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AQUATIC INSECT COMMUNITIES IN RELATION WITH WATER QUALITY OF SELECTED TRIBUTARIES OF TASIK KENYIR TERENGGANU

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Abstract: Composition and distribution of aquatic insect communities in relation with the water quality were studied in two selected tributaries of Taman Negara Terengganu Tasik Kenyir. A total number of 290 individuals of aquatic insects representing 21 families from six orders were collected using disturbance-removal sampling technique. Total abundance of aquatic insects was significantly higher in Sungai Perpek (198 individuals) compared with Sungai Cacing (92 individuals). In terms of taxon richness, a slightly more diverse and richer fauna was recorded in Sungai Perpek (16 families), but was lower in Sungai Cacing (11 families). Philopotamidae (Order: Trichoptera) was the most dominant family recorded in Sungai Perpek, whereas the most abundant family collected in Sungai Cacing was Perlidae (Order: Plecoptera). A relatively high abundant of Heptageniidae (Order: Ephemeroptera) was also found in both streams. Family Biotic Index (FBI), Biological Monitoring Work Party (BMWP) and Average Score Per Taxon (ASPT) showed that both streams were moderately good water quality. The findings reveal that the diversity and abundances of aquatic insect communities in this study were closely related to the physico-chemical parameters and hydrological characteristics of the streams.

Keywords: Tasik Kenyir, aquatic insects, bioindicator, water quality.

Introduction

Tasik Kenyir is located in Hulu Terengganu (District between latitude of 4°43'N to 5°15'N and longitude of 102°30' to 102°53'N), in the state of Terengganu, sharing its border with Kelantan in the west and Pahang in the south. Tasik Kenyir is the largest man-made lake in South East Asia, with the total water surface area of the lake is about 38,000 ha and surrounding catchment area of approximately 260,000 ha (Zulkafli & Ashhar, 2000). It was created in 1986 by the damming of the Kenyir River to build the Sultan Mahmud Hydro-electric Power Plant. Tasik Kenyir has a very diverse range of terrestrial and aquatic habitats that support interesting species of flora and fauna. The forest is one of the oldest tropical rainforest in the world, which serves as part of the Malaysian National Park or Taman Negara. It is also a home for numerous species of freshwater fishes and exotic wildlife (Sayed & Mohd. Azmi, 2005).

Tasik Kenyir also supports a wide range of benthic macroinvertebrates, including the aquatic insects that live in various stream habitats. Aquatic insects have been used to assess the water quality of streams and rivers for managing water use, ambient monitoring and evaluating the effectiveness of pollution control measures throughout the world (Armitage *et al.*, 1983; Che Salmah, 2001; Bonada *et al.*, 2006; Wahizatul *et al.*, 2011). They are a very abundant and diverse group that inhabits a variety of aquatic environments. Some of them are very sensitive to pollution, while others are tolerant. Many species of aquatic insects are very susceptible to pollution or alteration of their habitat (Merritt & Cummins, 1996).

To date, very few studies on the community of aquatic insects as bioindicator in Malaysia has been carried out particularly from the east coast of Peninsular Malaysia, as most of the studies have focused more on chemical pollution in contaminated rivers of west coast

Peninsular Malaysia (e.g. Al-Shami *et al.*, 2010; Azrina *et al.*, 2005; Al-Shami *et al.*, 2011). Indeed, the freshwater of the Malaysian region are recognized as a home to a wide variety of aquatic invertebrates but the majority of species are yet to be described and some of the fauna are still unknown even at the phylum level. Results from previous studies in Malaysia suggest that changes in water quality influence the structures of aquatic insect communities. For example, Azrina *et al.* (2005) found that distribution of benthic macroinvertebrates was significantly influenced by the impacts of anthropogenic activities at the Langat River, Selangor. In the polluted rivers of the Juru River Basin, Penang, Al-Shami *et al.* (2010) reported that Chironomidae was the most dominant aquatic insect family and is associated with deterioration in the water quality and heavy metal pollution. Another study by Al-Shami *et al.* (2011) found that high diversity and abundance of macroinvertebrates, especially the intolerant taxa, Ephemeroptera, Plecoptera, and Trichoptera, were observed in the least polluted river in Juru River Basin, Penang. In Terengganu, Wahizatul *et al.* (2011) reported the composition and distribution of aquatic insect communities were strongly related to water quality in two freshwater streams of Hulu Terengganu.

As the diversity and distribution of aquatic insects in Taman Negara Tasik Kenyir has not yet been reported in the literature, this study was carried out with the aim of documenting the composition and distribution of aquatic insect communities in two selected tributaries (Sungai Cacing and Sungai Perpek) of Tasik Kenyir, Terengganu. This study is important to picture the current status diversity of aquatic insects in Tasik Kenyir and will provide a valuable baseline when monitoring future changes in the freshwater ecosystems of Terengganu.

Materials and Methods

Sites Description

The study was conducted at Sungai Cacing (4°48'41.52"N, 102°47'44.78"E) and Sungai Perpek (4°47'32.68"N, 102°44'37.89"E), which are located at the southern part of Tasik Kenyir. Both streams flow into Tasik Kenyir from the south, each has similar vegetation, land use patterns and hydrological characteristics. Sungai Cacing is approximately 3.5 km long, 0.5-4.0 depth and 1.0-4.0 m width, whereas Sungai Perpek is about 4.5 km long, 0.2-2.5 m in depth, 2.0-4.5 m in width and the water velocity of both streams are slow to fast (0.10-0.35 m/s).

The upper reaches of the streams are heterogeneous with typically of hilly type with gravels, cobbles and boulders substrates, fine roots, leaf packs, woody debris, and overhanging vegetation. Some reaches are totally exposed to sunlight with fast flowing water (mainly in the dry season) and the riparian vegetation along the streams are mainly characterized by high abundance of *Melastoma malabastricum*, *Imperata cylindrica*, *Commnela diffisa, Limnocharis flava* and mosses. *Hydrilla verticiliata* is one of the most abundant submerged macrophyte species in the streams. The lower reaches of the streams are mostly canopied with large trees like *Kompasia* sp., *Shorea* sp., *Hopea* sp., *Areca catechu* and *Vatica* sp. Some part of the stream reaches was totally exposed to sunlight, but banks were mostly covered by forest canopy, with grasses and shrubs growing in the undergrowth along the stream edges.

There are some recreational activities along the upper part of the streams like fishing and boating, where visitors can hire a houseboat and stay for overnight on the lake. Although the streams received small amount of domestic effluent from the recreational activities, they could be categorized as clean (good water quality) because the streams contained high dissolved oxygen (8.80-10.50 mg/L), high pH (6.60-6.90), low water temperature (24.5-27.5^{0}C) and low conductivity (23.0-25.0 *u*s/cm).

Sampling of Aquatic Insects

Sampling of the aquatic insect communities was carried out from 14 to 17 October 2010

during the scientific expedition organized by the UMT Tasik Kenyir Special Interest Group. Sampling for each stream covered ~100 m^2 in area, each replicated 5 times at three different stations (distance was approximately 50 m apart) in order to obtain reasonable estimates of population density. Aquatic insects were collected using an aquatic net with the size of sampler of 40 x 40 cm frame, 60 cm long net of 250 µm mesh (Model 425-K53, Wildco Turtox ® Dip Net Design). In the stream, disturbance-removal sampling technique was used to dislodge organisms from the substrates with 1m ×1m area. Large stones in swift water were hand-lifted and checked for insects. The insects and the content of each sample (net) was transferred into properly labeled plastic containers, preserved in 75% ethanol and taken back to the laboratory for analysis. Samples were washed in white trays and screened through 1 mm sieves. The invertebrates were initially sorted into functional feeding groups (Merritt & Cummins, 1996; Gooderham & Tsyrlin, 2002) and then identification was made until the family taxonomic level. All samples were identified according to taxonomic classification based on the book of "Freshwater Invertebrates of the Malaysian Region" (Yule & Yong, 2004).

Physico-chemical Parameters

Physico-chemical parameters such as dissolved oxygen (mg/L), water temperature (ºC), pH and conductivity (µS/cm) were recorded using multiparameter system (Model YSI 556) *in situ*. Stream depth and width were measured *in situ* using a Stanley measuring tape (3.2 m/12 feet). Stream lengths were determined through geographic scales from topographic map provided by the Drainage and irrigation Department of Hulu Terengganu District. Component of substrates were determined according to the six textural classes (Andrews, 1987). Canopy cover of the riparian zone was estimated based on the openness of sites and categorized into three groups; shaded (80-100%); partly-shaded (30-80%) and open (<30%). Water velocity was determined using Hydroprob flow-meter. Data were converted to the following nominal categories for analysis; fast flowing (>0.35 m/s); slow flowing (0.10-0.35 m/s) and stagnant (<0.10 m/s).

Data Analysis

T-test was used to compare the significant differences in aquatic insect communities represented at Sungai Cacing and Sungai Perpek. One way ANOVA was used to evaluate differences in aquatic insect abundances and functional feeding groups at different stations of each site. Data were $\log(x+1)$ transformed first to ensure normality in calculations of means and ANOVA. Detrended Correspondence Analysis (DCA) was used to identify the aquatic insect families' assemblage ordinations which could then be related to measure how much the distribution differed along physico-chemical variables. All the analyses were performed using the SPSS 19.0 statistical program (SPSS, 2009). Four water quality indices were used to monitor the impact of disturbances and pollutions on the streams. The indices used including Family Biotic Index (FBI) (Armitage *et al.*, 1983), Biological Monitoring Work Party (BMWP) (Armitage *et al.*, 1983), Average Score Per Taxon (ASPT) (Metcalfe, 1989) and Stream Invertebrate Grade Number – Average Level (SIGNAL) (Chessman, 2001). These metrics were based on the idea that unstressed streams and rivers have richer invertebrate taxa that were dominated by intolerant species. Conversely, polluted streams have fewer numbers of invertebrate taxa and were dominated by tolerant species.

Results and Discussion

Composition and Distribution of Aquatic Insects

A total of 290 individuals from 21 families of aquatic insects were collected from Sungai Cacing and Sungai Perpek (Table 1). Significantly, more aquatic invertebrates were collected in Sungai Perpek (198 individuals) compared with Sungai Cacing (92 individuals)

(T-test = 5.286; $p<0.05$). However, no significant differences were detected between total abundance of aquatic insects at all stations of each study site.

Stoneflies (Plecoptera) were the most dominant order, comprising 36% of the total abundance at Sungai Cacing. Mayflies (Ephemeroptera) were the second most abundant comprising 31% in Sungai Cacing, followed by aquatic beetles (Coleoptera) (13%), caddisflies (Trichoptera) (11%), aquatic midges (Diptera) (8%) and the least was aquatic bugs (Hemiptera) with only 1%. In Sungai Cacing, a relatively high abundance of Perlidae (Order: Plecoptera) with 33 individuals were collected, followed by Heptageniidae (Order: Ephemeroptera) with 22 individuals and Elmidae (Order: Coleoptera) with 12 individuals. Other families were considered low as less than 5 individuals were recorded (Table 1).

On the other hand, the most dominant order in Sungai Perpek was caddisfly naiads (Trichoptera) (49%), the second most dominant was mayfly naiads (Ephemeroptera) (41%), followed by aquatic midges (Diptera) (5%),

Table 1: Composition, abundance and functional feeding group of aquatic insects in Sungai Cacing and Sungai Perpek (Notes: scr = Scraper; c-g = Collector-gatherer; c-f = Collector-filterer; shr = Shredder; prd = Predator)

Order	Family	Sungai Cacing	Sungai Perpek	Functional Feeding Group
Ephemeroptera	Baetidae	3	47	c-g / scr
	Caenidae	3	0	c-g / scr
	Ephemerellidae	0	6	c-g
	Heptageniidae	22	24	scr
	Neophemeridae	0	4	c-g / scr
	Potamanthidae	1	0	c-g
	Tricorythidae	0	1	c-g
Plecoptera	Perlidae	33	4	prd
Trichoptera	Hydropsychidae	3	19	c-f
	Philopotamidae	6	78	c-f
	Odontoceridae	0	1	shd
	Stenopsychidae	1	0	shd
Odonata	Gomphidae	0	1	prd
	Libellulidae	0	1	prd
Hemiptera	Naucoridae	1	0	prd
Coleoptera	Dytiscidae	0	1	prd
	Elmidae	12	2	prd
Diptera	Chironomidae	0	5	c-g / prd / shd
	Ptychopteridae	0	1	shd
	Simuliidae	7	0	c-f
	Tipulidae	0	3	c-f
	Total	92	198	

aquatic beetles (Coleoptera) and stonefly naiads (Plecoptera) both with 2% each and dragonfly naiads (Odonata) with only 1%. The most abundant family in Sungai Perpek was Philopotamidae (Order: Trichoptera) with 78 individuals, followed by Baetidae (Order: Ephemeroptera) with 47 individuals, Heptageniidae (Order: Ephemeroptera) with 24 individuals and Hydropsycidae (Order: Trichoptera) with 19 individuals. A number of families (e.g. Odontoceridae, Gomphidae, Libellulidae, Dytiscidae) were represented by less than 1.0 % of the total abundance at Sungai Perpek. Interestingly, more Diptera larvae were recorded in Sungai Perpek compared than Sungai Cacing, and odonate naiads were only recorded in Sungai Perpek.

Various ecologists have reported that there are few factors influence the distribution of aquatic insects in the stream (Armitage *et al.*, 1983; Che Salmah, 2001; Bonada *et al.*, 2006). One of the factors is component of the substrates which include of cobbles, pebbles, fine sediment, over hanging terrestrial vegetation, aquatic vegetation and leaf packs (Department of Irrigation and Drainage Malaysia, 2009). In addition, water quality parameters which consist of pH, water temperature, light intensity, turbidity and velocity together with food availability in the water also influence the distribution and diversity of aquatic insects (Merritt & Cummins, 1996; Al-Shami *et al.*, 2011). Velocity of water system such as fast-flowing water, standing water and slow-flowing water have been found strongly influenced aquatic insect assemblages (Mitchell & William, 1996).

In this study, the distribution and abundances of aquatic insect communities could be related to the component of substrates and hydrological characteristics of the streams. For example, the highly abundant of Perlidae in Sungai Cacing could be influenced with the depth and substrates of the stream. In general, Sungai Cacing is deeper (0.5-4.0 m) than Sungai Perpek (0.2-2.5 m). The substrates in Sungai Cacing are typically of hilly types with more gravels, cobbles and boulders substrates, while some stretches of Sungai Cacing are slow moving water with fine sand and silt. Perlidae naiads require high concentration of dissolved oxygen, relatively clean water and restricted to lotic water or rapidly moving freshwater. Their presence is usually indicates clean water quality (Sivec & Yule, 2004). Thus, they are considered as good bioindicators for good quality water.

The high abundance of philopotamids and baetids in Sungai Perpek also might probably due to the suitable substrates found in Sungai Perpek which was full of pebbles and gravels. Both families like to live and feed on the sides or bottoms of rocks with their protected shelter made of silk and debris (Morse, 2004). Their special morphological and behavioral adaptations favour their distribution and domination. The naiads are sprawlers along the bottom and climbers among debris and vegetation. Philopotamidae and Baetidae use their long, laterally extended legs to support the body on or among a matrix, usually of detritus and macrophytes (Minshall, 1984).

Sungai Cacing and Sungai Perpek had relatively high abundant of Heptageniidae naiads too. As both streams were quite fast-flowing, it supported high numbers of Heptageniidae family which live among crevices in relatively stable substrates such as stones and rocks in moderately fast-flowing streams (Khoo, 2004). In general, this family is considered as indicator species for clean water ecosystem and most sensitive to environmental disturbance as they are strictly inhabitants and reach their development in clean, fast flowing and running water habitats (Merritt & Cummins, 1996).

Based on our observation, there was more houseboat activities at Sungai Perpek compared with Sungai Cacing. The activities probably cause slight pollution to the area as the houseboat might discharge sewage water into that area. According to PERHILITAN Hulu Terengganu (Department of Wildlife and National Parks), there is a restriction of houseboat or fishing activities in Sungai Cacing,

thus the area is considered less disturbed compared to Sungai Perpek. The presence of Chironomidae larvae in Sungai Perpek (Table 1) indicated that the area is influenced by anthropogenic activity as Chironomidae is a pollution tolerant invertebrate and considered as bioindicator for polluted aquatic systems (Azrina *et al.*, 2005; Al-Shami *et al.*, 2010). However, based on stream health classification by National Interim Water Quality Standards of Malaysia (NIWQS, 2006), Sungai Perpek is still considered as good water quality. The presence of chironomid in Sungai Perpek was very low (8% of total abundance) and usually depends on seasonal changes where more chironomids could be found during dry season (Al-Shami *et al.*, 2010).

Although both streams shared similar components of substrates structures, there still a number of explanations that could be related to these associations. Nevertheless, the presence of certain microhabitats could be correlated to the assemblages of certain species. For example, more ephemeropterans, trichopterans and coleopterans were found in submerged macrophytes like *H. verticiliata*, rooted plants and filamentous algae than they were on stones. While the plecopterans were strictly inhabiting running water with various types of substratum. In this study, the odonate naiads and chironomids larvae were entirely or almost confined to slow moving water and soft streambeds. Their morphology and behaviour appear to depend partly upon the particle size of the substrates in which they inhabit either in sand, grit, silt or debris of streams, rivers, lakeshores and ponds (Yule & Yong, 2004).

Aquatic insects showed marked variation in functional feeding groups in both streams (Table 1). Using the criteria of Merritt and Cummins (1996) and Gooderham and Tsyrlin (2002), of a total of 21 families, approximately one third (37%) were categorized as collector-filterers. Other taxa were considered as collector-gatherers (23%), predators (19%), scrapers (18%) and shredders (3%). It should be noted that some of the families can be included into two or three functional feeding groups (e.g. Chironomidae, Baetidae, Caenidae). Collector-filterers were about more than 10 times more abundant in Sungai Perpek compared with Sungai Cacing. Collector-filterers were dominated by Philopotamidae in Sungai Perpek. The abundance of collector-gatherers and scrapers were also significantly greater in Sungai Perpek than Sungai Cacing. The abundance of predators and shredders were higher in Sungai Cacing than Sungai Perpek but the differences were not significant.

Collector-filterers increased in numbers as they may benefit from an increase in fine particulate organic matter caused by the activities of shredders and collector-gatherers. Collector-filterers and collector gatherers were more abundant in slow moving water in shaded areas of Sungai Cacing. It has been suggested that this is a result of more 'clean' attachment sites being available in shaded areas (Merritt & Cummins, 1996). Usually, a lower abundance was found in shaded areas due to lower availability of quality food such as algae and algal detritus (Behmer & Hawkins, 1986).

Classification of Water Quality based on Water Quality Indices

In order to categorize the health of the streams based on aquatic insects composition and abundance, the Family Biotic Index (FBI), Biological Monitoring Work Party (BMWP), Average Score per Taxon (ASPT) and Stream Invertebrate Grade Number – Average Level (SIGNAL) were calculated (Table 2). The difference between those biotic approaches and commonly used ecological indices (e.g. Shannon Wiener Diversity Index, Margalef Richness Index, etc.) is that the common ecological indices are totally included the measure of abundance only. While the FBI, BMWP, ASPT and SIGNAL are based on the sensitivity of key groups to pollution and on the number of component groups in a sample. Thus, the biotic water quality indices demand more effort and less practical to use, but may provide more information (Metcalfe, 1989).

Both streams had excellent water quality based on FBI with the scores of 3.09 and 3.55 respectively. This index assumes that no organic compound pollution was detected in both streams (Armitage *et al.*, 1983). Based on BMWP, all sites were shown with moderately good water quality, with the value of each site was 64 for Sungai Cacing and 90 for Sungai Perpek. The classification of water quality based on ASPT for Sungai Cacing and Sungai Perpek were rather clean with the values of 7.11 and 6.92 respectively. With the presence of high numbers of Ephemeroptera, Plecoptera and Trichoptera (EPT) in Sungai Cacing and Sungai Perpek, thus this study is consistent with the idea that the EPT members were usually found in undisturbed area and they act as bioindicators for good water quality stream system as they are generally considered to be intolerant or sensitive to water pollution. In addition, both streams were classified as Class I by NIWQS (2006), which indicated a very good water quality and suitable for drinking water without any treatment except for bacteria disinfections through boiling.

Further analysis using DCA shows that only four parameters were significantly influenced to the aquatic insect assemblages (Figure 1). Axis 1 represented increased water velocity, conductivity, pH and total dissolved oxygen (DO), whereas Axis 2 showed increased of canopy cover. The analysis showed that some group of aquatic insects were highly correlated to the velocity, conductivity, pH and DO, such as Caenidae, Naucoridae and Potamantidae. However, some aquatic insects such as Hydropsychidae, Chironomidae, Odontoceridae and Tipuliidae were decreased along Axis 2. It shows that the higher canopy cover of the water, the fewer of these invertebrates they were.

In this study, DO and water velocity was strongly corresponded to the composition and distribution of aquatic insect community. Usually, the concentration of DO is higher at high current speed of water. While, lower concentration of DO occurred during slow current speed at the river which contains muddy substrate and organic matters (Armitage *et al.*, 1983). More abundant and diverse of the aquatic insects in Tasik Kenyir were found in high DO and water velocity. In terms of pH, the water in Sungai Cacing and Sungai Perpek were almost neutral. Most of aquatic insects prefer to inhabit in water where the pH ranges from 5 to 8 (Pollard & Berrill, 1992). The pH of water in this study ranged from 6.63-6.91, thus well within the tolerance range for the aquatic insects in Tasik Kenyir. However, conductivity was found positively correlated with the abundance of aquatic insects, which probably due to the run-off from recreational activities along the streams. The open canopy in both streams were slightly warmer (24.5-27.5 ^{0}C) and had more nutrients (organic matter) than the fully and partly shaded treatments. This is an indication that availability of quality food (e.g., microbial, diatoms, algae) might be influencing

Table 2: The classification of water quality based on water quality indices (FBI, BMWP, ASPT and SIGNAL)

Biological Indices / Class	**Sungai Cacing**	**Sungai Perpek**
Family Biotic Index (FBI)	3.09	3.55
Class	Excellent	Excellent
Biological Monitoring Work Party (BMWP)	64	90
Class	Moderately good	Moderately good
Average Score Per Taxon (ASPT)	7.11	6.92
Class	Rather clean water	Rather clean water
Stream Invertebrate Grade Number – Average Level (SIGNAL)	5.33	5.22
Class	Mild pollution	Mild pollution

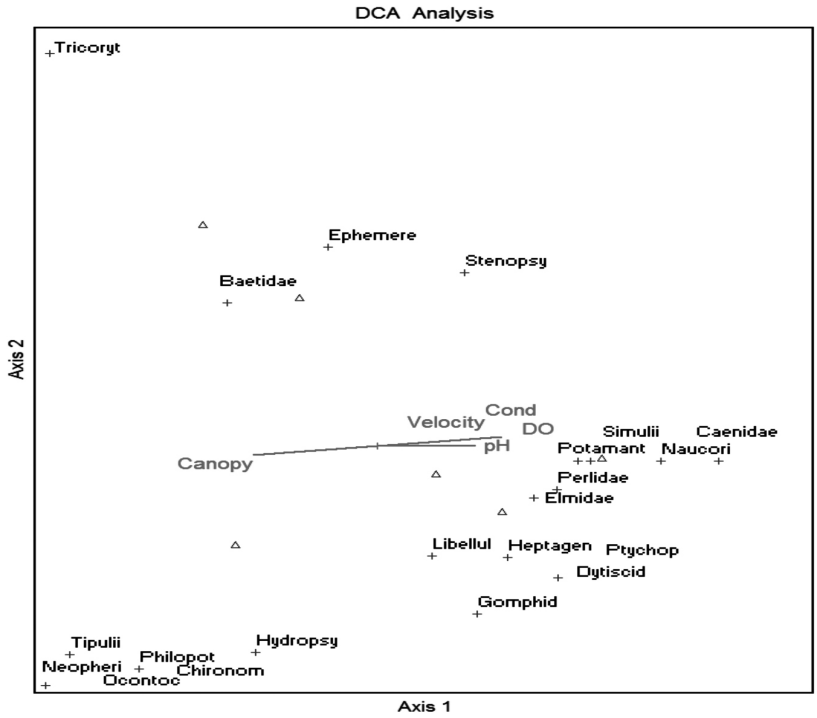

Figure 1: Detrended correspondence analysis (DCA) plots showing taxa assemblage ordinations which related to the physico-chemical parameters

the composition of aquatic insect assemblage in streams lacking a riparian canopy. A study done by Mokany *et al.* (2008) found that increasing light increased the biomass of filamentous algae (metaphyton) which increased the overall productivity of the ecosystem, and shifted the invertebrate community. They suggested light may have a potentially strong indirect effect and may impact the communities through altered bottom-up structuring forces. These correlations showed that some physico-chemical parameters are important in determining the aquatic insect composition and could also recognize as a vital component of an integrated assessment utilizing physico-chemical and biological measure for assessing a waterway's condition.

Conclusion

In general, the study shows that the two selected tributaries of Tasik Kenyir supported a diverse and richer aquatic insect communities, which suggesting that probably more interesting findings could be found in other tributaries of Taman Negara Tasik Kenyir. Based on biotic indices, both streams were classified as good water quality although there were houseboat activities especially at the Sungai Perpek. This current study provides basic principles and information for the catchment management authorities which could be used in developing specific policies on sustainability of water resources management. This study is also important to picture the current status diversity of aquatic insects in Taman Negara Tasik Kenyir and to provide an outline in conservation of their habitats. As aquatic insect are particularly sensitive to human disturbance, it is necessary for us to preserve these unique creatures for our next generation to observe this spectacular insects in future.

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