Aquatic Animal Diversity of Manawar Tawi River, Jammu and Kashmir, India

Adhfur Sherwani and Dr. Malik Mukhtar

[1.] Research Scholar, Department of Environment Science
[2.] Professor, Department of Entomology SKUAST-K
showkat80ahmad@gmail.com

Abstract: Animal diversity is an important biotic component of any aquatic ecosystem. Huge biodiversity is found in Manawar water system. The Manawar Tawi is one of the most important rivers of Jammu region. It is one of the major tributaries of the Chenab River. In this study zooplankton and macro zoo benthos diversity was estimated. It was revealed on the basis of the present study on animal diversity that the members of the Ephemeroptera thrive well in the River Manawar Tawi, besides various other species. Besides others twenty two species of fishes belonging to five families have been recorded from the River Manawar Tawi. Therefore, these can be used as the most appropriate and efficient bio-indicators for assessing the health of the important aquatic ecosystem.
[Adhfur Sherwani and Malik Mukhtar, **Aquatic Animal Diversity of Manawar Tawi River, Jammu and Kashmir, India.** *Academ Arena* 2016;8(2):133-140]. ISSN 1553-992X (print); ISSN 2158-771X (online). http://www.sciencepub.net/academia. 2. doi:10.7537/marsaaj08021602.

Keywords: Aquatic, Animal, Diversity, Tawi, River

Introduction

Human survival depends on biodiversity, not only for food, fibre, health but also for recreation. Relationship of biodiversity with ecosystem stability and resilience has been the subject of concern of ecologists for some time now (Odum, 1971). Man has been the sole cause of concern in view of threats caused to these habitats in particular and biodiversity in general due to his greed and development activities and ignorance about the importance of these habitats. Freshwater biodiversity is increasingly threatened by unsustainable development worldwide. While the international strategies (Caring for earth agenda 21) produced in recent years have succeeded in highlighting guiding principles for improved management and conservation of inland freshwater ecosystems, much remains to be done in terms of information and public awareness, resource assessment, integral management, species protection and capacity building to define a set of practical action that could reduce effectively the degradation of fresh water biodiversity.

The aquatic habitat and their biodata have been extensively investigated since the early 19th century. However, a very few studies have been made on the aquatic animal diversity of Jammu and Kashmir. Dutta (1978) undertook studies on the limnology of gadigarh stream of Jammu region; Kaul et al. (1980) studied the ecology of freshwater snails of haigam wetland of Kashmir; Qadri et al. (1981) undertook study on the two trout streams of Kashmir; Pandit et al. (1985) studied ecological relationships between invertebrate and macrophytes of two Himalayan lakes; Gupta (1992) studied feeding biology of two lakes of Mansar of Jammu; Pandit (1992) studied the ecology of insect communities of some wetlands of Kashmir; Khajuria (1992) studied the nekton and benthos of lake Mansar of Jammu; Thakial (1997) studied the benthos of Jammu region; Kaul (2000) studied the effect of industrial water on Behlol nallah of Jammu; Jyoti et al. (2003) studied the effect of pilgrimage on the quality of benthos of stream Banganga of Jammu; Pandit and Yosuf (2003) conducted study on the rotifer community of Kashmir Himalayan lakes; Qadri and Yosuf (2004) conducted study on the ecology of macrozoobenthos of Nigeen lake; Bhat and pandit (2006) studied the substrate influence on macrozoobenthos dwelling a small tributary of vishav stream of Kashmir; Mahdi et al. (2006) undertook study of buniyar stream entomofauna.

However, no work has been done so far on the animal diversity of Manawar Tawi River of Jammu region. Therefore, it was felt desirable to undertake the study on animal diversity of Manawar Tawi River.

Study Sites

The Manawar Tawi is one of the most important rivers of Jammu region. It is one of the major tributaries of the Chenab River. There are eight main tributaries of the Manawar Tawi River. These areas- Rajouri Tawi, Sukhtao, Khandal, Nallah, Jamola Wali Tawi, Dhelloriwali Tawi, Kalar Kas, Panda Kas, Nehari Tawi. The main water source of Manawar Tawi is snow and some perennial springs. There are about 20 high altitude lakes along the northern boundary of the district in the Pir-Panjal range.

'Manawar Tawi' derives its name from a town 'Manawar', which is in Pakistan. There are different names of this river in Rajouri district. Locals used to call the tributaries of this River as 'Nallahs', and the tributaries of 'Nallah' Manawar Tawi is a third stream

order River. The head water stream of 'Manawar Tawi' rises on the southern slope of Pir-Panjal Mountains and is known as 'Thanna-Nallah'. Thanna-Nallah originates from a mountain (2,542m above m.s.I.). The head of Thanna-Nallah is located between $74^0 22^{1/2}$ East longitude and $33^0 32^{1/2}$ North latitude. It then flows southwards and is joined by another Nallah from the eastern side known as 'Darhali-Nallah'. These two Nallahs meet each other between **74^0 18\'** East longitude and **33^0 24\'** North latitude 'Darhali-Nallah' originates from a mountain which is (3,555 m above m.s.I.). Its head is located between **74^0 30\'** East longitudes and **33^0 26\'** North latitude. After confluence of these two Nallahs the river passes through the Rajouri town. For this study three sites (S_1, S_2 and S_3) have been taken a different depth of river.

Material and Methods

Standard methodology was followed for estimation of following parameters as described below:

Zooplankton: Zooplankton was sampled monthly during two annual cycles at three different sampling sites. Macro zooplankton were sampled by towing plankton net vertically in river water to the maximum depth of 10 cm and then hauled at a speed of 10 cm /sec. Horizontal towing through plankton net was also done to estimate the distribution of zooplankton in the surface water of the river. For micro zooplankton (naupli, rotifers, titinnids) 2 liter samples were collected and passed through a 35 µm mesh net. All the samples were immediately fixed with 4 % formalin solution and identification was done with the help of Inverted Compound Microscope.

Macrozoobenthos: Macrozoobenthos colonizing the substrate were collected with the help of the Surber Sampler (0.50nm mesh net) and by hand picking from the stones. The percentage cover of different sized substrata within each Surber quadrat was estimated visually using the substrate sized classes (after Bovee and Milhous 1978) of sand (0.06-2mm), fine gravel (2-32mm), coarse gravel (32-64), cobbles (64-256mm) and boulders (>256mm).

Quantitave estimation of macrozoobenthos was based on numerical counting i.e. units per square meter (ind. /sq. m).The macrozoobenthos were preserved in 4% formalin. These macrozoobenthos were identified to the possible lowest taxonomic level and counted. The qualitative analysis of the benthic samples were made with the help of Needham and Needham (1962); Hynes (1971); Macan (1974); Elliot *et al*.(1988); Wallace *et al*. (1990); Ward and Whipple (1992) and Edngton and Hildrew (1995) and many standard keys of Freshwater Biological Association. U.K.

Statistical Treatment of Data

Statistical mean (□), standard deviation (S.D), correlation ®, linear regression, multiple regression, diversity index, (Shannon Weiner, 1964 alpha diversity and beta diversity), Jaccard evenness, concentration of dominance, similarity indices and dissimilarity indices were under computed.

Diversity Index: Diversity s the mathematical expression that combine three components of community structure-richness (number of species present), evenness (the distribution of individuals among species) and abundance (total number of organisms present). It is used to describe the response of a community to the quality of its environment. For the statistical analysis of the biological components Shannon-Weiner diversity index (1964) and alpha diversity (Kent and Coker, 1994) were calculated.

Shannon-Weiner Diversity Index: Species diversity index ($\overline{H}$) was calculated using the Shannon Weiner information function (Shannon and Weiner, 1964;

$$\text{Diversity index } (\overline{H}) = \sum_{l-1}^{s} \left(\frac{ni}{N}\right) \log_2 \left(\frac{ni}{N}\right)$$

Where,
H = Shannon-wiener index of diversity;
Ni= Total no of individual of a species;
N=total no of individuals of all species

Alpha diversity (α): Alpha diversity is the measure of occurrence of species in any ecosystem (Kent and Coker, 1994). It was analyzed by counting the total number of species present during on sampling.

Alpha diversity=N
Where
N=Total number of species present

Beta Diversity (β): Beta diversity is a comparison of diversity between sites or communities, usually measured as a amount of species changed between the ecosystem. Following (Whittaker 1975), beta diversity was computed to determine the rate of species changed across the sites.

Concentration of Dominance (C): The concentration of Dominance (C) was computed following Simpson (1949):

$$C = -\sum_{i=1}^{s} \left(\frac{n_i}{N}\right)^2$$

Dominance
Where,
C= Concentration of Dominance
ni = total no. of individuals of a species
N=total no. of individuals of all species

Coefficient of Similarity (S): The coefficient of Similarity (S) will be computed following Jaccard (1942).

Coefficient of Similarity C = $\left(\frac{C}{A+B-C}\right)$

Where,

C= No. of common species

A=total no. of species in community A;

B= total number of species in community B;

Results

Aquatic animal diversity of Manawar Tawi is represented by zooplankton, Macrozoobenthos and fish. These aquatic animals act as secondary producers in the aquatic ecosystem of Manawar Tawi.

Zooplankton: The zooplankton in Manawar Tawi River were sparsely populated due to its high water velocity. The seasonal diversity and abundance of zooplankton has been presented in Table (1 species), rotifera (03 species) and copepoda (02 species) in the Manawar Tawi River. Zooplankton showed maximum abundance during spring season and minimum during monsoon. The zooplankton did not show the regular presence in the Manawar Tawi. Therefore, it was not possible to study the monthly variations in density of zooplankton of Manawar Tawi.

Table 1: Seasonal abundance of Zooplankton in River Manawar Tawi recorded for the period November 2009 – October 2011

Zooplankton	Winter (Nov-Jan)	Spring (Feb-Mar)	Summer (Apr-Jun)	Monsoon (Jul-Aug)	Autumn (Sept-Oct)
Protozoa					
Vorticella species	++	+++	++	-	+
Rotifera					
Lecane bulla	+	+++	+	-	++
Trichocera sps	++	++	++	-	+
Cephalodella	+	++	+	-	++
Copepoda					
Nauplius	++	+++	++	-	+
Cyclops sps	+	++	+	-	+

+++: Abundant; ++: Common; +: Rare; -: Absent

Macrozoobenthos: Macrozoobenthos of Manawar Tawi River were represented by the orders of Ephemeroptera (may flies), Trichoptera (caddis flies), Diptera (true flies), Coleoptera (beetles) of class insecta, and some members of Mollusca and Annelida. InManawar Tawi river, a total of 25 taxa of macrozoobenthos were recorded during the two year study period. These were represented by Ephemeroptera (54%), Trichoptera (17.5%), Diptera (9.5%), Coleoptera (5.5%), Mollusca (3.5%) and Annelida (10%) during the period of study.The Ephemeroptera was represented by the nymphs of *Heptagenia lateralis, Heptagenia fuscogrisea, Ecdyonurus insignis, Rhithrogena semicolorata, Caenis horaria, Epeorus, Leptophlebia Choroterpes, Baetis muticus, Ephmerella notata and Ameletus inopinatus*. The Trichoptera was represented by the nymphs of *Parapsyche, Psychomyia,Orthotrichiaand Allocapnia*. The Diptera was represented by two species *Tribe tendipedini and Antocha saxicola.* The Coleoptera was represented was only one species *Psephenus herricki*. The Mollusca was represented by *Gyraulus hirsutus and Sphaerium* simile and the Annelida was represented by *Placobdella multilineata, Placobdella spp., Helobdella and Haemopis.*

The monthly variations in the macrozoobenthos dwelling Manawar Tawi was calculated. The density of macrozoobenthos was found to be maximum (2,310 ind.m^{-2}) in the month of April at S_2 and minimum (644 ind.m^{-2}) in August at S_3 during the first year of observations. During the second year of observations, it was found to be maximum (2,095 ind.m^{-2}) in December at S_3 and minimum (447 ind.m^{-2}) at S_2 in August. The seasonal macrozoobenthos density was found to be maximum (2,061 ind.m^{-2}) in spring at S_2 and minimum (741 ind.m^{-2}) in monsoon at S_3 during the first year of observations. It was maximum (1,889 ind.m^{-2}) in spring at S_1 and minimum (641 ind.m^{-2}) in monsoon at S_2 during the successive year of observations.

Ephemeroptera (Mayflies): In the Manawar Tawi River, Ephemeroptera was represented by the families Heptageniidae, Caenidae, Leptophlebidae, Baetidae, Ephemerellidae and Siphlonuridae. Ephemeroptera was the most dominant Taxon in the Manawar Tawi River.

The density of Ephemeroptera was found to be maximum (1,179 ind.m^{-2}) in March at S_3 and minimum (352 ind.m^{-2}) in July at S_2 during the first year of observations. It was found to be maximum (1,177 ind.m^{-2}) in April at S_2 and minimum (249

ind.m^{-2}) in August at S_2 during the second year of observations. Seasonally, Ephemeroptera was found to be maximum (1,162 ± 88.4 ind.m^{-2}) in spring at S_3 and minimum (384.2 ± 45.3 ind.m^{-2}) in monsoon at S_2 during the first year of study. However, it was maximum (997.1 ± 176.7 ind.m^{-2}) in winter at S_3 and minimum (341.51 ± 131.19 ind.m^{-2}) in monsoon at S_2 during the second year of observations.

Trichoptera (Caddisfly): Trichoptera was represented by the families, Hydropsychidae, Psychomyiidae and Hydroptilidae. Trichoptera was found to be maximum (490 ind.m^{-2}) in March at S_2 and minimum (81 ind.m^{-2}) in August at S_1 during the first year of observations. It was found to be maximum (429 ind.m^{-2}) in February at S_2 and minimum (57 ind.m^{-2}) in August at S_2 during the second year of observations. The seasonal density of Trichoptera was found to be maximum (475.6 ± 202 ind.m^{-2}) in spring at S_2 and minimum (128 ± 51.7 ind.m^{-2}) in monsoon at S_3 during the first year of observations. It was found to be maximum (394 ± 38.2 ind.m^{-2}) in winter at S_1 and minimum (71.71 ± 6.90 ind.m^{-2}) in monsoon at S_3 during the second year of observations.

Diptera (True flies): Diptera of Manawar Tawi was represented by two families, (Tendipedidae and Tipulidae). The mean monthly density of Diptera fluctuated from 13 ind.m^{-2} – 281 indm^{-2} during the first year and 30 ind.m^{-2} – 411 ind.m^{-2} during the second year of observations. Seasonally, Diptera was found to be maximum in winter and summer seasons.

Coleoptera (Water beetles): Coleoptera was represented by one family (Psephenidae) in the Manawar Tawi River. The mean monthly density of Coleoptera ranged from 24 ind.m^{-2} – 201 ind.m^{-2} during the first year and 0.0 ind.m^{-2} – 291 ind.m^{-2} during the second year of study. Seasonally, they ranged from (12.58 ± 17.79 ind.m^{-2} – 185.6 ± 13.7 ind.m^{-2}) during the two year study period.

Mollusca: The members of Mollusca were present at two sites only in the Manawar Tawi River. Mollusca were represented by two families: Planorbidae and Lymnaeidae. The mean monthly density of Mollusca ranged from 0.01 ind.m^{-2} – 2 4.4 ind.m^{-2} during the period of study.

Annelida: Annelida was represented by only one family, Piscicolidae. The mean monthly density of Annelida fluctuated from 41 ind.m^{-2} – 558 ind.m^{-2} during the first year of study. However, it was 23 ind.m^{-2} – 266 ind.m^{-2} during the second year of observations.

Seasonally, it was minimum in (53.1 ± 17.1 ind.m^{-2}) in monsoon season at S_2 and maximum (426.4 ± 114.9 ind.m^{-2}) in summer season during the first year. It was minimum (50.5 ± 39.61 ind.m^{-2}) in monsoon at S_2 and maximum (228.6 ± 34.9 in.m^{-2}) in summer season at S_1 during the second year of observations.

Fish Diversity:

Twenty two species of fishes belonging to five families have been recorded from the River Manawar Tawi. These are *Schizothorax richardsonii, Tor tor, Tor putitora, Labeo dero, labeo rohita, Garra gotyla gotyla, Garra lamta, Barilius bandelisis, Cirrhinus mrigala, Crossocheilus latius, Punitus conchonius, Puntius ticto, Cyprinus caprio, Rasbora daniconius* belonging to family Cyprinnidae; *Glyptostemum reticulum, Glyptothorax kashmirensis, Glyptothorax telchitta,* belonging to family Sisoridae; *Nemacheilus botia, Nemachelius kashmirensis* belonging to family Homalopteridae; *Salmo gairdenerii gairdenerii, Salmo trutta fario* belonging to family Salmonidae and one species of family Mastacembelidae (*Mastacembelus armatus*) have been recorded from the River Manawar Tawi. Two species (*Salmo gairdenerii gairdenerii* and *Salmo trutta fario*) have been introduced on trial basis in the higher reaches of River Manawar Tawi. Results of their success in the river are still awaited.

Statist Ical Analysis

Shannon-Weiner Diversity Index (□): The monthly variations in diversity Index for macrozoobenthos have been estimated. The values of diversity index ranged from (2.7004-4.158) during the first year of observations. In the second year, it ranged from (2.973 ± 4.028). Seasonally, it was maximum (4.114 ± 0.062) during the spring season and minimum (2.846 ± 0.206) in monsoon season during the first year of study. It was again maximum (3.956 ± 0.062) in spring and minimum (3.037 ± 0.040) in monsoon during the second year of study.

Alpha Diversity: The mean monthly variations in Alpha diversity index (α) for macrozoobenthos dwelling Manawar Tawi have been estimated. Alpha diversity (α) for macrozoobenthos was calculated to be maximum (25) in February at S_2 and minimum (13) in the month of August at S_2 during the two year study period.

Seasonally, it was found to be maximum (24) in spring at S_2 and minimum (18) in monsoon at S_2 and S_3 during the first year of observations. It was maximum (23) in spring at S_1 and minimum (17) in monsoon at S_2 during the second year of observations (Table 6.15).

Beta Diversity: The variations in mean beta diversity of macrozoobenthos dwelling Manawar Tawi River has been estimated. Beta diversity was found to be (1.056) during the first year and (1.015) during the successive year of study.

Concentration of Dominance: The monthly variations in the concentration of dominance for macrozoobenthos have been estimated. The

concentration of dominance varied between 0.0498-0.0953 during the first year of study. During the successive year, the value of concentration of dominance fluctuated between 0.0499-0.1.

Coefficient of Similarity: The value for the coefficient of similarity has been calculated. The degree of similarity indices for the macrozoobenthos was statistically tested by using the coefficient of similarity. The value ranged from 92% between S_1, S_2 and S_1, S_3; 100% between S_2, S_3 and S_3, S_2.

Discussion

Aquatic macrozoobenthos are extremely diverse group of animals. They are very important food source for aquatic predators such as fish, amphibians and birds. They play a major role in herbivory and the decomposition of organic materials, and therefore affect nutrient availability and serve as an important part of food chain in the ecosystem. Benthic invertebrates exist within a wide range of environments, and as such, their environmental requirements for pollution and clean water vary greatly as well. They have relatively long life cycles, compared to groups such as zooplankton and phytoplankton and are appropriate for pollution response. The presence of some specific species is an indicator of clean, unpolluted waters, while some other species can thrive well in polluted waters. Because of these characteristics, macrozoobenthos are commonly used to evaluate the ecological integrity of streams and as indicators of water quality assessment (Lenat and Barbour, 1987; Fore *et al.*, 1996; Norris and Norris, 1995 and Plank fin *et al.*, 1989). Distribution, density and biomass of benthic organisms depend upon the physico-chemical characteristics of water, the nature of sediments or substratum, biological complexes such as food, predation and other factors.

The benefits of using macrozoobenthos in ecological assessment include their characteristics (Plankfin *et al.,* 1989). Macrozoobenthos are found in most aquatic habitats. There are a large number of species, and different stresses produce different macrozoobenthos communities. Macrozoobenthos generally have limited mobility and are therefore indicators of localized environmental conditions; since they retain (bio accumulate), therefore, can be utilized as indicators against different toxic substances. Macrozoobenthos are small enough to be easily collected and identified. Sampling of macrozoobenthos is relatively simple. It requires minimal equipment, and does not adversely affect the other organisms. Macrozoobenthos are the primary food source for recreationally and commercially important fish.

The riverine ecosystem of Manawar Tawi comprised of boulders, cobbles, pebbles, sand and silt. The nature of bottom substrate is one of the most significant environmental parameters in influencing the biodiversity of stream; wisely (1962); Minshall (1968) Hynes (1971); Hawkins (1984); and Angradi (1996). Ward (1994) also pointed out that the boulders and cobbles are the dominant feature of headwater streams. The substratum is one of the main factors controlling the composition of biotic communities. Bhat and Pandit (2006) found gravel to support more genera of Macrozoobenthos as against sand.

The density of macrozoobenthos showed a significant negative correlation with water temperature of Manawar Tawi River. Lekmkuhl (1972) studied the influence of water temperature alterations on a benthic community. Several studies have also concluded that insect taxa-richness may be influenced within the same stream ecosystem with annual water temperature variations (Stanford and Ward, 1982).

According to Hynes, (1971), water speed is an important factor of major importance in running waters. It controls the occurrence and abundance of species and hence the whole structure of aquatic insects community. The density of macrozoobenthos showed a significant negative correlation with water velocity. In the monsoon season, due to frequent flash floods substrate instability occurs and this is the major cause of disturbance of aquatic habitat of Manawar Tawi during monsoon season. Erman and Mahoney (1983) and Kamler (1967) had also analyzed the result of flow regime on macro invertebrate communities in lotic ecosystems.

The hydromedian depth of Manawar Tawi was significantly negatively related with the density of macrozoobenthos. Transparency of river water favours the abundance of macrozoobenthic communities. Transparency of Manawar Tawi River was significantly positively related with the macrozoobenthic density. Increased turbidity is unfavourable for macrozoobenthos because load of suspended solids reduce the benthic populations by creating unfavourable conditions on bottom due to blanketing action. Gusain (1994) also stated that the sediments carried by floods during the monsoon increase the turbidity. These sediments fill the interstices amomg the rocks and thereby reduce the density of macrozoobenthos. The macrozoobenthic density. Free carbon dioxide concentration showed a significant negative relationship with the macrozoobenthos. It was found to be highest in monsoon season.

Macrozoobenthic species are differently sensitive to any biotic and abiotic factor in the environment. They have been used as an indicator of the condition

of an aquatic ecosystem (Rosenbergh and Resh, 1993). Changes in the presence/absence, density, behaviour of these organisms can indicate that the physical and chemical conditions are outside their preffered limits (Rosenberg and Resh, 1993). Presence of numerous families of highly tolerant organism usually indicates poor water quality (Hynes, 1998).

The Shannon-Weiner diversity index for aquatic insects remained above 2.70 throughout the study period, indicating the good quality of water. Seasonally, diversity index for macrozoobenthos was recorded highest (4.114±0.06) in spring and lowest (2.846±0.206) in monsoon season. The high value of macrozoobenthos indicates that the communities were most diverse during the spring season.

Whittaker (1975) introduced the concept of alpha, beta and gamma diversity. The measurement of number of species at a particular site is example of alpha diversity. Given an environment gradient, beta diversity can vary among regions and also within a gradient. The total beta diversity is the 'gradient length'. A short gradient has low beta diversity. The beta diversity concept relate to changes in diversity between sites at local (beta) scales. An essential part of these relational concepts is the idea of species turnover, the degree to which species present at one side are replaced by other at a different gradient. Alpha diversity increases with decreasing altitude, while beta diversity increases as geographic range decreases and distribution of abundances among species becomes more equitable.

It is concluded from the above discussion that the density of macrozoobenthos was found to be maximum during spring season when low water current, high dissolved oxygen, low hydromedian depth and low turbidity were recorded in the Manawar Tawi River. A minimum density of macrozoobenthos was recorded in monsoon season when condition of torrential water current, high turbidity and high hydromedian depth prevails. Findings of Singh *et al*. (1994), Sharma (1985) and Sunder (1997) are also in conformity with the present observations.

Faith and Norris (1989) demonstrated that macrozoobenthos assemblages are strongly influenced by the habitat in which they live. Variations in distribution and abundance of benthic organisms may be due to the characteristic of the stream size and distance from the source (Minshall, 1985), substrate (Minshall and Minshall, 1996), vegetation (Vincent, 1983), and fluctuations in temperature and stream discharge (Newbury, 1984; Bournard *et al.,* 1987 and Boulton and Lake, 1992). The degree to which this spatial and temporal variability affecting richness, diversity or biotic indices depend on the species involved and effects on measures of richness/diversity.

A total of twenty five taxa of macrozoobenthos was recorded from the River Manawar Tawi during the period from November 2009-October 2011. These were represented by Ephemeroptera (54%), Trichoptera (17.5%), Diptera (9.5%), Coleoptera (5.5%), Mollusca (3.5%) and Annelida (10%).

Ephemeroptera was the most dominant group in the Manawar Tawi River. Mahdi *et al.* (2006) also found Ephemeroptera as the dominant group in their study on Bunyar stream of Kashmir. Ephemeropterans occupies a diverse range of fresh water habitats and are usually one of the best representative aquatic invertebrates in streams and rivers of high altitude Himalaya. They display ecological and behavioural specializations and constitute a very interesting group for assessing biodiversity in rivers (Dolisy and Dohet, 2003). Moreover, the knowledge of their ecology and life history is essential for understanding the biological structure of streams and lakes. They can be extensively used as indicator species of river water quality. Their study is essential in order to assess the more accurate conservation status and biodiversity of many aquatic ecosystems. In general, they are moderately to slightly tolerant of pollution and usually require high dissolved oxygen concentrations. Substrate preferences are also variable with species present on rocks or gravel, mud and organic debris or on amongst vegetation.

Trichoptera was the second most dominating taxon in the Manawar Tawi. Trichoptera was found to be the second most dominant group by Mahdi *et al.* (2006) in their study on Bunyar stream of Kashmir. Trichoptera is very common in cool streams and rivers and in general are quite intolerant of pollution, requiring high oxygen concentrations. In the Manawar Tawi River, Trichoptera contributed 17.5% of the total macrozoobenthos. Dipterans comprised an average 9.5% in Manawar Tawi River. They live in nearly every available freshwater aquatic habitat, and on the whole are quite tolerant of pollution, surviving in low dissolved oxygen (Clifford, 1991). Bhat *et al.* (2006) found Diptera and Trichoptera as dominant groups in their study on Wangant Nalla. Khajuria (1992) reported the dominance of *Chironomus* over other Dipteras in Manasar Lake. Diptera is one of the most diverse orders of Insecta and their larvae are common in aquatic systems.

The ability of the macrozoobenthos to cope with the environmental heterogeneity (extreme fluctuations in physico-chemical parameters) indicates that they are a sensitive indicator of both environmental and anthropogenic changes. Most aquatic habitats, particularly free flowing streams and waters with acceptable water quality and substrate conditions, support diverse macrozoobenthos communities, in which there is a reasonably balanced distribution of

species among the total number of individuals present. Such communities respond to changing habitats and water quality by alternations in community structure (invertebrate abundance and composition). However, many habitats especially distributed ones are dominated by few species. Macrozoobenthos have been used to assess the biological integrity of stream processes. The fluvial system of Manawar Tawi undergoes homeostasis after spates and regulates the quality and quantity of aquatic plants and animal life.

It was also revealed on the basis of the present study undertaken on animal diversity that the members of the Ephemeroptera thrive well in the River Manawar Tawi. Therefore, these can be used as the most appropriate and efficient bio-indicators for assessing the health of the important aquatic ecosystem.

References

1. Bhat, F.A., Mahdi, M.D., Yousuf, A.R., Siraj, S. and Qadri, B. 2006. Ecology of fish in Wangat nalla (tributary of Sind stream) with a note on the impact of Wangat Bridge on the spatial distribution of fish. *Journal of Research and Development,* 6: 117-128.
2. Bhat, S.U., and Pandit, A.K. 2006. Influence of substrate on the fate of macrozoobenthos in Saeskoom water quality, a small tributary of Vishav Stream. *Journal of Research and Development,* 6: 35-40.
3. Boulton, A.J. and Lake, P.S. 1992. The ecology of two intermittent streams in Victoria, Australia. III. Temporal changes in faunal composition. *Freshwater Biology,* 27: 123-138.
4. Bournard, M., Tachet, H., Roux, A. L. and Auda, Y. 1987. The effects of seasonal and hydrological influence of the macro-invertabrates of the Rhone River, France: *Archiv fur Hydrobioogie* 109: 287-304.
5. Bovee, K.D. and Milhous, R. 1978. *Hydraulic Simulations in In-stream Flow Studies: Theory and Techniques.* United States Fish and Wildlife Service, Stream Flow Group, Information Paper. 1-21.
6. Clifford, H.F. 1991. *Aquatic Invertebrates of Alberta.* The University of Alberta Press, 1-538.
7. Dolisy, D., and Dohet, A. 2003. The use of ephemeroptera to assess aquatic biodiversity in the Luxembourgish rivers. In: *Ephemeroptera and Aquatic Biodiversity.* University of Perugia, Perugia, Italy. 299-303.
8. Dutta, S.P.S. 1978. *Limnology of Gadigarh Stream (Miran Sahib, Jammu) with Special Reference to Consumer Inhabiting the Stream*. Ph.D. Thesis submitted to University of Jammu, Jammu, (J&K).
9. Dutta, S.P.S. 1978. *Limnology of Gadigarh Stream (Miran Sahib, Jammu) with Special Reference to Consumer Inhabiting the Stream*. Ph.D. Thesis submitted to University of Jammu, Jammu (J&K).
10. Elliot, J.M., Humpesch, U.H. and Macan, T.T. 1988. *Larvae of the British Ephemeroptera: A Key with Ecological Notes*. Scientific Publication No. 49. Freshwater Biological Association, The Ferry House, Ambleside, Cumbria, UK, 1-145.
11. Erman, D.C. and Mahoney, S.D. 1983. *'Recovery after Logging in Streams with and without Buffer stripes',* Calif. Water Research Centre, University of California, North California. 1-50.
12. Fore, L.S., J.R. Karr and Wisseman, R.W. 1996. Assessing invertebrate responses to human activities: evaluating alternative approaches. *Journal of the North American Benthological Society,* 15(2): 212-231.
13. Gupta, Arun Kumar. 1992. *Feeding Biology and Some Aspects of Ecology of Fishes Inhabiting lake Mansar, Jammu.* Ph.D. Thesis University of Jammu, Jammu (J&K).
14. Gusain, O.P. 1991. *Limnology and Primary Productivity in a High Altitude River Bhilangana.* D. Phil Thesis submitted to H.N.B. Garhwal University, Srinagar Garhwal. 1-217.
15. Hawkins, C.P. 1984. Substrate association and longitudinal distribution in species of Ephemerellidae (Ephemeroptera: Insect) from Western Oregon. *Freshwater Invertebrate Biology,* 3 (94): 18-88.
16. Hynes, H.B.N. 1961. The Invertebrates fauna of a Walsh mountain stream. *Arch. Hydrobiologia,* 57:344-388.
17. Hynes, H.B.N. 1971. *The Ecology of Running Waters,* Liverpool University Press Liverpool: 1-555.
18. Jyoti, M. K. Gupta, K. and Sharma, A. 2003. Effect of pilgrimage on the quality of biota of stream Ban-Ganga (Katra), Jammu. *Oriental Sc.,* 8: 41-50.
19. Kamler, E. 1967. Distribution of plecoptera and ephemeroptera in relation to altitude above sea level and current speed in mountain waters. *Pol. Arch. Hydrobiology*, 14(27): 29-42.
20. Kaul, V., Pandit, A. K. and Fotedar, D. N. 1980. Ecology of fresh water snails (gastropod molluscs) in Haigam, a typical wetland of Kashmir. *Tropical Ecology*, 21(1): 32-46.
21. Kaul, Vinita 2000. *Effect of Industrial Water and Domestic Sewage on Abiotic and Biotic (Macrobenthic Invertebrates and Fish) Components of Behlol Nallah Jammu* Ph. D. Thesis, University of Jammu, Jammu (J&K).
22. Khajuria, Anil 1992 *Studies on Nekton and Benthos of Lake Mansar*. Ph. D. Thesis, University of Jammu, Jammu (J&K).
23. Lekmkuhl, D.M. 1972. Change in themal regime as a cause of reduction of benthic fauna downstream of a resource. *J. Fish. Res. Board. Canada*, 29: 1322-1329.
24. Lenat, D.R. and Barbour, F. 1987. The macroinvertebrate fauna of the Little River, North

Carolina: Taxa list and seasonal trends. *Archiv fur Hydrobiologia*, 110: 19-43.
25. Macan, T.T. 1974. Freshwater Ecology. Longman Group Ltd., London.
26. Mahdi, M. D., Bhat, F. A. and Yousuf, A. R. 2006. Ecology of benthic entomofauna in Buniyar stream, Kashmir. *Journal of Research and Development*, 6: 61-67.
27. Minhall, G.W. 1985. Stream ecosystem theory: A global perspective. *J. North Am. Benthol. Soc.,* 7: 263-288.
28. Minshall, G.W. and Minshall. J.N. 1966. Note on the life history and ecology of Isoperla Clio (Newman) and Isogenus desicus Walker (Plecoptera: Perlidae). *Am. Midi. Nat.,* 76: 340-339.
29. Needham, J.G. and Christenson, R.O. 1927. Economic insects in some stream of northern Utah. *Utah Agr. Expt. Sta. Bull*., 201: 1-36.
30. Newbury, R. W. 1984. Hydrological determinants of aquatic insect habitat. In: Resh, V. B. and Rosenberg, D. M. (ed.) *The Ecology of Aquatic Insects* Praeger.
31. Norris, R. H. and Norris, K. R. 1995. "The need for biological assessment of water quality: Australian perspective." *Australian Journal of Ecology*, 2: 1-16.
32. Odum, E. P. 1971. *Fundamentals of Ecology*. W. B. Saunders Co. Philadelphia. 1-574.
33. Pandit, A. K. 1992. Ecology of insect community in some typical wetlands of Kashmir. 27-286 In: Yousuf, A. R., Raina, M. K. and Qadri M. Y. (eds.) *Current Trends in Fish and Fishery Biology and Aquatic Ecology*. University of Kashmir, Srinagar, Kashmir.
34. Pandit, A. K. and Yousul, A. R. 2003. Rotifer communitv in some Kashmir Himalayan lakes of varied trophic status. *Journal of Research and Development*, 3:97-108.
35. Pandit, A. K., Pandit, S. N. and Kaul, V. 1985. Ecological relations between invertebrates and submerged macrophytes in two Himalayan lakes. *Poll. Res.,* 4(2): 53-58.
36. Plankfin, J. L., Barbour, M. T., Porter, K. D., Gross, S. K. and Hughes, R. M. 1989. Rapid Bioassessment Protocols for Use in Streams and Rivers. *Benthic macroinvertebrates and fish assessment and water protection division, U.S. Environmental Protection Agency*. Report EPA/440/4-89-001. Washington, D.C.
37. Qadri, H. and Yousuf, A. R., 2004. Ecology of macrozoobenthos in Nigeen lake. *Journal of Research and Development*, 4: 59-63.
38. Qadri, M. Y., Naqash, S. A., Shah, G. M. and Yousuf, A. R. 198 l. Limnology of two trout streams of Kashmir, *J. Indian Inst. Sci*., 63: 137-141.
39. Rosenberg, D. M. and Resh, V. H. 1993. *Freshwater Biomonitoring and Benthic Invertebrates*. Chapman and Hall, New York. 1-488.
40. Sharma, R.C. 1985. Seasonal abundance of phytoplankton in the Bhagirathi river of Garhawal Himalaya. *Indian Journal Ecology*, 12(1): 157-160.
41. Singh, M. and Sinha, R.K. 1994. Primary productivity and limnological profile of two ponds of Patna, Bihar. *J. Freshwater. Biology*, 6(2): 127-133.
42. Stanford, J. A. and Ward, J.V. 1983 Insect species diversity as a function of environmental variability and disturbances in stream system In: Barnes, J. R. Minshall W. (eds.) *Stream Ecology: Application and Testing of General Ecological Theory*, New York, Plenium. 265-78.
43. Sunder, S. 1997. Biotic communities of Kumaon Himalayan river Gaula macrobenthie invertebrates. *Proc. Nat. Acad. Science. India* 167 (B) 11: 157-168.
44. Thakial, M. R. 1997. *Studies on Benthos in Some Habitats of Jammu*. Ph.D. Thesis submitted to the University of Jammu, Jammu (J&K).
45. Vincent, B. 1983. Variaions Spatiales et saisonnieres de La structure de groupcments macrobenthiques Lithoraux en climat froid. *Hydrobiologia*, 102: 175-183.
46. Wallace, Wallace, B. and Philipson, G.N. 1990. *A Key to the Case Bearing Caddis Larvae of Britain and Ireland*. Scientific Publication No. 51. Freshwater Biological Association. The Ferry House, Amble side, Cumbria.
47. Ward, H. B. and Whipple, G. C. 1992. *Freshwater Biology*. John Wiley and Sons (2nd edn). New York. 1-1248.
48. Whittaker, R.H. 1975. Evolution and measurement of species diversity. *Taxon*, 21: 213-251.
49. Wisely, B. 1962. Studies on ephemeroptera II. *Coloburiscus humeralis* (Walker); ecology and distribution of the Nymphs. *Trans R. Soc. N. N. Zool*., 2: 209-220**.**

2/1/2016