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Assessing Ecological Integrity of Barna Stream Network of Narmada River Basin by Using Macrozoobenthic Communities

Environmental Sciences

KEYWORDS : Narmada River, Barna stream, MWQI, ecological integrity.

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ABSTRACT

In the present study, the benthic diversity and physicochemical properties were evaluated to assess the ecological integrity of Barna stream network. During the study, a macroinvertebrate based new biotic index (MWQI) was evaluated against some of the biotic and abiotic indices viz., BMWP Index, Hilsenhoff's Index, National Sanitation Foundation Water Quality Index (NSFWQI, USA), Water Quality Index (WQI). The results showed that on the basis of MWQI the waters at Barna and Satdhar streams were of 'Excellent' quality; at Jamner and Narheri streams the water was of 'Very good' quality; at Palakmati stream it was found of 'Worst' quality and at Chamarsil stream it was of 'Good' quality which confirmed the fact that occurrence of benthic macroinvertebrates reflects the natural health of a stream/river and that they can be used in predicting the ecological integrity of the water bodies. The present survey is the preliminary work towards assessing the ecological health of the Barna stream network thus, forms the basis for any other research work in future.

Introduction

The benthic macroinvertebrate communities contribute immensely to the functioning of the aquatic ecosystems and are widely used as bioindicators because of their response to variety of human disturbances (Rosenberg and Resh, 1993). They are considered as one of the best biological indicators of aquatic ecosystem (Hilsenhoff, 1988; Subramanian and Sivaramakrishnan, 2005; Bhatt and Pandit, 2010). They are also considered as good indicators of habitat quality and health of an aquatic ecosystem and as they inhabit vital position in the food chain of aquatic systems, they can be used to make estimates of health of an ecosystem (Subramanian and Sivaramakrishnan, 2005; Bhatt and Pandit, 2010). Odiete (1999) confirmed that the most popular biological method in assessment of freshwater bodies receiving domestic and industrial wastewaters from their catchment is the use of benthic macroinvertebrates.

Benthic macrozoobenthos are common inhabitants of lakes and streams. Many studies have suggested that there is an urgent need to obtain biological information on the rivers and streams which are under pressure due to population growth and urbanization (Vyas and Bhat, 2010a; Vyas and Bhawsar, 2013). Additionally, water bodies are excellent systems to identify and test potential indicators of land use because they are intimately linked to their catchments, and thus integrate catchment-scale ecological processes and cumulative responses to disturbance (Edokpayi and Osimen, 2002). Information related to the processes that structure macroinvertebrate assemblages is important not only from the perspective of biomonitoring, but also for the purposes of restoration, management, and bioassessment of stream ecosystems (Allan 2004; Mykra, 2006, Vyas *et al.,* 2013). Hence, present study was taken into account to know the application of biotic indices based on benthic macroinvertebrates for assessment of ecological integrity of the Barna stream network.

Materials and methods

Study area

Barna, Dudhi, Ganjal, Kolar, Hallon, Banjar and Tawa are the major tributaries of river Narmada. The present study was conducted on the Barna stream network or Barna sub-basin of Narmada Basin, located between the latitude and longitude 22^0 50' -23.5^0N and $77^05^{0'}$-78.2^0E. The samples were collected from six streams *viz.,* Barna, Satdhar, Jamner, Palakmati, Chamarsil and Narheri, which forms the Barna stream network. These six streams joins an irrigation reservoir built across the Barna stream called as Barna-reservoir at Bari village in Raisen district of Madhya Pradesh, India. The reservoir is identified under National Wetland Conservation Programme by Ministry of Environment and Forests (Govt. of India) and encompasses rich aquatic diversity which also makes the present study significant.The geographical locations and land use type each at stream are given in Table:1 and map of the study area is shown in Fig.1

Table: 1 Land use type and geographical locations of stations in Barna stream network

S.No	Stations	Geographical Location	Land use Type
1	Barna (S_1)	Lat23004'24.2" N,Long770 47'2" E	Forest
2	Satdhar (S_2)	Lat2306' 11.3"N, Long77055'27.2"E	Forest
3	Jamner (S_3)	Lat2304'21.1N, Long77056'59.8"E	Forest, Residential and agriculture
4	Palakmati (S_4)	Lat2302'02.1"N, Long77056'11.7"E	Residential and field pasture
5	Chamarsil(S_5)	Lat230 9' 57.7" N, Long77057'48.5"E	Agriculture
6	Narheri (S_6)	Lat230 11' 38.6" N Long78002'23.2"E	Forests and anthropogenic activities

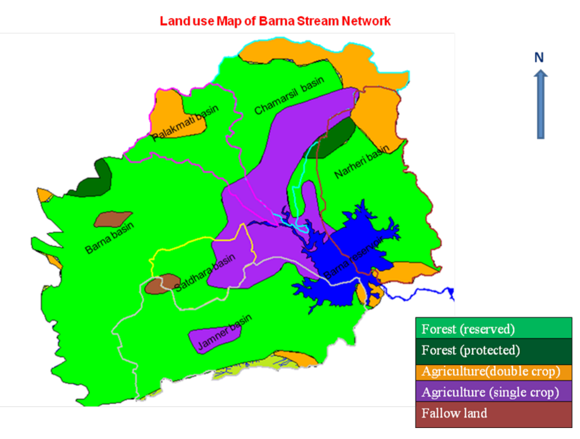

Fig. 1 Map showing land use type in Barna Stream Network.

Benthic fauna

Benthic macroinvertebrates were collected from Barna stream network. At each stream, benthic macroinvertebrates were collected by using D-net (mesh size: 500 µm; diameter: 30 cm;

depth 15 cm) from habitats *viz.,* pools, bedrocks, boulders, cobbles, pebbles, sand, mud, macrophytes, leaf litter, dead wood and by using kick-net (mesh size: 180 µm; net area 1 m^2) in riffles and, were picked up with the help of forceps and brush then preserved in the bottles containing 70% ethanol as preservative (Subramanian and Sivaramakrishnan, 2005). These samples were sealed, labeled and returned to the laboratory for sorting and identification under dissecting stereomicroscope by using keys and manuals (Subramanian and Sivaramakrishnan, 2005; Subramanian and Sivaramakrishnan, 2007).

Physicochemical characteristics

Water samples were collected in sterile polyethylene bottles for analysis of physicochemical parameters of the water bodies. pH, TDS, electrical conductivity, turbidity and water flow were measured on field by using respective digital meters. Temperature was measured by using mercury thermometer. The methodology for various physicochemical analyses was followed from APHA (1998).

Data analysis

Physicochemical analysis of water has been performed to know the water quality. Based on these parameters, water quality at all the six stations were calculated by using NSFWQI and WQI (Kalavathy, *et al.,* 2011). Water quality was also tested by BMWP score, Hilsenhoff Index and the MWQI (BMWP, 1978; Hilsenhoff, 1988; Bhatt and Pandit, 2010). We calculated and tested MWQI with that of other biotic and abiotic indices to evaluate the water quality and to recognize the governing factors in order to assess the ecological integrity of Barna stream network. The water quality ranges based on the MWQI is given in Table: 2. The macroinvertebrate taxa were identified up to family level and each family assigned with pollution sensitivity score (BMWP, 1978). The MWQI (Bhatt and Pandit, 2010) was calculated as follows:

$$\text{MWQI} = \frac{\Sigma N+1}{(\Sigma N+1)\ (\Sigma N'+1)}$$

$$N = n_i(s_i - m_s)$$

$$N' = n'_i(s'_i - m_s),$$

Where, N is the multiple product of density of ith taxon and the positive relative sensitivity score ($s_i - m_s$); m_s is the median value of the assigned scores, N' is the multiple product of ith taxon and the negative relative sensitivity score; n is the density of ith taxon having assigned pollution sensitivity score $\geq m_s$ (positive assigned scores); $n'i$ is the density of ith taxon having assigned pollution sensitivity score (s) < median score (negative score); 1 is the constant to account for such water samples in which taxa having pollution sensitivity score more than the median score may be absent.

Table : 2 Water quality ranges based on the MWQI

Index range	Water quality	Degree of organic pollution
≥ 0.9000	Excellent	No apparent pollution
≥ 0.7000–< 0.9000	Very good	Slight organic pollution
≥ 0.6000–< 0.7000	Good	Some organic pollution
≥ 0.5000–< 0.6000	Fair	Significant pollution
≥ 0.4000–< 0.5000	Fairly poor	Significant organic pollution
≥ 0.3000–< 0.4000	Poor	Very significant pollution
≥ 0.2000–< 0.3000	Very poor	High organic pollution
< 0.2000	Worst	Severe pollution

Results and discussion

During the present survey ecological conditions of Barna stream network were assessed using macrozoobenthic communities. The results obtained were compared with those derived from the NSFWQI values, WQI score, BMWP Score and HBI index. The results for various indices are summarized in Table 3 and categories in Table 4. Based on HBI index the water quality of the Barna stream network could be categorized into 'Excellent' water quality at all the six stations whereas on the basis of BMWP criterion, the water quality could be divided into three categories namely 'Good' at Barna, 'Moderate' in Satdhar, Jamner and Palakmati and, 'Poor' in Chamarsil and Narheri. On the other hand, the water quality obtained by abiotic indices showed one common category with different scores for each stream. Based on NSFWQI the water quality at all six stations comes under 'Medium' water quality and with the WQI the water quality comes under 'Good' rating at all the six stations. However, based on MWQI, the water quality of Barna stream network was classified into four classes. The first category of 'Excellent' water quality includes Barna and Satdhar; the second category 'Very good' quality includes Jamner and Narheri. Only Chamarsil was classified in the third category of 'Good' water quality and remaining Palakmati under 'Worst' water quality. The results of benthic macroinvertebrate occurrence and estimated MWQI are summarized in Table 5.

Table : 3 Water quality indices at different stations

Sampling stations	NSF water quality Index	Water Quality Index	BMWP Index	Hilsenhoff's Index	MWQI Index
Barna	59	41.80	87	1.010	0.9294
Satdhar	59	40.41	52	0.926	0.9996
Jamner	56	45.17	50	1.220	0.7666
Palakmati	56	34.01	64	1.562	0.0317
Chamarsil	56	44.63	37	0.816	0.6541
Narheri	58	42.40	16	2.883	0.7464

Table : 4 Categories obtained for various water quality indices at different stations

Index	NSF water quality Index	Water Quality Index	BMWP Index	Hilsenhoff's Index	MWQI Index
Barna	Medium	Good	Good	Excellent	Excellent
Satdhar	Medium	Good	Moderate	Excellent	Excellent
Jamner	Medium	Good	Moderate	Excellent	Very Good
Palakmati	Medium	Good	Moderate	Excellent	Worst
Chamarsil	Medium	Good	Poor	Excellent	Good
Narheri	Medium	Good	Poor	Excellent	Very Good

Table : 5 Showing benthic macroinvertebrate occurrence and MWQI calculated for Barna stream network

Family	BWMP Score s_i	S_i-m_s	d (S_1)	d(s_ixm_s)	d (S_2)	d(s_ixm_s)	d (S_3)	d(s_ixm_s)	d (S_4)	d(s_ixm_s)	d (S_5)	d(s_ixm_s)	d (S_6)	d(s_ixm_s)
Ephemeridae	10	4.5	171	769.5	156	702	101	454.5	0	0	0	0	111	500
Perlodidae	10	4.5	232	1044	202	909	170	765	0	0	144	648	110	495
Libellulidae	8	2.5	236	590	235	587.5	86	215	0	0	0	0	0	0

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Cordulegas-teridae	8	2.5	91	227.5	82	205	0	0	0	0	0	0	0	0
Gomphidae	8	2.5	94	235	96	240	0	0	0	0	0	0	0	0
Agridae	8	2.5	25	62.5	23	57.5	0	0	0	0	0	0	0	0
Caenidae	7	1.5	0	0	0	0	0	0	0	0	0	0	134	201
Coenagrio-nidae	6	0.5	0	0	0	0	0	0	0	0	0	0	167	84
Hydropsychi-dae	5	0.5	0	0	0	0	0	0	0	0	266	133	0	0
Dytiscidae	5	0.5	0	0	0	0	0	0	132	66	0	0	0	0
Nepidae	5	0.5	0	0	0	0	0	0	33	16.5	0	0	0	0
Hydrophili-dae	5	0.5	0	0	88	44	0	0	0	0	0	0	0	0
Gyrinidae	5	0.5	0	0	0	0	0	0	63	31.5	0	0	0	0
Corixidae	5	0.5	0	0	0	0	0	0	0	0	0	0	2t2	11
Mesovelidae	5	0.5	71	35.5	60	30	0	0	0	0	0	0	0	0
Pleidae	5	0.5	47	23.5	41	20.5	0	0	0	0	0	0	0	0
Baetidae	4	1.5	0	0	0	0	0	0	133	199.5	0	0	0	0
Sialidae	4	1.5	22	33	0	0	129	193.5	203	304.5	0	0	0	0
Planorbidae	3	2.5	16	40	0	0	97	242.5	0	0	0	0	0	0
Lymnaeidae	3	2.5	0	0	0	0	0	0	203	507.5	104	260	0	0
Physidae	3	2.5	0	0	0	0	0	0	82	205	61	152.5	0	0
Glossiphonii-dae	3	2.5	0	0	0	0	0	0	293	732.5	0	0	175	438
Chironomi-dae	2	3.5	0	0	0	0	0	0	138	483	0	0	0	0
Hirudinidae	2	3.5	0	0	0	0	0	0	48	168	0	0	0	0
Lumbricidae	1	4.5	0	0	0	0	0	0	46	207	0	0	0	0
Lumbricu-lidae	1	4.5	34	153	0	0	0	0	22	99	0	0	0	0
Tubificidae	1	4.5	0	0	0	0	0	0	134	603	0	0	0	0

In the present investigation, it was found that macroinvertebrates based MWQI reflects the land use type in the surrounding watershed of streams while, HBI and BMWP are based mostly on the presence or absence and range values of different taxa and do not reflect their abundance. Although, these indices contribute useful information to the final assessment of water quality, but are limited in their application. The majority of these indices do not reveal changes in water quality even if there are changes in the biotic communities of an aquatic ecosystem as they do not take into account the quantitative estimation of the taxa (Bhatt and Pandit, 2010). Similarly, the two used abiotic indices NSFWQI and WQI proved less significant in predicting the water quality as they have categorized the water quality in one common category at all the stations, not defining the role of having different land use type at each site.

Furthermore, it was observed that on the basis of MWQI, the waters in Barna stream network can be divided into four categories *viz.,* excellent, very good, good and worst.

Some experts opined that land use has great impact on water quality and biota of the river system (Sarkar *et al.,* 2005; Silveira *et al.,* 2006; Vyas and Bhat, 2010b). The same pattern was observed during the present study where land use type and water quality are synchronized with each other. The waters in Barna stream network can be divided into four categories viz., excellent, very good, good and worst. The waters in Barna and Satdhar streams were found of 'Excellent' water quality; in Jamner and Narheri streams the waters was found of 'Very good' water quality; in Chamarsil stream it was of 'Good' water quality and in Palakmati stream it was of 'Worst' water quality throughout the study. Likewise, the land use type at Barna and Satdhar streams were of similar type i.e., forest type; in Jamner and Narheri streams it was similar i.e., residential and anthropogenic activities; in Palakmati stream the land use types were residential and field pasture; and in Chamarsil stream the land use type was agricultural.

Bhatt and Pandit (2010) also stated that the MWQI yields water quality results which reflect the type of land use in the surrounding watershed of a stream. Therefore, it was endorsed that benthic macroinvertebrates can be used as to evaluate the ecological health of streams. Benthic macroinvertebrates provides the advantage of being tightly affiliated with local environmental conditions as opposed to the more expansive distribution patterns of freshwater vertebrates (Boonsoong and Sangpradub, 2008). Also, stream benthic macroinvertebrates are useful indicators of the impacts of disturbances on watershed level as their distribution is intimately linked to their catchments, and thus integrate catchment-scale ecological processes and cumulative responses to disturbance (Hepp *et al.,* 2010).

Hence, it was concluded that the benthic fauna composition in all the streams vary with respect to land use types which confirms the fact that there is an association between macroinvertebrate assemblages and ecological conditions of the stream waters.

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