Application of Rapid Bioassesment Protocol (RBP)-II for evaluation of water quality in headstreams of Nilwala river basin in Sri Lanka

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Abstract

Biological monitoring is more popular than chemical monitoring due to low cost, effectiveness and it is environmentally friendly. RBP, one of the biological monitoring tool is popular due to its efficiency, low cost and time saving. Present study was carried out to investigate the application of RBP (II) developed by United States Environmental Protection Agency using macro invertebrates, in surface runoff of freshwater bodies of head streams of Nilwala river basin, in Matara district. Four sites located in the upper and middle catchment areas of Nilwala river basin were sampled using artificial substrate samplers and conventional sampler from July 1999 to May 2000. Collected macro invertebrates were identified up to family level. The metric used in RBP (II) and the protocol used in Global Environmental Monitoring System (GEMS)/ Water system, were used to calculate points for each site. Water quality imparity of study sites was classified into four broad categories based on final percentage categories. Site ST 4 was moderately impaired while site ST 2 was non-impaired. Occurrence of the number of ephemeropteran, plecopteran and trichopteran families were higher in sites ST 1 and ST 2. Rapid Bioassesment Protocol (II) was successful in differentiating the water quality of the study sites.

Introduction

Freshwater ecosystem is indispensable to human life in aspects of daily domestic needs and as a raw material for industries, in agricultural fields etc., as such special attention should be given in water quality monitoring programs. Analyses and surveys of organisms in the framework of environmental monitoring are called biomonitoring (Rosenberg and Resh 1992). The purpose of biomonitoring is to characterize the status of water resources and to monitor trends in the condition of biological communities that are associated with anthropogenic perturbation. Most of the water quality monitoring agencies incorporates chemical, physical and biological monitoring systems in order to get a clear and complete spectrum of information for the proper management of water resources (Metcalfe 1989). Although, using modern techniques, chemical and physical analysis of water can be made with great precision, it will only reveal the presence of substances, which the analysis is specifically designed to detect. In addition, there is a high probability of missing the peak concentration of a pollutant when performing the chemical analyses, because the concentrations of pollutants in receiving waters fluctuate widely (Abel 1989). Incorporating biological monitoring methods can offset most of such limitations.

Rapid assessment approaches are popular due to their efficiency and cost effectiveness. Rapid bioassessment programs are designed to screen large regions, pinpointing trouble spots worthy of more detailed attention (Resh *et al.* 1995). Rapid bioassessment based on quality classification of streams always enables comparisons to be made between a reference area and areas of concern.

The Rapid Bioassessment Protocol (RBP) was developed by the US Environmental Protection Agencies (EPA) to provide basic aquatic life data for planning and management purposes. This protocol consists of three macroinvertebrate and two fish protocols namely RBP (I) to RBP (V). RBP (II) can be used to prioritize sites for more intensive evaluation or can be used instead of RBP (I) as screening techniques. It considers only family level taxonomic identification and therefore involves little additional time and effort. RBP (II) provides more intense assessment than RBP (I) and can detect sites of intermediate impairment.

Present study was carried out to investigate the applicability of RBP (II) developed by United States Environmental Protection Agency using macro invertebrates, to assess the water quality in surface run off of freshwater bodies of head streams of Nilwala River Basin, in Matara district.

Materials and Methods

Four sites located in the upper and middle catchment areas of Nilwala river basin were sampled using two types of gears, namely artificial substrate samplers (wire mesh cage filled with stones and wooden box) and conventional sampler (surber sampler) from July 1999 to May 2000. Surber sampler was operated monthly to collect samples while artificial substrate samplers were retrieved in two months intervals. Collected macro invertebrates were identified up to family level using several keys (MacCafferty 1981, Pennak 1978, Merritt and Cummnins 1988). The metric used in RBP (II) and the Protocol used in Global Environmental Monitoring System (GEMS) / Water system, were used to assign points for each site. Quality points per site were totaled and compared with the total quality points allocated to the reference site ST 1, and are expressed as percentages. Water quality imparities of study sites were classified into four broad categories based on final percentage categories.

Data analysis and details of the metric used in RBP (II)

The data analyzing scheme used in RBP II and GEMS/Water system, integrates several community, population and functional parameters into a single evaluation of biotic integrity. Each parameter measures a different component of community structure and has a different range of sensitivity to pollution stress (Plafkin *et al.* 1989)

The following criteria were used to evaluate water quality in the study sites using collected macroinvertebrates.

i). Taxa or family richness that measures the total number of taxa or families present and simply give an indication of the healthiness of the community. Generally it increases with augmentation of water quality, habitat diversity and habitat suitability.

ii). Modified Family Biotic Index, which was developed to summarize the various tolerances of the benthic arthropod community with a single value (Hilsenholf 1988a). It calculates a score based on an average tolerance per individual and therefore takes into account abundance as well as presence/absence. Tolerance score ranges from 0 to 10, indicating excellent water quality and very poor water quality with severe pollution respectively.

The following formula was used to calculate this index.

$FBI = \Sigma (x_i * t_i/n)$ where x_i- number of individuals within a taxon/family, t_i - tolerance value of a taxon (from Hilsenholf 1988), n - total number of organisms in the sample.

iii). Average Score Per Taxa (ASPT) values based on Biological Monitoring Working Party (BMWP) scores adopted for India; Accordingly each family has a score range of 1-10, reflecting its general tolerance to organic pollution. High scores are registered by the least tolerant groups and low scores for highly tolerant groups. The ASPT is calculated by dividing the sum of BMWP scores by the number of corresponding scoring families.

iv). Number of EPT (Ephemeroptera, Plecoptera and Tricoptera) families; the insect orders Ephemeroptera, Plecoptera and Trichoptera are considered to be pollution sensitive and therefore the total number of families of these three orders will proportionately be related to the water quality.

v). Ratio of EPT and Chironomid abundance; uses the abundance of these four indicator taxa as a measure of community balance. It is generally considered that unpolluted sites should have a fairly even distribution of these groups but the chironomids will become more dominant in a stressed environment.

vi). Percent contribution of dominant family: this metric simply measures the distribution of individuals among the families. Stressed communities typically consist of few families and have a high dominance index. Therefore environmental degradation can be measured by fluctuation of dominant family/taxon score. The formula used in this metric is $D = nmax /N *100$ where D = percent dominant index; n_{max} = maximum number of individuals in the sample, N = total number of individuals in the sample.

vii). Community Similarity/ Loss Indices: when different communities exist, community similarity indices can be used. In this study three types of community similarity/loss index were incorporated. a). Community loss index: this index developed by Courtemanch and Davies (1987) is more discriminating than many similarity indices (Plafkin *et al.* 1989). It measures the loss of benthic taxa between the reference site and a comparison site. Values range from 0 to infinity and increase with dissimilarity. The formula used is Community loss index = (D - A)/E; where A, number of families common to both samples; D, total number of families present in reference site; E, total number of families present in site of comparison.

Using the data on benthic macroinvertebrates, values were calculated for each metric and have been expressed as a percentage to the reference site, except in the case of percent contribution of the dominant

family in which the actual percent value itself is used. Quality points were allocated for each metric according to the following table 1.
In order to combine all indices and give a single score for each site, quality points are totaled for each site. Calculated totals are then compared to the total from the reference site and expressed as a percentage of these totals. Study sites can be classified into four broad categories of water quality based on final percentage classification as shown in Table 2.

Table 1. Quality point ranges for each score

Quality points	6	4	2	0
Taxa richness	> 80 %	61-80 %	40-60 %	<40 %
ASPT	>92 %	81-92 %	68-80 %	<68 %
BMWP	>80 %	51-80 %	20-50 %	<20 %
Modified FBI	>85 %	71-85 %	50-70 %	<50 %
EPT : Chironomids abundance	>75 %	51-75 %	25-50 %	<25 %
Community loss	<0.5	0.5-1.5	1.6-4.0	>4.0
% Dominant family	<30 %	30-40 %	41-50 %	>50 %
No. of EPT family	>90 %	81-90 %	70-80 %	<70 %

Source : Plafkin *et al.* (1989), Thorne (1993).

Table 2. Quality points ranges for the final classification of sites

% of reference score	Biological condition category	Attributes
>80 %	Non-impaired	comparable to the condition at the reference site, with good community structure. Loss of some
51-80 %	Slightly impaired	sensitive taxa/families. contribution of tolerant forms increased. Fewer families/taxa due to loss
20-50 %	Moderately impaired	of most of Sensitive groups especially EPT. Few families/taxa. Community dominated
<20 %	Severely impaired	by one or two groups

Results

Mean surface area per unit sampler is as follows: Stones in the WMC $0.18m^2 \pm 0.25$, WB sampler $0.13m^2 \pm 0.0005$ and surber sampler $0.0506\ m^2$. Since three sampling gear had three different surface areas, in order to standardize the data, taxa recorded from three sampling gears were converted to the number of animals/ taxa per square meter.
ANOVA based on abundance and species richness of macroinvertebrates collected from artificial substrate samplers and conventional sampler were significantly different ($p<0.05$) irrespective to sites. When compared the species richness among samplers it was higher in wire mesh cage (average 14 taxa) than in wooden box sampler (average 06 taxa) and conventional samplers (average 08 taxa), while wooden box sampler showed highest abundance of macroinvertebrates compared to wire mesh cage and surber sampler. When applying the RBP (II), data collected from the three sampling gears were pooled together. Results of the various metrics based on the pooled data were shown in table 3.
Taxa richness is highest in site ST1 (reference site), while it is lowest in site ST4. Number of EPT families and BMWP values are highest in site ST1 and these values are lowest in site ST4. Percent dominant family is highest in site ST4.
Chironomids, annelids and mollucs are the dominant taxa found in WB sampler and cased caddish fly, similum and plecopteran larvae prefer to colonize in WMC samplers. Water quality scores for pooled data are shown in table 4.

Table 3. Results of the various metrics based on the pooled data

Metric	Site			
	ST1	ST2	ST3	ST4
Taxa richness	10	8	6	4
ASPT	3.8	4	3.3	2.8
BMWP	34	28	20	12
Modified FBI	2.58	2.37	1.90	1.2
Number of EPT families	7	6	3	2
EPT : Chironomids abundance	2.58	4.8	2.89	1.85
% Dominant family	28.2	18.2	32.1	38.4

Table 4. Water quality scores for pooled data

Metric	Site			
	ST1	ST2	ST3	ST4
Taxa richness	6	6	2	2
ASPT	6	6	4	2
BMWP	6	6	4	2
Modified FBI	6	6	4	0
Number of EPT families	6	4	0	0
EPT : Chironomids abundance	6	6	4	2
% Dominant family	6	6	4	4
Total point scores	42	40	22	12
% refer to the reference site	100	95.2	52	28.5
Water quality imparity *	N	N	S	M

* denote N : Non impaired S : Slightly impaired M : Moderately impaired

Based on the water quality scores, Site ST1, and ST2 can be classified as non-impaired sites while site ST3 as slightly impaired site and site ST4 as moderately impaired site. Substrate diversity in four studied sites were varied considerably (Table 5). Sites in upper catchment area (ST 1, ST 2) showed higher species diversity as well as substrate diversity than sites in middle catchment area (ST 3 and ST 4).

Table 5. Habitat and substrate diversity in four studied sites

Substrate type	Percentage cover			
	ST1	ST2	ST3	ST4
Bedrock	90	82	0	0
Stone	4	8	10	0
Gravel	1	2	5	8
Sand	1	2	55	55
Silt	0	0	28	32
Leaf litter	4	5	2	5

Discussion

It can be more accurate and clear if we consider several biological parameters instead of depending on a single parameter in water quality monitoring. Since RBP (II) involves several parameters, it is a useful tool to categorize water bodies according to their impairments. Overall, RBP (II) performed well in this study, as it separated four study sites into three different water quality categories. One defect of this protocol is that the final outcome depends on the selection of reference site, because the allocation of point scores and final classification depends on the selected reference site. In some instances, for some parameters, reference site may also give lower scores.

Highest taxa richness, number of EPT families in sites ST1 and ST4, can be attributed to the highest substrate diversity in these sites. When more habitats and niches are available in a particular site, different types of taxa could be colonized and consequently show highest taxa richness. Especially, sites in upper catchment area, rich in allochthonous matter, which provides food sources for macroinvertebrates, are occupied by them in these area. RBP (II) is a good tool in water quality monitoring to acquire a clear decision on site impairments. However, for Sri Lanka and related regions, some indices use in RBP (II) matrics have to be improved especially by incorporating indices based on tolerance values. This improvement can be realized either by changing percent range of quality points or tolerance values.

When considering similar studies done in other Asian countries, RBP (II), has been applied to study the water quality of ten study sites belonging to four different lotic fresh water habitats i.e. stream, river, irrigation canal and sewage canal in Chiang Mai, Thailand (Guruge 1997) can be cited. According to the results obtained in that study author concluded, that RBP (II) could apply efficiently to evaluate the quality of water in running water ecosystem. However, he stressed the importance of using proper sampling gears in the collection of macroinvertebrates used as indicators.

Suwanrat (1996), conducted similar research in order to determine the applicability of RBP (II) in Thailand. The results revealed that the RBP (II) could be used in Thailand successfully. But some improvements or adjustments are being suggested to be incorporated into the procedure before using this protocol, as some indices used, such as EPT index and percent contribution of dominant family, were found to be less effective than the others in evaluating the water quality.

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