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Original Article

Physico-chemical water quality and macroinvertebrate distribution along Sungai Asah in Pulau Tioman, Johor, Malaysia

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Abstract

To gauge the quality of river in terms of biological health, an investigation on the distribution of macroinvertebrate along Sungai Asah, Pulau Tioman, Pahang, Malaysia at three main stations (downstream, midstream and upstream) was conducted. The river macroinvertebrates were represented by nine orders, 45 families and 329 individuals across the three sampling stations. The most commonly found family was Diptera contributing 99 individuals to the total macroinvertebrates, followed by Trichoptera (80 individuals) and the least found order was Haplotaxida with only two individuals. The pollution intolerant taxa Ephemeroptera was found at all the sampling stations. The biological monitoring working party (BMWP) score at midstream of the river indicated the area was not impacted by pollution, but the EPT index was Poor at 2.8. The low number Odonata aquatic macroinvertebrates in Sungai Asah indicates that Sungai Asah was disturbed and impacted by human recreational activities.

Keywords: macroinvertebrate, Pulau Tioman, river, health, EPT, BMWP

1. Introduction

Aquatic macroinvertebrate are organisms that dwell in water ecosystems, visible to naked eye and lacking internal skeleton (Goodnight, 1973). These aquatic macroinvertebrates that can be found in streams and other water ecosystem include insects, worms, snails and crustaceans. Many of the insect species found are closely interrelated to the freshwater ecosystem. Aquatic insects live on or near the freshwater surface and some can be found emerging to water surface for oxygen before diving into the water. This group of aquatic macroinvertebrates spends the juvenile stage underwater, which they leave as adults and usually can be found near freshwater even as adults (Doughty, 1994). Such insects include mayfly (order Ephemeroptera), dragonfly (order Odonata), stonefly (order Plecoptera), water strider (order Hemiptera), mosquito (order Diptera), caddisfly (order Trichoptera), and predaceous diving beetle (order Coleoptera) that are common inhabitants of freshwater bodies (Richard son, 2008). These aquatic macroinvertebrate, according to Watson-Ferguson *et al.* (2006), are crucial in nutrient cycles with decomposition and translocation of materials. Strayer (2006) has reported that aquatic freshwater invertebrates are able to survive mostly in any freshwater, with the exception of very highly polluted or deep ground water bodies. The river habitat type could predict the taxonomic composition present in a specific habitat. The distribution of aquatic insects present in a specific habitat is shaped by factors such as pH, elevation, substrate type and water depth (Demars *et al.*, 2012). The correlation of taxonomic representation of aquatic insects to state of the environment means that these insects can be used as bioindicators to assess the environmental health. Currently, in Malaysia researchers have reported the use of such bioindicators to investigate the effects of aquatic macro-invertebrates on the environment. This includes Aweng *et al.* (2011, 2012, 2014, 2015), Ishadi *et al.* (2014), and Omar *et al.* (2014), exploring the potential and justifying the role of aquatic insects as bioindicators at a local scale.

The Pulau Tioman (Tioman Island) is part of the state of Pahang, Malaysia. The island is situated 48 km off the

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coast of Pahang, covering 70 sq. km at longitude 104° 10' 11.4456" E and latitude 2° 47' 24.8964" N. The geology of Pulau Tioman is composed of rocky structures dominated by exposed granitoid boulder-beds found on the coast of Kampung Paya, Batu Sirau (747m), Nenek Si Mukut (695 m) and a thin layer of soil (Latiff *et al.*, 1999). The island has very little flatlands limited to the coasts, especially around Teluk Juara and Kampung Tekek. The very limited flatland and domination of steep slopes on the island further encourages the development of ecotourism as the primary economic activity. There are several rivers and a few other smaller streams on the island, including Sungai Asah, Sungai Benuang and Sungai Elin (Jaman & Latiff, 1999). Sungai Asah is a well-known tourist attraction for its cascading waterfall, the Asah Waterfalls locally known as the Mukut Waterfalls, as it is located near the Mukut village. The investigations of fauna of Pulau Tioman date back to 1966 by Bullock on the terrestrial arthropods of the island, and then much later by Hendrich and Yang (1999) on water beetle (order Coleoptera). However, until recently there is no published report on the distribution pattern of aquatic insects and the water quality of Asah Waterfall, regarding which this study provides insights into the ecological requirements of water insects that affect their diversity.

2. Materials and Methods

2.1 Study sites

The overall study site was located in Pulau Tioman and the focus catchment is along Sungai Asah (latitude 2°43'16.32", longitude 104°11'40.93", Figure 1). The study was conducted from 16th April to 17th April in year 2016, in the Wildlife Inventory Program organized by the Department of Wildlife and National Parks, Peninsular Malaysia (PERHILITAN). Three sampling stations with two replicate spots at each station were chosen for water quality analysis. The two replicates at each station were combined to a composite sample. The three sampling stations (Station 1, Station 2 and Station 3) were pinpointed using the Global Positioning System (GPS), being at upper stream, midstream and downstream of the Sungai Asah, and divided based on elevation from sea level. The sampling was started downstream, followed by same at the midstream station and finally the upstream station. Table 1 shows the geo-references of the sampling stations.

2.2 Water quality data in Asah river, Pulau Tioman.

Seven *in-situ* parameters were selected for water quality analysis namely pH, temperature, salinity, conductivity, dissolved oxygen, turbidity and total dissolved solids, as shown in Table 2 together with the equipment used for the readings. The sampling stations along the river were observed to have different substrate compositions and their water surfaces along the river are shaded to varying percentages by the canopy cover. In the upstream station 1 the substrate consists primarily of boulders and cobblestones. The water surface is covered by canopy to almost 75% and riparian coverage on both sides of the river was observed to be about 80%. At station 2, the majority of rocks observed were boulders, canopy was covering the water surface by 95% and

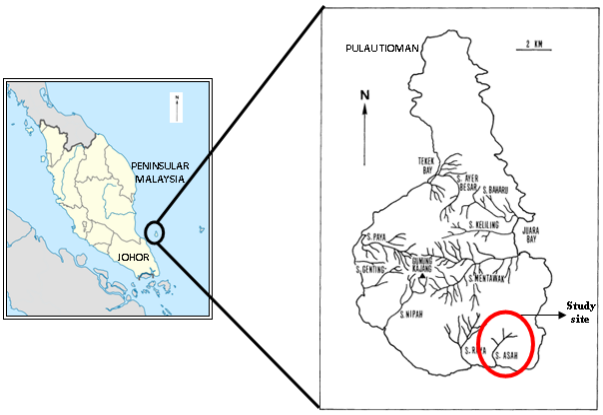

Figure 1. A map of the study area in Sungai Asah, PulauTioman, Johor. Modified from Hendrich & Yang (1999).

Table 1. Geo-reference of sampling locations.

Sampling Station	Latitude (N)	Longitude (E)	Water Body
1	02°43.527'	104°11.640'	Upstream
2	02°43.406'	104°11.700'	Midstream
3	02°43.224'	104°11.858	Downstream

Table 2. Parameters and instruments for water quality analysis.

Parameter	Equipment
pH Temperature Salinity Conductivity Dissolved Oxygen Total Dissolved Solid	Multi Paramater Probe Model YSI 6920 with 650 MDS Display/Logger
Turbidity	Thermo Orion AQ4500 Turbidity Meter

riparian growth at 80% were also seen at the site. At the final downstream station 3 the substrate composition was boulders and cobbles of varying sizes, with canopy covering the water surface by only 50%, while the riparian growth at the river sides was about 70%.

2.3 Macroinvertebrate sampling and analysis

For macroinvertebrate sampling in Sungai Asah, a quadrat of 30 cm x 30 cm (0.09 m^2) was placed at each of the three stations (Station 1, Station 2, Station 3) and sampled using a Surber Net with 500 micron mesh size (500 µm). As the Sungai Asah was covered to > 60% by boulders and cobbles, the two sampling points (A and B) at each station were chosen randomly. Macroinvertebrate samples collected were preserved in 70% ethanol (Sigma-Aldrich) for identification in laboratory. The identification using stereomicroscope of each macroinvertebrate was done up to family level using the morphological characters and keys described by Fiene-Severns *et al.* (2004) and Che Salmah *et al.* (2014) and samples were deposited in the Natural Resources Museum, Faculty of Earth Science, Universiti Malaysia Kelantan.

2.4 Data analysis

The following ecological indices were determined to summarize the data on benthic macroinvertebrate: Shannon Diversity Index (1963), Margalef Index (1958) for richness, Hill Index (1973) for evenness, and Simpson Index (1949) for taxa dominance. Biotic indices such as EPT Index are based on Wallace *et al.* (1996) and Biological Monitoring Working Party (BMWP; Tasneem & Abbasi, 2012).

3. Results and Discussion

The *in situ* parameters collected at each sampling station along Sungai Asah are summarised in Table 3. The physico-chemical water quality assessment at Sungai Asah showed that the minimum pH of the river was 6.03 and the maximum recorded was 6.98. The surface water dissolved oxygen content in the river ranged from 6.22 mg/L to 8.19 mg/L, whereas the temperature range recorded was from 25.00 °C to 26.91 °C. Salinity and conductivity along the Sungai Asah were constant across the three sampling stations at 0.02 PSU and 0.04 mS/cm, respectively. Turbidity of the river was recorded in the range from 1.72 to 2.28 NTU.

The sampled macroinvertebrates in Sungai Asah, Pulau Tioman represented 9 orders and 45 families with 329 individuals from the three sampling stations (Table 4). The most common family found in this study is Diptera contributing 99 individuals of the total macroinvertebrates, followed by Trichoptera (80 individuals), and the least found in Sungai Asah was the order Haplotaxida with only two individuals from the midstream station (Figure 2). Among the sampling sites, the midstream sampling station had the highest abundance of macroinvertebrate individuals (47.11 %) followed by the upstream station and the downstream station with the lowest abundance of macroinvertebrate (Table 4). Out of the 21 families that were collected at midstream station, Leptophlebiidae, Hydropsychidae, and Philopotamidae were present at high abundance (Table 4), which reflects the suitability of the river habitat to these macroinvertebrates. Chironomidae, Simulidae, Ceratopagonidae, Leptophlebiidae and Palaemonidae were found at all the three sampling stations, and Platysticidae, Stenopsychidae, Chloroperlidae, Peltoperlidae, Lumbricidae, Turridae, and Buccinidae families were found at only one of the sites sampled. The pollution intolerant taxa Ephemeroptera was found at all the sampling stations. However the macroinvertebrates from this order were abundant only upstream and midstream. Downstream the river, there was only one family of Ephemeroptera namely Leptophlebiidae with four individuals recorded. Plecoptera is another water pollution intolerant taxa, which was also present upstream and midstream, with only the family Perlidae (9 individuals) upstream but three families (Perlidae, Chloroperlidae, Peltoperlidae) with 6 individuals found midstream. All the three pollution intolerant macroinvertebrate taxa (Ephemerop-tera, Plecoptera and Trichoptera) with individuals numbering 84 were present midstream the Sungai Asah River.

Downstream a high density of larvae from Chironomidae (35) is an excellent bioindicator denoting poor quality of the water in Sungai Asah, as shown by a similar study done by Marques & Barbosa (2001) in Brazil. Hooper *et al.* (2003) suggested that high abundance of this particular macroinvertebrate in a water ecosystem could be due to its response to organic content build-up by anthropic actions, which ultimately reduces other macroinvertebrate organisms residing in the same water system. However, in Sungai Asah the organic content accumulation downstream could be mainly due to leaf litter from the trees forming a thick canopy and the riparian landscape upstream and midstream. A study done along River Ferreira, Portugal, to evaluate the decomposition of organic matter using benthic macroinvertebrate colonization, revealed high abundance of Chironomidae, especially filtering collectors identified to decompose leaves (Ribeiro & Vieira, 2013). The data from this current study in Pulau Tioman also corroborate others done in the Canadian Lake

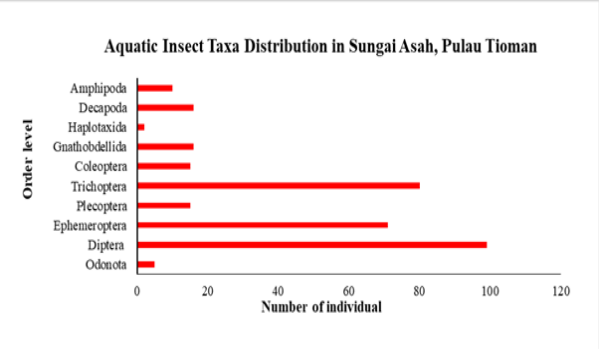

Figure 2. Abundance by taxa sampled in Sungai Asah, PulauTioman.

Table 3. Physicochemical water quality data collected at the three sampling stations on Sungai Asah, Pulau Tioman, Johor

Sampling Station	pH	Temperature (°C)	Salinity (PSU)	Conductivity (mS/cm)	Dissolved Oxygen		Total Dissolved Solid (mg/L)	Turbidity (NTU)
					(%)	(mg/L)		
1A	6.03	25.00	0.02	0.04	100.33	8.19	0.03	2.28
1B	6.24	25.69	0.02	0.04	93.03	7.57	0.03	2.14
2A	6.41	26.54	0.02	0.04	77.87	6.22	0.03	1.72
2B	6.96	26.06	0.02	0.04	90.70	7.34	0.03	1.68
3	6.78	26.91	0.02	0.04	102.20	8.11	0.03	1.94
Minimum	6.03	25.00	0.02	0.04	77.87	6.22	0.03	1.72
Maxsimum	6.96	26.91	0.02	0.04	102.20	8.19	0.03	2.28
Average	6.49	26.04	0.02	0.04	92.83	7.49	0.03	1.95

Table 4. Abundance and richness of aquatic insects at the three sampling points along Sungai Asah, Pulau Tioman.

Order	Family (Subfamily)	No of Individuals		
		Upstream	Midstream	Downstream
Odonata	Platysticidae	0	5	0
Diptera	Chironomidae(Chironominae)	17	7	35
	Tipulidae	0	1	0
	Simulidae	4	1	2
	Chironomidae(Tanypodinae)	13	14	0
	Ceratopagonidae	1	2	2
Ephemeroptera	Heptageniidae	7	9	0
	Leptophlebiidae	18	28	4
	Caenidae	5	0	0
Trichoptera	Polycentropodidae	2	3	0
	Hydropsychidae	23	20	0
	Philopotamidae	13	18	0
	Stenopsychidae	1	0	0
Plecoptera	Perlidae	9	2	0
	Chloroperlidae	0	3	0
	Peltoperlidae	0	1	0
Coleoptera	Unknown	6	8	0
	Unknown	0	1	0
Haplotaxida	Naididae	0	16	0
	Lumbricidae	0	2	0
Decapoda	Palaemonidae	1	13	2
Amphipoda	Gammaridae	0	0	5
Unranked order	Turridae	0	0	1
	Buccinidae	0	0	2
	Snail	0	0	1
Tricladida	Dugesiidae	0	1	0
Total Individuals	329	120	155	54
Percentage Abundance (%)	100	36.47	47.11	16.41
Number of Taxa	45	14	21	10

(Pope *et al.*, 1999) and in the Brazilian shallow lake by Goncalves *et al.* (2000), which suggest chironomids may use leaf litter as an alternative energy source supplementing algae and detritus. A further contributing factor to organic matter accumulation in Asah waterfall as suggested by Hooper *et al.* (2003) could be the human activity along the stream. Asah waterfall is known as the main attraction of this river and is situated 200 m upstream of the downstream station. Much of the recreational activity involves bathing using detergents containing organic substances that flowing to and amass at the downstream station. These factors contributed to the organic matter accumulation downstream in Sungai Asah, which eventually influences the BMWP score shown in Table 5.

Table 5. Biotic and ecology indices for the three sampling points along Sungai Asah, Pulau Tioman.

Index\Sampling Point	Upstream	Midstream	Downstream
Shannon-Wiener Index	2.53	2.75	1.38
Hill Index	0.89	0.84	0.56
Margalef Index	4.64	4.96	2.51
Simpson Index	0.11	0.09	0.43
EPT Index Score	2.23	2.8	0.1
BMWP score	58	78	29

Table 5 shows the taxonomic diversity, richness, dominance, evenness, and tolerance indices for aquatic macro-invertebrates at Sungai Asah, together with the two biotic indices BMWP (Tasneem & Abbasi, 2012) and EPT (Wallace *et al.*, 1996). The BMWP score upstream was 58 which is categorised as moderate water quality, whereas the BMWP score midstream was 78 which is regarded good, based on Mason (2002). Downstream in the Sungai Asah, the BMWP score recorded was 29 which is categorised as poor. On the other hand, the Ephemeroptera, Plecoptera, and Trichoptera (EPT) Index score upstream in Sungai Asah was 2.23, which falls into the poor category; and the findings were similar at both midstream and downstream samplings stations in the river, with indices 2.8 and 0.1 respectively, so that the EPT index at all the three locations falls in the poor category. The BMWP score upstream and downstream of Sungai Asah is in line with the EPT Index, but not midstream. For midstream samples the BMWP score indicates the area was not impacted by pollution, while the EPT index was Poor at 2.8, which could be due to the recreational human activities, such as swimming and bathing that were observed throughout the sampling duration. There are also very low numbers of aquatic macroinvertebrates from Odonata recorded in Sungai Asah as very few adult Odonata were spotted around this river. The relatively low abundance of its larvae in this stream could be due to a few factors. Odonata are reported by Che Salmah *et al.* (2014) as organisms that prefer pristine, undisturbed and

lowland streams, which could also indicate Sungai Asah was disturbed and impacted by human recreational activities, or in other words it is unhealthy. The visual observations affirm the index for Shannon-Wiener diversity; the index for Sungai Asah is between 1.38 and 2.75, which indicates it as a moderately polluted river (Mason, 2002). However, the visual observations contradict the report published by Kalkman (2014), which described twelve species of dragonflies in Pulau Tioman. Hence, future studies should include comparison of the abundance of Odonata in Sungai Asah with other rivers in Pulau Tioman, to confirm effects of human recreational activities on Odonata larval abundance. In Pulau Tioman island there are nine rivers functioning as important water and food sources for wildlife. The maintenance of river water quality is thus essential, since it largely contributes to the biodiversity conservation.

4. Conclusions

Overall, the quality of Sungai Asah could be considered partially polluted and the ecosystem is not healthy as shown by the diversity, abundance and biological indices of aquatic macroinvertebrates. BMWP score and EPT index both indicate that the water quality is impacted by human activities upstream and midstream of the river. The highest diversity and richness of macroinvertebrate was midstream in Sungai Asah and the lowest was downstream. Diptera were recorded as the most abundant in Sungai Asah (30.1 %) followed by Trichoptera (24.3 %) that were found mainly downstream and upstream. As one of the most frequented rivers for its waterfall in Pulau Tioman, Sungai Asah needs to be restored and monitored continuously to preserve this natural water source on the island.

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