TRICHOPTERA LARVAE DIVERSITY IN RIVERS AT VARIOUS ELEVATION OF GUNUNG JERAI FOREST RESERVE, KEDAH, MALAYSIA

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ABSTRACT

The abundance and composition of Trichoptera in selected rivers play a significant ecological role in the study of streams, therefore, a study was conducted in three rivers of Gunung Jerai Forest Reserve; Tupah, Batu Hampar and Teroi rivers at altitude range from 200 m to 1214 m above sea level. A total of 2,623 Trichoptera larvae from 11 genera and eight families were collected from the three rivers using a D-frame net. Tupah River recorded the greatest prevalence of Trichoptera (52.3%), followed by Batu Hampar River (42.9%) and Teroi River with the least prevalence (4.8%). Certain genera of Trichoptera such as *Cheumatopsyche, Hydropsyche, Macrostemum, Ganonema, Chimarra, Diplectrona* and *Lepidostoma* corresponds to river physical parameters such as altitude, water velocity and water temperature ($P<0.05$). Results showed *Cheumatopsyche* from Hydropsychidae had the greatest abundance and diversity associated with high composition in Tupah River which located at lower altitude (200 m above sea level) ($r=-0.739$, $P<0.05$). From the number of Trichoptera genera collected in the three rivers at different altitude, clearly show that these caddisflies genera have adapted to live in river with different altitude with stony substrates.

Keywords: Altitude, caddisfly, distribution, diversity, rivers.

ABSTRAK

Kelimpahan dan komposisi Trichoptera di sungai terpilih memainkan peranan ekologi yang signifikan dalam kajian sungai, justeru suatu kajian telah dilakukan di tiga sungai di Hutan Simpan Gunung Jerai; Sungai Tupah, Sungai Batu Hampar dan Sungai Teroi pada jarak ketinggian dari 200 m hingga 1214 m dari aras laut. Sejumlah 2,623 larva Trichoptera daripada 11 genus dan lapan famili telah dikumpulkan dari ketiga-tiga sungai menggunakan jaring 'kerangka-D'. Sungai Tupah mencatatkan jumlah Trichoptera tertinggi (52.3%), diikuti oleh Sungai Batu Hampar (42.9%) dan Sungai Teroi (4.8%). Genus tertentu Trichoptera seperti *Cheumatopsyche, Hydropsyche, Macrostemum, Ganonema, Chimarra, Diplectrona* dan *Lepidostoma* berkorelasi dengan parameter fizikal sungai seperti ketinggian dari aras laut, halaju air dan suhu air ($P<0.05$). Keputusan menunjukkan *Cheumatopsyche* daripada Hydropsychidae mempunyai kelimpahan dan kepelbagaian terbesar yang berkorelasi dengan ketinggian iaitu di Sungai Tupah yang terletak di ketinggian rendah (200 m di atas paras laut) ($r=-0.739$, $P<0.05$). Berdasarkan bilangan genus Trichoptera yang dikumpulkan dari ketiga-tiga sungai pada aras ketinggian yang berbeza, jelas menunjukkan bahawa genus lalat

kandul ini telah menyesuaikan diri untuk hidup di sungai ketinggian yang lebih rendah dengan substrat berbatuan.

Kata kunci: Aras ketinggian, lalat kandul, taburan, kepelbagaian, sungai.

INTRODUCTION

The aquatic insects in Gunung Jerai Forest Reserve (GJFR) are relatively poorly known and received less attention to study. Aquatic insects play an important role in determining the quality of water as they have different level of sensitivity towards water pollution (Merrit et al. 2008). Ephemeroptera, Plecoptera and Trichoptera (EPT) are the orders that sensitive towards pollution. Trichoptera or its common name, caddisflies are closely related to butterflies and moths (order Lepidoptera) but have only a single pair of abdominal prolegs which are located on the terminal segment and each are equipped with an apical anal claw. The wings of the adults are covered by hairs unlike scale wings of Lepidoptera. They also have well-developed maxillary and labial palps but never the coiled proboscis (Merrit et al. 2008). According to De Moor and Ivanov (2008), there were 12,627 species, 610 genera and 46 families of Trichoptera all over the world. Trichoptera larvae are best known for the cases (quite intricate in design) and fixed shelters and some are species construct.

Trichoptera are sensible towards habitat changes and severe natural events. Voshell and Reese (2002), make them as the best water quality indicator thus their relative abundance can be classified into very sensitive, sensitive, tolerant and very tolerant groups (Carter et al. 1996; Merrit et al. 2008). Caddisflies evolved in cool, fast flowing streams. Distribution and abundance of Trichoptera is strongly affected by its tolerance towards an array of environmental factors including river or stream physical. Altitude is important in structuring different fauna composition in lotic environment (Marchant et al. 1997) as it might have correlation with the temperature and thus probably influenced the trichopterans. According to Malicky and Chantaramongkol (1993) altitude which is part of the stream zonation could separate the caddisfly species. However, little documentation on the distribution of caddisflies from one water catchment area ranging from the lowest the highest elevation area being documented from Malaysia. Therefore, the objectives of this study were to investigate the Trichoptera assemblages at different elevations and the influence of physical parameters of the river on the trichopterans assemblage. This study provides a broad perspective of Trichoptera communities in GJFR catchment based on sample of tributary rivers draining the mountain ranges at elevations ranging from near the sea level up to 1214 meter above the sea level.

METHODOLOGY

Site Descriptions

Gunung Jerai Forest Reserve is located in Kedah, Peninsular Malaysia. Within Kedah itself, the Gunung Jerai stands at the border of Kuala Muda and Yan districts. The main vegetation here is dipterocarp forest (Corner 1988). Eight rivers flow down from the peak of Gunung Jerai Forest Reserve; Tupah, Batu Hampar, Teroi, Kubur Panjang, Seri Perigi, Titi Hayun, badak and Kunyit rivers (Kedah Department of Irrigation and Drainage). Nowadays, these rivers are used as picnic spots where visitors can enjoy refreshing air and cool water. Out of these eight rivers, three rivers were selected for this study as follows; Tupah River, Batu Hampar River and Teroi River based on their accessibility.

Tupah River
This second order river is situated within the catchment area of Gunung Jerai Forest Reserve. The fast flowing Tupah River (mean velocity, 0.56±0.157 m/s) has a water pH ranging from 5.03 to 6.66 while the yearly mean water temperature ranged from 22.8 to 25.7ºC. Tupah River flows through low land dipterocarp forest at 100-200 meters above sea level. The river substrates are predominantly cobbles and gravels (55%), and 45% are boulders. The sampling activities were done in this river at N5º45.008' E100º26.526'.

Batu Hampar River
This second order river flows through a populated village and fruit orchards in a low land dipterocarp forest at 300 meter a.s.l. The water flow is relatively fast (0.65±0.125 m/s) while pH of water ranges from 5.64 to 6.63. The mean water temperature ranges from 23.2 to 25.2ºC. In the Batu Hampar River, cobbles and gravel substrates were highly embedded (approximately 60%). The locals visit this place during the dry season, when the water flow is slower. Sampling activities for this study took place at N5º46.668' E100º23.835'.

Teroi River
This first order river is located high up on the Gunung Jerai at 1214 m a.s.l. in Gurun district. The water velocity of 1.22±0.123 m/s is the fastest among all rivers because the river flows over a steep slope. The water is acidic with pH values range from 4.06 to 6.21. The water temperature was between 19.1 to 22.0ºC. The sampling point was determined at N5º48.328' E100º25.913'.

Sampling of Trichoptera Larvae
Trichoptera larvae were sampled from Tupah, Batu Hampar and Teroi rivers, using kick sampling technique, a modified method of (Merritt et al. 2008). Twenty samples were collected randomly along a 100 m stretch at downstream area of each river. This was sufficient for EPT population representation (Elliott 1973; Radwell & Brown 2007) as defined a reasonable estimate of the population density as one that performs at least with standard error less than 20% as this study was carried out in the field.

Kick sampling technique requires a D-pond net frame (300 um mesh, 40 cm width and 30 cm height with 60 cm long of cone shaped net) was fitted to a 100 cm long handle. The D-pond net with its opening facing upstream was held vertically against the flow of water. One person positioned the net on river substrate while the other disturbed the substrates (boulders and gravels, leaf packs and woody debris) by feet, hands or pieces of wood in approximately 1 m^2 substrate area in front of the net for about two minutes. The larvae detached from the substrates were drifted into the net. Insects on pebbles, cobbles and woody debris were gently rubbed or scraped and collected inside the net. The content of each sample was transferred into a labelled plastic bag, fastened with a rubber band and brought to the laboratory.

In the laboratory, each sample was washed in a tray and screened through successive sieves of 1 mm followed by 250 mm mesh size. Trichoptera larvae were sorted visually using a pair of fine forceps. They were placed in universal bottles containing 75% ethyl alcohol (ETOH) and identified up to genus level to respective genera under a dissecting microscope, Olympus CX41 (Olympus Optical Co., Tokyo, Japan) using keys provided by Yule and Yong (2004).

River Physical Characteristics

River physical features such as hydrogenic potential (pH), water temperature and water velocity were recorded. The position of the rivers relative to sea level was recorded using Global Positioning System versatile navigator (GPS map 76 CSX Garmin®). The pH value and temperature was determined *in situ* using an electronic pH meter (HACH CO., Loveland, USA®). The river water velocity was determined by using a portable Velocity Autoflow Watch (JDC Instrument, Arizona, USA) and categorized following (Carter et al. 1996), fast flowing (>0.1 m/s), slow flowing (0.05-0.1 m/s) and non-moving (<0.05 m/s). The Rapid Bioassessment Protocols (Barbour et al. 1999) classified canopy cover into three categories: partly open received >70% of sunlight, partly shaded received 70%-40% of sunlight and shaded area was only penetrated by less than 40% sunlight. The amount of shaded water surface (canopy cover) was measured using a Densiometer (Wildco®).

Data Analysis

All data were subjected to Kolmogorov-Smirnov test to satisfy the normality of their distribution. The data were not normally distributed even after data transformation, so the distribution of mean abundance of Trichoptera among rivers was analyzed with Kruskal-Wallis test using the SPSS (Statistical Package for Social Science) version 23®. Sperman Correlation Analysis was also conducted using the same software to determine the correlation between the insects' taxa and river physical parameters that have been conducted. The ecological indices of Shannon-Wiener, Simpson, evenness or Pielou and Menhinick indices for each river were determined. The dominance (D) for each family in the habitat were calculated as described by (Oliveira &Vasconcelos 2010).

RESULTS

Throughout the sampling, 2,623 Trichoptera larvae of 11 genera from 8 families were collected from Tupah (1,425), Batu Hampar (1,126) and Teroi (129) rivers (Table 1). Tupah River recorded the highest prevalence of Trichoptera (52.3%), followed by Batu Hampar River (42.9%) and Teroi River (4.8%). The Kruskal-Wallis test shows there were significant differences of Trichoptera abundances among the three rivers (χ^2=145.19, *P*=0.00). Two Trichopteran genera (*Ganonema* and *Lepidostoma*) were not found from Teroi River and *Rhyacophila* and *Marilia* were not found in Tupah and Batu Hampar rivers. Among the trichopterans, *Cheumatopsyche* was the most common genus. Its mean abundance was the greatest in Tupah River and the least in Teroi River. Diversity of Trichopetra communities were much higher in Tupah River (H'=1.967) followed by Batu Hampar River (H'=1.561) and then Teroi River (H'=1.315) (Table 2). A similar pattern was shown by scores of Simpson Diversity Index (D). Tupah River (D=6.282) and the Batu Hampar River (D=3.899) scored high but low in Teroi River (D=2.605). Species richness for the Menhinick Index (R_1) was more or less similar among all rivers, ranging from 0.261-0.747.

Table 1. Mean of Density (ind/m^2±standard error) of Trichoptera in Tupah, Batu Hampar, Teroi rivers.

Family	Genus	Tupah River	Batu Hampar River	Teroi River
Hydropsychidae	*Hydropsyche*	15.1±6.9	30.1±1.0	1.4±0.4
	Macrostemum	9.5±3.46	3.17±0.73	1±0.35
	Cheumatopsyche	68.4±2.9	32.2±1.2	2±0.6
	Diplectrona	4.67±0.92	5.58±1.63	1.08±0.43
Ecnomidae	*Ecnomus*	0.5±0.26	3.08±0.63	0.92±0.36
Calamoceratidae	*Ganonema*	0.33±0.14	0.8 ± 0.08	0
Rhyacophilidae	*Rhyacophila*	0.83±0.27	0	1±0.3
Lepidostomatidae	*Lepidostoma*	0.67±0.31	2.08±0.57	0
Philopotamidae	*Chimarra*	12.9±1.2	19.2±5.2	3.5±0.6
Leptoceridae	*Setodes*	0.17±0.11	0.5±0.19	0.5±0.1
Odontoceridae	*Marilia*	0.33±0.19	0	0.17±0.11

Table 2. Evaluation of Trichoptera diversity using Shannon-Wiener Index (H'), Simpson's Index (D) and Menhinick Index (R), Pielou Evenness Index (E) for Tupah, Batu Hampar and Teroi rivers, Gunung Jerai, Kedah.

	River		
Ecological indices	Tupah	Batu Hampar	Teroi
Shannon-Wiener (H')	1.967	1.561	1.315
Simpson's (D)	6.282	3.899	2.605
Menhinick	0.747	0.261	0.291
Evenness	0.821	0.651	0.548

Ecnomidae and Lepidostomatidae occurred very frequently in Batu Hampar River (Table 3). Rhyacophilidae was frequently found in Tupah River but infrequent in Batu Hampar River. Calamoceratidae, Leptoceridae and Odontoceratidae were recorded infrequent in all studied rivers although encountered occasionally. Table 4 shows the water temperature in the three rivers ranging from 20.9 ºC to 24.4ºC. The water velocity was fastest in Teroi River (1.22±0.12 m/s) compared to other rivers. River physical parameters such as water temperature, canopy cover, water velocity and altitude showed significant correlations among the recorded genus of Trichoptera (Table 5). *Cheumatopsyche, Hydropsyche, Ganonema, Chimarra* and *Lepidostoma* showed significant correlation with canopy cover (open canopy), fast flowing water and cool water temperature ($P<0.05$). However, only *Macrostemum* did not show any significant difference with altitude ($P>0.05$) compared to other genus recorded.

Table 3. Number of genera, abundance (no. of individual), and dominance of Trichoptera families collected in three rivers of Gunung Jerai Forest Reserve, Kedah. TU-Tupah, BH-Batu Hampar, TR-Teroi rivers. D-Dominant ≥5%, A-Accessory 2.5%≤D≤5%, O-Occassional <2.5%.

Family	Number of genus			Abundance			Dominance (%)		
	TU	BH	TR	TU	BH	TR	TU	BH	TR
Philopotamidae	1	1	1	155	230	42	A	D	O
Hydropsychidae	4	4	4	1162	885	66	D	D	O
Calamoceratidae	1	1	0	4	2	0	O	O	O
Ecnomidae	1	1	1	6	39	11	O	O	O
Lepidostomatidae	1	1	0	8	25	0	O	O	O
Rhyacophilidae	1	0	1	10	0	12	O	O	O
Leptoceridae	1	1	1	2	6	6	O	O	O
Odontoceridae	1	0	1	4	0	2	O	O	O
Total	11	9	9	1351	1187	139			

Table 4. Mean (±standard error) values of physical parameters of the rivers in Gunung Jerai Forest Reserve, Kedah.

	River		
Physical parameter	Tupah	Batu Hampar	Teroi
Location	N5°45.008’ E100°26.526’	N5°46.668’ E100°23.835’	N5°48.328’ E100°25.913’
Position relative to sea level (m)	200	300	1214
Water acidity (pH)	6.02±0.12	6.06±0.11	4.97±0.21
Water temperature (°C)	24.4±0.28	24.2±0.198	20.9±0.28
Water velocity (m/s)	0.56±0.16	0.65±0.13	1.22±0.12
Canopy cover (% shaded)	20.2±0.12	70.1±0.14	50.2±0.23

Table 5. Correlation results between Trichoptera taxa and physical parameters of studied rivers that show significant correlation.

	Cheumatopsyche	*Hydropsyche*	*Macrostemum*	*Ganonema*	*Chimarra*	*Diplectrona*	*Lepidostoma*
Canopy	-0.700**	-0.572**	-0.10	-0.513*	-0.701**	-0.382	-0.421*
Velocity	0.526**	0.538**	0.512*	0.470*	0.439*	0.593**	-0.455*
Temperature	0.511*	0.588**	0.414*	0.501*	0.577**	0.679**	0.486*
Altitude	-0.739**	-0.639**	-0.232	-0.447*	-0.761**	-0.576**	-0.445*

*correlation is significant at the 0.05 level (2-tailed)
**correlation is significant at the 0.01 level (2-tailed

DISCUSSION

The alpha diversity indices which are Shannon-Wiener index and Simpson's index were recorded greates in Tupah River. Therefore, Tupah River has the most diverse Trichoptera assemblages compared to Teroi and Batu Hampar rivers. This indicates that Tupah River provided more suitable habitat for caddisflies with high preference of certain genera such as *Cheumatopsyche* from Hydropsychidae. It is important to consider the number of taxa (genus) because a richer community is reflecting a healthier environment. According to Mason et al. (2003), the Shannon-Wiener's Index (H') corresponded to undisturbed environments of high diversity and evenly distributed individuals among species.

Tupah River had more common genera of caddisflies compared to other rivers as it can be contributed by the differences in the river physical and hydrological conditions. Trichoptera had greatest abundance in Tupah River represented by *Cheumatopsyche* and *Hydropsyche.* Characteristics of river banks and the presence of solid substrates on the river bottom such as stones, gravel, roots, plants, dead woods and some artificial structures like concrete walls determine the abundance of this insect (Serafin 2004). The substrates of Tupah River consist of boulder, cobble and gravel accomodated the highest composition and abundance of Trichoptera. Tupah River of optimally embedded substrates has 85% surface area of its various sizes stony substrates available for Trichoptera habitats. According to Costa and Melo (2008), streams can provide a multiplicity of microhabitats with combination of environmental factors and it was found that similar habitat structure and hydrological conditions resulting in similar richness (Novelo-Gutierrez & Gomez-Anaya 2009).

Cheumatopsyche, Hydropsyche, Ganonema, Chimarra, Diplectrona and *Lepidostoma* showed preferences for rivers at middle altitude (Tupah and Batu Hampar rivers). Definition of lower altitude is, no higher than 200 m (660 ft) from above sea level, while uplands are considering from 200 m (660 ft) to 500 m (1,600 ft) from above sea level. Rivers located at lower altitude usually have rivers with warm, slow flowing water. The geology of rivers at the middle elevation dominated by coarse sediments and cooler water temperatures (Dean 2008). *Ganonema* and *Lepidostoma* were found in Tupah and Batu Hampar rivers but none in Teroi River mainly because Teroi River has slippery bedrock and fast water current. This type of habitat did not allow leaf accumulation in the river bed. *Ganonema* constructed its case with large pieces of leaves or bark while *Lepidostoma*'s case is usually square in cross section and composed of leaf and bark fragments (Triplehorn & Johnson 2005). Therefore, Teroi River cannot provide suitable habitat for these two genera. Meanwhile, *Rhyacophila* was absent in Batu Hampar River most likely because Batu Hampar River had less boulders and cobbles (large substrates) compared to Tupah and Teroi rivers. *Rhyacophila* larvae move actively but fasten themselves to large rock before pupation (Wiggins et al. 1994) so it requires boulders and cobbles substrate to complete their life cycle and Batu Hampar River was not suitable for that purpose. Trichoptera can be found in varied microhabitats, therefore the river bottom material should be diversified (Serafin 2004). Trichoptera diversity was usually great due to the differences in their type of cases that allows the species to exploit various resources of a habitat.

At middle elevation, it is found that the water velocity is medium for example the mean water velocity for Tupah River was 0.56±0.16 (m/s). This condition is preferred by the Hydropsychidae and correlation shows significant correlation with this parameter (*Hydropsyche*: r=0.526 $p<0.05$, *Cheumatopsyche*: r=0.538 $p<0.05$, *Macrostemum*: r=0.512, $p<0.05$). According to Philipson (2010), *Hydropsyche instabilis* larvae tend to increase the

number of their undulatory abdominal movements in slow water current. Slow moving water flow may cause stress to this larva. Hydropsychidae larvae are collector-gatherers thus it relies upon water current for feeding.

CONCLUSION

The Trichoptera fauna of GJFR was quite diverse. This was clearly shown in Hydropsychidae and Calamoceratidae. However, the diversity of hydropsychids in Teroi River (located at higher altitude) was low compared to other rivers and likely due to low water temperature and bedrock formation of the river. This suggests that different taxa of caddisfly require specific habitat and most of them may prefer river at middle elevation level due to substrate type, moderate water flow and warm water temperature.

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