Comparison of Diversity and Community Structure of Aquatic Insects Based on Habitat Class in Johor

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Abstract. Aquatic insects have been well used as a tool in monitoring water quality and this study is aimed to gauge their potential in Johor. The rapid development in the state of Johor may cause pollution to water resources that require a more efficient water quality monitoring program. The objectives of this study were to (i) collect, identify, determine and produce aquatic insect diversity data in selected rivers in Johor, (ii) relate the presence of aquatic insect diversity with some of the physical features of rivers in Johor. Seven sampling areas were selected based on their importance to local communities and geographical distribution: Taman Negara Johor Endau Rompin (PETA) (TNJER-PETA), Taman Hutan Lagenda Gunung Ledang (THLGL), Hutan Lipur Soga Perdana (HLSP), Hutan Lipur Gunung Belumut (HLGB), Hutan Lipur Sungai Bantang (HLSB), Hutan Lipur Gunung Pulai 1 (HLGP1) and Sungai Sayong Pinang. Insect samples were collected using a kick net method and slight modification made according to type of microhabitats. A total of 11,647 individuals of aquatic insects consisting of 68 families from nine orders were sampled. About 69% of insects collected were indicators of good water quality; among them are families Hydropsychidae from order Trichoptera, Baetidae from Order Ephemeroptera, and Simuliidae from Order Diptera. Based on family diversity analyzed using Shannon Index (H'), TNJER- PETA is recorded having the highest index (H' = 3.215) followed by HLSP (H' = 2.791) and HLGB (H' = 2.482). Comparison made and based on physical characteristics, the study sites were classified into three categories (i) the most preferred sites by aquatic insects (HLSB, THLGL, HLGP1, and HLGB), (ii) intermediate preferred sites (TNJER-PETA and HLSP) and (iii) least preferred site (Sg. Sayong). In conclusion, community structure of benthic organisms were influenced by many factors such as presence of variety of microhabitat, predation, surrounding environments, food availability, physical and chemical characteristics of water. Moreover, higher heterogeneity of habitat promote high abundance and diversity of aquatic insects. Any changes happened that involves human interference in the habitats, will affect the abundance of aquatic insects. Last but not least, results suggested that the quality of river water in Johor can be monitored using insects as biological indicators due to the abundance, distribution, and rapid response of aquatic insects to environmental conditions.
1. Introduction
Aquatic insects are known as a tool in monitoring water quality because of their predictable responses to changes in the array of aquatic habitats [1,2]. Presence or absence of certain families of aquatic insects could indicate quality of water bodies either good or bad [3]. Moreover, aquatic insects are good water quality indicator because of their varying tolerance toward the environment [1]. Several aquatic insects are very sensitive toward pollution while there are some that could live and able to tolerate habitat disturbances and highly polluted environment [4].

Aquatic insects are very important to aquatic habitats, where their presence in the water bodies provides many benefits such as food for fish and other invertebrates, as well as acting as vectors through which pathogens could be transmitted to humans and animals [4]. In addition, aquatic insects are economically and ecologically important. As such, they are major models for studying ecology, population growth, evolution, genetics and many other areas of biology. Some aquatic insects decompose leaves and other parts of plant that fall into water body [3].

Johor is in the midst of a rapid infrastructure development with several projects including the development of the Iskandar Malaysia Economic Region (Iskandar Malaysia), the Oil and Petroleum Refinery (RAPID) Integrated Development Project at Pengerang, the Kuala Lumpur- Singapore High Speed-Rail, the Desaru Coast and the Rapid Transit System (RTS) connecting Chagar Hill, Johor Bahru to Woodlands, Singapore and Forest City to support economic development of the state [5].

In addition, oil palm plantation in Johor remains the largest in Peninsular Malaysia with a total production of 3,328,311 tonnes from 10,935,731 tonnes total in Peninsular Malaysia based on data obtained in 2020 [6]. The development of these infrastructures and agricultural activities has led to loosening of the soil structure and a contributing factor to the erosion of the soil; and when it rains it will bring mud flowing into the river. When this happens widely, there is a decline in water quality and ultimately affects the amount of potable water.

To ensure human health, water quality should be monitored regularly and intensively. Ecologically freshwater is a very sensitive ecosystem, thus may be affected by the rapid development. Freshwater needs to be conserved as it is important to wildlife, humans and industry. To ensure adequate water quality and quantity, water quality monitoring is essential to know the current health status of freshwater ecosystems.

2. Material and Methods

2.1 Sample Collection
Sampleings were conducted starting from July 2016 until November 2017 (Table 1). Sample were collected from seven sites in Johor which are Taman Negara Johor Endau Rompin (PETA) (TNJER-PETA), Taman Hutan Lagenda Gunung Ledang (THLGL), Hutan Lipur Soga Perdana (HLSP), Hutan Lipur Gunung Belumut (HLGB), Hutan Lipur Sungai Bantang (HLSB), Hutan Lipur Gunung Pulai 1 (HLGP1) dan Sungai Sayong Pinang. Sampling areas were selected based on their geographical distribution and their importance to local community. Insect samples were collected using kicking net method with aquatic net (of size 45.72 cm X 22.86 cm with mesh size 900 μm) in various types of microhabitat. Insect sample were sorted directly in the field into aluminum cap glass vials containing 70% ethanol and brought back to the laboratory for identification purposed. All sample were identified to family level using identification key from various authors in Freshwater Invertebrates of the Malaysia Region edited by [7].

| Sampling sites | Date of sampling 1 | Date of sampling 2 | Date of sampling 3 |
|----------------|-------------------|--------------------|--------------------|
| TNJER          | 18,21,23 July 2016| 22-24 Aug 2016     | 28-30 July 2017    |
| THLGL          | 3-5 Dec 2016      | 24-26 Feb 2017     | 24-26 Apr 2017     |
2.2. Data analysis

In this study, several indices were selected to measure the diversity, distribution and richness of aquatic insect which are Shannon Diversity Index (H') where $H' = -\sum P_i \log_e P_i$ (P the ratio of individuals belonging to the species to the total species). The Shannon diversity index (H') is an informative statistical index. It assumes that all species represented are obtained by random sampling. This index is commonly used to measure the diversity of species in a community. Shannon's index increased as both richness and community evenness increased. H’ is sensitive to rare and abundant species [8]. This index value is usually found between 1.5 and 3.5 [9].

The second index selected is Shannon Evenness Index where $E = H'/H_{max}$ (H’ is an observed diversity index (Shannon diversity index) and $H_{max}$ is the value of ln S where S is the sum of the species. Maximum diversity (Hmax) occurs when species are found to be abundant [10]. The ratio of observed diversity to maximum diversity can be calculated as a measure of similarity. The E values range from 0 to 1.0 with 1.0 representing the conditions when in all sampling areas the number of individuals in the species are even. The assumption in this index is that all species in the community are calculated in the sample [9].

The third index selected was Simpson’s Diversity Index (D) where $D = \frac{\sum e^{-n_i}}{N^2}$ (n is the total of individual of each species and N is the total number of individuals of organisms of all species). For this index, value were ranging from 0 to 1, 0 represent the infinite diversity and 1 represent no diversity and value of the index were decreasing as species richness and species evenness increase.

The fourth index selected was Margalef Richness Index (Dmg) where $d = \frac{S-1}{\ln N}$ (S is the total species and N is the total individual in sample). For this index, data must be organized in absolute numbers rather than the data density matrix [11]. According definition from [11], the meaning of absolute numbers is the number of individuals per species at each sampling station or sample replication meanwhile the data density matrix is several individuals per square meter at sampling or replication stations. When the data density matrix is used in the Margalef index the value of the index is always lower than when using absolute numbers. The index is always misinterpreted and the difference is significant if the sample size is small [11].

2.3 Functional feeding group (FFG)

Functional feeding groups among aquatic insects refer to [12]. Some taxa of aquatic insects are classified into functional feeding groups (FFGs) according to the method in [12,13,14,15]. For this method two things are observed: the various feeding mechanisms among aquatic insects and the heterogeneity of size of food particles of various insects to validate the functional group of aquatic insect functions [16].

2.4 Cluster analysis

This analysis was used to determine the presence or absence of aquatic insects at each site of study. Based on these data, locations with similar characteristics can be identified by using cluster analysis. In the cluster analysis, similarity and dissimilarity coefficients were used to group the study sites according to their similarities in aquatic insect composition. The relationships between aquatic insect assemblages and study sites were measured based on their similarity using the Bray-Curtis similarity measure and the results were interpreted in a plotted dendrogram using Paleontological Statistics (PAST) v.2.17c software [17].
2.5 Analysis of physical features

In this study, there are several physical features taken during sampling activities conducted. Physical features were ranked as Table 2 below. Among the physical features taken are the water depth and width of the river using measuring tape, the presence of plants on the river bank and the type of substratum by observation, forest canopy cover using a densiometer, conventional river velocity by using measuring tape to measure river length along three meters and float a ping pong ball and the float time is determined by a stopwatch. River velocity is obtained in units of m²/second. The rate of river velocity is calculated based on the formula below.

River bottom area = length x width x 1/2 height
Water velocity rate = area x velocity

| Substrate | I | II | III |
|-----------|---|----|-----|
| Bedrocks, boulders, cobbles, and pebbles, leave litter and wood fragments | >60% | <60% | <10% |
| Forest canopy Vegetation | Dense vegetation on the riverbank | Least dense of vegetation on the riverbank | No vegetation on the riverbank |
| Micro habitat | Various micro-habits | Limited micro-habits | No micro-habitat |
| Water velocity | Water flows freely with a stable river structure | Water flows slowly with a stable river structure | Water flows freely with unstable river structures |

3. Result and discussion

3.1 Diversity of aquatic insects

In total, 11,647 individual aquatic insects comprising 68 families representing nine orders have been collected from all seven sampling sites in Johor. In this study, there are four ecological statistics indices used which Shannon Diversity Index (H'), Evenness Index (E), Simpson’s Diversity Index (D) and Margalef Richness Index (Dmg). Each index was calculated based on the diversity of aquatic insects collected. Then the values are compiled and given a score of 1 for the highest value of each index, 2 for the second-highest value, and 3 for the third-highest value up to 7 for the lowest value. This is done for the three indices namely H’, E and Dmg. However, for Simpson diversity index D, analysis would yield negatively, thus higher dominance index would indicate a poorer water quality. Therefore, the lowest score 1 is given to the lowest D value. Scores for all the indices were total up. The lowest scores represent the best conditions while the highest scores indicate the worst.

Results of Table 3 are analyses of all the indices H’, E, and Dmg and were ranked according to the score given. Table 3 shows that all four indices were highest for TNJER-PETA. On the other hand for Sg. Sayong three of the four indices (H’, D and Dmg) have lowest values. By totaling up the rank order for all the four indices this study indicated that river of TNJER-PETA has the best water quality with a total lowest score value of 4, followed by HLSP (10), HLGB (14), HLSB (18), THLGL (20) and HLP1 (21). The river with highest total score value of total of 25 is Sg. Sayong. This would means TNJER-PETA has the best water quality and Sg. Sayong the poorest.
To account for being a river with highest value for all four indices, is perhaps the existence of various micro-habitats attracting and harbouring many different kinds of aquatic insects. Based on the result, TNJER-PETA scored the highest value for all the indices. Observation showed that TNJER-PETA harbours an array of micro-habitats which attracted various types of aquatic insects. Each aquatic insects group has its own preference in choosing their habitat to live depending on their functional feeding group. According to [18], benthic macro invertebrates choose a balanced habitat with regard to their needs. Therefore, freshwater ecosystems should be conserved to protect aquatic insect habitats. Aquatic insects play a very important role in the ecosystem. Aquatic insects are not only indicators of water quality, but also play a role in food chain systems and biological control. Each group of insects has its habitat selection based on its adaptation. According to [19], the spatial distribution of some aquatic insects reacts and is influenced by environmental parameters such as water flow, temperature, pH, substrate particle size, and food source.

Functional feeding groups are also closely related to habitat structure because habitat structure could determine species diversity at a local scale. Generally, more complex habitats are associated with higher wealth values than non-complex habitats [20]. In water flow studies, most aquatic insects are closely related to the organic substratum in both flowing water and ponds. This may be closely linked to the capacity of the substratum to maintain organic matter present in the river, providing abundant shelter and food [21].

Table 3. Analysis of ecological statistics for each sampling site (* Values in brackets show study site scores based on the statistical ecological index)

| Ecology analysis | HLGB | HLSB | HLGP1 | HLSP | TNJER-PETA | THLGL | Sg. Sayong |
|------------------|------|------|-------|------|-------------|-------|-----------|
| H'               | 2.482(3) | 2.368(4) | 2.195(6) | 2.791(2) | 3.215(1) | 2.273(5) | 1.278(7) |
| E                | 0.4128(3) | 0.2427(7) | 0.3454(5) | 0.512(2) | 0.5415(1) | 0.249(6) | 0.3589(4) |
| D                | 0.1172(3) | 0.1484(5) | 0.1457(4) | 0.0853(2) | 0.0579(1) | 0.1678(6) | 0.415(7) |
| D_{mg}           | 3.642(5) | 5.444(2) | 3.224(6) | 4.493(4) | 6.944(1) | 4.785(3) | 1.728(7) |
| TOTAL SCORE      | 14 | 18 | 21 | 10 | 4 | 20 | 25 |

3.2 Associating diversity of aquatic insects and physical features of rivers.
Based on the methodology and observation it was found that HLGB, HLSB, HLGP1, and THLGL are classified as the most favoured habitat by aquatic insects. In this regard, habitat structure plays an important role in influencing the presence of aquatic insects. The stable habitat structure, which has a variety of micro-habitats with fast and slow water flow, woody debris, various substrates with good vegetation, and stable river banks are factors that contribute to high abundance and diverse composition of aquatic insects [22]. This is because each group of insects has its own habitat preferences according to the adaptation to the aquatic environment. Based on the observed data of physical characteristics, it was found that these four areas meet criteria of good habitat for aquatic insects. Among them are, having wide and diverse water bodies, having a wide variety of substratum of large rocks, small rocks, cobbles and pebbles, a pile of leaves and fragments of wood, fine sand, and even ponds. This is supported by data on the diversity of aquatic insects that are predominantly aquatic insects indicative of clean water quality.

Meanwhile, HLSP and TNJER-PETA are listed as intermediate habitats favoured by aquatic insects. Although TNJER-PETA is a study site located in a pristine area free of human activity, it is not classified
as a favorite area. This is closely related to the habitat structure which are habitat complexity and habitat size [23]. High habitat complexity will increase density and diversity by providing a new niche for the species [24], reducing competition [25]. On the other hand, increasing the size of the habitat opens up opportunities for species with specialized habitats and increases the likelihood of immigration leading to increased species density and diversity [26]. In addition, the complexity and size of these habitats also influence predation rates by providing absolute or stochastic protection for prey [27].

The least selected area is Sg. Sayong. Based on the physical features of the study site it was found that Sg. Sayong has a very limited microhabitat with only sandy and muddy substratum, as well as the absence of vegetation along the river bank. This contributes to poor habitat structure which could not support the wide diversity and composition of aquatic insects. In addition, Sg. Sayong is also exposed to anthropogenic activities such as sand mining, waste from oil palm factories, and chicken processing factories which are also factors in reducing the presence of aquatic insects. Generally, the abundance and diversity of aquatic insects depend on the type of substratum, the dissolved oxygen (DO) content in water as it is closely related to the adaptation of aquatic insects. For example, the Simuliidae family is an insect that requires a high oxygen saturation rate of about 78% to allow the Simuliidae larvae to survive [28,29]. Based on the findings of the study, Sg. Sayong is dominated by family Chironomidae which usually adapts to poor water quality.

Table 4 below shows a summary of the physical parameters in all seven sampling sites and 'I' refers to 'Good', 'II' refers to 'moderate', and 'III' refers to 'bad'. These criteria were then used to classify the seven river systems in the study.

### Table 4. Physical parameters for each sampling site

| Physical parameter | HLGB | HLSB | HLGPI | HLSP | TNJER-PETA | THLGL | Sg. Sayong |
|--------------------|------|------|-------|------|------------|-------|------------|
| Substrate         | I    | I    | I     | II   | I          | I     | III        |
| Forest canopy     | II   | I    | I     | I    | I          | I     | III        |
| Vegetation        | I    | I    | I     | I    | I          | I     | III        |
| Microhabitat      | I    | I    | I     | II   | I          | I     | III        |
| Water velocity    | I    | I    | I     | II   | I          | I     | III        |

**Total score**: 6 5 5 8 7 6 15

#### 3.3 Cluster analysis

Based on the similarity index on the value of the dendrogram (Bray-Curtis) (Figure 1), it is suggested that HLSB and HLGB can be grouped by similarity of 78%. Meanwhile, HLSP and TNJER (PETA) had a similarity index of 71%. Sg. Sayong Pinang is at least similar to other regions with a similarity of only 11%. Cluster analysis for sampling areas is based on the abundance and composition data of aquatic insects found in each sampling area. Based on results, shows that presence of variety of microhabitat influence the composition of aquatic insect and sampling areas with closely related in term of composition of aquatic insects were clustered together.

Community structure is basically about species composition which includes the number of species present in the community, species richness, and species diversity. Theoretically, more complex habitats support more species, and large habitat, range have more species than small habitat range. In terms of habitat availability, persistent habitats have more species than ephemeral habitats. There are many factors that give shape to community structure such as climate patterns, geography, heterogeneity of habitats, frequency of disturbance, and interactions between organisms. In order to know their distribution and how they react to biotic and abiotic factors around them, an observation at actual habitat
is compulsory. For example, adults of caddisflies, mayflies, and stoneflies are had short life and always stay near the place they breed. Heterogeneity of habitat also influences the functional feeding group, such as habitat with low water velocity enhance the accumulation of organic matters in areas, which allow the establishment of a predator group [30]. Meanwhile, a habitat with high water velocity was preferred by Ephemeroptera, Plecoptera, and Trichoptera group (EPT) because areas with high water velocity usually have high dissolved oxygen since the EPT group are less tolerant to pollution. In conservation management, it’s important to get a better understanding of their community structure to ensure our conservation effort are not wasted.

![Dendogram of similarity index of sampling areas](image)

**Figure 1.** Dendogram of similarity index of sampling areas

4. **Conclusion**

In conclusion, community structure of benthic organisms were influenced by many factors such as presence of variety of microhabitat, predation, surrounding environments, food availability, physical and chemical characteristics of water. Moreover, higher heterogeneity of habitat promote high abundance and diversity of aquatic insects. Any changes happened that involving human interference in the habitats, will affect the abundance of aquatic insects. Last but not least, results suggested that the quality of river water in Johor can be monitored using insects as biological indicators due to the abundance, distribution, and rapid response of aquatic insects to environmental conditions.

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References

[1] Adler P H, Currie D C, and Wood D M 2004 The Black flies (Simuliidae) of North America. ROM Publication in Sciences, New York, NY.

[2] Arimoro F O and Ikomi R B 2008 Ecological Integrity of upper Warri River, Niger Delta using Aquatic insects as bioindicators. Ecol. Indic. 395, 1-7 Arman-Hadi, M., & Maryati, M. (2004). The use of Aquatic Insects as Bioindicator of Fresh Water Quality. Proceedings of the 8th Sabah Inter-agency Tropical Ecosystem (SITE) “Integrated Catchment Management In Sabah: Issues and Challenges”, 86-97.

[3] Beisel J N, Usseglio-Polatera P, Thomas S, and Moreteau J S 1998 Stream community structure in relation to spatial variation: the influence of microhabitat characteristics. Hydrobiol. 389 73-88.

[4] Choudhary A and Ahi J 2015 Biodiversity of freshwater insects: a review. Int. J. Eng. Sci. 4(10), 25-31.

[5] Cummins K W and Lauf G H 1969 The influence of substrate particle size on the microdistribution of stream macrobenthos. Hydrobiol. 34 145-181.

[6] Cummins K W, Merritt R W, and Andrade P C N 2005 The use of invertebrate functional groups to characterize ecosystem attributes in selected streams and rivers in south Brazil. Stud. Neotrop. Fauna Environ. 40(1): 69-89.

[7] Doisy K E, Hall R D, and Fischer F J 1986 The Black flies (Diptera: Simuliidae) of an Ozark Stream in South Missouri and Associated Water Quality Measurement. J. KANSAS Entomol. Soc. 59 (1): 133-142

[8] Downes B J, Lake P S, Schreiber E S G, and Glaister A 1998. Habitat structure and regulation of local species diversity in a stony, upland stream. Ecol. Monogr. 68(2): 237-257.

[9] Dudgeon D 1999 Tropical Asian Streams: Zoobenthos, Ecology and Conservation. Hong Kong: Hong Kong University Press.

[10] Gamito S 2010 Caution is needed when applying Margalef diversity index. Ecol. Indic. 10(2), 550-551.

[11] Hammer Ø, Harper D A, and Ryan P D 2001 PAST: paleontological statistics software package for education and data analysis. Palaeontol. Electron. 4(1), 9.

[12] Hepp L U, Restello R M, and Milesi S V 2013 Distribution of aquatic insects in urban headwater streams. Acta Limnol. Bras. 25(1): 1-9.

[13] Langelotto G A, and Denno R F 2004 Responses of invertebrate natural enemies to complex-structured habitats: a meta-analytical synthesis. Oecologia, 139 1–10

[14] MacArthur R H, and Wilson E O 1967 The theory of island biogeography. Princeton Univeristy Press, Princeton

[15] Magurran A E 1988 Ecological diversity and its measurement. Princeton University Press.

[16] Magurran A E 2004 Measuring biological diversity, 2nd ed. Blackwell Science Ltd. Oxford, U.K.

[17] Malaysia Palm Oil Board 2020 production of crude oil palm 2020. Retrieved August 25, 2020, from http://bepi.mpob.gov.my/index.php/en/production/production-2020/production-of-crude-oil-palm-2020.html

[18] Merritt R W, and Cummins K W 2006 Trophic relationships of macroinvertebrates. In Methods in Stream Ecology, edited by Hauer, F.R. & Lamberti, G.A. Burlington: Elsevier. pp. 585-601.

[19] Mohd Rasdi Z, Fauziah I, Ismail R, Mohd Hafezan S, Fairuz K, Hazmi A D, and Che Salmah M R 2012 “Diversity of Aquatic Insects in Keniam River, National Park, Pahang, Malaysia”, Asian. J. Agric. Dev. 2(3): 312-328.

[20] Morris E K, Caruso T, Buscot F, Fischer M, Hancock C, Maier T S, and Socher S A 2014 Choosing and using diversity indices: insights for ecological applications from the German Biodiversity Exploratories. Ecol. Evol. 4(18): 3514-3524.

[21] Oliveira A L H D, and Nessimian J L 2010 Spatial distribution and functional feeding groups of aquatic insect communities in Serra da Bocaina streams, southeastern Brazil. Acta Limnol. Bras. 22(4), 424-441.
[22] Prommi T, and Payakka A 2015 Aquatic insect biodiversity and water quality parameters of streams in Northern Thailand. *Sains Malays.* 44(5), 707-717.

[23] Ramírez A, and Gutiérrez-Fonseca P E 2014 Functional feeding groups of aquatic insect families in Latin America: A critical analysis and review of existing literature. *Rev. Biol. Trop.* 62(2): 155-167.

[24] Saulino H H L, Corbi J J, and Trivinho-Strixino S 2014 Aquatic insect community structure under the influence of small dams in a stream of the Mogi-Guaçu river basin, state of São Paulo. *Braz. J. Biol.* 74(1) 79-88.

[25] Srivastava D S 2006 Habitat structure, trophic structure and ecosystem function: interactive effects in a bromeliad–insect community. *Oecologia,* 149 493–504.

[26] Suriyawong S H E, Thapanya P D, Bergey E A, and Chantaramongkol P 2018 Aquatic Insect Functional Feeding Groups in a Mountain Stream with a Series of Check Dams in Northern Thailand. *Sains Malaysiana* 47(7), 1379-1386.

[27] Uetz G W 1991 Habitat structure and spider foraging. In: Bell SS, McCoy ED, Mushinsky HR (eds) Habitat structure: the physical arrangement of objects in space. Chapman and Hall, New York, pp 325–348

[28] Young K 2001 Habitat diversity and species diversity: testing the competition hypothesis with juvenile salmonids. *Oikos,* 95 87–93.

[29] Yule C M, and Yong H S 2004 *Freshwater invertebrates of the Malaysian region.* Akademi Sains Malaysia.

[30] Zulhisham I 2018, May 8 Johor kuasa ekonomi baharu. Utusan Online.
