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A Preliminary Classification of Langkawi Island Streams Using Biotic Index Criteria

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ABSTRACT The benthic macroinvertebrate community of ten running-water sites in Langkawi Island was investigated for its potential as a water quality indicator. The structure metrics measured were total taxa richness, Ephemeroptera-Plecoptera-Trichoptera (EPT) taxa richness, and the habitat-related Biological Monitoring Working Party (BMWP) scores. The clean water indicating assemblage or EPT taxa is considerably poor in richness (less than ten genera) and diversity while Atyidae dominates the freshwater shrimp assemblage. The midges (Chironomidae: Diptera) living in soft tubes are reasonably well represented at the lentic ecosystem. The BMWP scores based on twenty-eight families of macro-invertebrates vary widely from 5.8 to 91.5. Three sets of independent classification schemes suggest that the running-water sites belong to Classes IV and V of the Malaysian National Water Quality Standards, classifiable as degraded quality.

ABSTRAK Kajian untuk menentukan komuniti makro-invertebrat bentik sebagai penunjuk mutu air di sepuluh batang sungai Pulau Langkawi telah dijalankan. Pengukuran metrik struktur komuniti adalah termasuk kekayaan taksa keseluruhan, kekayaan taksa tiga serangga (Ephemeroptera-Plecoptera-Trichoptera, EPT) dan skor Biological Monitoring Working Party (BMWP) yang berkaitan dengan habitat dimana organisma hidup. Kekayaan dan diversiti EPT (Indikator air bersih) berkurangan dari sepuluh genera manakala Atyidae berbilangan tinggi dalam kumpulan udang air-tawar. Midge (Chironomidae: Diptera) direkodkan di ekosistem lentik. Skor BMWP yang berdasarkan pada dua puluh lapan famili bernilai dari julat 5.8-91.5. Tiga set klasifikasi menunjukkan tapak kajian yang dikelaskan sebagai Kelas IV-V (Piawaian Kualiti Air Kebangsaan Malaysia) adalah tercemar.

(biotic index, benthic macroinvertebrate community, classification, Langkawi, stream)

INTRODUCTION

Freshwater biotic communities are known to respond to perturbation and pollution in a predictable manner [1, 2 and 3]. The community responses constitute a field of bio-assessment study that has spanned more than a century. Over a wide range of unpolluted running water sites in Great Britain, the biological responses and community structure of macro-invertebrates had been predicted, together with the classified habitat associations and selection based on a score system [4]. In the prediction of biological responses to environmental change, conservation studies normally require large number of sites to be sampled more than one occasion and the organisms to be identified to the level of species [5]. However, high-frequency samplings and species-level identifications may not be feasible due to lack of time, the sampling exercise being too costly or lack of sufficient taxonomic expertise. Biological surveillance as practiced by water management authorities often involves sampling a large number of sites in the shortest time possible and identifications to familial level only. Under further constraints in time and expertise, the surveillance does not necessarily consider all families. A pollution assessment index, the Biological Monitoring Working Party (BMWP) score system recommended by the Department of Environment in Great Britain [6], uses a reduced family list where families of rare species and with unknown pollution tolerance are excluded. The tolerance scores (values varying between 0 and 10) [7 and 8] of aquatic organisms are based on experts' opinion. Estimates of probability are made for a particular taxon's absence in an environment where recommended concentration limits are exceeded [9]. The BMWP score system is not based on quantified data because abundance is not considered. Besides, qualitative data on a reduced list of families have been proven to give comparable or better results than more detailed family treatments [5]. The score system is easy to apply and taxonomic difficulties are reduced. Such qualitative approach is sufficiently easy to understand and accessible to technical personnel with little training in biological assessment protocols or to volunteers in monitoring streams [10]. This paper reports the results of a rapid bio-assessment of the streams in Langkawi Island, West Malaysia. The benthic macro invertebrate community was predicted and the structure metric of the Ephemeroptera-Plecoptera-Trichoptera (EPT) insect orders as proposed by other workers [11 and12] was compared with the BMWP score scheme to serve as the biotic index criterion for assigning water quality rating and classification to the Langkawi streams.

MATERIALS AND METHODS

The Langkawi archipelago, situated at 6° 20' N and 99° 50' E off the extreme north-west coast of Peninsular Malaysia, is the only coastal limestone in Malaysia. Among the ninety-nine islands, limestone of Ordovician-Silurian age is abundant, especially in the eastern and southern aspects of the main Langkawi Island. The coastal hills and islets which descend gradually to the sea are often fringed on the seaward edge by narrow sandy beaches (probably derived from silicates or other geological formations). In the north and north-east of the main island, three main rivers comprising Air Hangat, Kilim and Kisap Rivers are connected and continuous with each other at downstream where they are noticeably transformed into estuaries with significant acreage of the low-lying floodplains and riparian vegetation under saltwater influence (*In-situ* measurement using the HACH DR/2000 Direct Spectrophotometer and Troll 9000 YSI HACH Kit recorded pH: 6.05-8.06, temperature: 26.6-30.8 °C, salinity: 0.5-36 ‰ and specific gravity: 0-1.33 gL^{-1}) [13, 14]. Headwater streams including Sungai(=River) Petang, Durian Perangin Waterfall, Gunung Raya and Telaga Tujuh (=Seven Wells) are steep, usually forested, lotic habitats with turbulent current velocities exceeding 1 $m.s^{-1}$ or even as fast as 2 $m.s^{-1}$ (*In-situ* measurement using the SBM11.30.40 General Oceanics Mechanical Flow-meter). The streams are characterized by a succession of rapids, riffles and pools created by waterfall splash-zones, cascades and seepages over rock faces. The other wadeable streams meandering over extensive floodplains and depressions are lentic ecosystems that are characterized by a succession of slow-flowing water with current velocity estimated at less than 0.2 to 1 $m.s^{-1}$, pools and exposed beds that support dense macrophyte thickets and riparian vegetation. The overall chemical water quality is at an acceptable condition when compared with the recommended standard and published guidelines for the maintenance of aesthetic values of nature reserve [15].

Details of the standard methodology for the site selections, macro-invertebrate and environmental samplings have been published [16]. Only a summary on the laboratory and analytical procedures as relevant to this study is given. The field surveys on ten stations (Figure 1) were conducted during the dry period on April 2004. A standardized sampling method of benthic macro invertebrates included the following practices: (1) the samplings started from the lower parts of the rivers to minimize the possible effect of faunal drift by currents; (2) constant sampling effort could be achieved when sampling duration last for one hour and same number of investigators were involved; and (3) a combination of two methods was used along a river continuum having sites belonging to rocky headwaters and soft-bottom potamonic water. For the first method, the boulder rubbing and visual-hand picking of larvae and larval cases at Sungai Petang, Durian Perangin Waterfall, Gunung Raya, and Telaga Tujuh were performed for one hour by five investigators at the rocky headwaters, waterfall splashing zone and seepage over cliff, submerged and exposed stones. For the second method, two investigators were involved to handle a 30 μm mesh nylon kick-net (40 x 40 x 60) cm^3 for sampling the benthic organisms at the low-lying muddy sites, one to hold the net and the other to agitate the stream bottom of 1 m^2 area (using the leg) immediately upstream from the net.

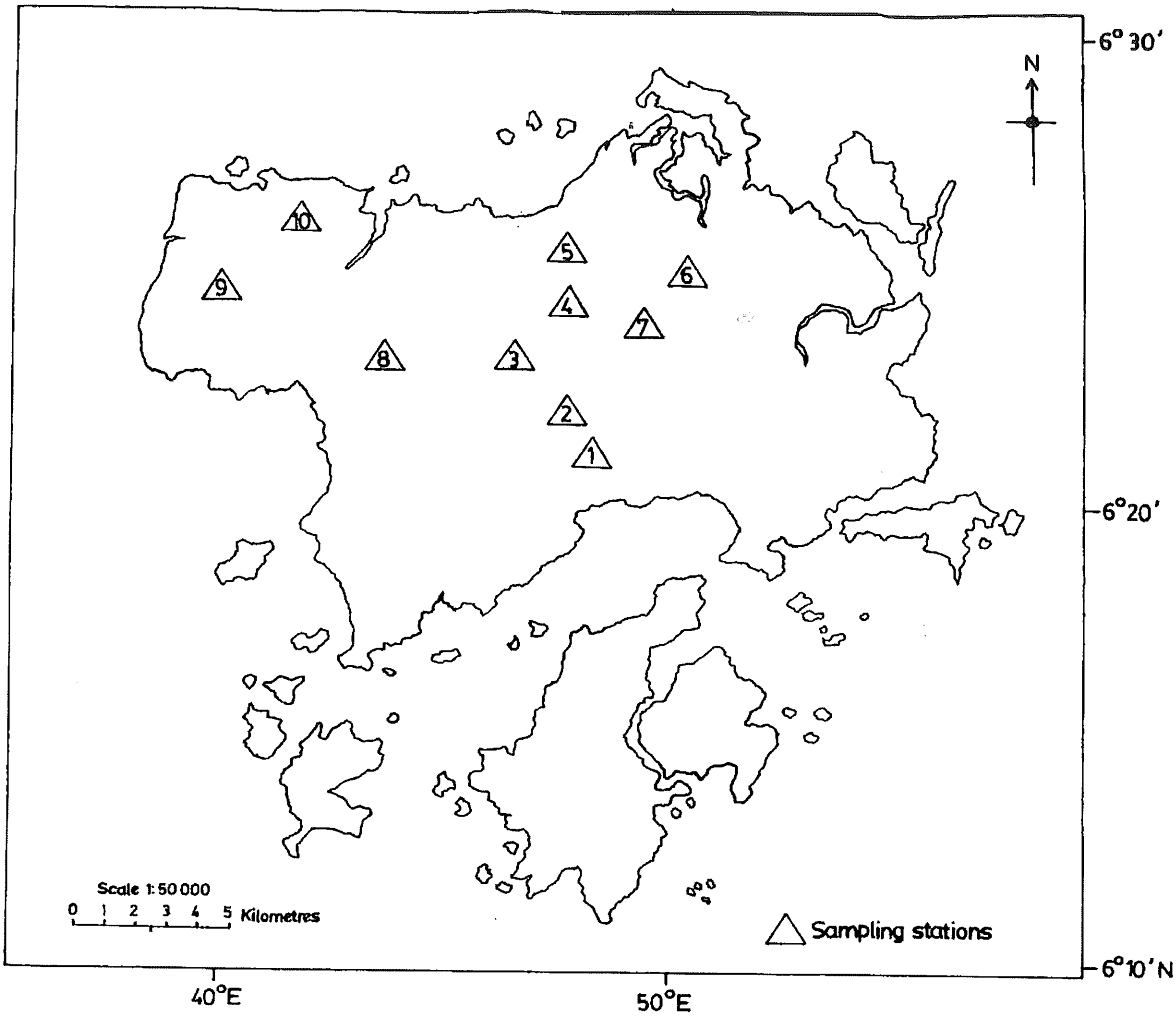
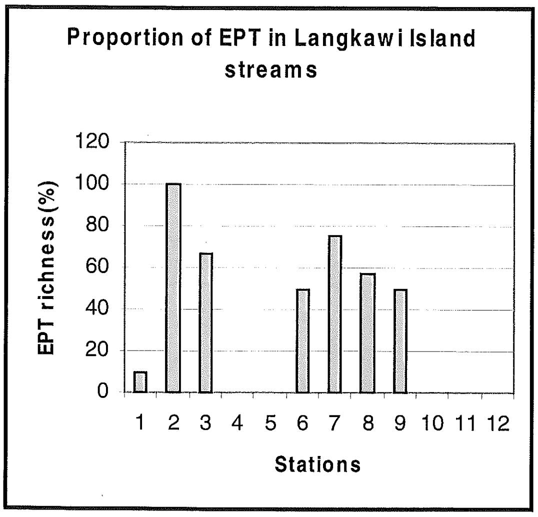


Figure 1. Langkawi Island showing the macro-invertebrate sampling stations



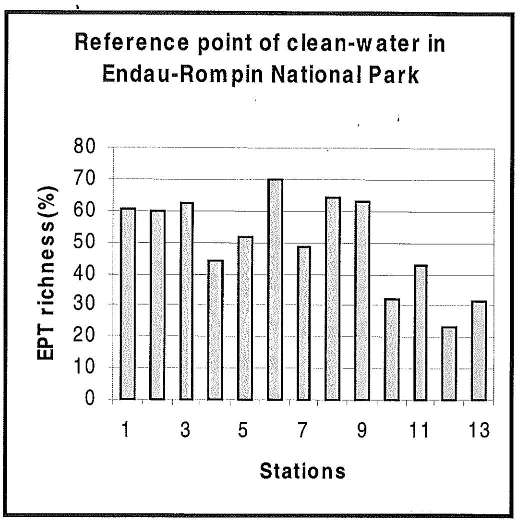


Figure 2. Langkawi island showing the macro-invertebrate sampling stations along ten streams. The stations are numbered as: 1, Batu Asah; 2, Korok; 3, Petang; 4, Tanah Liat Hitam; 5, Tok Puteri; 6, Durian Perangin Waterfall; 7, Gunung Raya; 8, Ulu Melaka; 9, Telaga Tujuh and 10, Temurun Rivers.

The collected organisms were sieved (1 mm mesh), sorted, stored in 75% alcohol and identified. They were identified using standard keys [17 to 22] according to orders, families and genera under dissecting and compound microscopes (Olympus SZ40 and BH-2). The identified organisms were counted, and their density (number m^{-2}) and relative abundance were computed. The benthic macro-invertebrate community structure was analyzed and described with respect to (1) total taxa richness, which refers to the number of genera of all orders, and (2) EPT taxa richness, which refers to the total number of genera of Ephemeroptera, Plecoptera and Trichoptera. Taxa richness and BMWP scores as biotic index criteria appropriate for assigning water quality classification rating to coastal plain [6 and 12] were referred to. The three sets of classification criteria were matched in parallel as below:

Biotic index criteria			**Water quality ratings**
Taxa richness*[12]*		BMWP [6]	
Total	EPT		
>83	27	>150	**I.** Excellent
65-83	21-27	101-150	**II.** Good
52-66	14-20	51-100	**III.** Good-fair
36-51	7 - 13	17-50	**IV.** Fair
35	0 - 6	0-16	**V.** Poor

The habitat-related BMWP scoring system published [23] in relation to riffles (lotic condition), riffles and pools (overlapping condition), or pools (lentic condition) was used, where the tolerance level of families present (t_i) were assigned to values ranging from 0 (organic pollution-tolerant) to 12.5 (sensitive). The biotic index was then expressed as the sum of the tolerance values for all families present; the resultant sums were matched with the above criteria to predict the plausible classes.

RESULTS AND DISCUSSION

The collected populations were sparse consisting of forty-three genera in thirty- two families and ten orders of aquatic insects, freshwater shrimps, crab, snails and worms (Table 1).

Table 1. Populations of benthic macroinvertebrates at stations along rivers of Langkawi island

Macroinvetebrates	**Stations:**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
EPHEMEROPTERA	(Mayflies)										
Baetidae	*Baetis*									1	
Caenidae	*Caenis*	1		3			1		1		
Heptageniidae	*Heptagenia*			2					1	1	
Siphlonuridae	*Siphlonurus*						1		1		
PLECOPTERA (Stoneflies)											
Peltoperlidae	*Cryptoperla*			1							
Perlidae	*Phanoperla*		1	1				1		1	
Perlodidae	*Stavsolus*									1	
Taeniopterygidae	*Strophopteryx*		1								
TRICHOPTERA (Caddisflies)											
Helicopsychidae(case)	*Helicopsyche*			1							
Hydropsychidae	*Diplectrona*			3						1	

Macroinvetebrates	**Stations:**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	Hydropsyche			1				1			
	Macrostemum									11	
	Potamyia							1			
Hydroptilidae	*Hydroptila*								1		
Philopotamidae	*Chimarra*			2							
Polycentropodidae	*Polycentropus*			1						3	
Psychomyiidae	*Tinodes*						3			3	
ODONATA, ZYGOPTERA (Damselflies)											
Chlorocyphidae	*Rhinocypha*									1	
Lestidae	*Lestes*				1						
ODONATA, ANISOPTERA (Dragonflies)											
Gomphidae	*Macrogomphus*				2						
Libellulidae	*Libellula*	1									
	Orthetrum			1							
DIPTERA (2-wing true flies) Chironomidae, sub-families											
Chironominae:	*Chironomus*	5									
	Kiefferulus	15							2		
	Pseudochironomus									3	
Tanypodinae:	*Conchapelopia*			1			5				
Simuliidae	*Prosimulium*				1		1				
	Simulium	1									
Tipulidae	*Pedicia*			1							
COLEOPTERA (Aquatic beetles)											
Scirtidae	*Cyphon*									2	
Staphylinidae	*Staphylinid larva*	1									
HETEROPTERA (Aquatic bugs)											
Gerridae	*Amemboa*									2	
	Halobates			1							
Veliidae	*Pseudovelia*									1	
	Rhagovella			2							
DECAPODA (Prawns & crab)											
Atyidae	*Atya*			2		1				4	1
	Caridina						1			1	
Grapsidae	*Geosesarma*		1		28				1		2
MOLLUSCA, GASTROPODA (Snails)											
Lymnaeidae1	*Lymnaea*	4									
Lymnaeidae 2								1			
Planorbidae	*Gyraulus*					56					
	Helisoma	12									
OLIGOCHAETA (Segmented worms)											
Haplotaxidae	*Hirudo*	3							1		
Lumbriculidae	*Lumbricus*	6								4	

Station numbers are as defined in Figure 1.

Insects predominated in terms of richness and abundance. The total taxa richness varied from 2 to 16. The insects comprised larvae of mayflies (Ephemeroptera), stoneflies (Plecoptera), caddisflies (Trichoptera), damselflies and dragonflies (Odonata, Zygoptera and Anisoptera respectively), two-winged true flies (Diptera), aquatic beetles (Coleoptera) and bugs (Heteroptera, Hemiptera). Among the aquatic insect orders, the Ephemeroptera, Plecoptera and Trichoptera were commonly sampled comprising fourteen families and the taxa richness varied from 1 to 9 constituting 10-100% of the total (Figure 2). Mayflies and stoneflies were fairly represented while caddisflies were rich. In comparison with other Malaysian records [16, 24 to 27 and Figure 2], the population size of this clean-water assemblage in a low-density tourist island was however low, estimated to be ≤10, a number that is considered to be the median number in a freshwater habitat designated as having a "diverse life". The highest faunal richness at Sungai Petang and the fifth well of Telaga Tujuh were attributable to the abundance of hydropsychids (caddisflies).

The non-Insecta including shrimps, crab and snails were found in patchy aggregates and they show no distinguishable distributional pattern. A comparative experimental study in a tropical island stream [28] had shown that freshwater shrimps are often the dominant macro-consumers and inhabit reaches along the river continuum over their migratory life cycle. Atyid shrimps dominate high altitudinal reaches while *Macrobrachium* shrimps are more abundant at the lower altitude. In Langkawi Island streams, atyids similarly dominated the shrimp assemblage. However, this present study which lacks in spatial-temporal scales does not show this shift in shrimp assemblage. Similar comparative experimental approach along altitudinal gradient of the seven-tier cascading falls of the steep Telaga Tujuh may elucidate this shift in shrimp taxa, thus depicting the stream structure and function in the pristine lotic erosional zones [e.g. 16 and 29].

The shrimps and snail assemblages reduced the biomass of chironomids which are sessile and were probably consumed by grazing shrimps and snails. There were generally more chironomids in the absence of highly mobile shrimps (at an organic-rich residential site along Sungai Batu Asah). The soft-tube dwellers like midges (Chironomidae: *Kiefferulus and Chironomus* spp) living in leaf-packs were found attached to logs among packed litter, silt and "aufwuchs" covering on the soft tubes, usually in situations where the litter, trapped against logs are embedded in submerged plants. This observation supports the study of shrimp's effect on chironomids living on artificial tiles in a Puerto Rico stream [28].

The BMWP scoring system was estimated based on twenty-eight families of benthic fauna, a significantly reduced family list [6]. The tolerant scores used here were habitat-related, reflecting the aquatic faunal adaptations to the basic distinction between lotic erosional and lentic depositional or lotic-lentic overlapping conditions. The families including Peltoperlidae and Perlidae of Plecoptera collected from riffles or fast-flowing erosional zone scored highest (12.5) while Hirudinidae in slow-flowing depositional zone scored lowest (0.3) (Appendix 1). The remaining families took the intermediate scores. The BMWP values varied from 5.8 (at Sungai Tok Puteri) to 91.5 (Sungai Petang). The contribution of each family varied from 2.9 to 12.2. Based on the median value of the three biotic indices, the Langkawi freshwater streams were classified as fairly good to poor water quality (i.e. belonging to Classes IV-V of the Malaysian National Water Quality Standards).

Table 2. A summary on the taxa richness, EPT taxa richness, BMWP scores and the water quality ratings of ten stations in Langkawi Island

Stations	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Total taxa richness	10	3	15	4	2	6	4	7	16	2
Water quality rating					**all**	**V**				

EPT taxa richness	1	2	9	0	0	3	3	4	8	0
Water quality rating	**V**	**V**	**IV**	**V**	**V**	**V**	**V**	**V**	**IV**	**V**
BMWP scores	28.1	33.3	91.5	27.5	5.8	36.6	21.8	51.2	84.2	13.9
Water quality rating	**IV**	**IV**	**III**	**IV**	**V**	**IV**	**IV**	**III**	**III**	**V**
Overall rating	**V**	**IV**	**IV**	**V**	**V**	**V**	**V**	**IV**	**IV**	**V**

Appendix 1. Habitat-related tolerance values of macro-invertebrates [23]

Family	**Habitat Specific Scores:**		
	Riffles	**Riffles/pools**	**Pools**
Baetidae	5.5	4.8	5.1
Caenidae	7.2	7.3	6.4
Heptageniidae	9.7	10.7	13
Siphlonuridae	11		
Peltoperlidae	12.5		
Perlidae	12.5	12.2	
Perlodidae	10.8	10.7	10.9
Taeniopterygidae	10.7	12.1	
Hydropsychidae	6.6	6.5	7.2
Hydroptilidae	6.7	6.8	6.5
Philopotamidae	10.7	9.8	
Polycentropodidae	7.8	7.7	8.1
Psychomyiidae	6.4	7.4	8
Lestidae			5.4
Gomphidae		8	
Libellulidae			5
Chironomidae	4.1	3.4	2.8
Simuliidae	5.9	5.1	5.5
Tipulidae	5.6	5	5.1
Scirtidae	6.9	6.2	5.8
Gerridae	4.5	5	4.7
Veliidae	4.9	4	5.1
Asellidae	1.5	2.4	2.7
Astacidae	8.8	9	11.2
Lymnaeidae	3.2	3.1	2.8
Planorbidae	2.6	2.9	3.1
Hirudinidae		0.3	0.3
Lumbriculidae	3.9	3.2	2.5

This study lacks the practical feedback of field trials. Until repeated samplings can be made, the predictions made on the macro-invertebrate community and site classification can only be regarded as interim. The classification of running-water sites in unpolluted area has predictive capabilities [4 and 5], depending on the levels of identification on macro-invertebrates. The familial level is valuable in site evaluation, pollution assessment and interpretation, while the species level identification has applications in conservation and prediction of biological response. The case study on Langkawi Island allows only the former usage but does meet the expedition's objective to provide at least qualitative data. Insight gained from using species-level data will certainly extend the usefulness of the classification but it depends on time and expertise. As an estimate, a sample took about 2 man-days (16 h) to process, sorting took 1 hr and identifying specimens consumed the rest. Mounting and identifying Chironomidae were time-consuming. Identification to species becomes more efficient with experience [30] and expert taxonomic verification would be required for caddisflies like hydroptilids and hydropsychids for which detailed keys are unavailable or if available, they are difficult to apply by non-specialists.

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