Correlation between Macroinvertebrates and Physicochemical Parameters in the Barna Basin of the Narmada River

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Research Article

Keywords: Macroinvertebrates, physicochemical parameter, water quality, Barna basin, Narmada River

Posted Date: April 4th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1500556/v1

Abstract

The ecological assessment of Barna basin was done using physicochemical parameters and benthic macroinvertebrates collected from 6 streams of Barna basin of Narmada River basin. The methodology was followed from scientific manuals (Adoni *et al.,* 1985; APHA, 1998). Principal component analysis (PCA) and correlation matrix were used to analyze the association between the physicochemical parameters and macroinvertebrate distribution. Nutrient levels were generally low however; significant differences existed between the values of physicochemical parameters as well as between the macroinvertebrate diversity at the different sampling sites. The results explained that the distribution and abundance of macroinvertebrates is governed by the physicochemical parameters of water quality of Barna basin hence, macroinvertebrates are good indicator of water quality and can be used for biomonitoring of water bodies which will help in making management and conservation strategies of the water resources.

Introduction

The macroinvertebrates shows a high taxonomic and functional diversity in lotic systems and are in several ways important components of the aquatic ecosystem (Cummins *et al.,* 2005; Anbalagan *et al.,* 2004). Their distribution patterns, movements and effects on ecological flows, testify to their importance in various landscape ecological processes (Baker, 2003). The distribution of benthic invertebrates in lotic habitats is governed by a number of factors that typically act at different scales. Hence, the local community structure can be seen as the result of a continuous sorting process through environmental filters ranging from regional or catchment-wide processes, involving speciation, geological history and climate, to the small-scale characteristics of individual patches, such as local predation risk, substratum porosity and current velocity (Hora, 1923; Palmer and Poff, 1997; Bhatt *et al.,* 2011).

In any aquatic ecosystem, the physicochemical parameters of water play an important role in determining the richness, abundance and species composition of macroinvertebrates (Garcia *et al.,* 2008; Boonsoong and Sangpradub, 2008). The degradation of freshwaters results from the increasing inputs of silt, nutrients and pollutants resulting from agriculture, forest harvest, urban areas (Carpenter *et al.,* 1997; Maddock, 1999) and industry (Paul and Meyer 2001; Azrina *et al.,* 2006). These impacts reduce both water quality and biological diversity of aquatic ecosystems (Allan, 1995; Schofield *et al.*, 2008). The objectives of the survey were to: (1) evaluate the physicochemical parameters of water and, macroinvertebrate composition in the Barna basin (2) to examine the correlation between physicochemical variables and the macroinvertebrate community to determine their response to the water quality of Barna basin.

Materials And Methods

Study area

Barna basin of Narmada River basin is located at latitude 22^0 4'-23.5^0 N and longitude $77^0$5'-78.2^0 E. In addition to Dudhi, Ganjal, Kolar, Hallon, Banjar and Tawa, Barna is one of the major tributaries of Narmada while Satdhar, Jamner, Palakmati, Chamarsil and Narheri are the tributaries of Barna which form the Barna basin or Barna stream network. An irrigation reservoir was built across the Barna located at $23^0$5' N and $78^0$7' E near Bari village of Madhya Pradesh and called as Barna Reservoir. Before construction of this reservoir these streams join the Barna stream which then meets the Narmada River. But, after construction of this reservoir the streams of Barna basin feed the Barna Reservoir. Hence, this stream network is of great importance for the ecology of this reservoir also. The Barna reservoir is identified under National Wetland Conservation Program by Ministry of Environment, Forests and Climate change (Govt. of India). The present study aims at analyzing the correlation between macroinvertebrates and physicochemical parameters of Barna basin.

A total of six stations namely, Barna, Satdhar, Jamner, Palakmati, Chamarsil and Narheri (Fig.1) were selected for sample collection in the Barna basin. Barna (Site-I) is situated near Goharganj village which is about 60 km from the Bhopal; Satdhar (Site-2) is approx. 15 km away from the Site-1; Jamner (Site-3) is situated in Semri village, which is about 20 km far from the Site-2. Palakmati Site-4 is situated in Sultanpur which is about 80 km far from the Bhopal. Chamarsil (Site-5) is 30 km away from the Site-4 and is on the way to Intkhedi village. Narheri (Site-6) is about 35 km far from the Site-4 and is situated in Intkhedi village. This site is surrounded by forest but human interference also prevailed.

Methodology

During the present investigation, samples were collected for two years in different seasons to evaluate the physicochemical parameters and benthic diversity of the Barna basin. The sampling was conducted in morning hours. After preliminary survey of the Barna basin, on the basis of ease of accessibility, a stretch of 100 m was sampled from six sampling stations.

Collection of water sample

Water samples were collected in polyethylene bottles for the analysis of physicochemical properties of water. Water current, pH, dissolved oxygen, total dissolved solids, conductivity, turbidity were measured on field by using respective digital meters. However, the sample was brought to lab for analysis of chloride, hardness, alkalinity etc. in water. Temperature was measured by Mercury thermometer. The methodology for analysis of water samples was followed from scientific manuals (Adoni *et al.,* 1985; APHA, 1998).

Collection of macroinvertebrate

The macroinvertebrates were searched and collected from various habitats within the stretch of 100 m at each sampling station in Barna basin. In pools and aquatic vegetations, an ‘all out search’ method was used to collect benthos by using D-net (mesh size: 500 µm; diameter: 30 cm; depth 15cm) while in riffles, where the water flows through boulders and cobbles, benthos were collected with the kick-net (mesh size: 180 mm) by kicking vigorously the substrate within the quadrant (1 m^2) (Subramanian and Sivaramakrishnan, 2005). After collecting benthos in the nets, the content of the nets were transferred to the bucket half filled with water by inverting it into the bucket. The water of the bucket then sieved (500µm). Macrozoobenthos retained in the sieve were picked up with the help of forceps and preserved in the jar containing 70% ethanol as preservative. These samples were labeled with water proof marker, sealed with the adhesive tape and returned to the laboratory for sorting and identification under the stereo microscope by using identification keys (Fraser, 1933; Morse *et al.,* 1994; Dudgeon, 1999; Thirumalai, 1999, Wiggins, 1996).

Results And Discussion

Physicochemical parameters

During the present study, the values for air temperature varied between 24^0 C -34.6^0 C and that of water temperature ranged between 22^0 C-32.9^0 C. The highest values for both air temperature and water temperature were recorded in summer at while the lowest in winter. In general, surface water temperature fluctuations appear to follow the atmospheric temperature (Golterman, 1975 and Hutchinson, 1976). Water current affects the invertebrate production in response to change in flow regime (Wetzel, 1983; APHA, 1998; Sharma *et al.,* 2004). During the present investigation, water flow lies within the range of 1.4 cms^{-1} in summer at Station-6 to 13 cms^{-1} in monsoon at Station-4.

Turbidity of any water sample is the reduction of transparency due to the presence of particulate matter such as clay or silt, organic matter, plankton and other microscopic organisms (Trivedi and Goel, 1986; Dutta *et al.,* 1988; Srivastava *et al.,* 2011). During the present investigation, the value for turbidity ranged from 7 NTUs at Station-1 in winter to 16 NTUs at Station-5 in post monsoon due to the turbid surface run off as also observed by Venkatesharaju *et al.* (2010) in Cauvery River.

pH is an important parameter which evaluate the acid-base balance of water (Trivedi and Goel, 1986; Hall *et al.,* 1987; Sharma *et al.,* 2011). pH is significant in determining the suitability of water for various purposes, including toxicity to animals and plants (Venkatesharaju *et al.,* 2010). During the present investigation, the range of pH varied from 6.1-8.8 representing slightly acidic to alkaline water in the Barna stream due to increased input of leached domestic wastes from several waste dumps, erosional and surface run off and other human activities within the watershed.

Total Dissolved Solids (TDS) gives an indication of the degree of dissolved substances and depends on various factors *viz.,* amount of surface runoffs, geological character of catchment area and rainfall (Golterman, 1975; Singh *et al.,* 2010a). During the present investigation, the range of TDS varied from 90-320 ppm at various stations. In the present study, the highest value was observed at Station-1 because of addition of domestic and other wastes through the catchment area (Kumar *et al.,* 2011a and Singh *et al.*, 2010b) while lowest value at Station-6 as the stream consist of soils and rocks which were not easily dissolved or of brief contact time with more easily dissolved rocks as explained by Neal *et al.* (2004) while preparing scientific investigation report of Indian River, Alaska.

Conductivity of water is a measure of capacity to conduct electrical current and depends on the concentration of ions and load of nutrients. The conductivity, thus also serves as a good and rapid measure of the total dissolved solids in water (Wetzel, 1983; Golterman, 1975; APHA, 1998; Srivastava *et al,* 2011). In the present investigation, the range of conductivity varied from 127 μScm^{-1} at Station-1 in summer 420 μScm^{-1} station-6 in monsoon. Some workers found the value for electrical conductivity within 189-1046 mhos in Ganga River, Ghazipur (Yadav and Srivastava, 2011); 340-734 mgl^{-1} in Yamuna River, Uttar Pradesh (Kumar *et al.,* 2011a); 194.5-1030 μScm^{-1} in Krishna River, Western Maharashtra (Prasad and Patil, 2008).

During the present investigation, the value for total alkalinity was recorded 180 mgl^{-1} at Station- 6 in post monsoon and 390 mgl^{-1} at Station-5 in summer. Same findings were recorded during summer in Thoubal River, Manipur (Singh *et al.*, 2010a) and in Cauvery River (Venkatesharaju *et al.,* 2010) with maxima in summer due to evaporation of water and minima in rainy season were due to dilution with rain water and the highest values recorded in the dry seasons were also accredited to low volume of stream water which brought about concentration effects (Kumar *et al.,* 2011a) as also observed during the present study. Similar values of total alkalinity were recorded by many workers. Such as 123-240 mgl^{-1} in Yamuna River, Uttar Pradesh (Kumar *et al.,* 2011a); 92-231 mgl^{-1} in Ganga River, Varanasi (Mishra *et al.,* 2009); 13-246 mgl^{-1} in Ganga River, Kanpur (Trivedi *et al.,* 2009).

An important indicator of the condition of an aquatic ecosystem is the concentration of dissolved oxygen in water. DO is considered as the factor which reflects physical and biological processes taking place in the water body (Hutchinson, 1976; Wetzel, 1983; Trivedi and Goel, 1986; Karthick and Ramchandra, 2007; Ridanovic *et al.,* 2010; Kumar *et al.,* 2011a). DO is greatly influenced by temperature, photosynthesis and respiration activities prevailing in the stream water (Varunprasath and Daniel, 2010). In the present study, the value for dissolved oxygen was ranging from 3.1–8.6 mgl^{-1} at different stations. Additionally, the higher value for DO was observed at Station-1 in winter and lower at Station-4 in pre monsoon. In the present study, higher values of DO were recorded at stations having forested land use in the catchment area while lower values at stations having other land use categories with human interference as also observed by Chattopadhyay *et al.* (2005) in Chalakudy river basin, Kerala. Similar values range from 6 to 9.27mgl^{-1} in Venkatapura catchment, Karnataka (Karthick and Ramchandra, 2007); 4.90-8.50 mgl^{-1} in Yamuna River, Uttar Pradesh (Kumar *et al.,* 2011a); 1.8-5.8 mgl^{-1} in Ganga River, Varanasi (Mishra *et al.,* 2009) and 4.2-4.6 mgl^{-1} in Narmada River (Sharma *et al.,* 2011) were recorded by many experts. Moreover, Venkatesharaju *et al.* (2010) and Thirumurugan (2000) opined that DO values were found maximum in winter due to natural turbulence and higher algal productivity that produces O_2 by photosynthesis or associated with the low temperature. Likewise, the lower value in pre monsoon was attributed to high temperature.

Total hardness is mainly imparted by the calcium and magnesium and describes the effect of dissolved minerals, determining suitability of water for domestic, industrial and drinking purposes and attributed to the presence of bicarbonates, sulphates, chloride and nitrates of calcium and magnesium (Wetzel, 1983; Trivedi and Goel, 1986; APHA, 1998; Singh *et al.,* 2010a and Kumar *et al.,* 2011a). During the present study, the value for total hardness was recorded between 75-230 mgl^{-1} at different stations. The maximum value was reported at Station-4 while the lowest value at Station- 2 & 6. The higher values of total hardness ascribed to reduced inflow, evaporation of stream water and discharge of sewage, use of soaps and detergents, washing, bathing by local inhabitants as also observed by Kumar *et al.* (2011b) in Sabarmati River and Singh *et al.* (2010a) in Manipur river system during their research work. Similar results for total hardness were recorded by several experts. For instance, the value for total hardness varying from 106-246 mgl^{-1} in Ganga River, Kanpur (Thareja *et al.,* 2011), 122-212 mgl^{-1} in Ganga River, Kanpur (Trivedi *et al.,* 2009), 230-475 mgl^{-1} in Yamuna River, Uttar Pradesh (Kumar *et al.,* 2011a), 182.1-300 mgl^{-1} in Ram Ganga River, Uttar Pradesh (Chandra *et al.,* 2011).

The value for Ca hardness was recorded between 26-101 mgl^{-1} at different stations during the present investigation. The highest value was observed at Station-5 in monsoon and lowest value at Station-2 in pre monsoon. These values were caused due to domestic sewage, addition of calcium and magnesium salts used for washing purposes in the catchment as also reported by Kumar *et al.* (2011a) in Yamuna River. Similar values for Ca hardness were observed 21.12-185.9 mgl^{-1} in Ramganga River, Moradabad (Srivastava *et al.,* 2011); 60.7-106.7 mgl^{-1} in Cauvery River, Karnataka (Venkatesharaju *et al.,* 2010); 6-36 mgl^{-1} in Chhoti Gandak River, Uttar Pradesh (Bhardwaj *et al.,* 2010); 12-21 mgl^{-1} in streams of Cauvery River (Begum and Harikrishna, 2008). In the present study, calcium content raised in wet spell due to its greater solubility at lower temperatures and while in dry spell it was due to rapid oxidation of organic matter in the substrate utilized by the phytoplankton that decline the values of calcium in the stream water as also declared by Sunder (1988) and Umamaheswari and Anbu saravanan (2009) while working in different rivers of India.

Chlorides are salts resulting from the combination of the chlorine with a metal and in combination with a metal such as sodium; it becomes essential for life (Golterman, 1975; Trivedi and Goel, 1986; APHA, 1998; Dikio, 2010; Singh *et al.*, 2010a). In the present study, the value for chloride ranged between 15.7-45.3 mgl^{-1} at various stations. The higher values were recorded at Station-1 in summer and lower at Station-3 in post monsoon. During the present investigation, the chloride enter the stream from different anthropogenic activities like sewage effluents, run off from agricultural fields, animal feeds, washing of cloths and use of leaching agents by launderers in the catchment area as also observed in river Kali near Dandeli, Karnataka (Murthi and Bharati, 1997) and in Cauvery River, Tamilnadu (Kalavathy *et al.,* 2011). Similar results for chloride ranging from 7-26 mgl^{-1} in Ganga River, Kanpur (Trivedi *et al.,* 2009; Thareja *et al.,* 2011) and 18-32 mgl^{-1} in Yamuna River, Uttar Pradesh (Kumar *et al.,* 2011a) were reported by many workers.

The main source of sulphur is the rocks present near to the water bodies and biochemical action of anaerobic bacteria (APHA, 1998; Umamaheswari and Anbu saravanan, 2009). In the present study, the concentration of sulphate ranged between 9-35.6 mgl^{-1} at various stations. The higher range was recorded in monsoon whereas the lower value in summer in the present study. The low content of sulphate recorded from different stations in the present study due to the absence of any industrial pollution in the catchment area of Barna stream network as also reported by Umamaheswari and Anbu saravanan (2009) in Cauvery river basin. The lower values of sulphate also associated with the easily precipitation and settlement to the bottom sediment of the stream as suggested by Kumar *et al.* (2011a) while working on Yamuna River, Uttar Pradesh.

Silica is one of the basic nutrients in water and it is quite abundant on the earth but silicates remain meager in water. The major source of dissolved silica in stream water is the weathering of rocks and mineral in the catchments area (Nath and De, 1998; Nath and Srivastava, 2001). In the present study, the concentration of silicate was ranged between 1.2-10.2 mgl^{-1} at different stations. The maximum concentration was observed at Station-5 in monsoon while the minimum value at Station-6 in winter. The pronounced reduction of silica ions in winter related to the low flow discharge of stream water as also recorded in Nile River (Shehata and Badr, 2010). The value for silicate was observed 2.80-13.80 mgl^{-1} in Chambal River (Saksena, *et al.,* 2008).

Nitrate and phosphate determinations are important in evaluating the potential biological productivity of surface waters and the source of nitrate is the biological oxidation of organic nitrogenous substances in stream waters (Nath and De, 1998; Adoni *et al.,* 1985; Venkatesharaju *et al.,* 2010). In the present study, the concentration of nitrate was observed between 0.16-0.901 mgl^{-1} at various stations. The maximum concentration of nitrate was recorded at Station-5 while the minimum values were recorded at Station-1 during the present investigation. The value of nitrate in the present study varied from one station to another and it was recorded higher at Station-5 due to agricultural practices and lower at Station-1 because of forested land in the watershed as also observed by Chattopadhyay *et al.* (2005) in Chalakudy river basin. Similar values for Nitrate with 1.38-2.6 mgl^{-1} in Ganga River, Varanasi (Mishra *et al.,* 2009) and 0.008-0.024 mgl^{-1} in Chambal River (Saksena *et al.,* 2008) were recorded by several workers. During the present study, the concentration of orthophosphate was recorded maximum 0.69 mgl^{-1} at Station-5 in monsoon and minimum 0.20 mgl^{-1} at Station-1 in summer. The increased application of fertilizers, use of detergents and domestic sewage very much contributed to the heavy loading of phosphorous in the stream water. Similar findings were recorded by many workers. For instance, the concentration of Phosphate in Narmada river water sample was found to be in the range of 0.16-0.28 mgl^{-1} (Sharma *et al.,* 2011).

The present study indicates that variations in water quality were seasonal and also linked to land use practices in the watershed. The stations having human interferences showed significant deterioration in water quality as also observed by Chattopadhyay *et al.* (2005). This study has brought out that there is a definite relationship between water quality and land use in the catchment area and anthropogenic activities are the main contributors to make changes in physicochemical component of Barna stream waters.

Principal Component Analysis

PCA quantifies relationship between the variables by computing the matrix of correlations for the whole dataset (Bhardwaj *et al.,* 2010). In the present investigation, PCA of physicochemical components resulted in three principal components (with eigen values more than one) together accounted for 95.14% of the total variance in the dataset. In the present investigation, PCA of physicochemical components resulted in three principal components (with eigen values more than one) together accounted for 95.14% of the total variance in the dataset. The first axis explained 39.50% of variance, second axis explained 35.57% of variance, and the third axis explained 20.06% of the total variance. The eigen values (more than one) and the high values for all 17 physicochemical variables were used to assess the physicochemical variables imposing more impact in the present study and hence principally responsible for causing alterations. First axis explaining 39.50% of variance was found to be highly correlated with Ca hardness followed by total hardness, Mg hardness, silicate and water flow. Second axis that was explaining 35.57% of variance was found to be positively correlated with orthophosphate and turbidity whilst strongly negative correlated with conductivity, TDS, free CO_2 and Chloride. The third axis explaining 21.80% of variance was found to be highly positive correlated with air and water temperatures and negatively related with DO and pH. The role of catchment area and anthropogenic activities on the water chemistry can be better assessed with the help of scatter diagrams elucidating the processes responsible for controlling the stream waters in the Barna stream network. The eigen values and component matrix is presented in Table 1 and Table 2.

Table 1 Total Variance Explained

Component	Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %
1	7.111	39.508	39.508
2	6.403	35.571	75.079
3	3.611	20.062	95.141

Extraction Method: Principal Component Analysis

Table 2 Component Matrix

Parameter	Component		
	1	2	3
Air temperature(^{0}C)	.494	.572	.654
Water temperature(^{0}C)	.495	.497	.667
Water flow	.808	.043	.569
Turbidity (NTUs)	.579	.788	.143
pH	.055	.445	-.876
Conductivity(μScm^{-1})	.079	-.987	-.005
TDS(ppm)	.408	-.854	.212
DO(mgl^{-1})	-.123	.012	-.953
Total alkalinity(mgl^{-1})	.756	.499	-.369
Total hardness(mgl^{-1})	.933	-.130	.280
Ca hardness(mgl^{-1})	.970	-.046	.034
Chloride(mgl^{-1})	-.087	-.820	.294
Orthophosphate(mgl^{-1})	.687	.713	.100
Nitrate(mgl^{-1})	.716	.633	.272
Sulphate(mgl^{-1})	.730	.602	.277
Silicate(mgl^{-1})	.855	.363	-.199

Extraction Method: Principal Component Analysis

Table 3 Correlation matrix

	AT	WT	WC	Tur	pH	Con	TDS	DO	TA	CaH	TH	CL	OP
AT	0												
WT	0.966	0											
WC	0.8006	0.7887	0										
Tur	0.8302	0.811	0.5712	0									
pH	-0.2935	-0.2974	-0.4548	0.2824	0								
Con	-0.5295	-0.4901	0.0247	-0.7527	-0.4515	0							
TDS	-0.1397	-0.0922	0.4485	-0.4218	-0.5711	0.8784	0						
DO	-0.6749	-0.6209	-0.6554	-0.1574	0.8768	-0.0562	-0.2762	0					
TA	0.4198	0.3289	0.4428	0.7476	0.5501	-0.4042	-0.169	0.21	0				
CaH	0.4668	0.4391	0.7843	0.5131	-0.0061	0.1463	0.4071	-0.1947	0.7159	0			
TH	0.5626	0.5798	0.8835	0.4825	-0.2387	0.2049	0.5084	-0.3861	0.5272	0.9549	0		
CL	-0.3169	-0.1343	0.037	-0.5838	-0.552	0.7323	0.7056	-0.1446	-0.6769	-0.1146	0.0995	0	
OP	0.816	0.7738	0.6516	0.9783	0.2676	-0.6576	-0.2901	-0.1577	0.8356	0.6135	0.5597	-0.5918	0
Ni	0.8962	0.8758	0.7626	0.9654	0.0935	-0.5834	-0.18358	-0.31224	0.742	0.649	0.651	-0.4532	0.9796
Su	0.8802	0.8566	0.7492	0.9493	0.0857	-0.5419	-0.1976	-0.3329	0.7299	0.71083	0.70961	-0.45408	0.94685
Si	0.5122	0.4954	0.6298	0.7557	0.3709	-0.3055	0.0631	0.1127	0.9054	0.73836	0.63918	-0.38556	0.8563
ShI	-0.1878	0.035742	0.171	-0.2271	-0.1921	0.505	0.6182	0.1262	-0.2758	0.11347	0.27448	0.8501	-0.2162
Si I	-0.0474	0.1747	0.2585	-0.1082	-0.2219	0.3875	0.5715	0.0485	-0.2341	0.11	0.2878	0.7996	-0.0987
MI	-0.4335	-0.2324	0.00016	-0.4131	-0.095	0.6879	0.6446	0.2701	-0.292	0.1601	0.2643	0.8433	-0.4007

Macroinvertebrate Community

During the present study, the mollusca formulated the dominating group in Barna basin and constituted 59.82% of the total macroinvertebrate population. In the present survey, 70 taxa were recorded out of which 25 taxa belonging to 9 families of the two molluscan classes *viz.,* gastropoda and bivalvia were recorded. The arthropoda comprised of second dominating group in Barna basin and constituted 38.86% of the total macrozoobenthos population and out of 70 taxa, 40 taxa belonging to 30 families were identified during the present investigation. The annelida was the third or least dominating group and constituted 1.32% of the total macrozoobenthic population collected during the present research work. In the present study, out of 70 taxa, 5 taxa belonging to 5 families of aquatic worms were collected in which 3 taxa of the class Oligochaeta, and 2 taxa of class Hirudinaria were identified.

Benthic macroinvertebrate assemblages are structured on the basis of physical and chemical parameters that in turn define the microhabitats, food availability, shelter to escape predators, and other biological parameters that influence reproductive success existing at the station (Silveira *et al.,* 2006).

In the present study, Barna was represented by maximum number of 46 taxa followed by Satdhar representing 26 taxa, Palakmati representing 26 taxa, Jamner representing 25 taxa, Chamarsil representing 16 taxa and Narheri was represented by minimum number of 11 taxa. Similar results were observed with 34 genera from sacred Himalayan streams (Singh *et al.*, 2010b) and 33 taxa from four Sonmarg streams of Kashmir (Bhat *et al.,* 2011). In abroad also, a total of 67 taxa of macroinvertebrate were recorded in the River Challawa, Nigeria (Indabawa, 2010); 51 invertebrate taxa in a temporary stream of Ibiza, Balearic Islands (Garcia *et al.,* 2008); 87 taxa were recorded in lotic ecosystems of Czech Republic (Fricova *et al.,* 2007) and 58 taxa were identified while studying the urban and agricultural impacts on macroinvertebrate assemblages in streams of Brazil (Hepp *et al.,* 2010). A total of 43 taxa comprising 36, 16, 19 taxa at three different stations were recorded in Ikpoba River, Nigeria (Ogbeibu and Oribhabor, 2002).

The composition, abundance and distribution of benthic macroinvertebrates can be influenced by water quality (Ezekiel *et al.,* 2011) and catchment area (Subramanian *et al.,* 2005). It was observed during the study that, high degree of human impact *viz.,* discharge of domestic effluents, waste dumps and other anthropogenic activities also influenced the benthic community structure of the Barna stream network as resulted in low diversity as also observed by Subramanian *et al.* (2005) and, Dinakaran and Anabalgan (2007a) in certain streams of Western Ghats. Furthermore, such streams reported taxa that are more tolerant to pollution viz., *Chironomus* sp., *Tubifex* sp., *Glossiphonia hetroclita*, *Hemopis* sp. etc. while stations with less or no disturbance showed presence of taxa that are indicator of fresh water *viz., Caenis* sp., *Hydropsyche instabilis*, *Hydrophilus* sp. and so on.

Biodiversity Indices

Biological indices are “classical ecological indexes”, created to measure diversity as well as density in ecological communities. In the present investigation, the highest benthic diversity was observed in Barna (H’=3.39) followed by Satdhar (H’=3.075), Palakmati (H’=3.071), Jamner (H’=3.068), Chamarsil (H’=2.53) and least in Narheri (H’=2.25). The variation in diversity indices occurred at various stations was very low due to the same river basin, but variation visible was due to thermal conditions and bottom structure and local scale disturbances as also observed by Subramanian and Sivaramakrishnan (2005), Vioinskiene (2005), Rios and Bailey (2006) during their exploratory studies.

During the present research work, the value for Shannon's index range between 2.25-3.39. In the present investigation, the highest value was recorded in Barna (3.39) followed by Satdhar (3.075), Palakmati (3.071), Jamner (3.068), Chamarsil (2.53) and least in Narheri (2.25).The value for Simpson's Index was calculated between 0.884-0.956. The highest value was recorded in Barna while the lowest value was recorded at Narheri. In the present work, the highest value was observed in Barna (0.956) followed by Jamner (0.948), Palakmati (0.947), Satdhar (0.946), Chamarsil (0.908) and least in Narheri (0.884). During the present study, the range for Margalef's index recorded between 1.39-5.35. The highest value was recorded in Barna (5.35) followed by Palakmati (3.09), Satdhar (3.07), Jamner (3.02), Chamarsil (1.82) and least in Narheri (1.39). Similar results with Shannon-Wiener index values vary from 0.346-2.608 in Ganga River, Patna (Jhingran *et al.,* 1989) while Shannon's index 0.7-2.28 , Simpson's index 0.4 - 0.86, Margalef's index 0.5-2.35 varied in six streams of Western Ghat (Dinakaran and Anbalagan, 2007a), Shannon-Weiner index 1.88-2.49, Simpson's index 4.07-6.62 in five falls stream, Courtallam hills, Western Ghats and Shannon-Weiner index 1.36-2.14 in a temporary stream of Ibiza (Garcia *et al.,* 2008) were reported by many workers in their studies.

Correlation Matrix between Physicochemical Parameters and Macroinvertebrates

The present study also highlighted the impact of water quality on the distribution and species diversity of macrozoobenthic invertebrates. The statistical relationship of molluscs with physicochemical properties revealed a positive correlation with silicate (r= 0.693 and p=0.02). It was observed that these stations were mainly comprised of molluscan species and, the higher values of silicate were due to irrigational practices and use of fertilizers in the catchment area as also observed by Subba Rao and Devadas (2003) and Bhardwaj *et al.* (2010) during their studies on different Indian water bodies.

The statistical relationship of arthropoda with physicochemical properties revealed a significant negative correlation with DO (r= -0.857; p=0.02). It was observed that these stations were comprised of macrozoobenthos belonging to pollution tolerant arthropods and also dissolved oxygen value depleted significantly at these stations ascribed to land use categories and local scale events other than forest here at this sampling station the same was observed in Chalakudy River basin and streams of southern Eastern Ghats which confirms the presence of pollution tolerant groups (Chattopadhyay *et al.*, 2005 and Dinakaran and Anbalagan, 2007b).

The statistical relationship of annelids with physicochemical properties revealed a significant negative correlation with dissolved oxygen (r= -0.856; p=0.02) which confirms that some habitats in these stretches have good running water condition due to which less count of annelids and more number of arthropods were recorded from these stretches. The habitat conditions at these stations were assessed under sub optimal conditions which directly ensure the rich benthic diversity (Barbour *et al.,* 1999).

Conclusion

It was concluded that, there was a clear separation between physicochemical parameters and their relative values in the different sites and seasons in the PCA ordination diagram. The results based on correlation matrix showed that in any aquatic ecosystem the physicochemical parameters of water, land use, environmental factors such as temperature, food resources play an important role in determining the richness, distribution and species composition of macroinvertebrates. The present study suggests macroinvertebrates should be used for biomonitoring of water bodies and provides an overview of change in macroinvertebrate assemblage with change in physicochemical variables within the Barna basin.

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Figures

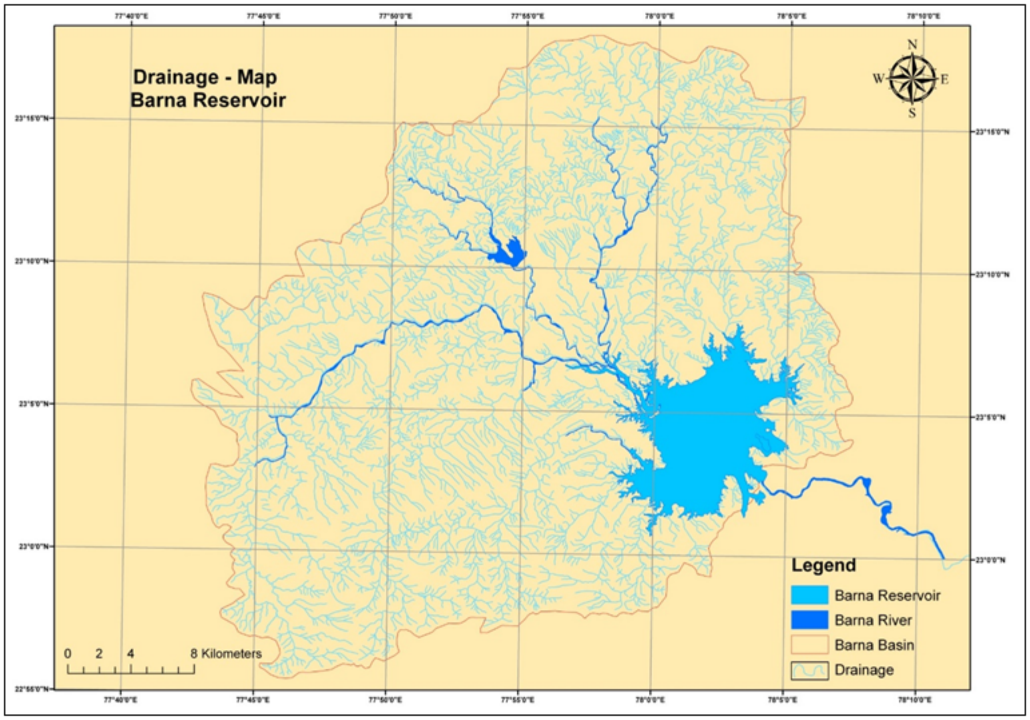

Figure 1

Map of Barna Basin