278	0.0299	

Table 8a. :Mean value of different diversity indices of Macrophyte associated macro-invertebrate fauna in lake and pond.

Indices	Lake	Pond
Species Richness	27	18
Menhinick (Menhinick (1964)	0.2868	0.1965
Maargalef's (Margalef, 1957)	2.8600	1.8824
Simpson Measure of Diversity D (Pielow,1969)	0.8356	0.6219
Shannon-Wiener diversity index ($\bar{H}$) Shanon and Weiner (1949)	2.8085	1.0922
Evenness (J) (Pielow, 1969)	0.6487	0.5002
Dominance Index D1 (Berger and Parker, 1970)	0.2400	0.5308
Dominance Index D2 (McNaughton, 1967)	0.4690	0.8358

The analyses of qualitative and quantitative similarity indices are given in Table 8b. There were marked differences in the values obtained by qualitative and quantitative indices. The qualitative index of Greig-Smith (1984), indicated comparatively larger extent of similarity between the lake and pond (33.33) but the quantitative index based both and number of species and their density found very little similarity between the two (6.48).

Table 8b. : Indices of similarity between lake and pond.

INDICES	Values
Greig-Smith (1964) Qualitative	33.33
Romanizyn (1970) Quantitative	6.48

DISCUSSION

The studies revealed significant differences in the diversity of macrophytes associated macroinvertebrate fauna in the two wetlands. The comparatively higher species richness of the lake can be safely related to a diverse macrophytic community consisting of 17 commonly occurring taxa. The significance of diverse macrophyte flora in the distribution of freshwater macro-invertebrate

fauna has been well documented (Pieczynska and Ozimek, 1976) and it has been stated that diverse flora are responsible for greater faunal assemblage and the establishment of stable communities, especially of insects (Boyd, 1971). The lower species diversity in the pond was mainly due to dense growth of the water hyacinth, *Eichhornea sp.*, which covered the entire pond and did not allow the other macrophytes to grow. The water hyacinths are known to survive well in extremely degraded (polluted/eutrophicated) waters.

Out of 49 taxa recorded during the course of present studies, only few were of regular occurrence contributing substantially to density and biomass in both wetlands. These included 5–6 species of gastropods, both species of oligochaetes and all the four species of Diptera.While other groups like crustaceans, odonates, hemipterans and coleopterans were represented by several species in the lake, their occurrence and abundance were extremely restricted in the pond. In fact these species of gastropods, oligochates and chironimids comprise the typical macroinvertebrate communities of highly polluted and eutrophic water bodies of the region. The oligochaetes and chironomids are well known to flourish in eutrophic or organically polluted waters and their increased density represent increasing levels of eutrophication. In pond, the oligochaetes and chironomids together contributed nearly 90% of the total macrophyte associated macroinvertebrate density. Gastropods contributed only 7.5% and rest 2.5 % was contributed by all other species. The considerably high density of chironomids and oligochates alongwith the abundance of macrophyte *Eichhornea sp.* are indicative of highly eutrophic/polluted condition of the pond. Similar conclusion based on phytoplankton primary productivity (Khan, 1981) has already been drawn.

Although these two groups also contributed significantly to the lake macroinvertebrate fauna, the contribution was considerably lesser, which was only 52% of the total density. The gastropods represented by a number of species contributed nearly 33% of the total density. The lesser contribution of oligochaetes and chironomids, significantly higher density of gastropods, occurrence of several species of insects and crustaceans alongwith diverse macrophyte flora exhibited a comparatively lower degree of eutrophication of the lake. Nevertheless, the lake too exhibited eutrophic conditions. In fact most of the waterbodies in this region are eutrophic but the degree varies, depending on the local conditions. The uniformly high temperature, greater intensity of solar radiation and absence of critical winter in this region of the country, result in high biological productivity resulting in rapid decay and consequent eutrophication (Khan, 1979, 1981).

The occurrence of gastropods was of some interest. The group was not only represented by largest number of species but also by highest density in the lake. The drastic reduction in their diversity and density in pond was probably due to monospecific strands of the macrophyte, *Eichhornia sp*, which was probably not preferred by many gastropod species.

The overall drop in the diversity and density of macrophyte associated macroinvertebrates in both lake and pond during monsoon season was probably due to flooding which resulted in

dislocation of macrophyte strands. This instability of macrophytes affected the colonisation of macrofauna.

A preliminary analysis of habitat preference in lake, where a variety of macrophyte species were available, revealed no significant preference of any plant species by any group of macrofauna. While a number of workers have reported that plants do not support specific faunal associations (Rook, 1984, Schramn *et al.*, 1987 and Korinjow, 1989), Kornijow and Gulati (1992) observed that species diversity and abundance of animal communities inhabiting the different plant species differed markedly. This requires further detailed investigations.

Excepting dissolved oxygen concentration, none of the physico-chemical parameters of water quality studied could be related to the variations in faunal abundance. The D.O. content of the pond during hot premonsoon months was very low, sometimes creating almost anoxic conditions. This has resulted in the reduction of many susceptible species and abundance of few tolerant ones belonging to Chironomidae and Gastropoda. This exhibited the tenacity of some species to tolerate the extremes of the condition in an eutrophic or organically polluted environment.

The suitability of diversity indices for the analysis of macroinvertebrate communities of freshwaters has been discussed by several workers (Whilm and Dorris, 1968; Eberhardt, 1969, Pielow, 1969, Chandler, 1970, Whilm, 1970, Cook, 1976) but none of the indices has yet been able to provide universal information. However, the community diversity index of Shannon -Wiener (Pielow, 1969) has been able to convey comparatively satisfactory information. During present investigations eight different indices were applied to draw parallel conclusions. Almost all indices pointed towards the significantly lower diversity in the pond, placing it in grossly polluted category. The analyses revealed comparatively cleaner condition of the lake.

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SUMMARY

Qualitative and quantitative diversity of macroinvertebrate fauna associated with submerged macrophytes of a large man-made lake and a medium sized highly polluted pond of Calcutta were studied for three years (1994-95, 1995-96 and 1996-97). While macrophyte flora of the lake were diverse, comprising 17 commonly occurring taxa (11 floating and 6 submerged), the pond was fully covered by monospecific strands of *Eichhornia sp.* The pond was also characterised by low dissolved oxygen and high chlorides.

Altogether 49 commonly occurring taxa of macrophyte associated macroinvertebrate fauna were recorded during the period of study from the two wetlands. These belonged to Mollusca : Gastropoda (11 species) Oligochaeta (2 species) and Hirudinea (3 species), Hydroacarina (2 species), Crustacea : Decapoda (3 species), Odonata (6 species), Hemiptera (8 species), Coleoptera (10 species) and Diptera (4 species). Gastropods were represented by the largest number of taxa followed closely by Coleoptera and Hemiptera.Wetland wise, the faunal diversity was considerably high in lake throughout the period of investigation, where 43 species were recorded, but it was significantly low in pond where only 25 species were noticed. Most of the species were common to both wetlands. Out of 25 species which occurred in pond, 17 also occurred in the lake

The total density varied between 3225/m^2 and 5993/m^2 with a mean of 4644.0 in lake and between 2198/m^2 and 6510/m^2 with a mean of 4344 in pond. Three groups, Oligochaeta, Gastropoda, and Diptera-Chironomidae formed the bulk of density in both, lake and pond. While total density in the two wetlands did not differ much, the contribution of individual group varied greatly.The contribution of oligochaetes was only 29.54% in lake but their share in pond was more than half (52.39%). Contrary to this the contribution of gastropod was considerably higher in lake (33%) than pond (7.5%). The chironomids also contributed differently in the two wetlands. The dry weight biomass in the two wetlands varied from 174.8 g/m^2 to 244.5 g/m^2 with a mean of 174.8 g/m^2 in lake and from 69.0 g/m^2 to 201 g/m^2 with a mean of 130 g/m^2 in pond. The contribution of gastropods was highest in both wetlands.

The application of diversity indices revealed considerably high diversity of lake fauna and very poor diversity of pond fauna. Very little similarity (6.48) was found between the two wetlands.

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