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Biodiversity of benthic macroinvertebrates in Sungai Kisap, Langkawi, Kedah, Malaysia

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Abstract

A study on macroinvertebrate diversity was conducted in Sungai Kisap, Langkawi, Kedah. Five stations were selected with a distance of approximately 500 metres apart with three replications of benthos and two replications of water sample. The results classified Sungai Kisap in Class I, which indicates very good water quality based on WQI recommended by the Department of Environment. A total of 2 phyla, 3 classes, 8 orders, 29 families, and 3564 individuals were successfully sampled and recorded. The presence of Hydropsychidae, Baetidae, and Chironomidae with a high abundance of the families show the potential to be used as biological indicators of a clean ecosystem. The analysis showed that the average value of Shannon Diversity Index, *H'* (1.28), Pielou Evenness Index, *J'* (0.45), and Margaleff Richness Index, D_{MG} (2.80) indicates that Sungai Kisap is in moderate condition and the distribution of macroinvertebrates is uniform between stations. The correlation test showed that the WQI has a strong relationship with the diversity indices involved. BMWP, ASPT, and FBI showed that Sungai Kisap has good water quality.

1. INTRODUCTION

Clean freshwater is one of the main and most important sources of living organisms (Kenney et al., 2009). Apart from water resources, freshwater including streams play an important role as habitats, food sources, transportation, energy and recreational resources for life. Streams are also a lotic habitat that is flowing water environment (Ahmad and Asmida, 2008).

Benthic macroinvertebrates live at the bottom of the freshwater habitat substrates such as streams for at least part of their life cycle and their sizes range between 200 to 500 µm (Rosenberg & Resh, 1993). Benthic macroinvertebrate is a good bio-indicator based on the biological monitoring agent specified by Hellawell (1986), which is easy to identify, easy to sample, and having a cosmopolitan distribution.

Sungai Kisap is a main stream of Langkawi, Kedah. According to a report released by Ministry of Natural Resources and Environment, which was also reported in Sinar Harian on July 21, 2011, Langkawi's community worry on water quality deterioration of Sungai Kisap because of human activity and garbage disposal.

The study of benthic macroinvertebrates diversity in Sungai Kisap, Langkawi, Kedah was carried out as no previous studies have been conducted in Sungai Kisap. Hence, this study aims to determine the water quality based on the water quality index (WQI) for Sungai Kisap. Also, this study determines the diversity and abundance of benthic macroinvertebrates. In addition, analysis from this study recognised certain families of macroinvertebrates as a bio-indicator agent.

2. MATERIALS AND METHODS

2.1. Study sites

Sampling was conducted on July 2011 at Sungai Kisap, Langkawi, in Kedah. Sungai Kisap is located at North 03056'19.8", East 102001'42.6" (Figure 1). Five sampling stations were selected starting from upstream to downstream and the distance between stations is 500 metres. Three replicates for both water quality sample and benthic macroinvertebrates were collected for each sampling station.

2.2. Water quality parameters

There are six main parameters which are emphasized in this study introduced by the Department of Environment Malaysia namely pH, dissolved oxygen, biological oxygen demand (BOD_5), chemical oxygen demand (COD), ammoniacal nitrogen (NH_3-N) and total suspended solid (TSS). These parameters are used in calculation of Water Quality Index (WQI). In situ parameters were taken by using YSI Pro Series multiprobe parameter reader. The parameters are temperature, pH, dissolved oxygen and conductivity. Ex situ parameters such as biological oxygen demand (BOD_5), chemical oxygen demand (COD), ammoniacal nitrogen (NH_3-N) and total suspended solid (TSS) are done in the laboratory.

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All samples were preserved with ice (<4 °C) before being taken to laboratory for analysis. COD was measured using reactor digestion method, while ammoniacal nitrogen was measured using Nessler's Method (APHA, 1992). TSS analysis was done using gravimetric method (HACH, 2007) and 1 Litre of water was used since the water was clear.

2.3. Benthic macroinvertebrates

Benthic macroinvertebrates were sampled after the sampling of water quality. A Surber's net was placed in the water facing the water flow and the area inside the quadrate was disturbed for 3-5 minutes. The samplings of benthic macroinvertebrates at each of the five stations were done in triplicate. Samples trapped in the net were transferred to a tray for cleaning. Samples then were filtered to remove impurities and transferred into a labelled plastic sample containing 70% ethanol. In the laboratory, the samples were sorted from substrates and debris using forceps and white background tray. Benthic macroinvertebrates were then transferred into the bottles containing 70% ethanol. The identification of benthic macroinvertebrates was done under stereo microscope and using the reference books such as Merritt and Cummins (1996), Throp & Covich (1991), Yule & Yong (2004) and Sangpradub & Boonsoong (2006).

Figure 1: Map of Pulau Langkawi, Location of Sungai Kisap

2.4. Water quality index and ecology indices

The six parameters of water quality were analysed based on the Water Quality Index used by the Department of Environment (2010). The ecological data analyses performed were based on two types of indices, biotic indices and diversity indices. The biotic indices are Biological Monitoring Working Party (BMWP) (Ahmad et al., 2015), Average Score Per Taxon Index (ASPT) (Ahmad et al., 2015), Family Biotic Index (FBI) (Zimmerman, 1993) and Ephemeroptera, Plecoptera and Trichoptera Index (EPT) (Mandaville, 2002). For the diversity indices, Shannon Diversity Index (*H'*), Pielou Evenness Index (*J'*), and Margaleff Richness Index (D_{MG}) were used. Correlations between WQI and ecology indices were carried out to examine the relationship between both types of data.

3. RESULTS AND DISCUSSION

3.1. Water quality

Table 1 shows the average value of physico-chemical parameters for Sungai Kisap, Langkawi. The average values of each parameter are dissolved oxygen (DO) 7.0 ± 0.32 mg/L, pH 6.96 ± 0.03, temperature 27.34 ± 0.11˚C, conductivity 47.34 ± 0.68 µS/cm, flow 2.08 ± 0.69 (m/s), and total suspended solid (TSS) 1.05 ± 0.27 mg/L.

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Based on six physico-chemical parameter data for Water Quality Index, (BOD5, COD, pH, NH3N, TSS, and DO), one-way ANOVA test were conducted, and the results showed that all the data had no significant difference ($p < 0.05$). Table 2 shows WQI values by stations and results show that the five stations are in class I.

Table 1: Average value of physico-chemical parameters by stations of Sungai Kisap

Parameter	Station 1	Station 2	Station 3	Station 4	Station 5	Average Value
Temperature (˚C)	27.3 ± 0.00	27.3±0.06	27.2±0.00	27.5±0.12	27.4±0.00	27.34±0.11
Conductivity (µS/cm)	46.37 ±0.06	46.93±1.18	47.57±0.40	48.01±0.25	47.83±0.06	47.34±0.68
pH	6.93±0.01	6.97±0.04	6.96±0.18	6.94±0.03	7.00±0.03	6.96±0.03
Flow (m/s)	2.38±0.91	2.75±0.90	1.38±0.04	2.32±0.35	1.38±0.30	2.08±0.69
DO (mg/L)	7.04±0.08	7.25±0.04	6.65±0.28	6.71±1.16	7.37±0.02	7.0±0.32
TSS(mg/L)	1.4±0.20	0.97±0.85	0.7±0.66	1.23±0.47	0.97±0.12	1.05±0.27
BOD_5(mg/L)	2.47±0.06	2.29±0.23	2.21±0.66	2.55±0.40	2.34±0.26	2.37±0.14
COD(mg/L)	0.01± 0.01	0.09±0.16	0.19±0.27	0.02±0.04	0.28±0.14	0.12±0.10
NH_3N(mg/L)	0.05±0.05	0.04±0.05	0.04±0.03	0.06±0.02	0.03±0.02	0.04±0.01

Table 2: Water Quality Index (WQI) by stations

Station	SIDO	SIBOD	SICOD	SIAN	SISS	SIpH	WQI	Class
1	96	90	99	96	97	99	96	I
2	98	91	99	96	97	100	96	I
3	92	91	99	97	97	100	95	I
4	93	90	99	95	97	100	95	I
5	100	91	99	97	97	99	97	I

3.2. Distribution of benthic macroinvertebrates

The total number of individuals sampled was 3564 individuals from phylum Arthropoda and Mollusca. In general, there are four dominating orders which are Trichoptera, Diptera, Ephemeroptera, and Coleoptera from Class Insecta of phylum Arthropoda. Table 3 shows Hydropsychidae family dominating 98 percent of overall sample. According to Albert et al., (2008) Hydropsychidae is a family of Trichoptera order that do not have any case and this family traps food by constructing nets. This family tend to inhabit moderate to fast flowing waters with stable substrata such as rocks, boulders, or submerged logs (Dean et al., 2004) like Sungai Kisap.

Next, Chironomidae is the second most represented family in the sample. Chironomidae is one of the important aquatic insects which have a high density and diversity (Merrit, 1984). Cranston (2004), mentioned that Chironomidae are extremely important ecologically due to their abundance and diversity and presence in lotic and lentic habitat. Although Chironomidae known as tolerant family (Ahmad et al., 2013), previous studies showed Chironomidae also recorded in Class 1 rivers (Ahmad et al., 1999, Azrina et al., 2006, Ahmad et al., 2013, Ahmad et al., 2015, Nurhafizah-Azwa & Ahmad, 2016, Siti Hafizah 2017). Three main genera dominating Chironomidae population in sample are *Microtendipase* spp., *Polypedilum* spp., and *Cricotopus* spp.. According to Nurcan (2010), though Chironomidae is a pollution resistant organism, these three genera are usually found in sandy substrate areas and are among the only genera that can only live in a clean area.

Table 3: Total number of benthic macroinvertebrates by stations

Famili	S1	S2	S3	S4	S5	Total
Palaemonidae	4	4	1	0	0	**9**
Atyidae	0	0	1	0	0	**1**
Astacidae	0	1	0	0	0	**1**
Dytiscidae	4	3	4	13	5	**29**
Hydrophilidae	2	6	0	1	0	**9**
Elmidae	32	44	7	9	5	**97**
Gyrinidae	0	0	1	3	5	**9**
Scirtidae	1	0	1	1	0	**3**
Chironomidae	251	73	32	53	86	**495**
Tipulidae	49	14	19	18	3	**103**
Baetidae	55	11	1	51	36	**154**
Ephemerellidae	4	0	1	1	0	**6**
Heptageniidae	9	0	1	1	0	**11**
Siphlonuridae	2	0	2	2	0	**6**
Leptophlebiidae	3	3	9	5	0	**20**
Pyralidae	9	8	6	4	0	**27**
Cossidae	0	0	0	1	0	**1**
Perlodidae	2	0	2	1	0	**5**
Pteronarcyidae	2	0	0	2	0	**4**
Perlidae	13	19	17	15	6	**70**
Hydropsychidae	576	412	464	741	162	**2355**
Leptoceridae	3	0	0	2	0	**5**
Philopotamatidae	1	0	0	2	0	**3**
Hydroptilidae	6	0	1	1	1	**9**
Phryganeidae	2	0	1	1	0	**4**
Psychomyiidae	3	3	2	1	0	**9**
Sericostomatidae	3	8	2	1	0	**14**
Lymnaeidae	16	50	9	14	14	**103**
Planorbidae	0	0	0	0	2	**2**
Total	**1052**	**659**	**584**	**944**	**325**	**3564**

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3.3. Relationship between water quality and benthic macroinvertebrates

Correlation test was conducted to analyse the relationship between benthic macroinvertebrates and water quality. Results show that Shannon diversity index has a positive and strong correlation with WQI ($r = 0.846$, $p = 0.07$). According to Ahmad et al, (2002), in general, most diversity indices will indicate changes in value based on WQI value changes. This is because theoretically, diversity index has a positive relationship with the water quality index (WQI).

Table 4: Value of WQI, diversity index and biotic index by stations.

Index	Station 1	Station 2	Station 3	Station 4	Station 5
WQI	96	96	95	95	97
	I	I	I	I	I
Shannon (*H'*)	1.49	1.45	1.00	1.01	1.44
	moderate	moderate	moderate	moderate	moderate
Pielou (*J*)	0.48	0.52	0.32	0.31	0.60
Margaleff (D_{Mg})	3.16	2.30	3.30	3.50	1.73
BMWP	153	101	141	150	63
	very good	very good	very good	very good	moderate
ASPT	6.40	6.30	6.40	6.00	5.70
	Clean	clean	clean	clean	Clean
FBI	4.89	4.59	4.13	4.20	5.13
	good	good	very good	very good	good
EPT	15	6	12	15	4
	Clean Water	Clean Water	Clean Water	Clean Water	Probable Moderate Pollution

Table 5: Value of diversity index without dominant family and WQI.

Indeks	Station 1	Station 2	Station 3	Station 4	Station 5
WQI	96	96	95	95	97
	I	I	I	I	I
Shannon (*H'*)	1.78	2.09	2.37	2.28	1.48
	moderate	moderate	moderate	moderate	moderate
Pielou (*J*)	0.58	0.77	0.79	0.72	0.64
Margaleff (D_{Mg})	3.41	2.54	4.18	4.33	1.77

Table 4 details the relationship between the water quality index, diversity index and ecological index. It explained that the ASPT, BMWP, FBI and EPT indices classify Sungai Kisap as clean based on how each index classification corresponds to the value obtained from WQI. Station 5 was located at downstreams and classified as moderately clean based on FBI and EPT index. The number of intolerant families reduced rapidly from station 4 to station 5 shows the impacts of anthropogenic activities. Wahizatul et al. (2011) mentioned that the number of individuals and families was different between the upstream and downstream stations especially for EPT's members which considered to be sensitive to environmental stress.

The use of the Shannon diversity index (*H'*) corresponds to a large sample population and random sampling method (Mason, 1996), however, the weakness of this index is the presence of domination in the sample. The presence of a dominant family in the sample completely obscured the entire sample in determining biological diversity (Magguran, 2005). This is proven by removing Hydropsychidae from the calculation of Shannon index. Table 5 showed a high increase in the value of Shannon index compared with Table 4, when the dominant family of samples (Hydropsychidae) was excluded and clearly indicated that Sungai Kisap classified in good quality ecologically. Despite excluding the dominant family, average value of Shannon index for Sungai Kisap is 2.00±0.37 (moderate). This is because, the calculation of the diversity index is only done up to the level of the family, resulting in the calculated value being lower than the actual estimated value if measured at the species level.

3.4. Potential use of benthic macroinvertebrates as biological indicators

Previous studies show that the benthic macroinvertebrate community changes correlate with water quality change (Hellawell, 1986; Mason, 1996; Ahmad et.al, 2002; Ahmad et.al, 1999). Therefore, benthic macroinvertebrate can be classified into certain groups according to their sensitivity and resistance towards different water quality levels.

The results from analysis showed that benthic macroinvertebrates such as Hydropsychidae (Trichoptera), and Chironomidae (Diptera) are able to act as biological indicators for clean ecosystems due to the presence of these families as well as the distribution.

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4. CONCLUSION

Based on the results of the study, it can be concluded that Sungai Kisap has good water quality and classify in Class I based on Malaysia Water Quality Index (WQI). Sungai Kisap also has a high diversity and abundance of benthic macroinvertebrates. Families such as Hydropsychidae (Trichoptera), and Chironomidae (Diptera) are able to serve as biological indicators for clean river ecosystems.

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