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Development of biomonitoring Protocols for Assessing the Water Quality of Dal Lake of Kashmir Himalaya (India)

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ABSTRACT

The present study encompasses the first case study to assess the water quality of Dal Lake of Kashmir Himalaya by using different biomonitoring protocols. Monthly sampling was done from all sampling sites in five replicates for a period of one year (Jan 2015-Dec 2015). The sampling of macroinvertebrates was done on the same day at same place where water samples were collected. A total of 22 families of macroinvertebrates were collected with Chironomidae being most dominant in macroinvertebrate community. The result of water quality analysis on the basis of various biotic indices indicates that the water of Dal Lake is polluted. The statistical relationship between air temperature, water temperature, pH, conductivity, dissolved oxygen and density of macroinvertebrates were also analysed for ensuring the impact of these physico-chemicals parameters on macroinvertebrates.

Keywords : ASPT, Bioindicators, BMWP scores, FBI, Kashmir Himalaya, Macroinvertebrates

I. INTRODUCTION

Freshwater ecosystems are important components for all living beings; among them streams, rivers, lakes and wetlands harbor disproportionately a high fraction of the earth's biodiversity (Saunders *et al*., 2002). Throughout the world these ecosystems are threatened by anthropogenic activities that directly alter the hydrology, such as construction of physical barriers to flow, extraction of water and filling or draining of these habitats. Toxic substances and excessive nutrient through waterways, as well as destructive land use practices in surrounding areas of freshwater ecosystems, leading to reductions in water quality.

Biodiversity is used as a tool for assessing, prediction and transformation landscape structure, making it a valid component of policies applicable to rural, industrial and urbanized areas so as to decrease human mismanagement and to lessen pollution levels (Wilson, 1997). The importance of biodiversity in directing environmental policy, presupposes that organisms and their complex interactions respond favourably to human landscape management and impacts in different ways, with some organisms responding quicker and more definitively than others (Paoletti, 1999). There have been urgent demands to develop the monitoring methods that can indicate the ecological status of these ecosystems as they respond to natural and biotic activities, such monitoring feeds directly into practicable conservation strategies. These monitoring methods are Physico-chemical and biological. Physico-chemical measurements are common form to check the pollution, but the biological one is more advanced comprehensive methodological approach to evaluate these ecosystems, because they provide complete spectrum of information for proper management.

There has been a serious concern about the decline in water quality in the streams and lakes of the Himalayan region because of encroachment, inflow of heavy metals, sewage and other chemical wastes. Dal Lake of Kashmir Himalaya is very rich in biodiversity and has received little attention as far as ecological investigations are concerned. This study it has been planned because yet no such work have been done on this water body.

II. THE STUDY AREA

Dal lake is a postglacial lake bounded on south west by state capital of Jammu and Kashmir India, Srinagar, and the other sides are encompassed by terraced gentle

slopes at the base of precipitous mountains. Dal lake is situated at an altitude of 1584ms above the sea level, lies between $34^{o}6'N$; $34^{o}10'N$ latitude and $74^{o}50'E$; $74^{o}54'E$ longitude and covers an area of about $11.50km^2$. The lake is mainly fed by Telbal nala, which contributes to about 80% of total inflow of lake (Jellani, 2006) and other small streams, like Peshpaw nala, Shalimar nala, Merakhsha nala, Harshi koal, etc also drains into this lake. The Telbal nala with other streams enters the lake at Hazratbal basin and finally drains into Jhelum river at Dal Gate side of lake.

This study was conducted on this lake by selected five study sites viz, site I Dal gate, site II Nerhu Park, site III Nishat Ghat, site IV Shalimar Ghat and site V Hazratbal Ghat.

III. MATERIALS AND METHODS

1) Sample Collection

Before sampling, the study area was stratified based on broad ecological variables (altitude, latitude, riparian land use etc.), or disturbance regime (polluted, unpolluted etc). Monthly sampling was done for analysis of physico-chemical parameters of water from Jan 2015 to Dec 2016. Water samples were collected at different depths by using grab sampler, and were kept in polyethylene plastic bottles. All water samples were properly stored and kept in laboratory at $4^{o}C$ until processing and analysis (APHA, 2006). The parameters like pH, temperature, conductivity, were checked on spot while other parameters i.e. dissolved oxygen was determined by APHA (Clescerl et al., 1999).

2) Collection and Preservation of Macroinvertebrates

Macroinvertebrates was collected at different sites by using dip net, aquatic vegetation was also taken out and vigorously searched for aquatic organisms by using fine forceps.

The collected samples were individually sorted out and stored in 70% ethanol or 4% formalin (Subramanian, and Sivaramakrishanan, 2007).

3) Identification of Samples

Collected samples shall be examined under a dissected or stereozoom microscope (10X and above), these samples was assigned upto the family level by using taxonomic keys as designed by Wetzel and Likens (2000); Mandaville (2002); Subramanian and Sivaramakrishanan (2007).

4) Calculating Biomonitoring Scores

I. BMWP Scores: The BMWP score can be obtained by summing the individual score of all families present (Sivaramakrishanan, 1992 and Maue and Spring, 2008).
II. ASPT: The Average Score per Taxon (ASPT) represents the average tolerance score of all taxa within the community, and was calculated by dividing the BMWP by the number of families represented in the sample (Armitage et al., 1983 and Sivaramakrishanan, 1992).
III. Family Biotic Index: FBI is the number of individuals in the taxon with their tolerance value, and the total number of organisms in the sample (Plafkin et al., 1989; Bode et al., 1991).
IV. Taxa Richness: Taxa Richness (TR) equals the total number of taxa represented within the sample. (Plafkin et al., 1989).
V. EPT Index: The Ephemeroptera, Plecoptera, and Trichoptera (EPT) index displays the taxa richness within the insect groups which are considered to be sensitive to pollution (Plafkin et al., 1989). The EPT index is equal to the total number of families represented within these three orders in the sample.
VI. ETO Index: The Ephemeroptera, Trichoptera, and Odonata represent the taxa richness of these groups (Gerritsen et al., 1998). The ETO index is equal to the total number of families represented within these three orders in the sample.
VII. Percent Contribution of Dominant Family (%DF): Percent dominance (%DF) equals the abundance of the numerically dominant family relative to the total number of organisms in the sample (Plafkin et al., 1989).

IV. RESULTS:

The mean of seasonal physico-chemical parameters of Dal Lake of Kashmir Himalaya are presented in Table 1. The maximum temperature of air was recorded

(31.2±1.92°C) in summer and minimum in winter (7.83±1.83°C). The water temperature of Dal lake were fluctuated with air temperature i.e. maximum (25.33±1.90°C) in summer and minimum in winter (9.29±2.10°C).The pH of water was (8.24±0.15°C) winter and (7.13±0.20°C) in summer. The dissolved oxygen of Dal Lake was highest in spring (7.36±0.61mg/l) and lowest in summer (4.63±0.36mg/l). While as the Conductivity of water were maximum in summer (0.33±0.07mS/m) and minimum in winter (0.17±0.01mS/m).

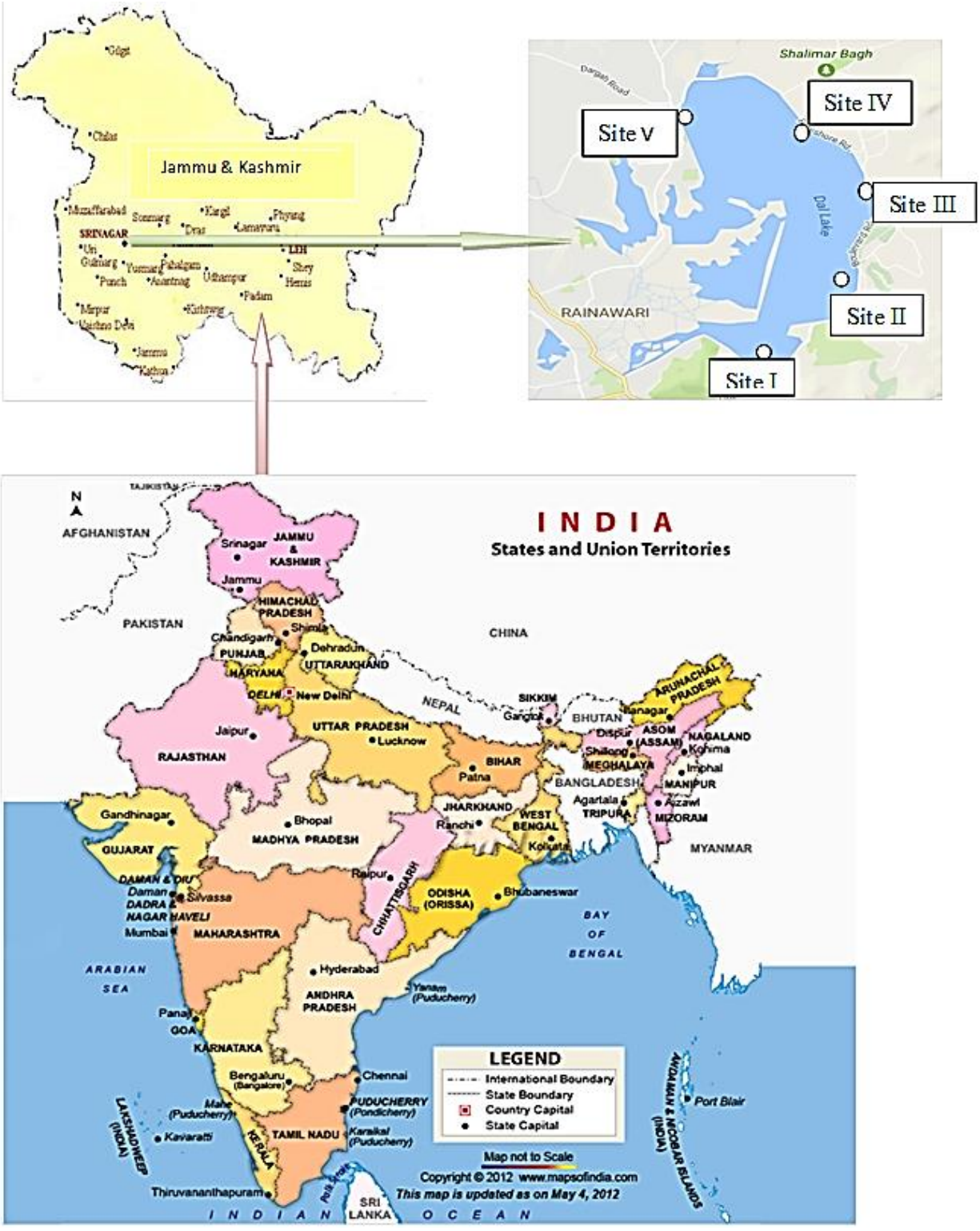

Table 1. Seasonal variation (Mean±SD) in physico-chemical parameters of Dal Lake, Kashmir Himalaya from Jan. 2015 to Dec. 2015.

Parameters	Winter	Spring	Summer	Autumn
Air Temp.	7.83±1.83	22.06±4.16	31.2±1.92	21.4±5.56
Water Temp.	9.29±2.10	17.8±4.10	25.33±1.90	15.86±5.28
pH	8.24±0.15	7.83±0.27	7.13±0.20	8.14±0.14
Dissolved O_2	4.96±0.21	7.36±0.61	4.63±0.36	7.13±0.71
Conductivity	0.17±0.01	0.32±0.02	0.33±0.07	0.18±0.032

V. BIOTIC INDEXES

In this study, 22 taxa comprising of 3122 individuals was collected. The maximum numbers of individual were collected in spring season, while the fewest were collected in winter season. The macroinvertebrates collected from different sites of Dal Lake were to belonging to 22 families included in 3 higher taxonomic groups i.e. Arthropods, Molluscs and Annelids. The arthropods show highest percentage 70% in all seasons fallowed by molluscs 17% and annelids 9% (Fig.1). The arthropods were represented by 7 orders (Ephemeroptera, Odonata, Hemiptera, Diptera, Coleoptera, Megaloptera, and Amphipoda). The annelids were represented by two orders (Rhynchobdellida and Oligocheata) and molluscs by one order (Basommatophora). The Odonata were the most diverse group with five families (Aeshnidae, Platycnemididae, Coenagrionidae, Lestidae, and Protoneuridae) among them dipterans are most abundant group with 639 specimens, contributes 32% of total number of collected samples Fig 2.

The mean BMWP scores, ASPT, ETO FBI, Taxa richness and Percentage of DF of Dal lake varies according to seasonal variation, while as EPT remains same throughout the year Table 2. According to water quality categories of Maue and Springer 2008 the BMWP scores of Dal Lake were remains in between 61-100, that indicates the regular quality or medium pollution of water. The ASPT score were high in winter 4.2 but lowest value in summer season 4.1. EPT remains same throughout the year but ETO has lowest value in summer. The family biotic index of Dal Lake is 3.44 in winter and 3.51 in other seasons; according to Hilsenhoff's FBI, these results indicates that there is no apparent organic pollution in winter due to the low eutrophication rate, but slight organic pollutants where added in other seasons by heavy rush of tourists, and high eutrophication rate. The Taxa richness value of Dal Lake was 19 in summer and 22 in spring and autumn, indicates that fluctuation in physico-chemical parameters affects the macroinvertebrate diversity. The lower value of Taxa richness more will be the pollutant load in water. The dominant family among the collected samples was Chironomidae which is indicator taxa of pollution and the percentage of dominant family (% DF) was high in summer (0.23) and low in spring (0.15).

Macroinvertebrates are very sensitive to physico-chemical changes in aquatic habitats. In Dal Lake the density of macroinvertebrates was positively correlated with air temperature, water temperature, dissolved oxygen and conductivity but negatively correlated with pH of water (Table 3)

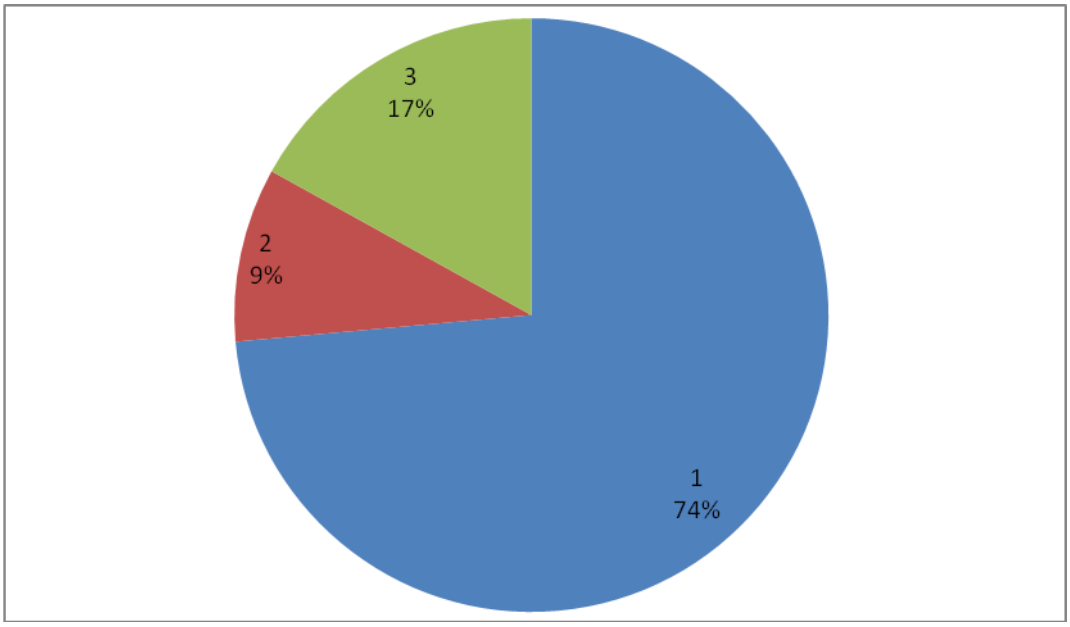

Figure 1385: Density of different phylum's in Dal Lake: 1 Arthropods, 2 Annelids and 3 Molluscs.

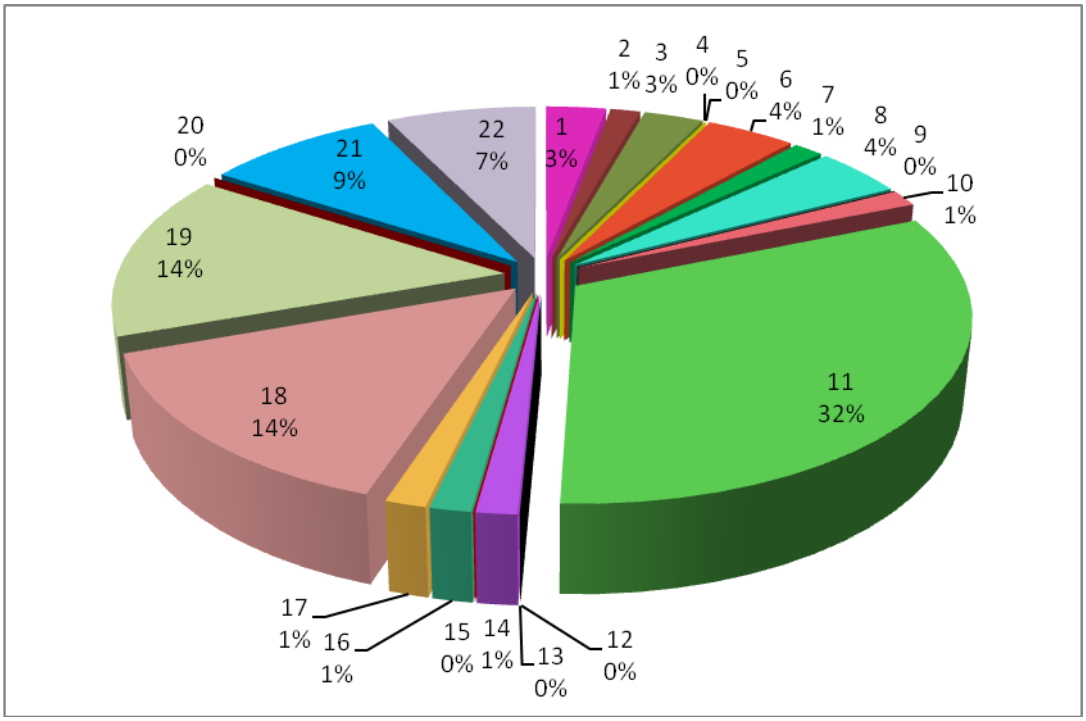

Figure 2: Density of macroinvertebrates families in Dal lake: 1 Baetidae. 2 Tricorythidae, 3 Aeshnidae, 4 Platycnemididae, 5 Coenagrionidae, 6 Lestidae, 7 Protoneuridae, 8 Corixidae, 9 Pleidae, 10 Belostomatidae, 11 Chironomidae, 12 Hydrophilidae, 13 Dytiscidae, 14 Elimidae, 15 Psephenidae, 16 Corydalidae, 17 Sialisae, 18 Gammaridae, 19 Glossiphoniidae, 20 Tubificidae, 21 Planorbidae, 22 Lymnaeidae

Table 2. Biotic indexes of Dal Lake in the year 2015.

Biotic indexes	Winter	Spring	Summer	Autumn
BMWP	84	91	78	91
ASPT	4.2	4.13	4.10	4.13
EPT	2	2	2	2
ETO	7	7	5	7
FBI	3.44	3.86	3.61	3.60
Taxa richness	20	22	19	22
% of DF	0.41	0.15	0.23	0.18

Table 3. Correlation between physico-chemical parameters and density of macroinvertebrates of Dal lake during 2015.

Year 2015	Density	Air Temp.	Water Temp.	pH	Dissolved Oxy.	Cond.
Density	1					
Air Temp.	0.84942	1				
Water Temp.	0.80781	0.95971	1			
pH	-0.56642	-0.81788	-0.88002	1		
Dissolved Oxy.	0.65276	0.31726	0.16262	0.138	1	
Cond.	0.74006	0.732052	0.79865	-0.7652	0.109831	1

VI. DISCUSSION

The analysis of physico-chemical parameters of Dal Lake was done in order to assess the seasonal comprehensive changes in the water quality due to anthropogenic activities. The results of various physico-chemical characteristics of the aquatic habitat were presented in different seasons. The water temperature is one of the important ecological parameter of aquatic habitat that plays prominent role in regulating to other parameters related to water like all physico-chemical parameters as well as biological productivity (Wetzel, 1983) and also in controlling the nutrient input and turnover. The average water temperature in all seasons fluctuates between 9.29 in winter to 25.33 in summer. The temperature variation of water is broadly agreed with the results of Siraj *et al*., 2006, Praveen *et al*., 2013, Mushtaq *et al*., 2013 and Mukhtar *et al*., 2014.

The pH of water decrease from 8.24 in winter towards 7.13 in summer, the fluctuation from highly alkaline in low temperatures towards the neutral pH with increase in temperature, agreed with the observations of Sharma and Rawat (2009) in Asan wetland and Mushtaq *et al*., (2013). The pH variation of water body with respect to temperature is due to the production value of that water body (Garg *et al*., 2010) but challenges the findings of Khan et al., 2012 upon Dal lake. The pH shows negative correlation with all other parameters and density of macroinvertebrates, this negative correlation indicates that increase in temperature increases the rate of ionization in aquatic habitat which in turn affects the water quality. Sharma and Rawat also observed that pH is inversely proportion to temperature.

Conductivity is the capacity of a substance or a solution to conduct the electric current in aquatic habitat the conductivity is determined by total dissolved salts or electrolytes present in water. During winter and autumn seasons the conductivity is low while as in spring and summer the conductivity was higher values. Conductivity shows positive correlation with temperature. Sharma and Rawat, 2009 also has been reported the same results on Asan wetland. The conductivity is increased at the rate of 1.9% per ^{o}C, because temperature adds more dissolved salts and more electrolytes in water (Bartram and Balance, 1996).

Dissolved oxygen is one of most reliable parameters in assessing the trophic status and the magnitude of eutrophication in an aquatic ecosystem. In this study, the average dissolved oxygen concentration was higher in spring and autumn and lower in summer season. Higher value of dissolved oxygen in spring and autumn could be the result of vigorous photosynthetic rate of producers and the decrease in summer is because of high decomposition rate by increased temperatures of the water body (Kumar *et al*., 2007, Ganie *et al*., 2012 and Parveen *et al*., 2013).

Macroinvertebrates are the most popular for biomonitoring of freshwater ecosystem due to their relatively large size, low cast, easy sampling and relatively long life cycles (Hellawell, 1986: Metcalf, 1989: Rosenberg and Resh, 1993: Metcalf-Smith, 1996: Kazanci *et al*., 1997). Biomonitoring was first developed in Europe and subsequently in the United States (Woodiwiss, 1964). In the present study 3122 number of individuals has been found belonging to 22 families and 3 phyla's, the density and diversity changes among macroinvertebrates depends on various factors such as hydrological characteristics (Armitage *et al*., 2001), presence of riparian vegetation (Roy *et al*., 2003), suitable substrate (Buss *et al*., 2004), availability of habitat (Stwert, 2000), fluctuation in physico-chemical parameters (Buss *et al*., 2002 and Silveria *et al*., 2006), addition of various pollutants by anthropogenic activities (Smith and Lamp, 2008) and biological interactions (Tomanova *et al*., 2006). The riparian vegetation may provide the protection to these macroinvertebrates from predators and suitable environment for the growth of different vegetations, which is important food source for many macroinvertebrates. The physico-chemical parameters are also important factor for the growth and survival for biological indicators. In current study the water quality of Dal lake was examined in light of various biotic indices like BMWP, ASPT, EPT, ETO, FBI, Taxa richness and % of DF was slightly polluted this may be due to, any change in physico-chemical parameters of water affects the diversity and density of macroinvertebrates. Hence these macroinvertebrates acts as bio-indicators to assess the water quality.

In conclusion Dal Lake is not threatened by intensive pollution effect but in future the water quality of Dal Lake may be changed into acidic if the rate of disturbances remains same.

VII. ACKNOWLEDGEMENT

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