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Macroinvertebrate Community Assossiciations on Three Different Macrophytic Species in Manasbal Lake

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ABSTRACT

Three macrophytic species namely *Ceratophyllum demersum*, *Hydrilla verticillata* and *Potamogeton lucens* were investigated for the macroinvertebrate association in Manasbal Lake. A total of 15 macroinvertebrate taxa were reported from these macrophytic species belonging to three phyla including Annelida, Mollusca and Arthropoda. Arthropoda was the dominant phyla comprising of class Insecta, Crustacea and Arachinida. Annelida was the second dominant phyla represented by two classes Hirudinea and Oligochaeta. Mollusca were only represented by families, Lymnaeidae and Planorbidae. All the three phyla showed dominance pattern with respect to macrophytic species in the order of *Ceratophyllum demersum* followed by *Hydrilla verticillata* and then *Potamogeton lucens*. The results of study also showed that, the *Ceratophyllum demersum* comparatively harboured large density of macroinvertebrates than the other two macrophytic species, despite the fact that the total number of macroinvertebrate taxa remained the same on all the three macrophytic species thereby reflecting homogeneity of habitats. Among the insects, Chironomidae was dominant taxa on *Ceratophyllum demersum* followed by *Hydrilla verticillata* and then *Potamogeton lucens*.

Key words: Macroinvertebrate, Manasbal lake, habitat, *Ceratophyllum demersum*, *Hydrilla verticillata*, *Potamogeton lucens*

INTRODUCTION

Macrophytes are vital constituents of fluvial ecosystems. They can alter the physical conditions of water bodies, such as current velocity, substrate and detritus type, increasing the heterogeneity of the habitat for aquatic macroinvertebrates (Wetzel, 2001; Allan and Castillo, 2007). Macrophyte structural design is supposed to structure macroinvertebrate communities because design influences a plant's surface-to-biomass ratio (Feldman, 2001). Greater surface area is favourable for periphyton colonization (Duran, 2006) and may harbour more macroinvertebrates as there is precisely more habitat to use. Change in macrophytic specific composition could then in some way modify phytophilous macroinvertebrate community composition and biomass (Lalonde and Downing, 1992; Wetzel, 2001; McAbendroth *et al.*, 2005; Allan and Castillo, 2007). Macrophytes offer more surface locale attachment for periphyton, protection against visual predators and are appropriate sites for insect egg deposition (Cattaneo, 1983; Campeau *et al.*, 1994; Gosselain *et al.*, 2005). *Caulerpa prolifera* (Forsskal), a seaweed, is avoided by many of macroinvertebrates

as a habitat or feeding grounds because of the production of toxic secondary metabolites (Gab-Alla, 2007). The littoral region is of significant ecological magnitude since it is considered the main site of secondary production in lakes and having greatest macroinvertebrate richness and density (Strayer, 1985; Vadeboncoeur *et al.*, 2002). Littoral region make available three types of habitats including marshes dominated by emergent plants species, low turbulence areas populated by floating leaved macrophytes and aquatic meadows consists of species of submerged macrophytes. Submerged and floating-leaved aquatic plants have a different design offering different opportunities for epiphytes. Submerged plants provide a well illuminated substratum in the water column whereas floating plants form wide-ranging meadows but much of the substratum is unfavourable for epiphytes because it is emergent or dappled by the floating leaves. Submerged macrophytes provide more diversified setting for periphyton especially in the canopy as it contains more ecological niches than harmonized systems (Cheruvelil *et al.*, 2002; Vis *et al.*, 2006). However, emergent plants offer fewer substratums for periphyton growth, less protection against instability and higher exposure to visual predators (Gosselain *et al.*, 2005). Similarly, floating-leaved macrophytes provide little environment in the vertical aspect compared to emergent plants and reduce light dissemination into the water column, thus limiting the growth of periphyton. Differences in architecture between macrophyte species are striking, ranging from species with bare stems (simplest architecture) to species with very delineated and dissected leaves that form complex canopies (most complex architecture). Macrophytes with finely dissected leaves may support more macroinvertebrates than macrophytes with broader, undissected leaves (Cheruvelil *et al.*, 2006). As macrophyte-epiphyte complexes are the most important primary producers in the littoral zone, significant alteration of these plant assemblages could cause trophic cascades in higher trophic levels of the food web by altering phytophilous macroinvertebrate communities and the fish populations that feed on them (Downing, 1986; Bertolo *et al.*, 2005). The distribution of the macroinvertebrate community seems to be influenced by the habitat preference of the species for food, shelter and protection (Olomukoro and Nduh Tochukwu, 2006; Bhat *et al.*, 2011). Macroinveretebrate community forms an integral part of freshwater ecosystems which influences sediment (Othman *et al.*, 2002), water quality (Zorriasatein *et al.*, 2009), bottom water chemistry (Arimoro *et al.*, 2007), organic matter and structure (Aller, 1980; Pearson and Rosenberg, 1978) and serve as a major prey species for crustaceans and fish (Virnstein, 1977). In recent years applied ecologists have recognized the utility of biological monitoring, with particular attention given to survey designed to sample benthic macroinvertebrates (Rosenberg and Resh, 1993; Shokat *et al.*, 2010: Anbalagan *et al.*, 2012). Keeping in view the importance of macrophyte community composition to the dynamics of macroinvertebrates, study was carried on three macrophytes namely *Ceratophyllum demersum*, *Hydrilla verticillata* and *Potamogeton lucens* to assess the influence of habitat and macrophyte architecture of these aquatic plants on macroinvertebrate density and richness in Manasbal lake.

MATERIALS AND METHODS

Study area and sites

Manasbal lake: Manasbal Lake is located about 30 km north of Srinagar, falling in district Ganderbal. Manasbal is considered as the 'Supreme Gem of all Kashmir lakes' with lotus (*Nelumbo nucifera*). It is the deepest lake of Kashmir valley and perhaps the only one that develops stable summer stratification. It is oblong or dumbbell shaped lake measuring 3.2 km in length, 1 km in

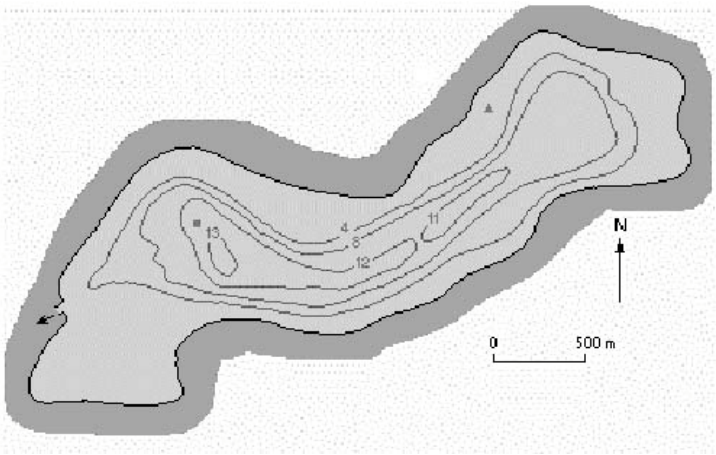

Fig. 1: Bathymetric map of Manasbal lake

breadth with mean depth of 4.5 m and catchment of 33 km^2. Manasbal is classified as warm monomictic lake and circulates once in a year for a short time. Close to the northern shore are the ruins of a fort which was built in 17th century by a Mughal king. On the south, overlooking the lake is a hillock-Ahtung which is used for limestone extraction. The eastern part is mainly mountainous and towards the north is an elevated plateau known as 'Karewa' consisting of lacustrine, fluviatile and loessic deposits. It has predominantly rural surroundings with three villages, Kundabal, Jarogabal and Gratbal overlooking the lake. The lake has no major inflow channels and the water supply is maintained through spring water inflow and precipitation. An outlet channel connects the lake with the Jhelum River. The outflow of water is regulated artificially.

The following four sites were selected in Manasbal lake for the present study (Fig. 1):

- **Site I:** This site is located towards eastern side at the Ghat (harbour for Shikaras) and is disturbed mostly due to human activities. The site lies in the littoral region of the lake and was often characterized by low transparency (Plate 1)
- **Site II:** This site is located towards northern side of the lake near the village Kundabal where Larkul enters into the lake (Plate 2). This site is marked by abundant growth of macrophytes due to its nutrient enrichment by the nearby Larkul stream. This site is thus dominated by *Ceratophyllum demersum, Hydrilla verticillata* and *Potamogeton lucens*
- **Site III:** This site is located towards the southern side of the lake near the village Jarogabal (Plate 3). It is comparatively less polluted as compared to Site I and II. This site was selected near the water lifting station in the northern side of the lake. Among the three kinds of macrophytes, *Ceratophyllum demersum* and *Hydrilla verticillata* were dominating
- **Site IV:** This site is located towards the western side of the lake near the outlet in the Nuninar area from where the water is fed to River Jhelum. This site characteristically has sparse growth of macrophytes (Plate 4)

Plate 1: Site 1 (Ghat)

Plate 2: Site 2 (Inlet -Larkul)

Plate 3: Site 3 (Towards village Kundabal)

Plate 4: Site 4 (Outlet near Nuninar)

Methods: One of the problems faced with the collection of macrophytes was at regions of high macrophyte density where even the cutter type sampler cannot prove efficient. Therefore, the collection of macrophytes was done in such a way that it could prove more efficient. Downing box sampler 30×21.2×11.5 cm was used at the sites with low macrophytic density (Downing, 1984). The sampler was slowly lowered on the vegetation strand from the boat. The macrophytes were cut in their sub-canopy region into the sampler and brought up for their package in the polythene bags meant for the purpose.

As already mentioned in the regions of high macrophytic density, the sampler does not work efficiently thus making the collection of macrophytes little bit cumbersome. So, an alternative method (Beckett *et al*., 1991) was devised. A long club (wooden rod) fitted with an iron hook at one end was used. It was lowered into water in the region of macrophytes strands and within the macrophytes strand the club was rotated so that the macrophytes get twirled or interwined with the hook of the club. Only two to three rotations of the club were sufficient to cut out quantum of macrophytes more than that required for the analysis. The club was immediately taken out of the water and the macrophytes attached with it were transferred into the polythene bags. Quadrats of size 1 m^2 were used to collect the macrophytes of a fixed area for the proper analysis of the data.

In the laboratory, 100 g of each kind of macrophyte were taken one by one in a big conical flask of 1000 mL capacity. Now about 200 mL of water was added to the flask and was vigorously shaken to dislodge the invertebrates associated with it. This process dislodged most of the macroinvertebrates associated with the macrophytes. The macrophytes were now placed in dissection trays or petri dishes to scratch those macro-invertebrates which were not dislodged due to the process of shaking in the flask. The water from the flask was passed through a sieve (0.5 mm mesh size) into a beaker so that any macroinvertebrates which may occasionally squeeze out through the sieve could be collected from the collected water. The macro-invertebrates were picked up from the sieve and the dissection tray with a fine camel hair brush and kept in 70% alcohol for preservation. Identifications were made to the lowest taxonomic level possible, using keys (Borror *et al*., 1976; Pennak, 1978; McCafferty and Provonsha, 1998; Engblom and Lingdell, 1999; Ward, 1992; Edmondson, 1992).

Statistical analysis: The data was evaluated for percentage contribution of Annelida, Mollusca and Arthropoda to the total macroinvertebrate count from the three macrophytic species. Even, it was evaluated for the percentage contribution of Chironomidae and Halidae to the total macroinvertebrate count from the three macrophytic species. Percentage contribution of order Diptera was also evaluated with the help of Microsoft excel (Analysis ToolPak).

RESULTS

A total of 15 macroinvertebrate taxa were found associated with three species of submerged macrophytes in Lake Manasbal (Table 1-3). In all 15 taxa of Macroinvertebrates, insect as well as non-insect forms were recorded from three species of macrophytes collected from four sampling sites, belonging to Annelida (Hirudinea-1 and Oligochaeta-1), Mollusca (Lymnaeidae-1 and Planorbidae-1) and Arthropoda-11 (Insecta-9, Crustacea-1 and Arachinidae-1). The species rich class Insecta is itself an assemblage of different forms extending to 5 different orders (Odonata-1, Trichoptera-1, Lepidoptera-1, Coleoptera-1 and Diptera-5). Interestingly all three macrophytes including *Ceratophyllum demersum*, *Hydrilla verticillata* and *Potamogeton lucens* shelter 15 macroinvertebrate taxa. Among the macroinvertebrates, the two numerically dominant taxa found on all the three species of macrophytes during the study period included Chironomidae sp. and Helidae sp. However, the least abundant taxa found included Tipulidae sp., Coleoptera sp. and

Table 1: Population density of macroinvertebrates associated with *Ceratophyllum demersum* (100 g FW) from four sites in Manasbal lake from September 2008-June-2009

	Months											
Macroinvertebrates	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Mean	SD
Annelida												
Hirudinea	13	15	6	4	0	5	11	12	15	19	10.0	6.0
Oligochaeta	13	9	8	1	0	7	8	11	10	14	8.1	4.6
Mollusca												
Lymnaeidae	16	12	6	0	0	0	8	12	17	20	9.1	7.5
Planorbidae	14	15	10	1	0	0	12	13	20	18	10.3	7.4
Arthropoda												
Insecta												
Odonata	10	7	7	3	4	9	11	13	13	15	9.2	4.0
Trichoptera	9	7	7	4	5	9	8	11	12	13	8.5	2.9
Lepidoptera	5	4	7	7	4	7	12	11	9	11	7.7	2.9
Coleoptera	5	3	6	5	3	8	8	9	8	10	6.5	2.5
Diptera												
Chironomidae	151	120	98	77	59	76	111	144	195	196	122.7	48.2
Culicidae	9	9	8	7	5	8	13	11	12	14	9.6	2.8
Rhagionidae	11	5	10	5	3	8	8	5	11	15	8.1	3.7
Tipulidae	4	8	7	5	3	11	10	5	4	7	6.4	2.7
Helidae	33	24	22	22	15	28	39	38	46	47	31.4	10.9
Crustacea												
Gammarus	10	8	7	10	7	7	12	9	11	15	9.6	2.6
Arachinidae												
Mites	7	9	2	8	6	2	12	6	9	16	7.7	4.2

Table 2: Population density of macroinvertebrates associated with *Hydrilla verticillata* (100 g FW) from four sites in Manasbal lake from September 2008-June-2009

	Months											
Macroinvertebrates	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Mean	SD
Annelida												
Hirudinea	11	6	4	1	0	7	6	7	12	17	7.1	5.1
Oligochaeta	10	6	6	10	0	5	3	4	8	10	6.2	3.4
Mollusca												
Lymnaeidae	10	4	0	0	0	2	6	6	13	12	5.3	5.0
Planorbidae	12	8	2	0	0	4	11	11	17	14	7.9	6.1
Arthropoda												
Insecta												
Odonata	11	8	9	10	3	7	9	11	15	18	10.1	4.1
Trichoptera	9	6	9	7	6	9	10	7	12	16	9.1	3.1
Lepidoptera	8	5	8	6	2	6	8	5	9	14	7.1	3.2
Coleoptera	6	3	4	5	2	7	4	4	9	12	5.6	3.0
Diptera												
Chironomidae	104	85	89	76	56	71	85	90	138	158	95.2	30.9
Culicidae	28	19	30	22	4	10	11	8	19	24	17.5	8.8
Rhagionidae	20	9	13	4	0	7	8	5	17	20	10.3	6.9
Tipulidae	11	8	10	1	4	7	4	6	10	13	7.4	3.7
Helidae	54	32	33	30	9	24	44	41	39	53	35.9	13.5
Crustacea												
Gammarus	11	6	9	7	4	4	9	10	10	15	8.5	3.4
Arachinidae												
Mites	10	3	4	5	2	3	9	9	9	19	7.3	5.1

Lymnaeidae sp. were found to be associated with *Ceratophyllum demersum, Hydrilla verticillata and Potamogeton lucens*, respectively (Table 1-3). Population density of macroinvertebrates associated with *Ceratophyllum demersum, Hydrilla verticillata* and *Potamogeton lucens* (100 g FW) from four sites in Manasbal lake (Table 1-3). Population density of macroinvertebrates associated with *Ceratophyllum demersum* ranged from a maximum of 196 ind./100 g FW in the month of May to a minimum of 1 ind./100 g FW in the month of December. However, population density of macroinvertebrates associated with *Hydrilla verticillata* varied from a maximum of 158 ind./100 g FW in the month of June to a minimum of 1 ind./100 g FW in the month of December. While, in case of *Potamogeton lucens* population density of macroinvertebrates varied from a maximum of 171 ind./100 g FW in the month of June to a minimum of 1 ind./100 g FW in the month of December and January, respectively (Table 1-3).

Total macroinvertebrate density was greatest on *Ceratophyllum demersum* (2649 ind./100 g FW) followed by *Hydrilla verticillata* (2405 ind./100 g FW) and then *Potamogeton lucens* (2032 ind./100 g FW) (Table 4). Annelida abundance ranged from a high of 6.8% on *Ceratophyllum demersum* and with lowest value of 5.5% on *Hydrilla verticillata*. Mollusca showed its maximum value of 7.3% on *Ceratophyllum demersum* and lower value of 4.5% on *Potamogeton lucens*. While Arthropoda abundance ranged from a high of 89.7% on *Potamogeton lucens* to a low of 85.8% on *Ceratophyllum demersum*. Insecta, Crustacea and Arachinidae contributed more than 85% in each case (Fig. 2). However, the most dominant order Diptera reported from all the three macrophytic species showed highest abundance ranging from 71.5% on *Potamogeton lucens,*

69.1% on *Hydrilla verticillata* and 67.2% on *Ceratophyllum demersum* (Fig. 3). Two taxa (Chironomidae and Helidae) comparatively exhibited high densities on macrophytes. Total mean

Table 3: Population density of macroinvertebrates associated with *Potamogeton lucens* (100 g fresh wt.) from four sites in Manasbal lake from September 2008-June-2009

	Months											
Macroinvertebrates	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Mean	SD
Annelida												
Hirudinea	5	5	3	1	0	7	6	7	12	14	6.0	4.4
Oligochaeta	7	3	5	8	0	7	4	7	6	8	5.5	2.5
Mollusca												
Lymnaeidae	4	0	0	0	0	0	4	6	7	15	3.6	4.9
Planorbidae	4	4	2	0	0	2	8	9	13	14	5.6	5.1
Arthropoda												
Insecta												
Odonata	9	3	9	6	3	9	9	10	12	14	8.4	3.5
Trichoptera	7	5	5	2	3	9	5	5	13	15	6.9	4.2
Lepidoptera	4	3	6	3	0	8	6	4	8	13	5.5	3.6
Coleoptera	2	1	3	3	0	5	3	4	7	9	3.7	2.7
Diptera												
Chironomidae	66	74	66	65	46	69	83	110	157	171	90.7	42.0
Culicidae	11	1	11	11	0	8	11	9	14	18	9.4	5.4
Rhagionidae	11	1	10	1	0	6	6	7	14	18	7.4	5.9
Tipulidae	6	1	7	1	3	6	4	7	11	19	6.5	5.3
Helidae	35	21	28	23	6	22	39	39	42	58	31.3	14.4
Crustacea												
Gammarus	4	0	6	5	4	3	7	8	10	14	6.1	3.9
Arachinidae												
Mites	9	5	7	4	1	2	8	9	7	14	6.6	3.8

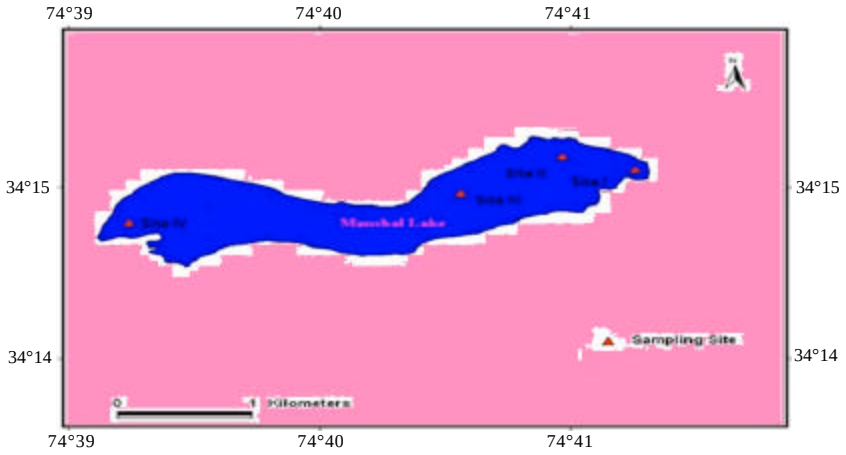

Fig. 2: Map showing different sampling sites

Table 4: Total Mean Density of macroinvertebrates associated with *Ceratophyllum demersum, Hydrilla verticillata* and *Potamogeton lucens* (100 g FW) in Manasbal lake from September 2008- June- 2009

Macroinvertebrates	*Ceratophyllum demersum*	*Hydrilla verticillata*	*Potamogeton lucens*
Annelida			
Hirudinea	100	71	60
Oligochaeta	81	62	55
Mollusca			
Lymnaeidae	91	53	36
Planorbidae	103	79	56
Arthropoda			
Insecta			
Odonata	92	101	84
Trichoptera	85	91	69
Lepidoptera	77	71	55
Coleoptera	65	56	37
Diptera			
Chironomidae	1227	952	907
Culicidae	96	175	94
Rhagionidae	81	103	74
Tipulidae	64	74	65
Helidae	314	359	313
Crustacea			
Gammarus sp.	96	85	61
Arachinidae			
Mites	77	73	66
Total (A+M+A)	2649	2405	2032

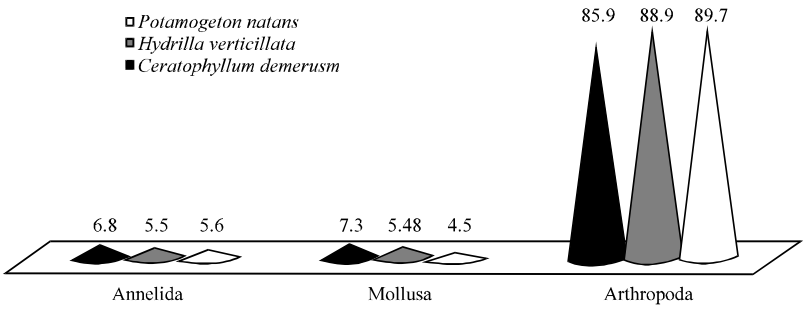

Fig. 3: Percentage contribution of Annelida, Mollusca and Arthropoda to the total macroinvertebrate count from *Ceratophyllum demersum, Hydrilla verticillata* and *Potamogeton natans* in Manasbal lake from September 2008 to June 2009

density of Chironomidae ranged from a high of (1227 ind./100 g FW) on *Ceratophyllum demersum* to a low of (907 ind./100 g FW) on *Potamogeton lucens*. However, percentage contribution of Chironomidae to the macroinvertebrate count from three different macrophytes was of the order of 46.3% on *Ceratophyllum demersum* and 39.5% on *Hydrilla verticillata* (Fig. 4). In case of Helidae percentage contribution to the macroinvertebrate count from three different macrophytes was of the order of 11.8% on *Ceratophyllum demersum*, 14.9% on *Hydrilla verticillata*

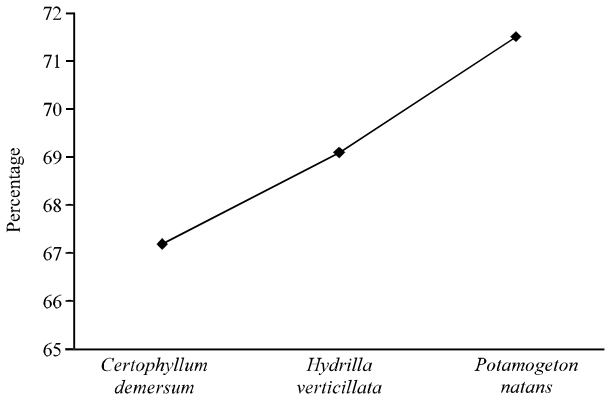

Fig. 4: Percentage contribution of order Diptera to the total macroinvertebrate count from *Ceratophyllum demersum*, *Hydrilla verticillata* and *Potamogeton natans* in Manasbal lake from September 2008 to June 2009

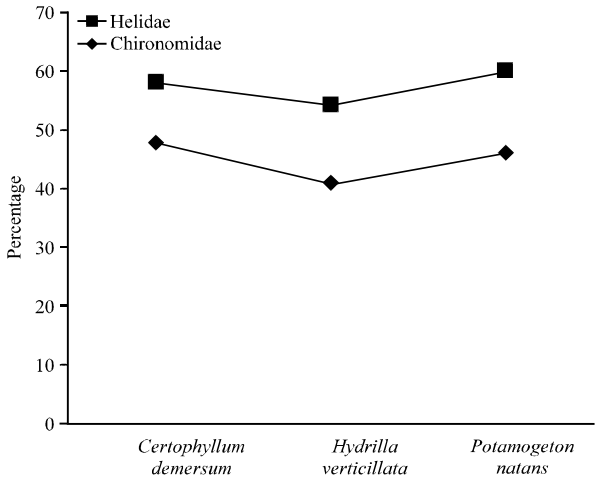

Fig. 5: Percentage contribution of Chironomidae and Helidae to the total macroinvertebrate count from *Ceratophyllum demersum*, *Hydrilla verticillata* and *Potamogeton natans* in Manasbal lake from September 2008 to June 2009

and 15.4% on *Potamogeton natans* (Fig. 5). The remaining groups comprised less density on macrophytes as compared to the Chironomidae and Helidae. Density of Hirudinea ranged from a maximum of (100 ind./100 g FW) on *Ceratophyllum demersum* to a minimum of (60 ind./100 g FW) on *Potamogeton lucens*. Oligochaeta density varied from a maximum of (81 ind./100 g FW) on *Ceratophyllum demersum* to a minimum of (55 ind./100 g FW) on *Hydrilla verticillata*. Lymnaeidae had their highest density of (91 ind./100 g FW) on *Ceratophyllum demersum* and lowest density (36 ind./100 g FW) on *Potamogeton lucens*. Density of Planorbidae showed a highest value for its density (103 ind./100 g FW) on *Ceratophyllum demersum* and lowest value of (56 ind./100 g FW) on *Potamogeton lucens*. Odonata density showed highest peak value of density (101 ind./100 g FW) on Hydrilla verticillata and low density of (84 ind./100 g FW) on *Potamogeton lucens*. Trichoptera represented their maximum value of density (91 ind./100 g FW) on *Hydrilla verticillata* and low of (69 ind./100 g FW) on

Potamogeton lucens. Lepidoptera showed density from (77 ind./100 g FW) on *Ceratophyllum demersum* to (55 ind./100 g FW) on *Potamogeton lucens*. Coleoptera was the least represented order and showed density values ranging from maximum value of (65 ind./100 g FW) on *Ceratophyllum demersum* and minimum of (37 ind./100 g FW) on *Potamogeton lucens*. The most dominant order Diptera exhibited highest value of density (1686 ind./100 g FW) on *Ceratophyllum demersum* and to a low of (1453 ind./100 g FW) on *Potamogeton lucens*. Crustacea density values were found to range from a high value of (96 ind./100 g FW) *Ceratophyllum demersum* and to a low of (61 ind./100 g FW) on *Potamogeton lucens*. Density of Arachinidae was found to show a maximum value of (77 ind./100 g FW) on *Ceratophyllum demersum* and a minimum value of (66 ind./100 g FW) on P*otamogeton lucens* (Table 4).

Population density of phylum Annelida varied from 19 ind./100 g FW in June to 1 ind./100 g FW in December on *Ceratophyllum demersum*. However, in case of *Hydrilla verticillata* population density showed its peak value of 17 ind./100 g FW in June and lowest of 1 ind./100 g FW was recorded in December. Similarly, in case *Potamogeton lucens* population followed the same trend with highest value of 14 ind./100 g FW in June and lowest of 1 ind./100 g FW in December. Phylum Annelida was found altogether absent in the month of January from all the three macrophytes. Total mean density of Annelida was reported to be highest on *Ceratophyllum demersum* (181 ind./100 g FW) and least on *Potamogeton lucens* (115 ind./100 g FW) (Table 4). The percentage contribution of Annelida to the population density of macroinvertebrate counted from the three macrophytes was found to be of the order of 6.8% on *Ceratophyllum demersum,* 5.5% on *Hydrilla verticillata* and 5.6% on *Potamogeton lucens*, respectively. However, the overall percentage contribution of Annelida was reported as 6% to the total macroinvertebrate population recorded during the study period (Fig. 3).

Phylum Mollusca showed highest value for population density of 20 ind./100 g FW in May and June to 1 ind./100 g FW in the month of December on *Ceratophyllum demersum*. Population density varied over a maximum range of 17 ind./100 g FW in May and to a low of 2 ind./100 g FW in the month of November on *Hydrilla verticillata*. Similarly, in case of *Potamogeton lucens* population density varied from a maximum of 15 ind./100 g FW in June and to a minimum of 2 ind./100 g FW in the month of November and February, respectively. Mollusca was found altogether absent in the month of January. The total mean density of Mollusca showed highest value of (194 ind./100 g FW) on *Ceratophyllum demersum* and lowest value of (92 ind./100 g FW) on *Potamogeton lucens* (Table 4). The percentage contribution of Mollusca to the population density of macroinvertebrates from the three individual macrophytes was reported as 7.3% on *Ceratophyllum demersum*, 5.5% on *Hydrilla verticillata* and 4.5% on *Potamogeton lucens*, respectively. However, the overall contribution of Mollusca was found to be of the order of 6% total the total macroinvertebrate count from the three species of macrophytes (Fig. 3).

Phylum Arthropoda showed highest value for population density of 196 ind./100 g FW in June and to a maximum of 2 ind./100 g FW in the month of November on *Ceratophyllum demersum*. Population density varied over a maximum range of 158 ind./100 g FW in June and to a low of 1 ind./100 g FW in the month of December on *Hydrilla verticillata*. Similarly, in case of *Potamogeton lucens* population density varied from a maximum of 171 ind./100 g FW in June and to a minimum of 1 ind./100 g FW in the month of October and December, respectively (Table 1-3). The total mean density of Arthropoda showed highest value of (2274 ind./100 g FW) on *Ceratophyllum demersum* and lowest value of (1825 ind./100 g FW) on *Potamogeton lucens* (Table 4). The percentage contribution of Arthropoda to the population density of

macroinvertebrates from the three individual macrophytes was reported as 85.8% on *Ceratophyllum demersum,* 88.9% on *Hydrilla verticillata* and 89.8% on *Potamogeton lucens*, respectively. However, the overall contribution of Arthropoda was found be of the order of 87.9% total the total macroinvertebrate count from the three species of macrophytes (Fig. 3).

DISCUSSION

This study work studied the aquatic macrophyte influence on the diversity of macroinvertebrates in Lake Manasbal, a hydrosystem invaded by the floating and submerged macrophytes. Though, invertebrate species composition was generally similar in association with *Ceratophyllum demersum, Hydrilla verticillata* and *Potamogeton lucens,* yet differences in invertebrate abundance occurred for the taxonomic groups. Although, each macrophyte does not appear to have a characteristic fauna associated with it, different submersed plants do provide a specific substratum or resource that can be utilized by different types of invertebrates (Krecker, 1939). Differences in epiphytic algae and invertebrates among submerged macrophytes have been previously observed and mostly ascribed to the degree of plant dissection (Cattaneo and Kalff, 1980; Cyr and Downing, 1988; Lalonde and Downing, 1991; Pennak, 1966). Submerged macrophytes provide oxygen during day time and remove toxic factors such as ammonia and carbon dioxide. Thus, the densities of both the zooplankton and other invertebrates are generally higher among the macrophyte communities than in the open water (Soszka, 1975).

The total density of macroinvertebrates found in the microhabitat created by *Ceratophyllum demersum* was slightly higher than that found *Hydrilla verticillata* and *Potamogeton lucens* macrophyte habitat. *Ceratophyllum demersum* form bowl-shaped whorls set tightly together, particularly near the tip of the stem. The abundance of epiphytic invertebrates on aquatic macrophytes can be influenced by different plant architecture types (Cheruvelil *et al.*, 2006).

The most abundant insects on submerged macrophytes were Chironomidae (Diptera) showing maximum density on *Ceratophyllum demersum* followed by *Hydrilla verticillata* and then *Potamogeton lucens*. Chironomidae occupy many trophic levels, some feed mainly on periphyton, some mine macrophytes and others are predaceous (Dvorak and Best, 1982; Merritt and Cummins, 1984; Giovani *et al.*, 1996). Chironomidae is almost always found to be numerically predominant, both in lotic and lentic environments, due to its tolerance to extreme conditions. The range of conditions under which chironomids are found is more extensive than that of any other group of aquatic insects and their wide ecological amplitude related to the very extensive array of morphological, physiological and behavioral adaptations (Merritt and Cummins, 1996; Berg, 1938). Among the non-insect arthropoda, crustacean amphipod *Gammarus* sp. does not show any significant density on all the three macrophytes. This may be attributed to their low reproductive potential with a yearly production of about 100 eggs per female (Hynes, 1955; McGaha, 1952).

Both phylum Annelida and Mollusca showed the same trend for dominance with highest density on *Ceratophyllum demersum,* followed by *Hydrilla verticillata* and then *Potamogeton lucens* likely to be as a result of the greater surface area provided by the vegetation types (Krull, 1970; Downing, 1981; Harrod, 1964). Increased surface area of vegetation may provide protection from predators and more substrate for growth of periphytic algae which is an important food source of many invertebrates (Cattaneo and Kalff, 1980; Harrod, 1964; Merritt and Cummins, 1984; Vis *et al.*, 2006); Cheruvelil *et al*, 2002). Invertebrates utilize plants as a direct food source, sites for oviposition and sources of respiratory oxygen (Cattaneo, 1983; Krecker, 1939; Campeau *et al.*, 1994; Gosselain *et al.*, 2005).

CONCLUSION

In conclusion, this study demonstrates that the plant architecture is having slight effect on density and development of epiphytic organisms. *Ceratophyllum demersum* having more surface area than the other two macrophytes, because of its dissected leaves and forms bowl shaped whorl set near the tip of the stem supports large number macroinvertebrate individuals. This difference does not seem to be attributable to plant-related variation in plant structure but is more likely to be related to variation in available periphyton food resources.

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