Biological Water Quality Indices Performance Based on Aquatic Insects in Recreational Rivers

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Highlights

- Lubok Semilang had the greatest number of aquatic insects with 250 individuals, followed by Telaga Tujuh (181 individuals) and Sungai Durian Perangin (171 individuals).

- Family Biotic Index (FBI), Malaysian Family Biotic Index (MFBI) and Biological Monitoring Working Party (BMWP) were used and compared with Water Quality Index (WQI) to determine the water quality at the study areas.

- Biotic indices were more sensitive towards changes in water parameters than the WQI.
Biological Water Quality Indices Performance Based on Aquatic Insects in Recreational Rivers

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Abstract: Abundance and distribution of aquatic insects respecting to several water chemical parameters from six rivers were studied in order to determine the performance of biological index in monitoring the water quality. A total of 960 individuals of aquatic insects from nine orders were recorded using kick and drag sampling techniques. Lubok Semilang had the greatest number of aquatic insects with 250 individuals, followed by Telaga Tujuh (181 individuals) and Sungai Durian Perangin (171 individuals). EPT (Ephemeroptera, Plecoptera and Trichoptera) order were the most dominant order recorded in all six rivers. Lata Kekabu had more diverse and richer aquatic insect assemblages based on ecological indices compared to the other five rivers. In order to evaluate the water quality of recreational rivers in Malaysia, Family Biotic Index (FBI), Malaysian Family Biotic Index (MFBI) and Biological Monitoring Working Party (BMWP) were used and compared with Water Quality Index (WQI) to determine the water quality at the study areas. Results demonstrated that the biotic indices were more sensitive towards changes in water parameters than the WQI. Among all the biological indices, MFBI was the most suitable index to be adopted in Malaysian river water assessment as it is more reliable in assessing the status of water quality.

Keywords: Water Quality, Biological Indicator, Pollution, Recreational River

Abstrak: Kelimpahan dan taburan serangga akuatik serta parameter kimia air di enam kawasan sungai telah dikaji untuk melihat prestasi indeks biologi dalam pemantauan tahap kualiti air sungai. Sejumlah 960 individu daripada sembilan order serangga akuatik telah direkod dengan menggunakan teknik persampelan secara kick and drag. Lubok Semilang telah mencatatkan bilangan serangga akuatik yang tertinggi dengan 250 individu diikuti oleh Telaga Tujuh (181 individu) dan Sungai Durian Perangin (171 individu). Order Ephemeroptera, Plecoptera and Trichoptera (EPT) didapati mendominasi kesemua sungai. Lata Kekabu mempunyai taburan dan kekayaan serangga akuatik yang tinggi berdasarkan semua indeks ekologi jika dibandingkan dengan lima sungai yang lain. Untuk menilai kualiti air di kawasan rekreasi di Malaysia, penggunaan indeks biologi seperti Family Biotic

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Index (FBI), Malaysia Family Biotic Index (MFBI) dan Biological Monitoring Working Party (BMWP) telah dibanding dan diguna bersama dengan Water Quality Index (WQI) untuk menentukan kualiti air di semua kawasan kajian. Keputusan menunjukkan bahawa indeks biotik merupakan indeks yang lebih sensitif terhadap perubahan parameter air berbanding WQI. Di antara semua indeks biologi yang dikaji di Malaysia, MFBI merupakan indeks yang paling sesuai digunakan di Malaysia kerana lebih efisien dalam menilai status kualiti air sungai.

Kata kunci: Kualiti Air, Penunjuk Biologi, Pencemaran, Kawasan Rekreasi Sungai

INTRODUCTION

Land use activities have affected the condition of aquatic ecosystems worldwide including Malaysian that cause river physical modification, habitat loss, water pollution and flora and fauna overexploitation. According to Hepp et al. (2013), most water bodies such as rivers has consequently been subjected to increasing the quantity of pollutants present in a river, affecting greatly their quality and health status. This definitely alters the physicochemical properties of water. Variations in these water properties greatly influence the structure and distribution of aquatic insects in the water (Hepp et al. 2013). There are many methods and techniques developed by the researchers to analyse the impairments of water quality in aquatic ecosystem. For example, a study done by Aweng et al. (2011) and Zarei and Bilondi (2013) indicated that analyses of both physical parameters (turbidity, sedimentation, siltation, flow patterns, water temperature and riparian cover) and chemical parameters [dissolved oxygen (DO), biochemical oxygen demand (BOD), pH, alkalinity, metals and organic compounds] have been investigated further to assess the quality of water.

Above and beyond, biological monitoring act as the main principal of indicator towards the two major condition which is past conditions as well as current conditions (Suhaila et al. 2014). Oliveira and Cortes (2006) stated that, the supplemental integration of biological parameters to physical-chemical assessments has proven to be a more complete method to fully assess pollutant effects in aquatic ecosystems most particularly in river and streams area. According to Engel and Voshell (2002), biological monitoring is defined as scientifically and economically valid approach evaluation of the condition of a water body. The evaluation process is specifically using biological monitors and other direct measurements of the biota in surface waters for indicator and monitoring program to assess the water quality of rivers or streams (Kopciuh et al. 2004). Based on the definition above, there are many advantages of using the biological assessment to evaluate the water quality of rivers. Biological assessment is more reliable in evaluating the presence and impact of pollutants in water. Benthic macroinvertebrates and aquatic insects have been used in numerous biological monitoring indicating their usefulness as bioindicators and the continuous advantages they offer in evaluating the presence and extent of environmental pollutants (Xu et al. 2014).
Among the benthic macroinvertebrates, aquatic insect is one of the most common group of organisms that can be used to determine the river condition (Lavoie & Campeau, 2010). According to Xu et al. (2014) aquatic insects have been chosen as the useful indicator to assess the water quality of the rivers because they represent a diverse and various group of sedentary organisms that react strongly to environmental changes. For example, some aquatic insects are highly responded to specific changes in water conditions and have become indicators of river health condition (Xu et al. 2014) compared to fish and other macroinvertebrates. This can be seen when aquatic insects provide a more accurate understanding of the changing freshwater ecosystem than chemical and physical monitoring. Responsive behaviour of aquatic insect towards the pollution or contaminations gives an early warning to any possible harm of the water resources. To date, very few studies on the community of aquatic insects in recreational river as biological indicator has been carried out as most of the studies give focused on chemical pollution in contaminated rivers (Al-Shami et al. 2013; Al-Shami et al. 2011). Others preferred to concentrate on the diversity and abundance of benthic fauna (Suhaila et al. 2011; Che Salmah et al. 2012).

Based on the research by Leunda et al. (2009), although there were local researches that adopting biological indices which were developed in temperate countries for water quality assessment in Malaysia but it would be less accurate and thus requires some modification (Hilsenhoff 1988) as being practiced in Thailand (Mustow 2009) and Vietnam (Hoang 2009). Meanwhile in 2016, Wan Mohd Hafezul has developed a Malaysian Family Biotic Index (MFBI) based on Malaysia aquatic insects. Thus, this study was carried out to determine the diversity, abundance and composition of aquatic insect at selected recreational rivers and to evaluate the performance of MFBI with other establish biological indices.

MATERIALS AND METHODS

Description of Study Area

This study was carried out at six selected rivers: Lata Kekabu and Sungai Gelok in Perak, and Sungai Sedim, Sungai Durian Perangin, Lubok Semilang and Telaga Tujuh in Kedah. Lata Kekabu and Sungai Gelok are frequently visited by the local and located 10 km from Lenggong, Perak. Meanwhile, Sungai Sedim is located within the Gunung Inas Forest Reserve. Sedim Recreation Park is the only location for white water rafting located in the north-west states and been classified as lowland dipterocarp forest by Forestry Department of Peninsular Malaysia. Durian Perangin Waterfall is located on the northern slope of Gunung Raya, the highest mountain in Langkawi. This river was surrounded by dipterocarp trees along the river margins and has partly shaded canopy cover. Lubok Semilang is an open shaded area and this river substrate consisted of 70% cobble, 15% gravel, 10% boulder and 5% sand. Nevertheless, there were not many visitors at this river as
compared to other famous recreational river like Durian Perangin Waterfall and Telaga Tujuh Waterfall that provide many water sports activities. Telaga Tujuh Waterfall is an open area and was surrounded by many type of plant like unique lime plants and sintuk, a climbing type of foliage, which grow abundantly.

**Sampling and Identification of Aquatic Insects**

Samples of aquatic insect communities were carried out using kick sampling techniques which is a modified technique of Merritt *et al.* (2008). Ten samples were collected during the sampling occasional at each sampling site by random samples across approximately 100 m stretch in each river using D-frame aquatic net. The content of each sample was transferred into properly labelled plastic bags filled with a small amount of river water, tied by rubber band and was brought to the laboratory for further laboratory work. In the laboratory, each bag was washed and sorted in a tray. Sorted aquatic insects were preserved in bottles that contained 75% ethanol (ETOH). Later, the aquatic insects were identified to the lowest taxa using reference keys from Yule and Yong (2004), Morse (2004), Webb and McCafferty (2008) under a stereo microscope (LEICA EZ4, Leica Microsystems (SEA) Pte Ltd., Singapore).

**Physicochemical Parameter Measurements**

DO, pH, total suspended solids (TSS) were measured *in situ* by using MPS YSI 556/550A (Yellow Spring Instrument, OH, US) which is a multi-parameter handheld meter. Water samples were collected concurrently with the aquatic insects sampling. The polyethylene bottle was rinsed with river water first before the actual sample was taken. Chemical oxygen demand (COD), BOD, ammonia-nitrogen (NH$_3$-N) and TSS were analysed in the laboratory using a standard kit of HACH DR/900 Calorimeter (HACH Company, Loveland, USA).

**Data Analysis**

Pearson Correlation Analysis was used to measure the association between aquatic insect abundance and physico-chemical parameters using SPSS version 23. Biological Monitoring Working Party (BMWP), Average Score Per Taxon (ASPT), FBI and MFBI were calculated to classify the river water quality (Table 1). Malaysian tolerance value and formula for MFBI calculation was followed from Wan Mohd Hafezul (2016).
Table 1: The MFBI classifications of the water quality.

| Class | Index range | Category     |
|-------|-------------|--------------|
| 1     | > 5.9       | Very good    |
| 2     | 4.5–5.8     | Good         |
| 3     | 3.8–4.4     | Moderately polluted |
| 4     | 2.7–3.7     | Polluted     |
| 5     | < 2.7       | Poor         |

Source: Wan Mohd Hafezul (2016)

RESULTS

A total of 960 individuals from 32 families of aquatic insects from 9 order (Coleoptera, Diptera, Ephemeroptera, Hemiptera, Odonata, Plecoptera, Trichoptera, Lepidoptera and Megaloptera) were collected from all rivers (Table 2). Most of the aquatic insects were collected from Lubok Semilang (26%) followed by Telaga Tujuh (18.9%), Sungai Durian Perangin (17.8%) and Lata Kekabu (17%). Meanwhile, Sungai Gelok had a lower number of aquatic insects collected which less than 15%, followed by Sungai Sedim which only had 7% with 67 number of individuals collected. Kruskal Wallis test showed that the abundance of aquatic insects among the six selected rivers ($\chi^2 = 9.17$, $P = 0.10$) are not statistically significant. Stoneflies (Plecoptera), mayflies (Ephemeroptera) and caddisflies (Trichoptera) were the most dominant order in all selected rivers. In area of Perak, Lata Kekabu and Sungai Gelok showed a relatively high abundance of Perlidae (Plecoptera) with 76 individuals were collected, followed by Simuliidae (Diptera) with 45 individuals and Hydropsychidae (Trichoptera) with a total of 29 individuals (Table 3).

Table 2: Abundance of aquatic insect collected from the selected rivers in Perak and Kedah, Malaysia.

| Areas of sampling          | Number of individuals | Percentage |
|---------------------------|-----------------------|------------|
| Lata Kekabu               | 166                   | 17.3       |
| Sungai Gelok              | 125                   | 13.0       |
| Sungai Sedim              | 67                    | 7.0        |
| Sungai Durian Perangin    | 171                   | 17.8       |
| Lubok Semilang            | 250                   | 26.0       |
| Telaga Tujuh              | 181                   | 18.9       |
| Total                     | 960                   | 100.0      |
Table 3: Composition and abundance (mean ± SE) of aquatic insect collected from Lata Kekabu, Sungai Gelok, Perak and Sungai Sedim, Durian Perangin, Lubok Semilang and Telaga Tujuh, Kedah.

| Order       | Family     | Genus       | Lata Kekabu | Sungai Gelok | Sungai Sedim | Durian Perangin | Lubok Semilang | Telaga Tujuh |
|-------------|------------|-------------|-------------|--------------|--------------|-----------------|----------------|--------------|
| Ephemeroptera | Baetidae   | Baetis      | 2.00 ± 0.0  | 1.00 ± 0.6   | 2.67 ± 0.7   | 4.67 ± 1.2      | 10.00 ± 1.2    | 7.67 ± 2.3   |
|             |            | Platybaetis | 3.33 ± 0.7  | 1.33 ± 0.3   | 2.33 ± 0.3   | 3.00 ± 0.6      | 9.00 ± 0.6     | 4.67 ± 1.7   |
| Caenidae    |            | Caenis      | 2.33 ± 0.7  | -            | -            | 0.67 ± 0.3      | 6.33 ± 1.2     | 3.33 ± 1.2   |
| Ephemeridae |            | Ephemera    | 0.66 ± 0.3  | -            | -            | -               | -              | 0.67 ± 0.3   |
| Heptageniida |            | Thalerosphyrus | 0.33 ± 0.3 | 0.67 ± 0.7   | -            | 3.33 ± 0.9      | 2.33 ± 1.2     | 4.00 ± 1.5   |
| Isonychidae |            | Isonychia   | -           | 1.00 ± 0.6   | -            | 1.33 ± 0.9      | 1.67 ± 0.6     | 1.00 ± 0.6   |
| Trichonytidae |            | Trichorythus | -           | -            | -            | -               | 1.33 ± 0.7     | 2.33 ± 0.9   |
| Plecoptera  | Perlidae   | Etrocorema  | 5.00 ± 0.6  | 3.67 ± 0.9   | 2.33 ± 1.2   | 2.33 ± 1.3      | 4.33 ± 1.7     | -            |
|             |            | Neoperla    | 8.00 ± 3.0  | 3.00 ± 0.6   | 2.67 ± 0.3   | 6.67 ± 2.2      | 5.00 ± 0.6     | 1.33 ± 0.7   |
|             |            | Kamimuria   | 3.33 ± 0.3  | 2.33 ± 1.5   | 1.33 ± 0.3   | 2.67 ± 0.3      | 0.67 ± 0.3     | 0.00 ± 0.0   |
|              | Peltoperlidae | Cryptoperla | 1.00 ± 0.6  | 1.00 ± 0.6   | -            | 3.67 ± 1.9      | 1.00 ± 0.6     | -            |
| Trichoptera | Hydropsychidae | Hydropsyche | 3.33 ± 0.7  | 2.67 ± 1.3   | 1.00 ± 0.6   | 5.00 ± 1.5      | 0.67 ± 0.3     | 5.00 ± 1.0   |
|             |            | Cheumatopsyche | 1.67 ± 0.7 | 1.67 ± 0.9   | -            | 5.00 ± 1.2      | 7.00 ± 2.0     | 3.00 ± 0.6   |
|             |            | Macrostemum | -           | 0.33 ± 0.3   | -            | 2.00 ± 0.6      | 3.67 ± 0.3     | 2.00 ± 1.5   |
| Polycyrtopodidae |            | Polycentropus | 3.67 ± 1.5 | 2.67 ± 0.3   | 1.00 ± 0.6   | 1.67 ± 0.9      | 1.33 ± 0.7     | 1.33 ± 0.7   |
| Philopotamidae |            | Chimarra spp. | 1.67 ± 0.7 | 0.67 ± 0.7   | -            | 0.67 ± 0.3      | -              | -            |
| Stenopsyctidae |            | Stenopsyche | 0.67 ± 0.3  | -            | 3.33 ± 1.3   | 1.00 ± 0.6      | 2.00 ± 0.9     | 0.67 ± 0.3   |
| Leptoceridae |            | Triadenodes | 0.33 ± 0.3  | -            | -            | -               | -              | -            |
| Lepidostomatidae |            | Lepidostoma | -           | -            | -            | -               | 0.67 ± 0.2     | -            |

(Continued on next page)
| Order          | Family        | Genus       | Lata Kekabu | Sungai Gelok | Sungai Sedim | Durian Perangin | Lubok Semilang | Telaga Tujuh |
|----------------|---------------|-------------|-------------|--------------|--------------|-----------------|----------------|-------------|
| Odonata        | Corduliidae   | Onychotemis | 1.00 ± 0.6  | 0.33 ± 0.3   | 0.67 ± 0.3   | 0.33 ± 0.3      | -              | 2.33 ± 1.5   |
|                | Euphaeidae    | Euphaea     | 0.33 ± 0.3  | 1.00 ± 0.6   | 0.33 ± 0.3   | -               | -              | -            |
|                | Gomphidae     | Nepogomphus | 1.00 ± 1.0  | 0.33 ± 0.3   | -            | -               | -              | 1.00 ± 0.6   |
|                | Libelulidae   | Zygonyx     | 1.33 ± 0.7  | 0.33 ± 0.3   | 0.67 ± 0.3   | -               | -              | 0.67 ± 0.7   |
|                | Platysticidae | Platysticta | -           | -            | 0.33 ± 0.3   | -               | -              | -            |
| Coleoptera     | Eulichadidae  | Eulichas    | 1.00 ± 1.0  | 0.67 ± 0.3   | 3.33 ± 1.3   | 0.33 ± 0.3      | 0.33 ± 0.3      | 1.67 ± 0.9   |
|                | Elmidae       | Potamophilus| 1.00 ± 0.6  | -            | -            | -               | 0.33 ± 0.3      | -            |
|                | Hydrophiilidae| Laccobius    | 2.00 ± 0.6  | 2.00 ± 1.2   | -            | 0.67 ± 0.7      | 1.00 ± 0.6      | -            |
| Diptera        | Simulidae     | Simulium    | 7.00 ± 1.7  | 8.00 ± 0.6   | -            | 4.67 ± 1.9      | 14.00 ± 4.4     | 14.67 ± 4.6  |
|                | Tipulidae     | Hexatoma    | 1.00 ± 0.6  | 2.00 ± 0.6   | -            | 4.33 ± 1.2      | 0.67 ± 0.7      | 1.00 ± 0.6   |
|                | Chironomidae  | Chironomus  | -           | -            | -            | 2.33 ± 1.2      | 0.33 ± 0.3      | 1.33 ± 0.7   |
| Hemiptera      | Gerridae      | Metrocorsis | -           | -            | 0.33 ± 0.0   | -               | -              | -            |
|                | Velidae       | Rhagodotarsus| -           | 0.33 ± 0.3   | -            | -               | -              | -            |
|                | Nauoridae     | Nauoris     | 0.33 ± 0.3  | -            | -            | -               | -              | -            |
|                | Apheloceridae | Aphelocherius| 0.67 ± 0.3  | -            | -            | -               | -              | -            |
| Lepidoptera    | Pyralidae     | Parapoynx   | 1.00 ± 1.0  | -            | -            | -               | -              | -            |
| Megaloptera    | Corydalidae   | Neochauliodes| 0.33 ± 0.3  | -            | -            | -               | -              | 0.67 ± 0.7   |
In Kedah, Lubok Semilang indicated the greatest abundance of Baetidae (Ephemeroptera) with 57 individuals and 50 individuals from the family of Hydropsychidae. On the other hand, Hydropsychidae was the most dominant family in Sungai Durian Perangin with 36 individuals. In contrast, Telaga Tujuh had the greatest number of Simuliidae (Diptera) with 44 individuals compared to Baetidae (37 individuals) and Perlidae (30 individuals). Based on the Table 4, pH and Ammonia Nitrogen (NH$_3$-N) had a negative correlation with aquatic insect abundance in all six selected rivers with ($r = -0.122$, $P = 0.073$) and ($r = -0.061$, $P = 0.373$), respectively. Throughout the sampling period at all the six rivers, there was a significant relationship between aquatic insect abundance and several water parameters (DO and TSS). Telaga Tujuh had the highest concentration value of DO with 8.79 mg/L while Sungai Sedim had the lowest concentration compared to other rivers with only 7.23 mg/L.

The abundance of aquatic insects at all the six rivers had a considerable significant positive correlation with the concentration of DO ($r = 0.175$, $P = 0.007$). The highest value of TSS was recorded at Sungai Sedim with 32.37 mg/L, while the lowest value of TSS was 1.00 mg/L in Telaga Tujuh. There was a significant correlation between the TSS and abundance of aquatic insects ($r = -0.140$, $P = 0.040$). This indicate that the abundance of aquatic insects decreased as the TSS (dry weight of suspended particles that are not dissolved) in the rivers increased.

Furthermore, Sungai Gelok and Sungai Sedim were classified into Class II (Table 4) based on the Water Quality Index (WQI). Class II indicates that the water is still good and suitable for recreational use with body contact, but conventional treatment is required for livestock drinking. Lata Kekabu, Sungai Durian Perangin, Lubok Semilang and Telaga Tujuh had the high number of WQI value (Class I) which indicates that these rivers have better water quality compared to Sungai Gelok and Sungai Sedim.

In order to categorise the health of the streams based on aquatic insects composition and abundance, the FBI, MFBI and Biological Monitoring Work Party (BMWP) were calculated (Table 5). This index score equals the sum tolerance scores of all macroinvertebrate families with higher BMWP score is considered to reflect better water quality. For the BMWP index score, each aquatic insect family is calculated according to their sensitivity towards the organic pollution. Tolerance values are assigned from 1 (the most tolerant taxa) to 10 (the most sensitive taxa). Based on the value of BMWP, Lata Kekabu (165) and Sungai Gelok (134) shows good water quality while Sungai Sedim was classified as the moderately good according to the BMWP index. Scores from Sungai Durian Perangin (81), Lubok Semilang (80) and Tujuh Telaga (89) shows moderately good water quality according to the BMWP index.
Table 4: Summary of water physico-chemical parameters (mean ± standard error) for Lata Kekabu, Sungai Gelok, Durian Perangin, Lubok Semilang, Telaga Tujuh and Sungai Sedim.

| Parameter                        | Unit   | Lata Kekabu       | Sungai Gelok   | Sungai Sedim | Durian Perangin | Lubok Semilang | Telaga Tujuh |
|----------------------------------|--------|-------------------|----------------|--------------|-----------------|----------------|--------------|
| Dissolved Oxygen (DO)            | mg/L   | 8.67 ± 0.01       | 8.30 ± 0.00    | 7.23 ± 0.99  | 8.48 ± 0.01     | 8.77 ± 0.00    | 8.79 ± 0.04  |
| Biochemical Oxygen Demand (BOD)  | mg/L   | 0.96 ± 0.07       | 1.17 ± 0.03    | 1.24 ± 0.00  | 0.26 ± 0.99     | 1.40 ± 0.03    | 0.29 ± 0.02  |
| Chemical Oxygen Demand (COD)     | mg/L   | 1.33 ± 0.88       | 1.00 ± 0.58    | 2.33 ± 2.33  | 8.00 ± 0.67     | 8.33 ± 0.55    | 8.10 ± 0.78  |
| Ammoniacal Nitrogen (AN)         | mg/L   | 0.02 ± 0.01       | 0.08 ± 0.01    | 0.01 ± 0.01  | 0.01 ± 0.00     | 0.01 ± 0.01    | 0.02 ± 0.02  |
| Total Suspended Solids (TSS)     | mg/L   | 23.10 ± 0.12      | 24.20 ± 0.12   | 32.37 ± 0.70 | 1.50 ± 0.00     | 4.50 ± 0.00    | 1.00 ± 0.00  |
| Temperature                      | ºC     | 23.50 ± 0.00      | 25.02 ± 0.00   | 23.20 ± 0.00 | 25.30 ± 0.01    | 25.00 ± 0.00   | 25.50 ± 0.02 |
| Conductivity                     | S/m    | 23.00 ± 0.01      | 35.60 ± 0.02   | 13.03 ± 0.01 | 20.00 ± 0.33    | 25.00 ± 0.21   | 28.00 ± 0.26 |
| pH                               | -      | 7.10 ± 0.05       | 7.50 ± 0.13    | 7.63 ± 0.15  | 6.72 ± 0.05     | 5.91 ± 0.04    | 8.23 ± 0.02  |
| WQI                              | -      | 93.03             | 89.83          | 89.51        | 96.95           | 97.70          | 95.52        |
| Class                            | -      | I                 | II             | II           | I               | I              | I            |
| Biological Indices/Class | Lata Kekabu | Sungai Gelok | Sungai Sedim | Durian Perangin | Lubok Semilang | Telaga Tujuh |
|--------------------------|------------|-------------|-------------|----------------|----------------|-------------|
| Family Biotic Indices (FBI) Class | 3.49 | 2.33 | 3.26 | 4.27 | 4.27 |
| Quality | Very good | Good | Very good | Moderately good | Moderately good |
| Malaysia Family Biotic Indices (MFBI) Class | 5.85 | 5.60 | 5.43 | 5.34 |
| Quality | Good | Good | Good | Good |
| Biological Monitoring Working Party (BMWP) Class | 165 | 134 | 71 | 80 | 89 |
| Quality | Very good | Good | Moderately good | Moderately good | Good |
| Average Score Per Taxon (ASPT) Class | 6.71 | 6.92 | 7.12 | 7.02 | 7.10 |
| Quality | Rather clean water | Rather clean water | Rather clean water | Rather clean water | Rather clean water |
| **Table 5:** The classification of the rivers based on water quality indices (FBI, MFBI, BMWP and ASPT). | | | | | |
Biotic Index (BI) was subsequently modified to the family-level with tolerance value ranging from 0 (very intolerant) to 10 (highly tolerant) based on their tolerance to organic pollution creating the FBI (Mandaville 2002). Based on the calculated value of FBI, Lata Kekabu (3.49), Sungai Sedim (2.33) and Sungai Durian Perangin (3.26) were classified as having very good water quality and organic pollution is unlikely. Meanwhile, Sungai Gelok (3.88) was classified under good water quality, even though there might be slight organic pollution.

DISCUSSION

Those six selected rivers show different pattern of aquatic insect’s assemblages. Plecoptera (31%) was found dominating most of the river studied, followed by the Trichoptera (20%) and Ephemeroptera (16%). Meanwhile, the most dominant order was Plecoptera (24%) and Diptera (24%) found in Sungai Gelok and the second most dominant was Trichoptera (19%). In addition, family of ephemeropterans dominates the aquatic insect communities in Telaga Tujuh (39%) and Lubok Semilang (37%). In Telaga Tujuh, there are many dipteran families present with 181 individuals and Simuliidae is the most dominant family that was predominated in Telaga Tujuh (88%).

Members of Ephemeroptera, Plecoptera and Trichoptera (EPT) are considered to be sensitive towards the environmental stress, thus, their dominance in all six rivers signifies a relatively clean environment (Suhaila et al. 2014; 2017; Wan Mohd Hafezul 2016). EPT are very much intolerable to any presence of pollutants in the water bodies and thus EPT are crucial biological indicators in determining water quality of the river.

DO is the most important parameter in classifying a river’s class in WQI. Based on the coefficient of DO, it influences the water quality index by 22%. When the value of DO is lower, WQI tends to have lower value and if the value of DO is higher, it is vice versa. However, our study found that the high richness of EPT families (such as Baetidae and Hydropsychidae) of the river contributed to the high scores of all BMWP indices, thus classified the rivers into having clean water. In contrast, the presence of tolerant taxa such as chironomids in the river led to poor water quality classification by the BMWP indices. In this regard, it is safe to conclude that the BMWP displayed higher sensitivity towards organic pollutants in the river compared to the WQI.

According to Allan (2004), land use disturbance does impacts local habitat, features and diversity in the rivers. Aquatic insects react differently towards the several changes in water quality parameter (Batty 2005). Previous study by Rife and Moody (2004) showed EPT orders are sensitive to water quality changes with respects to their low levels of adaptive mechanisms. Based on the findings, it could be simplified that the water parameters in Lata Kekabu, Sungai Gelok, Sungai Sedim, Sungai Durian Perangin, Lubok Semilang and Telaga Tujuh are in tolerable limits since EPT are the dominant orders found.
According to Semenchenko and Moroz (2005), the water quality classification and wide application of BMWP for river water assessment is related to its simplicity and convenience for water evaluation. Unlike the FBI, the BMWP considered all macroinvertebrate groups that contributed to the condition of the monitored rivers (Mustow 2009). For example, this study found that the high richness of EPT families (such as Perlidae and Baetidae) and dipteran Simuliidae in Lubok Semilang contributed to the high scores of BMWP, thus classified the river as clean water quality. In contrast, the presence of tolerant taxa such as chironomids and Tipulidae in Sungai Durian Perangin led to moderately good water quality classification by the BMWP index. This is because, the BMWP was calculated based on the tolerance score of each family of macroinvertebrate that were collected not their abundance.

In this study, the performances of three biotic indices were compared to biologically assess the water quality with tendencies of some indices to be more suitable for use in certain river conditions. The FBI, MFBI and BMWP are based on the sensitivity of key groups to pollution and on the number of component groups in a sample. Since many years ago, a lot of biological indices have been developed and used in many countries. Nevertheless, the development and performance of MFBI in this study is a step forward in the study of bioindicator and biological water assessment in Malaysia. The MFBI formula are specifically generate value to indicate definite condition of the rivers undergoing assessment with variant in terms of assemblages of the aquatic organisms in Malaysia. The MFBI are considering the abundance of taxa in the estimation of the index score that increase the accuracy of the river condition.

Therefore, five classes of water quality were suggested as for MFBI (Wan Mohd Hafezul 2016). These five classes are considered optimum and efficient in evaluating the water quality of the rivers. In this study, all the five rivers had been classified into the second class (Class II) that ranged between 4.5 to 5.9, referred to good water quality. Most of rivers in this range, recorded the composition of intolerant taxa such as Baetidae and Perlidae. Thus, rivers fell within range values were having good water quality.

In this study, the newly developed index which is MFBI (Wan Mohd Hafezul 2016) that used locally located taxa was assessed for their validity in order to confirm their accuracy and reliability for river health bioassessment. Changes in biotic index along the river should be consistent with changes in the water chemistry. It was found that the changes in MFBI scores were driven by oxygen content, BOD and nitrogen in the water (Wan Mohd Hafezul 2016). Consequently, the low oxygen contents contributed to the decrease of MFBI scores that indicated river impairment. For example, Telaga Tujuh and Lubok Semilang that recorded high DO (8.79 mg/L and 8.77 mg/L, respectively) had very high scores of the MFBI consequently fell into Class II (good water quality).

Inconsistence of the water categorisations among rivers by various indices were observed. Some rivers were classified into having “good” water quality by the MFBI and comparable to WQI (Class I) but “moderately good” water quality by the BMWP. Lubok Semilang was a good example for this case. This
situation was presumably prompted by the presence of intolerant taxa such as Baetidae (tolerance value = 6) with high abundance. In addition, Lata Kekabu was classified as very good water quality by the BMWP, but the MFBI classified the rivers as good water quality. For this river, the MFBI classification was more appropriate because this river was surrounded by the residential area (chalet area) and recreational activities and its impairment was expected due to anthropogenic discharges. Therefore, the MFBI classified this river close to its actual condition. For instance, the MFBI and BMWP indices classified the river of Sungai Gelok into Class II (good water quality). Considering the differences and similarities of water classification by MFBI and BMWP index, the potential of the MFBI was comparable to the BMWP indices and the WQI, which indicated that the use of this MFBI in Malaysian rivers is reliable for water quality evaluation.

CONCLUSION

Through this study, Lata Kekabu had the high abundance and diversity of aquatic insect collected compared to other rivers. Lata Kekabu had lesser recreational activity at the surroundings area which lead to the low level of chemical contamination in the water. EPT were the dominant order collected in all rivers. Based on the calculated WQI, Lata Kekabu, Sungai Durian Perangin, Lubok Semilang and Telaga Tujuh was classified into Class I as having a very good water quality. Meanwhile, MFBI classified all rivers into Class II which is a good water quality. MFBI is more reliable to evaluate the water quality as the tolerance value for the taxa is derived from Malaysian specimens and are based on abundances of the taxa.

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REFERENCES

Allan J D. (2004). Landscapes and riverscapes: The influence of land use on stream ecosystems. *Annual Review of Ecology, Evolution, and Systematics* 35: 257–284. https://doi.org/10.1146/annurev.ecolsys.35.120202.110122

Al-Shami S A, Che Salmah M R, Abu Hassan A and Madrus M R. (2013). Biodiversity of stream insects in the Malaysian Peninsular: Spatial pattern and environmental constraints. *Ecological Entomology* 38: 238–249. https://doi.org/10.1111/een.12013
Al-Shami S A, Che Salmah M R, Abu Hassan A and Nor S A M. (2011). Distribution of Chironomidae (Insecta: Diptera) in polluted rivers of the Juru River Basin, Penang, Malaysia. *Journal of Environmental Sciences* 22(5): 1718–1727. https://doi.org/10.1016/S1001-0742(09)60311-9

Aweng E R, Ismid M S and Maktetab M. (2011). The effect of land uses on physicochemical water quality at three rivers in Sungai Endau watershed, Kluang, Johor, Malaysia. *Australian Journal of Basic and Applied Sciences* 5(7): 923–932.

Batty M. (2005). Agents, cells and cities: New representational models for simulating multiscale urban dynamics. *Environment and Planning A: Economy and Space* 37: 1373–1394. https://doi.org/10.1068/a3784

Che Salmah M R, Al-Shami S A, Madziatul Rosemahanie M and Abu Hassan A. (2012). Local effects of forest fragmentation on diversity of aquatic insects in tropical forests rivers: Implications for biological conservation. *Aquatic Ecology* 47: 75–85. https://doi.org/10.1007/s10452-012-9426-8

Engel S R and Voshell J R Jr. (2002). Volunteer biological monitoring: Can it accurately assess the ecological condition of streams? *American Entomologist* 48(3): 164–177. https://doi.org/10.1093/ae/48.3.164

Hepp L U, Restello R M and Milesi S V. (2013). Distribution of aquatic insects in urban headwater streams. *Acta Limnologica Brasiliensia* 25(1): 1–9. https://doi.org/10.1590/S2179-975X2013005000014

Hilsenhoff W L. (1988). A modification of the biotic index of organic stream pollution to remedy problems and permit its use throughout the year. *Great Lakes Entomologist* 31(1): 1–12.

Hoang H. (2009). Monitoring and assessment of macroinvertebrate communities in support of river management in northern Vietnam. Unpublished doctoral dissertation, Ghent University, Belgium.

Kopciuch R G, Berecka B, Bartoszewicz J and Buszewski B. (2004). Some considerations about bioindicators in environmental monitoring. *Polish Journal of Environmental Studies* 13(5): 453–462.

Lavoie I and Campeau S. (2010). Fishing for diatoms: Fish gut analysis reveals water quality changes over a 75-year period. *Journal Paleolimnology* 43: 121–130. https://doi.org/10.1007/s10933-009-9321-z

Leunda P, Miranda R, Oscoz J and Arino A H. (2009). Longitudinal and seasonal variation of the benthic macroinvertebrate community and biotic indices in an undistributed Pyrenean river. *Ecological Indicator* 9: 52–63. https://doi.org/10.1016/j.ecolind.2008.01.009

Mandaville S M. (2002). *Benthic macroinvertebrates in freshwater—taxa tolerance values, metrics, and protocols, Project H-1*. Soil & Water Conservation Society of Metro Halifax, Canada, 128 p.

Merritt R W, Cummins K W and Berg M B. (2008). *An introduction to the aquatic insects of North America*. Dubuque: Kendall/Hunt Publishing Company.

Morse J C. (2004). *Insecta: Tricoptera*. In: Yule C M and Yong H S. (Eds.). *Freshwater invertebrates of the Malaysian Region*. Malaysia: Academy of Sciences Malaysia, 501–539.

Mustow S E. (2009). Biological monitoring of rivers in Thailand: Use and adaptation of the BMWP score. *Hydrobiologia* 479: 191–229. https://doi.org/10.1023/A:1021055926316

Oliveira S V and Cortes R M V. (2006). Environmental indicators of ecological integrity and their development for running waters in northern Portugal. *Limnetica* 25(1): 479–498.
Rife G S and Moody D L. (2004). Aquatic macroinvertebrate communities from the Protage River watershed headwater streams (Wood Country, Ohio). The Ohio Journal of Sciences 104: 29.

Semenchenko V P and Moroz M D. (2005). Comparative analysis of biotic indices in the monitoring working system of running water in biospheric reserve. Water Resources 32: 200–203. https://doi.org/10.1007/s11268-005-0025-0

Suhaila A H and Che Salmah M R. (2011). Influence of substrate-embeddedness and canopy cover on the abundance and diversity of Ephemeroptera, Plecoptera and Trichoptera (EPT) in recreational rivers. Aquatic Insects 33: 281–292. https://doi.org/10.1080/01650424.2011.640940

Suhaila A H, Che Salmah M R and Nurul Huda A. (2014). Seasonal abundance and diversity of aquatic insects in rivers in Gunung Jerai Forest Reserve, Malaysia. Sains Malaysiana 43(5): 667–674.

Wan Mohd Hafezul W A G. (2016). Development of Malaysian water quality indices using aquatic macroinvertebrates population of Pahang River Basin, Pahang, Malaysia. Unpublished doctoral dissertation, Universiti Sains Malaysia.

Webb J M and McCafferty W P. (2008) Heptageniidae of the world, Part II: Key of the genera. Canadian Journal of Arthropod Identification 7: 1–55. https://doi.org/10.3752/cjai.2008.07

Xu M, Wang Z, Duan X and Pan B. (2014). Effects of pollution on macroinvertebrates and water quality bio-assessment. Hydrobiologia 729: 247–259. https://doi.org/10.1007/s10750-013-1504-y

Yule C M and Yong H S. (2004). Freshwater invertebrates of the Malaysian region. Kuala Lumpur: Academy of Sciences Malaysia, 443–456.

Zarei H and Bilondi M P. (2013). Factor analysis of chemical composition in the Karoon River basin, southwest of Iran. Applied Water Science 3: 753–760. https://doi.org/10.1007/s13201-013-0123-0