SEASONAL INFLUENCE ON STRUCTURING AQUATIC INSECTS COMMUNITIES IN UPSTREAM RIVERS BELUM-TEMENGOR FOREST COMPLEX

[PENGARUH MUSIM TERHADAP STRUKTUR KOMUNITI SERANGGA AIR DI HULU SUNGAI KOMPLEKS HUTAN BELUM-TEMENGOR]

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ABSTRACT

The plausible effect of seasonal change (wet and dry) on the structure of aquatic insect community was investigated at rivers in Belum-Temengor Forest Complex (BTFC), Perak, Malaysia. The amount of rainfall received was considered as seasonal changes in the tropical regions. The rivers were visited twice in dry and wet seasons to sample aquatic insects using rectangular aquatic nets. Their abundance and richness varied significantly between both dry and wet seasons (P = 0.000; Mann-Whitney U test). More aquatic insect was collected in dry seasons (17,633 individuals) compared to wet seasons (6,542 individuals). The aquatic insect abundance decreased tremendously during the wet seasons (45% reduction) and diversity showed fewer species richness in the wet season (98 genera) compared to the dry season (114 genera). The most affected taxa caused by the heavy water flow were *Ceratopsyche* sp. (family Hydropschidae and subfamily Limoniinae which huge reduction in density occurred during the wet season. Water temperature, BOD_3, DO and COD were significantly different between seasons (Kruskal Wallis test, $P < 0.05$). The presence of phosphorus and ammonia-nitrogen in water during dry season had major influence on the aquatic insect composition while rainfall was the main factor that regulated the insect communities in wet seasons.

Keywords: Bioindicator, biomonitoring, seasonal change, undisturbed rivers.

ABSTRAK

Kesan perubahan musim kering dan basah terhadap struktur komuniti serangga akuatik di kaji di sungai kompleks Hutan Belum-Temengor, Perak, Malaysia. Jumlah taburan hujan yang diterima dianggap sebagai perubahan musim bagi negara di rantau tropika. Sungai yang dipilih telah dilawati sebanyak dua kali pada musim kering dan musim basah bagi tujuan persampelan serangga akuatik dengan menggunakan jaring akuatik berbentuk segiempat tepat. Kelimpahan dan kekayaan spesies serangga akuatik adalah sangat ketara di kedua-dua musim kering dan basah (P = 0.000; Mann-Whitney U *test*). Lebih banyak serangga akuatik dikumpul pada musim kering (17,633 individu) berbanding musim basah (6542 individu). Kelimpahan serangga akuatik menunjukkan penurunan yang mendadak pada musim basah (45%

penurunan) dan kepelbagaian spesies juga adalah kurang pada musim basah (98 genus) berbanding musim kering (114 genus). Taksa yang paling terjejas disebabkan oleh arus air sungai yang deras adalah *Ceratopsyche* sp. (famili Hydropschidae), manakala subfamilii Limoniinae mengalami pengurangan individu yang tertinggi semasa musim basah. Suhu air, BOD_3, oksigen terlarut dan COD menunjukkan perbezaan signifikan antara musim (Kruskal Wallis test, $P < 0.05$). Kehadiran fosforus dan ammonikal-nitrogen dalam air pada musim kering memeberikan kesan utama terhadap komposisi serangga akuatik, manakala kadar hujan pula merupakan faktor utama dalam mengawal komuniti serangga akuatik pada musim basah.

Kata kunci: Bioindikator, pemantauan biologi, perubahan musim, sungai tidak terganggu.

INTRODUCTION

In a freshwater study, aquatic insects' assemblages have been widely established as an important element in the ecological dynamics of lotic environments (Bispo et al. 2006). The distribution pattern of aquatic insects' communities resulted from the interaction of physicochemical parameters has been an interest to the river ecologists in earlier studies (Vannote et al. 1980). Among the parameters commonly encountered in the river studies, the water temperature (Merritt et al. 2008) and seasonal changes (Melo & Froehlich 2001; Suren & Jowett 2006) have received much attention over the years. The hydrological variability in an ecosystem is a primary factor controlling the distribution of biotic fauna (Wood et al. 2001). This variation can be one of the causes of decreasing of insects abundances in rivers (Death 2008). During the wet season, the flushing effect caused by heavy flow has decreased the insects' density (Bispo et al. 2006).

Several studies have been conducted regarding seasonal influence on insects' population in tropical region for long time ago while the interest on seasonal effects in Peninsular Malaysia mostly is focused on Ephemeroptera, Plecoptera and Trichoptera (Suhaila et al. 2011, 2014). This study took place in five selected rivers of Belum-Temengor Forest Complex (BTFC), one of the biggest protected areas in Perak state of Peninsular Malaysia. Therefore, the present study aimed to investigate the influence of seasonal changes on the diversity and distribution pattern of aquatic insects' communities in highland areas.

MATERIALS AND METHODS

Study Area

Belum-Temengor Forest Complex (BTFC) is a dipterocarp rain forest located in the most northerly region of Perak, Malaysia. As described by Aiman Hanis et al. (2014), the climate of BTFC is typical monsoon in general with a comparatively high temperature ranging between 24.2 °C to 29.9 °C. The BTFC also is considered as humid area which data recorded from 70-98% humidity and also received high rainfall, almost 3,000 mm especially in April and October.

Two rivers were selected from tributaries of the Temengor Forest (Sungai Telang and Ular) and three rivers from the Belum Forest (Sungai Tan Hain, Temin, Selantan) based on their physical characteristic differences. Sungai Telang (N 05 28' 022" E 101 17' 223") is partially shaded area covered by the riparian canopy trees. The river substrate ranges from gravel to cobble with water depth increase from lower part to upper part of river and the water flow moderately. Sungai Ular (N 05 18' 39.5" E 101 24' 02.1") is mostly shaded river constituted of stony substrate ranges from coarse gravel to boulder. River depth varies from average to high depth depends on the raining season. Meanwhile, Sungai Temin (N 05 42' 49.4" E 101 21' 50.4") in Belum Forest is quite shallow with slow water flow. The river is partly shaded and the river substrate ranges from sand to small cobbles. Sungai Tan Hain (N 05 44' 45.1" E 101 22' 47.1") is the widest river (15.6m wide) and open area with coarser gravel to boulder. Lastly, Sungai Selantan (N 05 45' 52.4" E 101 23' 29.2") has shaded canopy cover. The substrate ranges from sand to boulders.

Sampling of Aquatic Insects

All five selected rivers of BTFC are made up of stony substrate ranging from small pebble to boulder size. Thus, a modified kick sampling technique was employed to sample aquatic insects (Merritt et al. 2008). Aquatic insects were collected four times, twice during dry and wet seasons using a rectangular aquatic net with 50 cm x 50 cm frame size of 300 µm mesh. An area approximately $1m^2$ in front of the net was physically disturbed by kicking the substrate and net's opening was positioned against the water current to allow the aquatic insects carried together with water flow into the net. Ten samples were collected from each river for every sampling occasion. Aquatic insects' samples were transferred into plastic bags, sealed properly and stored cool in an ice chest (Coleman®) during transportation to the laboratory. The specimens were sorted in the laboratory and preserved in universal bottles containing 75-80% ethanol (ETOH). All specimens were identified to the lowest possible taxa under a dissecting microscope Olympus CX41 (Olympus, Tokyo, Japan) following identification keys and descriptions of Yule and Yong (2004) and Orr (2005).

Measurement of Water Quality Parameters

The water parameters for DO, pH and water temperature were measured *in-situ* using a YSI Professional Plus (Pro Plus) meter. Three random readings were taken for each parameter. Three water samples were collected randomly for each sampling occasion. Each water sample was kept in a 500 ml polyethylene bottle and stored chilled in a Coleman® chest during transportation to the laboratory. Six water parameters namely chemical oxygen demand (COD), biochemical oxygen demand (BOD_3), ammonia-nitrogen (NH_3-N), phosphorus (PO_4^{3-}), nitrate (NO_3) and total suspended solid (TSS) were analyzed using a DR/890 HACH Calorimeter following the manufacturer procedures with specific reagents for each analysis.

Climatic Data

The seasonal limit in tropical country is determined according to the amount of annual rainfall (White 1998). The Malaysian Meteorological Department (MMD) classified the climate of Malaysia into two seasons, dry and wet-based on the monthly amount of rainfall. The dry season is decided when the precipitation falls below 200 mm while the monthly precipitation above 200 mm is categorized into the wet season (www.met.gov.my). According to the Malaysian Meteorological Department, the amount of rainfall for the east coast states (Kelantan, Perak and Terengganu) are higher during November, December and January while the driest months in the year are June and July.

Data Analysis

All the aquatic insects' taxa data and the environmental data were examined for the normality of distribution using Kolmogorov–Smirnov test. Based on the result, both data were not normally distributed and the non-parametric analyses were employed. The Mann Whitney U test was used to clarify the difference of aquatic insects' collection during dry and wet seasons. All the statistical analyses were run using the Statistical Package for the Social Sciences (SPSS) version 20.0 for Windows®. Some of the ecological indices were calculated to compare the aquatic insects' distribution between dry and wet seasons. As for comparison, gamma diversity was estimated using jackknife resampling procedures (first-order jackknife estimator), $\gamma_{estimated} = \gamma + \alpha_{average}\ (n\text{-}1)/n$, where γ is the observed number of taxa in each site and n is the number of sites at each river (Al-Shami et al. 2013) in the SDR IV programs (Seaby & Henderson, 2006). Other than species richness, species diversity was also calculated for each river. Spearman's rho correlation analysis was used to assess the influence of various environmental parameters on the observed species richness, abundance and Shannon diversity index in two different seasons (Martin-Vega et al. 2014) and to verify the relationship of aquatic insects' taxa composition with all recorded physicochemical data. The Canonical Correspondence Analysis (CCA) was used to investigate the influence of environmental variables on the distribution and abundance of the aquatic insect families (CANOCO 4.5). The Monte-Carlo test was run to test the significance of the produced canonical axes with 499 permutations at $P < 0.05$. The biplot ordination diagram was produced using the CanoDraw for Windows 4.1.

RESULTS

The Composition and Distribution of Aquatic Insect Communities in Rivers of Belum-Temengor Forest Complex (BTFC), Perak during Wet and Dry Season.

Overall, a total of 17633 individuals from nine orders, 70 families and 114 genera were collected in all five rivers of BTFC, Perak during the dry seasons while 9 orders, 51 families, 98 genera with 6,542 individuals were obtained in wet seasons (Figure 1). In the dry season, the mean density of aquatic insects collected was significantly different among all rivers (Kruskal Wallis test, $P < 0.05$) and the abundance and richness of aquatic insects in BTFC rivers differed significantly between the two seasons ($z_{dry} = -8.346$, $P = 0.000$; $z_{wet} = -9.706$, $P = 0.000$). Besides the seasonal difference, the variations in insect density were significant among the five rivers ($\chi2 = 12.80$, $P < 0.05$).

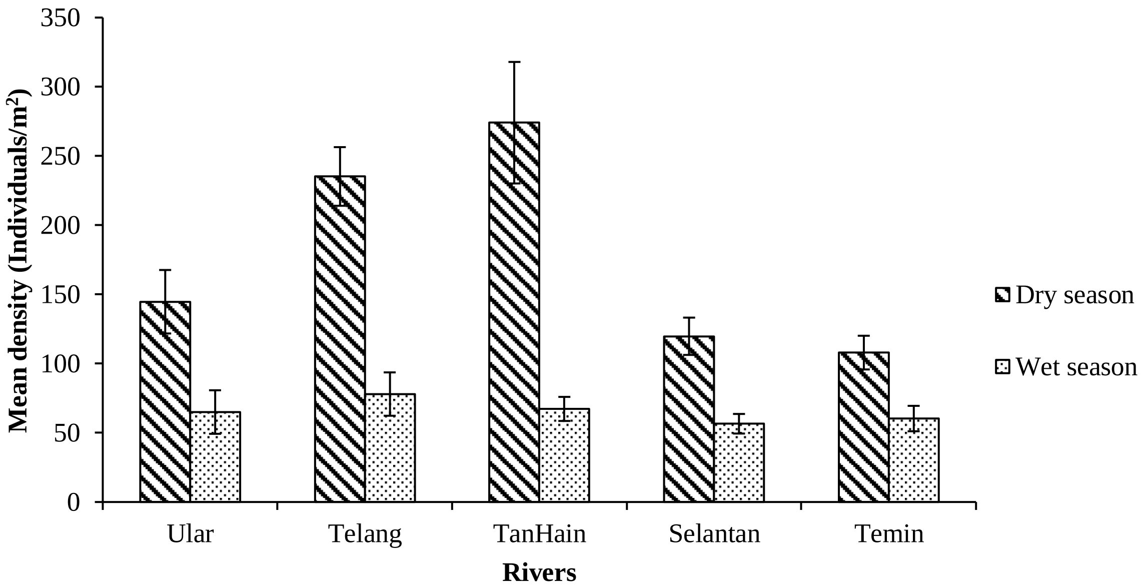

Figure 1. Mean density of aquatic insects in five rivers of Belum-Temengor Forest Complex (BTFC), Perak during dry and wet season

During the dry season, the diversity of aquatic insect was high (114 genera) with a range of nine taxa (Sungai Ular) to 48 taxa (Sungai Telang) ($\alpha_{average} = 27.17\pm1.31$) and a total of 71 to 90 ($\gamma = 82.6\pm3.37$) in each river (Table 1). Whilst, 98 genera of aquatic insect collected in the wet season was in the range of 3 (Sungai Ular) to 31 (Sungai Telang) taxa per samples ($\alpha_{average}$ = 16.47±0.75) and 61 to 67 taxa (γ = 6 ±1.05) in each river.In the dry season, the greatest gamma diversity value (γ) of 90 taxa was recorded in Sungai Selantan while Sungai Ular was reported to harbor poor aquatic insect diversity (γ = 71). However, in the wet season, the variation of insect diversity was low. The greatest gamma diversity was recorded in Sungai Ular (γ = 67) while the lowest gamma value was reported in Sungai Tan Hain (γ=61). The $\alpha_{average}$ value of 30.2 was reported in dry season from Sungai Telang while in wet season Sungai Temin ($\alpha_{average}$ = 17.95) scored the greatest value. Sungai Ular scored the lowest $\alpha_{average}$ in both dry and wet seasons (23.25; 14.3 respectively). However, beta diversity value (β) was reported to be greatest at Sungai Selantan (β = 3.30) and lowest at Sungai Telang (β = 2.78) during dry season. In the wet season, the high value of β (4.69) was observed in Sungai Ular and Sungai Temin showed the lowest value of β (3.68).

A high abundance of crane fly larvae density (Subfamily: Limoniinae) with a total of 2241 individuals were collected in dry seasons while only 683 individuals found in wet seasons (Table 2). Meanwhile in wet seasons, the number of individuals reduced almost ¾ compared to dry seasons (458 individuals) and the percentage of taxa density reduction is 5.94%. However, there were several aquatic insect taxa that least affected by the seasonal changes, yet the number of individuals increase during the wet season. The most remarkable increase was observed in *Platybaetis* sp. (Order: Ephemeroptera) which was about 240 individuals found in wet seasons, higher than in dry seasons.

Table 1. Biodiversity indices of aquatic insects for all rivers of Belum Temengor Forest Complex (BTFC) during wet and dry season

Diversity Indices	**UlarRiver**		**TelangRiver**		**Tan Hain River**		**Selantan River**		**Temin River**	
	Dry	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**
Alpha minimum (α_{min})	9	3	21	5	22	39	10	34	14	10
Alpha maximum (α_{max})	31	24	48	31	5	25	9	26	40	28
Alpha average ($\alpha_{Average}$)	23.25	14.3	30.2	17.3	29.75	15.05	27.3	17.75	25.35	17.95
Beta (β)	3.05	4.69	2.78	3.76	2.96	4.05	3.30	3.72	3.16	3.68
Gamma (γ)	71	67	84	65	88	61	90	66	80	66
Estimated Gamma	89.6	78.44	108.16	78.84	111.8	73.04	111.84	80.2	100.28	80.36
Shannon (H')	3.05	3.24	3.58	3.33	3.18	3.07	3.66	3.56	3.65	3.54
Simpson's (1-D)	0.90	0.94	0.96	0.95	0.90	0.90	0.96	0.96	0.96	0.96
Menhinnick (R2)	1.32	1.86	1.23	1.65	1.19	1.66	1.84	1.96	1.72	1.90
Equitability	0.72	0.77	0.81	0.80	0.71	0.75	0.81	0.85	0.83	0.84
Dominance	0.40	0.27	0.18	0.24	0.35	0.35	0.18	0.20	0.20	0.18

Table 2. Differences in the abundance of most dominant aquatic insect taxa in dry and wet seasons in rivers of BTFC, Perak. (DS = Dry season; WS = Wet season)

Taxa	**DS**		**WS**		**Difference in abundance**	**% Difference**
	ni	**(ni/Nx100)**	**ni**	**(ni/Nx100)**		
Platybaetis	101	0.42	133	0.55	32	0.13
Crinitella	364	1.51	58	0.24	-306	1.27
Habrophlebiodes	445	1.84	216	0.89	-229	0.95
Thalerosphyrus	258	1.07	37	0.15	-221	0.91
Euphaea	840	3.47	207	0.86	-633	2.62
Macromia	238	0.98	1	0	-237	0.98
Cryptoperla	599	2.48	140	0.58	-459	1.9
Tetropina	453	1.87	209	0.86	-244	1.01
Rhopalopsole	471	1.95	166	0.69	-305	1.26
Indoneumura	398	1.65	3	0.01	-395	1.63
Ceratopsyche	1894	7.83	458	1.89	-1436	5.94
Stenopsyche	638	2.64	155	0.64	-483	2
Chimarra	709	2.93	218	0.9	-491	2.03
Eubrianax	290	1.2	1	0	-289	1.2
Psephenus	13	0.05	253	1.05	240	0.99
Cyphon	432	1.79	–	–	-432	1.79
Stenelmis	152	0.63	1	0	-151	0.62
Hydrophilidae	200	0.83	–	–	-200	0.83
Simulium	418	1.73	36	0.15	-382	1.58
Limoniinae	2241	9.27	683	2.83	-1558	6.44
Suragina	266	1.1	106	0.44	-160	0.66

N= total number of aquatic insects in 100 samples (5 rivers x 2 seasons x 10 samples).
ni = total number of each taxa. (+) = increase (-) = decrease.

Influence of Water Chemical Parameters and total Rainfall on the Aquatic Insects Composition and Distribution

The lowest DO value in water was recorded in Sungai Temin during the wet season (7.05±0.10) (Table 3). All rivers were reported to have a higher oxygen level during the wet season compared to the dry season. Meanwhile, the dry season also contributed to a level of nitrate in Sungai Telang (0.07±0.05) and Sungai Temin (0.04±0.03). In fact, all rivers of BTFC were recorded to have a high level of BOD_3 and DO during the wet season but COD content was diluted during the rainy season except for Sungai Ular. Water temperature, depth, BOD_3, DO and COD showed significant differences between both seasons (Kruskal-Wallis test, $P < 0.05$). Although some physicochemical parameters did not differ significantly between seasons, there were variations in values recorded in dry and wet seasons.

A biplot graph (Figure 2) showed the influence of chemical parameters (13 variables) on the aquatic insects' abundance in BTFC during the dry season with the total inertia of the multivariate relationship (Table 4). The overall inertia or variance was 2.179 which equaled to the sum of all unconstrained eigenvalues with the unexplained variation of 1.186. Variables in the first axis contributed 30.6% of the variance in a species-environmental relationship, and 52.8% of the variance was accounted in the second axis.

Table 3. Mean (±SD) of water chemical parameters in the rivers of Belum Temengor Forest Complex, Perak

Rivers	**Ular**		**Telang**		**Tan Hain**		**Selantan**		**Temin**	
Water Parameters	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**
Temperature (°C)	23.6±0.35	22.6±0.00	23.9±0.05	22.5±0.00	24.3±0.75	22.7±0.05	23.7±0.30	22.5±0.10	23.3±0.20	22.7±0.00
pH	6.3±0.44	6.1±0.01	5.9±0.29	6.4±0.00	6.8±0.68	6.9±0.02	6.3±0.12	6.5 ±0.09	7.0±0.83	6.9±0.00
BOD (mg/L)	4.0± 0.47	4.9±0.97	4.2±0.03	5.8±0.13	4.3±0.46	5.4±0.38	5.4±0.27	5.4±0.59	3.7±0.25	5.6±0.05
Nitrate (mg/L)	0.01± 0.00	0.0±0.00	0.1±0.05	0.01± 0.00	0.01±0.01	0.01±0.00	0.01±0.01	0.01±0.01	0.04± .03	0.01±0.00
COD (mg/L)	0.0± 0.00	8.0±0.00	1.7±1.67	0.0±0.00	41.7±3.9	0.00±0.00	59.6±5.92	4.8±4.75	46.1±1.42	0.0±0.00
Phosphorus (mg/L)	2.8± 2.22	1.3±0.50	0.7±0.06	0.7±0.25	0.2±0.22	0.4±0.35	0.02±0.02	0.4±0.43	0.4±0.40	2.0±1.85
TSS (mg/L)	8.0± 3.00	27.5±22.5	2.0±1.00	4.17±3.84	1.00±1.00	1.5±0.50	3.8± 2.75	4.0±1.00	4.0±3.00	19.0± 16.00
Ammonia-nitrogen (mg/L)	0.04±0.00	0.0±0.00	0.1±0.03	0.0±0.01	0.00±0.00	0.01±0.01	0.01±0.00	0.01±0.01	0.02±0.01	0.0±0.00
DO (mg/L)	7.7±0.33	8.6±0.23	7.6±0.45	8.5±0.06	7.6±0.52	8.3±0.14	7.4±0.22	8.1±0.27	7.1± .10	8.3±0.09

Table 4. Correlation, eigenvalues and the variance explained for the four axes of canonical correspondence analysis (CCA) for aquatic insects' abundance and environmental variables (13 variables) in five rivers of Belum Temengor Forest Complex (BTFC), Perak in dry season. Total Inertia (TI) = 2.176, Sum of all canonical eigenvalues = 0.856. Total variance explained = 39.34%

Variables	Axis 1	Axis 2	Axis 3	Axis 4
Temperature	-0.64	0.479	-0.21	0.021
pH	-0.78	0.291	0.163	0.262
Depth (m)	-0.5	0.193	-0.56	0.079
Width (m)	-0.7	0.53	-0.07	0.037
Velocity (ms-1)	-0.54	0.672	0.256	0.073
BOD (mg/L)	-0.33	0.107	0.306	-0.47
Nitrate (mg/L)	0.454	-0.07	0.149	0.043
COD (mg/L)	-0.26	0.392	0.531	-0.16
Phosphate (mg/L)	0.233	-0.26	-0.31	0.076
TSS (mg/L)	0.285	-0.04	-0.26	0.078
Ammonia-nitrogen (mg/L)	0.484	-0.39	-0.23	0.096
DO (mg/L)	-0.77	-0.18	-0.03	0.117
Rainfall (mm)	-0.88	-0.26	0.115	0.081
Eigenvalues	0.261	0.191	0.125	0.088
Species-environment correlations	0.96	0.902	0.857	0.777
Cumulative percentage variance				
of species data	12	20.8	26.5	30.6
of species-environment relation	30.6	52.8	67.4	77.7

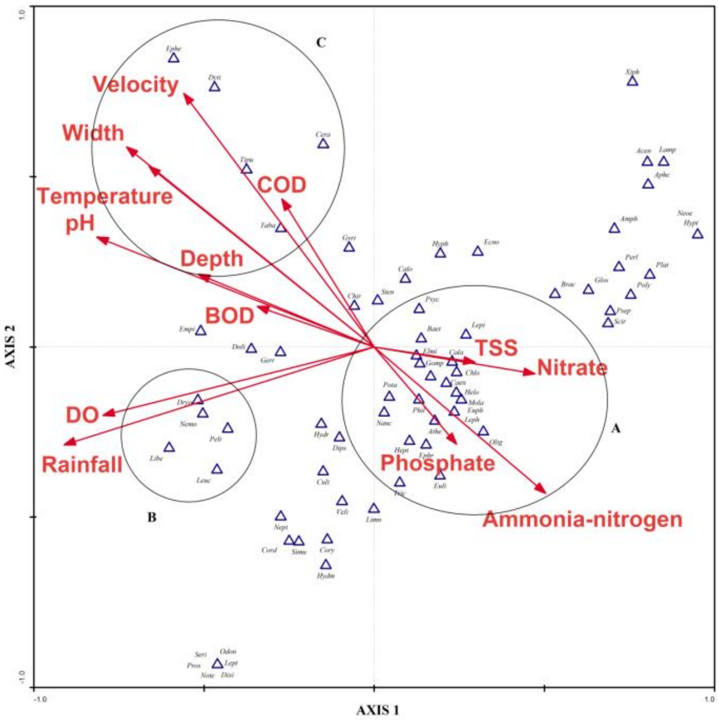

Figure 2. Ordination of CCA biplot showing the relationship between aquatic insects' families and environmental variables during dry season in Belum Temengor Forest Complex (BTFC)

During the dry season, most of aquatic insects' distribution was disassociated with water temperature, pH value, dissolved oxygen concentration and quantity of precipitation at rivers of BTFC. However, based on CCA ordination, the aquatic insects' assemblages can be classified into three groups. The first assemblage of aquatic insects (Baetidae, Caenidae, Lepidostomatidae, Gomphidae, Elmidae, Oligoneuridae) showed tolerance over chemical contents in rivers (TSS, phosphorus, ammonia nitrogen and nitrate content). Another group of aquatic insect taxa (Libellulidae, Nemouridae, Peltoperlidae) showed negative correlation with rainfall and DO. Meanwhile the other group (Ephemerellidae) preferred environmental conditions with fast-flowing water and able to sustain in the range of pH, COD and water temperature in the rivers.

Meanwhile, Figure 3 illustrates the association of physicochemical water parameters on aquatic insects' families during different the wet season. The total extent of variation or total inertia (TI) in the aquatic insects' assemblages had an eigenvalue of 3.378 whereas eigenvalues of the 13 variables explained 31.68% of the total variance explained (TVE) (Table 5). In the first axis, 32.6% of the variance in species-environmental relationships was contributed by its variables and 54.9% of the variance was accounted for the second axis. Based on the CCA ordination, the aquatic insects' assemblage was fairly distributed over physicochemical water parameters measure. However, based on the eigenvalues on axis 1, the aquatic insects' assemblages (A) were positively correlated with the range of water temperature and BOD_3 during the rainy season and able to tolerate over certain amount of phosphate content in the water. Meanwhile, another group of insect taxa (B) was negatively correlated with heavy rainfall and concentration of ammonia-nitrogen in the water during the rainy season.

Table 5. Correlation, eigenvalues and the variance explained for the four axes of canonical correspondence analysis (CCA) for aquatic insects' abundance and environmental variables (13 variables) in five rivers of Belum Temengor Forest Complex (BTFC), Perak in wet season. Total Inertia (TI) = 3.378, Sum of all canonical eigenvalues = 1.07. Total variance explained = 31.68%

Variables	**Axis 1**	**Axis 2**	**Axis 3**	**Axis 4**
Temperature	0.369	0.045	-0.34	0.014
pH	-0.07	0.58	-0.07	0.055
Depth (m)	-0.39	-0.56	-0.09	-0.01
Width (m)	0.399	0.477	0.05	0.003
Velocity (ms-1)	-0.04	0.559	0.236	0.407
BOD (mg/L)	0.388	0.262	0.499	-0.05
Nitrate (mg/L)	0.067	0.364	0.329	-0.19
COD (mg/L)	0.324	-0.37	-0.36	-0.1
Phosphate (mg/L)	0.661	-0.08	-0.11	-0.08
TSS (mg/L)	0.149	-0.25	-0.12	0.603
Ammonia-nitrogen (mg/L)	-0.6	0.057	0.421	-0.36
DO (mg/L)	0.21	-0.56	-0	-0.07
Rainfall (mm)	-0.86	-0.24	-0.11	-0.03
Eigenvalues	0.349	0.239	0.138	0.102
Species-environment correlations	0.935	0.863	0.786	0.741
Cumulative percentage variance				
of species data	10.3	17.4	21.5	24.5
of species-environment relation	32.6	54.9	67.8	77.4

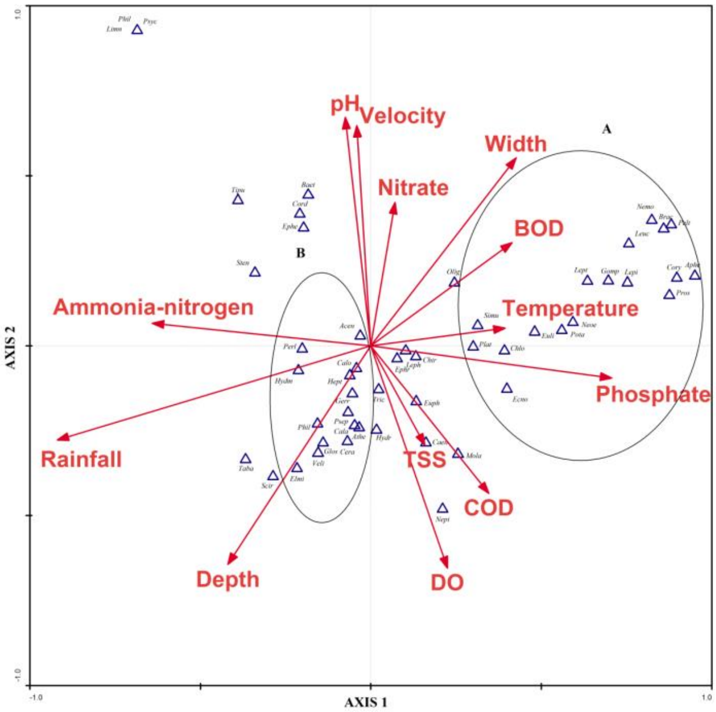

Figure 3. Ordination of CCA biplot showing the relationship between aquatic insects' families and environmental variables during wet season in Belum Temengor Forest Complex (BTFC)

DISCUSSION

In this study, BTFC rivers have proven to hold large number of aquatic insects (24175 individuals). Yet, more aquatic insects' larvae (17,633 individuals) were collected during dry season instead of in wet season (6,542 individuals). In general, all values of ecological indices calculated, pointed towards higher aquatic insects' abundance and diversity in BTFC rivers in dry season compared to wet season. High diversity of aquatic insects in dry season was related to the presence of habitat heterogeneity and complexity. Vinson and Hawkins (1998) also agreed that habitat heterogeneity has major influenced on insects' diversity in rivers. Meanwhile, Dudgeon (1997) clarified that an increase in insect density during dry season was associated with reduced availability of habitat area and hence, increased in clustering of the individuals in low water level. Among all rivers, Sungai Selantan recorded the greatest ecological indices during both seasons (γ diversity = 90 taxa; β diversity = 3.30) which indicates that this river provided most preferable habitat for fauna regardless of seasonal influences. This river was located far inside BTFC and was hardly disturbed by any human activity and on few occasions during the sampling trips to the area, wildlife footprints were spotted on the riverbanks (personal observations). The river was surrounded by thick canopy that can shelter almost all the water surface especially during heavy rains. This heterogeneous, undisturbed environment had apparently supported various fauna in large quantities. In such habitat, Callisto and Goulart (2005) also discovered an increase in invertebrate diversity and richness during the rainy season due to the variation in water discharge.

In Sungai Tan Hain, the insect communities showed the lowest equitability but with the highest dominance values, especially in the wet season. According to Martin-Vega et al. (2014), the complimentary of indices (dominance and equitability) relationship explained a high number of species may present in a certain locality but fewer species had dominated the areas in term of number of individuals. Therefore, Sungai Tan Hain showed a high number of recorded species but its high value of dominance indicated that most of the individuals sampled belonged to a few dominant species and hence the equitability value was low. Sungai Tan Hain was the only river that had an open canopy. Lesser aquatic insects' composition and less evenly distributed fauna observed could be explained by the river characteristics itself. High precipitation during wet season resulted in an instantaneous increase in water flow that causes wash off aquatic insects' community in the river (Righi-Cavallaro et al. 2010). Several studies dealing with the effects of precipitation on invertebrate community structure also considered some river characteristics such as size, elevation and slope that played important roles in regulating the current velocity and water flow in rivers (Silveira et al. 2006).

Other than aquatic insect abundance and diversity, the seasonal changes also had displayed direct influence on the several aquatic insect taxa. A high abundance of Limoniinae larvae (Family: Tipulidae) during the dry season and the most reduced taxa during the wet season can be explained by their biological factors. A well-known researcher on Tipulidae (crane flies) (Pritchard 1983) has mentioned that high occurrence of tipulids eggs and first instar larvae was found in dry weather which determined high abundance of tipulids population in their habitat. In addition, he also reported a wide range of tipulids habitats such as intertidal zone to accumulated leaves of terrestrial plants in the presence of adequate moisture. Associated with highly preferable habitat to occupy, high numbers of tipulid larvae were well explained in the environment with plenty of food sources. Most of the Tipulidae (crane flies) consumed on leaf litter and other coarse particulate organic matter (CPOM) while others can be classified into predators and collector gatherers (Young 2004). Thus, a high reduction of Limoniinae larvae from dry seasons to wet season (6.44%) was caused by the habitat diminished by heavy water flow. Potentially rich food resources also were flushed away with the fast water current during the rainy season.

The net-spinning caddisfly larvae (Genus *Ceratopsyche*) was another most affected taxa during wet season. The high density of individuals were observed in the dry season (1894 individuals) while only 458 individuals recorded during wet season. The huge reduction of *Ceratopsyche* sp. (5.94%) during wet season could be related to the habitat disturbances aggravated by rain since they preferred to live in riffle areas (Baptista et al. 2001), constructing nets on the substrate surface. According to Suhaila et al (2019), individuals from family of Hydropsychidae preferred stony substrates. This family relies upon water current for food as they are collector-gatherers and stony substrates provide a good habitat for them. Despite diminishing the abundance of many insect taxa, some aquatic insect communities responded positively to the rain. Among others, higher abundance of *Platybaetis* sp. (Order Ephemeroptera) nymphs was observed during wet season. The current finding was comparable with a study from Suhaila et al. (2014), where *Platybaetis* sp. collected in rivers from Gunung Jerai Forest Reserve, Kedah was more abundant in the wet season. Increased number of ephemeropteran nymphs in the wet season could possibly due to high egg hatchability in the river during the season.

The reduction in precipitation was predicted to associate with the global climate change. Several studies have reported the variation in climatic data concerning the climate change in Malaysia (Tangang et al. 2010; Wan Zin et al. 2010). In fact, the distribution of aquatic insect in tropical highland rivers was not only affected by the drought and flood condition caused by the variation of rainfall, but many other physicochemical water parameters were also influenced by the seasonal changes. Hence, all these factors are inter-correlated to sustain our freshwater ecosystems.

Meanwhile, the aquatic insect abundance and dominance was positively correlated with the amount of rainfall in wet season. It can be explained that most insects taxa preferred wet season because all chemical contents in the water have been diluted due to high water level and water flow (Bispo et al. 2006). In this study, several plecopterans genera have high correlation values with the amount of precipitation. In addition, the stoneflies larvae were known as aquatic insects that prefer to inhabit very aerated microhabitat which provided high dissolved oxygen with clean water (Silveira et al. 2006). Furthermore, their preferences over the amount of precipitation during both dry and wet seasons explained that the reproduction of aquatic insects in the tropical rivers occurred continuously throughout the year (Ramirez et al. 2006). Thus, it is one of the mechanisms for insects to maintain their population.

CONCLUSION

In conclusion, the aquatic insect community in rivers of BTFC was influenced by seasonal variation. The dry and wet seasons caused by the amount of precipitation determined the patterns of aquatic insect abundance and diversity. The aquatic insect abundance and diversity was greatest during the dry seasons. The subfamily of Limoniinae and genus *Ceratopsyche* sp. were the most affected taxa by the seasonal change (from dry to wet seasons) while *Platybaetis* sp. shows the opposite. The difference of aquatic insect communities' inthe dry and wet seasons was associated with the water chemical parameters measured. Water temperature, BOD_3, DO and COD were proved significantly different between the two seasons.

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