Pertanika J. Trop. Agric. Sci. 26(2): 139 - 146 (2003)

ISSN: 1511-3701

Species Diversity of Macrobenthic Invertebrates in the Semenyih River, Selangor, Peninsular Malaysia

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Keywords: Macrobenthic invertebrates, Semenyih River, Peninsular Malaysia

ABSTRAK

Kajian ini dijalankan di sebuah sungai di Semenanjung Malaysia, Sungai Semenyih. Sungai ini menyokong pelbagai makrobentik invertebrata di mana stesyen yang berada di hulu sungai didominasi oleh Crustacea, Ephemeroptera, Odonata, Gastropoda, Trichoptera, Coleoptera dan Diptera sementara Hirudinea and Oligocheata adalah organisma-organisma bentik yang mendominasi stesyen di hilir sungai ini. Species-species 'caddisfly' seperti Microstenum similior *dan* Amphipsyche meridiana *didapati berpotensi menjadi penunjuk biologi kepada ekosistem yang bersih. Cacing yang berketahanan tinggi,* Limnodrilus hoffmeisteri, *ditemui sebagai species yang berdominasi di bahagian hilir sungai ini dan dianggap sebagai penunjuk biologi kepada ekosistem yang tercemar. Spesies diversiti yang rendah dan kewujudan spesies yang berketahanan tinggi menunjukkan bahawa hilir sungai ini telah tercemar disebabkan oleh degradasi kualiti air. Dengan pertambahan penduduk yang pesat, perindustrian and aktiviti pertanian di Malaysia telah menyebabkan masalah serius kepada kualiti air di kebanyakan sungai, makrobentik invertebrata yang ditemui di sepanjang sungai-sungai boleh digunakan sebagai penunjuk biologi kepada pengaruh ekotosikologi oleh pencemaran sungai di Malaysia.*

ABSTRACT

This study was carried out on one of the rivers in Peninsular Malaysia, the Semenyih River. The river supported diverse macrobenthic invertebrates in which the upstream sampling stations were dominated by Crustacea, Ephemeroptera, Odonata, Gastropoda, Trichoptera, Coleoptera and Diptera while Hirudinea and Oligocheata were the benthic organisms found predominant at downstream stations. Some caddisfly species such as Microstenum similior *and* Amphipsyche meridiana *were found to be potential bioindicators for a clean ecosystem. The resistant worm,* Limnodrilus hoffmeisteri, *was found to be the most dominant species at the downstream of the river and is considered a potential bioindicator for a polluted ecosystem. Low species diversity and occurrence of resistant worm species indicated that the downstream of the river deteriorated due to water quality degradation. As rapid increases in population growth, industrialization and agricultural activities in Malaysia have caused serious problems to the water quality of many rivers, the macrobenthic invertebrates found along the rivers can be used as bioindicators of the ecotoxicological effects of river pollution in Malaysia.*

INTRODUCTION

In recent years, numerous publications have critically reviewed the use of macrobenthic invertebrates as bioindicators as well as the appropriateness and shortcomings of certain indices. Macrobenthic invertebrates have been much used for biological monitoring of environmental quality in aquatic ecosystems in Europe and North America (Hellawell 1986; Metcalfe 1989; Rosenberg and Resh 1993; Pinel-Alloul *et al.* 1996). They have sedentary lifestyles that reflect local sediment conditions, life spans that integrate contaminant impacts over time, they live in the sediment and water interface where contaminants accumulate, and most importantly they show differential levels of tolerance to contaminants (Dauer 1993). Since changes in taxonomic richness and composition of macrobenthic invertebrates were considered sensitive tools for detecting alterations in aquatic ecosystems (Pinder *et al.* 1987), methods based on indicator species have been developed. Most of the indices based on the presence-absence of pollution scored taxa focussed on the detection of organic pollution (Hilsenhoff 1987, 1988). Later, assessment of macrobenthic community structure was used as a measure of contamination by organic matter and pollutants (Jones *et al.* 1981; Johnson and Wiederholm 1989).

In Malaysia, the use of macrobenthic invertebrates in the study of river pollution has not been practised because the Department of the Environment (DOE 2001) has not included this methodology for the river pollution studies. For the year 2000 (DOE 2001), there were 34 river basins (28.3%) found to be clean, 71 (61.7%) were slightly polluted and 12 (10%) were polluted. These classifications were based on a river water quality index (WQI) which focussed on six parameters (ammoniacal nitrogen (NH_3-N), biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), pH and suspended solids). This paper provides a list of macrobenthic invertebrates found in Semenyih River in Peninsular Malaysia which could be used to assess water quality.

MATERIALS AND METHODS

Study Area and Sampling

This study, which was carried out in June 1997 during the dry season, covered the riverine system of the Semenyih River in the district of Ulu Langat, Selangor, Peninsular Malaysia (*Figure 1*). The depth of the river ranged from 0.15 to 0.33 m. The Semenyih River (2° 54' N to 3° N and 101° 48'E to 101° 53'E) is a tributary of the Langat River. The Semenyih Dam, across the Semenyih River, is one of the major sources of water supply for the densely populated Klang Valley. Seven sampling stations were established (*Fig. 1*). The substrata of stations 1 to 3 consisted mostly of cobbles or pebbles and a modified

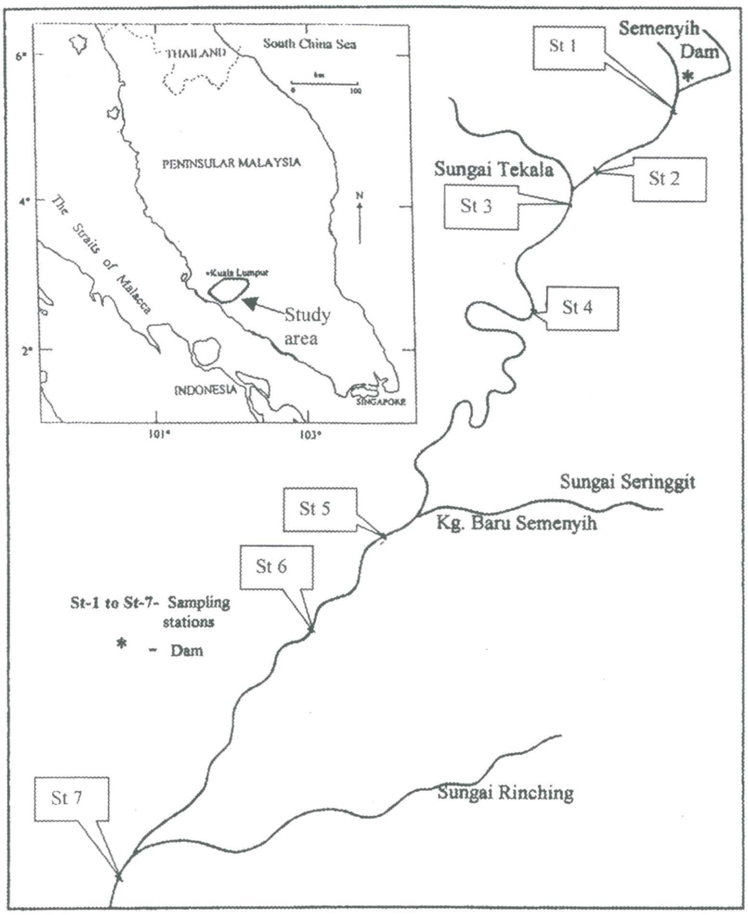

Fig. 1: Sampling stations of macrobenthic invertebrates from Semenyih River

Surber sampler (1256.8 cm^2) was used at these two sites. The bottom of Station 4 consisted mainly of sand while Stations 5 to 7 were characterized by silt or muddy sand, where a PVC tube (10.19 cm^2) was used for sampling in these stations. Three sites were located at each sampling station. At each sampling site, three replicates were sampled. Thus, a total of 63 samples were collected for this study.

Storage and Identification of Macrobenthic Invertebrates

The samples collected were sieved using an 80 mm mesh. After field collection, the samples were put into polyethylene bottles and preserved with 80% alcohol. In the laboratory, the macrobenthic invertebrates were sorted, enumerated and identified to the lowest possible taxon. The keys used were Gloyd and Wright (1966), Brinkhurst and Jamieson (1971), Merritt and Cummins (1978), Pennak (1978), McCafferty (1981), Scott (1983) and Ismail (1993). Data on individuals per taxon were used to calculate various biological parameters.

A biotic index, the Biological Monitoring Working Party (BMWP) system (Armitage *et al.* 1983) which depends on family level identification, was employed for pollution assessment. By using this system, families of macrobenthic invertebrates were allocated scores in the range of 1 (tolerant) to 10 (intolerant) according to their tolerance to organic pollution and the scores of all the families present were then summed up to obtain the BMWP score (Wright *et al.* 1993).

Statistical Analysis

Simple statistical analyses were done by using the Statistical Analysis System Version 6.0 (SAS 1987). At each station, parameters such as density (numbers/m^2), number of species (R0), Margalef's species richness index (R1), Menhinick's species richness index (R2), Shannon's diversity index (H'), Hill's diversity index (N1) and Hill's evenness index (E4) and Alatalo's evenness index (E5) (Ludwig and Reynolds 1988), were calculated using a statistical software that had been exclusively programmed in SAS by Rashid *et al.* (1998) to use count data (Ludwig and Reynolds 1988), that is, the number of individuals (N) of each species and the total number of individuals sampled.

RESULTS AND DISCUSSION

Density and Distribution of Macrobenthic Invertebrates

The densities of macrobenthos are shown in Table 1. High diversities were observed at upstream stations (Stations 1 to 3), but at downstream stations (Stations 4 to 7) the populations were characterized by the sand-bottomed substratum (Station 4) and the anoxic conditions of silt or mud (Stations 6 and 7) and only one or two species could survive (Thorne and Williams 1997). Station 7 was found to have only one single species, namely *Limnodrilus hoffmeisteri* (Oligochaeta) and this worm species is known to be able to tolerate unfavourable conditions such as low dissolved oxygen and high pollutant concentrations (Brinkhurst and Kennedy 1965; Brinkhurst 1967). For example, a high density of oligochaetes is a good indication of organic pollution (Slepukhina 1984; Lang 1985). Therefore, *L. hoffmeisteri* is a potential bioindicator for the polluted ecosystem of the river. On the other hand, clean areas with cobbles and pebbles were the major substrata composition at the upstream sampling stations (Stations 1 to 3) and Station 2 was recorded to have the highest number of species (R0= 18). Among the caddisfly species found, *Microstenum similior* and *Amphipsyche meridiana* were found to be potential bioindicators for the clean ecosystem since they could be found at the clean upstream stations (Stations 1 to 3) of Semenyih River. At the sandy substratum of Station 4, it was only dominated by a single bivalve species, *Corbicula javanica.*

Of all the taxa recorded, Hirudinea and Oligocheata were the organisms found predominately at downstream stations (Stations 5 to 7) with *L. hoffmeisteri* being the most abundant species. On the other hand, the other taxa (Crustacea, Ephemeroptera, Odonata, Gastropoda, Trichoptera, Coleoptera and Diptera) were recorded mainly at upstream sampling stations with Baetidae and *Filopaludina martensi martensi* showing the least number of individuals at Station 1. These species, although low in density, were still of importance in contributing toward the species richness. The taxa Leptophlebiidae, *Hydropsyche annulata, Polymorphanisus* species and Tipulidae were only found at Station 3. This occurrence might be due to drift from the Tekala River (*Fig. 1*) which

TABLE 1
Densities (numbers/m^2 ± standard error; N= 3) of macrobenthos in the 7 stations of the Semenyih River, Selangor, Peninsular Malaysia. St: Sampling station; NF= Not found

Taxa	St-1	St-2	St-3	St-4	St-5	St-6	St-7
Hirudinea							
Piscicola sp.	NF	15.91 ± 7.96	NF	NF	654 ± 327	NF	NF
Batrachobdella sp.	NF	5.30 ± 2.65	NF	NF	3598 ± 865	3598 ± 865	NF
Oligochaeta							
Limnodrilus hoffmeisteri	NF	NF	NF	NF	13413 ± 865	70985 ± 5675.3	30095 ± 3980
L. hoffmeisteri (Juvenile)	NF	NF	NF	NF	9814 ± 1499	109910 ± 4840.9	21263 ± 2852
Crustacea							
Penaeus sp.	5.30 ± 2.65	NF	NF	NF	NF	NF	NF
Ephemeroptera							
Caenidae	15.9 ± 4.60	5.30 ± 2.65	47.7 ± 9.19	NF	NF	NF	NF
Baetidae	2.65 ± 2.65	NF	61.0 ± 16.1	NF	NF	NF	NF
Heptageniidae	15.9 ± 4.60	5.30 ± 2.65	39.8 ± 4.59	NF	NF	NF	NF
Leptophlebiidae	NF	NF	5.30 ± 2.65	NF	NF	NF	NF
Odonata							
Leucorrhinia sp.	5.30 ± 2.65	13.3 ± 2.65	2.65 ± 2.65	NF	NF	NF	NF
Ophiogomphus sp.	NF	5.30 ± 2.65	5.30 ± 2.65	NF	NF	NF	NF
Gastropoda							
Filopaludina martensi martensi	2.65 ± 2.65	5.30 ± 2.65	NF	NF	NF	NF	NF
Melanoides turberculata	NF	5.30 ± 2.65	NF	NF	NF	NF	NF
Bivalvia							
Corbicula javanica	42.4 ± 7.02	21.2 ± 7.02	NF	1636 ± 327	NF	NF	NF
Trichoptera							
Macrostemum similior	1172 ± 375	504 ± 44.1	66.3 ± 11.6	NF	NF	NF	NF
Amphipsyche meridiana	76.9 ± 29.9	7.96 ± 4.59	NF	NF	NF	NF	NF
Hydropsyche annulata	NF	NF	10.6 ± 2.65	NF	NF	NF	NF
Polymorphanisus sp.	NF	NF	101 ± 37.1	NF	NF	NF	NF
Beraeidae	66.3 ± 7.02	39.8 ± 4.59	NF	NF	NF	NF	NF
Polycentropodidae	82.2 ± 29.9	7.96 ± 4.59	5.30 ± 2.65	NF	NF	NF	NF
Coleoptera							
Limnebiidae	5.30 ± 2.65	NF	NF	NF	NF	NF	NF
Diptera							
Tipulidae	NF	NF	34.5 ± 7.02	NF	NF	NF	NF
Simuliidae	39.8 ± 12.2	7.96 ± 4.59	NF	NF	NF	NF	NF
Chironomidae							
Pentaneura sp.	519.8 ± 78.3	286 ± 41.3	196 ± 45.3	NF	NF	NF	NF
Parachironomus sp.	3846 ± 987	1578 ± 636	321 ± 38.5	NF	NF	NF	NF
Ceratopogonidae	13.3 ± 5.30	13.3 ± 2.65	18.6 ± 7.02	NF	NF	NF	NF
Empididae	5.30 ± 2.65	5.30 ± 2.65	NF	NF	NF	NF	NF

was believed to have very high species richness due to its pristine condition.

Diversity Indices

The results of species richness, diversity and evenness indices of the macrobenthic invertebrates found in the Semenyih River are shown in Table 2. Diversity indices give better information about the environmental conditions under which the organisms live (Gaufin 1973; Hawkes 1979; Teles 1994) than a consideration of individual taxa alone.

A detailed analysis of the species richness in the macrobenthic communities at several sampling stations along the Semenyih River has led us to consider the factors responsible for the establishment and maintenance of the macrobenthic community structure in the river.

TABLE 2
Species richness, diversity and evenness indices for macrobenthic invertebrates found in the Semenyih River. St: Sampling station

Indices	St-1	St-2	St-3	St-4	St-5	St-6	St-7	Overall
Number of individuals (N)	17,848	7,640	2,760	4,905	82,404	544,455	154,017	814,029
Number of species (R0)	17	18	14	1	4	3	2	27
Richness								
Margalef (R1)	1.63	1.90	1.64	0.00	0.27	0.15	0.08	1.91
Menhinick (R2)	0.13	0.21	0.27	0.014	0.014	0.004	0.005	0.03
Diversity								
Shannon (*H'*)	1.13	1.20	1.96	0.00	1.07	0.69	0.68	0.98
Hill (N1)	3.09	3.32	7.12	1.00	2.92	1.99	1.97	2.66
Evenness								
Hill (E4)	0.69	0.68	0.71	1.00	0.90	0.96	0.99	0.84
Alatalo (E5)	0.54	0.55	0.67	1	0.84	0.93	0.97	0.74
Biotic								
BMWP	72	75	66	0	5	5	1	
Status	(good)	(good)	(good)	(poor)	(poor)	(poor)	(poor)	

Types of substrata and pollution levels are two important factors that determine the distribution of macrobenthic invertebrates found in Semenyih River.

The richness indices (R1 and R2) varied differently with numbers of species and numbers of individuals. The Margalef's species richness index (R1) values were higher at the upstream (Stations 1 to 3) (R1= 1.63-1.90) than those (R1= 0.00-0.27) at the downstream (Stations 4 to 7). Similarly, Menhinick's species richness indices (R2) show higher values (R2= 0.13-0.27) at the upstream (Stations 1 to 3) than those (R2= 0.004-0.014) at the downstream (Stations 4 to 7). Although these richness values computed here are for illustrative purposes (Ludwig and Reynolds 1988) we can conclude that species richness generally declined from the upstream to the downstream stations.

The diversity indices are suitable for addressing any question that a heterogeneity index can answer (Peet 1974). These indices showed higher values of Shannon's diversity index (H'= 1.13-1.96) and Hill's diversity index (N1= 3.09-7.12) at the upstream (Stations 1 to 3) than those (H'= 0-1.07; N1= 1.00-2.92) at the downstream (Stations 4 to 7). These numbers indicate an increase in dominance of fewer species especially at the downstream stations.

For the evenness indices, the highest values were found at Station 4 since there was only one species found at all three sites of this station. The lowest values are computed for the upstream stations. For instance, lower values of Hill's evenness index (E4= 0.68-0.71) and Alatalo's evenness index (E5= 0.54-0.67) were found at upstream (Stations 1 to 3) than those (E4= 0.96-1.00; E5= 0.84-1.00) at the downstream (Stations 4 to 7). This indicates the evenness indices (E4 and E5) increased from the upstream to the downstream stations. The lower values of E4 and E5 at the upstream Station 1 seemed to be related to the co-dominance by two species out of the 17 present and their numbers of individuals were very high (1,172 and 3,846) when compared to the remaining 15 species (Tables 1 and 2). As for Station 7, E4 and E5 values were 0.99 and 0.97, respectively. At this station, only one species of Oligochaeta was found. As both the juvenile and adult worms were considered as *L. hoffmeisteri*, the sampling site thus was dominated by a single worm species. When all species in a sample were equally abundant, it seems reasonable that an evenness index should be maximum and this value decreases toward zero as the relative density of the species diverges away from evenness (Ludwig and Reynolds 1988). In addition, conditions of unstable substrata at downstream stations could be a contributing factor to the low species richness of the river ecosystem.

Another important characteristic of ecological communities is the spatial heterogeneity (Allen 1984) of macrobenthic invertebrates-namely random, clumped and uniform (Rosenberg and Resh 1993). The preferences of macrobenthic invertebrates to aggregate in the more favourable parts of the river substrata had caused their distributions to be clumped. Furthermore, nature is multifactorial (Quinn and Dunham 1983) in which many interacting processes, both biotic and abiotic, may contribute to the existence of the pattern. Hewitt *et al.* (1997) revealed that macrobenthic invertebrates in a dynamic estuarine system exhibited stability of spatial pattern, even when they were undergoing movement and changes in mean density. The distribution of the macrobenthic invertebrates in the Semenyih River could possibly remain in the clumped pattern for a period of time unless the river is disturbed by natural and anthropogenic activities.

Based on the scores of BMWP, the three stations located at the upstream (Stations 1 to 3) were found to be 'good' status (66-75) while the stations found located at the downstream (Stations 4 to 7) had 'poor' status (0-5), as shown in Table 2. This is in agreement with the report by DOE (2001) that rivers in Malaysia were generally clean at the upstream while those located at the downstream were either slightly polluted or polluted due to urban wastes and agricultural activities. This has strengthened our ecotoxicological point of view that pollution level rather than types of substrate contributed to the distribution of macrobenthic invertebrates in Semenyih River.

CONCLUSION

The present study established a list of macrobenthic invertebrates in a typical river in Malaysia. The collection for certain macrobenthic species present particularly in polluted and non-polluted parts of a river indicated that they could be used as good bioindicators for river pollution studies. Since information on the life histories of macrobenthic invertebrates from Malaysia is lacking, our list of macrobenthic invertebrates found in the Semenyih River is useful and more taxonomic work should be done for the identification of the organisms at the generic level. Future studies should also include the physico-chemical parameters of rivers and relate them to the macrobenthic invertebrate data.

ACKNOWLEDGEMENTS

The authors wish to thank laboratory assistant Mr. Sharom Khatim for his help during field sampling and Mr. Mansor Rashid for his help with the statistical analysis.

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(Received: 11 January 2003)
(Accepted: 8 July 2003)