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Article

Macroinvertebrate Population Dynamics of an Urban Lentic Ecosystem of Kashmir Himalaya

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Abstract: An extensive ecological study was conducted on famous Dal Lake situated in the heart of the Kashmir valley from March, 2015 to February, 2016 in order to assess the physico-chemical features and macroinvertebrate population dynamics of lake. During the investigation a total of 24 macroinvertebrate species were recorded. The mean population density of macroinvertebrates was estimated 1410 ind./m^2. Arthropods were found to be most dominant with relative contribution of 42% followed by Molluscs with relative contribution of 35% and Annelids with relative contribution of 23%. The study revealed that water quality, abundance and architecture of macrophytes and nature of bottom sediment plays a significant role in determining the diversity and distribution of macroinvertebrates in lake-ecosystem. pH, electrical conductivity, nitrates, total phosphorous, and chloride content depicts alkaline, eutrophic and organically polluted nature of lake waters. Further, it was observed that undesirable anthropogenic activities like sewage loading, waste dumping and agricultural run-off are emerging as most detrimental threats to aquatic ecosystems, which need to be mitigated immediately to maintain the health and vigor of lake..

Keywords: Diversity, Macroinvertebrates, Macrophytes, Dal Lake.

1. Introduction

The beautiful valley of Kashmir aptly referred as "paradise on earth" has been known for its scenic heart throbbing beauty. The high altitude valley of Kashmir is of tectonic origin, lying between 33^{o} 25^{1} to 34^{o} 50^{1} North latitude & 74^{o} $72^{\mathbf{1}}$to $75^{o}30^{1}$ East longitude. It encompasses a great array of fresh water bodies like lakes, ponds, rivers, springs, streams etc. These fresh water bodies of the Kashmir Himalayas have been playing a great role in the sociocultural and economic status of the valley since historic times. Besides being a source of attraction for tourists from all over the world, the valley lakes are great source of natural products like fish, fodder and a variety of economically important aquatic plants. However, the ecology of these lakes have changed considerably in the last few decades due to unplanned and unethical anthropogenic activities which have adversely effected these water bodies and are posing threat to aquatic biota of these water bodies. To deal with these threats and associated problems (e.g. chemical contamination, loss of diversity) it is necessary to implement adequate restoration measures. However, the primary step towards this ecological restoration process is to assess the status of these lakes by analyzing the structure of its biological communities. In this regard macroinvertebrates have been considered as the most familiar targets for carrying out biological monitoring of water body because they represent the most diverse group of organisms that react to anthropogenic influence on aquatic ecosystem strongly and often predictably (Rosenberg and Resh, 1993). Macrozoobenthic fauna constitute an ecologically important community in aquatic ecosystems and are of immense ecological value. Reports have indicated that the composition and diversity of macro-zoobenthic community is closely linked to aquatic habitat conditions with many species serving as biological indicators of pollution (Malik and Ali, 2012). Study of the macrozoobenthos has received considerable attention due to their significance as biological indicators of environmental change in aquatic ecosystem, source of food for fishes and components of aquatic food chains. (Lonkar and Kedar, 2014).They also play an active role in cycling of organic materials (Mir et al, 2016). Macroinvertebrates are specified as the important areas for maintaining the biodiversity (Mayer *et al*, 2007, Richardson and Danehy, 2007).

The present study was undertaken to study the population dynamics of macroinvertebrate fauna of the Dal Lake in order to understand the status of the lake, so that necessary steps could be taken towards the ecological restoration of the lake.

2. Materials and Methods

2.1. Study Area

The present study was carried out on Dal Lake, one of the most famous and beautiful lake of world, Dal Lake is a world renowned tourist spot and an integral part of glorious heritage and culture of Kashmir and is aptly regarded as a cradle of Kashmir civilization. Dal Lake is a natural Himalayan urban lake of fluviatile origin surrounded by mountains on its three sides. Dal lake is situated in the north east of Srinagar at an altitude of 1886 m above sea level between geographical coordinates of 34^{o} 6' -34^{o} 10' N latitude and 74^{o} 8' -74^{o} 9' E longitude in the heart of the Kashmir valley on the north east of the state summer capital Srinagar at the foot of the Zabarwan mountains. This beautiful lake is bounded on the east by Mahadev mountain range, on the south by Kohi Suleiman and on the west by Hari Parbat Hill. The total catchment area of the Dal Lake is about 317 km^2 and has been divided into five sub-catchments. The major one is Dachigam-Telbal which alone is spread over 228 km^2 and constituting about 72% of the total area. The catchment area of the Dal Lake is more than twenty times the area of the lake. The total water surface area of the lake is 11.45 Km^2 of which 4.1 Km^2 is under floating gardens. 1.151 Km^2 to 2.25 Km^2 are land marsh respectively, whereas a total volume estimated is 9.05×10 m^3 and the ratio between the mean and maximum depth (m) ranges between 0.20 and 0.25 indicating the gentle slope of the lake bed. It is believed that the Dal is fed up by a number of underground springs, but the main source is the perennial stream known as Telbal Nallah from north side which brings water from high altitude Marsar Lake. A small canal "Nalla Amir Khan" connects the Dal with Anchar Lake through Nigeen and acts as an additional outflow channel. .The Lake is multi basined comprising of four basins viz., Hazratbal, Bod Dal, Gagribal and Nigeen with an average depth varying from 1.4 to 1.8 meter (Mukhtar and Chisti, 2013 and Shah2012).

2.2. Location of Study Sites

SITE-D1: This site is located on eastern side of the lake at its exit (Dalgate).

SITE-DII: This site is situated on western side of lake locally known as BOD Dal basin.

SITE-DIII: This site is located on northern side of the lake, where Telbal nallah along with heavy organic nutrient load enter into the part of Dal Lake locally known as Hazratbal basin.

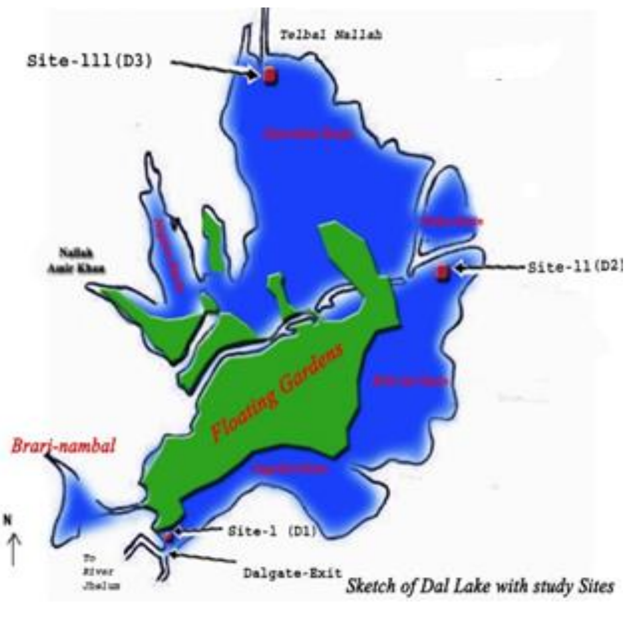

Fig. 1. Sketch of Dal Lake

2.3. Collection of Water Samples

Water samples were collected at three study sites on monthly basis from March 2015 to February 2016. The samples were collected in iodine treated polyethylene plastic bottles. Evaluation of various fundamental and ecologically important physico-chemical parameters was carried out according to the standard methods of APHA, 2004. Certain parameters like water temperature, transparency, depth, dissolved oxygen (DO), pH and free carbon dioxide were determined on spot during sample collection, while as the other parameters including electrical conductivity, total alkalinity, total hardness, chlorides, total phosphorous and nitrates, were determined in the laboratory.

2.4. Collection, Preservation & Identification of Macroinvertebrates

Sampling was done on monthly basis for a total period of one year from March 2015 to February 2016. Macroinvertebrates were collected by help of D-Frame net having 0.2mm mesh size and Ekman's Dredge each having an area of $15\times15cm^2$. The samples were filtered through a series of different mesh sized sieves. The individuals were sorted out manually using forceps and brushes and were preserved in plastic bottles containing 4% formalin and 70% alcohol depending upon the type of organisms to be preserved. The soft-bodied organisms were preserved in 70% alcohol while the shelled organisms like molluscs in 4% formalin (Borror *et al*, 1976). For qualitative analysis preserved samples were identified to the lowest possible taxonomic level according to standard taxonomic works of Edmondson (1959) Pennak (1978), Adoni (1985) and Tonapi (1980). However for quantitative analysis animals were counted individually species wise. The density of macroinvertebrate was calculated as individuals per meter square by using the formula:

$N= (O\div A\times S) \times 10{,}000$ (Welch, 1948)

Where,
N = no. of organisms/m^2.
O = no. of organisms counted.
A = area of sampler
S = number of samples taken at each site.

2.5. Biological Indices

For calculating species diversity and richness, Shannon-Wiener diversity index and Margalef's richness index was applied.

2.5.1. Shannon-Wiener diversity index (H)

Shannon-wiener diversity index was calculated by the formula given below

$$H = -\sum_{i=1}^{S} pi \times \ln pi$$

Where,

H = Shannon-Wiener index

Pi = fraction of the entire population made up of species i

S= number of species encountered

∑= sum from species i to species s

ln = log normal

2.5.2. Margalef's richness index

Margalef's richness index was calculated by the formula given below:

D = (S-1) ÷ Ln (N)

Where,

D = Margalef's richness index

S = total number of species

N = total number of individuals in a sample

ln = log normal

2.5.3. Species evenness

Species evenness was calculated by using the formula given below

E = H /Ln (S)

Where,

E = species evenness

H = Shannon diversity index

S = number of species recorded

3. Results

3.1. Physico-chemical Analysis of Dal Lake

During present Study, water temperature fluctuated from 2.10ºC at site-D1 in December, 2015 to 22ºC at site-DIII in July, 2015 with mean value of 9ºC. Minimum depth of 1.35 m was recorded at site-DIII in June, 2015 and maximum depth of 2.65 m at DI in March, 2015 with an average depth of 2.10 m. Minimum pH of 7.23 at site-DI in January, 2016 and maximum pH of 8.19 at site-D3 in June, 2015 was recorded with an average pH of 8.03. Free CO_2 content was recorded minimum of 6.93 mg L^{-1} at site-DI in April, 2015 and maximum of 25.11 mg L^{-1} at site-DIII in January, 2016 with a mean value of 14.23 mg L^{-1}. Minimum DO content of 3.3 mg L^{-1} was recorded at site-DIII in July, 2015 and maximum DO of 7.53 mg L^{-1} at site-DI in April, 2015 with a mean value of 6.11 mg L^{-1}. Minimum conductivity of 244 µScm^{-1} was recorded at site-DI in March, 2015 and minimum conductivity of 349 µScm^{-1} was recorded at site-DIII in August, 2015 with mean value of 297.44 µScm^{-1}. Minimum total alkalinity of 184 mg L^{-1} was recorded at site-DI in May, 2015 and maximum total alkalinity of 288.00 mg L^{-1} at site-DIII in October, 2015 with an average value of 229.00 mg L^{-1}. Minimum total hardness of 144.00 mg L^{-1} was recorded at site-DI in March, 2015 and maximum total hardness of 301 mg L^{-1} at site-DII in January, 2016. Minimum chloride content of 13 mg L^{-1} was recorded at site-DI in December, 2015 and maximum chloride content of 23.33 mg L^{-1} at site-DIII in May, 2015 with a mean value of 18.51 mg L^{-1}. Minimum total phosphorus content of 282 µg L^{-1} was recorded at site-DI in January, 2016 and maximum total phosphorous content of 411µg L^{-1} was recorded at site-DIII in August, 2015 with a mean value of 351 µg L^{-1}. Minimum nitrate content of 279 µg $L^{-1}$was recorded at site-DI in January, 2016 and maximum nitrate content of 411 µg L^{-1} was recorded at site-DIII in August, 2015 with a mean value of 341 µg L^{-1}. The physico-chemical analysis of Dal Lake is summarized in table 1.

Table 1: Physico-chemical analysis of water in Dal Lake

Parameters (Unit)	Min.	Max.	Mean
Water temperature(0C)	2.10	22.00	9.00
Depth (m)	1.35	2.65	2.10
pH	7.23	8.19	8.03
Free CO_2 (mg L^{-1})	6.93	25.11	14.23
DO (mg L^{-1})	3.3	7.53	6.11
Conductivity (µScm^{-1})	244.00	349.00	297.44
Total Alkalinity (mg L^{-1})	184.00	288.00	229.00
Total Hardness (mg L^{-1})	144.00	301.00	208.41
Chlorides (mg L^{-1})	13.00	23.33	18.51
Total Phosphorus (µg L^{-1})	282.00	411.00	351.00
Nitrates (µg L-1)	279.00	411.00	341.00

3.2. Biological Analysis of Dal Lake

During present investigation, 24 macroinvertebrate taxa belong to three major phyla viz., Annelida (5 species), Arthropoda (12 species) and Mollusca (7 species) were recorded. The recorded macroinvertebrate taxa belong to 6 classes, 11 orders and 19 families of which 11 families belonging to Arthropoda, 4 to Annelida and 4 to Mollusca.

The systematic list of macroinvertebrates recorded from Dal Lake is given in table 2.

Table 2: The systematic list of macroinvertebrates in Dal Lake

S.No.	Phylum	Class	Order	Family	Genus/Species
1	**Annelida**	Hirudinea	Rhynchobdellida	Glossiphonidae	*Hirudo sp.*
2			Pharyngobdellida	Erpobdellidae	*Erpobdella sp.*
3		Oligochaeta	Haplotoxida	Tubificidae	*Limnodrillus sp*
4					*Tubifix tubifix.*
5				Naididae	*Nais communis*
6	**Arthropoda**	Insecta	Diptera	Chironomidae	*Chironomous sp.*
7				Tabanidae	*Tabanus sp.*
8				Ceratopgonidae	*Bezzia sp.*
9			Odonata	Coenagrionoidea	*Enallgama sp*
10				Gomphidae	*Gomphus sp.*
11				Aeshnidae	*Anax junius*
12			Ephemeroptera	Baetidae	*Baetis sp.*
13			Coleoptera	Dytisicidae	*Coptotomus sp*
14			Hemiptera	Corixidae	*Corixa sp.*
15					*Sigara sp.*
16				Gerridae	*Gerris sp.*
17		Maxillopoda	Amphipoda	Gammaridae	*Gammarus sp.*
18	**Mollusca**	Gastropoda	Basommatophora	Lymnaeidae	*Lymnaea auricularia*
19					*Lymnaea stagnalis*
20					*Lymnaea columella*
21				Planorbidae	*Promenetus sp.*
22					*Planorbis sp.*
23		Bivalvia	Veneroida	Corbiculidae	*Corbicula sp.*
24				Sphaeriidae	*Sphaerium sp.*

The mean population density of macroinvertebrates in Dal Lake was estimated 1410 ind/m^2. Arthropods were observed most dominant contributing 42% (fig. 2) with mean population density of 590 ind./m^2 (table 3). The Arthropods were followed in decreasing order by Molluscs contributing 35%

(fig. 2) with mean population density of 494 ind./m^2 (table 3). The population density of Annelids was least among the three phyla contributed 23% (fig. 3) with mean population density of 326 ind./m^2 (table-3). The species wise population density of macroinvertebrates (ind./m^2) is given in fig. 2.

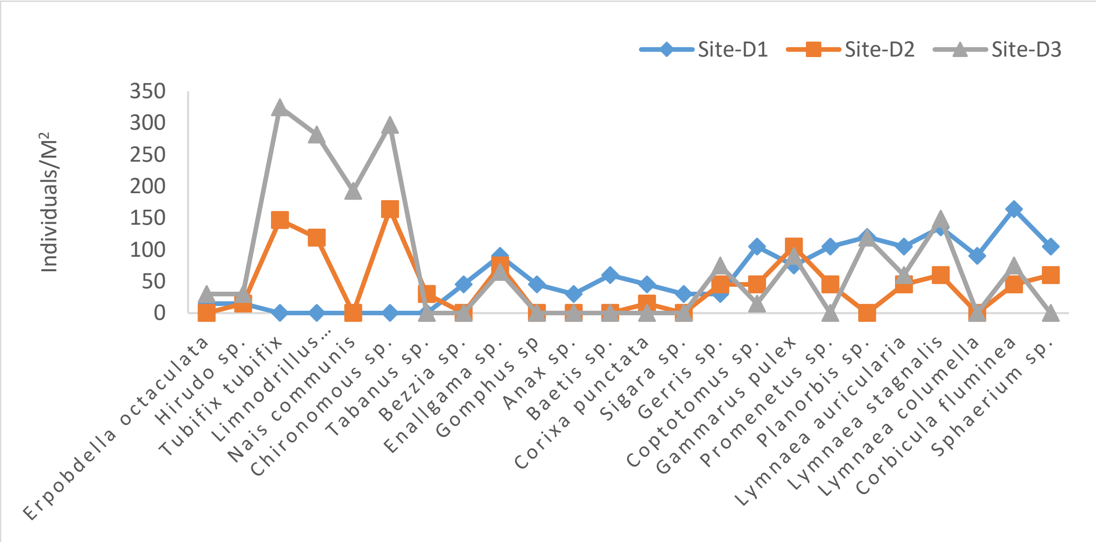

Fig. 2: Population density of macroinvertebrates (ind/m^2) at three study sites in Dal Lake

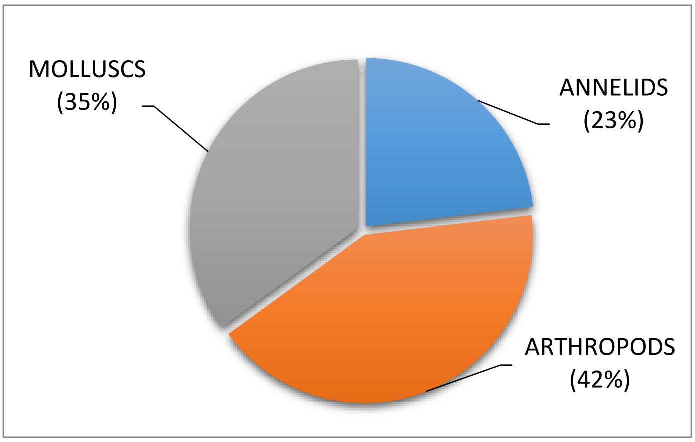

Fig. 3: Percent contribution of Annelids, Arthropods and Molluscs in Dal Lake

The total population density of macroinvertebrate fauna at site-D1 was 1409 ind/m^2 with Arthropods being most dominant (555 ind/m^2) followed by Molluscs (824 ind/m^2) and Annelids with 30 ind/m^2 (table 3). A total of 19 species were recorded from this site throughout the survey of which *Erpobdella octaculata* and *Hirudo sp* belong to phylum Annelida, *Bezzia sp.*, *Enallgama*, *Gomphus sp.*, *Anax sp.*, *Baetis sp.*, *Corixa punctata*, *Sigara sp.*, *Gerris sp.*, *Coptotomus sp.* and *Gammarus pulex belong* to phylum Arthropoda and *Promenetus sp.*, *Planorbis sp.*, *Lymnaea auricularia*, *Lymnaea stagnalis*, *Lymnaea columella*, *Corbicula fluminea*, *and Sphaerium* species belong to phylum Mollusca.

Shannon-Wiener diversity index, Margalef's richness index and Evenness at this site was computed 2.75, 2.48 & 0.93 respectively (fig. 4).

Table 3: Population density (ind./m^2) of Annelids, Arthropods and Molluscs at three study sites in Dal Lake

Site	Annelids (ind./m^2)	Arthropods (ind./m^2)	Molluscs (ind./m^2)	Total (ind./m^2)
D1	30	555	824	1409
D2	281	479	255	1015
D3	667	735	403	1805
Mean	326	590	494	1410

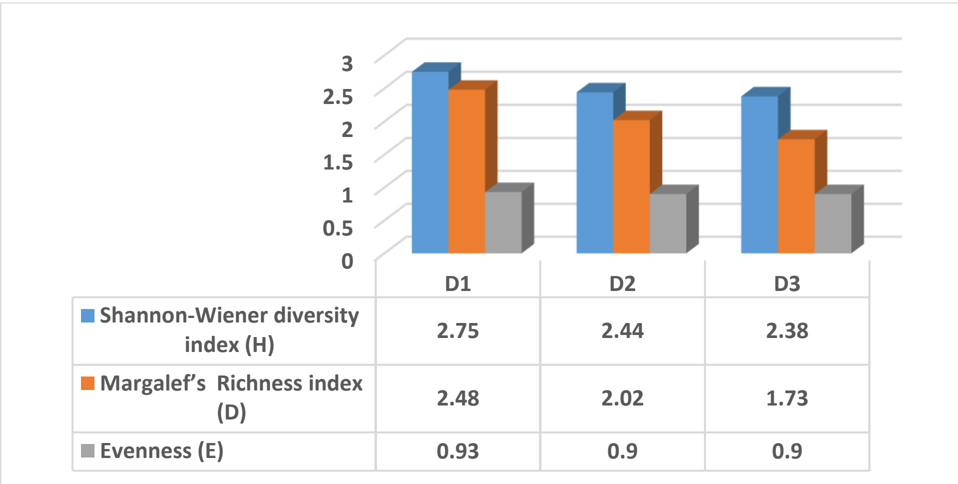

Fig. 4: Diversity, Richness & Evenness of Macroinvertebrates at three sites of Dal Lake

The total population density of macroinvertebrate fauna at site-D2 was computed 1015 ind/m^2 with Arthropods being most dominant (479 ind/m^2) followed by Annelids (281 ind/m^2) and Molluscs with 255 ind/m^2 (table 3). A total of 15 species were recorded from this site throughout the survey of which *Hirudo sp. Tubifix tubifix, and Limnodrillus hoffmeisteri* belong to phylum Annelida, *Chironomous sp., Tabanus sp, Enallgama sp., Corixa punctata, Gerris sp., Coptotomus sp.* and *Gammarus pulex* belong to phylum Arthropoda and *Promenetus sp, Lymnaea auricularia, Lymnaea stagnalis, Corbicula fluminea, Sphaerium* species belong to phylum Mollusca. Shannon-Wiener diversity index, Margalef's richness index and Evenness at this site was computed 2.44, 2.02 & 0.90 respectively (table 3).

The total population density of macroinvertebrate fauna at site-D3 was estimated 1805 ind/m^2 with Arthropods being most dominant (735 ind/m^2) followed by Annelids (667 ind/m^2) and Molluscs with 403 ind/m^2 (table 3). A total of 14 species were recorded from this site throughout the survey of which *Erpobdella octaculata, Hirudo sp. Tubifix tubifix sp., Limnodrillus hoffmeisteri,* and *Nais* *communis* species belong to phylum Annelida, *Chironomous sp, Enallgama sp., Gerris sp., Coptotomus sp.* and *Gammarus pulex* belong to phylum Arthropoda and *Planorbis sp., Lymnaea auricularia, Lymnaea stagnalis and Corbicula fluminea,* belong to phylum Mollusca. Shannon-Wiener diversity index, Margalef's richness index and Evenness at this site was computed 2.38, 1.73 & 0.90 respectively (fig. 4). The species composition of macroinvertebrate at three different study sites in Dal Lake in given in table 4.

Table 4: Species composition of macroinvertebrates at three different study sites of Dal Lake

Genus	Site-A1	Site-A2	Site-A3
Hirudo sp.	+	+	-
Erpobdella octaculata.	+	-	+
Limnodrillus hoeffmeisteri.	-	+	+
Tubifix tubifix.	-	+	+
Nais communis	-	-	+
Chironomous sp	-	+	+
Tabanus sp.	-	+	-
Bezzia sp.	+	-	-
Gomphus sp.	+	-	-
Anax junius	+	-	-
Enallgama sp	+	+	+
Baetis sp.	+	-	-
Coptotomus sp	+	+	+
Corixa sp.	+	+	+
Sigara sp.	+	-	-
Gerris sp.	+	+	+
Promenetus sp.	+	+	-
Planorbis sp	+	-	+
Gammarus pulex.	+	+	+
Lymnaea auricularia	+	+	+
Lymnaea stagnalis	+	+	+
Lymnaea columella	+	-	-
Corbicula sp.	+	+	+
Sphaerium sp.	+	+	-

4. Discussion

During present investigation, the biotic as well as abiotic components of habitat were found to be the most influential factors in determining the composition and distribution of macroinvertebrates in lake. The macroinvertebrate fauna recorded from three sites of Dal Lake differ with respect to their habitat selection. The diversity and density of macroinvertebrates was found to be primarily determined by abundance of macrophytes and organic matter loading in lake. The abundance of phytophilous macroinvertebrates was found to be positively influenced by architecture of macrophytes. Macrophytes having large surface area were found to harbor large number of macroinvertebrate taxa, attributed to the fact that macrophytes provide resources, refuge and suitable breeding sites to macroinvertebrates. The similar type of relationship between macrophytes and macroinvertebrates was observed by Cheruvelil *et al*. in 2006, Siraj et al (2010), Bhat *et al* (2012) and Habib et al (2015) in their respective studies. pH (8.03) depicts well buffered and alkaliphilous nature of lake water (Venkateshwarlu, 1983). Electrical conductivity (297.44 μScm^{-1}) in reference to reports of Olsen (1950) and total phosphorous (282.00) and nitrate content (279.00) in reference to reports of Vollenweider, (1968) reveals eutrophic nature of lake waters. However, relatively better water quality was observed with low conductivity, alkalinity, hardness, chlorides, nitrates and phosphorous and high dissolved oxygen content at site-DI as compared to other sites, which may be ascribed to less anthropogenic pressure like sewage input and other wastes at this site.

Further at site-D1 located at the exit of Dal Lake, the bottom was found sandy with prevalence of gravely sediment and low availability of organic matter. The abundance of molluscs (824 ind,/m^2) at this site reported during the present study clearly indicates that macroinvertebrates belong to this phyla prefer to inhabit such type of habitat especially with high sand content and macrophytic cover. Qadri and Yousuf in 2004 found similar type of results while carrying out an ecological study on macrozoobenthos of Nigeen Lake. However, such features of habitat at site-D1 like presence of sandy bottom, gravely sediment and low availability of organic matter were observed to interfere negatively with the numerical strength of oligochaetes. Such results are in agreement with the findings reported by Lin and Yo in 2008, Schenkova and Helesic in 2006 who in their respective studies justified the fondness of oligochaetes to organically enriched habitat.

Relatively higher numerical density of macroinvertebrates especially of pollution tolerant species was encountered at site-DIII (1805 ind/m^2), which may be correlated to abundant macrophytic growth and favorable bottom for macroinvertebrates to flourish at this site. Shah and Pandit (2001) hold the view that high species density and species composition of macroinvertebrate taxa is positively correlated to richness of macrophytic species as they spent much of their life on host macrophytes. Tessier et al. (2004) stated that submerged macrophytes dwell larger number and greater taxonomic diversity of benthic macroinvertebrate species. The higher chlorides content, conductivity, nitrates and total phosphorus and low DO in lake especially at site-DII and site- DIII shows clear signs of organic pollution (Munawar, 1970) and eutrophication (Olsen, 1950 and Vollenweider, 1968) in lake as a result of input of organic wastes, fertilizers and agricultural runoff into the lake. The heavy organic nutrient loading into Dal Lake from nearby commercial enterprises like hotels and from Telbal area via an inflow channel locally known as Telbal nallah at site-DIII was found to influence macroinvertebrate spectrum to a greater extent. The abundance of certain species like *Hirudo* sp., *Limnodrillus hoffmeisteri, Tubifix tubifix and Nais communis* (oligochaetes) and Chironomids (Diptera) was recorded maximum at site-DIII followed by their maximum presence at site-DII, which may be attributed to preference of these species and their maximum range of tolerance to organic matter rich bottom at site-DII and site-DIII of lake. The results obtained coincides with the findings of Linn *et al* (2008) and Slepukhins (1984). The abundance of *Hirudo* sp., *Limnodrillus hoffmeisteri*, *Tubifix tubifix*, *Nais communis* and *Chironomous* sp. clearly confirmed the fact that these species prefer organic matter rich habitat and register themselves as organic pollution indicator species. Such results correlate with findings of earlier studies carried out on different water bodies by Aston in 1973, Verdonschot in 1989, Wilham and Dorris in 1968, Adholia *et al* in 1990, Oliver in 1971 in Brinkhurst & Cook in 1974, Saether in 1979, Milbrink in 1980 and Bazzanti in 1983).

Chironomids have also been targeted as pollution indicators in biological monitoring of water body (Bay *et al*, 1966 and Kaushik *et al*, 1991). Canedo and Rieradeval (2009) correlated the abundance of chironomids with higher trophic status of water bodies. Elipek *et al*. (2010) correlated oligochaetes and chironomids with eutrophication, low dissolved oxygen level and high nutrient level in water bodies. The wide range of pollution tolerance by pollution tolerant taxa is attributed to their ability to undergo characteristic physiological or morphological adaptations in undesirable circumstances. For instance *Chironomous* species possess hemoglobin as a physiological adaptation to enhance process of absorption and transportation of oxygen (Pennak, 1978). Further, peak density of macroinvertebrates was recorded during spring and summers because of dense growth of macrophytes, low depth due to which light penetrates deep up to bottom and speed up the process of decomposition of organic matter which in turn enhance fertility and productivity of lake. Soszka in 1975 reported that higher population density of macrozoobenthos is a result of provision of appropriate conditions for breeding, sheltering, egg laying, anchorage and good oxygen supply by luxuriant growth of macrophytes during summers and spring. Arthropods were found to be most dominant in terms of number of taxa. During the study 12 species among arthropods were recorded from three different sites, when only 5 species among annelids and 7 species among molluscs were recorded. Mir and Yousuf in 2005 reported a total of 19 macroinvertebrate species from Dal Lake. Yakoob and Pandit in 2009 reported 11 macrozoobenthic invertebrate fauna from the lake. Malik and Ali in 2012 reported only 9 macrozoobenthic invertebrate species from Dal Lake. The Shannon- wiener diversity index was computed 2.75, 2.44, and 2.38 at sites D1, DII and DIII respectively.

According to Willhm and Dorris (1966) species diversity index value above 3 indicates clean water and values between 1.00 to 3.00 indicates moderate pollution and between 0 to 1.00 indicates heavy pollution and with reference to this criterion Dal Lake can be categorized as moderately polluted water body. Cairns and Dickson (1971) holds the view that healthy water bodies are generally associated with high diversity but little numbers of individuals per species, and unhealthy water bodies reflect less diversity but large number of individuals per species. Margalef's richness index was computed 2.48, 2.02 & 1.73 at site-D1, DII & DIII respectively. Somasheker and Ramaswamy (1984) related higher richness index value with healthy conditions of water body.

5. Conclusion

From the present study it is concluded that macroinvertebrate diversity is positively correlated to macrophytic density and architecture as macrophytes provide food, shelter and suitable breeding sites to macroinvertebrate fauna. The predominance of mostly pollution tolerant species like *Limnodrillus hoffmeisteri, Tubifix tubifix, Nais communis* and *Chironomous* sp. etc and higher chloride, nitrate, phosphorous content and low DO content in lake waters clearly depicts the severe organic pollution and eutrophication in Dal Lake. Dal lake is under great stress and is losing its aesthetic and ecological value as a result of severe pollution in lake not only due to the large amount of untreated sewage flushed into the lake from nearby residential areas, floating gardens, commercial enterprises in and around lake, but also due to the heavy organic nutrient rich slit loading into the lake via various tributaries especially telbal nallah.

6. Recommendation

Though, present study depicts the pathetic condition of lake, but there is lot of scope for ecorestoration of this lake. No doubt, that concerned government, authorities like LAWDA are making effort for safeguard of lake by regular examination of lake waters but the implementation of more healthy strategies like installation of highly efficient sewage treatment plants at various inlets of lake, mass awareness programs about importance of lakes and an accurate and vast ecological understanding of environmental factors that affect the biological diversity of lake must be taken into consideration so that lake could be protected from further deterioration.

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