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Study the wetland water quality using biotic indexes: A case study of Asan wetland of central Himalaya

[*1] Gulzar Ahmad Bhat, [2] RK Jauhari, [3] Manzoor Ahmad Paray, [4] N Pemola Devi
[1, 2] Department of Zoology, DAV (PG) College Dehradun, Uttarakhand, India
[3] Research and Training Centre for Pollinators, Pollinizers and Pollination Management SKUAST- K, Shalimar, Kashmir, Jammu & Kashmir, India
[4] Department of Zoology, DBS (PG) College Dehradun, Uttarakhand, India

Abstract
The Himalayan region is dotted with hundreds of freshwater resources in the form of lakes and wetlands. These freshwaters were affected by an adverse effect of the environment. The present study aims to analyze the health of Asan wetland of central Himalaya by using various biotic indexes. The most polluted waters are presently restricted to summer season of the wetland. Samples were collected seasonally over a period of one year (2016) at four sampling sites. A total of 20 families of macroinvertebrates were collected with the Notonectidae and Baetidae being the most abundant component of macroinvertebrate communities. The absolute values of the biotic indices showed high spatio-temporal variation, the BMWP, ASPT scoring proved useful because water quality were changed throughout the seasons. The abundance of different classes of macroinvertebrates decreased from Hemiptera 35% to Plecoptera 0% and the total density of macroinvertebrates in different seasons are lowest in summer season 15%, but highest in winter season 31%. The statistical relationship between air temperature, water temperature, pH, dissolved oxygen and the density of macroinvertebrates were also analyzed to ensure the affect of these physiochemical parameters upon the macroinvertebrates. The macroinvertebrate community relying on the benthic substrate of Asan wetland is still poor, and the water quality was still moderately polluted.

Keywords: Himalaya, freshwaters, BMWP, ASPT

Introduction
Wetlands are very productive ecosystem on the earth's surface which exhibits the substantial biodiversity according to their genesis, geographical location, water regime and chemistry, dominant species; sediment and soil characteristics. Wetlands are helpful in regulation of hydrological cycles, water quality maintenance, movement of nutrients and support for tropic levels of food chains (Pramod *et al*., 2011; Sarkar and Upadhyay, 2013) [18, 19]. A diverse number of living organisms like animals, plants and other organisms are present in wetlands; their survival is totally depends upon the existence of these habitats.

Macroinvertebrates are the important group of organisms which act as a key component in ecosystem processing like nutrient cycling, pollution metabolism, dispersion and secondary production of aquatic ecosystem (Parulekar *et al*., 1980, Amar *et al*., 2011) [15, 1]. In lentic ecosystem these organisms constitutes an important component of tropic levels among aquatic biodiversity (Merritt and Cummins, 1996) [12]. Macroinvertebrates and the quality of water are interrelated to each other, as they are sensitive and showing response to both anthropogenic and natural changes in ecological characteristics of wetland (Dubuque *et al*., 1993) [6].

The density and diversity of benthic organisms depends upon the physico-chemical properties of water, soil and biological components of that ecosystem (Shrivastava, 1997) [21]. According to aquatic ecologists some macroinvertebrates respond to the specific changes in water conditions and have become indicators of wetland. Their presence and absence of such macroinvertebrates indicates the degree of pollution through a specific causative pollutant may be identified by physico-chemical methods.

There is serious concerning issue for declining the water quality in wetlands of India. The rapid changes in water quality are particularly more alarming in case of small water bodies like lakes, tanks and ponds. Wetlands are polluted through agricultural runoff, sewage discharge and other wastes from urban areas. However the increase in urbanization and the land use changes, the nutrient loading in wetlands far exceed their capacity to retain the pollutants by recycling it through nitrification, sedimentation, adsorption and uptake by phytoplankton's.

Study Area
Asan wetland is presently known as Asan conservation reserve, situated on a major national highway (NH 72). It is manmade reservoir came into existence in the year 1967 due to the construction of a barrage at the confluence of Asan river and the outlet channel from Dhalipur power house. It falls in the geographical coordinates of 30º25'-26' N and 77º40'-41' E with its net geographical area is 3.2 km^2 the barrage is 287.5m long located in Doon Valley of central Himalayas. The Asan wetland represented a typical wetland habitat along the course of Yamuna and Asan river near their confluence. The Asan wetland is consisting both shallow and deep water areas with catchment basin surrounded by a dense Sal forest

of Timil range, Kuja Village, cultivated and pastures lands, Rampur forest block of mixed forest and the land of irrigation department. In the western side of wetland, barrage is 287.5m long and the riverbed being 389.4asl with minimum and maximum of pond levels between 395.95m asl and 401.50m asl and fall in biogeographic province of 4.8.4 (Indo-Gangetic monsoon forest) and belongs to type 17 wetland (water storage reservoir dams) (Hussain and De Roy, 1993) [9]. The total catchment area of wetland is 1600 km2, contributed by Asan river and Yamuna river. It is one of the biodiversity hotspots and ecologically sensitive habitat in Doon valley, having humid sub-tropical climate with heavy rainfall of 1817mm, high humidity rate is 20-84% and large variation in air temperatures during the days in different seasons of the year.

In monsoon seasons, the wetland is covered by the water with large debris and slit carried from the watersheds of Yamuna and Asan rivers. This wetland provides a suitable habitat for migratory birds migrating annually from Arctic and across the Himalaya, so the Government of Uttarakhand has declared it as the Conservation Reserve under the Indian Wildlife Protection act 1972.

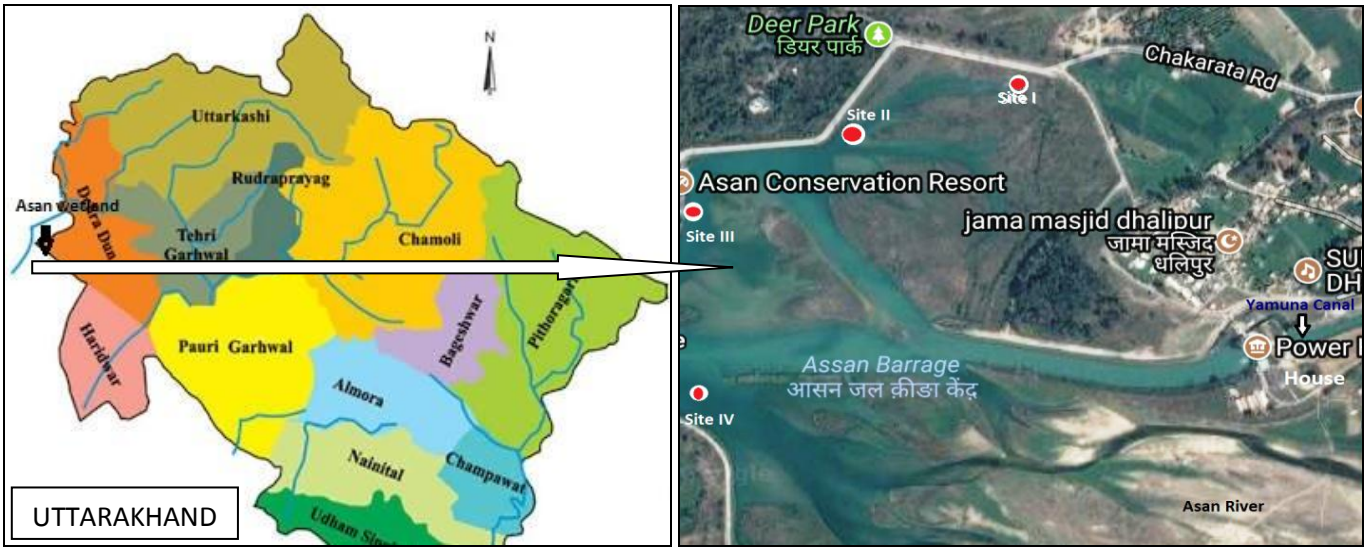

Fig 1

Materials and Methods

1. Sample collection

Before sampling, the wetland is divided into three different sampling zones i.e. reservoir zones, pools of wetland zone and marshy vegetative zone. Seasonal sampling was done from all three stations for analysis of physico-chemical parameters of water and the collection of macroinvertebrates. Water samples were collected at different depths by using grab sampler, and were kept in polyethylene plastic bottles. Samples were properly stored and kept in laboratory at 4°C until processing and analysis has been done (APHA, 2006). The parameters like pH, temperature, conductivity, were checked on spot but the dissolved oxygen was determined by APHA (Clescerl *et al*., 1999) [5].

2. Collection and Preservation of Macroinvertebrates

Macroinvertebrates was collected at different sites by using dip net, aquatic vegetation, debris was also taken out from the sampling site and the aquatic organisms were searched by using fine forceps. The collected samples were sorted out and stored in 70% ethanol or 4% formalin (Subramanian, and Sivaramakrishanan, 2007) [24].

3. Identification of Samples

Collected samples was examined under a dissected or stereozoom microscope (10X and above), the samples were identified upto the family level with the help of taxonomic keys as designed by Wetzel and Likens (2000) [25]; Mandaville (2002) [10]; Subramanian and Sivaramakrishanan (2007) [24].

4. Calculating Biomonitoring Scores

BMWP Scores

The BMWP scores (Biological Monitoring Working Party) provides the single values, at the family level, representative of the organisms tolerance to pollution. The greater the tolerance value towards pollution, lower is the BMWP score. BMWP was calculated by summing the individual score of all families within the community (Sivaramakrishanan, 1992 and Maue and Spring, 2008) [23, 11].

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) [2, 23].

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) [17]. The EPT index is equal to the total number of families represented within these three orders in the sample.

ETO Index

The Ephemeroptera, Trichoptera, and Odonata (ETO) index represents the taxa richness of these groups (Gerritsen *et al*., 1998) [8]. The ETO index is the total number of families represented within these three orders in the sample.

Results

Physio-chemical parameters

In present study the physio-chemical parameters of Asan Wetland of central Himalaya were represented in table 1. Physio-chemical parameters like air temperature, water temperature and conductivity was highest in summer but lowest in winter. The air temperature of Asan Wetland was ranged from the lowest value (22.56±1.25 ºC) in winter to highest value (33.16±1.04 ºC) in summer. The temperature of water also shows fluctuation with respect to the air temperature i.e. (17.03±1.00 ºC) in winter; (23.00±1.00 ºC) in summer. The Conductivity of water remained (0.31±0.02mS/m) in summer but (0.20±0.01mS/m) in winter. The pH and dissolved oxygen values of water were recorded opposite to the other physio-chemical parameters; the pH of water was (7.4±0.1) in summer; (8.4±0.45) in winter. The dissolved oxygen level of Asan Wetland was recorded at lowest value in summer (4.66±1.25mg/l) and highest in winter (8.76±0.58mg/l).

Table 1: Seasonal variation in Physio-chemical parameters of Asan wetland of central Himalaya.

Year 2016	Winter	Summer	Rainy	Post Rainy
Air Temp.	22.56±1.25	33.16±1.04	28.86±1.20	25.33±1.52
Water Temp.	17.03±1.00	23±1	24±2	23.66±2.51
pH	8.4±0.45	7.4±0.1	7.73±0.32	8.03±0.47
Dissolved O_2	8.76±0.58	4.66±1.25	5.63±1.18	7.66±0.70
Conductivity	0.2±0.01	0.31±0.02	0.25±0.03	0.21±0.03

Biomonitoring with Biotic Indexes

The results obtained during the habitat assessment of Asan wetland in 2016 year were summarized in figure 1. Altogether 20 different families of macroinvertebrates were collected comprising of 343 individuals. The maximum density of macroinvertebrates was observed in winter season as compared to the other three seasons. In the present study 20 taxa were collected in Asan wetland, among them family Notonectidae shows dominance in all seasons. The identified macroinvertebrates were belonging to three major categories of invertebrates group, Arthropoda, Annelida and Mollusca. Arthropoda shows higher density of 81% of total macroinvertebrates but Annelida shows low density i.e. 2%. Among Arthropoda, order Hemiptera shows highest contribution value of 35% of total Arthropoda, and Plecoptera shows lowest value 0 %.

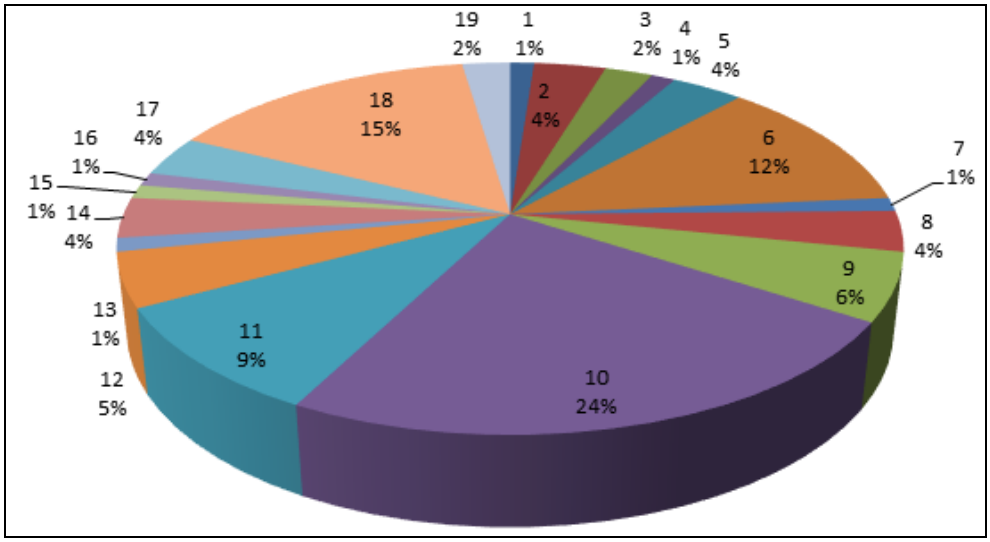

Fig 1: Density of macroinvertebrates families in Asan wetland: 1 Baetidae. 2 Heptageniidae, 3 Euphacidae, 4 Platysticidae, 5 Coenagrionidae, 6 Lestidae, 7 Gomphidae, 8 Glossinidae, 9 Naucoridae, 10 Belostomatidae, 11, Notonectidae, 12 Chironomidae, 13 Culicidae, 14 Ceratopogenidae, 15 Hydrophilidae, 16 Curculionidae, 17 Corydalidae, 18 Glossiphoniidae, 19 Planorbidae, 20 Lymnaeidae.

The Biotic indexes BMWP scores, ASPT, EPT and ETO values also fluctuates with respect to the seasonal environmental changes throughout the study period (Table 2). The BMWP scores of Asan wetland is 101 in winter, 87 in summer, 76 in rainy and 101 in post rainy indicates that the water quality is good in winter and post rainy season but slightly polluted in summer and rainy. The ASPT value of water were 5.05 in winter, 5.11 in summer, 5.06 in rainy and 5.05 in post rainy season. The EPT and ETO values were 3, 3, 1, 3 and 8, 7, 4, 8 in winter, summer, rainy and post rainy respectively indicates that the pollution of water was high in summer and rainy, than in winter and post rainy.

Table 2: Water quality analysis by using Biological indexes in Asan wetland

Indexes	Winter	Summer	Rainy	Post Rainy
BMWP	101	87	76	101
ASPT	5.05	5.11	5.06	5.05
EPT	3	3	1	3
ETO	8	7	4	8

The density of Macroinvertebrates in a particular habitat shows spatio-temporal variation with respect to the physio-chemical parameters of an ecosystem (Table 3). In Asan

wetland, the findings of correlation between density of macroinvertebrates with physio-chemical parameters indicates that the density of macroinvertebrates shows negatively correlation with dissolved oxygen, air and water temperatures but shows positively correlation with pH and conductivity of water.

Table 3: Correlation between densities of macroinvertebrates with physio-chemical parameters of Asan wetland

Year 2016	Density	Air temp.	Water temp.	pH	Dissolved O_2	Conductivity
Density	1					
Air temp.	-0.89041	1				
Water temp.	-0.44104	0.64872	1			
pH	0.859431	-0.99192	-0.74	1		
Dissolved O_2	0.794132	-0.98371	-0.69634	0.985858	1	
Conductivity	-0.91834	0.98034	0.486977	-0.94753	-0.94539	1

Discussion

The present study describes that the physio-chemical parameters moderately influenced with the climatic changes. The air temperature of Asan wetland showed that there is maximum temperature in summer than in winter may be due to seasonal temperatures changes of the study area. The water temperature fluctuates with respect to air temperature, the water temperature of wetland ranges from 17 to 24. The results of variation in temperatures with seasonal changes were related with the observations of Siraj *et al*., 2006, Praveen *et al*., 2013, Mukhtar *et al*., 2014 and Bhat *et al*., 2017 [22, 16, 13, 4].

The pH distribution of water showed that the Asan wetland was slightly alkaline. High pH value of 8.4 was observed in winter season while as the pH dropped during summer and rainy seasons. The pH change from 8.4-7.4 was due to the temperature changes of water with seasonal fluctuations. In winter the temperature of water were low and the pH value shifts towards alkalinity while as in summer the pH value moves towards acidity with increase in temperature. The results of shifting of pH from alkalinity towards acidity is due to the ionization rate of water with respect to temperature changes, the results agreed with reports of Sharma and Rawat, 2009; Mushtaq *et al*., 2013 and Bhat *et al*., 2017 [20, 14, 4].

The dissolve oxygen is another parameter to assess the health of a water bodies. The dissolved oxygen is essential component for survival of living organisms. In this study the dissolved oxygen was lowest in summer 4.66mg/l and highest in winter 8.76mg/l, this decrease in summer may be due to the high photosynthetic rate of producers with increase in temperature by increasing the mortality rate of heterotrophs and high rate of decomposition (Kumar *et al*., 2007, Ganie *et al*., 2012, Parveen *et al*., 2013 and Bhat *et al*., 2017) [18, 7, 16, 4].

Conductivity of water was determined by total density of salts or electrolytes, the conductivity of water of Asan wetland were high in summer 0.31mS/m and low in winter 0.2mS/m. In summer season high conductivity indicates that, when temperature increases it adds more salts and electrolytes by high ionization and decomposition rate (Bartram and Balance 1996; Sharma and Rawat, 2009; Bhat *et al*., 2017) [3, 20, 4]. Another reason for change in conductivity is heavy load of tourists in other seasons than in winter season.

In lentic ecosystem Macroinvertebrates constitutes an important component of tropic levels among aquatic biodiversity. These organisms played an important role in processing of ecosystem like nutrient cycling, metabolism of pollution, dispersion and secondary production of aquatic ecosystem (Merritt and Cummins, 1996; Amar *et al*., 2011,) [12, 1]. The quality of water were now a days observed by using these macroinvertebrates, as they are sensitive and showing strong response to both anthropogenic and natural changes in ecological characteristics of water (Dubuque *et al*., 1993) [6].

According to the BMWP scoring classification method as adopted by Armitage *et al*., 1983 [2]; Maue and Springer, 2008 [11], in this study the results of Asan wetland in year 2016 indicates that the most serious impaired water was recorded in summer season relative to winter. Based on our results the Asan wetland could not be considered as having very clean water (>150), despite being located in an environmental protection area. This impaired water quality of Asan may be due to fact that the two rivers i.e. Asan river and Yamuna river flows through the wetland, these rivers drains all the drainage from local areas into the Asan wetland. Another factor is responsible to the impaired water quality is hydroelectric project on this wetland, these factors affects the macroinvertebrate community. The result of EPT and ETO value of Asan wetland also shows the pollution level of water. The indication of pollution was due to absence of EPT and ETO families, because these macroinvertebrate families are sensitive to the pollution.

Table 4: Water qualities categories of BMWP index according to Armitage *et al*., 1983 [2]; Maue and Springer, 2008 [11].

Class	BMWP Score	Category	Interpretation
I	>150	Good	Very clean water
	101-150		Good quality, no pollution or obvious distortions
II	61-100	Acceptable	Regular quality, eutrophic, medium pollution
III	36-60	Questionable	Bad quality, polluted
IV	15-35	Critical	Bad quality, very polluted
V	<15	Very critical	Bad quality, extremely polluted

In present work 20 families of macroinvertebrates was collected belonging to three different phyla, the spatio-temporal variations in diversity and density among the macroinvertebrates depends on the physio-chemical characteristics of water, availability of suitable habitat and their biological interactions. The results of correlation between density of macroinvertebrates and physio-chemical parameter indicates that macroinvertebrates shows positive correlation with pH and conductivity; when pH value increases towards alkalinity (above pH 7) the macroinvertebrates shows increases in density and diversity

but opposes when pH moves towards acidity (below pH 7). This is because that alkalinity of water favors the density as well as diversity of organisms. The conductivity of water also favors the survival of living diversity by adding of necessary salts and electrolytes.

The macroinvertebrates shows negative correlation with dissolved oxygen, air and water temperatures of an ecosystem, the dissolved oxygen rate increases when there may be low utilization of oxygen by increasing the rate of mortality of heterotrophs with the increase in pollution of water. The air and water temperatures also influence the pollution of fresh waters by increasing the rate mortality of heterotrophs which in turn increases the decomposition rate and high eutrophication rate. Hence after all these observations, if the rate of pollution in Asan wetland may remain increased in same manner; then in future water of this freshwater body of Central Himalaya would be unable to taste.

In conclusion if any organization would not take major steps for conservation of Himalayan and its freshwaters, in future we can miss all these blessed freshwaters recourses of Himalaya.

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