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Seasonal Abundance and Diversity of Aquatic Insects in Rivers in Gunung Jerai Forest Reserve, Malaysia

(Kelimpahan Bermusim dan Kepelbagaian Serangga Akuatik di Sungai-Sungai di Hutan Simpan Gunung Jerai, Malaysia)

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ABSTRACT

Seasonal changes in Ephemeroptera, Plecoptera *and* Trichoptera *(EPT) community was studied at rivers in Gunung Jerai Forest Reserve, Kedah, Malaysia. The rivers were visited monthly from September 2007 to August 2008 to sample aquatic insects using D-pond nets. More EPT were found in the wet season (10664 individuals) compared with the dry season (6599 individuals). In all rivers,* ephemeropteran *populations was highest during the wet season (z=-2.465,* p*=0.014). Meanwhile, the* plecopteran *population was low and almost constant throughout seasons in all rivers (z=-2.280,* p*=0.023).* Trichopterans *exhibited the highest peak of abundance in the dry season (z=-6.096,* p*=0.00). Concomitantly, higher diversity was recorded in the dry season (29 taxa) compared with 25 taxa recorded in wet season from all rivers. Tupah River had the most diverse EPT assemblage during the dry season. In wet season, the abundance of* ephemeropterans *genera such as* Baetis, Platybaetis, Campsoneuria *and* Thalerosphyrus *increased tremendously especially in Teroi River.*

Keywords: EPT; seasonal fluctuation; temporal distribution

ABSTRAK

Kelimpahan bermusim bagi komuniti Ephemeroptera, Plecoptera *dan* Trichoptera *(EPT) telah dikaji di sungai-sungai di Hutan Simpan Gunung Jerai, Kedah, Malaysia. Sungai yang dipilih telah dilawati setiap bulan dari September 2007 hingga Ogos 2008 untuk menyampel serangga akuatik menggunakan jaring akuatik berbentuk D. Lebih banyak EPT ditemui pada musim hujan (10664 individu) berbanding pada musim kering (6599 individu). Di dalam semua sungai, bilangan* Ephemeroptera *adalah tertinggi semasa musim hujan (z=-2.465,* p*=0.014). Sementara itu, bilangan* Plecoptera *adalah rendah dan hampir malar sepanjang musim di semua sungai (z=-2.280,* p*=0.023).* Trichoptera *menunjukkan bilangan tertinggi pada musim kering (z=-6.096,* p*=0.00). Kepelbagaian spesies yang lebih tinggi dicatatkan pada musim kemarau (29 taksa) berbanding hanya 25 taksa yang dicatatkan pada musim hujan di semua sungai. Sungai Tupah mempunyai himpunan EPT yang pelbagai semasa musim kering. Pada musim hujan, terdapat banyak genus* Ephemeroptera *seperti* Baetis, Platybaetis, Campsoneuria *dan* Thalerosphyrus *dengan bilangan yang meningkat terutamanya di Sungai Teroi.*

Kata kunci: EPT; fluktuasi bermusim; kelimpahan mengikut masa

INTRODUCTION

Most of Asian countries were affected by the unpredictable monsoon and seasonal rainfall (Gopal 2002). These rainfalls dictated many features of the river (Payne 1986) and play major role in changes of the benthic community (Robinson & Minshall 1986) in the tropical rivers (Silveira et al. 2006). Rainfall varies with an annual seasons to some extent the quantity of rainfall which enters the streams is extremely variable (Hynes 1970). Rainfall in mountainous regions can increased water flow in lotic environments (Oliveira & Froehlich 1997). At the advent of the rains, headwater streams respond rapidly and can change from quiet, trickling streams to torrents in an hour or two (Payne 1986). During the periods of high water, the invertebrate fauna in streams tend to be low (Dudgeon 2008).

Many studies have been conducted in tropical insect population (Denliger 1980; Owen & Owen 1974; Wolda 1978, 1979; Wolda & Flowers 1985) but rare in Peninsular Malaysia (Ameilia 2000; Bishop 1973; Che Salmah et al. 2001; Jongkar 2000). Studies on seasonal effects in abundance and diversity of Ephemeroptera (Wolda & Flowers 1985) and other aquatic insects are scarce especially in Asian streams (Bishop 1973). In Gombak River (Bishop 1973) and in Palau (Bright 1982), both researchers found the abundance of mayflies fluctuated during wet season due to scouring from heavy rains. The extant of heavy rains creates floods and it has been shown that densities of *Baetis rhodani* (Ephemeroptera) in alpine streams in southern Norway decreased (Brittain 2008) possibly being shifted downstream because of high discharge (Fjellheim et al. 1993). In tropical region, rainfall is the main factor that needs to be considered when studying the temporal distribution of Ephemeroptera, Plecoptera and Trichoptera (EPT) fauna (Flecker & Feifarek 1994) as these insects responds quickly to environmental changes.

Macroinvertebrates that have been used as bioindicator responded to precursor flows (Konrad et al. 2008; Suren & Joweet 2006). Few studies have addressed the influence of seasons on EPT community in semi-humid tropical region (Bispo et al. 2006; Bispo & Oliveira 2007). At certain period of the year, seasonal variations influenced the EPT assemblages (Hawkins & Sedell 1981). Meanwhile, Oliveira and Froehlich (1997) and Bispo et al. (2004) observed a declining density of Trichoptera during the rainy season because of sudden increases in flow rate that may lead to stone rolling and consequential insect removal (Flecker & Feifarek 1994). In contrast, densities of Plecoptera nymphs in Almas River basin, Brazil were not affected by heavy rainfall (Bispo & Oliveira 2007). Thus, temporal distribution of EPT communities is controlled by the rainfall seasonality. In this regard, temporal variability of macroinvertebrate community needs consideration in order to establish reliable biomonitoring programs (Álvarez-Cabria et al. 2010). Hence, in detecting environmental disturbance, biomonitoring should be integrated from different season. In the present study, data on EPT abundance and environmental factor (rainfall) were obtained in order to determine the distribution of the EPT fauna on different season. This study was conducted with hypothesis that EPT assemblages in the Gunung Jerai Forest Reserve (GJFR) were different by seasonal variation.

Materials and Methods

Study Sites

This study was carried out in rivers of Gunung Jerai Forest Reserve (GJFR) in the state of Kedah, in the northern peninsular Malaysia. The localities of the sites are: Tupah River (N5°45.008' E100°26.526'), Batu Hampar River (N5°46.668' E100°23.835') and Teroi River (N5°48.328' E100°25.913'). Tupah and Batu Hampar rivers flow through low land dipterocarp forest at 100-300 m above sea level while the Teroi River flows through a hill dipterocarp forest at 1200 m above sea level.

EPT Sampling

Ephemeroptera, Plecoptera and Trichoptera (EPT) were sampled every month (September 2007-August 2008) from Tupah, Batu Hampar and Teroi rivers, using kick sampling technique, a modified method of Merritt et al. (2008). A detailed description of the sampling procedure can be found elsewhere (Suhaila & Che Salmah 2010).

Weather Data

In tropical region, seasonality was determined from periodic change in rainfall, caused by movements of the inter-tropical convergence zone (ITCZ) (Van Schaik et al. 1993). The Malaysian Meteorological Department divided the climate of northern part of Malaysia into dry and wet seasons based on the amount of precipitation collected. Precipitation below than 200 mm per month was considered as dry month and precipitation more than 200 mm per month was categorized as wet month (www.met.gov.my). The period, January 2008 to July 2008 represented the dry season, while September 2007 to December 2007 and August 2008 represented the wet season (Figure 1). Mean annual rainfall for the year 2008 was 2301.3 mm in Kuala Muda district.

Data Analyses

The Kruskal-Wallis test was used to determine the influence of seasonal variation on the abundances of EPT because the abundance data were not normally distributed. It is also

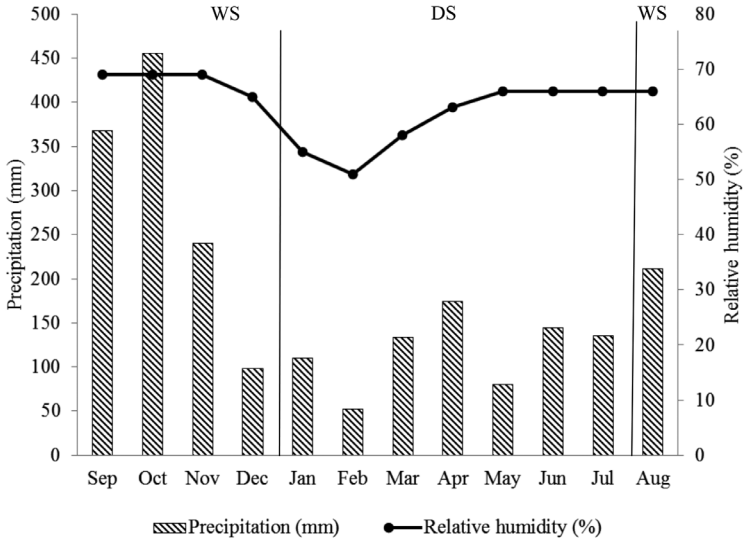

FIGURE 1. Climatic conditions in Tupah, Batu Hampar and Teroi rivers, Kedah. The data shown are (1) relative humidity (%) and (2) monthly precipitation from September to December 2007 and from January until August 2008 provided by Meteorology Department of Malaysia, Kuala Lumpur

used to determine any significant difference in scores of all indices across the months of sampling in all rivers. All statistical analyses were analyzed using the SPSS (Statistical Package for Social Science) version 14®. The diversity of the EPT fauna was evaluated through an index of diversity (Shannon-Wiener index), richness (Menhinick index) and evenness (Pielou index) in both wet and dry seasons.

RESULTS

Overall, Teroi River had higher EPT abundance than Batu Hampar and Tupah rivers regardless of season. More EPT were found in the wet season (10664 individuals) compared with the dry season (6599 individuals) (Table 1). In contrast, higher diversity was recorded in the dry season (29 taxa) compared with 25 taxa recorded in wet season from all rivers. Based on Table 2, the three most abundant genera were *Baetis* (Ephemeroptera: Baetidae) (58.5%), *Neoperla* (Plecoptera: Perlidae) (8.2%) and *Cheumatopsyche* (Trichoptera: Hydropsychidae) (7.1%). Among the three rivers, the genus *Baetis* (Ephemeroptera: Baetidae) was widely distributed, especially in the Teroi River (81.6%). *Neoperla* (Plecoptera: Perlidae) (24.7%) and *Cheumatopsyche* (Trichoptera: Hydropsychidae) (19.3%) were most abundant in the Tupah River.

Figure 2 shows the pattern of EPT distribution in three rivers during the two seasons, wet and dry. In all three rivers, ephemeropteran populations peaked during the early phase of the first wet season. Thereafter, their populations in Batu Hampar and Tupah rivers sharply decreased as seasons progressed. In Teroi River, ephemeropteran populations rebounded at the end of the dry season, showing a second but lower peak of abundance in May 2008 (Figure 2(a)). The Mann-Whitney U test shows there was a significant difference in Ephemeroptera abundances in both wet and dry seasons ($z=-2.465$, $p=0.014$).

The plecopteran population was low and almost constant throughout seasons in all rivers. Plecopterans exhibited different pattern of abundance during the wet season in Teroi, Tupah and Batu Hampar rivers (Figure 2(b)). The population fluctuated through the seasons with no apparent peak in Batu Hampar River but in Tupah River, a very low peak was observed at the beginning of the dry season. Very low population of Plecoptera occurred in Teroi River. Based on the results of Mann-Whitney U test, there was a significant difference in Plecoptera abundances in both wet and dry seasons ($z=-2.280$, $p=0.023$).

Trichopterans exhibited the highest peak of abundance in Tupah River at the beginning of the dry season and decreased drastically thereafter. In contrast, Trichoptera population in Batu Hampar River increased to a peak at the end of the second wet season. In Teroi River, the population of level of this group was low and almost constant throughout the seasons (Figure 2(c)). The Mann-Whitney U test shows a significant difference in Trichoptera abundances in both wet and dry seasons ($z=-6.096$, $p= 0.00$).

All scores of ecological indices (Shannon-Wiener, Pielou Evenness and Menhinicks indices) were higher during the dry season (Figure 3). The Shannon-Wiener index recorded in Tupah River in this season was generally higher than those obtained from Batu Hampar and Teroi rivers. The Menhinicks Index was recorded higher during the dry season. However, the highest Menhinicks Index was recorded in Batu Hampar River in October 2007 during the wet season ($r=1.877$). The evenness index was high during the dry season in all rivers except in Teroi River. All indices tested were recorded lowest in Teroi River compared with other rivers. The Kruskal-Wallis test showed there was a significant difference among indices in all rivers (Shannon-Wiener index, $X^2=22.091$, $p=0.00$; Simpson's index, $X^2=19.645$, $p=0.00$; Pielou index, $X^2=27.648$, $p=0.00$; Menhinick index, $X^2=15.689$, $p=0.00$).

DISCUSSION

In the GJFR, more immature (10664 individuals) were collected during the wet season (September to December 2007 and August 2008) than in the dry season (January to July 2008) (6599 individuals). This present study observed high occurrence of EPT during the wet season, which is compatible with the findings of Bispo et al. (2004) and Flecker and Feifarek (1994). Studies carried out in the Cerrado region (Oliveira & Froehlich 1997) and other tropical regions (Flecker & Feifarek 1994; Jacobsen & Encalada 1998) found that rainfall influenced the abundance of macroinvertebrate fauna. However, the patterns of abundance were not similar to all EPT orders.

The EPT abundance was high in wet season while the diversity was at its highest in dry season. Based on Shannon-Wiener index, Tupah River had the most diverse EPT assemblage during the dry season, due to the presence of many genera in the collection. In this case, the dissimilarity between the three rivers could be explained

TABLE 1. Abundances and diversity of EPT in Tupah, Batu Hampar and Teroi rivers of Gunung Jerai Forest Reserve, Kedah

River	Wet season		Dry season		Total	
	Abundance	Diversity	Abundance	Diversity	Abundance	Diversity
Tupah	2403	24	1895	28	4298	28
Batu Hampar	2080	21	1270	24	3350	25
Teroi	6181	17	3434	20	9667	22
Total	10664	25	6599	29	17315	29

TABLE 2. Mean abundances of Ephemeroptera, Plecoptera and Trichoptera (individuals/samples ± SE) collected in Tupah, Batu Hampar and Teroi rivers from Gunung Jerai Forest Reserve, Kedah. All samples were collected from September 2007 to August 2008 (N = 240 samples/river), SE = standard error

Taxa		Mean abundance ± SE		
		Tupah River	Batu Hampar River	Teroi River
Ephemeroptera				
Baetidae	*Baetis*	117.1 ± 42.3	55.3 ± 35.6	606.8 ± 91.7
	Platybaetis	19.0 ± 4.7	5.8 ± 1.3	53.8 ± 23.0
	Centroptilum	1.7 ± 0.3	0.2 ± 0.1	3.3 ± 0.7
Caenidae	*Caenis*	5.8 ± 0.5	4.2 ± 0.6	0
Heptageniidae	*Campsoneuria*	1.2 ± 0.4	1.8 ± 0.8	7.7 ± 3.9
	Thalerosphyrus	14.2 ± 6.7	13.9 ± 2.0	53.8 ± 14.0
	Epeorus	2.5 ± 0.7	0.9 ± 0.3	2.2 ± 0.8
Leptophlebiidae	*Habrophlebiodes*	4.0 ± 2.0	5.3 ± 2.4	0
Tricorythidae	*Tricorythus*	3.8 ± 2.0	4.8 ± 2.5	0.2 ± 0.2
Ephemerellidae	*Crinitella*	1.2 ± 0.6	0	0.3 ± 0.2
Teloganodidae	*Teloganodes*	0.23 ± 0.1	0	1.1 ± 0.7
Oligoneuridae	*Isonychia*	0	1.2 ± 0.8	0
Plecoptera				
Perlidae	*Neoperla*	41.5 ± 5.2	65.2 ± 6.2	2.6 ± 0.8
	Phanoperla	2.7 ± 0.5	4.5 ± 0.8	0.6 ± 0.3
	Kamimuria	3.1 ± 0.5	1.2 ± 0.3	0.8 ± 0.3
	Etrocorema	0.8 ± 0.2	0.2 ± 0.2	0
Peltoperlidae	*Cryptoperla*	1.6 ± 0.4	1.4 ± 0.4	0
Nemouridae	*Indonemoura*	0.8 ± 0.3	0.8 ± 0.3	0.2 ± 0.1
Tricoptera				
Philopotamidae	*Chimarra*	12.1 ± 1.4	17.7 ± 5.0	3.2 ± 0.6
Hydropsychidae	*Hydropsyche*	18.6 ± 7.3	29.8 ± 11.3	1.7 ± 0.5
	Cheumatopsyche	63.2 ± 27.4	30.0 ± 8.7	1.8 ± 0.5
	Macrostemum	8.8 ± 3.3	3.2 ± 0.7	0.9 ± 0.3
	Diplectrona	4.3 ± 0.9	5.2 ± 1.6	1.1 ± 0.4
Calamoceratidae	*Ganonema*	0.3 ± 0.1	0.2 ± 0.1	0
Ecnomidae	*Ecnomus*	0.5 ± 0.2	3.0 ± 0.6	0.8 ± 0.3
Lepidostomatidae	*Lepidostoma*	0.6 ± 0.3	1.9 ± 0.5	0
Rhyacophilidae	*Rhyacophila*	0.8 ± 0.3	0	0.9 ± 0.3
Leptoceridae	*Setodes*	0.2 ±0.1	0.4 ± 0.2	0.5 ± 0.1
Odontoceridae	*Marilia*	0.3 ± 0.1	0	0.2 ± 0.1

by a possible difference of environmental conditions. In environments with higher quantity of shelters such as boulders, cobbles and leaf litters, the effect of flow during spates maybe less drastic (Scarsbrook & Townsend 1993). In the dry season, the occurrence of high amount of organic matter in Tupah River favored certain genera of EPT to thrive well in its environment. However, high diversity index was scored by Batu Hampar River, which could be related to many genera collected in a sample. The abundance of insects per unit area was correspondingly high in the dry season. Low diversity, richness and evenness of EPT assemblages in Teroi River were mainly associated with its higher altitudes that made up a distinctive fauna (Bispo et al. 2006).

High abundances of Ephemeroptera were observed in the wet season in all rivers. In wet season, the abundance of ephemeropterans genera such as *Baetis*, *Platybaetis*, *Campsoneuria* and *Thalerosphyrus* increased tremendously. During the wet season in Teroi River, ephemeropterans such as *Epeorus, Baetis, Platybaetis, Centroptilum, Tricorythus, Teloganodes* and *Crinitella* were present (Suhaila et al. 2011). The improvement in water quality through reduction in organic matter or pollutant concentration (Bispo et al. 2006) provided more suitable environment for the ephemeropterans. However, higher total suspended contents have increased survivorship of *Thalerosphyrus, Campsoneuria, Epeorus, Baetis, Platybaetis, Centroptilum, Tricorythus, Teloganodes* and *Crinitella* species (Suhaila et al. 2011). Suspended particles can serve as carriers of nutrients thus have effect on food availability (Dahlgren et al. 2004). In addition, the abundance of Ephemeroptera could be attributed to other possible factors such as high recruitments of immature EPT. Study by Flint (1991) has

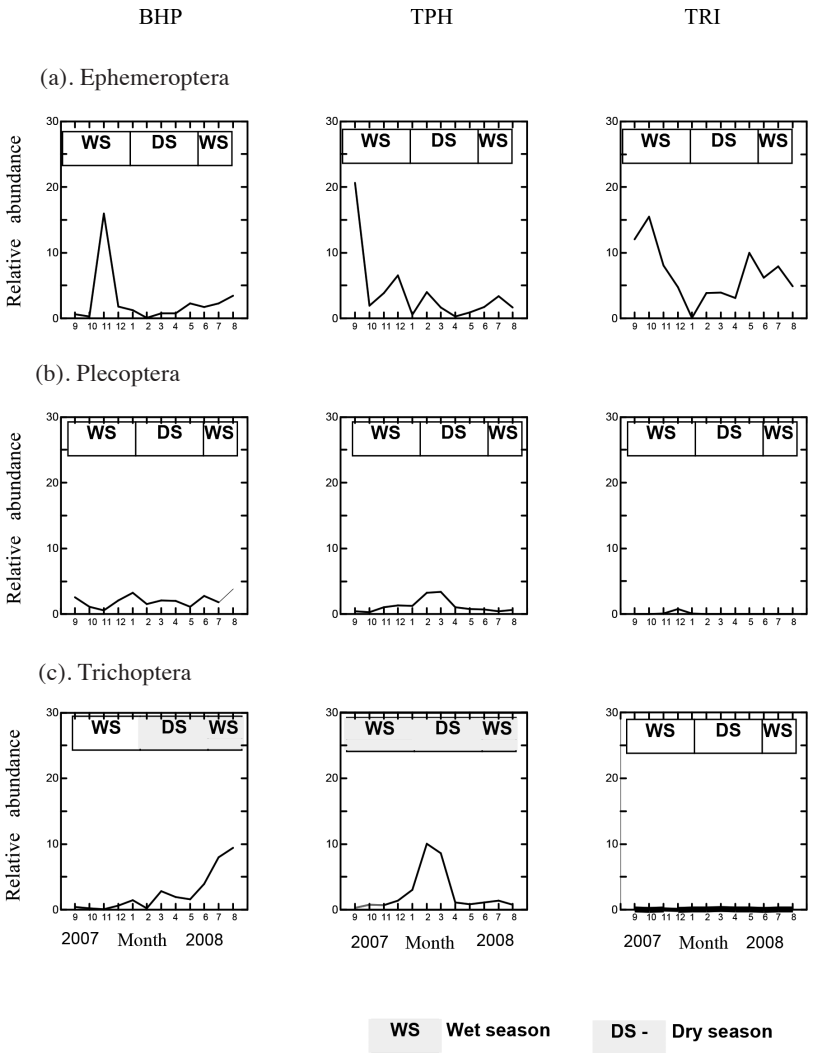

FIGURE 2. Monthly and seasonal variation patterns of ephemeropterans (a), plecopterans, (b) and trichopterans (c) in three rivers; Batu Hampar (BHP), Tupah (TPH) and Teroi (TRI) rivers of the Gunung Jerai Forest Reserve, Kedah

found aquatic insects adult emerge in large numbers in the wet season and disperse eggs with the stream discharge.

Ephemeropterans *Baetis* recorded the highest abundance in all rivers especially in Teroi River. In Cowan Creek and South Duck River, Manitoba, Flannagan et al. (1990) found over 80% of the specimens collected were Baetidae. Edmunds (1972) recognized Baetidae as the most opportunistic family. The greater abundance of *Baetis* present in Teroi River was probably attributed to the stable bedrock surfaces (Suhaila et al. 2011). For *Thalerosphyrus*, the flattened body and streamlined dorsum help them to scrape off periphyton on substrate surface (Rice & Greenwood 2001). It was observed that Teroi River has plenty of periphyton on its bedrock surface confluence the *Thalerosphyrus*. Furthermore, periphyton favored large, hard substrates as their habitat (Feminella & Hawkins 1995; McCormick 1996). This rheophilic (current loving) creatures (*Thalerosphyrus*) are excessively abundant in Teroi River where current was very fast especially in wet season. Survivals of *Baetis* and *Thalerosphyrus* were higher in the wet season, which confirmed that *Baetis* and *Thalerosphyrus* were highly adapted to live in large substrates and fast current. According to Buss et al. (2004), the effect of a spate act differently depending on the stream discharge. Scrimgeour and Winterbourn (1989) observed that insects utilize a mechanism such as refuge-seeking behavior to resist spates. Meanwhile Ramirez and Pringle (2001) have found benthic communities in tropical streams had continuous reproduction throughout the year and remain high in abundance.

In contrast, Trichoptera had a decreased in abundance in all rivers during the wet season. The trichopteran fauna was influenced by the rainfall probably because the river received greater disturbance of their beds (bedrocks) with increased in drift and dispersion of the fauna (Bispo et al. 2004). In addition, higher water level in the wet season turned the riverbed to less conducive for Trichoptera, thus reduce their abundance (Dudgeon 1997). The higher frequencies of disturbances due to increase of flow rate

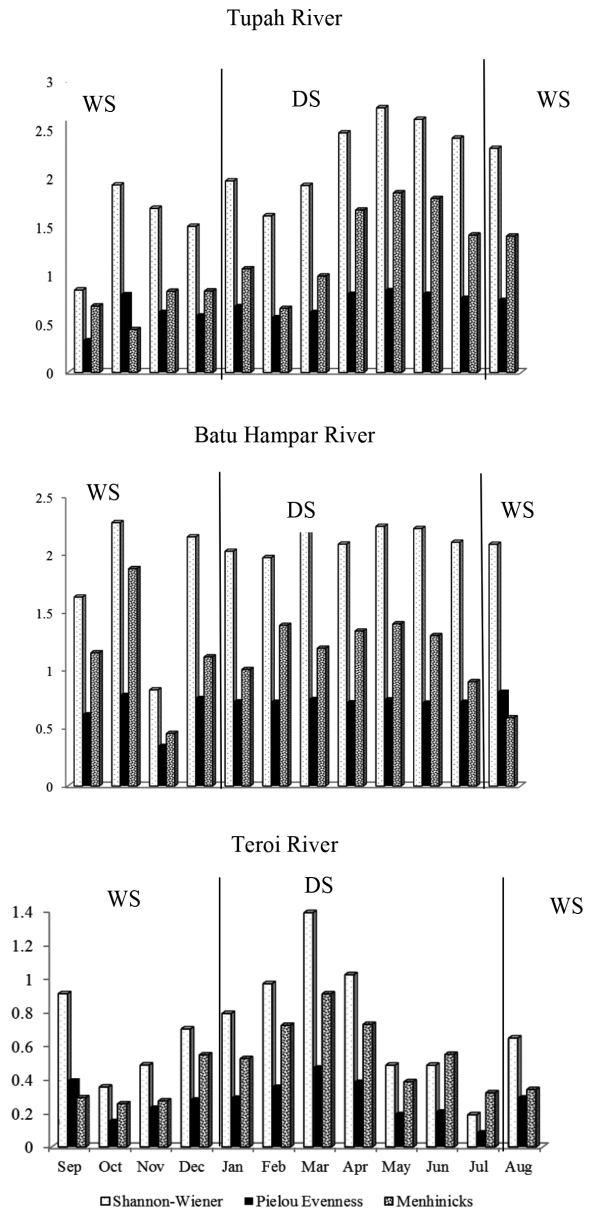

FIGURE 3. Spatial and temporal variations in the diversity, richness and evenness indices of EPT. WS-wet season, DS-dry season

have decreased the number of Trichoptera in wet season (Flecker & Feifarek 1994; Jacobsen & Encalada 1998).

The reduction of Trichoptera abundance during the wet season can be related to environmental disturbances provoked by rain in certain periods of the year or by diminution of organism aggregation, due to rising of the water level in rainy periods (Bispo & Oliveira 2007). *Cheumatopsyche* and *Hydropsyche* constructed nets and reside on the substrates surface. The nets probably collapsed or diminished by the fast current or the movement of the loose substrate. Moreover, frequent spates probably flushed away certain genera of Trichoptera especially the free living genera that cannot withstand the hydraulic stresses. At this time, sudden increases in flow caused streambed translocation (Bispo et al. 2006), with the consequent removal of insects and a reduction in their local abundance (Flecker & Feifarek 1994). In the wet season, the perturbations are more intense and frequent; disturbed habitats take longer time to recover (Bispo et al. 2006).

Meanwhile, the Plecoptera population was low and almost constant throughout the seasons in all rivers of GJFR. Among the three rivers, more Plecoptera were found in Batu Hampar River that had high stability of the riverbed, hence low disturbance because of less surface runoff. Plecoptera preferred many type of microhabitats such as boulder surfaces, cobble and gravel interstices, debris accumulations and leaf packs (Che Salmah et al. 2001). In Batu Hampar River dense riparian vegetation formed thick canopy cover (65% shaded). In addition, denser vegetation may provide more leaf debris (allocthonous) as food for the plecopterans. There is more allocthonous material in places with dense vegetation cover (Bispo et al. 2006). A number of plecopteran families feed upon the decaying plant material (Hynes 1976).

CONCLUSION

EPT fauna in rivers of GJFR was influenced by seasonal variations. The EPT abundance was highest during wet season while their diversity was highest in dry season. The effect of season on temporal and spatial changes in this study was dissimilar for the three insect orders. Ephemeroptera was abundant in the wet season while Trichoptera preferred the dry season. Improvements of water quality such as reduction in water pollutants and high nutrient during the wet season provided a better environment for the ephemeropterans. Trichopterans survived well in slow current and low water level in dry season as these condition helped to reduce their net from collapsed or diminished. However, plecopteran's abundance was not influenced by seasonal variations. Plecoptera preferred stable riverbed so indirectly they are less susceptible to surface run-off. Season variation have formed changes in the environmental characteristics and thus influenced the number of individual and diversity of EPT at GJFR rivers.

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REFERENCES

Álvarez-Cabria, M., Barquin, J. & Antonio, J.J. 2010. Spatial and seasonal variability of macroinvertebrate metrics:

Do macroinvertebrate communities track river health?. *Ecological Indicators* 10: 370-379.

Ameilia, Z.S. 2000. *Komposisi dan Kepelbagaian Serangga Akuatik di 16 sungai di Lembangan Sungai Kerian (LSK) dan Kaitannya terhadap Kualiti Air Sungai*., MSc. thesis. Universiti Sains Malaysia, Penang (Unpublished).

Bishop, J.E. 1973. *Limnology of Small Malayan river, Sungai Gombak*. The Hague. Netherlands: Dr Junk W. Publishers.

Bispo, P.C. & Oliveira, L.G. 2007. Diversity and structure of Ephemeroptera, Plecoptera and Trichoptera (Insecta) assemblages from riffles in mountain streams of Central Brazil. *Revista Brasileira de Zoologia* 24: 283-293.

Bispo, P.C., Oliveira, L.G., Bini, L.M. & Sausa, K.G. 2006. Ephemeroptera, Plecoptera and Trichoptera assemblages from riffles in mountain streams of central Brazil: Environmental factors influencing the distribution and abundance of immatures. *Brazilian Journal of Biology* 66: 611-622.

Bispo, P.C., Oliveira, L.G., Crisci-Bispo, V.L. & Sousa, K.G. 2004. Environmental factors influencing distribution and abundance of trichopterans in Central Brazilian mountain streams. *Studies on Neotropical Fauna and Environment* 39: 233-237.

Bright, G.R. 1982. Secondary benthic production in a tropical island stream. *Limnology Oceanography* 27: 472-480.

Brittain, J.E. 2008. Mayflies, biodiversity and climate change. In *The International Advances in the Ecology, Zoogeography and Systematics of Mayflies and Stoneflies,* edited by Hauer, F.R., Stanford, J.A. & Newell, R.L. Berkeley and Los Angeles, California. University of California Press. DOI:10.1525/california/9780520098688.003.0001.

Buss, D.F., Baptista, D.F., Nessimian, J.L. & Egler, M. 2004. Substrate specificity, environmental degradation and disturbance structuring macroinvertebrate assemblages in neotropical streams. *Hydrobiologia* 518: 179-188.

Che Salmah, M.R., Amelia, Z.S. & Abu Hassan, A. 2001. Preliminary distribution of Ephemeroptera, Plecoptera and Trichoptera (EPT) in Kerian River Basin, Perak, Malaysia. *Pertanika Journal Tropical Agriculture and Science* 24: 101-107.

Dahlgren, R., van Nieuwenhuyse, E. & Litton, G. 2004. Transparency tube provides reliable water quality measurements. *California Agriculture* 58: 149-153.

Denlinger, D.L. 1980. Seasonal and annual variation of insect abundance in the Nairobi National Park, Kenya. *Biotropica* 12: 100-106.

Dudgeon, D. 1997. Life histories, secondary production and microdistribution of hydropsychid caddisflies (Trichoptera) in a tropical forest stream. *Journal of Zoology* 243: 191-210.

Dudgeon, D. 2008. *Tropical Stream Ecology*. California: Elsevier Inc.

Edmunds, G.F. 1972. Biogeography and evolution of Ephemeroptera. *Annual Review of Entomology* 17: 21-42.

Feminella, J.W. & Hawkins, C.P. 1995. Interactions between stream herbivores and periphyton: A quantitative analysis of past experiments. *Journal of North American Benthological Society* 14: 465-509.

Fjellheim, A., Harvardstun, J. & Raddum, G.G. 1993. Effects of increased discharge on benthic invertebrates in a regulated river. *River Research and Applications* 8: 179-187.

Flannagan, J.F., Cobb, D.G. & Friesen, M.K. 1990. The relationship between some physical factors and mayflies emerging from South Duck River and Cowan Creek, Manitoba. In *Mayflies and Stoneflies,* edited by Campbell, I.C. Netherlands: Kluwer Academic Publishers.

Flecker, A.S. & Feifarek, B. 1994. Disturbance and temporal variability of invertebrate assemblages in two Andean streams. *Freshwater Biology* 31: 131-142.

Flint, O.S. 1991. Studies of neotropical caddisflies, XLV: The taxonomy, phenology and faunistics of the Trichoptera of Antioquia, Colombia. *Smithsonian Contributions to Zoology* 52: 1-113.

Gopal, B. 2002. Conserving biodiversity in Asian wetlands: issues and approaches. In *The Asian Wetlands: Bringing Partnerships into Good Wetland Practices*, edited by Ali Ahyaudin, Che Salmah Md Rawi, Mashhor Mansor, Reiko Nakamura, Sundari Ramakrishna & Taej Mundkur. Pulau Pinang, Malaysia: Penerbit Universiti Sains Malaysia.

Hawkins, C.P. & Sedell, J.R. 1981. Longitudinal and seasonal-changes in functional-organization of macroinvertebrate communities in 4 Oregon streams. *Ecology* 62: 387-397.

Hynes, H.B.N. 1976. Biology of Plecoptera. *Annual Review of Entomology* 21: 135-153.

Hynes, H.B.N. 1970. *The Ecology of Running Waters*. Toronto, Canada: University of Toronto Press.

Jacobsen, D. & Encalada, A. 1998. The macroinvertebrate fauna of Ecuadorian high-land streams in wet and dry season. *Archives fur Hydrobiology* 142: 53-70.

Jongkar ak Grinang. 2000. Kepelbagaian serangga akuatik di sungai-sungai kawasan hutan tadahan empangan Temenggor, Perak. MSc Tesis. Universiti Sains Malaysia, Penang. (Unpublished).

Konrad, C.P., Brasher, A.M.D. & May, T. 2008. Assessing streamflow characteristics as limiting factors on benthic invertebrate assemblages in streams across the western United States. *Freshwater Biology* 53: 1983-1998.

McCormick, P.V. 1996. Resource competition and species coexistence in freshwater algal assemblages. In *Algal Ecology–Freshwater Benthic Ecosystems,* edited by Stevenson, R.J., Bothwell, M.L. & Lowe, R.L. New York: Academic Press.

Merritt, R.W., Cummins, K.W. & Berg, M.B. 2008. *An Introduction to the Aquatic Insects of North America*. 4th ed. Iowa: Kendall/Hunt Publishing Company.

Oliveira, L.G. & Froehlich, C.G. 1997. The Trichoptera (Insecta) fauna of a Cerrado stream in Southeastern Brazil. *Naturalia* 22: 183-197.

Owen, D.F. & Owen, J. 1974. Species diversity in temperate and tropical Ichneumonidae. *Nature* 249: 583-584.

Payne, A.I. 1986. *The Ecology of Tropical Lakes and Rivers*. Chichester: John Wiley and Sons.

Rami´rez, A. & Pringle, C.M. 2001. Spatial and temporal patterns of invertebrate drift in streams draining a Neotropical landscape. *Freshwater Biology* 46: 47–62.

Rice, S.P. & Greenwood, M.T. 2001. Macroinvertebrate community changes at coarse sediment recruitment points along two gravel bed rivers. *Water Resources Research* 37: 2793-2803.

Robinson, C.T. & Minshall, G.W. 1986. Effects of disturbance frequency on stream benthic community structure in relation to canopy cover and season. *Journal of the North American Benthological Society* 5: 237-248.

Scarsbrook, M.R. & Townsend, C.R. 1993. Stream community structure in relation to spatial and temporal variation: A habitat template study of two contrasting New Zealand streams. *Freshwater Biology* 29: 395-410.

Scrimgeour, G.J. & Winterbourn, M.J. 1989. Effects of floods on epilithon and benthic macroinvertebrate populations in an unstable New Zealand river. *Hydrobiologia* 171: 33-44.

Silveira, M.P., Buss, D.F., Nessimian, J.L. & Baptista, D.F. 2006. Spatial and temporal distribution of benthic macroinvertebrates in a southeastern Brazilian River. *Brazilian Journal of Biology* 66: 623-632.

Suhaila Abdul Hamid, Che Salmah, M.R., Hamady, D., Abu Hassan, A., Tomomitsu, S., Fumio, M. & Michael, B. 2011. Seasonal changes in mayfly communities and abundance in relation to water physico-chemistry in two rivers at different elevations in northern Malaysia. *Wetland Science* 9(3): 240-250.

Suhaila, A.H. & Che Salmah, M.R. 2010. Influence of substrate, embeddedness and canopy cover on the abundance and diversity of Ephemeroptera, Plecoptera and Trichoptera (EPT) in tropical rivers. *Aquatic Insects* 33: 281-292.

Suren, A.M. & Jowett, I.G. 2006. Effects of floods versus low flows on invertebrates in a New Zealand gravel-bed river. *Freshwater Biology* 51: 2207-2227.

Van Schaik, C.P.V., Terborgh, J.W. & Wright, S.J. 1993. The phenology of tropical forests: Adaptative significance and consequences for primary consumers. *Annual Review of Ecology and Systematics* 24: 353-377.

Wolda, H. & Flowers, W. 1985. Seasonality and diversity of mayfly adults (Ephemeroptera) in a 'non-seasonal' tropical environment. *Biotropica* 17: 330-335.

Wolda, H. 1979. Seasonality parameters for insect populations. *Research Population and Ecology* 20: 247-256.

Wolda, H. 1978. Seasonal fluctuations in rainfall, food and abundance of tropical insects. *Journal of Animal Ecology* 47: 369-381.

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