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COMPOSITION AND DISTRIBUTION OF AQUATIC INSECT COMMUNITIES IN RELATION TO WATER QUALITY IN TWO FRESHWATER STREAMS OF HULU TERENGGANU, TERENGGANU.

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Abstract: The impact of human disturbance and agricultural activity on aquatic insect communities in two freshwater streams (Sungai Peres and Sungai Bubu) in Hulu Terengganu, Terengganu were studied. A total of 3409 individuals of aquatic insects representing 42 families from 9 orders were successfully collected from August until November 2006. No significant difference was detected for the total abundance of aquatic insects between Sungai Peres and Sungai Bubu (Mann-Whitney Test = -1.550, P = 0.121). However, total abundance of aquatic insects was significantly higher at the upstream stations than downstream stations in both streams (Kruskal-Wallis Test = 2.519, P = 0.012). Heptageniidae (Ephemeroptera), Perlidae (Plecoptera) and Hydropsychidae (Trichoptera) were the most abundant groups collected in both streams. The Ephemeroptera, Plecoptera, Trichoptera (EPT) Index and EPT to Chironomidae ratio (EPT:C) showed that the pollution-sensitive group (EPT) were highly abundant and more diverse at the upstream stations, but higher numbers of pollution-tolerant taxa (Chironomidae) were found at the downstream stations in both streams. Unexpectedly, the Family Biotic Index (FBI), Biological Monitoring Work Party (BMWP) and Average Score Per Taxon (ASPT) indicated that the water quality of both streams varied from clean-to-excellent categories, even though both streams received pollutants from various anthropogenic activities. Width and pH of the streams were positively correlated with the total abundance of aquatic insects (R_{width} = 0.360, P = 0.014; R_{pH} = 0.509, P = 0.003), whereas lower abundance of aquatic insects was found in more turbid water with high total suspended solids (TSS) in both streams (R_{TSS} = -0.291, P = 0.050). This study shows that distribution of aquatic insect communities could provide useful bioindicators of the biomonitoring approach in relation to water physico-chemical parameters to assess, classify and compare the water quality of freshwater streams in Malaysia.

KEYWORDS: aquatic insects, abundance, distribution, water quality, bioindicator

Introduction

Studies of aquatic insects of freshwater river and stream ecosystems have frequently examined the species-habitat relationship with regard to the water quality of the habitat (e.g., Compin & Céréghino, 2003; Azrina *et al*. 2005). Some species are known to have particular requirements with regard to nutrients, water quality, substrate components and the structure of vegetation. Once these are defined, the presence of a particular species in a habitat indicates that the given determinants or parameters are within the tolerance limits of the species. Thus, the species is considered to belong to the habitat or ecosystem (Hellawell, 1986).

Indicator species are those taxa known to be particularly sensitive to specific environmental factors, so that changes in their incidence or abundance may directly reflect an environmental change (New, 1984). The concept of biological indicators using aquatic insects is based on their diversity, abundance and distribution in relation to the physical and chemical conditions of the habitats. Data provided by indicator organisms can be used to estimate the degree of environmental impact and its potential dangers for other living organisms (Kovacs, 1992). Biological monitoring,

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whereby living organisms are used to estimate the water quality or its chemical contents, is important in determining the health of an aquatic ecosystem. Physicochemical monitoring of a water body is known to be insufficient to fully characterise its status or reliably detect adverse impacts (Mandaville, 2002). However, it has been recognised as a vital component of an integrated assessment utilising physicochemical and biological measure for assessing a waterway's condition (Hellawell, 1986).

Studies of freshwater aquatic insects as biological monitoring techniques have been widely reported and described. Many have studied on the effects of anthropogenic activities, such as agriculture and recreational (Azrina *et al*., 2005; Wahizatul *et al*., 2006), silviculture (Hutchens Jr. *et al*., 2004), aquaculture (Loch *et al*., 1996), runoff from land clearing and urban development (Arienzo *et al*., 2001; Compin and Céréghino, 2003; Iliopoulou-Georgudaki *et al*., 2003), river impoundment (Ogbeibu and Oribhabor, 2002), organic and metal contamination (Grumiaux *et al*., 1998).

Although the impact of anthropogenic activities on aquatic insect communities has been reported previously, very little is known about such effects particularly on Malaysian aquatic insect communities. Thus, this research attempted to determine the potential use of aquatic insect communities as bioindicators, as well as assess, classify and compare the health status of two freshwater streams in Hulu Terengganu, Terengganu. It is hoped that the results from this study will provide baseline information that can be used as a first step towards establishing an efficient monitoring tool for the development of water-management system across Malaysia.

Materials and Methods

- ***Sites description***

The study was conducted at the two third-order streams of Sungai Peres and Sungai Bubu in Hulu Terengganu, Terengganu, Peninsular Malaysia (Figure 1). The locality of the study site is approximately 16 km from Kuala Berang town and 56 km from Kuala Terengganu. Both basins received similar annual rainfall of approximately 2050 mm per year. During this study, the monthly rainfall was between 54.8 to 555 mm, with the highest amount of rain recorded in November but lowest in September. Both streams flow into Sungai Tersat, a tributary of Sungai Terengganu. Each has a different land use patterns, sources of disturbance and pollution, and hydrological characteristics. At each stream, upstream and downstream stations were determined, and were then further divided into three substations.

Both Sungai Peres and Sungai Bubu are about 40 kilometers in length and have a catchment area approximately 12.5 km^2 and 6.25 km^2. Width of the upstream station ranged from 12.4−26.35 m and 0.23−0.76 m deep, whereas width of the downstream station ranged between 3.30− 20.08 m and 0.10− 0.25 m deep. Sungai Peres is a typical lowland stream, located within Sekayu Recreational Forest. The stream bed of each station is almost debris-free, mainly comprising sand, pebbles, cobbles and small boulders. The upstream site is used for recreational activities. Therefore, more human disturbances were observed as compared to the downstream. Some parts of the stream reaches, particularly at the middle between banks, were totally exposed to sunlight, but banks were mostly covered by forest canopy, with grasses and shrubs growing in the undergrowth along the stream edges.

Lower part of Sungai Bubu is situated within the vicinity of agricultural areas but the upper reaches were within an intact forest, adjacent to Sekayu forest reserved. The upstream of Sungai Bubu was used for recreational activities but the downstream section was surrounded by agricultural areas, thus vegetation cover was relatively denser. Substrate of the streams changed drastically between upstream and downstream. Further down the stream, the substrata of the substations consisted of muddy sediment, with little pebbles and contained a lot of suspended sediment.

- ***Sampling of aquatic insects***

Aquatic insects were collected using various

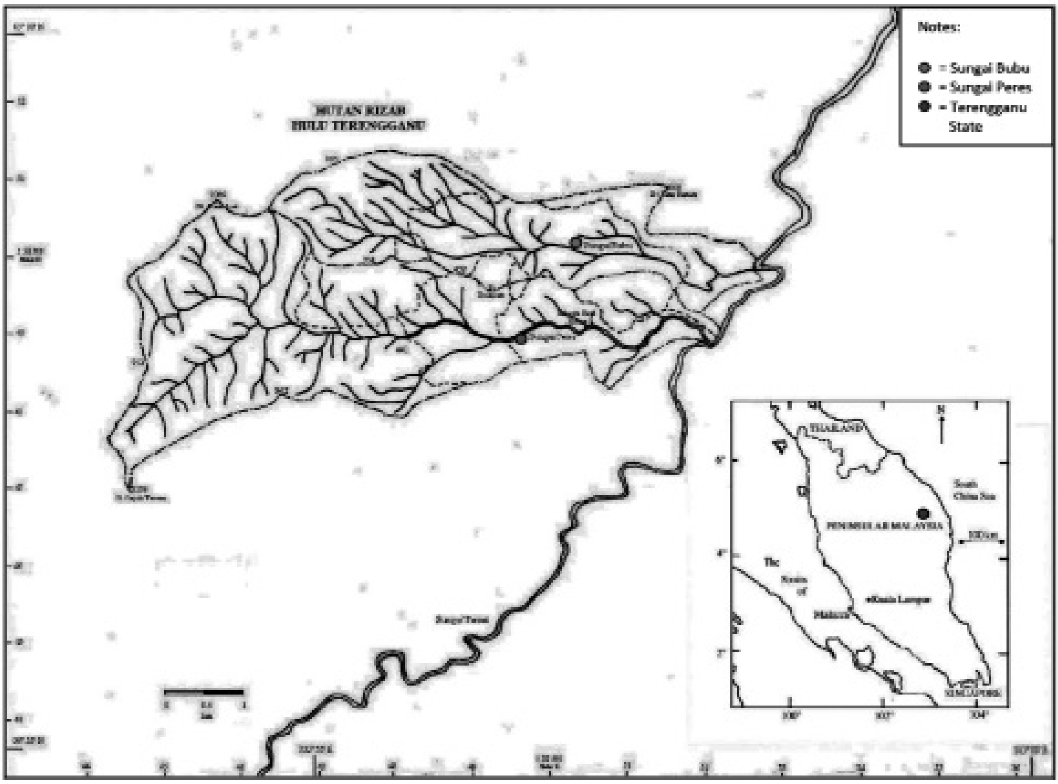

Figure 1. Location of the study sites.

methods, but an aquatic insect net (D-pond net) with a dimension of 40 x 40 cm frame, 60 cm long net of 250 mm mesh was used throughout the sampling.

Big stones in swift-flowing water were hand-lifted and washed by rubbing on the rock surface to remove the aquatic insects into the net. Samples were placed in white trays for sorting and screening. The content of each sample (net) was transferred into properly-labelled plastic containers, preserved in 80% ethanol and taken back to the laboratory for analysis. In the laboratory, aquatic insects were sorted on a Petri dish and identified to the Family level using taxonomic keys by several authors in Yule and Yong (2004). Large aquatic insects were sorted by naked eyes whereas the sorting of the smaller ones was done under a dissecting microscope. All the sorted samples were kept in properly-labelled vials containing 80% ethanol.

- ***Physico-chemical measurement***

Width and depth of the streams were measured by using a marked pole and measuring tape at each station. Three replicates of water temperature, conductivity, pH level and dissolved oxygen (DO) were recorded at each substation, using a multiparameter digital meter (MPS YSI 556, Yellow-Spring Instrument). Velocity of the stream was measured using a pygmy mini hydropropeller and a stopwatch. The time taken for a propeller to stop was recorded and later used to calculate water velocity. Total suspended solids (TSS) were measured through filtration of water samples using millipore (Swinnex-47), with pre-weighted glass microfibre filter papers (Whatman GF/C 47mm). The millipore was used to sieve the suspended solids out of 1 L of water sample from each substation on filter paper. The filter papers were then oven-dried and weighed.

- ***Data analysis***

Four biological indices were used to monitor the impact of disturbances and pollutions on the streams. The index value will indicate but not specify what type of disturbances negatively impact the water quality (Water Action Volunteers, 2003). The indices used in this study were widely known and used in such similar studies elsewhere, including Family Biotic Index (FBI) (Armitage *et al*., 1983), Biological Monitoring Work Party (BMWP) (Armitage *et al*., 1983), Average Score Per Taxon (ASPT) (Metcalfe, 1989), Ephemeroptera, Plecoptera and Trichoptera (EPT) abundance and richness (Mandaville, 2002). These metrics were based on the idea that unstressed streams and rivers have richer invertebrate taxa that were dominated by intolerant species. Conversely, polluted streams have fewer numbers of invertebrate taxa and were dominated by tolerant species. Mann-Whitney Test and Kruskal-Wallis Test were used to evaluate the differences of the distribution and abundance of aquatic insect communities between stations and study sites (SPSS, 2006). Spearman Correlation Analysis was used to measure the association between water-quality parameters and the diversity and abundance of aquatic insect communities (SPSS, 2006).

Results and Discussion:

A total of 3409 individuals of aquatic insects representing 42 families from 9 orders were successfully collected and identified from both Sungai Peres and Sungai Bubu from August until November 2006. Table 1 shows the overall composition and distribution of aquatic insect communities in both streams. More aquatic insects were recorded in Sungai Peres (2205 individuals) than in Sungai Bubu (1354 individuals). However, the total number of individuals recorded in both streams were not significantly different (Mann-Whitney Test = -1.550, $P = 0.121$). Ephemeroptera was the most dominant order with the highest number of individuals in both streams. It was followed by Trichoptera (20.19 %), Plecoptera (11.14 %), Odonata (4.77 %), Diptera (3.60 %), Coleoptera (2.34 %) and Hemiptera (1.07 %) in Sungai Peres. In contrast, Sungai Bubu supported a slightly different aquatic insect community. The second highest order was Plecoptera (14.25 %), followed by Odonata (10.86 %), Trichoptera (8.86 %), Coleoptera (3.84 %), Hemiptera (3.03 %) and Diptera (2.14 %). The least dominant orders in Sungai Peres and Sungai Bubu were Megaloptera and Lepidoptera.

There was a significant difference of total individuals between the upstream and downstream stations in both streams. The number of individuals was higher at upstream stations than downstream stations in both streams (Kruskal-Wallis Test = -2.519, $P < 0.005$). Ephemeroptera, Plecoptera and Trichoptera (EPT) were significantly abundant in both streams, especially at the upstreams. Members of EPT are considered to be sensitive to environmental stress, thus their presence in high abundance at the upstream signified a relatively clean environment (Armitage *et al.,* 1983). Therefore, EPT were found to be a potential bioindicators for a clean ecosystem.

Diptera (primarily Chironomidae) were more abundant at the downstreams of both streams. Chironomidae was the most abundant and was found in all stations, followed by Tipulidae. They showed no habitat restriction as they exhibit a great variety of feeding types. According to Yule (2004), Chironomidae is probably the most diverse and abundant group of all stream macroinvertebrates. The number of Chironomidae was higher at the downstream of both Sungai Peres and Sungai Bubu. Standing and slow-flowing streams and muddy or sandy areas, with high fine-sediment particles are known to support higher diversity and abundance of Chironomidae (Yule, 2004).

The water-quality data of Sungai Peres and Sungai Bubu collected during the survey is summarised in Table 2. In this study, total suspended solids (TSS), pH and width of the streams showed a significant correlation to the abundance of aquatic insects. The TSS concentration was negatively correlated with the number of aquatic insect orders (R = -0.417, $P = 0.004$), families (R = -0.362, $P = 0.014$) and total individuals (R = -0.291, $P = 0.050$) of aquatic insects. This result indicated that, as

Table 1. The composition and total abundance of aquatic insect communities in Sungai Peres and Sungai Bubu.

Order	Family	Sungai Peres			Sungai Bubu		
		Upstream	Downstream	Total	Upstream	Downstream	Total
Ephemeroptera	Baetidae	166	312	478	54	126	180
	Caenidae	6	3	9	0	4	4
	Ephemerellidae	16	5	21	1	4	5
	Ephemeridae	0	0	0	0	1	1
	Heptageniidae	481	132	613	471	64	535
	Leptophlebiidae	16	8	24	6	15	21
	Potamanthidae	2	1	3	0	1	1
	Tricorythidae	15	1	16	9	7	16
Plecoptera	Perlidae	132	97	229	151	42	193
Trichoptera	Ecnomidae	0	0	0	1	0	1
	Hydropsychidae	223	60	283	16	65	81
	Philopotamidae	65	22	87	9	26	35
	Polycentropodidae	1	1	2	0	0	0
	Stenopsychidae	38	5	43	3	0	3
Odonata	Calopterygidae	0	0	0	0	1	1
	Chlorocyphidae	1	0	1	1	0	1
	Chlorogomphidae	0	0	0	0	1	1
	Euphaeidae	22	1	23	57	7	64
	Gomphidae	1	36	37	7	20	27
	Lestidae	0	1	1	4	5	9
	Libellulidae	8	26	34	0	33	33
	Platycnemididae	0	0	0	0	1	1
	Platystictidae	1	1	2	8	2	10
Hemiptera	Corixidae	0	0	0	0	18	18
	Gerridae	0	1	1	1	2	3
	Naucoridae	0	14	14	0	14	14
	Notonectidae	0	0	0	0	6	6
	Veliidae	3	4	7	0	0	0
Coleoptera	Dryopidae	1	0	1	0	0	0
	Dytiscidae	2	1	3	5	1	6
	Elmidae	0	6	6	9	1	10
	Gyrinidae	3	1	4	3	1	4
	Hydrochidae	0	1	1	0	0	0
	Hydrophilidae	4	15	19	9	0	9
	Psephenidae	5	6	11	12	1	13
	Scirtidae	3	0	3	7	3	10
Megaloptera	Corydalidae	3	0	3	1	6	7
Lepidoptera	Pyralidae	1	1	2	1	1	2
Diptera	Chironomidae	10	41	51	4	19	23
	Culicidae	6	0	6	0	0	0
	Tabanidae	1	1	2	0	0	0
	Tipulidae	8	7	15	2	4	6
Total		1244	811	2055	852	502	1354

Table 2. The physico-chemical parameters for each station in Sungai Peres and Sungai Bubu.

Physico-chemical parameters	Sungai Peres		Sungai Bubu	
	Upstream	Downstream	Upstream	Downstream
Velocity (cm/s)	0.012 ± 0.005	0.024 ± 0.011	0.007 ± 0.005	0.01 ± 0.009
Temperature (°C)	24.71 ± 0.66	26.08 ± 1.27	24.74 ± 0.20	25.84 ± 1.24
pH	7.45 ± 0.82	7.02 ± 0.51	6.34 ± 0.41	6.92 ± 0.41
Total Suspended Solids (mg/L)	23.33 ± 18.20	24.00 ± 22.10	32.58 ± 33.13	32.17 ± 27.48
Conductivity (µS/cm)	23.00 ± 3.33	22.67 ± 2.90	21.08 ± 1.73	22.25 ± 3.47
Dissolved Oxygen (mg/L)	7.37 ± 0.72	7.43 ± 0.35	7.93 ± 0.66	7.45 ± 0.63

TSS concentration increased, the diversity and abundance of aquatic insects declined. However, the pH level was positively correlated to the number of orders (R = 0.360, P = 0.014). There was also positive correlations between width of streams and number of families (R = 0.393, P = 0.029) and individuals (R = 0.509, P = 0.003) in both streams. Other water-quality parameters did not show a significant correlation to the aquatic insect communities.

Data generated from this study were used to classify water quality for both streams. The classifications of the water quality of Sungai Peres and Sungai Bubu are presented in Table 3. All these biological indices provided better information about the environmental conditions under which they lived than a consideration of the individual taxa alone (Armitage *et al*., 1983). The FBI values in Sungai Peres and Sungai Bubu were 3.67 and 4.08, indicating that the water quality of both streams was excellent. Based on the BMWP value, both streams scored a very high/good water quality but Sungai Bubu has slightly higher BWMP value than Sungai Peres. ASPT indicated that upstream and downstream stations in Sungai Peres and Sungai Bubu had clean water. The ASPT score for Sungai Peres was 6.58, whereas Sungai Bubu scored 6.64. The EPT Index indicates the EPT taxa richness was higher in Sungai Bubu than in Sungai Peres. Both upstream and downstream of Sungai Bubu had higher EPT Index than both stations in Sungai Peres. The sensitive taxa (Ephemeroptera, Plecoptera and Trichoptera) were abundant in both streams, especially at upstreams. Diptera, especially Chironomidae, were found comparatively more abundant at downstreams. Thus, the results indicated that a better water quality was recorded in upperstreams compared with downstreams of both Sungai Bubu and Sungai Peres, where the impact of anthropogenic activities on the water quality and distribution of aquatic insects were clearly associated.

Human activities might change the normal development of these fragile ecosystems, especially at the downstream of Sungai Bubu. The poorer water quality at downstream stations than at upstream stations in both streams could be attributable to several man-induced activities, such as sedimentation, sewage/ nutrients runoff and agricultural pesticides. A similar study done by Wahizatul *et al.* (2006) in Sekayu stream also found that human activities, such as recreational and agricultural activities, were clearly associated with a reduction in species diversity of aquatic insect communities in Sekayu Recreational Forest.

Table 3. Classifications of water quality in Sungai Peres and Sungai Bubu based on biological indices. (Notes: FBI = Family Biotic Index; BMWP = Biological Monitoring Work Party; ASPT = Average Score Per Taxon; EPT = Ephemeroptera, Plecoptera and Trichoptera).

Study site		FBI	Class	BMWP	Class	ASPT	Class	EPT index	EPT : Chironomidae
Sungai Peres	Upstream	3.63	Excellent	135	Good	6.75	Rather clean	12	116 : 10
	Downstream	3.73	Excellent	158	Good	6.76	Rather clean	12	15 : 78
	Total	3.67	Excellent	158	Good	6.58	Rather clean	12	35 : 45
Sungai Bubu	Upstream	3.42	Excellent	110	Good	6.47	Rather clean	10	180 : 25
	Downstream	4.08	Very good	161	Good	6.71	Rather clean	11	18 : 68
	Total	3.67	Excellent	166	Good	6.64	Rather clean	13	46 : 7

It shows that the variation of the aquatic insect assemblages is moulded by their different levels of sensitivity to pollution, together with many other abiotic factors in the stream ecosystem. Therefore, the water physico-chemical data, together with the presence/absence of aquatic insects at upstream and downstream stations indicated a function of a combination of natural and anthropogenic influences. Thus suggests that aquatic insects could be used as potential bioindicators for better water management in Malaysia.

Conclusion

Generally, the water quality of Sungai Peres and Sungai Bubu can be considered as clean, based on the diversity and abundance of aquatic insects and values of biological indices used in this study. There were no significant differences between both streams in number of individuals, families and orders. The ratio of EPT to Chironomidae was much higher at the downstreams stations in both streams, which shows the impacts of anthropogenic activities on the water quality, diversity and distribution of aquatic insects were clear. The biological indices (FBI, BMWP and ASPT) indicated the water quality of Sungai Peres and Sungai Bubu as rather clean to excellent water quality. An updated list of aquatic insects found in Sungai Peres and Sungai Bubu would be useful in determining the responses of aquatic insects to their surrounding environment. In conclusion, distribution of aquatic insect communities provides useful bioindicators of the biomonitoring approach in order to provide a complete spectrum of information for appropriate water management of freshwater streams in Malaysia.

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