BIOMONITORING OF STREAMS: USING EPHEMEROPTERA, PLECOPTERA AND TRICHOPTERA (EPT) IN RESPONSES TO THE DIFFERENT TYPES OF LAND USE AT TABIN WILDLIFE RESERVE (TWR), LAHAD DATU, SABAH, MALAYSIA

Arman Hadi Fikri, Audrey Ang Chii Shian, Sahana Harun & Kueh Boon Hee

Institute for Tropical Biology and Conservation (ITBC)
Universiti Malaysia Sabah (UMS),
Jalan UMS, 88400 Kota Kinabalu,
Sabah, Malaysia

ABSTRACT. *A preliminary study on three aquatic insect orders, namely Ephemeroptera (mayfly), Plecoptera (stonefly), and Trichoptera (caddisfly) (EPT) was conducted at Tabin Wildlife Reserve (TWR), Lahad Datu, Sabah in January and February 2015. The objectives of this study were to determine (i) the composition of EPT along a stream at TWR, (ii) the distribution of EPT in each different land use at TWR, and (iii) the relationship between EPT communities and the water quality of the stream at TWR. Kick net sampling technique was used for collecting the EPT communities along Sg. Lipad of TWR. The most dominant order was Ephemeroptera consisting of 11 families with 1,354 individuals out of the total of 1,724 individuals and 26 families of EPT communities sampled. Trichoptera was the second most abundant order with nine families and 258 individuals, and lastly, Plecoptera with only six families and 112 individuals. There were more families of EPT communities distributed in secondary forest as compared to the oil palm plantation. Several exclusive families were found in secondary forest, while only one family was found in oil palm plantation. The habitat run showed the highest in abundance of EPT, while pool recorded the least in abundance. Four biotic indices (BMWP, ASPT, FBI, and INWQS) and a few physico-chemical parameters (pH, temperature, conductivity, and DO) were used in this study to determine the water quality of the sampling location. Based on the biotic indices and physico-chemical parameters, the status of water in Sg. Lipad was in excellent condition. The two water quality tests showed profound consistency. This serves as a confirmation that the EPT communities are effective to be used as a biomonitoring tool at TWR.*

KEYWORDS. Aquatic insects EPT physico-chemical parameters biomonitoring Sg. Lipad Tabin

INTRODUCTION

There is a total of 6-10% of all species found on Earth exists in the freshwater ecosystems, and among the 126,000 freshwater animal species, about 60.4% of them are composed of insects (Dudgeon *et al.*, 2006; Balian *et al.* 2008). This makes freshwater ecosystems to be considered as biodiversity hotspots which are heavily threatened by habitat loss and other anthropogenic activities (Conservation International, 2014). According to the World Wide Fund for Nature, WWF (2012), the organization pointed out that the 'Heart of Borneo' is listed as a biodiversity hotspot region which is inclusive of Malaysia, Brunei, and Indonesia.

Freshwater ecosystems are considered as tough habitats for small bodied animals, such as grasshoppers, mantises, or mosquitoes, but yet aquatic insects are successful in colonizing the ecosystems due to their wide range of adaptations (Susheela *et al.*, 2014). By viewing the anthropogenic disturbances globally, aquatic ecosystems can definitely be affected in great extent and intensity (Quist and Schultz, 2014), without any doubt can also bring about effects towards the aquatic organisms which rely on it. Thus, maintaining the integrity of the freshwater ecosystems from different forms of anthropogenic disturbance is of utmost importance, and for this reason, much attention should be given to it.

Aquatic macroinvertebrates or benthic macroinvertebrates are mainly aquatic insects that spend most of their lives in the freshwater ecosystems. The term benthic is used to define aquatic insects as they are found in abundance associated with the bottom or with a substrate (Susheela *et al.*, 2014). Aquatic insects are found ubiquitous in stream ecosystems, and present throughout a wide range of environmental conditions which make them to become a successful and appropriate model group for investigation at different levels of process, including at the individual, populational, and also community level (Heino and Peckarsky, 2014). At multiple space (spatial) and time (temporal) scales, the variation in the structure and organization of the aquatic insect communities are greatly influenced by abiotic environmental conditions, biotic conditions, and dispersal processes (Malmqvist, 2002; Heino *et al.*, 2013).

The physical, chemical and biological conditions of streams have a direct influence towards aquatic insects which make them good indicators for stream water quality (Budin *et al.*, 2007). Ephemeroptera, Plecoptera, and Trichoptera (EPT) are orders for aquatic insects which have the common names of mayflies, stoneflies, and caddisflies respectively. EPT is considered as an essential taxonomic group due to its wide range of distribution with high abundance and species richness (Righi-Cavallaro *et al.*, 2010). EPT is also the three major orders of aquatic insects that can be found abundantly in freshwater systems (Corona, 2010).

According to Bispo and Oliveira (2007), EPT makes up a rich collection of taxa in low and medium order cobble streams which occur primarily in clean and well-oxygenated water. The diversity and composition of EPT which functions as indicator species make them possible to determine the status of aquatic system water quality (Che Salmah *et al.*, 2001). EPT is highly sensitive towards any anthropogenic and environmental disturbances which allow them to become excellent indicators in evaluating and accessing the water quality of streams (Corona, 2010; Myers *et al.* 2011). Thus, EPT can be considered as the key aquatic insect orders as they play vital roles in the aquatic ecosystems.

There is not much in the database of EPT in Malaysia as compared to temperate regions. According to Susheela *et al.* (2014), aquatic insects are usually overlooked and unfamiliar to the public. In view of the fact that EPT has not been widely examined in Malaysian ecological studies (Suhaila *et al.*, 2012), this study could provide baseline data for the records of EPT in Malaysia, especially in Sabah. Previous research done by Arman (2004) at Tabin Wildlife Reserve (TWR) focused on the diversity, composition, and distribution of aquatic insects at the study site, without focusing on the EPT communities. Therefore, this study was able to concentrate on the EPT communities at the same study site. This study also helped to provide more information for future research in terms of the composition and distribution of EPT communities at Tabin Wildlife Reserve.

Apart from that, EPT has been used to evaluate the water quality of freshwater ecosystems as EPT is highly specific to environmental stressors, such as temperature, anthropogenic disturbances, and pollutions (Corona, 2010). The study could also highlight the effects of anthropogenic disturbances towards Malaysian aquatic insect communities as there is very little information available on the subject matter (Wahizatul *et al.*, 2011).

Hence, the aim of this research was to understand in details the composition and distribution of EPT to provide more ecological information on EPT community in Malaysian streams. Integrated approaches of conservation would be able to be tested in order to determine the success of conservation efforts through the comparison between the EPT community at the study site and the EPT found in previous studies on aquatic insects. The objectives of this study were to determine: (1) the composition of EPT along the stream at TWR, (2) the composition and distribution of EPT in each different land use and habitat, and also (3) the relationship between EPT communities and the water quality of streams.

METHODS

Study Site

Tabin Wildlife Reserve (TWR) is a forest reserve gazetted under the Forest Enactment 1984. Dawson (1992) reported that TWR was initially gazetted with the main purpose of conserving three endangered large mammal species (Asian Elephant, Sumatran Rhinoceros, and Tembadau). TWR is located at 5°10’N, 118°40’E in the middle of the Dent Peninsula in eastern Sabah. It is a protected area situated at the north-east of Lahad Datu Town. The area is made up of approximately 120,521 hectares (WWF Malaysia, 1986).

Sampling

Sampling activities for EPT were carried out in Sg. Lipad of Tabin Wildlife Reserve. Sg. Lipad represented the secondary forest area located inside TWR, and another sampling area where the stream was used for agricultural purpose (oil palm plantations) was situated outside the boundary of TWR. The upstream of Sg. Lipad flowed into the oil palm plantation. The stream flowing into the secondary forest was less succumbed to human activities, while in the oil palm plantation the stream was often exposed to human disturbances.

A total of four stations with 12 sub-stations were selected from Sg. Lipad. A 100m range of the stream was selected for each station. Two of the stations (upstream and downstream) were located in secondary forest area, while the other two were in oil palm plantation area. A 500m difference in distance was made between the stations for each of the two land use types. The samplings for EPT communities from three different habitats (pool, run, and riffle) for each station were replicated three times.

Kick net technique was the standard method used for sampling at all the stations. Kick net has the net frame size of 390mm x 320mm with 210µm as the mesh size. As suggested by Hazelton (2003), some aquatic insects that clung onto larger rocks were removed by brushing them off into the net with hands. For the stream profile, the width was measured using a measuring tape and the depth of the stream was measured using a steel ruler. The measurement of stream profile required three replications at different habitats of pool, run, and riffle for each station. Water quality of the stream was measured at the sampling sites where kick net was carried out. Physico-chemical parameters, such as dissolved oxygen (DO), pH, temperature and conductivity were measured using a HANNA multi-parameter water quality meter (HI9828).

RESULTS AND DISCUSSION

Throughout this study, a total of 1,724 individuals representing 26 families of the three EPT orders were collected (Table 1). The overall diversity index of EPT communities in Sg. Lipad with H'=2.3074 indicated that the EPT communities were relatively diverse, and the habitat structure was rather intact with minimal pollution effects. The same pattern on the abundance of EPT could also be seen in the previous study done by Arman (2004) at the same study site. From all the sampled individuals, Ephemeroptera appeared to have the highest number of individuals with 4,551, followed by Trichoptera with 2,459, and Plecoptera with 1,845 individuals. However, the study done by Che Salmah *et al.* (2001) at Kerian river basin, Perak obtained different results with Ephemeroptera being the most abundant, to be followed by Plecoptera and Trichoptera.

[1] **Table 1:** List of EPT families distributed across different land uses.
[2]

[3]	**Orders**	**[4]**	**Families**	**[5]**	**No. of Individuals**		
				[6]	**Oil Palm Plantation**	**[7]**	**Secondary Forest**
[8]	Ephemeroptera	[9]	Baetidae	[20]	31	[31]	46
		[10]	Behningiidae	[21]	15	[32]	18
		[11]	Caenidae	[22]	40	[33]	3
		[12]	Ephemerellidae	[23]	120	[34]	151
		[13]	Heptageniidae	[24]	19	[35]	118
		[14]	Leptophlebiidae	[25]	218	[36]	311
		[15]	Neophemeridae	[26]	31	[37]	0
		[16]	Oligoneuriidae	[27]	1	[38]	7
		[17]	Potamanthidae	[28]	0	[39]	5
		[18]	Siphlonuridae	[29]	89	[40]	102
		[19]	Tricorytidae	[30]	18	[41]	11
[42]	**Total**	**[43]**	**11**	**[44]**	**582**	**[45]**	**772**
[46]	Plecoptera	[47]	Capniidae	[53]	2	[59]	5
		[48]	Chloroperlidae	[54]	0	[60]	23
		[49]	Leuctridae	[55]	4	[61]	4
		[50]	Peltoperlidae	[56]	8	[62]	12
		[51]	Perlidae	[57]	0	[63]	52
		[52]	Perlodidae	[58]	1	[64]	1
[65]	**Total**	**[66]**	**6**	**[67]**	**15**	**[68]**	**97**
[69]	Trichoptera	[70]	Brachycentridae	[79]	1	[88]	2
		[71]	Glossosomatidae	[80]	20	[89]	3
		[72]	Hydrascyhidae	[81]	5	[90]	1
		[73]	Hydropscyhidae	[82]	9	[91]	175
		[74]	Hydroptilidae	[83]	11	[92]	4
		[75]	Leptoceridae	[84]	0	[93]	2
		[76]	Limnephilidae	[85]	0	[94]	1
		[77]	Polycentropodidae	[86]	5	[95]	5
		[78]	Psychomyiidae	[87]	4	[96]	10
[97]	**Total**	**[98]**	**9**	**[99]**	**55**	**[100]**	**203**
[101]	**Grand Total**	**[102]**	**26**	**[103]**	**652**	**[104]**	**1072**

The difference in diversity and composition in the study was due to the variation in sampling method. Kick net was the only sampling technique used in this study, while Arman (2004) used kick net and dip net method. Apart from that, the number of habitats and microhabitats where samplings were done differed in which only three habitats (pool, run, and riffle) were covered in this study, while for Arman (2004), there were three additional microhabitats studied (leaf litters, stone substrates, and aquatic vegetation). For Che Salmah *et al.* (2001), 16 tributaries were selected as the sampling sites without being further divided into habitats and microhabitats.

Ephemeroptera yielded the highest abundance along Sg. Lipad with 1,354 individuals (78.54%) out of the total 1,724 individuals sampled. The second highest was from the order Trichoptera which consisted of 258 individuals constituting 14.96% of the total individuals sampled. The least number of the individuals captured was from Plecoptera with only 112 individuals (6.50%) (Table 2). A total of 25 families were sampled from the stream flowing through the secondary forest, while for oil palm plantation, only 21 families were collected. A total of 1,072 individuals (62.18%) were sampled in the secondary forest, whereas only 652 individuals with 37.82% were captured during the sampling activities in oil palm plantation.

Table 2: List of families and respective abundance of EPT in different habitats.

Orders	Families	Habitats			Total
		Pool	Run	Riffle	
Ephemeroptera	Baetidae	19	39	19	77
	Behningiidae	2	10	21	33
	Caenidae	14	29	0	43
	Ephemerellidae	84	140	47	271
	Heptageniidae	51	59	27	137
	Leptophlebiidae	68	168	293	529
	Oligoneuriidae	0	0	8	31
	Neophemeridae	13	11	7	8
	Potamanthidae	0	0	5	5
	Siphlonuridae	35	92	64	191
	Tricorytidae	19	4	6	29
Total	**11**	**305**	**552**	**497**	**1354**
Plecoptera	Capniidae	2	4	1	7
	Chloroperlidae	5	14	4	23
	Leuctridae	0	3	5	8
	Peltoperlidae	9	7	4	20
	Perlidae	11	21	20	52
	Perlodidae	0	2	0	2
Total	**6**	**27**	**51**	**34**	**112**
Trichoptera	Brachycentridae	2	1	0	3
	Glossosomatidae	11	9	3	23
	Hydrascyhidae	3	3	0	6
	Hydropscyhidae	39	87	58	184
	Hydroptilidae	7	4	4	15
	Leptoceridae	0	2	0	2
	Limnephilidae	0	0	1	1
	Polycentropodidae	2	4	4	10
	Psychomyiidae	0	11	3	14
Total	**9**	**64**	**121**	**73**	**258**
Grand Total	**36**	**396**	**724**	**604**	**1724**

Generally, Ephemeroptera are commonly known to be nearly cosmopolitan, which can be found inhabiting a wide range of habitats (Che Salmah *et al.*, 2001). The large quantity of ephemeropterans may be contributed by the suitability of the habitats, behavioral adaptation, and their sensitivity in detecting predators through chemical cues (Che Salmah *et al.*, 2001).

Apart from that, the population of ephemeropterans was also proven by Suhaila *et al.* (2014) to be in the highest abundance, especially during the wet season, while the population of trichopterans resulted in the highest abundance during the dry season. The sampling was carried out in January, which according to Malaysian Meteorological Department (MMD) (2013), had the maximum rainfall in Sabah. This might resulted in the highest number of individuals recorded for order Ephemeroptera. As for Plecoptera, it showed the lowest in abundance as they are insects that are most sensitive and intolerant to pollution (Galdean *et al.*, 2000). As for the study conducted by Suhaila *et al.* (2014), the population of plecopterans remained low and showed consistency throughout the year, which was similar to Arman (2004), the plecopterans remained the lowest in individuals among the others, probably due to the fact that they are not affected by either the wet or dry season.

Neophemeridae from the order Ephemeroptera was the only family that was found exclusively from the stream in oil palm plantation. On the other hand, there were five families discovered only from the stream in the secondary forest, namely Potamanthidae (Ephemeroptera); Chloroperlidae, Perlidae (Plecoptera), and Leptoceridae, Limnephilidae (Trichoptera). The remaining 20 families out of the total of 26 families were those that had been identified in both land uses.

Apart from being one of the families found only in stream in the secondary forest, Perlidae was also the most abundant among the plecopterans which was similar to the findings by Che Salmah *et al.* (2001) due to their preference towards clean, cool, and well-oxygenated moving water (Fochetti and Tierno de Figueroa, 2008). Their distribution is rather confined to particular type of substrate and stream size (Che Salmah *et al.* 2001).Sg. Lipad was an ideal and suitable habitat for it to live in.

The families Heptageniidae and Hydropscyhidae were found in both oil palm plantation and the secondary forest areas. However, the families were both being highly distributed in the secondary forest, and very low number of individuals in the oil palm plantation. This could be due to the higher canopy coverage at the secondary forest, which was required, enabling them to survive better in the secondary forest (Boonsoong and Braasch, 2013).

There was an increasing trend in terms of the number of families for orders Ephemeroptera and Plecoptera with 11 and six families respectively as compared to the previous study by Arman (2004). From the previous study, only nine families from Ephemeroptera and two families from Plecoptera were recorded. Being of limited mobility, this increase in the number of families sampled over time could be seen as a sign of improvement of the stream condition to be a much healthier stream (Metzeling *et al.*, 2006).

The number of families found in a stream is generally affected by several factors, such as the quality of the habitat, stream size, and nutrient enrichment which in unison help in assessing the health of a stream (Metzeling *et al.*, 2006).

The Shannon-Weiner Diversity Index (H') calculated for EPT communities in stream in the secondary forest area was slightly more diverse as compared to the EPT communities sampled in the stream in oil palm plantation. In contrast, the Evenness Index (E) for the EPT assemblages in oil palm plantation showed a higher evenness (E=0.71) as compared to the secondary forest area (E=0.68).

The stream flowing through the oil palm plantation area which received agricultural runoff, showed greater quantity of suspended solids and sediments, nutrient concentrations, and particulate organic matters which contributed to the lower abundance and diversity of EPT communities (Pliūraitė and Mickėnienė, 2009). With the introduction of anthropogenic influences, it reduced the overall diversity of EPT in the stream as sensitive taxa would eventually decrease to be followed by an increase in the tolerant taxa (Bispo and Oliveira, 2007). In oil palm plantation, it showed a higher evenness than the secondary forest. This could be due to the reason that there were some of the families in the secondary forest which had relatively low number of individuals with some other families that were exceptionally abundant.

The habitat run appeared to be having the highest number of families and number of individuals as well. This was followed by the habitat riffle, which left the pool habitat with the lowest number of families and individuals. The study done by Thambiratnam (2009) also showed the same pattern in the richness of EPT across different habitats with the run recorded the most to be followed by riffle and lastly, the pool.

Pool has been characterized as having fine substrates which resulted in the lowest abundance (Tickner *et al.*, 2000; Fenoglio *et al.* 2004). The low abundance was due to the higher predatory effect attributable to the fine substrate of the pool (Pringle, 1996). As for run and riffle, the depth of the water that was shallow provided more microhabitats on the banks and in leaf litters that could serve as a refuge to protect the EPT communities from predators (Thambiratnam, 2009). Riffle with the highest turbulence and velocity creates aeration, and thus, enables filter-feeders to obtain their food through the help of the water current without the need of spending much energy (Cummins and Meritt, 2008).

However, from the calculation of the Shannon-Weiner Diversity Index (H'), it showed that the pool was more diverse among all three habitats to be followed by run and riffle as the least diverse. The high diversity in the pool in this study could be due to the percentage of canopy coverage which contributed to the huge amount of allochthonous input presence in the form of leaf pack (Subramanian and Sivaramakrishnan, 2005). The input of leaf litters helps to provide nutrient flow into the stream system as they provide energy for the aquatic insect communities, while the emerging aquatic insects provide energy for other organisms, including terrestrial animals, such as birds (Compson *et al.*, 2013).

Allochthonous input was found to be more significant in streams that experience longer flood period, such as in the tropical rainforest than forest in the temperate region (Hein *et al.*, 2003). Apart from that, pool could also have more diverse communities of algae than in riffle habitat that contributes to its greater diversity (Mullner and Schagerl, 2003). These algae also serve as a source of organic matters, and play a role as food sources in the food web (Menninger and Palmer, 2007).

Similarly, the Evenness Index (E) also resulted in the same pattern as for the Diversity Index with even distribution of the EPT communities in habitat pool, while riffle showed uneven distribution. The highest evenness value of 0.82 was calculated for the pool habitat to be followed by run with a value of 0.74. The high diversity in pool was due to the high evenness of the assemblages of EPT living in it (Principe, 2008). A study carried out by Subramanian and Sivaramakrishnan (2005) showed that run and riffle were similar in composition as compared to pool.

The EPT communities are able to reflect the condition of their environment due to their sensitivity toward their surroundings (Che Salmah *et al.*, 2001). Biotic indices were used in this study to evaluate the water quality in the stream at TWR. There were 25 families of EPT found in the stream in the secondary forest, which showed a higher richness for EPT communities as compared to the stream in oil palm plantation with only 21 families, despite that both have been categorized as non-impacted streams. The higher EPT richness in the secondary forest implied that the water at that particular area was much cleaner as it was able to support a much higher number of species of EPT (Phillips *et al.*, 2005).

Both the Family Biotic Index (FBI) calculated showed an excellent water quality of the stream for both land uses with stream in the secondary forest area (2.98) being cleaner, and indicating a better water quality with organic pollution unlikely to occur in comparison to the stream flowing in oil palm plantation (3.12). Family Caenidae with a tolerance value of seven was highly abundant in the stream of oil palm plantation area as compared to the individuals found in the secondary forest. The pollutant intolerant families (Perlidae and Chloroperlidae) with pollution tolerance value of one were only found in the stream in the secondary forest area that resulted in a slightly better water quality as compared to the oil palm plantation area. The FBI has the potential to detect and evaluate the tolerance of EPT communities towards organic toxic pollutants (Mandaville, 2002). The index is used for making rapid assessment of streams, and is advantageous in determining the general status of organic pollution in streams that could help in making decision related to the streams (Hilsenhoff, 1988).

According to the Biological Monitoring Work Party (BMWP) scoring system (Armitage *et al.*, 1983), the score for the oil palm plantation was lesser than the score obtained for the secondary forest area. Stream in the secondary forest was classified as having very high water quality with a value of 158, whereby the stream in oil palm plantation scored a value of 111. The BMWP score was obtained from the families present which were scored respectively in accordance to their tolerance to disturbance in their habitat regardless of the number of individuals (Azrina *et al.*, 2006). Higher BMWP score indicates much cleaner water, which could be seen from the obtained scores for the two different land uses.

The Average Score Per Taxa (ASPT) was also calculated in this study as it was less sensitive towards the degree of sampling effort and seasonal change as compared to BMWP, by dividing the BMWP score with the number of families (Zamora-Munoz *et al.*, 1995). ASPT for streams in oil palm plantation and the secondary forest denoted the same description of very clean water with values of 8.54 and 8.78 respectively. Despite the large difference in their BMWP scores, the ASPT index values for these two land uses had little difference probably due to immense difference in the abundance of insects obtained from each of the site (Roche *et al.*, 2010).

Physico-chemical water parameters were also measured and analyzed in addition to the biotic indices. Physical water parameters, such as pH, temperature, conductivity, and dissolved oxygen were recorded during sampling (Table 3). By comparing with the Interim National Water Quality Standards for Malaysia (INWQS, 2006), the stream in this study was classified into Class I and Class IIA, whereby Class I stream is important in the conservation of natural water supply with no water treatment required for its water. As for Class IIA stream, it can be used as a water supply provided that conventional water treatment has been done.

Table 3: Range of water quality parameters for streams in different land uses with respective Interim National Water Quality Standards of Malaysia (INWQS).

Parameters	Land Uses	Range	INWQS	Class
DO (mg/l)	Oil Palm Plantation	4.52-6.91	5-7	IIA
	Secondary Forest	5.41-5.93	5-7	IIA
pH	Oil Palm Plantation	7.64-7.79	6.5-8.5	I
	Secondary Forest	7.96-8.01	6.5-8.5	I
Temperature (°C)	Oil Palm Plantation	25.98-26.85	Normal	-
	Secondary Forest	24.85-25.20	Normal	-
Conductivity (µS/cm)	Oil Palm Plantation	80-140	1000	I
	Secondary Forest	151-183.5	1000	I

In general, the physico-chemical water parameters measured indicated a good water quality in which the same could also be seen in the use of biotic indices in this study. There was a strong relationship between the abundance of EPT communities and the good water quality indicated. EPT communities were known to inhabit abundantly, specifically clean water in the stream at TWR. This indicated that the streams at TWR were undisturbed, and had good water quality.

CONCLUSIONS

This study was the first study at TWR which focused only on the EPT communities, and possibly be the first that was done in Sabah. Among the three orders of insects sampled, Ephemeroptera had the highest abundance among all others, possibly due to it being capable in tolerating more pollutants than the other two orders, making the ephemeropterans to have a much wider range of habitats. Plecoptera, at the opposite end, is more sensitive to their environment, and is intolerant to pollutions. Thus, it explainedthe abundance obtained for Plecoptera was the lowest among the other orders. An increase in the number of families of the EPT communities as compared to the previous study done by Arman (2004) could suggest that the condition of the stream at TWR is improving. However, further study is required as it involves many more factors than what had been assessed in this study, such as the quality of the habitat, nutrient flows, and also stream size.

In addition, the EPT communities were found to be more diverse in the secondary forest than oil palm plantation. There were more species that were exclusively found in the secondary forest as compared to plantation area, hinting that the secondary forest was able to support a much richer community. Some of the families, such as Heptageniidae and Hydropscyhidae, were able to be found in both land uses, but were highly abundant in the secondary forest with only very little individuals in oil palm plantation. This is probably due to the ability of the secondary forest to supply these insects with the requirements to strive well in the environment. Across different habitats of sampling, the EPT communities were found to be abundant in the run habitat, while the least abundant was in the habitat pool. This could be caused by the predatory effect present at pool area, and it had less diverse microhabitats available for the insects.

Biotic indices were used in this study to assess the water quality of the steam at TWR. The indices showed that the water quality in both oil palm plantation and the secondary forest belonged to the same category for EPT Richness, FBI, and ASPT. The indices for the secondary forest indicated that it was of slightly better water quality, despite being classed into the same category. However, the BMWP score for oil palm plantation was in different category as for the secondary forest where it belonged to high water quality, while the secondary forest belonged to very high water quality.

Nonetheless, BMWP value alone cannot be used to determine the quality of the water as it is susceptible to the abundance of insect families obtained from the sampled location. Physico-chemical parameters were measured as well to be cross-checked with the biotic indices. In accordance to INWQS, the water quality in both land uses belonged to Class I water quality for pH and conductivity, while the dissolved oxygen content was categorized into Class IIA. Both biotic indices and physico-chemical water quality parameters implied that the water quality in the stream at TWR were of rather clean water quality. Therefore, it showed that the EPT communities at TWR could be used to establish biological criteria which serve as bioindicators for stream pollution. The information in this study is important to serve as a baseline study in the area for future studies, and assists in environmental monitoring and management of the area.

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