SHORT COMMUNICATION

Indicator Organisms of Environmental Conditions in a Lotic Waterbody in Sri Lanka

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Abstract

The species diversity and abundance of benthic invertebrates and some environmental parameters including dissolved oxygen level, BOD_5, COD, pH, temperature, salinity and turbidity of the Dutch canal in the Muthurajawela swamp in the west coast of Sri Lanka were monitored from December 1994 to June 1995. Dissolved oxygen level ranged from 0.2 mg l^{-1} to 9.9 mg l^{-1}. The pH, salinity and turbidity ranges were 6.0-7.4, 0-1.6 ppt and 2-35 ppm respectively. The ranges of the values for BOD_5 and COD were 0.01-0.91 mg l^{-1} and 1.2-5.6 mg l^{-1} respectively.

The species diversity was found to be low at low dissolved oxygen levels. The low abundance of the gastropod *Melanoides tuberculata* and the three oligochaete species namely *Nais raviensis*, *Dero zeylanica* and *Dero dorsalis* was observed to be indicative of low dissolved oxygen levels while high abundance of gastropod *Neritina perottetiana* indicated slight saline conditions less than 1.6 ppt. The high abundance of *Nais raviensis*, *Dero zeylanica* and *Dero dorsalis* was also indicative of slightly acidic pH conditions while low abundance of chironomid species indicated high turbidity.

Introduction

Benthic organisms are good indicators of past and present conditions of water and the composition of benthic communities is found to be closely related to environmental pollution. The dominant organisms in polluted freshwater environments are recorded to be oligochaetes and chironomids that are often capable of adapting to anaerobic conditions associated with organic pollution (Bruse et al. 1975).

Use of benthic invertebrates as indicator organisms has several advantages, mainly due to their limited mobility and small size (Weber 1973). However, there are some disadvantages too, i.e., most benthic organisms have stronger seasonal cycles in abundance and activities, and have short life cycles (Patrick 1975). Chemical and physical parameters of water including Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), dissolved oxygen content (DO), pH, temperature and turbidity are frequently used to determine the water quality to some extent (Lobe & Space 1993). Published research on diversity indices of benthic organisms and use of benthic fauna as indicator organisms of environmental conditions are sparse in Sri Lanka. Present study was carried out from December 1994 to June 1995 in the Dutch canal, a slow flowing lotic environment in the Muthurajawela swamp in the Western coastal region of Sri Lanka (6°59'N; 79°53'E) to investigate on the biodiversity of benthic macroinvertebrates and to determine the feasibility of using them as indicator organisms of environmental conditions.

Materials and Methods

Sampling of benthic invertebrates was carried out monthly at 5 sites along a 50 m stretch in the Dutch canal 300 m upstream of the point where it joins the Kelani River (Fig. 1). At the sampling area, this canal was 14 m in width. At each sampling site, pH, temperature, turbidity, dissolved oxygen content, salinity, BOD_5 and COD were measured once a month during the study period.

The temperature, pH and turbidity were measured using toss-in type water quality checker (Model WQC-2A) and salinity was measured using a salinity refractometer. Water samples were collected and preserved in the field for the determination of BOD_5, COD and dissolved oxygen level. COD was measured using 4 hour Permanganate Value test and BOD_5 was measured using the BOD test as described by Best & Ross (1977). Dissolved oxygen content was measured by the Winkler method.

Benthos at each site were collected using a Peterson grab. These samples were taken to the laboratory and were immediately subjected to wet sieving through 4 mm, 1 mm, 500 µm, and 125 µm mesh sieves. The organisms were then collected, preserved in 70% alcohol and identified as far as possible using the keys provided by Fernando (1990) and Brinkhurst & Jamieson (1971). The number of organisms in each species were counted and the Shannon-Wiener index (H') for each site was calculated. Statistical analysis of data was carried out using one way ANOVA and Pearson's correlation coefficient (Zar 1984).

Results

No significant differences were observed in the dissolved oxygen content, BOD_5, COD, pH temperature salinity and turbidity among the sampling sites. Therefore, for each month the values for a particular parameter at different sampling sites were pooled together and the mean value for the month was calculated. These values are given in Table 1. The ranges of these parameters are also given in Table 1. The lowest value for dissolved oxygen content was recorded in January and February while the highest value was recorded in June. The salinity values recorded in March were higher than those recorded in other months. Maximum surface water temperature, which was 31.2°C, was recorded in March and the lowest value, which was 26°C, was recorded in February. The highest pH value of 7.4 was recorded in March. In December and January, pH values were in the acidic range.

A total of 15 species of benthic invertebrates were recorded in the Dutch canal during the present study. Abundance of these animals in each month are given in Table 2. Gastropods, chironomids and oligochaetes were the most abundant groups. Four species of gastropods, namely *Melanoides tuberculata*, *Thiara acanthica*, *Faunas ater* and *Neritina perottetiana* and three species of oligochaetes, namely *Nais raviensis*, *Dero zeylanica* and *Dero dorsalis* were recorded in the samples. Larval stages of ceratopogonid, corethrid and culicine species were also found in the samples. Two species of chironomids and three species of oligochaetes could not be identified to the generic level. The abundance of the major invertebrate groups showed marked monthly variation being low in January and high in June (Table 2).

Values for correlation coefficients between the abundance of identified species of macrobenthos and some physico-chemical parameters are given in Table 3. The abundance of *Melanoides tuberculata*, *Nais raviensis*, *Dero zeylanica* and *Dero dorsalis* significantly increased with the dissolved oxygen content. Abundance of *Neritina perottetiana* significantly increased with salinity. Significant negative correlations were recorded for the abundance of *Nais raviensis*, *Dero zeylanica* and *Dero dorsalis* with pH and abundance of chironomids with turbidity. The abundance of *Melanoides tuberculata*, *Thiara acanthica* and *Neritina perottetiana* significantly increased with temperature.

Monthly values for Shannon-Wiener index calculated for each sampling site are shown in Table 4. Significant differences in Shannon-Wiener indices at different sites were not evident (P>0.05). Correlation coefficient between the physico-chemical parameters and Shannon-Wiener indices are given in Table 5. Shannon-Wiener index showed a significant positive correlation with dissolved oxygen content.

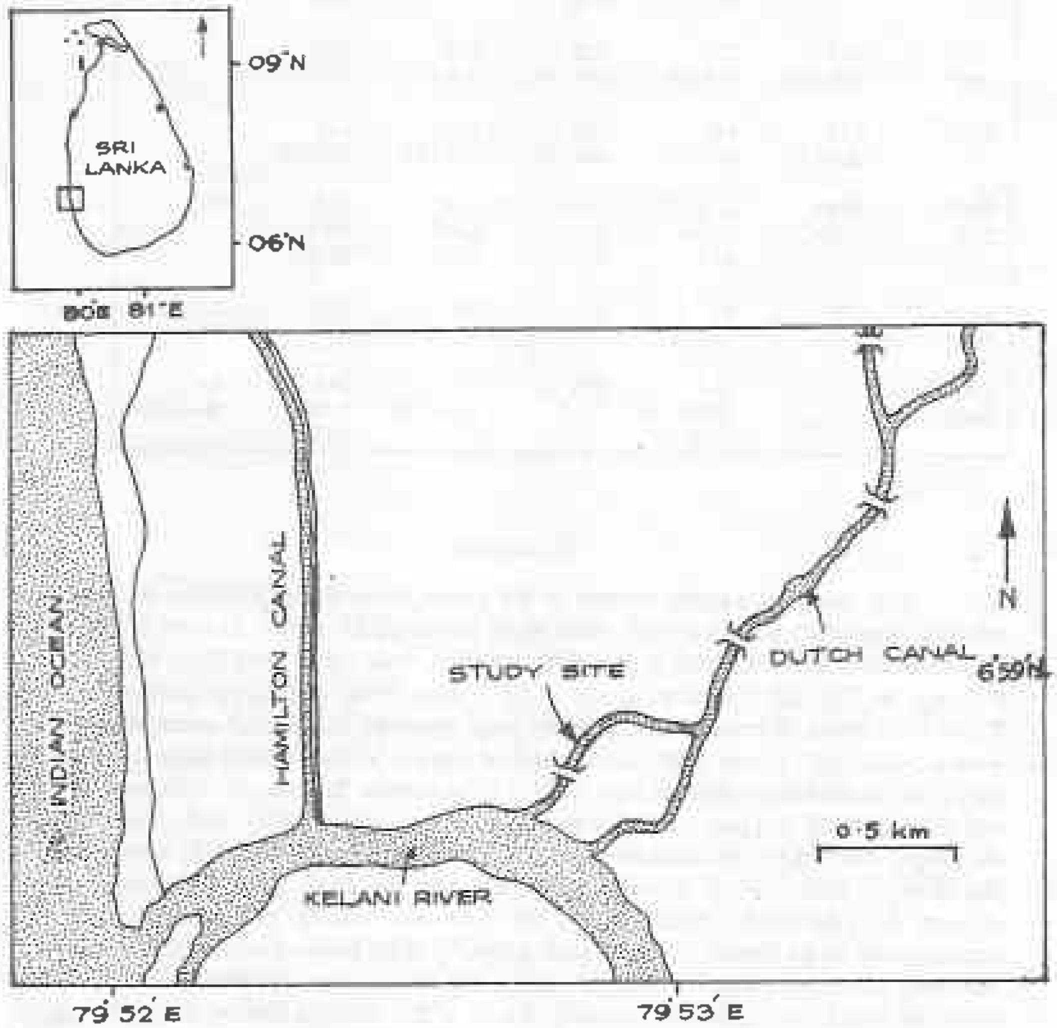

Fig. 1. Location of the study site.

Table 1. Monthly variations of the physico-chemical parameters in the Dutch canal. (The ranges of values are given parentheses)

Physico-chemical parameter	Month of Sampling					
	Dec 94	Jan 95	Feb 95	Mar 95	May 95	Jun 95
DO (mgl^{-1})	1.60 (1.44-2.02)	0.26 (0.2-0.3)	0.28 (0.2-0.35)	2.31 (1.58-3.5)	0.78 (0.5-1.0)	9.26 (8.6-9.9)
BOD_5 (mgl^{-1})		0.27 (0.01-0.97)	0.17 (0.03-0.39)	0.32 (0.01-0.9)	0.03 (0.01-0.06)	0.25 (0.14-0.4)
COD (mgl^{-1})	2.68 (2.0-2.72)	3.32 (1.2-5.6)	2.28 (2.0-2.8)	2.72 (1.8-3.2)	3.04 (2.8-3.4)	
pH	6.16 (6.0-6.4)	6.42 (6.3-6.6)	7.06 (6.9-7.3)	7.24 (7.1-7.4)	6.74 (6.7-6.9)	
Temp (°C)	27.1 (27.0-27.5)	27.2 (27.0-27.5)	28.4 (26.0-29.0)	30.9 (30.7-31.2)	29.1 (29.0-29.5)	29.0
Salinity (ppt)	0.0	0.1	0.8	1.6	0.0	0.1
Turbidity (ppm)		15.0 (10.0-19.0)	15.2 (12.0-17.0)	9.0 (8.0-11.0)	21.4 (15.0-35.0)	8.4 (2.0-11.0)

Discussion

The dissolved oxygen content in the Dutch canal from December to May was relatively low when compared with other water bodies of Sri Lanka. In most of the lentic environments in Sri Lanka such as perennial reservoirs, these values were found to range from 6.33 mgl^{-1} to 10.5 mgl^{-1} (Amarasingha et al. 1983; Silva 1996). In lotic environments such as Kelani river, about 10 km upstream from the point where the Dutch canal opens, these values were 3.5-13.2 mgl^{-1} (Anon 1995). Low dissolved oxygen levels recorded from December to May could be related to relatively high COD in these months. In June, the COD was very low and the dissolved oxygen content was found to be comparatively high. The effluents discharged into Dutch canal from the nearby factories may have been partially responsible for this relatively high COD. It should be noted however, that at the point of discharge of the effluents from the nearby textile factory, the COD value was far below the standard level recommended by the Central Environmental Authority of Sri Lanka; eventhough this may have drastically affected the dissolved oxygen level in this environment. The Muthurajawela swamp where the Dutch canal is located, consists of soils with 1-7% iron content and 2-6% sulphur content mostly occurring as iron pyrite (Samarakoon & van Zon 1991). Therefore, oxidation of Fe^{+2} and S^{-2} ions in soil may also have significantly contributed to high COD.

In February and March, the salinity values were found to be significantly higher than in other months. It may possibly be due to high evaporation occurred in these months in which the rainfall is usually very low. Further, in these months, due to low rainfall, salinity in the lower reaches of the Kalani river also increases (Anon. 1995). Since Dutch canal is connected to the Kelani river, this may also have contributed for high salinity in these months. Salinity values were found to be low in December, January, May and June. Surface runoff caused by relatively high rainfall resulted due to intermonsoonal and south-west monsoonal rains may have contributed to these low values. The low pH values recorded in these months may also be due to mixing of canal water with rain water.

Table 2. Mean abundance of different species of benthic invertebrates in the Dutch canal (No./m^2).

Species	Dec	Jan	Feb	Mar	May	June
Gastropods						
Melanoides tuberculata	282.4 (118-588)	176.4 (0-294)	270.8 (118-471)	623.6 (59-1176)	600 (118-1235)	764.6 (529-941)
Thiara acanthica	200 (59-412)	141.2 (0-529)	164.8 (0-588)	694 (118-1588)	211.6 (0-588)	541.2 (59-1118)
Faunas ater	23.6 (0-59)	11.8 (0-59)	35.4 (0-118)	11.8 (0-59)	0	0
Neritina perottetiana	0	0	0	223.4 (59-588)	0	0
Insect larvae						
Chironomid spp. C_1	882.4 (118-2471)	59 (0-118)	176.6 (59-471)	152.8 (59-235)	59	317.6 (235-412)
Chironomid spp. C_2	329.4 (0-882)	23.6 (0-59)	47 (0-176)	35.4 (0-59)	0	129.4 (59-176)
Ceratopogo-nid spp	94 (0-235)	0	23.6 (0-118)	11.8 (0-59)	0	0
Corethrid spp.	82.4 (0-176)	0	35.2 (0-176)	0	0	0
Culicine spp.	23.6 (0-59)	0	23.6 (0-59)	0	0	0
Oligochaetes						
Nais raviensis	329.6 (118-471)	0	0	94.4 (59-118)	94.4 (0-118)	3670.6 (3059-4294
Dero zeylanica	317.8 (59-471)	0	0	23.6 (0-59)	59 (0-118)	315.3 (2412-3706
Dero dorsalis	270.6 (118-412)	0	0	11.8 (0-59)	0	823.4 (588-1235)
Hermithid sp.	0	0	0	11.8 (0-59)	0	0
Unidentified sp. X_1	0	0	0	0	0	223.4 (118-353)
Unidentified sp. X_2	0	0	0	0	0	176.6 (59-471)

Table 3. Correlation coefficients between physico-chemical parameters and abundance of benthic invetebrates in the Dutch canal.

Species	Physico-chemical parameters						
	DO	Salinity	pH	Turbidity	Temperature	BOD_5	COD
Melanoides tuberculata	0.42*	0.10	0.25	-0.38	0.44*	-0.14	-0.05
Thiara acanthica	0.30	0.33	0.32	-0.39	0.44*	0.04	-0.08
Faunas ater	-0.21	0.12	-0.01	0.01	-0.05	-0.13	-0.01
Neritina perottetiana	-0.04	0.64*	0.39	-0.29	0.55*	0.23	-0.03
Chironomid spp.	0.09	-0.19	-0.33	-0.45*	-0.23	0.10	-0.21
Ceratopogonid spp.	-0.02	-0.12	-0.39	-0.17	-0.25	0.02	-0.09
Corethrid spp.	-0.16	-0.13	-0.35	0.07	-0.26	-0.06	-0.04
Culicine spp.	-0.19	-0.02	-0.13	0.13	-0.11	0.15	-0.25
Nais raviensis	0.96*	-0.28	-0.51*	-0.40	0.11	0.06	-0.08
Dero zeylanica	0.95*	-0.29	-0.62*	-0.39	0.08	0.06	-0.07
Dero dorsalis	0.89*	-0.34	-0.57*	-0.39	-0.03	0.11	-0.15

Table 4. Monthly values for Shannon-Wiener index (H') (base 10) at each sampling site.

Month of sampling	Site number					Mean
	Site 1	Site 2	Site 3	Site 4	Site 5	
12/94	0.85	0.62	0.71	0.93	0.86	0.89
01/95	0.39	0.45	0.45	0.36	0.22	0.55
02/95	0.38	0.50	0.80	0.30	0.39	0.74
03/95	0.65	0.58	0.79	0.76	0.57	0.69
05/95	0.46	0.40	0.49	0.47	0.59	0.51
06/95	0.70	0.72	0.68	0.74	0.69	0.71

Table 5. Correlation coefficients between physico-chemical parameters and Shannon-Wiener index. * Significant at 5% level

Physico-chemical parameter	DO	BOD_5	COD	Temperature	Salinity	Turbidity	pH
Correlation coefficients	0.45*	0.19	-0.18	0.13	0.06	-0.35	-0.16

These variations in physico-chemical parameters may have contributed significantly to the variation of abundance and species diversity of benthic invertebrates in the Dutch canal. The gastropods *Melanoides tuberculata* and *Thiara acanthica* are present in large numbers in the Dutch canal probably due to high abundance of decaying plant matter and mud as recorded in other freshwater environments in Sri Lanka by Fernando (1990).

The Chironomids were the most abundant group of the insect larvae in the benthic environment of Dutch canal. They can tolerate low oxygen concentrations due to presence of a form of haemoglobin that can bind oxygen at low concentrations (Jonasson & Kristiansen 1967). Lemly (1982) has shown that pH values of 6 or slightly below can cause significant reductions in the survival of most stream insects. The pH level of above 6.6 may have been one of the reasons for high abundance of aquatic insects in the Dutch canal. Further, chironomids are recorded to be capable of tolerating pH levels above 8.5 too (de Smet 1982). High abundance of oligochaetes in the Dutch canal may be attributed to muddy substrate with high amount of organic matter as recorded by Maher (1984) in the benthic habitats in south-western New South Wales.

Most freshwater animals in Sri Lanka are found to spawn during or after floods (Fernando 1990). The study area is also subjected to floods in April - May after heavy intermonsoonal rains. Therefore, the significant increase in most benthic organisms in June may possibly be due to increase in the number of offspring after the spawning of adults in April - May.

Many species of benthic organisms are used as indicators of environmental conditions. Presence of certain species as well as absence of some others indicate aquatic pollution (Lobe & Space 1993; New 1995). Most chironomid species can survive in low dissolved oxygen levels (Hart & Fuller 1974). Therefore, high abundance of chironomids is used as an indicator of low dissolved oxygen levels (de Smet 1982). However, in the present study no significant correlation was observed between the abundance of chironomids and dissolved oxygen content. Therefore, in addition to dissolved oxygen content a complex of factors may be acting together in determining their abundance. However, turbidity was found to have a significant negative, effect on the abundance of chironomids. Therefore, it may be possible that the abundance of chironomids is negatively correlated with dissolved oxygen content only in unturbid clean waters.

Although benthic organisms are rare in heavily organically polluted waters (Pearson & Rosenberg 1978), oligochaetes are generally dominant species in organically polluted water (Hart & Fuller 1974). Therefore, they are frequently used in field surveys as indicators of organic pollution (Bruse et al. 1975; Lobe & Space 1993). In the present study, however, significant positive correlations were recorded between the abundance of *Melanoides tuberculata*, *Nais raviensis*, *Dero zeylanica* and *Dero dorsalis* and dissolved oxygen level. Therefore, low abundance or absence of these species in a certain habitat may indicate low dissolved oxygen levels. Since the absence of clean water species is considered to be a better indication of environmental condition than the presence of tolerant ones (Hart & Fuller 1974), absence of these species in the water bodies in this region may be used as an indicator of low oxygen levels. Abundance of *Neritina perottetiana* was positively correlated with salinity. However, since salinity in the Dutch canal varied within a very narrow range, it may not be prudent to conclude that *Neritina perottetiana* can be used as an indicator organism of salinity.

Significant negative correlations were recorded for the abundance of *Nais raviensis*, *Dero zeylanica* and *Dero dorsalis* with pH. However, the pH levels recorded in the present study are within the optimum range for most aquatic organisms and therefore, with the present results, it is difficult to come into definite conclusions on the indicator organisms of pH levels.

The abundance of *Melanoides tuberculata* and *Thiara acanthica* were found to increase significantly with increasing temperature (Table 3). However, the temperature in the study site during the period of investigation varied between 26.0°C and 31.2°C, which is within the optimum range of tolerance for most of the tropical animals. It may not be prudent therefore, to conclude on indicator organisms of water temperature in this habitat.

No significant correlation was recorded for the abundance of any species with BOD_5 and COD. This may be mainly due to the very small variation of these parameters in the study site.

High values for Shannon-Wiener index indicate high species diversities. In January, February and March, the values for Shannon-Wiener index are lower than those for other months. This indicates that the species diversity of benthic macroinvertebrates in the Dutch canal is lower in January, February and March than in other months. Slight seasonal variations in the abundance of benthic invertebrates coupled with their shorter life spans may be the reason for such variations. A significant positive correlation between dissolved oxygen content and Shannon-Wiener index was observed during the present study. Therefore, it appears that the values for Shannon-Wiener index can be used as an indicator of dissolved oxygen levels in some environments such as the Dutch canal of Sri Lanka.

It should be noted that the present findings are based on a study carried out over a period of seven months. Further studies, possibly extending over a period of one year should be carried out to confirm these findings.

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