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Assessment of the Water Quality of the Ninglad Stream, Uttarakhand, India by using various Biotic Indices

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ABSTRACT

The present study is carried out to check the validation of the different biotic indices over the biological samples collected from Ninglad stream.

The present study reports the compilation of macroinvertebrate data of two different stations and compares it with the actual study. We use SIGNAL Score, SIGNAL Score 2, BMWP, FBI biotic indices and they report the similar kind of water quality of results as done in actual study.

We can say that combination of these biotic indices would be a cost effective and reliable tool to assess the water quality of the rivers and streams. Due the geographical variation in the presence of macro invertebrates across the globe, there is a need to develop the biotic index especially for Indian context for the monitoring and assessment of the water quality of rivers and streams.

Keywords- Ninglad Stream, Water Quality Assessment, Macroinvertebrates, Biotic Indices, Water Quality Class, Organic Pollution

1. Introduction

Assessment of the biological quality of rivers and streams is an important aspect to determine the effects of the different stressors, their level and how these stresses accumulate. Healthy water bodies exhibit ecological integrity, representing a natural or undisturbed state. Ecological integrity is a combination of three components: chemical integrity, physical integrity, and biological integrity. When one or more of these components is degraded, the health of the water body will be affected and, in most cases, the aquatic life living there will reflect the degradation.

Bioassessments are the primary tool to evaluate the biological condition of a water body. Their status is being assessed with “Biological Quality Elements” (BQEs), i.e. organism groups which integrate the effects of various stressors such as nutrient enrichment, acidification, hypoxia or habitat degradation [1-3]. The BQEs to be investigated are phytoplankton, aquatic flora (phytobenthos and macrophytes in rivers and streams. The benthic macro invertebrates have been found as the most common faunal assemblages and provide more reliable assessment of long term ecological changes in the quality of aquatic system compared to its rapidly changing physic-chemical characteristics.

Well developed water quality monitoring programs involve the measurement of physical, chemical and biological parameters and provide Valuable information on the impacts of water quality on the benthic macro invertebrates which respond differentially to biotic and abiotic factors in their environment and consequently, the structure of macro invertebrates has long been used as bio-indicators to assess the water quality of a water body.

Various biotic indices has been developed according to tolerance and intolerance level of different macro invertebrates taxa with respect to stresses, which leads to assign a numerical score to specific indicator organisms at a particular taxonomic level. The presence/absence, numbers, morphology or behaviour of these indicator organisms can significantly predict the physic-chemical conditions defining the status of given water body at a given location.

To collect the macro invertebrates, field sampling has been done by using either Kick or Sweep sampling procedure (for wadeable streams only), but deep rivers have been sampled by using other modified methods like artificial substrate sampler, airlift sampler, dredging etc. Various indices for the wadeable streams has been developed and they are quite accurate, reliable and precise too, but for non-wadeable streams (deep rivers) still the reliability of the available methods is questionable because defining and identification of reference condition, representative sample, understanding of ecological condition, diagnosing source and cause of impairment is very important for the sensitivity and preciseness of the method.

2. Data Collection And Analysis

2.1. Sampling site

The stream, an important tributary of river Kosi, is located in subtropical pine forest ecoregion in Nainital District of Uttarakhand state. Total catchment area of the Ninglad stream is about 22.20km^2 .Sampling sites were located one at upstream and another at downstream of kanchi temple.

The details of both the sites are given as below: Station 1: Downstream of city Bhowali: The global positioning system (GPS) information of the site in terms of longitude, latitude and altitude are 79º30'42'', 29º23'24'' and 1631 m respectively. The stream carries the effluents of the Bhowali city and consists of large amount of suspended particles. The foam is easily detectable and the riverbed and the river banks are characterized by huge amount of waste (including slaughter house waste).

Average stream width is 3.5 m, mean depth 8 cm and mean current velocity 35 cm/s. Station 2: Eight km d/s of city Bhowali d/s Kainchi Temple: The GPS information of the site in terms of longitude, latitude and altitude are 79º30'30", 29º25'44" and 1300 m respectively. Average stream width is 10 m, mean depth 25 cm and mean current velocity of 40 cm/s. The water carries small amount of foam and suspended solids.

2.2. Method

A sample consists of 20 sub-samples each of 0.25 × 0.25 m collected from all microhabitat types. The sampling was done using for 1.25m^2 stream bottom area using net of 500µm mesh size for collecting the macro invertebrates. Samplings of the large boulders or cobbles were done by washing them vigorously with hand or brush to collect samples in the net. Small boulders were sampled by kick sampling method.

Finally separate individuals of each available taxa carefully and preserved them immediately in 80% ethanol or 4% formaldehyde solution. Collected samples were sorted and identified to operational taxonomic level i.e. upto family level using regional keys in the laboratory and microscope for identifying the fauna. The identified macro invertebrates at family level are given in table 1[2].

3. Result and Discussions

The calculated results of different biotic indices of Ninglad stream as reported in Table 3. Sharma et al. basically used the NEPBIOS/ASPT biotic index to identify the water quality class of the sampling sites.

On the basis of the calculated result station 1 shows water quality class 3 and station 2 shows water quality class 2 [2]. These water classes indicated that station 3 has more input of effluent from domestic as well as industrial areas. Major stressing factors are Stone quarrying and mining, vehicle crossing, waste dumping, embankment, open defecation, agricultural runoff [3].

We analyze the biological data of the Ningland stream with various different biotic indices and compared the results with the actual study. Summary of the different biotic indices and their calculated results has been described below:

Table 1. Analysis of Ningand stream macro invertebrate data with different available Biotic Indices [2]

Sr. No.	Family	No. of Individuals		NEPBIOS Score	Family Biotic Index Score	Signal Score	SIGNAL Score 2	BMWP Score
		Station 1	Station 2					
1	Turbellaria	0	16	-	4	-	2	-
2	Dugesiidae	0	1	-	4	3	2	-
3	Lumbricidae	9	3	3	6	-	-	-
4	Tubificidae	13	0	1	9	-	3	-
5	Salifidae	1	0	3	-	-	-	-
6	Baetidae	0	294	7	4	5	5	4
7	Caenidae	0	17	6	6	7	4	7
8	Ephemerellidae	0	2	7	1	-	-	10
9	Ephemeridae	0	11	6	3	-	-	10
10	Heptageniidae	0	53	7	3	-	-	10
11	Leptophlebiidae	0	1	10	3	10	8	10
12	Gomphidae	0	1	4	3	7	5	8
13	Aeshnidae	1	0	-	3	6	4	8
14	Libellulidae	12	0	6	2	8	4	8
15	Psephenidae	0	4	7	4	5	6	-
16	Dytiscidae	27	0	4	5	5	2	5
17	Elmidae	1	0	8	4	7	7	-
18	Ecnomidae	0	1	6	-	4	4	-
19	Glossosomatidae	0	1	7	1	8	9	-
20	Goeridae	1	3	9	3	-	-	10
21	Hydropsychidae	0	14	6	4	5	6	5
22	Hydroptilidae	0	2	6	4	6	4	6
23	Lepidostomatidae	0	4	10	1	-	-	10
24	Leptoceridae	0	1	10	4	7	6	10
25	Odontoceridae	0	2	5	0	8	7	10
26	Psychomyiidae	0	2	-	2	-	-	8
27	Rhyacophilidae	0	2	8	1	-	-	7
28	Uenoidae	0	3	10	3	-	-	-
29	Pyralidae	0	3	8	5	-	3	-
30	Chironomidae	6	1	1	8	1	3	2
31	Limoniidae	9	72	8	-	-	-	-
32	Muscidae	97	0	0	6	3	1	-
33	Simuliidae	631	137	7	6	5	5	5
34	Tabanidae	7	3	0	5	5	3	-
35	Pediciidae	0	4	0	-	-	-	-
36	Ceratopogonidae	0	7	0	6	6	4	-

Table 2. Calculations and descriptions of equations used for the metrics

Sr. No.	Index/Metric	Calculation	Description
1	Family biotic index	Σ(x × t)/n	x = number of individuals within a taxon t = tolerance value of a taxon n = total number of organisms in the sample
2	Signal Biotic Index	Σ (t)/n	t = tolerance score of individual taxon. n = number of scored taxon present.
3	Signal 2 Biotic Index	Σ(t × w)/ Σ (w)	t = tolerance score of individual taxon w= weighting factor
4	NEPBIOS/ASPT	Σ (t)/n	t = tolerance score of individual taxon. n = number of scored taxon present.
5	BMWP	Σ (t)	t = tolerance score of individual taxon.

Table 3. Description of various biotic index score of two different sampling sites of Ninglad stream

Sr. No.	Sampling sites	NEPBIOS/ASPT	Family Biotic Index	SIGNAL Score Biotic Index	SIGNAL Score 2 Biotic index	BMWP
1	Station 1 (S1)	5.5	5.9	5.0	3.14	38
2	Station 2 (S2)	6.7	4.4	5.5	4.8	132

3.1. Family Biotic Index

Family Biotic Index (FBI) was developed to detect organic pollution and is based on the original species-level index (BI) of Hilsenhoff. As we saw in other biotic indices where higher value of the index indicates high water quality but in FBI high value indicate low water quality vice versa [appendix 3] .

Calculated results of the station 1 indicates water quality is fairly poor and substantial level of organic pollution is present whereas for station 2 water quality is good and some level of organic pollution is present [Table 3].

3.2. SIGNAL Biotic Index

SIGNAL (Stream Invertebrate Grade Number – Average Level) is a simple biotic index for Australian river macro invertebrates [1]. SIGNAL score results indicates that station 1and 2 both lies in quadrant 1[appendix 2] which suggests that the diversity of physical habitats is high and that stress factors like toxic chemicals and harsh physical conditions are not present. Streams in undisturbed native forest will often fall in this quadrant [1].

3.3. SIGNAL Score 2 Biotic Index

SIGNAL 2 has version which is suitable for both family and order-class-phylum identification [1]. The calculated results indicate that water quality of the station 1 lies in quadrant 2 [appendix 2], which shows that station 1 likely to have higher levels or turbidity, salinity or nutrients. These levels may be high either naturally, because of local geology and soil types, or as a result of human activities [1]. Whereas for station 2 water quality lies in quadrant 1, which reveals that diversity of physical habitats is high and that stress factors like toxic chemicals and harsh physical conditions are not present.

3.4. BMWP/ASPT

Calculated result of station 1 [table 3.] shows that the site has poor water quality and substantial amount of pollution present. Whereas station 2 water quality is very good and least impacted [appendix 3].

4. Conclusions

Generally all of the used biotic indices gave similar kind of water quality class with respect to the calculated biotic index value and we found that SIGNAL 2 has more accuracy than its old version. Our calculated results gave similar class of water quality, extent of impact and level of organic pollution at the site.

Finally, it is concluded that combination of these biotic indices may be a suitably used as quick and cost effective tools for assessing the water quality of the streams and rivers.

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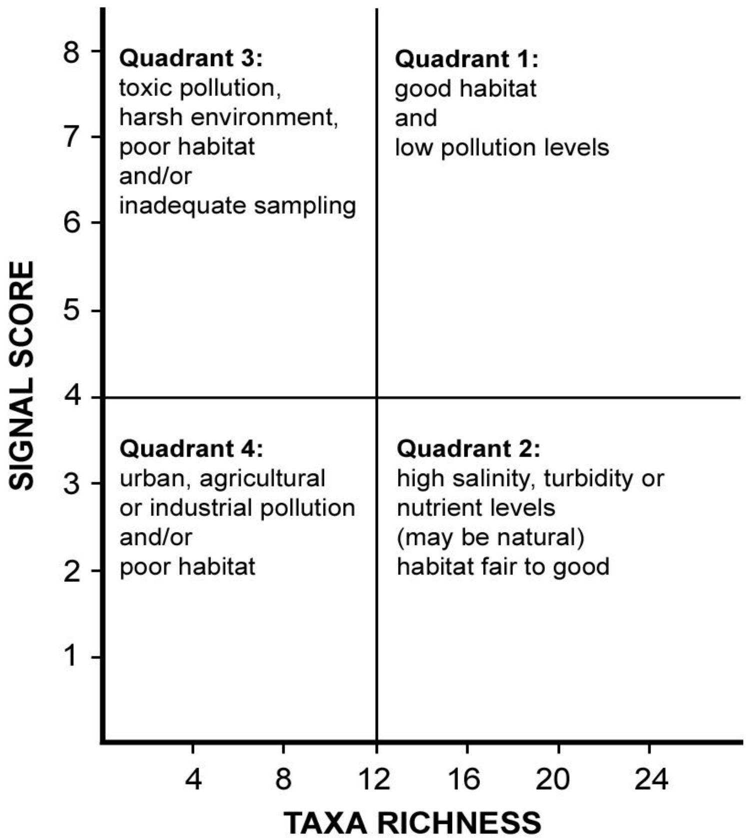
APPENDIX 1

Description of the different water quality classes and their interpretation

	Water Class				
Description	**1**	**2**	**3**	**4**	**5**
Water Use	None, tapped in reservoir, drinking, irrigation, washing	irrigation, bathing and washing & drinking	Bathing , washing and Irrigation, fishing, boating , animal wallow	Bathing , washing and Irrigation, fishing, boating , animal wallow	-
Effluents	None	Domestic, agriculture and industry, leachate from land-filled	Domestic, agriculture and industry	Domestic, agriculture and industry	Domestic, agriculture and industry
Stressing factors	Reference site	Stone quarrying and mining , vehicle crossing, waste dumping, embankment, open defecation, agricultural runoff, impoundment, bank erosion and flood, fishing, natural suspended loads	Sand extraction, waste dumping, squatter settlements, irrigation, agricultural runoff, vehicle crossing, weir and embankment; water pools & fish catching	Sand extraction, waste dumping, squatter settlements, irrigation, agricultural runoff, vehicle crossing, weir and embankment; water pools & fish catching	Wastewater effluents, waste disposal; bank encroachment; open defecation
Settlements	None to spars	Sparse to medium	Sparse to medium	Sparse to medium	Dense
Development	none	Weir	agricultural fields, vehicle crossing	agricultural fields, vehicle crossing	Concrete embankment, roads on the banks and waste dumping
Bank fixation	None, natural embankment	Natural, channelization	None, concrete and bamboo embankments, channelization	None, concrete and bamboo embankments, channelization	-

APPENDIX 2
The quadrant diagram for the family version of SIGNAL Score



APPENDIX 3

Transformation table of different Biotic Indices values to describe the saprobic water quality/site quality

Table 4. Transformation table of NEPBIOS values to describe the saprobic water quality

NEPBIOS/ASPT Value Obtained	Water Quality Classes
8.00-10.00	1
7.00-7.99	1-2
5.50-6.99	2
4.00-5.49	2-3
2.50-3.99	3
1.01-2.49	3-4
1.00	5

Table 5. Transformation table of SIGNAL Biotic Index values to describe the Saprobic Water Quality

Site Score	Water Quality Rating
>6	Healthy Habitat
5-6	Mild Pollution
4-5	Moderate Pollution
<4	Severe Pollution

Table 6. Transformation table of Family Biotic Index values to describe the Saprobic Water Quality

Family Biotic Index	Water Quality	Degree of Organic Pollution
0.00-3.75	Excellent	Organic pollution unlikely
3.76-4.25	Very good	Possible slight organic pollution
4.25-5.00	Good	Some organic pollution probable
5.01-5.75	Fair	Fairly substantial pollution likely
5.76-6.50	Fairly poor	Substantial pollution likely
6.51-7.25	Poor	Very substantial pollution likely
7.26-10.00	Very poor	Severe organic pollution likely

Table 7. BMWP Score categories and interpretation

BMWP Score	Category	Interpretation
0-10	Very poor	Heavily polluted
11-40	Poor	Polluted or impacted
41-70	Moderate	Moderately impacted
71-100	Good	Clean but slightly impacted
>100	Very good	Unpolluted / unimpacted