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Research Article

Aquatic Insects and Water Quality Study at Kimanis River, Crocker Range National Park, Sabah, Malaysia

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Abstract
A survey on the aquatic insect communities was conducted in Kimanis River, Ulu Kimanis, Crocker Range Park (CRP), Sabah with the objectives to study (i) the composition of stream insect communities, (ii) stream water quality and (iii) the relationships between aquatic insects and freshwater quality parameters in Kimanis River, Ulu Kimanis, CRP. The sampling was carried out using surber net in October 2015 and January 2016. A total of 1,801 individuals from nine orders of 28 families were collected from Kimanis River. Trichopterans fauna was found to be the prominent taxa in this study. Shannon-Wiener Index of upstream strata was recorded slightly higher than downstream strata with H'= 1.97 and H'= 1.85 respectively. Water integrity of Kimanis River could be considered as excellent with minimal pollution. Both water quality parameters and biotic indices indicated that the aquatic insect population was affected by the water quality in their surroundings. This proved the use of aquatic insect communities as bioindicator for rapid assessment of water quality in CRP.

Keywords: aquatic insect communities, trichopterans fauna, Shannon-Wiener Index, physico-chemical parameters, biotic indices, water integrity

Introduction
Aquatic macroinvertebrates are the key inhabitant of the freshwater ecosystem and serve an important role in keeping the ecosystem intact. Among the macroinvertebrates, insects are by far the most speciose and abundant macroinvertebrates established in freshwater ecosystems (Macadam & Stockan, 2015). Aquatic insects possess a vast array of morphological, physiological, and behavioural adaptations enabling inhabitation of virtually all bodies of water

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(Ward, 1992). Aquatic insect communities have the capacity to exploit most types of aquatic habitats and occur in a diverse group (Barman & Gupta, 2015). They are very wealthy inhabitants of freshwater environments that are in enormous number of broad distribution.

As one of the most widespread groups of organisms used to evaluate the health of the aquatic ecosystem (Rosenberg & Resh, 1993; Sharma & Rawat, 2009), benthic macroinvertebrates are ideal as bioindicator. Since macroinvertebrates constitute a heterogenous assemblage of animal phyla, consequently some members respond well to whatever stresses are placed upon them (Hellawell, 2012). Among macroinvertebrates, aquatic insects are often chosen for biomonitoring since aquatic insects are considered as good indicators of environmental condition. Aquatic insects are good indicators as they fulfil these few criteria: (i) abundant and sufficiently diverse in their habits and habitats; (ii) sensitive and predictable in their response to changes in environmental conditions, (iii) relatively easily sampled and identifiable to meaningful taxonomic resolutions, and (iv) bioaccumulate chemicals such that the pathways of toxins in the environment can be traced (Macadam & Stockan, 2015).

Since aquatic macroinvertebrates are feasible indicators of water quality, macroinvertebrates and water quality are interrelated (Sharma & Rawat, 2009). Therefore, the study of composition and structure of aquatic macroinvertebrates will be able to help in monitoring changes in water quality and the ecological integrity of streams and rivers (Arimoro & Ikomi, 2009). There is a considerable increase in the number of publications regarding biological monitoring using indicator species. This implies widespread and continuous growth in the use of indicator species in environmental monitoring and management (Siddig et al., 2015). In Malaysia, studies on aquatic insects and water quality have been carried out in Peninsular Malaysia (Che Salmah et al., 1999); Sarawak (Mercer *et al.*, 2014) and Sabah (Fikri et al., 2013; Harun *et al.*, 2015; Wong & Fikri, 2016; Shafie et al., 2017).

Crocker Range National Park (CRP) is located at the southern section of the Crocker Range in Northwest Borneo, Sabah, Malaysia (Zaini et al., 2012). CRP consists of about 139,919 ha, stretched from south of Kundasang in the north to Tenom in the south, approximately between latitudes 5^0 and 6^0 N and longitudes 115^0 and 119^0 E (Rahim et al., 2002). The CRP is bordered by the floodplain of the Pegalan/Padas River to the east and by the coastal plain of the west coast of Sabah (Rahim et al., 2002). CRP has been chosen as the study area since the site is less influenced by anthropogenic activities and hence the result obtained from this study provides a benchmark towards the use of aquatic insect communities as biological indicator.

Numerous studies on aquatic ecosystems have been carried out in CRP, mostly focused on other freshwater organisms, especially anurans (eg. Ramlah et al., 2001; Rahim et al., 2002; Kueh et al., 2004; Das, 2006; Zaini et al., 2012). However, aquatic insect populations and water quality of the streams have received minimum amount of attention in CRP. The most recent studies regarding the aquatic insect communities and water quality of the CRP streams were by Long et al. (2002) and Manshoor & Fikri (2004) which were carried out in 2002.

Thus, in order to provide a more complete understanding towards the conservation effort of the aquatic ecosystems in CRP, it is critical to gain a better understanding on the health and the integrity of the aquatic ecosystem and the changes that have occurred throughout the years. The study of the capability of aquatic insect communities as bioindicators in freshwater streams is also important to improve understanding on the characteristics of aquatic habitats and to also monitor the water quality of freshwater which are needed to sustain the aquatic ecosystem in CRP, Sabah, Malaysia. As there is lack of a recent study in aquatic insect communities study in CRP, Sabah, this study was carried out to produce information on the aquatic insect communities as well as water quality and ecology health of Kimanis River, CRP. The objectives of the present study are therefore: (1) to study the diversity of stream insect communities; (2) to study the stream water quality and (3) to investigate the relationships between stream insect communities and water quality parameters in Kimanis River at Ulu Kimanis, Crocker Range National Park, Sabah, Malaysia.

Methodology

Study Area

Crocker Range Park (CRP) is located in the west coast of Sabah and stretches from Kundasang in the north to Tenom in the south. Ulu Kimanis River is the main river in the park, and consists of primary forest with lowland vegetation at 300 to 600 m asl (Nurhuda & Arman, 2002; Zaini et al., 2011). The average temperature is around 23 to 27°C (Zaini et al., 2011).

Sampling Campaign

Four stations were chosen from upstream and downstream of the Kimanis River respectively as indicated in Figure 1 and Table 1.

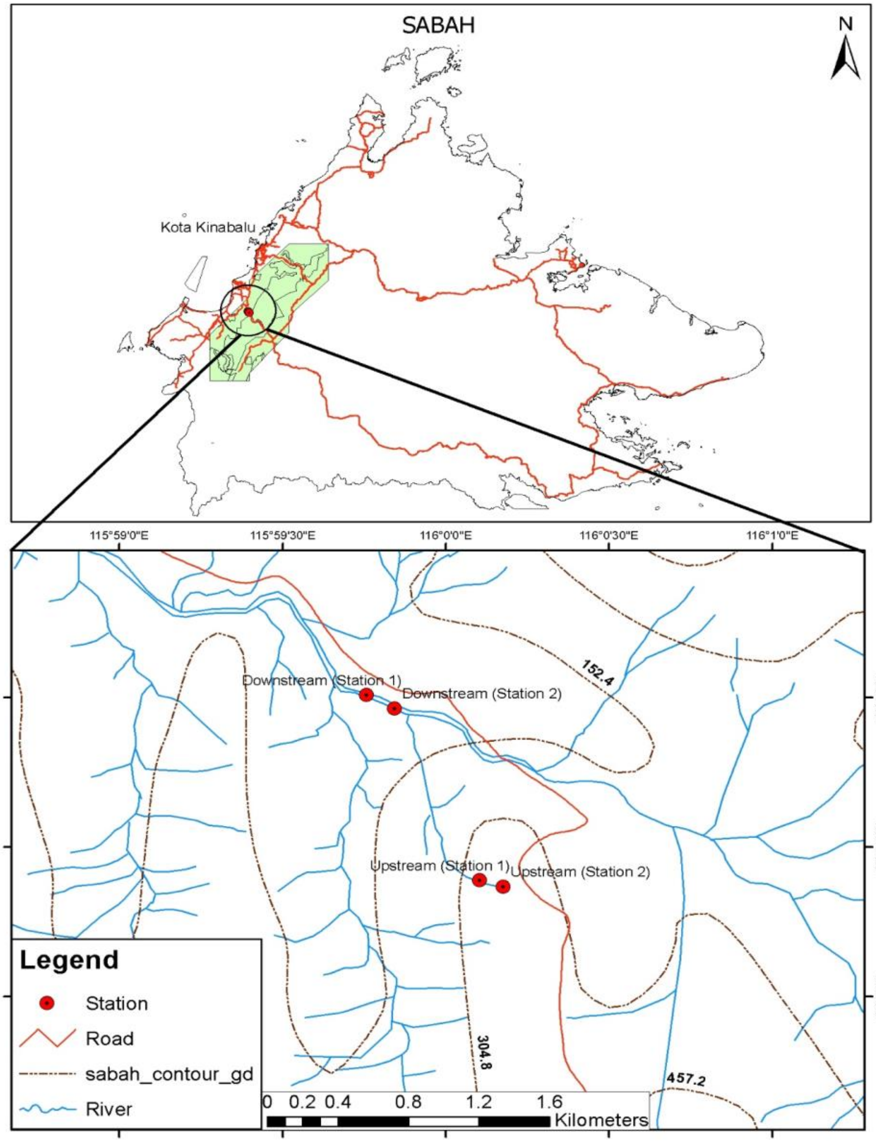


Figure 1. Map of Kimanis River, Crocker Range National Park, Sabah, Malaysia

Table 1. Site description of the sampling areas.

Sampling stations		Longitude	Latitude	Elevation	Habitat description	
					October 2015	January 2016
Upstream	Station 1	05^0 31’ 44.6’’ N	116^0 00’ 13.9’’ E	130 m	Moderate flowing and clear water, rocky bottom	Moderate flowing and clear water, rocky bottom
	Station 2	05^0 31’ 39.9’’ N	116^0 00’ 17.9’’ E	162 m	Moderate flowing and clear water, rocky bottom	Moderate flowing and clear water, rocky bottom
Downstream	Station 3	05^0 31’ 91.9’’ N	115^0 59’ 74.8’’ E	116 m	Swift flowing and milky water, sandy bottom, partially covered by forest canopy	Moderate flowing and clear water, sandy bottom, partially covered by forest canopy
	Station 4	05^0 31’ 92.3’’ N	115^0 59’ 83.8’’ E	122 m	Swift flowing and milky water, sandy bottom partially covered by forest canopy	Moderate flowing and clear water, sandy bottom, partially covered by forest canopy

Prior to sampling, the surrounding condition of the riparian zone was observed and recorded. Three substations, composed of different habitat types, were selected in each station. The selected sites were about 100 m from each other. Sampling was carried out in three different habitats, pools, riffles and runs for comparisons among the habitats of Kimanis River.

Aquatic Insects

Aquatic insects were collected over two sampling occasions between October 2015 and January 2016. Samplings for aquatic insects were done during the day using surber sampler, which is commonly used for quantitative sampling aquatic insects. Three substations, composed of three different habitat types, pool, riffle and run were sampled. The device is positioned with the opening facing upstream (Jalil & Mohamed, 2004) and the surroundings were agitated for 2 minutes. Big stones in swift-flowing water were hand-lifted and washed by rubbing on the rock surface to remove the aquatic insects into the net. Aquatic insects were identified to the family level using taxonomic keys of Yule and Yong (2004) and Merritt et al. (2008) and also preserved specimens from BORNEENSIS, ITBC in the laboratory. Four biotic indices specifically EPT Richness, Family Biotic Index (FBI), Biological Monitoring Work Party (BMWP) and Average Score Per Taxon (ASPT) were used to assess the water quality of Kimanis River at CRP. The values attained from the indices helped to determine the current status of water integrity with the standard description for each range when compared with the standard range of scores.

Water Quality Parameters

Water samples were collected near the surface of the river and stored in 250 ml high-density polyethylene (HDPE) bottles. *In situ* parameters, pH, temperature (^{0}C), conductivity (µS/cm), dissolved oxygen (DO) (mg/l), salinity, total dissolved solids (TDS) (mg/l) and ammonia nitrogen were tested using YSI Professional Plus (ProPlus model 6026 S/N Y 5173), multi-parameter water quality instrument. YSI ProPlus must be fully submerged into the water to obtain accurate readings. YSI ProPlus was placed in the middle of the stream and permitted to stabilize before readings were taken (Harun et al., 2010). Three replicates of in-situ parameters were recorded at each station. Total suspended solids (TSS) was conducted following Gravimetric Method (Harun et al., 2015) and dissolved organic carbon (DOC) was analysed by using Shimadzu TOC-V-SCH analyzer with auto – sampler TOC-ASI-V. Samples were acidified with hydrochloric acid (HCl). The acidified samples (pH ~2) were sparged for 8 minutes at 75 or 100 ml/min with ultra-pure oxygen to remove all inorganic carbon from samples prior to measurement.

Data Analyses

Diversity of aquatic insects was computed using the Shannon-Wiener Diversity Index (H') and Evenness Index (E'). Sørensen's Quantitative Index (C_N) used to compare the diversity among two sites. The number of taxa (taxa richness) was calculated by counting the number of aquatic insect families found in the samples. Discriminant function analysis (DFA) is a multivariate statistical modelling and supervised pattern recognition technique and can be used to classify objects into exhaustive and mutually exclusive groups depends on set of independent variables (Gazzaz et al., 2012). DFA analysis in this study used statistical package SPSS to construct the graphs to identify the significance of certain water quality parameters in particular sites. Canonical correspondence analysis (CCA) is a multivariate method to elucidate the relationships between biological assemblages of species and their environment (Braak & Verdonschot, 1995). In this study, CCA is used to study the relationships between the aquatic insect communities and water quality parameters.

Results

Composition and Distribution of Aquatic Insects

Table 2. The list of aquatic insects distributed across downstream and upstream of Kimanis River, CRP.

Order	Family	Downstream			Upstream		
		Station 1	Station 2	Total	Station 1	Station 2	Total
Coleoptera	Elmidae	8	8	16	17	10	27
	Hydrophilidae	0	0	0	2	0	2
	Gyrinidae	0	0	0	10	0	10
	Psephenidae	2	0	2	5	6	11
Diptera	Tipulidae	4	1	5	4	9	13
	Chironomidae	15	1	16	3	0	3
	Stratiomyidae	0	0	0	2	0	2
Ephemeroptera	Baetidae	35	28	63	101	47	148
	Heptageniidae	22	16	38	42	58	100
	Leptophlebiidae	13	7	20	59	40	99
	Siphlonuridae	0	0	0	15	1	16
	Ephemerellidae	1	0	1	0	6	6
	Caenidae	1	2	3	2	2	4
	Potamanthidae	0	0	0	1	2	3
	Tricorytidae	0	0	0	2	0	2
Hemiptera	Mesoveliidae	0	0	0	0	2	2
	Gerridae	1	0	1	1	0	1
	Veliidae	0	0	0	1	0	1
Lepidoptera	Pyralidae	0	0	0	33	4	37
Megaloptera	Corydalidae	6	2	8	18	6	24
Odonata	Euphaeidae	3	0	3	2	1	3
	Gomphidae	1	0	1	0	0	0
Plecoptera	Perlidae	15	7	22	28	25	53
Trichoptera	Hydropscyhidae	110	92	202	272	309	581
	Philopotamidae	34	8	42	93	112	205
	Limnephilidae	0	0	0	2	0	2
	Polycentropodidae	0	0	0	1	1	2
	Phryganeidae	0	0	0	1	0	1
Grand Total		**271**	**172**	**443**	**717**	**641**	**1358**
Shannon-Wiener Index (H’)				1.85			1.97
Evenness Index (H’)				0.67			0.60

A total of 1,801 individuals of aquatic insects representing 28 families from nine orders were collected and identified along Kimanis River, Crocker Range Park, Ulu Kimanis, Sabah, Malaysia throughout the sampling during October 2015 and January 2016. The nine aquatic insects orders collected belong to Coleoptera (68 individuals; 3.78% of total abundance), Diptera (39 individuals; 2.17% of total abundance), Ephemeroptera (503 individuals; 27.93% of total abundance), Hemiptera (5 individuals; 0.28% of total abundance), Lepidoptera (37 individuals; 2.05% of total abundance), Megaloptera (32 individuals; 1.78% of total abundance), Odonata (7 individuals; 0.39% of total abundance), Plecoptera (75 individuals; 4.16% of total abundance) and Trichoptera (1035 individuals; 57.47% of total abundance) (Table 2). Hydropscyhidae yielded the highest in abundance in which it comprised 783 individuals, made up of almost half of the total collection of 43.48% out of 1,801 individuals followed by Philopotamidae which contributed 247 individuals or 13.71%.

Ephemeroptera, Plecoptera and Trichoptera (EPT) were significantly abundant especially at upstream stations in Kimanis River at CRP. Families Elmidae, Psephenidae, Chironomidae, Tipulidae, Baetidae, Caenidae, Ephemereliidae, Heptageniidae, Leptophlebiidae, Gerridae, Perlidae, Hydropscyhidae, Philopotamidae, Euphaeidae and Corydalidae were found at both upstream and downstream areas. Although family Chironomidae (Diptera) was present at both the upstream and downstream, the high individual count (16) was present in downstream strata. Shannon-Wiener Diversity Index (H') is higher in upstream with 1.97 and lower in downstream with 1.85. However, for Evenness Index (E'), the index is higher in downstream with 0.67 and lower in upstream with 0.60. Sørensen's Quantitative Index (C_N) between aquatic insect communities from upstream and downstream is 0.48 which indicates there is about 48% similarity in terms of species of aquatic insects between the downstream and upstream.

Water Quality Parameters

Biological Parameters

A total of 14 families of EPT were sampled in Kimanis River. Therefore, Kimanis River is categorized as having very good water quality. All the 14 families of EPT existed at upstream but only eight families were represented at the downstream. FBI values for downstream strata (3.88) and upstream strata (3.97) were both classified as very good. In addition, BMWP shows upstream has higher value (138) and is cleaner than downstream (96). BMWP value for Kimanis River is 152 indicating that the river is unpolluted and has not been impacted (unimpacted). ASPT for upstream strata and downstream strata are 6.90 and 6.86 respectively with the same description as good water quality and probably some organic pollution. Overall, Kimanis River has high water integrity and upstream strata of Kimanis River showed a better water condition in comparison to downstream strata (Table 3).

Table 3. Biotic Indices of Crocker Range Park.

Study Site/ Biotic Indices	Upstream		Downstream		Total	
	Value	Class	Value	Class	Value	Class
EPT Richness	14	Very Good Water Quality	8	Good Water Quality	14	Very Good Water Quality
FBI	3.97	Very Good	3.88	Very Good	3.71	Excellent
BMWP	138	Unpolluted, Unimpacted	96	Clean but slightly Impacted	152	Unpolluted, Unimpacted
ASPT	6.90	Good Water Quality, Some organic pollution probable	6.86	Good Water Quality, Some organic pollution probable	7.23	Good Water Quality, Some organic pollution probable

Water Quality Parameters

Table 4 summarises the water quality parameters in each sampling station. Overall, the value for each water quality parameter is higher in January 2016 in comparison to October 2015.

Table 4 Water quality parameters in each sampling stations.

Parameter	October 2015				January 2016			
	Upstream		Downstream		Upstream		Downstream	
	Station 1	Station 2	Station 3	Station 4	Station 1	Station 2	Station 3	Station 4
pH	6.51	6.95	6.50	6.93	6.76	6.62	7.75	7.42
Temperature (^{0}C)	24.57	25.67	24.60	25.37	25.30	25.63	26.77	25.23
Conductivity (µS/cm)	44.47	59.80	53.27	53.60	79.83	88.67	92.80	87.50
DO (mg/l)	7.45	7.66	7.16	7.30	7.94	7.84	8.97	7.39
Salinity	0.02	0.03	0.02	0.02	0.04	0.04	0.04	0.04
TSS (mg/l)	2.13	2.27	3.71	1.83	1.87	1.87	3.73	2.40
TDS (mg/l)	29.25	35.02	35.10	34.45	54.38	56.98	57.20	56.55
Ammonia Nitrogen (mg/l)	0.33	0.70	0.29	0.44	0.00	0.00	0.24	0.00
DOC (mg/l)	2.49	1.91	1.53	1.48	11.37	2.02	4.20	6.15

Table 5 explains the classification of water quality physico-chemical parameters for Kimanis River in accordance with the Interim National Water Quality Standards for Malaysia (INWQS).

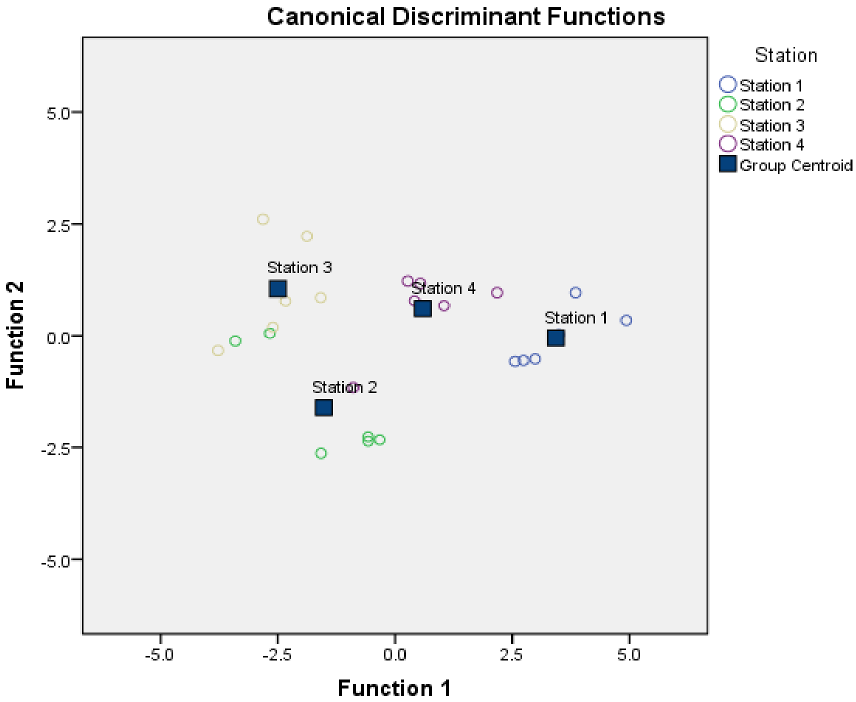
Table 5. Range of different water quality parameters and their classifications by INWQS of Kimanis River at CRP.

Parameter	October 2015	INWQS	January 2016	INWQS
pH	6.50-6.95	I	6.62-7.75	I
Temperature (^{0}C)	24.57-25.67	-	25.23-26.77	-
Conductivity (µS/cm)	44.47-59.80	I	79.83-92.80	I
DO (mg/l)	7.16-7.66	I	7.39-8.97	I
Salinity	0.02-0.03	I	0.04	I
TSS (mg/l)	1.83-3.71	I	1.87-3.73	I
TDS (mg/l)	29.25-35.10	I	54.38-57.20	I

Table 6 presents the factor structure coefficients from the discriminant analyses, while Figure 3 plots the first and second discriminant function from water quality physico-chemical parameters and sampling stations. The plot suggests that Station 1 and Station 4 are homogenous while Station 3 the most heterogeneous group. In Function 1, dissolved organic carbon (DOC), temperature and conductivity were dominant at sampling Station 1. Meanwhile total suspended solids (TSS), pH, salinity and ammonia nitrogen were prominent at sampling Station 3.

Table 6. Structure matrix from discriminant analyses for each stations and water quality parameters.

Variables	Function	
	1	2
Temperature	-.202*	-.054
DOC	.133*	.078
Conductivity	-.103*	-.037
TSS	-.151	.315*
pH	-.114	.310*
Salinity	-.030	-.161*
Ammonia Nitrogen	-.087	-.141*
DO	-.083	.031
TDS	-.058	.001



Upstream: Station 1; Station 2; Downstream: Station 3; Station 4

Figure 3. Plots for discriminant functions for water quality parameters against stations

Influence of Water Quality Parameters on Abundance of Aquatic Insects

Canonical correspondence analysis (CCA) demonstrated that the total inertia in aquatic insect abundance had an eigenvalue of 0.3885; eigenvalues of the nine water quality parameters explained 51% of the total variance (TVE) (Table 7).

Table 7 Axis summary statistics of canonical correspondence analysis (CCA): eigenvalues, variance percentage, species-environment correlations for the first two axes and total inertia. Total variance ("inertia") in the species data: 0.3885

	Axis 1	**Axis 2**
Eigenvalue	0.123	0.075
Variance in species data		
% of variance explained	31.7	19.3
Cumulative % explained	31.7	51.0
Pearson Correlation, Spp-Envt*	0.847	0.888
Kendall(Rank) Corr., Spp-Envt	0.727	0.727

The order of aquatic insects are positively correlated with total suspended solids (TSS) (r=0.024) and dissolved organic carbon (DOC) (r=0.516) but negatively correlated with pH, temperature, conductivity, DO, salinity, TDS and ammonia nitrogen (Table 8).

Table 8. Intraset and interset correlations for nine physico-chemical parameters.

Variables	Intraset Correlations		Interset Correlations	
	Axis 1	Axis 2	Axis 1	Axis 2
pH	-0.069	0.286	-0.058	0.254
Temperature	-0.202	0.474	-0.171	0.421
Conductivity	-0.444	0.333	-0.376	0.296
DO	-0.201	0.074	-0.170	0.066
Salinity	-0.719	-0.133	-0.609	-0.118
TSS	0.024	0.354	0.020	0.314
TDS	-0.473	0.134	-0.401	0.119
Ammonia Nitrogen	-0.282	0.289	-0.239	0.256
DOC	0.516	0.558	0.437	0.496

Two environmental variables had high intra-set correlations, thus were more important in predicting community composition. Salinity strongly correlated with the first CCA axis while DOC correlated with the second CCA axis (Figure 4). The CCA output depicted that Coleoptera, Hemiptera, Ephemeroptera, Plecoptera and Diptera preferred high concentration of DOC.

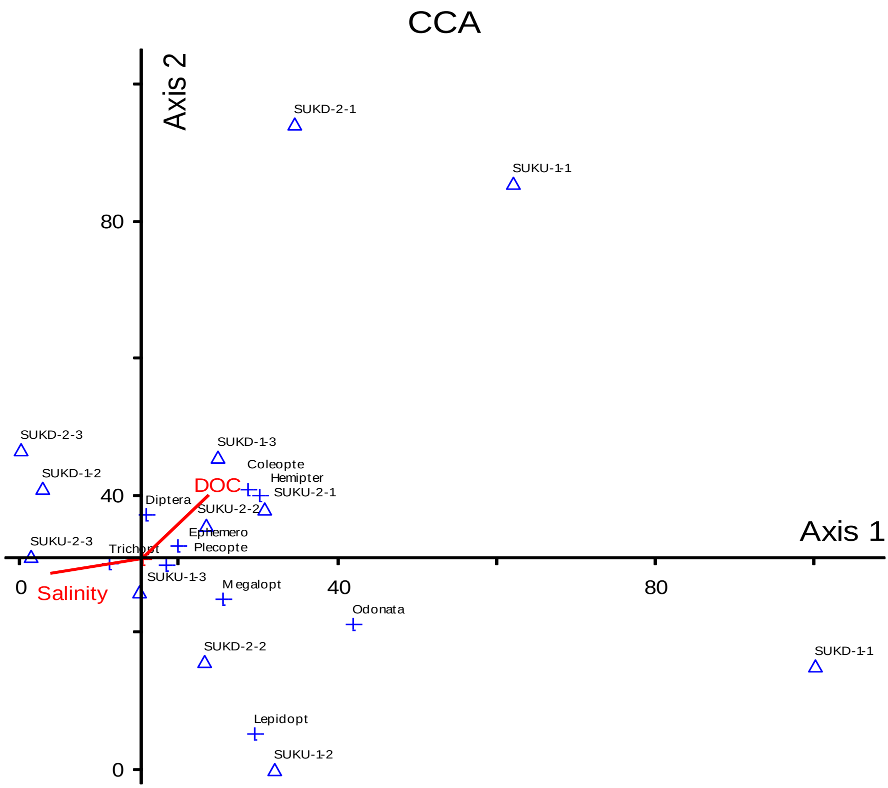


Figure 4. Canonical correspondence analysis (CCA) for the first two canonical axes of the aquatic insects (orders) and water quality parameters in Kimanis River.

Discussion

Composition and Distribution of Aquatic Insects

A total of 1,801 individuals of aquatic insects from nine orders and 28 families were collected from the sampling done at Kimanis River, Ulu Kimanis, CRP in October 2015 and January 2016. The orders are Coleoptera, Diptera, Ephemeroptera, Hemiptera, Lepidoptera, Megaloptera, Odonata, Plecoptera and Trichoptera. Ephemeroptera, Plecoptera and Trichoptera (EPT) communities composed of a large proportion of 89.56% of the total individuals sampled. Presence of high abundance of EPT communities marks high stream quality as EPT communities are prevalent in undisturbed streams (Che Salmah et al., 1999) and exhibit low tolerance toward water pollutants (Keçi et al., 2012). Therefore, Kimanis River at CRP can be customarily considered clean.

Seven orders of aquatic insect species and hexapodan Collembola were encountered in the six rivers surveyed by Long et al. (2002) in 2001. Orders attained in a study done by Long *et al.* are similar with this study with the exception of Lepidoptera and Megaloptera. In addition, in this study, trichopteran hydropscyhids fauna was dominant but a study conducted by Long *et al.* showed dipteran chironomid fauna as prominent aquatic insect taxa. The difference in diversity and composition with this study was possibly due to the variation in the sampling method. Surber net was the only sampling technique utilized in this study while Long et al. (2002) took sediment samples and used plankton net with a mesh size of 100 µm. Moreover, Long et al. (2002) surveyed Sg. Mawau, Sg. Tandulu, Sg. Liawan, Sg, Ulu Senagang, Sg. Tikolud and Sg. Balayo but not Kimanis River. Stream insects possess ubiquitous nature in stream ecosystems, diverse behavioural, morphological and ecological traits, and are highly variable in community structure even between adjacent streams (Heino & Peckarsky, 2014). Hence, this might give an assumption that the composition of aquatic insect communities is distinctive between different rivers.

Trichoptera was the dominant taxa in aquatic insect population (57.47%) in Kimanis River at CRP in which the aquatic insects collected was dominated by family Hydropscyhidae (43.48%), followed by family Philopotamidae (13.71%). The large quantity of trichopterans may be associated with the presence of high food quality (Perterson, 1987; Harding, 1997; Prommi et al., 2014), stable water flow and stable substrata common in these habitats (Georgian & Thorp, 1992; Prommi et al., 2014). In addition, similarly low numbers and diversity of Plecoptera are reported in this study (Hamid & Rawi, 2011; Prommi & Payakka, 2015). The absence of high density of Plecoptera in Kimanis River is probably due to unfavourable conditions for their growth and reproduction as they prefer cooler, more northern latitudes (Sivec & Yule, 2004; Prommi & Payakka, 2015) while Kimanis River recorded relatively high surface water temperature.

In this study, significant differences were encountered for several abundance of orders of aquatic insect communities at different strata of Kimanis River. Family Chironomidae from order of Diptera was more abundant at the downstream of Kimanis River at CRP. A comparative example of distribution of Chironomidae has been attained by Prommi and Payakka (2015) in Mae Tao and Mae Ku watersheds, Northern Thailand. According to Yule (2004) and Wahizatul et al. (2011), family Chironomidae thrive in standing and slow-flowing streams and muddy or sandy areas with high fine-sediment particles. Therefore, it can be argued that stations at the downstream with sandy bottom is more suitable for family Chironomidae to live compared to stations at the upstream which have a rocky bottom.

On the other hand, family Pyralidae was found abundant in the upstream strata but are not sampled from the downstream strata. Pyralidae larvae thrive in rapid streams on the surface of submerged rocks which provide protection from the current by a case consisting of an irregular sheet of silk cemented around most of its periphery to the rock (Lavery & Costa, 1973). Hence, it is suggested that the rocky bottom at the upstream of Kimanis River serves as a better habitat for Pyralidae as compared to sandy bottom at the downstream.

Shannon-Wiener Index (H') of aquatic insect communities in Kimanis River shows that the diversity of aquatic insects of upstream is slightly higher than downstream with 1.97 and 1.85 respectively. The differences between diversity indices among the stratum are not apparent probably due to the short distance between the sampling sites. The diversity and evenness indices were basically higher at upper stream and decreased at downstream (Salman et al., 2011; Mohd Rasdi et al., 2012). However, in this study, downstream has slightly more evenness with the index value of 0.67 than in the upstream with an index value of 0.60. The lower evenness of upstream could possibly be due to the occurrence of high abundance of trichopterans at the upstream which caused unbalanced distribution of aquatic insects at upstream. This study recorded 48% similarity in terms of species of aquatic insects between downstream and upstream based on the Sørensen's Quantitative Index (C_N). The composition of aquatic insect population that thrive in downstream and upstream of the Kimanis River was similar and this was probably due to less variation of water quality parameters between downstream and upstream areas.

Biotic Indices

Biotic indices values for upstream and downstream strata of Kimanis River do not vary significantly. EPT richness was calculated based on the number of families of EPT communities found in the upstream and downstream respectively. The overall EPT richness of Kimanis River at CRP is 14. From the study, Kimanis River can be assumed as a non-impacted stream as the EPT richness value exceed 10, which is the cut-off value to be qualified as a non-impacted stream (Fikri, 2004). Family biotic index obtained at downstream strata and upstream strata are 3.97 and 3.88 respectively, both indicating very good water quality. Biological Monitoring Work Party (BMWP) of Kimanis River depicts that the river is unpolluted and unimpacted. Pollution intolerant families have high BMWP scores, while pollution tolerant families have low scores (Barman & Gupta, 2015). Presence of immense abundance of pollution intolerant families such as Heptageniidae, Leptophlebiidae and Perlidae in Kimanis River enable the river to be classified as unpolluted. Meanwhile, the Average Score Per Taxon (ASPT) that represents the average tolerance score of all taxa within the community (Barman & Gupta, 2015) was measured for both downstream and upstream strata and show that they were both considered as having good water quality.

Water Quality Physico-Chemical Parameters

The water quality physico-chemical parameters readings did not show much variation between October 2015 and January 2016, implying that the level of stream disturbance in Kimanis River at CRP was not serious. Concentration of dissolved organic carbon (DOC) is a general description of the dissolved organic matter (DOM). DOC concentration in this study varied between 1.48 mg/l to 11.37 mg/l. DOC was the most important water quality parameter in predicting the order of aquatic insect community. Aquatic insect communities in the upstream particularly families Coleoptera, Hemiptera, Ephemeroptera, Plecoptera and Diptera positively correlated with DOC concentration. Harun *et al.* (2015) reported correlation between hemipterans and DOC at the Lower Kinabatangan River Catchment, Sabah and proposed Hemiptera as indicators of elevated (present or past) nutrient levels in the stream systems. From this study, CCA results support the use of Hemiptera as nutrient level indicators. The correlation is possibly due to more abundance of preys (food) at locations with increased nutrient concentrations (Maul et al., 2004; Harun et al., 2015).

Total dissolved solids (TDS) in January 2016 documented almost two-fold of the values recorded in October 2015. The range of TDS in October 2015 is between 29.25 mg/l and 35.10 mg/l while TDS in January 2016 ranged between 54.38 mg/l and 57.20 mg/l. A similar pattern is observed for the recorded conductivity. The conductivity documented in October ranged from 44.47 μS/cm to 59.80 μS/cm but increased significantly in January, recording 79.83 μS/cm to 92.80 μS/cm. The large variation in TDS and conductivity between sampling periods is possibly due to rainy days in the October sampling which influence the TDS and conductivity values. The rainy period may alter conductivity substantially as rain water has lower conductivity due to lack of minerals (Mahazar *et al.*, 2013). Apart from this, the increment of TDS and conductivity could also be attributed to weathering intensity during the wet season (Makwe & Chup, 2013) which January is known for here.

Total suspended solids (TSS) is usually due to the introduction of external factors carried by runoff rain waters which cause the increment in concentration of this parameter (Jonnalagadda & Mhere, 2001; Rossi et al., 2005; Suratman *et al.*, 2006; Suratman et al., 2015). Low TSS was recorded in Kimanis River suggesting that the river is undisturbed and unimpacted by human activities. On the other hand, ammonia nitrogen ranged from 0.29 mg/l to 0.44 mg/l in October 2015 and 0.00 mg/l to 0.24 mg/l in January 2016.

The surface temperature ranged from 24.57 ^{0}C to 25.67 ^{0}C in October and 25.23 ^{0}C to 26.77 ^{0}C in January. The rise in water temperature probably due to low flow conditions and strong sunshine occurred in January 2016. Temperature impacts both the chemical and biological characteristics of surface water (Prommi & Payakka, 2015). As temperature is one of the major factors determining the distribution of Hydropsychidae (Kimura et al., 2008; Prommi & Payakka, 2015), in the present study, a slight temperature rise in Kimanis River from October to January has caused drastic increase in the abundance of Hydropsychidae species. This implies that higher water temperatures favour the density and diversity of Hydropsychidae.

The surface water dissolved oxygen (DO) concentrations ranged from 7.16 mg/ to 8.97 mg/l. Meanwhile, salinity is relatively constant in Kimanis River, Ulu Kimanis, CRP. As salinity affects dissolved oxygen solubility, the constant salinity enables relatively stable dissolved oxygen concentration present in Kimanis River. High dissolved oxygen content recorded implies that condition of Kimanis River is suitable for the establishment of aquatic insect communities. With regard to the pH, this varied between 6.50 and 7.75. Among the water quality parameters, pH would be the most stable parameter with small differences and also most stable for every 3 months with no drastic changes (Mahazar et al., 2013). However, a polluted river usually would have unstable pH rather than stay in a durable form (Mahazar et al., 2013). As the pH value stayed relatively stable in this study, this can therefore infer that Kimanis River is unpolluted and unimpacted.

Regarding the Interim National Water Quality Standards for Malaysia (INWQS) classification, the water quality of the Kimanis River (except ammonia nitrogen) were categorized as Class I stream. Class I stream functions as conservation of natural water supply with no water treatment required. Class I is defined as very clean and treatment is not required at this stage, except by disinfection or boiling (Harun et al., 2010).

Conclusion

Diversity index was basically higher at upstream and decreased at downstream followed the same trend as that of the river water quality. The water quality parameters readings did not indicate much variation between October and January. Hence, it infers that the stream condition in Kimanis River at CRP was relatively stable. The water quality in Kimanis River was classified in Class I for most of the water quality parameters, which is consistent with the assessment made by the biotic indices. This implies that the aquatic insect communities are useful as a faster and cheaper way for rapid assessment of stream water quality. In view of the above, more research would provide a better representation of the aquatic insect communities of Ulu Kimanis, Crocker Range Park. This will help in representing the species richness and composition available in the streams of CRP. Meanwhile, current species checklist could be further extended with more research conducted.

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Appendix

Table 9. The list of aquatic insects distributed across downstream and upstream of Kimanis River, Ulu Kimanis, CRP.

Order	Family	Downstream			Upstream		
		Station 1	Station 2	Total	Station 1	Station 2	Total
Coleoptera	Elmidae	8	8	16	17	10	27
	Psephenidae	2	-	2	5	6	11
	Gyrinidae	-	-	-	10	-	10
	Hydrophilidae	-	-	-	2	-	2
	Total	**10**	**8**	**18**	**34**	**16**	**50**
Diptera	Tipulidae	4	1	5	4	9	13
	Chironomidae	15	1	16	3	-	3
	Stratiomyidae	-	-	-	2	-	2
	Total	**19**	**2**	**21**	**9**	**9**	**18**
Ephemeroptera	Baetidae	35	28	63	101	47	148
	Heptageniidae	22	16	38	42	58	100
	Leptophlebiidae	13	7	20	59	40	99
	Siphlonuridae	-	-	-	15	1	16
	Ephemerellidae	1	-	1	-	6	6
	Caenidae	1	2	3	2	2	4
	Potamanthidae	-	-	-	1	2	3
	Tricorytidae	-	-	-	2	-	2
	Total	**72**	**53**	**125**	**222**	**156**	**378**
Hemiptera	Mesoveliidae	-	-	-	-	2	2
	Gerridae	1	-	1	1	-	1
	Veliidae	-	-	-	1	-	1
	Total	**1**	**0**	**1**	**2**	**2**	**4**
Lepidoptera	Pyralidae	-	-	-	33	4	37
	Total	**0**	**0**	**0**	**33**	**4**	**37**
Megaloptera	Corydalidae	-	-	-	18	6	24
	Total	**6**	**2**	**8**	**18**	**6**	**24**
Odonata	Euphaeidae	3	-	3	2	1	3
	Gomphidae	1	-	1	-	-	-
	Total	**4**	**-**	**4**	**2**	**1**	**3**
Plecoptera	Perlidae	15	7	22	28	25	53
	Total	**15**	**7**	**22**	**28**	**25**	**53**
Trichoptera	Hydropscyhidae	110	92	202	272	309	581
	Philopotamidae	34	8	42	93	112	205
	Limnephilidae	-	-	-	2	-	2
	Polycentropodidae	-	-	-	1	1	2
	Phryganeidae	-	-	-	1	-	1
	Total	**144**	**100**	**244**	**369**	**422**	**791**
Grand Total		**271**	**172**	**443**	**717**	**641**	**1358**