Life Science Informatics Publications

Research Journal of Life Sciences, Bioinformatics, Pharmaceutical and Chemical Sciences

Journal Home page http://www.rjlbpcs.com/

RJLBPCS

ISSN 2454-6348

Original Research Article **DOI: 10.26479/2018.0405.06**

AQUATIC MACROINVERTEBRATE DIVERSITY AND WATER QUALITY OF MARA BHARALI RIVER IN SONITPUR DISTRICT OF ASSAM

A. Das*, S.P. Biswas

Department of Life Sciences, Dibrugarh University, Dibrugarh, Assam, India.

ABSTRACT: The present investigation was conducted in the remnants of old channel of Jia Bharali called as Mara Bharali at Tezpur in the Sonitpur district of Assam during the period from January to December, 2017. Five sampling stations were selected from Pumpani village (N-26º45'10.52" and E-92º50'07.93") to Maithan (N-26º37'05.69" and E-92º49'34.34"), Tezpur where Mara Bharali meets the river Brahmaputra. The 05 sampling stations has been demarcated as MB5 (Pumpani village, N-26º45'10.52" and E-92º50'07.93"), MB4 (Amlopam village, N-26º41'16.84" and E-92º48'58.88"), MB3 (Dolabari village, N-26º40'00.65" and E-92º49'43.64"), MB2 (Porowa Bridge, N-26º39'10.05" and E-92º47'49.28") and MB1 (Maithan, N-26º37'05.69" and E-92º49'34.34") that covers a stretch of 16.5 km. The mean water temperature, transparency, TDS, dissolved oxygen, free CO_2, hardness, alkalinity and pH were found to be within the WHO permissible limits. However, turbidity was found to range between 58 NTU and 228.5 NTU which is above WHO permissible limits. Twenty (20) species of aquatic insects belonging to 13 families and 7 orders were identified from five sampling stations. *Laccotrephes sp.*, *Notonecta sp.*, *Hydaticus sp.* and *Hydrophilus sp.* were the most abundant species. Insect species were dominated by the orders Hemiptera and Decapoda with 4 and 5 representatives of each respectively. Moreover, six (6) molluscan species belonging to 5 different families, Viviparidae, Planorbidae, Pachychilidae, Ampullariidae and Bithyniidae were identified with most dominant species being *Gyrulus convexiusculus*, *Brotia costula* and *Pila globosa*.

KEYWORDS: Water quality, R.Mara Bharali, Hemiptera, Bivalvia, Gastropoda.

Corresponding Author: A. Das

Department of Life Sciences, Dibrugarh University, Dibrugarh, Assam, India.

Email Address: abhijitd23@gmail.com

1. INTRODUCTION

On Earth, water circulation is one of the most important processes for the maintenance of the environment. Pollution of these waters occurs through industrial or municipal discharges or runoff from agricultural land, urban land or construction. As a result of pollution, aquatic organisms such as macro-invertebrates and fish may become oxygen-stressed, which indeed increases mortality rates of sensitive species [1]. Rapid industrialization, water abstraction and the extensive use of pesticides in agriculture have severe strains on rivers and resulted in deterioration of water quality. Freshwater habitats harbour diverse fauna, with fish and macro-invertebrates serving as prime indicators of ecosystem status [2]. Riverine fauna show a high degree of endemism, with most endemic fish species living in headwater streams and/or short stretches of river [3, 4]. It is very important to assess the quality of river water. The surface water quality deteriorates due to anthropogenic activities, industrialization, farming activities, transportation, urbanization, animal and human excretions and domestic wastes. Aquatic organisms need a healthy environment. Maximum productivity depends on optimum level of physicochemical parameters [5]. Aquatic insects, an important component of aquatic ecosystems are very abundant and diverse group that inhabits a variety of aquatic environments [6]. They play an important role in ecosystem functioning and are used as bioindicator. These bioindicators have the advantage of monitoring anthropogenic stress of an ecosystem over a long period of time [7]. The northeast Indian biogeographic zone is most significant as it represents the transition zone between the Indian, Indo-Malay and Indo-Chinese biogeographic regions, as well as a meeting-place of Himalayan Mountains with those of Peninsular India [8]. In north-east India studies on aquatic insect community are scanty in lotic systems and most of the studies were done in lentic systems [9]. Aquatic insect diversity of the study area has not been studied so far. The present study was therefore conducted on physico-chemical parameters of river Mara Bharali and the diversity of aquatic macro-invertebrate community with their distribution and abundance.

2. MATERIALS AND METHODS

Study area:

Sampling stations were selected in the old channel of Jia Bharali named as Mara Bharali from Pumpani village (N-26º45'10.52" and E-92º50'07.93") to Maithan (N-26º37'05.69" and E-92º49'34.34") where it meets river Brahmaputra. The 05 sampling stations has been demarcated as MB5 (Pumpani village), MB4 (Amlopam village, N-26º41'16.84" and E-92º48'58.88"), MB3 (Dolabari village, N-26º40'00.65" and E-92º49'43.64"), MB2 (Porowa Bridge, N-26º39'10.05" and E-92º47'49.28") and MB1 (Maithan) that covers a stretch of about 16.5 km.

Methodology

Studies on physico-chemical parameters of water

The water samples were collected from 02 sampling stations of river Mara Bharali (MB1 and

MB2). The selected parameters were studied for a period of 01(one) year from January to December, 2017 on a seasonal basis. For ecological study of the river, following aspects were undertaken:

Physical parameters

1. Temperature: Water temperature was recorded by a mercury thermometer.
2. Transparency: Transparency was measured by Secchi disc.
3. Turbidity: Turbidity of the river water was measured by a turbidimeter.
4. TDS: Total dissolved solids (TDS) was determined with the help of a TDS meter.
5. Flow rate: Flow rate of the water body was measured by a flow meter.

Chemical parameters

1. Hydrogen-ion-concentration (pH): It was determined by an electronic pH meter.
2. Dissolved oxygen (DO): It was estimated as per modified Winkler's method.
3. FCO_2 and total alkalinity was determined as per standard protocols [10].
4. Total hardness: The parameter was measured by EDTA titrimetrically, following methods discussed earlier [10].

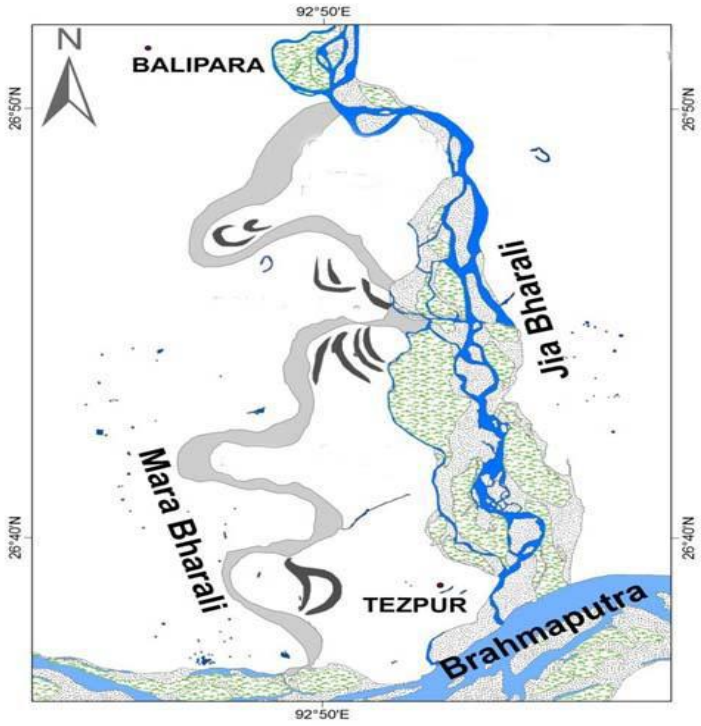

Fig1: Map showing the study area, R. Mara Bharali at Tezpur, Assam

Studies on macro-invertebrate diversity

Macro invertebrates (Arthropods and Molluscs) from each sampling stations (MB1, MB2, MB3, MB4 and MB5) were collected using dragging net following standard protocols [11, 12]. Families of macroinvertebrates present were preserved in 70% ethanol and transported to the laboratory for further studies. Collected species were washed, photographed with the help of a digital camera and

then identified as per methods discussed earlier [13, 14, 15, 16].

3. RESULTS AND DISCUSSION

In the present investigation seasonal variation of certain physico-chemical parameters of river Mara Bharali has been studied together with macro-invertebrate diversity.

Assessment of physico-chemical parameters

Temperature

Mean water temperature was found to vary with atmospheric temperature and was found to be maximum during post monsoon season at 33^0C and minimum during winter at 21.6^0C (Table 1).

Transparency

Transparency of water fluctuates from 21.8 cm to 65.3 cm. The maximum (65.3 cm) was recorded in pre-monsoon season and minimum (21.8 cm) was recorded in monsoon season (Table 1).

Turbidity

Turbidity which is the measure of water clarity indicates the degree to which light entering a column is scattered by suspended solids. Turbidity was found to be minimum at 58 NTU during pre-monsoon and maximum at 228.5 NTU during post-monsoon (Table 1).

Total dissolved solids

Water is desirable for drinking up to a TDS permissible limit of 500 mg/L. The mean total dissolved solid was found to range between 220 mg/L to 361.5 mg/L which was within the WHO permissible limit. However, during the post monsoon the mean TDS was found to be maximum at 361.5 mg/L and minimum during winter at 220 mg/L (Table 1).

Flow rate

The mean flow rate was found to range between 0.47 m/s to 0.54 m/s. Maximum flow rate of water was recorded during pre-monsoon at 0.54 m/s whereas the minimum was found to be 0.47 m/s during the post-monsoon season (Table1).

DO

Dissolved oxygen (DO) content has a vital role for maintaining aquatic life and is susceptible to slight environment changes. In the present investigation, DO value depleted in monsoon and was found to be 6.9 mg/L whereas in post-monsoon season the mean dissolved oxygen value was found maximum at 8.1 mg/L (Table 2).

FCO_2

The value of FCO_2 was found to range from 7.2 mg/L to 21.2 mg/L (Table 2). The maximum value (21.2 mg/L) was recorded in post-monsoon season and the minimum value of 7.2 mg/L was estimated in pre-monsoon.

Hardness

The value of hardness fluctuates from 86.5 mg/L to 180 mg/L. The maximum value, 180 mg/L was recorded in pre-monsoon and a minimum value of 86.5 mg/L was recorded in winter (Table 2).

Alkalinity

Total alkalinity ranges from 115 mg/L to 167.5 mg/L. The maximum value (167.5 mg/L) was recorded in pre-monsoon and the minimum of 115 mg/L was estimated during winter. During the monsoon season the alkalinity was found to be 162 mg/L (Table 2).

pH

Significant difference was not found in pH during the assessment period. During the present investigation it was found that during the pre-monsoon season the mean pH was 7.3, during monsoon 6.8, post-monsoon 7.4 and in winter 7.05 (Table 2).

Distribution and abundance of macro-invertebrates

The study revealed the presence of 20 species of aquatic insects belonging to 13 families and 7 orders at five different sampling sites of river Mara Bharali (Table 3 & Fig. 2). The orders are Ephemeroptera, Hemiptera, Trichoptera, Coleoptera, Decapoda, Diptera and Odonata. Insect species were dominated by the orders Hemiptera and Decapoda with 4 and 5 representatives of each respectively. The representative species of Hemiptera are *Laccotrephes sp., Curicta sp., Micronecta sp.* and *Notonecta sp.* The representative species of Decapoda include *Macrobrachium carcinus, Macrobrachium malcolmsonii, Macrobrachium choprai*, *Macrobrachium assamense* and *Macrobrachium birmanicum*. Moreover, 6 molluscan species has also been recorded from the area of study. The molluscan species belonged to 5 different families and they are Viviparidae, Planorbidae, Pachychilidae, Ampullariidae and Bithyniidae. Molluscs were dominated by Gastropods with 5 representatives (*Bellamya bengalensis, Gyrulus convexiusculus, Brotia costula, Pila globosa* and *Gabbia sp.*). Only, 1 representative of Bivalvia was identified from the area of study (*Lamellidens sp.*). The Site-1, 4 and 5 were found to be rich in macro-invertebrate species diversity and Site-1(MB1) was found to harbour all the 6 molluscan species collected and identified from the riverine system. Among the insects, *Laccotrephes sp., Notonecta sp., Hydaticus sp.* and *Hydrophilus sp.* were the most dominant species. *Gyrulus convexiusculus, Brotia costula* and *Pila globosa* were the dominant molluscan species in the aquatic system (Table 3 & Fig. 2).

Table 1: Means of different physical parameters at sampling station MB1 (Maithan) and MB2 (Porowa Bridge) of river Mara Bharali

Season	Temperature°C			Tranaparency (cm)			Turbidity NTU			TDS mg/lit			Flow rate m/s		
	MB1	MB	Mean	MB	MB	Mean	MB	MB	Mean	MB	MB	Mean	MB	MB	Meann
Winter	21.2	22	**21.6**	50	70	**60**	106	36.5	**71.3**	290	220	**255**	0.60	0.40	0.50
Pre Monsoon	27.5	28	**27.7**	55	75.5	**65.3**	98	18	**58**	250	190	**220**	0.66	0.42	0.54
Monsoon	31	32	**31.5**	18.5	25	**21.8**	250	198	**224**	370	320	**345**	0.50	0.48	0.49
Post Monsoon	31	35	**33**	21.5	23	**22.3**	245	212	**228.5**	378	345	**361.5**	0.54	0.40	0.47

Table 2: Means of different chemical parameters at sampling station MB1 and MB2 of Mara Bharali

Season	Dissolved oxygen			Free CO_2			Hardness			Alkalinity			pH
	MB	MB	Mean	MB	MB2	Mean	MB	MB2	Mean	MB1	MB2	Mean	Mean
Winter	8.5	7.4	**7.95**	14.5	16.2	**15.4**	85	88	**86.5**	120	110	**115**	**7.05**
Pre Monsoon	7.4	6.8	**7.1**	6.6	7.8	**7.2**	185	175	**180**	180	155	**167.5**	**7.3**
Monsoon	7.1	6.7	**6.9**	17.6	21.1	**19.4**	145	159	**152**	175.5	148.5	**162**	**6.8**
Post Monsoon	8.4	7.8	**8.1**	22.1	20.2	**21.2**	110	120	**115**	150.5	140.2	**145.4**	**7.4**

Value expressed in mg/lit

Table 3: Distribution of macro-invertebrate fauna of Mara Bharali river

Sl. No.	Macro-invertebrate species	Family	Order	Site	Abundance
1	*Isonychia sp.*	Isonychidae	Ephemeroptera	MB(1,4,5)	+
2	*Caenis sp.*	Caenidae	Ephemeroptera	MB(1,2,4,5)	+
3	*Diplonychus sp.*	Belostomatidae	Ephemeroptera	MB(1,2,3,4,5)	++
4	*Laccotrephes sp.*	Nepidae	Hemiptera	MB(1,2,3,4,5)	+++
5	*Curicta sp.*	Nepidae	Hemiptera	MB(1,2,4,5)	++
6	*Micronecta sp.*	Notonectidae	Hemiptera	MB(1,4,5)	+
7	*Notonecta sp.*	Notonectidae	Hemiptera	MB(1,3,4,5)	+++
8	*Stenopsyche sp.*	Stenopsychidae	Trichoptera	MB(1,4,5)	+
9	*Hydaticus sp.*	Dytiscidae	Coleoptera	MB(2,4,5)	+++
10	*Macrobrachium carcinus*	Palaemonidae	Decapoda	MB(1,2,3,4,5)	++
11	*Macrobrachium malcolmsonii*	Palaemonidae	Decapoda	MB(1,,4,5)	++

12	*Macrobrachium choprai*	Palaemonidae	Decapoda	MB(1,4,5)	+
13	*Macrobrachium assamense*	Palaemonidae	Decapoda	MB(4,5)	++
14	*Macrobrachium birmanicum*	Palaemonidae	Decapoda	MB(1,2,3,4,)	+
15	*Chironomus sp.*	Chironomidae	Diptera	MB(1,2,3,4,5)	+
16	*Culex sp.*	Culicidae	Diptera	MB(1,2,3,4,5)	+
17	*Lestes sp.*	Lestidae	Odonata	MB(1,3,4)	++
18	*Hydrophilus sp.*	Hydrophilidae	Coleoptera	MB1	+++
19	*Laccophilus sp.*	Dytiscidae	Coleoptera	MB(1,2,3)	+
20	Dragon fly (nymph)	Aeshnidae	Odonata	MB(1,4,5)	++
21	*Bellamya bengalensis*	Viviparidae	---	MB(1,4)	++
22	*Gyrulus convexiusculus*	Planorbidae	---	MB(1,5)	+++
23	*Brotia costula*	Pachychilidae	---	MB(1,4)	+++
24	*Pila globosa*	Ampullariidae	---	MB(1,2,3,4,5)	+++
25	*Lamellidens sp.*	Ampullariidae	Unionoida	MB(1,4)	+
26	*Gabbia sp.*	Bithyniidae	Littorinimorpha	MB(1,4,5)	++

Hydaticus sp.

Hydrophilus sp.

Dragonfly (nymph)

Micronecta sp.

Notonecta sp.

Lestes sp.

Diplonychus sp.

Laccotrephes sp.

Gabbia orcula

Brotia costula

Gyrulus convexiusculus

Lamellidens sp.

Fig 2: Photographic representation of macro-invertebrates of river Mara Bharali

DISCUSSION

Different physico-chemical parameters are important in deciding the quality and productivity of an aquatic system. Temperature is an important ecological feature that influences the behavioral characteristics of organisms, solubility of gases and content of salts in water. The fluctuation of temperature usually depends on the season, geographic location, sampling time and content of effluents entering the river system [17]. In the present investigation, the water temperature was found to vary with atmospheric temperature and was found maximum during post monsoon and minimum during winter. Temperature exerts a strong influence on many physical and chemical characteristics of water including the solubility of oxygen and other gases [18]. A higher temperature depletes solubility of dissolved oxygen in water and reduces its concentration. Vulnerability of organisms to the toxins e.g. cyanide, zinc, phenol and xylene is found intensified as temperature increases [19]. Change in alkalinity is a result of change in pH. The pH value increases due to the activity of photosynthetic algae which consumes CO_2 dissolved in water [20]. The pH of a water body has importance in determination of water quality as it chemically reacts with remaining factors. Aquatic organisms are sensitive to pH fluctuations and their biological treatment requires pH control or monitoring [21]. Significant difference was not found in pH during the assessment period. The range of pH value (6.8 – 7.4) was found to be within the WHO permissible limit. Turbidity which is the measure of water clarity indicates the degree to which light entering a column is scattered by suspended solids. The Maithan site (MB1) had turbidity in the range of 98 NTU to 250 NTU during the period of study. Comparatively, Porowa Bridge site

(MB2) showed lower turbidity range of 18 NTU to 212 NTU. The turbidity of site MB2 was lower than that of site MB1 which indicated high amount of suspended particles present at the Maithan site and therefore more polluted than Porowa Bridge site. The WHO permissible limit for turbidity of drinking water is between 5 – 25 NTU. As water became more turbid, less sunlight can penetrate and therefore the rate of photosynthetic activity is lowered. In addition, suspended materials absorbed heat from sunlight and raise the water temperature which indicate limited amount of dissolved oxygen in water [22]. Turbidity of river water can be low or high depending on the water current and sedimentation [23]. Total dissolved solid depends on various factors such as geological character of watershed, rainfall and amount of surface runoffs and gives an indication of the degree of dissolved substances [24]. Water is desirable for drinking up to a TDS permissible limit of 500 mg/L. TDS in water is found due to content of carbonates, bicarbonates, chlorides, phosphates and nitrates of calcium, magnesium, sodium, potassium, manganese, organic matter salt and other particles [21]. The total dissolved solids ranged between 320 - 370 mg/L during monsoon, 345 – 378 mg/L during post-monsoon, 220 – 290 mg/L during winter and 190 – 250 mg/L during pre-monsoon which are within the WHO permissible limits. Dissolved Oxygen (DO) content has a vital role for maintaining aquatic life and is susceptible to slight environment changes. Oxygen depletion often results during times of high community respiration and hence DO has been extensively used as a parameter delineating water quality and to evaluate the degree of productivity of water [25]. Dissolved oxygen affects the growth, survival, distribution, behavior and physiology of aquatic organisms [26]. It is also found to be an important limnological parameter indicating level of water quality and organic pollution in the water body [27]. In the present investigation DO was found to be highest during post-monsoon and winter and it ranged between 7.8 – 8.4 mg/L and 7.4 – 8.5 mg/L respectively. Seasonal variation in DO content was related to temperature and biological activities [28]. The results were similar to as recorded earlier [29, 30]. In the present study the mean water hardness value ranged between 86.5 mg/L and 180 mg/L. According to WHO, the permissible value is 500 mg/L. This proves that the water of the Mara Bharali is suitable for the growth and production of fish. The use of living organisms for monitoring water quality originated in Europe and it is widely used throughout the world. In the present study the order Hemiptera and Decapoda was found most diverse and relatively abundant in the stream. A study in the lower reach of Moirang River in Manipur and Bakuamari stream in Assam also showed high Hemiptera diversity [31]. Moreover, also in Du river basin in northern Vietnam, Hemiptera was found to be the most diverse order [32]. Change in community structure is mainly due to changes in the geomorphology and the associated destruction of in-stream physical habitats. The relatively more abundance or dominance of order Hemiptera in the stream could be due to their modified body structure [33]. The dominancy of Gerridae and Veliidae of order Hemiptera has also been recorded in the study of aquatic and semiaquatic Heteroptera

(Insecta) in high altitudinal stream systems of Cuba [34]. The causes of fluctuations in insect abundance, dominance and distribution include macroclimatic and microclimatic changes and variation in the availability of food resources. Six molluscan species belonging to two classes and five families has been identified so far from the area of study. A similar study was conducted on the molluscan community of Bharathapuzha river in Kerala and thirteen species of molluscs belonging to five orders, eight families and ten genera were reported [35]. Biodiversity studies of molluscs from river Godavari reported 24 species of freshwater molluscs. The abundance of the molluscan fauna indicates rich productivity. The species inhabiting bottom of the river play an important role in converting organic matter into biomass which in turn is consumed by fishes. Thus the molluscs help in secondary productivity and form an important component in the food web of the river ecosystem [36]. The molluscan diversity of river Mara Bharali indicates that productivity of the aquatic system is moderately rich.

4. CONCLUSION

In the present investigation seasonal variation of certain physico-chemical parameters of river Mara Bharali has been studied together with macro-invertebrate diversity. Physical parameters were found to within the permissible limits but turbidity was found to be minimum at 58 NTU during pre-monsoon and maximum at 228.5 NTU during post-monsoon. These values were found to be above the WHO permissible limit for drinking water quality (5-25 NTU). Regarding chemical parameters, DO value depleted in monsoon and was found to be 6.9 mg/L whereas in post-monsoon season the mean dissolved oxygen value was found maximum at 8.1 mg/L. During the present investigation it was also found that during the pre-monsoon season the mean pH was 7.3, during monsoon 6.8, post-monsoon 7.4 and in winter 7.05. The values were within the range of WHO permissible limit of 6.5 – 8.5. The study also revealed the presence of 20 species of aquatic insects belonging to 13 families and 7 orders at five different sampling sites of river Mara Bharali (Table 3 & Fig. 2). The orders are Ephemeroptera, Hemiptera, Trichoptera, Coleoptera, Decapoda, Diptera and Odonata. Insect species were dominated by the orders Hemiptera and Decapoda with 4 and 5 representatives of each respectively. Moreover, 6 molluscan species has also been recorded from the area of study. The molluscan species belonged to 5 different families and they are Viviparidae, Planorbidae, Pachychilidae, Ampullariidae and Bithyniidae. In future investigations diversity index will be studied to evaluate the variety of a data group consisting of different types of components. Features of a population such as number of existing species (Richness), distribution of individuals equally (Evenness) and total number of existing individuals underlie the basis of diversity indices. Thus, any changes in any of these three features will affect the whole population. The diversity indices depending upon these features can be used effectively to determine the changes in a population. Diversity index can therefore be used to measure environmental stress.

ACKNOWLEDGEMENT

We thank the Head, Dept. of Life Sciences, Dibrugarh University for providing necessary laboratory facilities. The first author also express thanks to the Principal, Darrang College, Tezpur, Assam, for granting permission to conduct certain research activities in the laboratory of Department of Zoology, Darrang College. We also express our gratitude to the fishermen of river Mara Bharali who helped us significantly in collection of specimens. Lastly, we express our heartfelt thanks to all the members of the team involved in the field work, for their help and co-operation.

CONFLICT OF INTEREST

No financial interest or any conflict of interest does exist.

REFERENCES

1. Mason CF. Biology of freshwater pollution. Longman scientific and Technical, New York, 1991.
2. Karr JR, Fausch KD, Angermeier PL, Yant PR, Schlosser IJ. Assessing biological integrity in running waters: a method and its rationale III. Natural Hist. Survey, 1986; 5: 28.
3. Groombridge B. Global biodiversity status of earth's living resources. Chapman and Hall, London, 1992.
4. Kottelat M, Whitten T. Freshwater biodiversity in Asia with special reference to fishes. The World Bank Technical Report No. 343, Washington DC, 1997.
5. Sadia A, Feroza HW, Imran Q, Muhammad Hamid SW, Tirmizi SA and Muhammad AQ. Monitoring of anthropogenic influences on underground and surface water quality of Indus River at district Mianwali-Pakistan. Turk. J. Biochem., 2013; 38(1): 25-30.
6. Zborowski P, Storey R. A Field Guide to Insects in Australia. Reed Books Chatswood, New South Wales, 1995.
7. Rosenberg DM, Resh VH. Introduction to freshwater biomonitoring and benthic macroinvertebrates, In: Rosenberg DM, Resh VH, editors. Freshwater biomonitoring and benthic macroinvertebrates. Chapman and Hall, New York, 1993.
8. Myers N, Mittermeier RA, Mittermeier CG, Fonseca GAB, Kent J. Biodiversity hotspots for conservation priorities. Nature, 2000; 403: 853-858.
9. Gupta A, Michael RG. Diversity, distribution and seasonal abundance of *Ephemeroptera* in stream of Meghalaya State, India. Hydrobiologia, 1992; 228: 131-139.
10. Trivedy RK, Goel PK, Trisal CL. Practical methods in Ecology and Environmental Science. Enviro Media Publication, Karad (India), 1987.
11. Barbour MT, Gerritsen J, Snyder BD. Stribling rapid Bioassessment protocols for use in streams and wadeable rivers: Periphyton benthic macroinvertebrates and fish (2nd Edition). U.S. Environmental Protection Agency, Washington D.C., 1999.

12. Mandaville SM. Benthic macroinvertebrates in freshwater – Taxa Tolerance Values, Metrics and Protocols. Project H – 1, Soil and Water Conservation Society of Metro Halifax. xviii, 48p, Appendices A – B, 2002.
13. Pennak RW. Freshwater invertebrates of the United States; Protozoa to Mollusca. John Wiley and Sons, New York, 1989.
14. Subba Rao NV. Hand Book- Freshwater Molluscs of India. Zoological Survey of India, Calcutta, 1989.
15. Edmondson WT. Ward and Whipple's Fresh Water Biology (2nd Edition). John Wiley and Sons, New York, 1993.
16. Merritt RW, Cummins KW. An introduction to Aquatic insects of North America (3rd ed.). Kendall-Hunt, 1996.
17. Dallas, Day J. The Effect of Water Quality variables on aquatic Ecosystems: A Review, WRC Technical Report No. 224/04. Water research Commission, Pretoria, South Africa, 2004.
18. Duffus JH. Environr Toxicology resource and Environr series. Edwards Arnold (Publishers) Ltd., 1980.
19. Merritts D, Dewet A, Menking K. Environmental Geology: An Earth System Science Approach, New York, W.H. Freeman and Company, 1998.
20. Kang JK, Song Y, Moon JW, Moon HS. Water quality impact of mining in the Wolmyoung area of Korea, and its short term changes. Water Air Soil Poll., 2001; 129: 349 – 367.
21. Fakayode SO. Impact assessment of industrial effluents in fisheries research, Auburn University, Alabama. Principles, 2005; 10: 1 – 13.
22. Thorvat AR, Sonaje NP, Majumdar MM, Swami VA. A study on the physico-chemical characteristics of Panchaganga river in Kolhapur city, MS, India. Res. J. Chem. Sci., 2012; 2(8): 76 – 79.
23. Smitha AD, Shivashankar P. Physico-chemical Analysis of the Freshwater at River Kapila, Nanjanguda Industrial Area, Mysore, India. Int. Res. J. Environ. Sci., 2013; 2(8): 59 – 65.
24. Siebert S. Groundwater use for irrigation – a global inventory. Hydrol. Earth Syst. Sci., 2010: 1863 – 1880.
25. Chapman D, Kimstach V. Selection of water quality variables. In: Water assessment (Ed. Champman D). UNESCO, WHO and UNEP, 1992: 59 – 126.
26. Joshi BD, Bisht RC. Some aspects of physic-chemical characteristics of Western Ganga canal near Jwalapur at Haridwar. Himalayan J. Environ. Zool., 1993; 7: 76 – 82.
27. Kataria HC, Jain OP, Gupta SS, Srivastava RM, Shandilya AK. Physico-chemical analysis of water of Kubza river of Hoshangabad. Orient. J. Chem., 1995; 11(2): 157 – 159.

28. Parashar NB, Kaushik P, Pandey S. Physico-chemical and Microbiological Studies of Ganga Canal at Haridwar during Kumbh period, 1998. Himalayan J. Environ. Zool., 2003; 17(2): 167 – 171.
29. Chetana SA, Somasekhar RK. Ecological study of the riverine ecosystem of Karnataka, India, Physico-chemical characteristics of river Cauvery. J. Environ. Pollution, 1997; 4(1): 57 – 63.
30. Bhattarai KR, Shrestha BB, Lekhak HD. Water Quality of Sundarijal Reservoir and its feeding streams in Kathmandu. Sci. World J., 2008; 6(6): 99 – 106.
31. Barman B, Gupta S. Aquatic insects as bio-indicator of water quality- A study on Bakuamari stream, Chakrashila Wildlife Sanctuary, Assam, North East India. J. Entomol. Zool. Stud., 2015; 3(3): 178 – 186.
32. Huang TH, Lock K, Chi Dang K, De Pauw N, Goethals PLM. Spatial and temporal patterns of macroinvertebrate communities in the Du river Basin in Northern Vietnam. J. Freshwater Ecol., 2010; 25: 637 – 647.
33. Selvakumar C, Sivaramakrishnan KG, Janarthanan S, Arumugam M, Arunachalam M. Impact of riparian land use patterns on Ephemeroptera community structure in river basins of the southern Western Ghats, India. Knowl. Managt. Aquatic. Ecosyst., 2014; 412: 11.
34. Naranjo C, Riviaux SM, Moreira FFF, Court RC. Taxonomy and distribution of aquatic and semiaquatic Heteroptera (Insecta) from Cuba. Int. J. Trop. Biol., 2010; 58: 897 – 907.
35. Bijukumar A, Sushama, Biswas T. Molluscs collected from the Bharathpuzha River, Kerala. J. Inland Fish. Soc. India, 2001; 33(2): 68 – 69.
36. Suryawanshi AV, Bhowate CS, Kulkarni AN. Freshwater Molluscs from Nanded, Maharashtra, India. Bioinfolet, 2012; 9(4B): 732 – 733.