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Preliminary Study on Abundance of Aquatic Insects in Sungai Sat, Taman Negara Pahang, Malaysia

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ABSTRACT. The abundance of aquatic insects has been studied in seven (7) points at Sungai Sat, Pahang, Malaysia, specifically in Orang Asli settlements along with Sungai Sat. The focuses are to identify the aquatic insect families, to compare the abundance of aquatic insects in seven sampling areas and to investigate the effect of physical factors (water temperature, water depth, and water velocity) and chemical factors (pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD)) of streams on the abundance of aquatic insects. The samples were collected by using kicking sampling techniques using an aquatic net for two days. Physicochemical parameters have been measured *in situ* and recorded. Pearson Correlation analysis has been used to measure the association between physicochemical parameters and the abundance of aquatic insect communities. A total of 731 individuals were classified into 7 orders, and 19 families of aquatic insects were identified. The largest percentage of samples collected is from the order Ephemeroptera 49.5%, and the least is Blattodea 0.1%. The aquatic insects collected from Tanjung Sami have the highest abundance of 170 individuals from 5 orders and 8 families. Tanjung Sami has a moderate stream flow (0.6 m/s) with a water temperature of 27.21ºC, 0.8 m depth, pH value of 8.08, DO level of 91.8%, BOD level of 6 mg/L, and COD level of 34 mg/L. The results reveal that the abundance of aquatic insects is high in moderate water temperature, deeper water, low water velocity, neutral range of water pH value, optimum dissolved oxygen (DO) level, and clean river.

Keywords: Aquatic insects, Physicochemical parameters, River, Sungai Sat

INTRODUCTION

Aquatic insects spend most of their life cycle in water, living under or on the water surface. Physical and chemical parameters such as water depth, water temperature, water velocity, pH and dissolved oxygen are often used in studying the diversity of aquatic insects. Insects entirely have terrestrial life cycles; however, they still enter the water to feed. The warm, wet climate of the Malaysia region is ideal for the life cycles of many aquatic insects, which are usually dependent on moist habitats. The presence of a wide variety of environments, particularly in tropical rainforests, provides an enormous number of ecological niches. Unfortunately, habitat destruction is causing the extinction of many aquatic insects (Yule and Yong, 2004). The pH, richness of nutrients, temperature, the concentration of oxygen, predators and quality of water are among the factors that contribute to the population habitat of the aquatic insects.

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As aerobic organisms, all insects must obtain sufficient oxygen to carry out their metabolic machinery (Thorp and Covich, 2009). This shows a particular challenge for aquatic insects because water, even when saturated, contains much less oxygen than terrestrial environments. Dissolved oxygen plays an important role in affecting aquatic invertebrates' abundance and diversity. Therefore, many forms of lentic larvae can supplement atmospheric oxygen with dissolved oxygen. The concentration of oxygen levels below 2 mg/L may reduce the fitness and chances of survival for many aquatic insects. For instance, Caddisfly larvae are especially vulnerable to decreased oxygen levels because their locomotion is restricted (Thorp and Covich, 1991). The other factor is pH, which is a measure of the intensity of acidity or alkalinity and the concentration of hydrogen ions in water. Ngodhe et al. (2014) indicated that the pH of water affects the normal physiological functions of aquatic organisms, including the exchange of ions with water and respiration. Such important physiological processes operate normally in most aquatic under a relatively wide pH range, for example, 6-9 pH units.

Any changes in water quality due to the physical and chemical environment can affect the aquatic insect's assemblages or richness. The water quality of a waterfall or river can be determined by carrying out a study on aquatic insect assemblages and richness to examine the species-habitat relationship. Aquatic insects have been widely used as indicators for monitoring river quality (Yoshimura, 2012) due to their continuous response to a variety of perturbations, present in a wide array of aquatic habitats, relatively easy to sample and process and standardized methods of collection and analysis have been greatly progressed (Al-Shahmi et al., 2011). The degree of environmental impact can be determined using the data provided by these indicator organisms. Indicator organisms refer to those taxa known to be sensitive to environmental changes.

The objectives of this research are to study the composition of aquatic insects' families from seven points at Sungai Sat, to compare the abundance of aquatic insects in those seven sampling areas and to investigate the influence of physicochemical factors (water temperature, water velocity, depth of water, pH, COD, BOD and dissolved oxygen) on the abundance of aquatic insects. Any changes in water quality due to chemical and physical environment can affect the aquatic insect's assemblages or richness.

METHODOLOGY

Sampling of the aquatic insect

The study was conducted at Sungai Sat, Pahang, Malaysia, at latitudes (3° 31' 6" N) and longitudes (102° 19' 28" E) in the northeastern coastal region of Peninsular Malaysia. Sungai Sat is a stream in Pahang with an elevation of 126 meters above sea level and is situated north of Kampung Murai, north of Sungai Batu Kaloi. The mouth of the river is narrow, offering shallow rapids and riffles upstream.

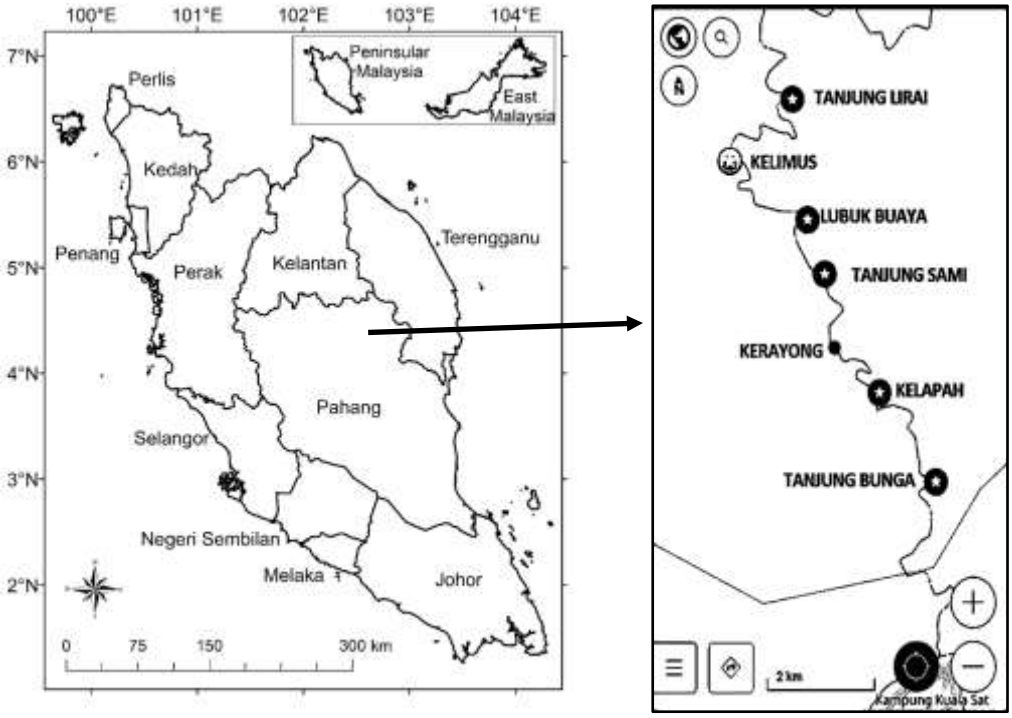

Figure 1. Sample locations at Sungai Sat

Seven points were selected for the sample collection in the research field, including Tanjung Lira, Kelimus, Lubuk Buaya, Tanjung Sami, Kerayong, Kelapa, and Tanjung Bunga, as shown in Figure 1 as there are Orang Asli settlements along with Sungai Sat. The water flows upstream of the river, Tanjung Liral, to the downstream, which is Tanjung Bunga. Water samples were taken from seven (7) points for 2 days from 6th September 2020 until 7th September 2020. All measurements were performed in triplicate, and the findings were expressed as average. These rivers have different water temperatures, water velocity, depth of water, pH value and amount of dissolved oxygen. The aquatic insects were sampled at riffle habitats using the kick sampling technique, aquatic D-net.

Identification of aquatic insects collected

In the laboratory, the aquatic insects were sorted on a tray and identified to the family level using taxonomic keys. Small aquatic insects were sorted using a dissecting microscope, while the larger ones were identified using the naked eye. The sorted specimens are kept in properly labelled universal bottles containing 70% ethanol.

Physicochemical parameters of rivers

Physical parameters such as water velocity, water temperature, and water depth, together with chemical parameters, which are pH value, dissolved oxygen level, COD and BOD level, have been measured in situ and recorded.

Statistical analysis

Pearson Correlation analysis has been used to measure the association between physicochemical parameters and the

abundance of aquatic insect communities.

RESULTS AND DISCUSSION

Table 1 shows the total number of aquatic insects collected in seven sampling sites of Sungai Sat, Pahang.

Table 1. Numbers of aquatic insects collected in seven sampling sites of Sungai Sat, Pahang

Order	Family	Abundance of Aquatic Insects							Total
		Tanjung Liral	Kelimus	Lubuk Buaya	Tanjung Sami	Kerayong	Kelapah	Tanjung Bunga	
Ephemeroptera	Baetidae	27	0	13	25	20	15	62	162
	Heptageniidae	48	2	15	32	25	3	47	172
	Tricorythidae	0	0	5	0	0	0	10	15
	Polymitarcyidae	1	1	3	0	7	0	0	12
Hemiptera	Gerridae	15	44	10	31	9	2	3	114
	Veliidae	2	4	0	0	0	4	2	12
	Naucoridae	2	1	2	0	0	4	2	11
	Hydrometridae	0	0	0	0	1	0	0	1
	Belostomatidae	1	0	4	0	0	0	0	5
Plecoptera	Perlidae	17	0	5	15	7	8	9	61
Odonata	Libellulidae	3	0	2	9	7	2	0	23
	Euphaeidae	3	0	0	3	2	1	0	9
	Gomphidae	4	1	1	0	0	2	1	9
Coleoptera	Tenebrionidae	3	0	0	0	0	2	1	6
	Hydrophilidae	1	0	1	0	0	0	0	2
	Dytiscidae	1	1	0	0	0	9	0	11
Trichoptera	Philopotamidae	3	1	4	22	1	4	5	40
	Polycentropodidae	2	0	1	33	3	6	20	65
Blattodea	Ectobiidae	0	0	0	0	0	0	1	1
Total No. of Individual		133	55	66	170	82	62	163	731
Total No. of Order		6	5	6	5	5	6	7	7
Total No. of Family		16	8	13	8	10	13	12	19

The total number of individuals in all sampling areas is 731, with the highest number of 170 individuals from Tanjung Sami and 55 individuals from Kelimus, which is the least (see Table 1). The largest percentage of samples collected is from the order Ephemeroptera 49.5% (361 individuals), followed by Hemiptera 19.6% (143), Trichoptera 14.4% (105), Plecoptera 8.4% (61), Odonata 5.6% (41), Coleoptera 2.6% (19) and Blattodea 0.1% (1). Figures of some aquatic insects' orders are shown in Figures 2 to 5.

Figure 2. Order Ephemeroptera

Figure 3. Order Trichoptera

Figure 4. Order Plecoptera

Figure 5. Order Odonata

Three physical factors that were recorded were water temperature, water velocity, and depth of water (see Table 2). Meanwhile, the other four chemical factors recorded are pH value, level of dissolved oxygen (DO), biochemical oxygen demand (BOD), and chemical oxygen demand (COD).

Table 2. The average value of physicochemical parameters in four rivers and the Pearson correlation value

Parameters	unit	Points							Pearson's Correlation value, r
		Tanjung Liral	Kelimus	Lubuk Buaya	Tanjung Sami	Kerayong	Kelapah	Tanjung Bunga	
Water Depth	m	1.3	0.7	0.5	0.8	0.8	0.1	1.1	0.6704
Water Flow	m/s	0.2	0.5	0.3	0.6	0.6	0.6	0.7	0.2006
pH		8.23	10.85	9.62	8.08	9.9	9.59	9.74	-0.69
Dissolve Oxygen	%	97.7	98.1	97.7	91.8	93.6	97.2	92.5	-0.7285
Temperature	˚C	27.37	26.57	28.08	27.21	28.71	28.71	28.58	-0.0564
BOD_5	mg/L	5	4	6	6	5	5	5	0.3727
COD	mg/L	31	28	33	34	28	28	25	0.1165

Abundance of aquatic insects

In this study, Ephemeroptera, Plecoptera, and Trichoptera (EPT) were significantly abundant in all locations, especially at upstream locations (i.e., Tanjung Liral, Kelimus, Lubuk Buaya, and Tanjung Sami). EPT communities

were composed of a large proportion of 72.09% of the total individuals sampled. Members of EPT are often used as indicators of good water quality (Crisci-Bispo et al., 2007; Vian et al., 2018). The presence of a high abundance of EPT communities signifies a high stream quality as EPT communities are prevalent in undisturbed streams, as stated by Vian et al. (2018), Armitage et al. (1983), Jumaat and Hamid (2021), Abdul (2016), and Hamid and Rawi (2017), and are considered sensitive to water pollutants (Keci et al., 2012). Therefore, Sungai Sat Taman Negara can be customarily considered clean. The EPT index showed that all seven locations have excellent water quality except Kelimus, which recorded a poor EPT index, 4. Tanjung Bunga recorded higher EPT taxa richness, 153. The high EPT taxa showed that the streams were well-oxygenated and clean since the EPT taxa are highly sensitive to pollution (Azrina et al., 2006).

One family in the order of Plecoptera was recorded in this study, which is similarly low numbers and diversity of Plecoptera are reported in the previous study (Hamid and Rawi, 2011; Prommi and Payakka, 2015). According to Hamid and Rawi (2011), the diversity of Plecoptera families is generally low in tropical Asian streams. The unfavourable conditions of Sungai Sat, such as the relatively high surface water temperature for Plecoptera growth and reproduction as they prefer cooler, more northern latitudes (Prommi and Payakka, 2015; Sivec and Yule, 2004), might explain the presence of low density of Plecoptera in Sungai Sat. The water quality measurements of Tanjung Liral, Kelimus, Lubuk Buaya, Tanjung Sami, Kerayong, Kelapah and Tanjung Bunga are presented in Table 2.

Temperature

The measurement of temperature is the most common physical assessment of water quality. Both chemical and biological characteristics of surface water can be impacted by temperature (Prommi and Payakka, 2015), influencing the aquatic insects' abundance. There was only a slight temperature variation in Sungai Sat, Taman Negara watershed in the present study. Kelapah and Karayong showed the highest reading (28.71°C) for the water temperature, while Kelimus had the lowest readings, 26.57°C. There was no correlation between water temperature and the abundance of aquatic insects ($r = -0.0564$). The warmer temperature can influence the increase in the metabolism of aquatic insects. According to Hasmi et al. (2021), the warmer temperature can lead to insects' earlier emergence. For example, the egg may hatch when the temperature reaches a certain level. If temperatures are outside their optimal range for a prolonged period, organisms can become stressed and die. Depth and velocity are some of the important factors in the model for taxonomic richness and abundance of invertebrates. The velocity of a river refers to the rate of water movement, which is mainly measured in meters per second. The water velocities, however are not the same in different depths of the river. Stream velocity is greatest below the water surface and is slowest along the benthos section due to friction with the river substrate (Michell and Stapp, 2000).

Water velocity

Water velocity and sediment type influence taxa distribution, abundance, richness, and diversity. In this study, the water velocity was low and positively correlated with aquatic insect abundance, $r= 0.2006$. Lower abundances were recorded from Kelimus, Lubuk Buaya, and Kelapah, attributed to the higher water velocities and lower total

suspended solids. Rock, rubble, and sand offer different niches for aquatic insects in the fast-flowing stream of Sungai Sat Taman Negara. Leaf litter, algae, and aquatic plants provide suitable habitats for macroinvertebrates in slow-moving streams. Macroinvertebrates have developed adaptations to live in these environments. Moreover, aquatic invertebrates rely on the current of the stream to bring nutrients down from the upstream. The sudden increase in water flow causes streambed translocation with the consequent removal of insects and reduced local abundance (Hasmi et al., 2021).

Water depth

Sungai Sat depth varied between 0.1 and 1.3 m, with higher values in Tanjung Liral. In Lake Moaralmsee, Austria, aquatic mite and insect distributions were strongly related to water depth, which mainly determines in-lake variability in temperature, substrate, and water chemistry (Luoto, 2012). This statement supports the result where water depth was high and positively correlated with the number of aquatic insects (r=0.6704). For example, the highly abundant Perlidae in Tanjung Liral and Baetidae in Tanjung Bunga might be influenced by the depth and substrates of the stream. In general, Tanjung Liral is deeper, with 1.3 m. Perlidae naiads require a high concentration of dissolved oxygen, relatively clean water, and restricted to lotic water or rapidly moving freshwater. Their presence is usually indicated in clean water quality (Sivec and Yule, 2004). Thus, they are considered as good bioindicators for good quality water.

The abundance of baetidae in Tanjung Bunga and Tanjung Liral might be due to the suitable substrates found in Tanjung Bunga, full of pebbles and gravel. 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 particular morphological and behavioural adaptations favour their distribution and domination. The naiads are sprawlers along the bottom and climbers among debris and vegetation. Baetidae use their long, laterally extended legs to support the body on or among a matrix, usually detritus and macrophytes (Minshall, 1984).

Tanjung Bunga streams were quite fast-flowing. Thus, it had a relatively high abundance of Heptageniidae. The fast-flowing stream supported high numbers of the 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 an indicator species for a clean water ecosystem and is most sensitive to environmental disturbance as they are strictly inhabitants and reach their development in clean, fast-flowing, and running water habitats (Merritt and Cummins, 1996).

Dissolved oxygen (DO) and pH

Determining dissolved oxygen (DO) is important in biological assessment since it influences biological and chemical processes, which is vital for aquatic insect communities (Hasmi et al., 2021). In this study, the DO concentration was highest in the upstream compared to the downstream. This could be due to temperature variation from upstream (27.37^{o}C) and downstream (28.58 ^{o}C) - an increase in temperature resulting in the decrease of dissolved oxygen. Low

DO concentrations were registered in Tanjung Sami and Tanjung Bunga, attributed to organic matter decomposition. There was a strong, negatively correlated correlation between DO and the abundance of aquatic insects, r = -0.7285. The insects prefer to live in higher dissolved oxygen concentrations since cold-water mayflies and stoneflies cannot tolerate dissolved oxygen concentrations much below 5 mg/L (Gauffin et al., 1974).

Stoyanova et al. (2014) found that usually gill-breathing aquatic insects (mayflies, caddisflies, and stoneflies) are affected by conditions that reduce the water's dissolved oxygen, like pollution. Therefore, the presence of mayflies, caddisflies, and stoneflies indicates high stream quality. Usually, the concentration of DO is higher at the high current speed of the water. Meanwhile, lower concentrations of DO occurred during slow current speed at the river, which contains muddy substrate and organic matter (Armitage et al., 1983). Azmi et al. (2016) found that more abundant and diverse aquatic insects in Tasik Kenyir were found in high DO and water velocity.

Sungai Sat showed the water was slightly alkaline (pH= 8.08 to 10.85). The pH level was negatively correlated to the number of aquatic insect orders (r = -0.690). Scheibler et al. (2014) stated that a pH range of 6.5 to 8.0 provides adequate protection for the life of freshwater fish and bottom-dwelling macroinvertebrates. Thus, Sungai Sat is still in the acceptable pH range for aquatic life, in which all freshwater aquatic life is unharmed and no harmful impacts occur. This result indicated that, as pH and dissolved oxygen increased, the abundance of aquatic insects declined.

BOD and COD

Sungai Sat showed that BOD varied between 4 and 6 mg/l and COD between 25 and 34 mg/L. There was a low, positively correlated between BOD and the abundance of aquatic insects, r = 0.3727. There was a low, positively correlated between COD and the abundance of aquatic insects, r = 0.1165. The results reveal that the abundance of aquatic insects is high in moderate water temperature, deeper water, low water velocity, neutral range of water pH value, optimum dissolved oxygen (DO) level, and clean river.

CONCLUSION

Based on this study, it can be concluded that the physical and chemical parameters of seven locations of Sungai Sat, which are water temperature, water velocity, water depth, dissolved oxygen level, pH value, COD and BOD, strongly influence the abundance of aquatic insects. Thus, we can develop an alternative bioindicator for water conditions by using aquatic insects. Almost all ecosystems, especially freshwater ecosystems, have an abundance of insects which can be used as the measurement of environmental change. By studying their diversity, population, behaviour and taxonomy of species, an estimation of the current degradation rate and future consequences can be assumed.

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AUTHOR CONTRIBUTIONS

All authors contributed to the studies from concept to publication. Material preparation, data collection, and analysis were performed by Nur Atirah Hasmi, Safari Zainal and Rosmawati Abdul Aziz. The first draft of the manuscript was written by Nur Atirah Hasmi and Nurul Izza Taib, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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DATA AVAILABILITY

Not applicable, all data, pictures and figures are taken by the author and research team.

COMPETING INTEREST

Not applicable - The authors declare that there are no competing interests.

COMPLIANCE WITH ETHICAL STANDARDS

Not applicable, no tests were conducted on humans, animals, and plants.

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