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Aquatic Macroinvertebrates as Bioindicators of Stream Water Quality- A Case Study in Koratty, Kerala, India

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Abstract

The paper discusses the results of an attempt to test the suitability of aquatic macroinvertebrates as bioindicators of stream water quality in a natural water course locally referred as Koratty chal that runs through the length of agricultural lands in Koratty region. Rapid bioassessment protocol recommended by Environmental Protection Agency (EPA) was followed utilizing Kicknet and D'net of 500µm mesh size to sample the macroinvertebrates. Family Biotic Index (FBI) calculated using the tolerance value of different taxa showed that there was remarkable variation in water quality along the stream. FBI values were around 4.1-5.0 in upstream reaches indicating good water quality. Deterioration of water quality downstream was evidenced in the FBI value of 5.3-5.5 in the mid reaches and 6.0-6.5 in the lower reaches. These values were also found to be in conformity with the water quality as assessed at the biomonitoring sites. It is thus concluded that biomonitoring is feasible in such streams in the region to obtain a quick assessment of water quality.

Keywords: Aquatic macroinvertebrates, bioindicators, stream water quality, Koratty.

Introduction

Human intervention in the name of development has adversely affected many natural ecosystems all over the world, the cumulative impact of which is now threatening the very existence of man through global warming and climate change. Air, water and soil, the most important primary natural resources have become polluted beyond tolerable limits[1]. Fresh air and good quality potable water have become commodities. Natural forests which are capable of buffering the adverse effects to a great degree have been constantly suffering large scale conversions and degradation adding to the magnitude of the problem.

Industries and vehicular traffic release various toxic gases into the atmosphere including carbon dioxide, sulphur dioxide, nitrous oxide, chlorine etc., all of which contaminate the air, soil and water[2]. Modern farming with an eye on quick profits employs the use of synthetic fertilizers, pesticides, weedicides and hormones. Urbanisation and its consequent demands on space and facilities is yet another factor contributing to pollution of the environment.

Pollutants have an influence on the organisms and exposure of organisms to sub-lethal doses of stress (e.g. a pollutant chemical) over a long time period results in many interactions[3, 4, 5]. Initially these interactions may occur at the level of biochemical and cellular processes and lead to physiological effects such as disruption of respiratory, excretory, locomotary, feeding, circulatory, reproductive and neural phenomena in animals and photosynthetic, transpiratory, respiratory, growth and reproductive processes in plants and microorganisms. The structure of the DNA and chromosomes in the organism may be affected leading to modification and eventual evolution of organisms which are capable of withstanding the stresses. This pattern of evolution of resistance or tolerance to the stress factors also occurs in entire communities, for example, shifts in the composition of plant communities in the vicinity of polluted sites which could result in the evolution of plant species that accumulate metals[6].

Nature has its own way of indicating the health of the environment through indicator species of plants and animals, generally termed as bio indicators. Most ecological and environmental bio indicators have strong relationship with some characteristic of their environment[7, 8, 9]. Any deviation from the normal habitat conditions is reflected in alteration of their health, population and distribution.

A bio indicator can be defined as "a species or group of species that readily reflects the abiotic or biotic state of an environment, represents the impact of environmental change on a habitat, community or ecosystem, or is indicative of the diversity of a subset of taxa, or the whole diversity, within an area. Such organisms are monitored for changes (biochemical, physiological or behavioral) that may indicate a problem within their ecosystem. Bio indicators can tell us about the cumulative effects of different pollutants in the ecosystem.

Aquatic macro invertebrates are an integral part of the food chain in lotic environments and they are sensitive to changes in the environment though degrees of sensitivity differ among various groups. Communities of organisms integrate the impact of different stressors and thus provide a broad measure of their aggregate impact. Macro invertebrates have limited migration and their assemblages are made up of species that constitute a broad range of trophic levels and pollution tolerances and thus are particularly suited for assessing site specific impacts. They are most frequently used in bio monitoring since many of them are sensitive to pollution and integrate short term and long term effects of environmental stressors[10,11,12,13]. Different taxa have different habitat preferences and pollution tolerances. Absence of sensitive species and presence of tolerant ones indicate water quality deterioration. Various indices based on these criteria such as Hilsenhoff's Biotic Index (HBI), Invertebrate Community Index (ICI), Biological Monitoring Working Party Score (BMWP), Macro invertebrate Water Quality Index (MWQI), Average score per taxon, percent model affinity and EPT richness index have been used to evaluate water quality.

Study Area: Koratty region lies between 10^{o} 19' and 10^{o} 32' N latitudes and 76^{o} 29' and 76^{o}44' E longitudes and is situated in the central part of Kerala State. The landscape is a mixed mosaic of level to rolling land with low lying paddy fields interspersed in between. Mixed crops of coconut, are canut, banana, vegetables and cash crops such as nutmeg cover most of the land, though rubber plantations are on the increase and paddy fields on the decline. High input farming using fertilizers and pesticides is being followed by most farmers to obtain quick returns. Koratty region is also blessed with a multitude of industries. These units while supporting the development of the area also adds to the pollution of the environment due to their effluents. *Koratty chal* drains through the length of Koratty and hence the impact of various activities in the watershed is expected in the *Koratty chal*.

Methodology

Rapid Bio assessment Protocol developed by United States Environment Protection Agency[14] was followed for estimating the Family Biotic Index (FBI) by assigning specific tolerance values for different families of macro invertebrates in stream water. For sampling these macro invertebrates, a length of 100m stream reach was considered as a unit and the macro invertebrates sampled using D-frame net as also kicks net both of which were of 500µm mesh size. The kick net was placed downstream and the stream bottom substrates 1m above kicked to dislodge invertebrates clinging to debris and stones into the kick net. The contents in the net were emptied into bucket and invertebrates collected. The D frame net was employed to trap specimens clinging to vegetation, root mats etc., along the boundary. Riffles and pools were sampled separately to account for sub habitat variations. The collected specimens were preserved in jars containing either 70% ethanol. They were identified using a microscope with the help of standard keys and the Family Biotic Index calculated.

For standardizing the sampling intensity we went for various sampling trials and by plotting the family accumulation curve concluded that 26 composite samplings were enough to get representative data from 100m stream reach is represented in figure-1.

Water quality parameters such as pH, DO, temperature and flow velocity were recorded onsite and water samples collected and analysed for various other parameters in table-3. Family Biotic Index was calculated using modified Hielsenhoff's formula[15] and Water Quality Index using the CCME WQI method[16]. Wilcoxon Signed Rank statistic[17]. which is a non parametric statistic preferred over the Student's 't' test when comparing populations which are not normally distributed was utilized in the present study to test the null hypothesis of no significant difference between the three sites.

Results and Discussion

The stream, *Koratty Chal* has been studied with respect to the quality of water in three sections along its flow viz., upstream, midstream and downstream to ascertain variations in properties as also to test the feasibility of utilizing bioindicators of pollution in monitoring the deterioration in the quality of water. Family Biotic Index values given in table-1 and figure-2 clearly demonstrate that there existed a gradual decrease in water quality downstream with midstream recording intermediate values.

The Wilcoxon Signed Rank Test used to test the null hypothesis of no statistical difference in total taxa between the three sites revealed that the midstream section was not significantly different while the downstream portion was significantly different from the upstream section. These FBI values were found to be in conformity with the WQI values calculated based on analysis of water samples. Qualitatively, it was seen that the upstream reach of the *Koratty chal* had fair water, the midstream reach had water of marginal quality and the downstream reach recorded poor water quality.

The families of organisms identified are given in table 2. It can be seen that Ephemeroptera (may flies) were represented by five families, Plecoptera by two, Trichoptera (caddisflies) by three, Odonata (anisoptera and zygoptera) by seven, Coleoptera by three, Hemiptera by two and Diptera by five families, Decapoda, Hirudinea and Aquatic oligochaeta were also present which could not be identified upto family level.

Water quality as evidenced in various parameters on samples collected during pre and post monsoon periods of 2010 are given below in table-3. Samples were collected simultaneously from the same sections that were sampled for macro invertebrates and water was analyzed with respect to physico-chemical and biological properties. It could be seen that the water was acidic with some amount of salts as reflected in the electrical conductivity. Both these properties did not show any appreciable differences or notable trend along the length of the *Koratty chal*. On the other hand, DO, BOD, COD, TDS, nitrate, phosphate, fluoride, oil and grease and phenolic compounds were found to register a progressive increase as we move down the stream. Post monsoon values were higher as compared to the pre monsoon samples.

The land use in Koratty region with a predominantly agrarian economy is influenced more by market forces and thus a shift from traditional coconut - paddy cultivation to money spinning cash crops is evidenced. Rubber and nutmeg as well as banana and vegetables are gaining importance. Most of these crops necessitate higher inputs through fertilizers and pesticides to fetch quick profits. The impacts of such practices are evident in the values of nitrates, phosphates, pesticide residues and some of the heavy metals in Koratty chal. Industries and municipal waste along with vehicular traffic also would have contributed to some of these pollution seen downstream of the *Koratty chal*.

Heavy metals such as iron, manganese, nickel, lead, copper and zinc were not present in detectable quantities during the pre monsoon season though their presence was detected during the post monsoon season. Presence of heavy metals in detectable quantities in stream water is a cause of concern as is other properties. They may bio-accumulate in the organisms, enter the food chain and affect them in various ways by disrupting their physiology. These toxic materials bio magnify in the food chain and eventually reach human beings causing several serious diseases. Similarly pesticide residues lindane and DDD were present during the post monsoon period. Total Coliforms and *E.coli* were present throughout the stream and their counts increased downstream. Post monsoon counts were higher than pre monsoon counts in this case too.

Water Quality Index of the three sampling sites is given below in table-4 and figure-3. It can be seen that the upstream water was fair in quality , the midstream marginal and the downstream poor in quality and this status remained similar in both pre and post monsoon periods along the stream course.

The organic pollutants such as oil and grease as well as phenolic compounds detected in the water samples indicate that the stream is being contaminated by organic wastes as it runs down the terrain. Organic wastes whether urban or rural from sewage or farm lands affect the quality of water. Increased turbidity in the water will reduce light penetration that in turn will reduce the volume of water capable of supporting growth of photosynthesizing plants that can provide oxygen. Particulate matter on settling will flocculate small floating animals and plants. As these floccules settle, sludge blankets are formed on the stream bed and many of the areas that formerly could have been inhabited by benthic organisms become covered and uninhabitable except by chironomid larvae, oligochaete worms and other sludge loving organisms[18]. Organic materials consume much of the dissolved oxygen in water during its decomposition depleting its levels in water. The COD values obtained in the study indicate that oxygen consumption by this process is on the increase downstream. Bacteria also consume lot of oxygen which is reflected in the BOD values which also is seen to increase as we move down the stream. The number of coliform bacteria which is seen to increase downstream could have influenced the BOD in water.

Aquatic insects are more easily constrained by a decrease in oxygen than any other water quality attribute because of their evolution from their ancestors on land with well developed tracheal respiratory system adapted to an atmosphere rich in oxygen. Aquatic invertebrates that utilize dissolved oxygen face serious limitations with its decreasing levels. Several factors such as temperature, salinity, turbulence, pollution etc., determine the amount of oxygen in water. Several adaptations to counter these environmental constraints have been developed by aquatic insects. Some have developed high tolerance while others remain sensitive. Respiratory adaptations in aquatic macroinvertebrates include air tubes, cutaneous and gill respiration, extraction of air from plants, haemoglobin pigments, air bubbles and plastrons. Air bubbles are seen in Hemiptera (Nepidae, Belostomatidae) and Diptera (Ptychopteridae, Culicidae, Syrphidae). Cutaneous and gill respiration is common in the immature stages of most insect orders. Most of them need oxygenated water for their survival though certain species of Chironominae are capable of surviving oxygen depletion using haemoglobin pigments that help in the transfer of oxygen. Coleoptera and Hemiptera adults make use of an air bubble and certain species within this group have evolved a system of micro-hairs or papillae that hold an air film called plastron which enables them to stay submerged for longer periods. Most of the Ephemeroptera, Plecoptera and Trichoptera species are sensitive to pollution due to low levels of adaptive mechanisms. On the other hand families such as chironomids with long cylindrical body have larger body surface area for diffusion of oxygen. These are also blessed with the respiratory pigment haemoglobin that releases oxygen at low external O_2 pressures. When chironomid larvae undulate their bodies in their mud burrows to get more O_2, their haemoglobin gets O_2 saturated which is released when necessary.

Thus the organisms that can tolerate pollution increase and sensitive groups decrease as the level of contamination increase downstream. Such an effect was evident in the composition of aquatic macroinvertebrates present in the upstream, midstream and downstream stretches of *Koratty chal.* Deterioration in water quality was reflected in both water quality index calculated based on different properties of water as well as family biotic index calculated based on the tolerance of organisms. These two indices gave similar estimates of water quality.

Conclusion

The Family Biotic Index utilized in the present study was found applicable in monitoring stream water quality in Koratty region.

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Table -1
FBI values and its interpretation during pre and post monsoon periods

Stream reach	FBI and its interpretation						
	Pre-monsoon		Post-monsoon		Wilcoxon Signed Rank of taxa	Impact	Agreement with WQ
	Value	Status	Value	Status			
Upstream	4.1	V. Good	4.95	Good			Yes
Midstream	5.3	Fair	5.5	Fair	NS	No	Yes
Downstream	6.0	Fairly poor	6.5	Fairly poor	S	Yes	Yes

NS - Non Significant; S - Significant p=0.05

Table -2
Organisms identified from the collected samples

Ephemeroptera	**Lestidae**
Baetidae	Coenagrionidae
Ephemerellidae	Decapoda
Caenidae	Coleoptera
Heptageniidae	Detiscidae
Potamanthidae	Carabidae
Tricorythidae	Sialidae
Plecoptera	Gerridae
Perlidae	Elmidae
Trichoptera	Hemiptera
Hydropsychidae	Corixidae
Limnephilidae	Balostomatidae
Glossosomatidae	Hirudineae
Polycentropodidae	Aquatic oligochaetae
Odonata	Diptera
Libellulidae	Chironomidae
Cordullidae	Simulidae
Gomphidae	Tipulidae
Platycnemidae	Athericidae
Calopterygidae	Culicidae
Chlorocyphidae	Nymphomidae
Macromiidae	Ceratopogonidae

Table-3
Variation in Water Quality along *Koratty Chal* during pre and post monsoon

Parameters	Pre-monsoon 2010			Post-monsoon 2010		
	Up	Mid	Down	Up	Mid	Down
P^H	6.2	6.1	6.2	6.4	6.2	5.9
EC (µs/cm)	58.50	63.40	68.60	56.00	68.00	72.43
DO	7.021	6.742	4.85	6.6	6.3	4.2
BOD	2.830	3.050	4.332	2.818	3.2	4.03
COD (mg/l)	18.0	20.0	34.2	19.00	25.24	37.00
TDS (mg/l)	37.44	40.58	52.36	39.00	42.45	56.00
Phosphate-P (mg/l)	0.043	0.052	0.12	0.030	0.060	0.080
Nitrate-N (mg/l)	0.12	0.35	0.54	0.13	0.34	0.46
Fluoride (mg/l)	00	00	00	0.05	0.10	0.20
Oil and grease (mg/l)	2.0	6.80	8.45	65.60	84.20	87.60
Phenolic compounds (mg/l)	00	0.01	0.12	0.10	0.20	0.25
Iron (mg/l)	00	00	00	0.09	0.24	0.26
Manganese (mg/l)	00	00	00	00	0.01	0.01
Nickel (mg/l)	00	00	00	0.001	0.01	0.020
Lead (mg/l)	00	00	00	0.001	0.01	0.024
Copper (mg/l)	00	00	00	00	0.01	0.01
Zinc (mg/l)	00	0.049	0.062	0.009	0.01	0.03
Lindane (µg/l)	00	00	00	00	0.001	0.001
DDD (µg/l)	00	00	00	00	0.001	0.001
Total coliform (CFU/100 ml)	4000	8000	10000	6000	12000	14000
E.Coli (CFU/100 ml)	500	800	1200	1000	1200	1400

Table - 4
Water Quality Index

Stream Reach	WQI			
	Pre-monsoon		Post-monsoon	
	Value	Status	Value	Status
Upstream	75	Fair	72	Fair
Midstream	58	Marginal	55	Marginal
Downstream	37	Poor	32	Poor

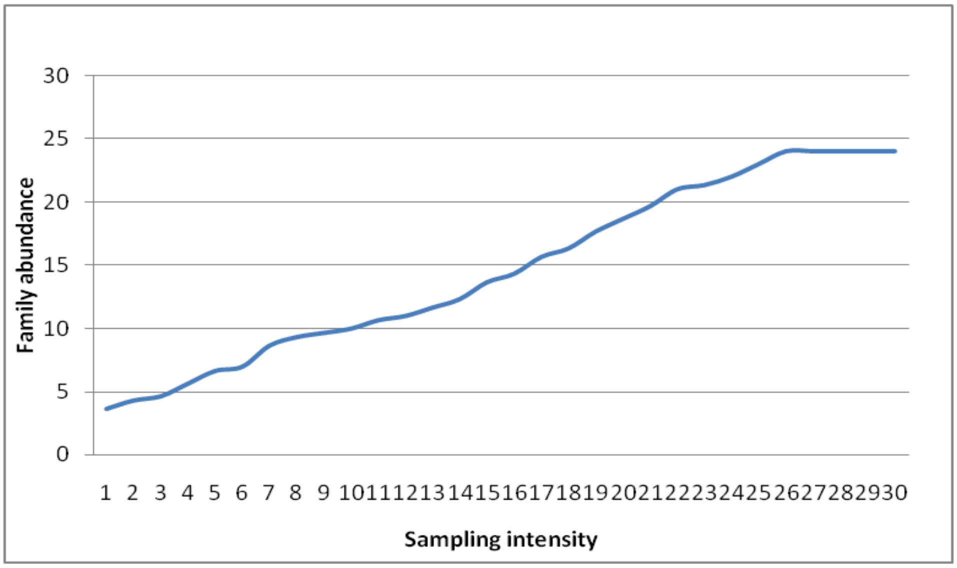

Figure-1
Family accumulation curve

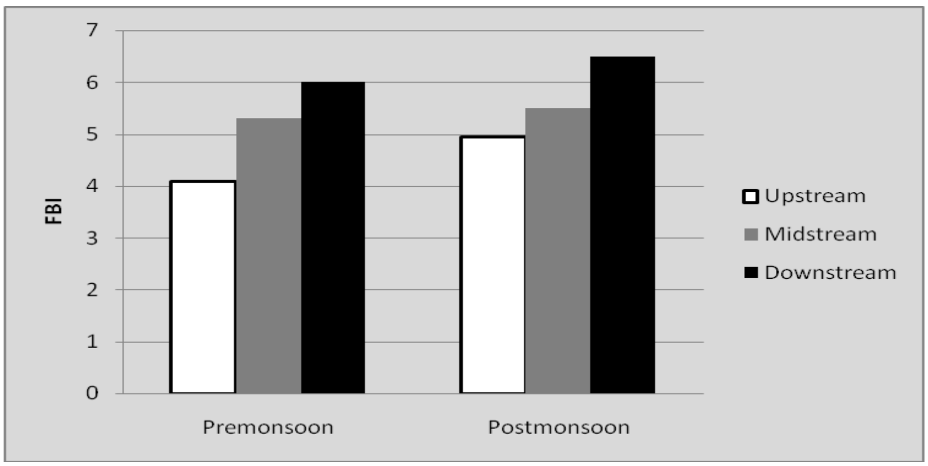

Figure-2
Variation in FBI along *Koratty chal* in the two seasons

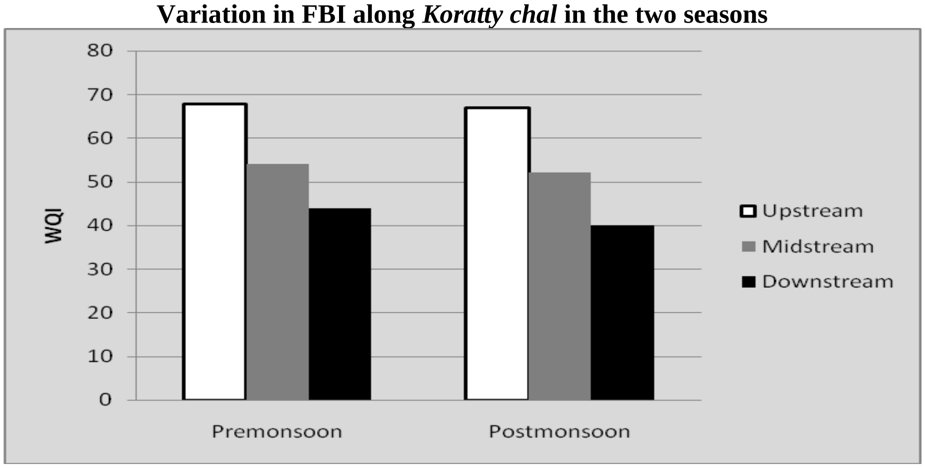

Figure-3
Graph showing Variation in Water Quality Index along *Koratty Chal*