Land use effects on Ephemeroptera, Plecoptera, and Trichoptera (EPT) communities in Ranau-Beluran District, Sabah, Malaysia

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Abstract. Ephemeroptera, Plecoptera, and Trichoptera (EPT) are particularly sensitive and well suited as bioindicators for monitoring stream health. This study aims to investigate the EPT communities between disturbed and undisturbed areas of Ranau-Beluran District. Based on National Water Quality Standards of Malaysia, the sampled streams were categorized as Class I and II of water classes. Nonparametric Mann-Whitney test showed that only canopy cover was significantly different between disturbed and undisturbed sites. The sampled insects were dominated by Ephemeroptera (80.42%), followed by Plecoptera (14%) and Trichoptera order (5.58%). The Leptophlebiid family was the most abundant (44.82%). Family richness, the Simpson's and Shannon-Weiner diversity indices all showed similar trends, EPT diversity being lower in disturbed sites. The diversity of EPT was strongly related to canopy cover.

Key Words: benthic macroinvertebrates, bioassessment, Borneo, EPT, land uses.

Introduction. For centuries, humans had relied on the resources near the aquatic environments for settlements, transportation, and water supply for domestic and agricultural use (Fang & Jawitz 2019). Yet studies had shown that alterations and deterioration in the riverine landscapes caused by deforestation, agriculture expansion, urbanization and industrialization had adversely impacted the freshwater environments (Habib & Yousuf 2016; Paul & Meyer 2016; Justus 2017). In addition, human activities including water extraction, fisheries overexploitation, water pollution, habitat destruction and exotic species introduction in freshwater had led to population decline and biodiversity loss (Dudgeon et al 2006; Strayer & Dudgeon 2010; Reid et al 2019).

Freshwater macroinvertebrates are constantly being studied due to their ubiquity in various freshwater habitats, as well as their use as for monitoring stream health, among others. From the freshwater macroinvertebrates, 3 orders, Ephemeroptera, Plecoptera and Trichoptera (EPT), are particularly sensitive to changes in their environments. They are well documented as indicators of better water quality or healthy streams (Lenat 1993; Barbour et al 1999). Therefore, studies on the responses of these 3 orders to the natural variation (Bispo et al 2006; Haidekker & Hering 2008) and anthropogenic effects (Fikri et al 2016; Hamid & Rawi 2017; Masese & Raburu 2017) enable the understanding of changes in freshwater ecosystems.

Liwagu, Sugut, Sapi, and Labuk River are a few important catchments in Ranau-Beluran District. These rivers and their tributaries act as water resources for highland vegetable farming, resort/tourism development, hydropower needs, and especially have a vital role as water supply for the scattered communities from Ranau to Beluran. Previous studies focused on the upper catchments at Kinabalu Park (Wong & Fikri 2016) and Kundasang area (Shafie et al 2017). This study aims to investigate the EPT communities in the disturbed and undisturbed areas of Ranau-Beluran District.

Material and Method

Study sites. This study was conducted at the tributaries of Liwagu Sugut, Sapi, and Labuk River, in the Ranau and Beluran districts, Sabah, Malaysia. These river catchments were subjected to anthropogenic activities from extensive small and medium scale agriculture to intensive monocultures dominated by oil palm plantations (Murtedza et al 2002).

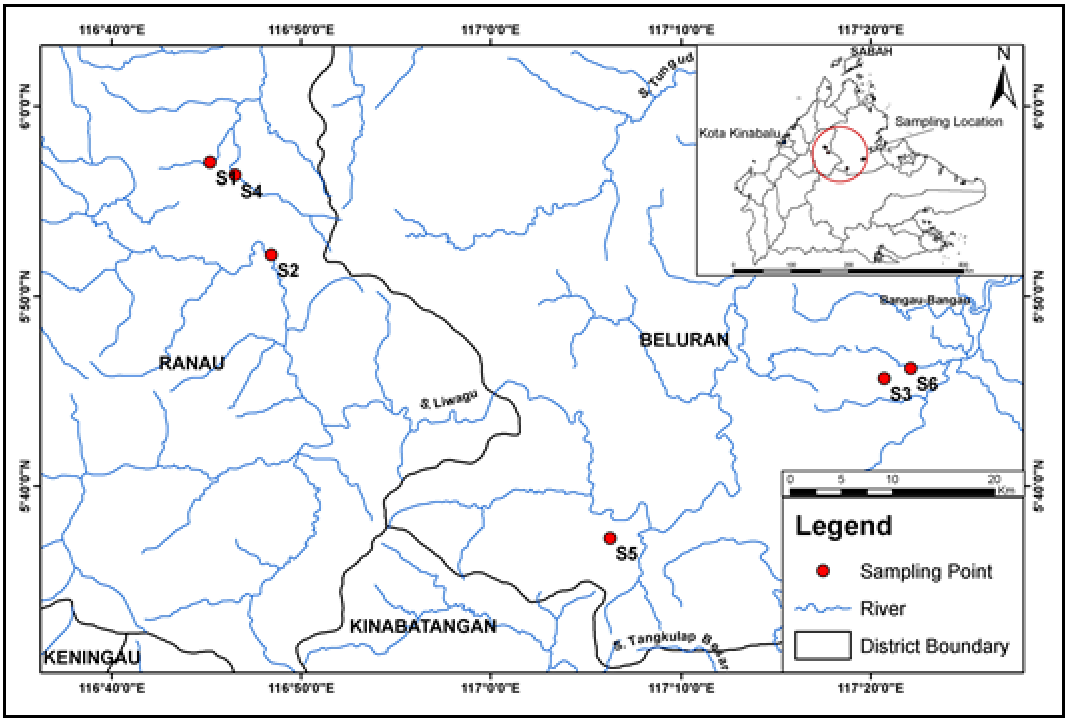

Figure 1. The six sampling sites (S1 to S6) at Ranau-Beluran District, Sabah, Malaysia.

Six sampling sites (streams) were selected: Kananapon (S1), Valanut (S2), Bidu-Bidu (S3), Bayaan (S4), Telupid (S5), and Kibut (S6), as presented in Figure 1. Kananapon (S1) and Bayaan (S4) are tributaries of Sugut River; Valanut (S2) flows into Liwagu River; Telupid (S5) connects to the Labuk River; Kibut (S5) is the tributary of Sapi River. S1, S2, and S3 were chosen as undisturbed sites, located in the forest area away from human activities, while S4, S5, and S6 were disturbed sites. S4 is located downstream of a human settlement, and S5 and S6 are located at oil palm plantations. The sampling was conducted from 19 to 25 June 2017.

EPT sampling. A 100 m reach of the stream was selected for sampling. For safety reasons, all stream sites had less than 1 m depth. The selected reach was subdivided into 3 sampling substations: upper, middle and lower reach (Mohd Rasdi et al 2012). At each sampling substation, 3 samples were collected from the following macrohabitats: riffle, run, and pool. EPT specimens were collected with a 500 µm mesh square net. The square net was placed on the streambed against the current flow. An area of approximately 1 m^2 in front of the net was disturbed for two minutes (Shafie et al 2017). Larger substrate components were lifted and attached insects were dislodged into the net before starting to disturb the remaining substrate. Samples collected in the net were removed into a white tray for further *in situ* sorting. Sorted insects were placed in 95% ethanol before being transferred back to the laboratory. The sorted insects were identified to family level using taxonomic keys (Yule & Yong 2004).

Physicochemical parameters. At each sampling station, *in situ* physicochemical parameters were measured. The pH, water temperature, dissolved oxygen (DO), and conductivity were measured with a YSI Professional Plus multiparameter. The depth and width of the streams were measured with a 1 m steel ruler and measuring tape. The spherical densiometer was used to measure canopy cover. The water velocity measurement was conducted by recording the time a buoyant object travels a distance of 2 m on the surface of the run macrohabitats (Hauer & Resh 2006). The fast and slow water velocity were separated by 0.3 m s^{-1} (Barbour et al 1999).

Statistical analyses. Nonparametric Mann-Whitney U test was conducted to compare the physicochemical parameters between disturbed and undisturbed sites. The Simpson's diversity index (1-D) and the Shannon-Weiner diversity index (H') were used to calculate the diversity of the sampled streams with PAST ver3.15 software (Hammer et al 2001). The nonparametric Spearman Correlation was conducted by IBM SPSS Statistic Version 20 software to test the relationships between the EPT diversity and physicochemical parameters.

Results and Discussion

Results of physicochemical parameters. Table 1 summarized the physicochemical parameters of the sampling sites. Mean water temperature for the 6 streams showed little variation, ranging from 23.93 to 26.67°C. DO concentration had the highest mean in S1 (9.18 mg L^{-1}) and lowest in S4 (5.25 mg L^{-1}). The highest (225.80 μS cm^{-1}) and the lowest (74.37 μS cm^{-1}) average conductivity were recorded at the disturbed streams S4 and S5, respectively. The average pH ranged from 7.75 to 8.39, with the highest at S4 and the lowest at S1. For physical measurements, the S2 riverbank shaded the most (50%) of its stream surface, while S6 (0%) had an open canopy area. Average stream width ranged from 5.81 m to 14.79 m in S2 and S5, respectively. The mean depth of the stream was highest at S2 (0.32 m) and lowest at S4 (0.19 m). Most streams had fast velocity (>0.3 m s^{-1}), except for S3 (0.21 m s^{-1}). The Mann-Whitney test revealed that only the canopy cover was significantly different (P<0.05) between disturbed and undisturbed streams.

Table 1
Physicochemical parameters at each site (mean±SD) and Mann-Whitney results between disturbed and undisturbed sites

Parameter	*Undisturbed*			*Disturbed*			*Mann-Whitney*	
	S1	*S2*	*S3*	*S4*	*S5*	*S6*	*U*	*P*
Temperature (ºC)	26.57 ±0.06	23.93 ±0.46	25.83 ±0.15	25.43 ±0.06	24.97 ±0.12	26.67 ±0.06	37	0.79
DO (mg L^{-1})	9.18 ±0.06	7.15 ±0.74	7.51 ±0.05	5.25 ±0.46	7.66 ±0.25	7.76 ±0.12	30	0.37
Conductivity (μS cm^{-1})	200.20 ± 0.10	109.7 ±1.04	142.50 ±17.76	225.80 ±0.17	74.37 ±0.72	152.63 ±0.15	39	0.09
pH	7.75 ±0.41	8.09 ±0.08	8.25 ±0.02	8.39 ±0.02	7.93 ±0.12	8.21 ±0.05	28.5	0.31
Canopy cover (%)	31.67 ±27.54	38.33 ±12.58	6.67 ±7.64	13.33 ±18.93	5.00 ±8.66	0.00 ±0.00	17	0.03 *
Width (m)	7.37 ±1.79	5.81 ±0.89	9.83 ±1.07	6.89 ±1.43	14.79 ±0.88	10.69 ±3.96	23	0.13
Depth (m)	0.23 ±0.11	0.32 ±0.12	0.29 ±0.10	0.19 ±0.02	0.22 ±0.04	0.27 ±0.09	29	0.33
Velocity (m s^{-1})	0.47 ±0.01	0.34 ±0.04	0.21 ±0.03	0.31 ±0.09	0.45 ±0.08	0.41 ±0.13	29.5	0.35

Note: DO - dissolved oxygen; S1 - Kananapon; S2 - Valanut; S3 - Bidu-Bidu; S4 - Bayaan; S5 - Telupid; S6 - Kibut; * - significant differences.

Based on the National Water Quality Standards of Malaysia (Zainudin 2010), the DO recorded classified most sites in Class I (>7 mg L^{-1}), and S4 in Class II (5-7 mg L^{-1}). All sites were classified by conductivity values in Class I (>1000 μS cm^{-1}). Lastly, pH values indicated that the sampled sites were in Class I (6.5-8.5).

Composition and diversity of EPT in Ranau-Beluran District. A total of 2278 individuals and 10 families were collected in this study. Most of the EPT collected were from the Ephemeroptera order and accounted for 80.42% of the total collection (Table 2). This was followed by Plecoptera (14%) and Trichoptera (5.58%), with both orders represented by two families. The EPT in these 6 sites was dominated by Leptophlebiidae, which comprised almost half of the samples (44.82%).

Among the 6 sites, Baetidae recorded the highest abundance in both S1 and S2, while the remaining sites were dominated by Leptohlebiidae. Most of the families were found in all sampled sites, except for Euthyplociidae, which was found only at S1 and S2. Peltoperlidae were collected only from S2. Both families had the lowest relative abundance, with 0.31% and 0.09%, respectively.

As presented in Table 3, the undisturbed sites had a high family richness (8 to 10 families). Disturbed site S4 also recorded 8 EPT families, while the number dropped to 5 and 6 families at the remaining two disturbed sites. Based on the Simpson Diversity Index, the EPT communities in undisturbed sites had a higher diversity compared to those from the disturbed sites. The highest values were recorded at S1, followed by S2, S3, S4, and S5. The similar pattern was indicated by the Shannon-Weiner Diversity Index (H'), except at S2, where the highest diversity was recorded.

Table 2
List of Ephemeroptera, Plecoptera, and Trichoptera orders with families collected from the six sampling sites at Ranau-Beluran District

Order	*Undisturbed*			*Disturbed*			*No. of*	*Relative*
Family	*S1*	*S2*	*S3*	*S4*	*S5*	*S6*	*individuals*	*abundance (%)*
Ephemeroptera								
Baetidae	143	69	20	204	40	13	489	21.47
Caenidae	25	4	4	8	4	0	45	1.98
Ephemerellidae	2	3	2	3	0	0	10	0.44
Euthyplociidae	1	6	0	0	0	0	7	0.31
Heptageniidae	7	12	31	28	166	16	260	11.41
Leptophlebiidae	97	16	74	336	307	191	1021	44.82
Plecoptera								
Perlidae	91	22	34	129	29	12	317	13.92
Peltoperlidae	0	2	0	0	0	0	2	0.09
Trichoptera								
Hydropsychidae	48	30	8	17	0	3	106	4.65
Philopotamidae	8	2	9	1	1	0	21	0.92
Total	422	166	182	726	547	235	2278	100.00

Note: S1 - Kananapon; S2 - Valanut; S3 - Bidu-Bidu; S4 - Bayaan; S5 - Telupid; S6 - Kibut.

Table 3
Ephemeroptera, Plecoptera, and Trichoptera (EPT) diversity of sampling sites at Ranau-Beluran District

Diversity indices	*Undisturbed*			*Disturbed*		
	S1	*S2*	*S3*	*S4*	*S5*	*S6*
EPT richness	9	10	8	8	6	5
Simpson (1-D)	0.77	0.76	0.75	0.67	0.58	0.33
Shannon (H')	1.63	1.75	1.64	1.32	1.08	0.72

Note: S1 - Kananapon; S2 - Valanut; S3 - Bidu-Bidu; S4 - Bayaan; S5 - Telupid; S6 - Kibut.

Relationships of EPT diversity to physicochemical parameters. The results of the Spearman Correlation test showed that EPT family richness, Simpson and Shannon-Weiner diversity indices had strong positive relationships with canopy cover (Table 4).

Table 4
Relationships of Ephemeroptera, Plecoptera, and Trichoptera (EPT) diversity with physicochemical parameters

Physicochemical parameters		*Diversity indices*	
	EPT richness	*Simpson (1-D)*	*Shannon (H')*
Temperature (ºC)	-0.23	-0.2	-0.49
Dissolved Oxygen (mg L^{-1})	-0.03	0.03	-0.37
Conductivity (μS cm^{-1})	0.23	0.14	-0.14
pH	-0.35	-0.37	-0.03
Canopy cover (%)	0.93**	0.89*	0.83*
Width (m)	-0.73	-0.66	-0.71
Depth (m)	0.2	0.31	0.6
Velocity (m s^{-1})	0.12	0.09	-0.37

Note: * - significant differences ($p<0.05$); ** - significant differences ($p<0.01$).

Leptophlebiidae family is ubiquitous in aquatic environments, in lotic and lentic environments (Brasil et al 2013). In this study, high abundance of leptophlebiids was found at the disturbed sites. Leptophlebiidae are generally considered as sensitive insects towards human disturbances (Everaert et al 2014; Xu et al 2014), even though some taxa are more tolerant towards anthropogenic impacts. For instance, Selvakumar et al (2014) found that the *Choroterpes* of Leptophlebiids was associated with agriculture areas. Another study showed that *Choroterpes* was related with mining areas, with shrubs and riparian vegetation (Subramanian et al 2005).

Based on the National Water Quality Standards of Malaysia, the sampled streams were categorized as Class I (natural environment, water supply with no treatment needed, and very sensitive of aquatic species) and II (water supply with conventional treatment and sensitive of aquatic species). However, EPT family richness, the Simpson's index and Shannon-Weiner diversity index all showed similar trends, in which EPT diversity was lower in disturbed sites. EPT communities often respond to human activities, including deforestation, agricultural activities, and urbanization (Righi-Cavallaro et al 2010; Iñiguez–Armijos et al 2014; Monteiro do Amaral et al 2015). Reduction in EPT diversity was observed in freshwater habitats subjected to anthropogenic impacts (Bertaso et al 2015; Fikri et al 2016). Interestingly, the diversity index of S4 was higher than that of S3, although the EPT family richness retains the same family number as in S3. This is probably due to the intact forest area on one side of the sampling site. However, both Shannon and Simpson diversity values showed that EPT diversity decreased at disturbed sites.

The significant correlation between EPT diversity and canopy cover showed the impact of the land use at disturbed sites. The study by Arimoro et al (2012) revealed that the canopy cover influences the abundance, richness, and diversity of macroinvertebrates. Dropped leaves and trees may increase the habitat heterogeneity, resulting in the colonization of diverse benthic macroinvertebrates. A study at Gunung Jerai catchment (Hamid & Rawi 2011) showed that EPT taxa react differently towards the shaded areas of their habitats. Conversion of riparian landscape for agriculture purposes leads to higher risk of agricultural runoff, which causes an increase of nutrient and the contamination of freshwater habitats (Brown et al 2017). Studies reported that riparian buffer significantly reduces the effect of deforestation on freshwater macroinvertebrates (Lorion & Kennedy 2009).

In addition, canopy at riparian drop leaf litters provides food resource and shelter for the stream inhabitant. The leaves, branches, and vegetation that fall into the stream convert to organic matter and detritus, which are food resources for aquatic insects (Lorion & Kennedy 2009). For instance, Peltoperlids and Euthyplociids occurred only at

S1 and S2, which had a higher percentage of canopy shading the streams. Peltoperlids, as shredders, break down the litter into fine particulate organic matter, ready to support collector-gatherers and collector filterers (Patrick 2013). The occurrence of Euthyplociids in S1 and S2 were related to streams with a width of 3-5 m and partially canopied (Nguyen & Bae 2003), similar to the physical characteristics of Vietnam streams.

Conclusions. Streams at Ranau-Beluran District showed that water quality remains intact, being categorized in Class I and II. Reduction in EPT diversity was observed at sites that suffered anthropogenic impacts. This indicates their suitability for a quick assessment of the health of the stream. The imperative information would enhance river catchment management by incorporating biological components of freshwater ecosystems.

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