Aquatic Macroinvertebrates as Bioindicators for stream and wetland health monitoring

Outline

Who are aquatic macro-invertebrates?

Macroinvertebrates are organisms that are large (macro) enough to be seen with the naked eye and without a backbone (invertebrate). They inhabit all types of running waters, from fast-flowing mountain streams to slow-moving muddy rivers. Examples of aquatic macroinvertebrates include insects (in their adult, larval or nymph form), mollusks, crustaceans and worms (Viklund, 2011). Most of them live part or most of their life cycle attached to submerged rocks, logs, and vegetation or else in soft sediment.

Some benthos for instance stoneflies are found more often and in larger amounts in water bodies that are generally clean, or unpolluted by organic wastes. Without too much organic matter, the water usually have lots of oxygen for these species often considered to be clean water benthos. But when thinking about worms and midges, water quality professionals often view these as indicators of dirty water, especially in rivers and streams (Invertebrates as indicators, 2008).

What is Biological Integrity?

The biological integrity of a stream or an aquatic ecosystem means how well the habitat can support biological communities, including algae, invertebrates, fish, aquatic mammals and birds. For a given habitat, to have high biological integrity, it should be unimpaired/ minimum disturbed by human or other activities and must contain a diverse assemblage of naturally occurring plants and animals (Jensen, 2007).

When human induced activities like land clearing, poor agricultural practices, urbanization, etc. come into action, those influence the habitat and change the physico-chemical conditions of the water body which ultimately reduce the biological integrity of the habitat. Therefore by measuring the biological communities present in a stream or a canal system, it is possible to determine the condition or health of the habitat which can be either stream or wetland.

What are Bioindicators?

Bioindicators are species used to monitor the health of a given ecosystem or environment. They are any biological species or group of species whose function, population, or status can be used to determine ecosystem or environmental integrity. Such organisms are monitored for changes of their physiological, population, status, or behavioural pattern to determine the ecosystem or environmental integrity.

Further McGeoch M. A. (1998) cited by Hodkinson and Jackson (2005) has defined a Bioindicator 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 of the wholesale diversity, within an area’’.

In general, freshwater invertebrates range from tiny animals that can hardly be seen with the naked eye (such as planktonic rotifers) to quite large crayfish (kōura) and mussels. Both these categories are more frequently used and identified as Bioindicators for water quality. This study was focused on the group of macroinvertebrates live in the littoral zone of Colombo Sri Jayawardhanapura canal system.

What can Invertebrates bioindicate?

In general, invertebrates can be used as Bioindicators to reveal;

1. A changing physical environment (temperature, substrate type, depth, light intensity, etc.)

2. A changing chemical environment (pH, heavy metal concentration, Nutrient factors, etc.)

3. The comparative quality or conservation value of the habitat (no of rare, local, or endangered species)

4. Changes in the ecological status of the habitat (naturally occurred/ human impacts)

(Hodkinson and Jackson, 2005).

How can invertebrates be used as Bioindicators?

Invertebrates can indicate changes in the environment through their responses at different levels of organization, ranging from the individual animal to the total invertebrate community (Hodkinson and Jackson, 2005). The appropriateness of the level of organization (individual/ species population/ community) chosen to indicate the variation of the environment depends on the particular factor that are thought to be acing there.

Individual animals may serve as short-term Bioindicator of particular environmental conditions and their response to the stress can be revealed from their physiology or behaviour. When considering the organization of species population level, changes in the population characteristics of the indicator species are considered. Though the monitoring process of community level responses is too complicated, it provides a valuable perception on the biological scale of variation of the environmental condition. It also acquires several attributes useful for bioindication for instance; species richness, relative abundances of different species and the presence of important / key species (Hodkinson and Jackson, 2005).

Ecological significance and suitability of macro-invertebrates as Bioindicators /

(Why use Invertebrates as Bioindicators?)

Invertebrates are abundant medium-sized organisms that, as a generality, have growth rates and population turnover times lying midway between those of microorganisms and higher plants and animals. Invertebrates also have effective active and passive dispersal mechanisms that often allow wide dissemination and rapid re-colonization of disturbed habitats (Hodkinson *et al*. 2002 cited by Hodkinson and Jackson, 2005).

In general aquatic invertebrates can be used as Bioindicators for assessing and monitoring the state of health of aquatic environments because they;

- live in the water for all or most of their life cycle.
- stay in areas suitable for their survival.
- are exposed directly to the stress of pollution and the prevailing conditions of the aquatic environment.
- are easy to collect.
- differ in their tolerance to amount and types of pollution.
- are easy to identify in a laboratory.
- often live for more than one year thus well suited to long-term observation of environmental stress.
- have limited mobility due to their sedentary habit and thus constantly exposed to the effects of pollution.
- Their high species diversity means many potentially different reactions to many different environmental effects (Invertebrates as indicators, 2008).

What are Multimetric Indices?

Multimetric indices are commonly used for evaluating the biological condition of water bodies. Most multimetric indices consist of a number of measures or metrics (attributes), describing a specific assemblage (e.g.; fish, macroinvertebrates or periphyton), which are combined into a single "multimetric" value representing the condition of a water body (Blocksom, 2003). These metrics can represent a wide range of ecological characteristics, including taxa richness, taxonomic composition, pollution tolerance, functional feeding groups, and behavioural habits. Hence the metrics included in an index may have a variety of units. Furthermore, some indices have incorporated diversity or pollution tolerance indices such as Shannon Diversity Index, Hilsenhoff Biotic Index, etc. Therefore these metric values must be converted into unitless numbers in order to combine them into a single value during the process of index development.

Comparison of the characteristics of a particular water system (impaired/ degraded sites) to those of a high quality system (one with minimal human disturbance/ reference sites) can determine the negative aspects impacting that system. Several variations of multimetric indices have been created since the early 1980s.

What is Macroinvertebrate Index of Biotic Integrity M-IBI and its application?

Indices of Biotic Integrity (IBI) are one form of Multimetric index that focuses on Fish, Periphyton, or Benthic communities (Wittman and Mundahl, 2002). As described by Stribling et al (1998), "Karr et al. (1986) developed the multimetric approach (the Index of Biological Integrity or IBI) that combined a series of metrics (biological descriptors) to characterize biological condition with fish assemblage data from streams of the Midwestern US. There have been numerous adaptations of the approach using different groups of organisms and calibrated for different geographic areas and water body types (Southerland and Stribling 1995, Davis et al. 1996, U.S. EPA 1997)".

It should be noted that these IBIs are region-specific due to the variations in communities across a wide range of ecological habitats. Therefore it is only applicable to the same habitat or similar areas.

Previous work done

Globally, particularly in USA, Macroinvertebrates have been widely used as indicators of water quality by state and federal monitoring agencies for many years. Many studies have shown them to be very useful indicators of water quality (Chirhart, J., 2003). Also Macroinvertebrates are widely used by citizen monitoring groups throughout the United States (U.S. EPA 1997).

Chirhart (2003) has said, "In an effort to understand and communicate biological information in a meaningful way, Dr Jim Karr developed the Index of Biotic Integrity (IBI) in the early 80's (Karr 1981). The Indices of Biotic Integrity (IBI) was first developed using attributes of fish communities in moderate size wadeable streams in Illinois. It has subsequently been modified for use throughout the country for aquatic macroinvertebrates (Ohio EPA 1988, Kerans and Karr 1994, Barbour et. al. 1996), terrestrial macroinvertebrates (Kimberling and Karr 2002) and algae (McCormick and Stevenson 1998). Each metric in an IBI denotes a quantifiable attribute of a biological assemblage that changes in a predictable way with different levels of human influence.". Further, he has mentioned that "Many states have begun to develop multimetric indices for rivers and streams with the ultimate goal of developing biological criteria for use within their own water-quality programs (U.S. EPA, 1996). And currently it is widely used in United States.".

The Maryland Biological Stream Survey (MBSS) carried out by the Department of Natural Resources in 1994 to monitor and assess small to medium-sized streams across the state using a probability-based network design, Benthic invertebrate-based Index of Biotic Integrity that developed to detect the effects of human influence on streams in Southeastern Minnesota, and the project for the Development of a Macroinvertebrate Index of Biological Integrity (MIBI) for Rivers and Streams of the St. Croix River Basin in Minnesota (2003) are some of the largest stream surveys done in US.

The IBI developed from the Maryland Biological Stream Survey (MBSS), was found to be most efficient when calibrated separately for 1) low-gradient Coastal Plain streams and for 2) higher gradient non-Coastal Plain streams, with classification efficiencies of 87% and 88%, respectively. Seven metrics were used in the Coastal Plain IBI, total number of taxa, number of EPT taxa, % Ephemeroptera, % Tanytarsini of Chironomidae, Beck's Biotic Index, number of scraper taxa, and % clingers. Nine metrics were used in the non-Coastal Plain; total number of taxa, number of EPT taxa, number of Ephemeroptera taxa, number of Diptera taxa, % Ephemeroptera, % Tanytarsini, number of intolerant taxa, % tolerant individuals, and % collectors (Stribling, et al, 1998).

Invertebrate data obtained from 43 stream sites in Southeastern Minnesota were used to determine the ability of 22 characteristics (metrics) of invertebrate assemblages to assess the healthiness of streams in the region. The final B-IBI was included with 10 metrics and 4 alternates.

As a part of the Minnesota Pollution Control Agency's long-term monitoring strategy, macroinvertebrates were collected from 88 streams in the St. Croix River Watershed Minnesota, between 1996 and 2000. The samples were collected primarily from small wadeable streams, and wadeable reaches of larger streams. The macroinvertebrate community data collected was used to develop a series of biologically meaningful measures or metrics. The resulting metrics were assigned scoring criteria, scored, and combined into a multimetric index, the Macroinvertebrate Index of Biological Integrity (MIBI). The MIBI, in conjunction with a similar index measuring the biological integrity of the fish community, was used to evaluate the biological integrity of selected stream reaches. The ability of the MIBI to discern differences between varying degrees of human influence on biological integrity was tested by evaluating streams with a wide range of upstream landuse patterns. Based on metric selection criteria the 13metrics were maintained for use in the M-IBI for each respective stream class (Glide Pool, Small Riffle-run and Large Riffle-run).

Apart from the work carried out in USA, several research methodologies and protocols were developed and studies were being carried out in all over the world in order seeking possibility of using macroinvertebrates as bioindicators and development of Macroinvertebrates / Benthic Index of Biotic Integrity (M-IBI or B-IBI). For instances;

In Canada a team of research scientists from Environment Canada studied the composition and spatial distribution of benthic communities in Lake Saint-Pierre using the methods of the Canadian Aquatic Biomonitoring Network (CABIN), which was designed by the National Water Research Institute (NWRI). In adopting a common approach to conduct biological assessments and using sampling protocols that are standard Canada-wide, a comprehensive overview of the status of Canada's fresh water can be produced. The job of Environment Canada was thus to determine if these aquatic organisms can be used as bioindicators for assessing and monitoring the state of health of aquatic environments like Lake Saint-Pierre.

British-Columbia (west – Canada) ; Assessment of Biological Integrity of Okanagan Streams: Using Benthic Invertebrates to Monitor Stream Health by Environmental Protection Program, Ministry of Environment, Penticton BC., The Okanagan B-IBI was developed specifically to assess Okanagan streams at low elevations in the valley bottom. During the study; benthic invertebrates were collected from 23 low elevation Okanagan stream sites between 1999 and 2004. And then it was used to rank the health of 31 stream sites. Five metrics that describe the community characteristics such as Total number of taxa, Number of stonefly taxa, Number of mayfly taxa, Number of intolerant taxa and Number of clinger taxa were selected for the index development. The second purpose of this work was to examine other tools available for collection and analysis of benthic invertebrates as estimates of aquatic ecosystem health. The Report says the main multivariate bioassessment programs currently in use worldwide are the UK's River Invertebrate Prediction and Classification System (RIVPACS), and the Australian River Assessment Scheme (AUSRIVAS), Environment Canada's Reference Condition Approach (RCA) and the Canadian Aquatic Biomonitoring Network (CABIN) (Jensen, 2006).

A Benthic Invertebrate Index of Biological Integrity (B-IBI) for Streams in the Bulkley TSA, BC was developed by Shauna Bennett and Kieran Rysavy (Bennett and Rysavy, 2003) as to create a tool to monitor the effectiveness of the forest management program specific to aquatic resources. In 2001, 26 stations in 21 streams were sampled, and in 2002, 14 stations were sampled in 8 streams. Using the method described, six metrics were chosen for inclusion in the BTSA B-IBI such as Plecoptera taxa richness, Trichoptera taxa richness, Intolerant taxa richness, Hilsenhoff biotic index (HBI), Clinger taxa richness and % dominance (3 taxa).

In Mexico; a group of scientists has developed Macroinvertebrate-based index of biotic integrity for protection of streams in West-Central Mexico restoration of streams in the Sierra de Manantla´n Biosphere Reserve based on data collected February through May 1999, and February 2000. Thirty-three sites on 21 streams within 6 major basins represented natural environmental conditions and human-influence types and intensities in the area. Eight metrics chosen a priori comprised the IBI: catch per unit effort, generic richness, % Ephemeroptera–Plecoptera–Trichoptera genera, % Chironomidae individuals, Hilsenhoff Biotic Index, % depositional individuals, % predator individuals, and % gatherer genera (Weigel, Henne and Martinez-Rivera, 2002). IBI was developed with data acquire from 27 sites and validated with 6 others. It was found that values obtained from the developed correlated well with the measures of human influence based on qualitative assessment of habitat and water quality (Pearson's r = 0.86). IBI values for 7 sites on Rı´o Ayuquila corresponded with a documented longitudinal pattern of human influence and the existing fish-based IBI (Pearson's r = 0.87) (Weigel, 2002). The study has confirmed the capability of developing biological standards need to measure the environmental degradation happening in Sierra de Manantla´n Biosphere Reserve due to various human influences.

In Australia; A National Technical Manual on monitoring Macro-invertebrates was developed by the Waterwatch Australia Steering Committee to provide guidance and technical support to the Waterwatch community monitoring network throughout Australia.

Other than monitoring the health of a natural freshwater ecosystem, M-IBI can be used for monitoring the progress of restored or constructed ecosystems particularly for a renovated wetland like Diyawannawa Oya. The study carried out by Galbrand et al (2007) in a constructed wetland (The Burnside Drive landfill, which was located near the northern boundary of the Burnside Industrial Park) has revealed that aquatic macroinvertebrates monitoring is an excellent indicator of water quality for the wetland and studies showed that the water quality improvement was low in the treatment wetland in the initial stage. And yet, the constructed wetland is expected to improve with its maturation, superior micro-habitat and water quality improvement in future.

In Sri Lanka; basically, published research on diversity indices of benthic/ macroinvertebrate communities and use of macrobenthos as indicator organisms of environmental conditions are sparse in Sri Lanka (Dahanayaka, 2004).

An investigation has been carried out by Dahanayaka, D.D.G.L. in March 2003 to determine the spatial variation in the diversity of macrobenthos and also to determine how the distribution of macrobenthos in the Negambo Estuary is affected the environmental factors such as salinity, depth, organic matter content, soil texture, presence of sea grasses and presence of mangroves. It was also to find out whether the distribution of macrobenthos of the study area is affected by anthropogenic activities. The study has concluded that these macrobenthos can be used as bioindicators for lagoon ecosystems.

Another study was carried out by Weerasundara, Pathiratne and Costa (1999) on Species Composition and abundance of aquatic Oligochaetes in Ihalagama Reservoir, which is a shallow Perennial minor reservoir in Sri Lanka. The study has attempted to find the possibility of using Oligochaetes as bioindicators for organic pollutants.

A recent study carried out in Colombo – Sri Jayawardhanapura Canal System has attempted to find the possibility of using aquatic macroinvertebrates as bioindicators for stream health monitoring. It was revealed that there is a potential of using *Tubifex* spp, Freshwater shrimps and Damsel flies larvae as individual bioindicators for monitoring stream (wetland) health particularly for some parameters like DO, BOD and TDS (Perera, Wattavidanage and Nilakarawasam, 2011a).

During the study seven macroinvertebrate species/taxa such as 1.*Tubifex* spp., 2.*Lymnaea stagnalis*, 3.Dragonfly nymphs, 4.Chironomidae larva, 5.Horsefly larva, 6.Freshwater shrimps and 7.Damsel fly larvae were selected as candidate bioindicators. Among them *Lymnaea stagnalis* was recorded in 55 samples out of 68 total samples.

Figure 03 shows their distribution pattern and abundance within ten sampling stations. Kirimandala Mawatha station showed the highest overall density while Wellawatta and St. Sebastian stations showed lower values. According to the graph plotted below (Fig 01) it has realized that the most abundant bioindicator taxa out of the seven taxa was fresh water shrimps in Kotte, Nawala and Buthgamuwa, which also reported high Dissolved Oxygen (DO) levels but it has replaced by Chironomidae larva in Kirimandala Mw and Beira Lake. Also there was a remarkable increase of Conductivity and Cl^- concentration values but least density from Wellawatta station which was located closer to the sea.

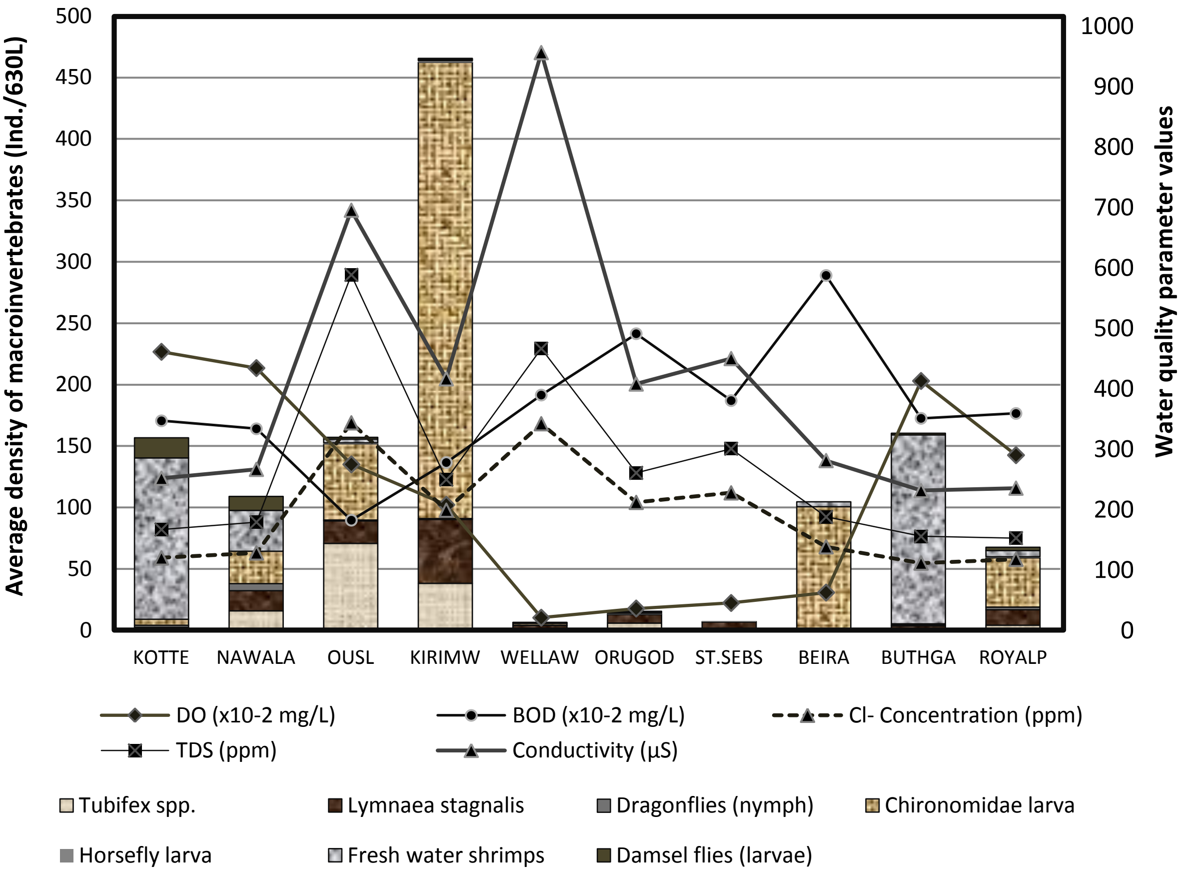

Figure 1: Distribution pattern and abundance of seven candidate bioindicator species/taxa and variation of some significant water quality parameters along ten sampling stations.

Pearson's correlation coefficient values (r) obtained for candidate bioindicator species/ taxa and some water quality parameters such as Dissolved Oxygen –DO (mg/L), Biochemical Oxygen Demand-BOD (mg/L), Cl^- concentration (ppm), Total Dissolved Solids - TDS (ppm) and Conductivity (µS) have given in table 01. They are most significant when considering the health of a stream or a wetland.

Table 1: Candidate bioindicator species/taxa, their number of occurrence, Hilsenhoff's tolerance values and Pearson's correlation coefficient values (r) between density values and some water quality parameters

	Candidate Indicator Species/ taxa	No. of Occurrence (out of 68 samples)	Tolerance value (Hilsenhoff)	r values obtained for parameters				
				DO	BOD	Cl^- concentration	Total Dissolved Solids (TDS)	Conductivity
1	*Tubifex spp.*	29	9	0.14	-0.72	0.52	0.64	0.34
2	*Lymnaea stagnalis*	55	6	0.10	-0.54	0.10	0.09	0.02
3	Dragonflies (nymph)	27	2	0.65	-0.21	-0.45	-0.37	-0.41
4	Chironomidae larva	34	8	-0.06	-0.23	0.01	-0.03	-0.04
5	Horsefly larva	15	10	-0.17	-0.44	0.22	0.20	0.05
6	Fresh water shrimps	38	6	0.72	-0.12	-0.52	-0.44	-0.45
7	Damsel flies (larvae)	33	6	0.73	-0.20	-0.44	-0.36	-0.38

As the next stage of the above mentioned study carried out in Colombo – Sri Jayawardhanapura a Macroinvertebrate – based multimetric Index of Biotic Integrity (M-IBI) has been developed by the same research team for the purpose of stream health monitoring.

As the final outcome, ten (10) out of forty one (41) candidate metrics were designated for the M-IBI development. The unitless scores obtained by each and every metric value ranges are given below in table 02.

Table 02: Scoring Criteria for the ten metrics used in Macroinvertebrates based Index of Biological Integrity (M-IBI)

Metrics	Predicted response to increasing stressors	M-IBI Score		
		5	3	1
Overall Species Richness	Decrease	>14.67	14.67 - 6.67	<6.67
No of Hemiptera Taxa	Decrease	>1.75	1.75 - 0.00	<0.00
No of Coleoptera Taxa	Decrease	>2.67	2.67 - 0.00	<0.00
No of Crustacea Taxa	Decrease	>2.25	2.25 - 0.25	<0.25
% of Diptera	Increase	<2.33%	2.33 - 51.79%	>51.79%
% of Odonata	Decrease	>2.04%	2.04 - 0.52%	<0.52%
No of Intolerant Taxa	Decrease	>1.25	1.25 - 0.50	<0.50
No of Collector - Gatherer Taxa	Decrease	>5.50	5.50 - 2.67	<2.67
Shannon-Wiener diversity index (H)	Decrease	>1.95	1.95 - 1.59	<1.59
Heterogeneity	Increase	<67.44%	67.44 - 87.77%	> 87.77%

Table 03 : M-IBI score ranges and corresponding narrative ratings

M-IBI Score	Stream condition (Narrative rating)
50 – 46	Excellent
38 – 45	Good
28 – 37	Fair
18 – 27	Poor
10 – 17	Very Poor

Then to interpret the score of a given site into standard status or the narrative rating, M-IBI scores were classed into five ranges (rating categories) as excellent, good, fair, poor and very poor as given in table 03.

To examine the validity of the index developed for the canal system, it has tested with a new independent data set obtained from ten sampling stations within the same study area in 2011. M-IMI scores and stream conditions obtained for the validation test done are shown in table 04. M-IBI scores were ranged from 17 to 40. Out of these 10 sites no any site was ranked as 'Excellent'. Site named as Royal Park was ranked as 'Good' while others were as 'Fair' for 6 sites (Nawala, OUSL Bridge, Kirimandala Mw., Torrington, Kotte Lake & Buthgamuwa), 'Poor' for the sites called Senanayake Ground (Kotte) and Kotte bridge, and "Very Poor" for Wellawatta. (Perera, Wattavidanage and Nilakarawasam, 2011c). Further these M-IBI scores were positively correlated (r = 0.578) with habitat parameter (DO values) recorded from the site and is known as a general environmental parameter to explain stream health or water quality.

Table 04 : M-IBI scores and narrative rating (stream condition) received for ten tested sites.

Tag No.	Site location	Canal name	M-IBI score	Stream condition (Narrative rating)
1	Senanayake Lane	Kotte canal	20	Poor
2	Nawala Road	Kotte canal	30	Fair
3	Narahenpita Rd - OUSL bridge	Kotte canal	36	Fair
4	Kirimandala Mawatha	Heen ela (canal)	32	Fair
5	Near St Peter's College	Wellawatta canal	17	Very Poor
6	Heen Marsh	Torington canal	28	Fair
7	Wetland restoration site	Kotte lake	28	Fair
8	Kotte bridge - near Lion's club	Kotte canal	18	Poor
9	Buthgamuwa - Kolonnawa Marsh	Kolonnawa canal	36	Fair
10	Heen Marsh - near Royal Park	Heen ela (canal)	40	Good

Metrics used in the index developed for Colombo – Sri Jayawardhanapura Canal System such as (1) overall species richness, (2) No of Hemipetera taxa, (3) No of Coleoptera taxa, (4) No of Crustacea taxa, (5) % of Diptera, (6) % Odonata, (7) No of intolerant taxa, (8) No of collector-gatherer taxa, (9) Shannon-wiener diversity index (H) and (10) Heterogeneity showed exceptionally strong discrimination between reference and degraded sites. Most of these metrics are universally accepted and widely in use for index development.

Table 05 shows a comparison of various merics used in 6 different locations for Benthic-invertebrates based Index of Biotic Integrity (B-IBI) / Macroinvertebrates based Index of Biotic Integrity (M-IBI) development in several other countries particularly in USA, Canada and Mexico. As per details given there, metrics that were used for Colombo - Sri Jayawardhanapura canal system such as; (1) Overall species richness, (7) No of intolerant taxa, (8) No of collector-gatherer taxa and (10) Heterogeneity have been used frequently. Remarkably, the metric called "No of intolerant taxa" has used five out of six IBI given there and for "overall species richness" it was four times.

Table 05 : Comparison of various metrics utilized for B-IBI / M-IBI developed in other regions of the world (USA, Canada and Mexico)

	Metrics	**M-IBI Colombo – Jaya.pura Canal system**	**B-IBI - Southeastern Minnesota**	**West-central Mexico**	**Okanagan Streams (5 metrics)**	**Maryland streams**	**Bulkley TSA B-IBI**	**M-IBI St. Croix River, Minnesota**
1	Overall Species Richness	✓	✓	✓	✓	✓	- -	- -
2	No of Hemiptera Taxa	✓	- -	- -	- -	- -	- -	- -
3	No of Coleoptera Taxa	✓	- -	- -	- -	- -	- -	- -
4	No of Crustacea Taxa	✓	- -	- -	- -	- -	- -	- -
5	% of Diptera	✓	- -	- -	- -	- -	- -	- -
6	% of Odonata	✓	- -	- -	- -	- -	- -	- -
7	No of Intolerant Taxa	✓	✓	- -	✓	✓	✓	✓
8	No Collector-Gatherer Taxa	✓	- -	✓	- -	- -	- -	✓
9	Shannon-Wiener index (H)	✓	- -	- -	- -	- -	- -	- -
10	Heterogeneity	✓	✓	- -	- -	- -	✓	✓
11	No Plecoptera Taxa	- -	✓	- -	✓	- -	✓	✓
12	No Ephemeroptera Taxa	- -	✓	- -	✓	✓	- -	✓
13	Avg No Clinger Taxa	- -	✓	- -	✓	- -	- -	- -
14	No Trichoptera Taxa	- -	✓	- -	- -	- -	✓	✓
15	No Chironomidae Taxa	- -	- -	- -	- -	- -	- -	✓
16	No POET Taxa	- -	- -	- -	- -	- -	- -	✓
17	% Tolerant Taxa	- -	- -	- -	- -	✓	- -	✓
18	No Clinger Taxa	- -	- -	- -	- -	- -	✓	✓
19	No Tanytarsini Taxa	- -	- -	- -	- -	- -	- -	✓
20	No Filterer Taxa	- -	✓	- -	- -	- -	- -	✓
21	% Amphipoda Taxa	- -	- -	- -	- -	- -	- -	✓
22	No of EPT taxa	- -	- -	- -	- -	✓	- -	- -
23	% Ephemeroptera	- -	- -	- -	- -	✓	- -	- -
24	% Tanytarsini of Chiron.	- -	- -	- -	- -	✓	- -	- -
25	Beck's Biotic Index	- -	- -	- -	- -	✓	- -	- -
26	No of scraper taxa	- -	- -	- -	- -	✓	- -	- -
27	% clingers	- -	- -	- -	- -	✓	- -	- -
28	No of Diptera taxa	- -	✓	- -	- -	✓	- -	- -
29	% collectors	- -	- -	- -	- -	✓	- -	- -
30	% EPT	- -	- -	✓	- -	- -	- -	- -
31	Hilsenhoff Biotic Index	- -	- -	✓	- -	- -	✓	- -
32	% Predator individuals	- -	✓	✓	- -	- -	- -	- -
33	% Gatherer taxa	- -	- -	✓	- -	- -	- -	- -
34	% Chironomidae inds	- -	- -	✓	- -	- -	- -	- -
35	% Plecoptera	- -	✓	- -	- -	- -	- -	- -
36	% Long-lived	- -	✓	- -	- -	- -	- -	- -
37	No Long-lived taxa	- -	✓	- -	- -	- -	- -	- -
38	No predator taxa	- -	✓	- -	- -	- -	- -	- -

However, as per Perera (2011) it was noted that some of the taxonomic groups that are common in those regions are not regular in a tropical country like Sri Lanka. Hence it clearly indicated that these indices are site specific; thus an accurate outcome can be obtained only using records belong to a canal system or stream with similar habitat characteristics.

Conclusions / Recommendations

This literature review has proven the ability of using Macroinvertebrates as bioindicators for stream or wetland health monitoring. Also it is understandable that it is already widely in used particularly in most of the states in America as well as Canada those are mainly connected with Great Lakes.

The study carried out by Perera, Wattavidanage and Nilakarawasam, (2011a) revealed the potential of using Tubifex spp, Freshwater shrimps and Damsel flies larvae as bioindicators for monitoring stream (wetland) health particularly for some parameters like DO, BOD and TDS. However, they have suggested that it would be more effective to use them collaboratively rather independently to give an overall view.

Meanwhile, the M-IBI developed by the same team for the same canal system has proven the potential of using it for biomonitoring and improving biotic integrity of streams/ wetlands.

Excluding monitoring the health of a natural freshwater ecosystem, M-IBI can be used for monitoring the progress of restored or constructed ecosystems particularly for a renovated wetland like Diyawannawa Oya and also for many other purposes like biodiversity conservation, habitat restoration and watershed management programmes.

The index developed for Colombo – Sri Jayawardhanapura Canal System may provide a valuable tool for government authorities and institutes engaged in water quality monitoring and maintenance as well as research groups and school-based educational programs. With appropriate training, citizens and students could use the index to obtain qualitative information on their local streams.

References:

1. Bennett, S. , and Kieran Rysavy. 2003. A benthic Invertebrate Index of biological Integrity for Stream in the Bulkley TSA (Filed Session 2002). Biologic Consulting Terrace, BC.
2. Blocksom, K.A. 2003. A Performance comparison of metric scoring methods for a multimetric index for Mix-Atlantic Highlands streams. Environmental Management vol. 31, no. 5.pp. 670-682.
3. Chirhart, J. 2003. Development of a Macroinvertebrate Index of Biological Integrity (MIBI) for Rivers and Streams of the St. Croix River Basin in Minnesota. Minnesota Pollution Control Agency, Biological Monitoring Program.
4. Dahanayaka, D. D. G. L., 2003. Some notes on macrobenthos in estuaries with an emphasis on macrobenthic community structure of Negambo estuary. Sri Lanka Naturalist, VI(03-04) :pp. 26-31.
5. Galbrand, C., Lemieux, A.E.G., Cote, R. and Verma, M., 2007. Assessment of Constructed Wetland Biological Integrity using Aquatic Macroinvertebrates. Biological Sciences [online], 7(2): 52-65.
6. Hodkinson, I.D., and Jackson, J.K. 2005. Terrestrial and Aquatic Invertebrates as Bioindicators for Environmental Monitoring, with Particular Reference to Mountain Ecosystems, Environmental Management Vol. 35, No. 5, pp. 649–666.

7. Invertebrates as indicators, 2008. Indicator species, Biological indicators of watershed health, USEPA, http://www.epa.gov/bioindicators/html/invertebrate.html [accessed on 5th Feb,2008].

8. Jensen, E.V. , 2006. Cumulative Effects Monitoring of Okanagan Streams using Benthic Invertebrates, 1999 to 2004. Environmental Protection Division, Ministry of Environment, Penticton, B.C.

9. Jensen, V. 2007. The biological Integrity of Okanagan Streams: Using Benthic Invertebrates to Monitor Stream Health in the Okanagan. Environmental Protection Program, Ministry of Environment, Penticton, BC.

10. Perera. L. G. R. Y. 2011. A Pilot Study on Macroinvertebrates as Bioindicators and Development of a Macroinvertebrate Based Index of Biotic Integrity (M-IBI) to Monitor Stream Health of Colombo – Sri Jayawardhanapura Canal System. MSc dissertation. Environmental Studies Unit, The Open University of Sri Lanka, Nawala, Nugegoda.

11. Perera, L.G.R.Y., Wattavidanage, J. and Nilakarawasam, N. 2011a. Diversity, Abundance and distribution of macroinvertebrates in Colombo canal system and the potential of using them as bioindicators for stream health monitoring. Annual Academic Sessions 2011-Open University of Sri Lanka. P. 262-265.

12. Perera, L. G. R. Y. , Wattavidanage, J. and Nilakarawasam, N., 2011c. Development of a Macroinvertebrate – based Index of Biotic Integrity (M-IBI) for Colombo-Sri Jayawardhanapura Canal System. Journal of Tropical Forestry and Environment. Accepted.

13. Stribling, J.B., Benjamin K. Jessup and Jeffrey S. White. 1998. Development of a Benthic Index of Biotic Integrity for Maryland Streams. Report no. CBWP-EA-98-3. Tetra Tech, Inc. Owings Mills, MD 21117 and Daniel Boward & Marty Hurd, Maryland Department of Natural Resources, Monitoring and Non-Tidal Assessment Division, Annapolis, MD.

14. Weerasundara, G.A., A. Pathiratne, and H. H. Costa, 1999. Species Composition and abundance of aquatic oligochaetes in Ihalagama Reservoir, a shallow perennial minor reservoir of Sri Lanka. Sri Lanka Journal of Aquatic Sciences 4: 61-67.

15. Viklund, A., 2011. Aquatic Macroinvertebrates [online]. Krisweb. Available from: http://www.krisweb.com/aqualife/insect.htm [last accessed 28 June 2011]

16. Weigel, B.M. , L.J. Henne and Luis M. Martinez-Rivera, 2002. Macroinvertebrate-based index of biotic integrity for protection of streams in West-Central Mexico. Journal of North American Benthological Society, 21(4) : 686-700.

17. Wittman, E. and Mundahl. N., 2002. Development and validation of a benthic index of biotic integrity (B-IBI) for streams in Southern Minnesota. Winona State University, Winona, MN 55987.