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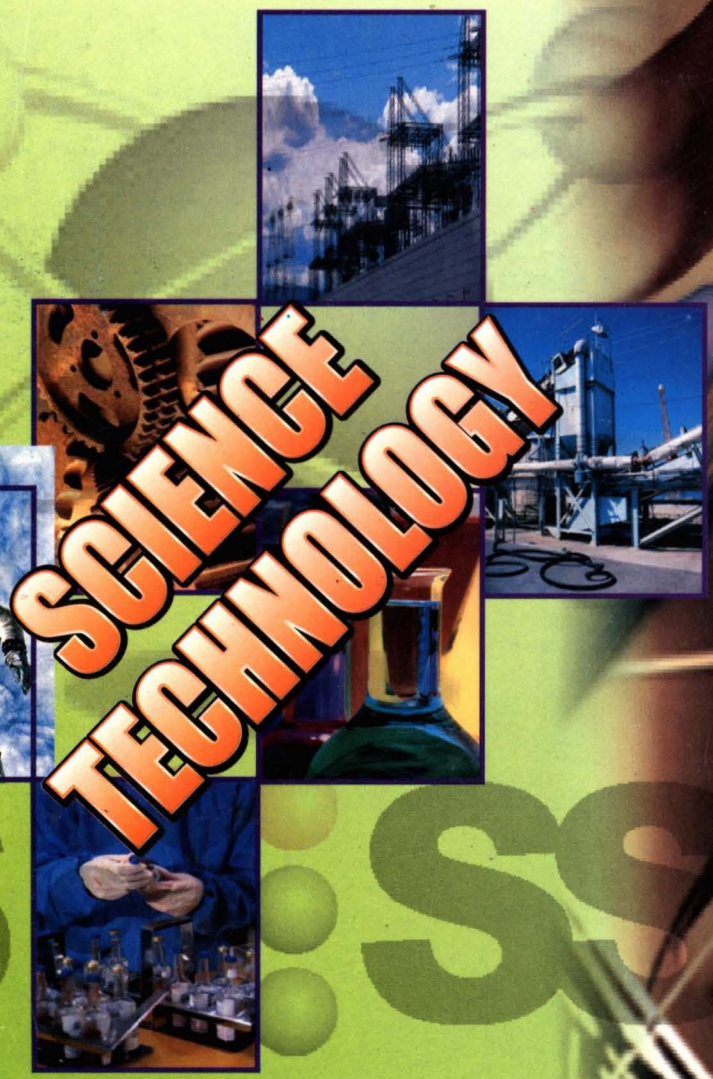

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Diversity of Aquatic Insects in Relation to Water Quality in Stream of Sekayu Recreational Forest, Terengganu

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ABSTRACT

A total of 1364 individuals of aquatic insects of 38 families belonging to eight orders had been collected from lower stream (LS), middle stream (MS) and upper stream (US) of Sg. Sekayu in Sekayu Recreation Forest, Hulu Terengganu, Terengganu from 5th to 7th September 2005. There are eight common orders of aquatic insects that had been identified namely Trichoptera (40%), Ephemeroptera (25%), Plecoptera (14%), Odonata (12%), Hemiptera (6%), Coleoptera (1%), Diptera (1%) and Megaloptera (1%) during this study. The most dominant order was Trichoptera and Heptageniidae (Order: Ephemeroptera) was the most abundant family which were found at all sampling site. Water conditions and human activities showed a difference in the distribution and abundance of the orders obtained in the three stations. However, there were no significant differences in the total individuals collected and taxonomic composition of aquatic insects in all three sampling sites ($ANOVA_{Individuals}$, $F_{2,18,0.05} = 0.472$; $ANOVA_{Taxon}$, $F_{2,18,0.05} = 0.512$). Interestingly, based on the Family Biotic Index (FBI) and Biological Monitoring Work Party (BMWP), all sites demonstrated a good water quality even though two sites were considered as disturbed areas.

Keywords: *aquatic insects, diversity, indicator, water quality*

Introduction

The idea that aquatic insects can provide a reliable indication of the environmental quality is widespread and basically sound. They are excellent indicators and have many advantages as biological indicators such as longer lifespan; mostly are sedentary, having wide and established taxonomic identification, played a major role in aquatic food-web and visible to the naked eye (Pattrick & Palavage 1994; Pinel-Alloul *et al.* 1995). Studies of aquatic insects of freshwater river and stream ecosystems have frequently examined the species-habitat relationship with regards to the water quality of the habitat. Some species are known to have particular requirements with regards to their environment such as nutrients, water quality, substrate components and vegetation structures. Once these requirements are defined, the presence of a particular species in a habitat indicates that the given determinant or parameter is within the tolerance limits of that species (Hellawell 1986).

Aquatic organisms especially the macroinvertebrates have been used to assess water quality of streams and rivers for managing water uses, for ambient monitoring and for evaluating the effectiveness of pollution control measures throughout the world (Hilsenhoff 1988; Lenat 1988, 1993; Metcalfe 1989; Resh *et al*, 1995). As an important component of macroinvertebrate community, aquatic insects have been proven useful biological indicators of both recent and long-term environmental conditions (Armitage *et al.* 1983; Arunachalam *et al.* 1991; Che Salmah 2001; Arthur & Regis 2003).

The concept of biological indicator using aquatic insects is based on the diversity, abundance and distribution of the insects in relation to the pysical and chemical conditions of the habitats. There are wealth of evidence from the field studies and from laboratory investigations that many aquatic insects show anatomical and physiological responses to environmental changes. Indices such as Family Biotic Index (FBI) and Biological Monitoring Work Party (BMWP) (Morse *et al.* 1994; Merritt & Cummins 1996) and many others are used in evaluating the condition of the water in a particular aquatic environment. However, similar study is lacking in the country. Therefore, this study was initiated to examine the relationship of data on diversity and composition of aquatic insects subjected to the different in water quality due to human interference.

Materials and Methods

Study sites

Sampling was conducted at Sg. Sekayu in Sekayu Recreational Forest, Hulu Terengganu, Terengganu, Peninsular Malaysia (Figure 1). This forest is a mixed dipterocarp type with its cascades are surrounded by its natural landscape of lush jungle-clad hills, a small river and countless species of flora and fauna (Nik 2005).

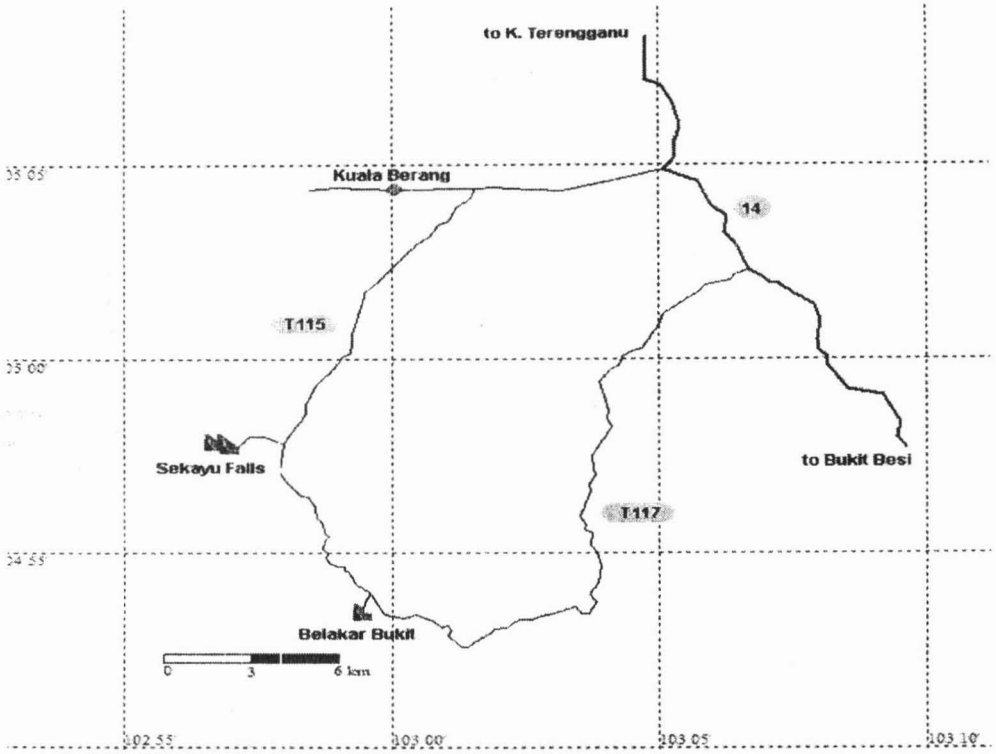

Fig. 1: The location of Sekayu Recreational Forest, Hulu Terengganu, Terengganu from the nearest town of Kuala Berang. T115 and T117 are the roads number

Three study sites were selected which representing three different degrees of human interference. Three stations were selected along the Sekayu stream which represents different land use patterns, presence of point or non-point source of pollutions and hydrological characteristics. The study site is located at the upper stream (US) represent a less disturbed environment, the middle stream (MS) and down stream (DS) of which each were partially disturbed with human activities such as recreational and agriculture, respectively. Since the upper stream is less disturbed by development, the present of very high diversity of aquatic insects would be expected. Nevertheless, the middle section is heavily utilized by visitors, thus, it is expected that the streams of would also received some level of disturbances. At the lower section of the stream, the sampling site is within agricultural areas and pollution from herbicides and pesticides is expected to influence the diversity and composition of aquatic insects. Table 1 shows the description of microhabitats of each study site.

Table 1: Types of microhabitats found in the lower, middle and upper streams of Sg. Sekayu, Hulu Terengganu

Study sites	Date	Microhabitats
Lower stream (LS)	5th Sept. 05	Biotopes: Exposed to direct sunlight particularly the middle section of the stream, bank sides partly covered by riparian vegetation canopy, floating vegetation are lacking. Water: Slow moving water in many parts in this section, water relatively shallow. Substrate : Mainly sandy bottom to pebbles
Middle stream (MS)	6th Sept 05	Biotopes: Streams well covered by forest canopy and riparian vegetations are plentiful. Water: Moderate to fast flowing water at rapids, deep pools are present Substrate: Some parts are sandy bottom, mainly rocky and boulders bottom
Upper stream (US)	7th Sept. 05	Biotopes: Stream exposed to direct sunlight Water : Fast flowing water, shallow rapids and deep pool present Substrate: Mainly bedrock with small cobbles and boulders

Aquatic insect sampling

Aquatic insects were sampled at three sites along the Sg. Sekayu using several methods. The insects were collected in a 1.0 m^2 of quadrate to represent the specific sampling location by holding a long handle D-pond net of approximately 300 µm mesh size at the downstream. All the materials in front of the net were disturbed and it will capture in the net. The insects were scooped by forcing the net through vegetation or surface layers of substrate. The scooping technique was done in a sideways motion. The kick technique was used to kick the bottom substrate allowing the material to flow into the net. The scrub technique also was used in rocky areas, allowing all the aquatic insects flow into the net. The collected specimens were then sorted in a clear tray before they were transported alive into properly labeled specimen bottles. All sorted specimens were preserved in 75% ethanol prior to detail identified to family level under dissecting microscope by using keys of Morse *et al.* (1994) and Catherine & Yong (2004) in the laboratory.

Water quality parameters such as dissolve oxygen, water temperature, pH, conductivity and water velocity were measured at each study sites before sampling. Dissolved oxygen (mg/L) and water temperature (0C) were measured with Oxygen meter (YSI-57). pH was recorded using pH meter (Termo Orion-Model 210), conductivity (µS/cm) with SCT meter (YSI-55) and water velocity were estimated using Hydropob flow meter. Three readings were taken for each parameter and the mean values were presented.

Data analysis

One-way analysis of variance (ANOVA) was used to evaluate differences in distribution of aquatic insects at different study sites. While, two biological indices were used in this study namely Family Biotic Index (FBI) and Biological Monitoring Work Party (BMWP). These indices have been used to monitor the impact of disturbances and pollutions on streams by many reseachers (Armitage *et al.* 1988; Hilsenhoff 1988; Green World Foundation of Thailand 1998).

Results and Discussion

Diversity and composition of aquatic insects

A relatively diverse assemblage of aquatic insects communities is recorded from Sekayu Recreational Forest, Hulu Terengganu. A total of 1364 individuals belonging to 38 families from eight orders had successfully been recorded during three days of samplings (Table 2). US demonstrate the highest total abundance of individuals collected among the sampling sites. The lowest number collected was at the DS site of Sg. Sekayu.

Table 2 : Composition and total abundance of aquatic insect communities in lower stream (LS), middle stream (MS) and upper stream (US) of Sg. Sekayu, Hulu Terengganu

Order	Family	Number of individuals			Total individuals
		LS	MS	US	
I. Ephemeroptera	1. Caenidae	40	32	4	76
	2. Potamanthididae	14	-	-	14
	3. Leptophlebiidae	3	6	-	9
	4. Heptageniidae	17	98	128	243
	5. Ephemeridae	-	1	-	1
	6. Neophemeridae	-	-	1	1
II. Trichoptera	7. Brachycentridae	19	-	122	141
	8. Hydroptilidae	5	19	75	99
	9 Helicopsychidae	32	59	98	189
	10. Philopotamidae	-	25	5	30
	11. Hydropsychidae	-	93	1	94
III. Plecoptera	12. Perlidae	18	93	80	191
VI. Odonata	13. Gomphidae	43	4	7	54
	14. Aeshnidae	-	8	-	8
	15. Corduliidae	3	-	-	3
	16. Libellulidae	38	8	1	47
	17. Calopterygidae	4	-	-	4
	18. Lestidae	2	-	-	2
	19. Coenagrionidae	3	-	-	3
	20. Euphaeidae	1	10	31	42
	21 Megapodognonidae	1	1	-	2
	22. Chlorogomphidae	1	-	-	1
V. Hemiptera	23. Naucoridae	29	-	-	29
	24. Veliidae	25	5	6	36
	25. Saldidae	-	15	-	15
	26. Mesovelidae	-	-	1	1
VI. Coleoptera	27. Psephenidae	-	3	1	4
	28. Hydroscaphidae	-	1	-	1
	29. Dytiscidae	-	1	-	1
	30. Noteridae	-	4	-	4
VII. Diptera	31. Chironomidae	1	-	-	1
	32. Calicidae	1	-	-	1
	33. Dixidae	1	-	-	1
	34. Ceratopogonidae	1	-	-	1
	35. Tabanidae	-	1	-	1
	36. Athericidae	-	1	-	1
	37. Dolichopodidae	-	4	-	4
VIII. Megaloptera	38. Sialidae	-	-	9	9
	TOTAL	302	492	570	1364

Figure 2 shows the composition of taxonomic group of aquatic insects in three study sites of Sg. Sekayu. Trichoptera was the most dominant group making up 40% of total individuals collected. The second highest was Ephemeroptera with 25% followed by Plecoptera (14%), Odonata (12%) and Hemiptera (6%). Meanwhile, Coleoptera, Megaloptera and Diptera were rare and considered as the minority groups as each of them only contributed 1% of total individuals recorded.

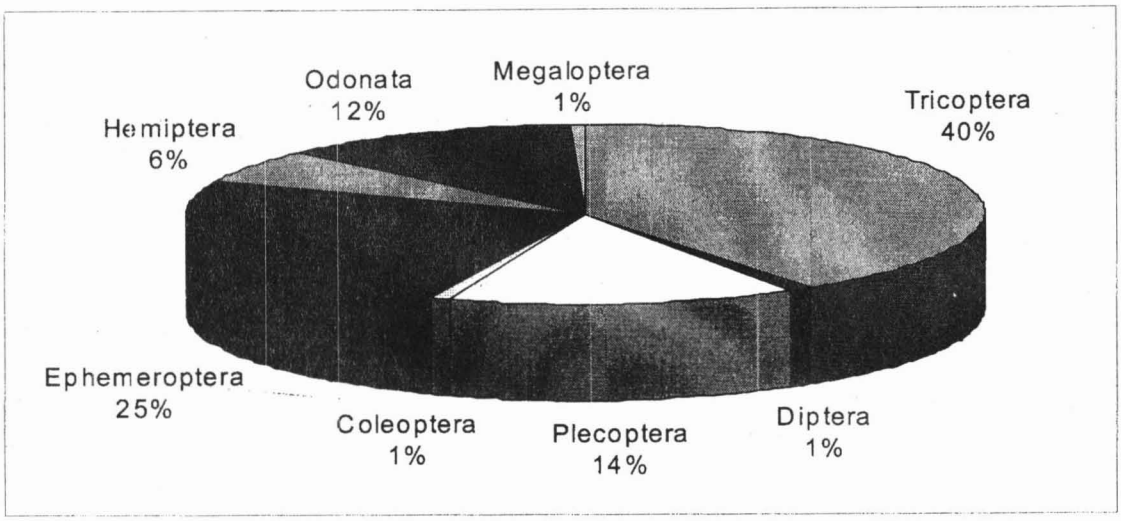

Figure 2: Composition of taxonomic groups of aquatic insect communities at Sg. Sekayu, Hulu Terengganu.

Table 2 showed that Heptageniidae which belongs to the order of Ephemeroptera formed the highest total individuals collected. This is the most abundant family and was found numerous at all sampling sites as 243 individuals were successfully recorded. Habitat structures especially at the US favored the abundance of Heptageniidae as variety of microhabitats were found at that site such as crevices among stones and gravel at stream bottom and trailing roots of plants along the sides of stream (Catherine & Yong 2004). This finding indicated that the heterogeneity of microhabitats in the upper stream is the key factor for Heptageniidae population in abundant.

The second most abundant family of aquatic insects recorded at Sekayu stream was Perlidae which belongs to the order of Plecoptera (191 individuals). Perlidae was the only diverse Plecoptera family in the Malaysian region and most of them occur on the underside of stone or in sandy stream (Catherine & Yong 2004). The order of Trichoptera was also found in abundance and Helicopsychidae represented as the third highest total abundance collected with 189 individuals. From our observation, this group of animals showed some specific habitat preferences such as surface of large rocks, interstitial spaces among gravel and on or below the surfaces of sand or silt. This is because of their ability to spin silk out of their lower lip and they use this material to glue together stones or pieces of vegetation into a small house for their protection during the larva and pupa stages (Catherine & Yong 2004).

Interestingly, three orders were found restricted only at one or two sites. Some families of Dipterans were strictly found at LS and MS, while Megalopterans were only collected at US. LS were frequented by dipteran chironomidae which were known as the indicator for stress and polluted aquatic environment (Arunachalam *et al.* 1991; Che Salmah 2001; Arthur & Regis 2003). Probably, it could be associated with the agricultural activities which were found closely to the stream. With the ongoing agricultural activities, it is expected that traces of insecticides used by the farmers could obviously be found in the water. Consequently, this site was represented as moderate of water quality and low individuals of aquatic insects.

US demonstrated an excellent water quality and more tolerant aquatic insects flourish there. At this site, Ephemeroptera, Plecoptera and Trichoptera (EPT) which are considered as the bioindicators for clean and undisturbed area (Arunachalam et al. 1991; Che Salmah 2001; Arthur and Regis 2003) are common. Meanwhile, MS recorded the second highest of individuals of aquatic insects. Even though this site represented as slightly disturbed area, it still demonstrated a good water quality and consist of wide variety of microhabitats compared to LS.

Table 3 shows the one-way analysis of variance (ANOVA) of total individuals and taxa of aquatic insects between US, MS and LS of Sg. Sekayu. There were no significant differences in the total individuals collected and taxonomic composition of aquatic insects in all three sampling sites ($ANOVA_{Individuals}$, $F_{2,18,0.05} = 0.472$; $ANOVA_{Taxon}$, $F_{2,18,0.05} = 0.512$). However, Coleoptera showed a significant different in total abundance recorded at the three sampling site ($ANOVA_{Coleoptera}$, $F_{2,11,0.05} = 7.300$). This value implied that the Coleopterans abundance in the upper, middle and down streams were different from each other.

Water quality and its influences on aquatic insect communities

Table 4 presents the mean readings of physico-chemical parameters in three study sites at Sg. Sekayu. During the study, five water quality parameters of water temperature, dissolve oxygen, conductivity, pH and velocity were recorded. In general, most of the parameters have close ranges among all study sites. However, certain variables slightly varied. Thus, they reflected the abundances of certain order or families which could be used as indicators of the pollution. The temperature and conductivity of the water gradually decreased DS-US pattern. The water in this stream was neutral to alkali with pH ranging from 7.00 to 8.26,. Dissolved oxygen ranges from 7.54 to 8.25 mg/L is a characteristic of headwater ecosystem. Low concentration of dissolved oxygen at LS and MS sections were probably influenced by the agricultural and human activities, which could be considered as disturbed areas. However, US represented as clean water as shown by high concentration of dissolved oxygen. This result indicated that this site has an excellent water quality and could be classified as undisturbed area.

Table 4: The mean readings of physico-chemical parameters of study areas at Sg. Sekayu, Hulu Terenggau

Study sites	Water Temperature	Dissolve oxygen	Conductivity	pH	Water Velocity
Lower stream	26.1°C	91.5%, 7.54mg/l	29.2 µs/cm	7.00	19 ms^{-1}
Middle stream	25.1°C	94.2%, 7.67mg/l	26.8 µs/cm	7.60	49 ms^{-1}
Upper stream	24.0 °C	98.0%, 8.25 mg/l	26.8 µs/cm	8.26	58 ms^{-1}

Table3: One-way analysis of variance (ANOVA) of total individuals and taxa of aquatic insects between upper, middle and lower streams of Sg. Sekayu, Hulu Terengganu.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Total individuals	Between Groups	5964.089	2	2982.044	.472	.632
	Within Groups	100995.6	16	6312.225		
	Total	106959.7	18			
Taxonomic composition	Between Groups	5.396	2	2.698	.699	.512
	Within Groups	61.762	16	3.860		
	Total	67.158	18			
Ephemeroptera	Between Groups	414.778	2	207.389	.140	.870
	Within Groups	22171.000	15	1478.067		
	Total	22585.778	17			
Trichoptera	Between Groups	6043.333	2	3021.667	1.989	.180
	Within Groups	18234.400	12	1519.533		
	Total	24277.733	14			
Plecoptera	Between Groups	1606.333	2	803.167	.313	.752
	Within Groups	7686.500	3	2562.167		
	Total	9292.833	5			
Odonata	Between Groups	251.267	2	125.633	.992	.384
	Within Groups	3420.200	27	126.674		
	Total	3671.467	29			
Hemiptera	Between Groups	294.500	2	147.250	1.454	.284
	Within Groups	911.750	9	101.306		
	Total	1206.250	11			
Coleoptera	Between Groups	12.167	2	6.083	7.300	.013
	Within Groups	7.500	9	.833		
	Total	19.667	11			
Diptera	Between Groups	2.240	2	1.120	1.399	.271
	Within Groups	15.214	19	.801		
	Total	17.455	21			

From the biological indicator perspective (Table 5), the water quality at the LS, MS and US were categorized as excellent water quality (organic pollution unlikely) as indicated by the Family Biotic Index (FBI). FBI for each site is 1.38, 2.31 and 2.88 scores, respectively. Based on the Biological Monitoring Working Party (BMWP), LS scored

1703, while MS and US each contributed scored 3163 and 3933, respectively. Thus, each site was considered as good water quality category. Overall, all sites examined demonstrated a good water quality even though two lower sites were considered as disturbed areas. This showed that Sg. Sekayu is generally clean and free from major organic pollution.

Table 5: Biological indices based on composition and abundance of aquatic insects community at Sg. Sekayu, Hulu Terengganu

Site	FBI	Class	BMWP	Class
Lower stream	1.38	Excellent	1703	Good water quality
Middle stream	2.31	Excellent	3163	Good water quality
Upper stream	2.88	Excellent	3933	Good water quality

Conclusion

The study showed that the three selected sampling sites supported higher diversity of aquatic insects. Heptageniidae was the most dominant family at the three selected sites of Sg. Sekayu, Hulu Terengganu. The assemblage and distribution of aquatic insect community were influenced by the characterization of physical and chemical condition of their habitat. Abundance of heterogeneous microhabitats influences the diversity and distribution of aquatic insects in this study. Several orders of aquatic insects recorded in the study play a key role as biological indicator for stream health and water quality. The study concludes that all sampling sites demonstrated a good water quality even though Sg. Sekayu was heavily utilized for recreational activities.

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