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Diversity and Density Patterns of Macroinvertebrates on Different Macrophytes in Dal Lake, Kashmir

Imadiya Javaid[1], Inam Sabha[1], Umara Qayoom[1] and Sami Ullah Bhat[1]*

[1]Department of Environmental Science, School of Earth and Environmental Sciences, University of Kashmir, Hazratbal, Srinagar-190006, J&K, India

***Corresponding author's email**: samiullahbhat11@gmail.com.

ABSTRACT

The present study was carried out during June - October, 2013 to see how differently macroinvererterbates colonise macrophytes in Dal Lake. For the purpose seven macrophytic species namely *Ceratophyllum demersum, Chara* sp., *Hydrilla vercillata, Myriophyllum spicatum*, *Potomogeton lucens, Potomogeton natans* and *Utricularia* sp. were investigated for the associated macroinvertebrates. The study revealed a total of 14 macroinvertebrate taxa belonging to three phyla Arthropoda, Annelida and Mollusca. Arthropoda being the most prominent phyla was represented by class Insecta and Arachinida. Class Insecta represented by 10 taxa contributing majority, whereas Class Arachnida was represented by only one taxa. Mollusca was the second dominant phyla represented by two families: Physidae and Planorbidae. The least prominent phyla Annelida was represented by just 1 order (Rhynenobdella) of class Hirudinia. The detritus feeding Annelida showed their presence on *Potamogeton natans*. Among the insects, Chironomidae larvae were much more diverse showing higher density on *Ceratophyllum demersum* followed by *Potamogeton lucens, Potamogeton natans* and then *Hydrilla verticellata.* The highest number of taxa was observed on *Potomogeton natans* (11) and highest mean number of individuals was observed on *Ceratophyllum demersum* (92.60). Biodiversity index result showed Shannon wiener diversity index and Simpson index was highest for *Potamogeton natans* and lowest for *Chara* sp. Principal component analysis of the data resulted in two PCs with eigen values greater than 1, which explained 83 percent of the variance in the data. The first two PCs explained 56.7 and 24.9 percent of the variance, respectively.

Key words: *Arthropoda, Annelida, Density, Macroinvertebrates, Macrophytes, Mollusca*

INTRODUCTION

Macrophytes constitute an important component of aquatic ecosystems. They play important role in maintaining the functioning and biodiversity, besides providing habitat to a large number of invertebrate fauna associated with them. (Scheffer, 1998). Aquatic vegetation provides habitat to several species belonging to various taxa like Arthopoda, Annelida and

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Mollusca (Habib and Yousuf, 2014). Floating and submerged macrophytes are especially important with regards to the energy dynamics of aquatic ecosystem besides providing shelter to a number of macroinvertebrates. Many species of macroinvertebrate which are of special concern are also being harbored by macrophytes. Macroinvertebrates consume macrophytes directly as food (Gregg and Ross, 1985). They also use the periphyton attached on the surface of these plants as a source of food (James *et al*., 2000; Hillebrand, 2002).

Some of the characteristics of macrophytes like architecture of leaves and growth habit of plant affect diversity, abundance and community composition of macro-invertebrates (Sharma *et al.,* 2015). Many macroinvertebrates show some sort of "preference" or substrate association for some specific macrophytes depending on the pants architecture, density (Dvorak and Best, 1982; Cyr and Downing, 1988), composition and abundance (Rooke 1986; Dudley 1988; Cattaneo *et al.,* 1998). From the ecological point of view, the littoral zone of a lake is of great ecological importance (Brinkhurst, 1974; Vadeboncoeur *et al.,* 2002). These vegetation sites have more diversity as well as richness in macoinvetebrates than those in open water (Olson *et al*., 1994; Savage and Beaumont, 1997).

Macrophytes also have some importance with regards to the habitat structure of an aquatic ecosystem (Danielle and Barmuta, 2004; McAbendroth *et al.,* 2005). They have been increasingly used to bio-monitor aquatic systems as they are immobile and cannot leave the substrate on which they are attached. This gives them the ability to tolerate unfavorable environmental conditions and indicate both short as well as long term hydrological stresses (Moore *et al.,* 2012). Macroinvetebrates in turn have also their importance with regards to food web interactions, comprising fish and birds (McQueen *et al.,* 1986; Cyr and Downing, 1988; Batzer *et al.,* 1993). Aquatic invertebrates have served as an effective biological indicator for decades but amongst these entomofauna has been found to be a much more stable and reliable indicator of pollution. The present work is an attempt to see the effect of the architecture of macrophytes on diversity and density pattern of macroinvetebrates. The Dal Lake is for most part infested with macrophytes of the four recognized categories, viz., submerged, rooted free floating leaf, emergent and free floating types. A total of 31 species of macrophytes have been reported from the lake (Qadri and Yousuf, 2008). The macrophytes like *Ceratophylum demersum, Potamogeton lucens, Potamogeton natans, Myriophyllum spicatum, Hydrilla verticillata, Utricularia* sp.and *Chara* sp. are the most prominent ones that are found in the lake. These submerged macrophytes with their characteristic finely dissected and densely packed leaves provide an adequate shelter and food source for macro-invetebrates (Lillie and Budd, 1992; Thorp *et al.,* 1997; Balci and Kennedy, 2003). Although, each macrophyte does not appear to have a characteristic fauna associated with it, different submerged plants do provide a specific substratum that can be utilized by different types of invertebrates (Krecker, 1939).

MATERIAL AND METHODS

Study area and study site

Dal lake of Kashmir is situated in the north–east of Srinagar at a latitude of 34^o 07’ N latitude and longitude of 74^{o}52’ E at an altitude of 1584 m above mean sea level. For the present study, four sampling sites of Dal Lake were selected. These sites are:

I) Hazratbal basin

This site is located within the Hazratbal Basin of Dal Lake (34^0 07′ 59.4″ N and 74^0 51′ 27.6″ E). It is severely infested with *Nymphoides peltata, Ceratophyllum demersum*, *Myriophyllum spicatum, Hydrilla verticillata* and *Potamogeton crispus. Ceratophyllum demersum* and *Potamogeton natans* which were collected from this site.

II) Nishat basin

This site is located within the Nishat Basin of Dal Lake close to the aeration pumps installed in the Lake just in front of the famous Nishat Garden (34^0 08’ 30.5” N and 74^{0}51′ 42.0” E). The area supports thick macrophyte growth of both submerged and floating macrophytes dominated by *Myriophyllum spicatum, Ceratophyllum demersum* and *Salvinia* sp. *Hydrilla verticillata* and *Potamogeton lucens* which were collected from this site.

III) Gagribal basin

This site lies within the Gagribal basin of Dal Lake between geographical coordinates of 34^0 05′25.5″N latitude and 75^0 51′05″E longitude. It is located in the centre of the basin. This site is quite open and is visited by tourists in Shikaras. *Myriophyllum spicatum* and *Utricularia* sp. were collected from this site.

IV) Gagribal basin

This site also lies within the Gagribal basin of Dal Lake between geographical coordinates of 34^0 55.1′N latitude and 74^0 51′E longitude. The site is surrounded by a number of houseboats. *Chara* sp. was collected from this site.

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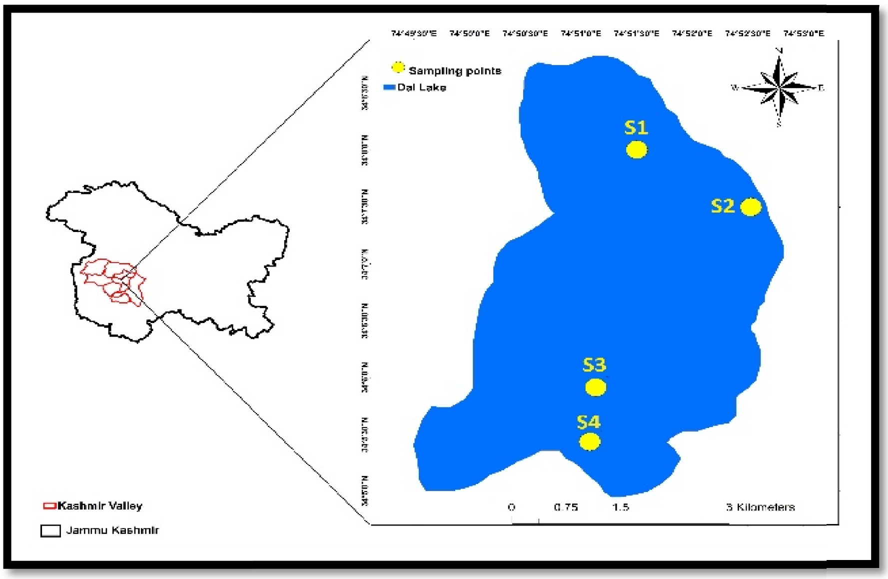


Fig.1. Satellite image of study area and study sites.

Methodology

The first and foremost aim of the present study was to obtain the baseline data on the diversity and density of the macroinvetebrates associated with different species of macrophytes i.e., *Hydrilla vercillata, Ceratophyllum demersum, Potomogeton natans, Potomogeton lucens, Myriophyllum spicatum*, *Chara* sp. *and Utricularia* sp. This necessitated the macrophytes to be brought to the laboratory from the sampling station. This was done by collecting the macrophytes in properly labelled transparent polythene bags which are light in weight and easy to transport. Macrophytes were collected by using a long club (wooden rod) fitted with an iron hook at one end. 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 inter-wined with the hook of the club (modified after Beckett *et al.,* 1991). 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 1m^2 were used to collect the macrophytes of a fixed area for the proper analysis of the macro invertebrates. In the laboratory, 100 g of each kind of macrophyte were taken one by one in a big flask of 1000 ml capacity. 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 macroinvetebrates associated with macrophytes. The macrophytes were then placed in dissection trays or petridishes to scratch those macroinvetebrates which were not dislodged due to the process of shaking in the flask. The water from the flask was passed through a sieve (0.5mm mesh size) into a beaker so that any macroinvetebrates which may occasionally squeeze out through the sieve could be collected from the collected water. Macroinvetebrates were picked up from the sieve and the dissection tray with a fine camel hair brush and were preserved in 10% formalin in properly labeled photographic film vials. The macroinvetebrates of each kind associated with a particular type of macrophytes were counted and preserved in the same vial. The identification of the macroinvetebrates was done by the help of standard taxonomic keys (Pennak, 1978; Mc Cafferty and Provonsha, 1981; Edmondson, 1992; Ward, 1992).

RESULTS AND DISCUSSION

A total number of 14 taxa of macroinvetebrates level were recorded from 7 macrophytic species of Dal Lake. The macroinvetebrate taxa belonged to 3 phyla were spread over 6 orders and 10 families. Annelida was represented by 1 order (Rhynenobdella) of class Hirudinia. Mollusca represented by 2 taxa (*Physella* sp. and *Gyraulus* sp.). Phylum Arthropoda was represented by 11 taxa, 10 taxa represented by only class Insecta. Class Arachnida was represented by 1 taxa (*Dolomedes* sp.) from the order Arenae. Class Insecta contributed majority of class forms with 10 taxa belonging to 3 different orders i.e., Diptera (8 species), Odonata (1 species) and Lepidoptera (1 species). Among 14 taxa of macro-inverebrates, Insecta was the most abundant group, dominated by species *Chironomidae, Diamesinae* sp. followed by *Bezzia* sp. and *Enallgma* sp. The highest number of taxa was observed on *Potomogeton natans* (11) followed by *Ceratophyllum demersum* (10), *Hydrilla verticella* (7), *Potomogeton lucens* (5), *Myriophyllum spicatum* and *Utricularia* sp. share same number of taxa (2) whereas, lowest number of taxa was found on *Chara* sp.(1)(Fig.1). During the study highest mean number of individuals was observed on *Ceratophyllum demersum* (92.60) followed by *Potomogeton natans* (63.20), *Potomogeton lucens* (57.30), *Hydrilla verticella* (43.40), *Myriophyllum spicatum* (8.00), *Chara* sp.(7.50) and lowest mean individuals was found on *Utricularia* sp. (4.50)(Fig.2).

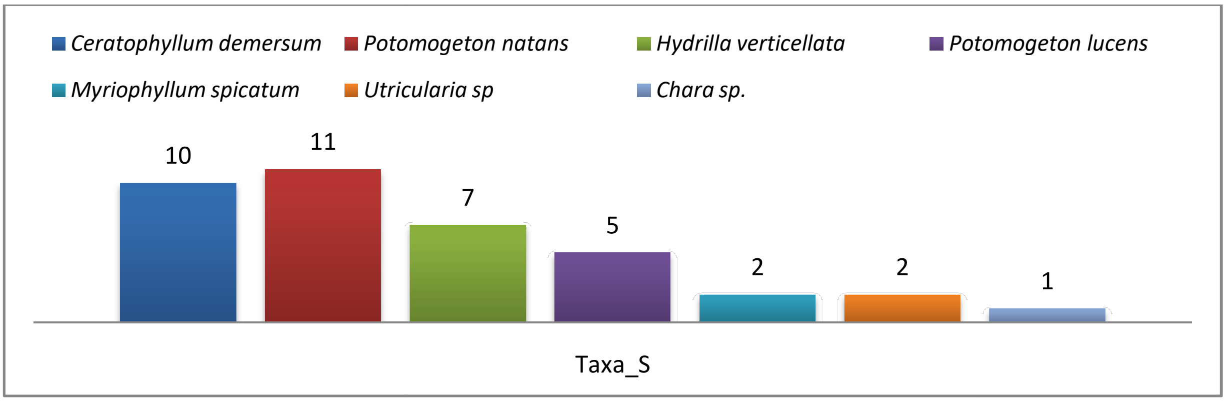


Fig. 1. Total number of taxa present during the study

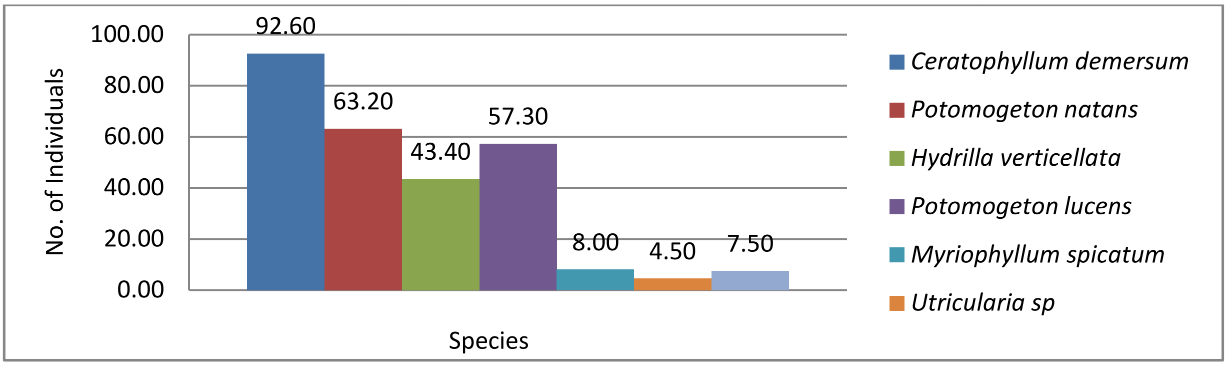


Fig. 2. Total number of mean individuals present during the study.

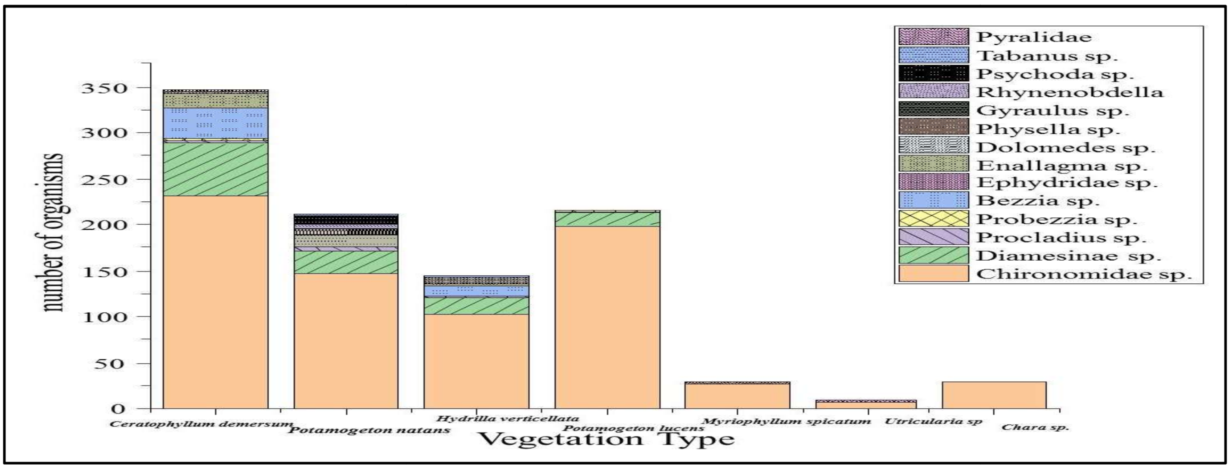
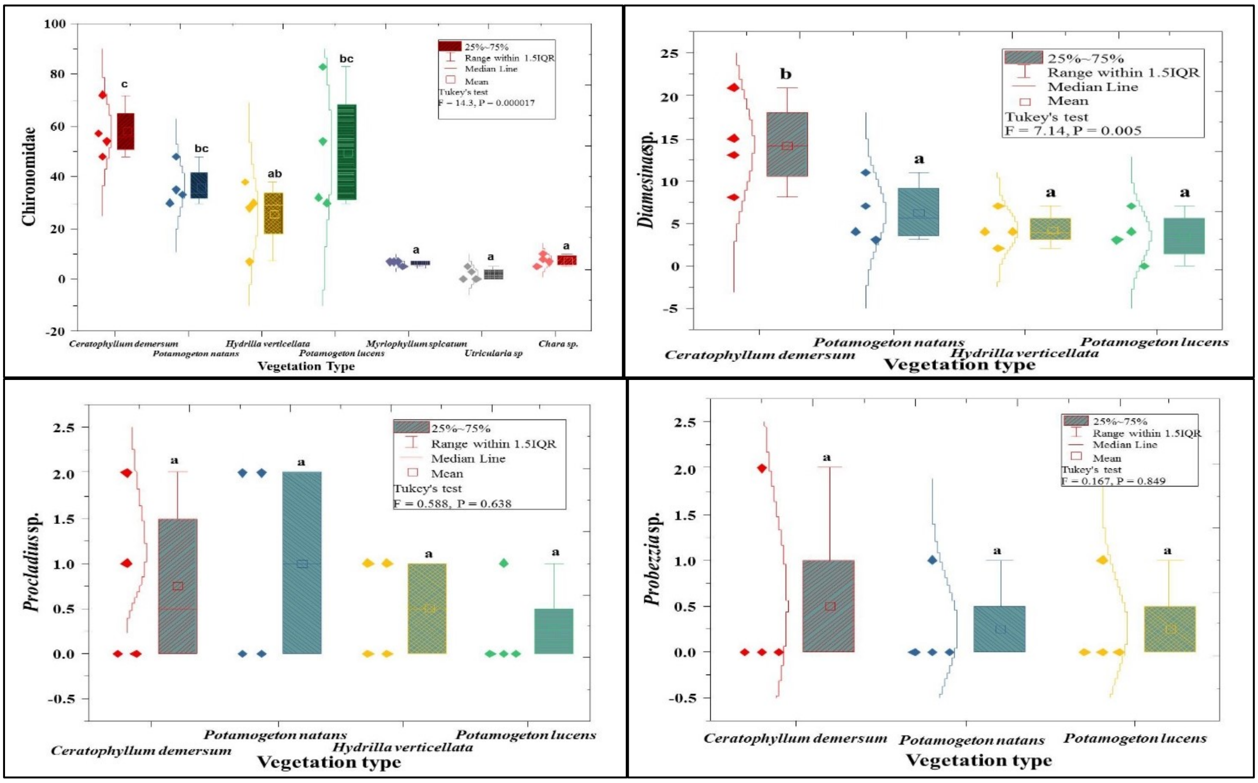


Fig. 3. Number of macroinvertebrates associated with vegetation type

During the study it was observed that *Chironomidae* sp. was the most abundant specie associated with all the seven macrophytes followed by *Diamesinae* sp. and *Procladius* sp. which was harbored by four macrophytes (*Ceratophyllum demersum, Potamogetan natans, Hydrilla verticellata* and *Potamogeton lucens*). Taxa *Physella* sp. was allied with four macrophytes namely (*Ceratophyllum demersum*, *Potam-ogeton natans, Hydrella verticellaria* and *Myriophyllum spicatum*). Whereas, taxa *Tabanus* sp. was found to be associated with three macrophytes only (*Potamogeton lucens, Hydrilla verticellata and Potamogeton natans*). Similarly taxa *Enallagma* sp. was associated with three macrophytes (*Ceratophyllum demersum, Potam-ogeton natans*, *Hydrilla verticellata*). Whereas, *Bezzia* sp. was associated with two macrophytes (*Hydrilla verticellata* and *Ceratophyllum demersum*). Probezzia sp. was also associated with two macrophytes only (*Ceratopyllum demersum* and *Potamogeton lucens*). Some of the macroinvertebrate taxa were harboured by only single macrophytic species such as *Psychoda* sp., *Gyraulus* sp., *Rhynenobdella* sp. and *Dolomedes* sp. were allied with only one macrophyte (*Potamogeton natans*). Similarly *Pyralidae* sp. was associated with (*Urticularia* sp.) and *Ephydridae* sp. was associated with (*Ceratophyllum demersum*) only (Fig.3 & 4).



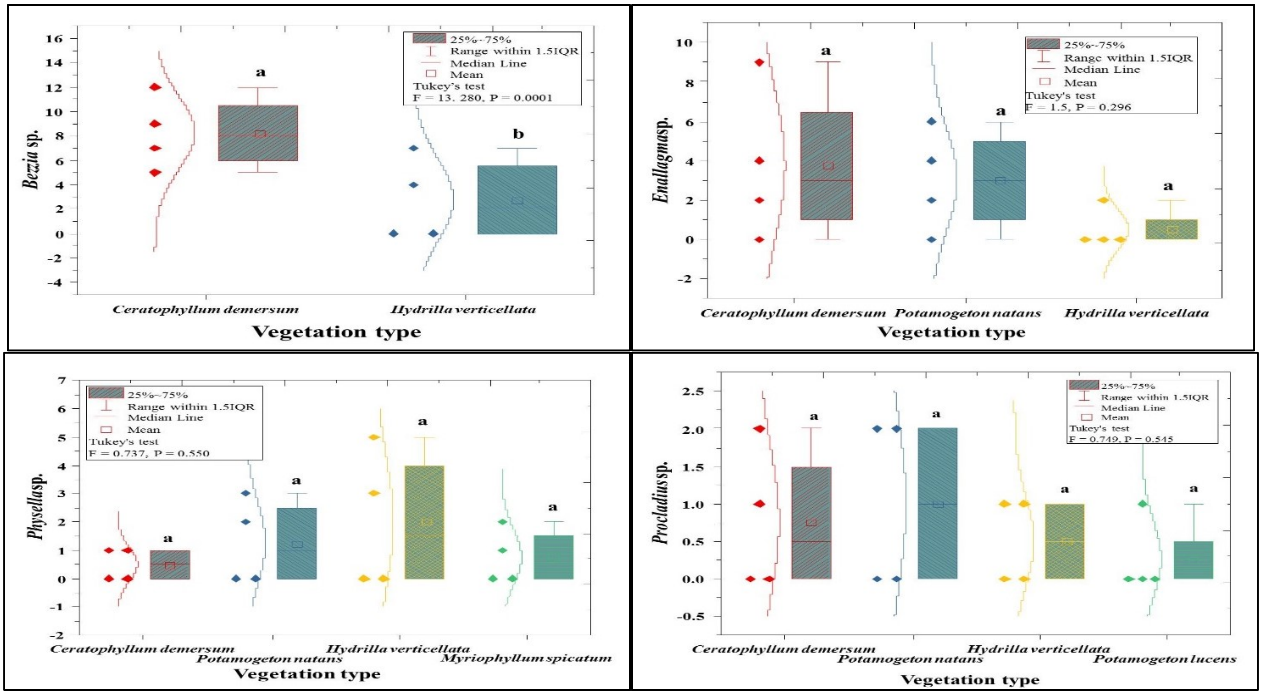


Fig.4. Box plot showing range, mean and ANOVA (Tukey's test) of macroinvertebrates across different vegetation type (dissimilar letters show significant variation).

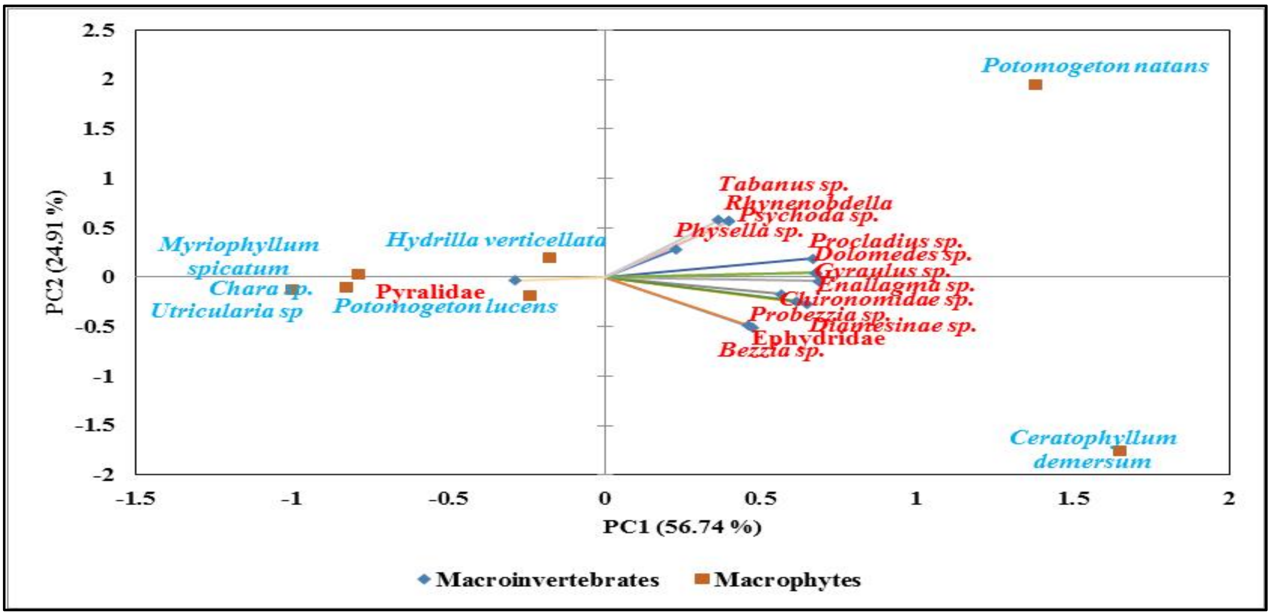


Fig. 5. Biplot of macroinvertebrate and macrophyte data from all samples

Table 1. Loadings of environmental variables on the first two principal components (PC) derived from principal components analyses of macroinvertebrate and macrophyte data from all samples (Boldfaced values, absolute value of loading were considered high).

Eigenvalue/Variability	PC1	PC2
Eigenvalue	7.943	3.488
Variability (%)	56.738	24.914
Cumulative %	56.738	81.652
Macroinvertebrates	PC1	PC2
Chironomidae sp.	**0.801**	0.244
Diamesinae sp.	**0.916**	0.380
Procladius sp.	**0.941**	-0.261
Probezzia sp.	**0.869**	0.343
Bezzia sp.	0.648	**0.691**
Ephydridae sp.	0.672	**0.718**
Enallagma sp.	**0.972**	0.061
Dolomedes sp.	**0.957**	-0.061
Physella sp.	0.325	-0.398
Gyraulus sp.	**0.957**	-0.061
Rhynenobdella sp.	0.563	**-0.797**
Psychoda sp.	0.563	**-0.797**
Tabanus sp.	0.516	**-0.814**
Pyralidae sp.	-0.408	0.051
Vegetation type		
Ceratophyllum demersum	**4.642**	3.283
Potamogeton natans	**3.889**	-3.646
Hydrilla verticellata	-0.498	-0.363
Potamogeton lucens	-0.679	0.344
Myriophyllum spicatum	**-2.215**	-0.043
Utricularia sp.	**-2.813**	0.234
Chara sp.	**-2.324**	0.191

Investigation of the factor loadings of the macroinvertebrates and macrophytes on the first two PCs of the data sets revealed that relationship existing between habitat gradients potentially affected epiphytic macro-invertebrates. Principal components analysis of the data resulted in two PCs with eigen values greater than 1, which explained 83 percent of the variance in the data. The first two PCs explained 56.7 and 24.9 percent of the variance, respectively. The first principal component represents a gradient in *Ceratophyllum demersum, Potamogeton natans* and correlated macro-invertebrates. No macrophyte loaded highly on PC2, but the moderate loadings of five macroinvertebrates indicate that this component represents a certain moderate relation (Table 5; Fig.1).

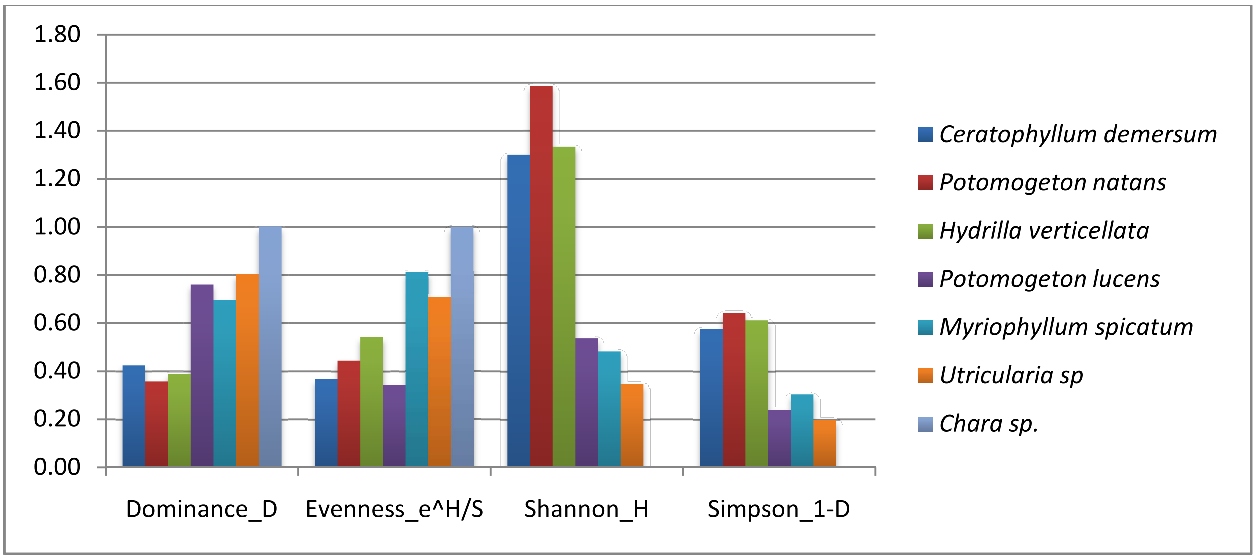


Fig.6. Various biodiversity indices for macroinvertebrates

While assessing the various biodiversity score, it was found that highest dominance and evenness score was shown by *Chara* sp. and lowest dominance score by *Potamogeton natans* and evenness score by *Potamogeton lucens*. Whereas, Shannon wiener diversity index and Simpson index was highest for *Potamogeton natans* and lowest for *Chara* sp. (Fig. 6).

Generally high numbers of macro-invetebrates were found attached to *C. demersum* followed by *P. natans, P.lucens* and *H. verticillata* and least for *Myriophyllum spicatum, Utricularia* sp. and *Chara* sp. *Ceratophyllum demersum* formbowl shaped whorls together, 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). Contrary to other studies (Chilton, 1990) a drastic decline in number of invertebrates associated with *M. spicatum* was observed despite of it having elaborate surface area for colonization. It may be as a result of increased release of all elopathically active compounds that might have hampered the growth of periphyton which in turn limited the invertebrate diversity (Sand-Jensen and Sondergaard, 1981; Leu *et al.,* 2002).

The Chironomidae larvae were much more diverse showing higher density on *Ceratophyllum demersum* followed by *Potamogeton lucens, Potamogeton natans*, and then *Hydrilla verticellata. Chironomidae* sp. was the dominant group and recorded its highest number in the highly polluted sections. It is well documented that the family Chironomidae is considered to be a pollution tolerant family of Order Diptera which may be due to the presence of haemoglobin pigment that helps them to collect oxygen directly from the atmosphere (Chowdhary *et al.,* 2013). *Psychoda* sp. was found only at Hazratbal site. Among insects worth-mentioning was *Enallgma* sp. (Odonata-Coenagrionidae) commonly called dragon fly. Among the non-insect arthropoda, Arachnida represented by 1 taxa (*Dolomedes* sp.) from the order Areneae, collected from *Ceratophyllum demersum* and *Potamogeton natans* does not show any significant diversity on any other macrophyte. Plant architecture is having effect on density and development of epiphytic organisms (Bhat *et al*., 2012).

Phylum Mollusca shows their presence on *Hydrilla verticillata* followed by *Potamogeton natans, Myriophyllum spicatum* and *Ceratophyllum demersum* to be as a result of the greater surface area provided by the vegetation types (Krull, 1970; Downing, 1981; Harrod, 1964). Generally *Physella* sp feed on periphyton but they can also consume living plant material and detritus. This species has a wide distribution and tolerance of a broad range of habitats, and tolerance to habitat modification (Burch, 1989). Phylum Annelida shows their presence on *Potamogeton natans* as they feed on detritus. Thus Aquatic macrophytes have been shown to be significant habitat structurers, are very much influential on the composition of the associated fauna. Increase in macroinvertebrate abundance, richness and diversity due to macrophyte habitat complexity may be explained by simple mechanisms that involve the availability of habitat, which increases the possibility of available food and consequently attracts other organisms, which then relate to each other while utilizing this complexity as shelter (Sidine and Eduardo, 2010).

CONCLUSION

In conclusion, this study demonstrates that macrophytes like *Ceratophyllum demersum, Potomogeton lucens, Potomogeton natans* and *Hydrilla verticellata* offer a conducive substrate for growth and development of macroinvetebrates as compared to others like (*Myriophyllum spicatum, Utricularia* sp. and *Chara* sp.). *Ceratophyllum demersum* having dissected leaves and bowl shaped whorl set harboured higher macroinvetebrate density. Among the insects *Chironmidae* sp was dominant taxa due to its wide ecological amplitude. From the present study it is thus safe to conclude that there is a significant role of macrophytic architecture on diversity and density pattern of macro-invertebrates.

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