BIODIVERSITY OF BENTHIC MACROINVERTEBRATES IN AIR TERJUN LATA KINJANG, CHENDERIANG, PERAK, MALAYSIA.

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ABSTRACT

A study on benthic macroinvertebrate diversity was conducted in Air Terjun Lata Kinjang, Chenderiang, Perak, Malaysia. Five stations were selected with a distance of approximately 500 metre interval. Three replicates of benthic macroinvertebrates and water samples were taken from each station. Result indicates that Air Terjun Lata Kinjang is in class I condition based on Malaysian water quality index. A total of two phyla, three classes, eight orders, 30 families, and 1177 individuals were successfully identified. The average Shannon Diversity Index, (H') is 2.07, Pielou Evenness Index, (J') is 0.46, and Margaleff Richness Index, (D_{Mg}) is (3.08). These values describe Air Terjun Lata Kinjang as in good conditions but macroinvertebrates are not uniformly distributed between stations. Biological Monitoring Working Party (BMWP) and Family Biotic Index (FBI) score are 150 and 4.75, respectively which also explain this stream as having good water quality. The CCA test was conducted to show environmental factors towards benthic macroinvertebrate distribution. The presence of Baetidae with a high abundance of the families shows the potential to be used as biological indicators of a clean ecosystem.

Keywords: benthic macroinvertebrates, water quality, bio-indicator

ABSTRAK

Suatu kajian mengenai kepelbagaian makroinvertebrat bentik telah dijalankan di Air Terjun Lata Kinjang, Chenderiang, Perak. Lima stesen persampelan telah dipilih dengan jarak di antara stesen adalah 500 meter. Tiga replikasi sampel makroinvertebrat bentik dan sampel air diambil. Hasil mengklasifikasikan Air Terjun Lata Kinjang dalam Kelas I berdasarkan pengkelasan indeks kualiti air Malaysia (WQI). Dua filum, tiga kelas, lapan order, 30 famili dan 1177 individu telah dicamkan. Purata nilai Indeks Kepelbagaian Shannon, H' (2.07), Indeks Keseragaman Pielou, J' (0.46) dan Indeks Kekayaan Margalef, D_{Mg} (3.08) meletakkan Air Terjun Lata Kinjang dalam keadaan baik dan penyebarannya yang tidak seragam di antara stesen. BMWP (150) dan FBI (4.75) mengkelaskan sungai ini dalam keadaan baik. Ujian CCA yang dijalankan menunjukkan faktor persekitaran mempunyai impak terhadap sebaran makroinvertebrat bentik. Kehadiran Baetidae dengan kelimpahan tertinggi menunjukkan potensi tinggi sebagai penunjuk biologi bagi ekosistem bersih.

Kata kunci: Makroinvertebrat bentik, kualiti air, penunjuk biologi.

INTRODUCTION

Water quality monitoring consists of three different methods which are physical, chemical and biological to provide complete information to ensure the health of the freshwater ecosystem. Water quality monitoring based on the physical and chemical parameters only, is unable to illustrate the condition of the whole ecosystem (Nurhafizah & Ahmad 2015), especially on the biological effect influenced by water flow (Shuhaimi-Othman et al. 2010). Biological monitoring or biomonitoring is a biological response to changes in the environment due to anthropogenic causes using bio indicators (Ramakrishnan 2003). These methods that can demonstrates the integrity of the ecosystem and show the cumulative effects of physical, chemical, and biological stresses in an aquatic system (Uyanik et al. 2005).

Benthic macroinvertebrates are animals without backbones that are larger than ½ millimeter and live on rocks, logs, sediment, debris and aquatic plants in aquatic ecosystem (Aweng et al. 2012). Benthic macroinvertebrates are amongst the best biomonitoring agents because (a) they have large range of sensitive to any changes in their habitat (Aweng et al. 2010) as (b) sedentarily (Voshell 1997), (c) sensitive to trace different types of pollutions by many common species (Alvial et al. 2013), (d) able to illustrate pollution effects for extended period by long life cycles of the same species (Bonada et al. 2006). A healthy aquatic ecosystem supports high diversity of benthic macroinvertebrates which include the variety of pollution sensitive macroinvertebrates (Uyanik et al. 2005). The presence of high diversity of benthic macroinvertebrates provide good information about the health of a stream (Aweng et al. 2012).

However, research on benthic macroinvertebrates as biological indicators in Malaysia is still not comprehensive (Ahmad et al. 2015; Mustaqim-Alias 2013). Therefore, a study on benthic macroinvertebrates in Air Terjun Lata Kinjang, Chenderiang, Perak, Malaysia was conducted to estimate the distribution, diversity of benthic macroinvertebrates and to assess potential biological indicators.

MATERIALS AND METHOD

Sampling was conducted on 4th December 2015 at Air Terjun Lata Kinjang, Chenderiang, Perak, Malaysia (Figure 1). Five sampling stations were selected with 500 metres intervals. Three replicates of water and benthic macroinvertebrates samples were collected for each sampling station to represent the ecosystem.

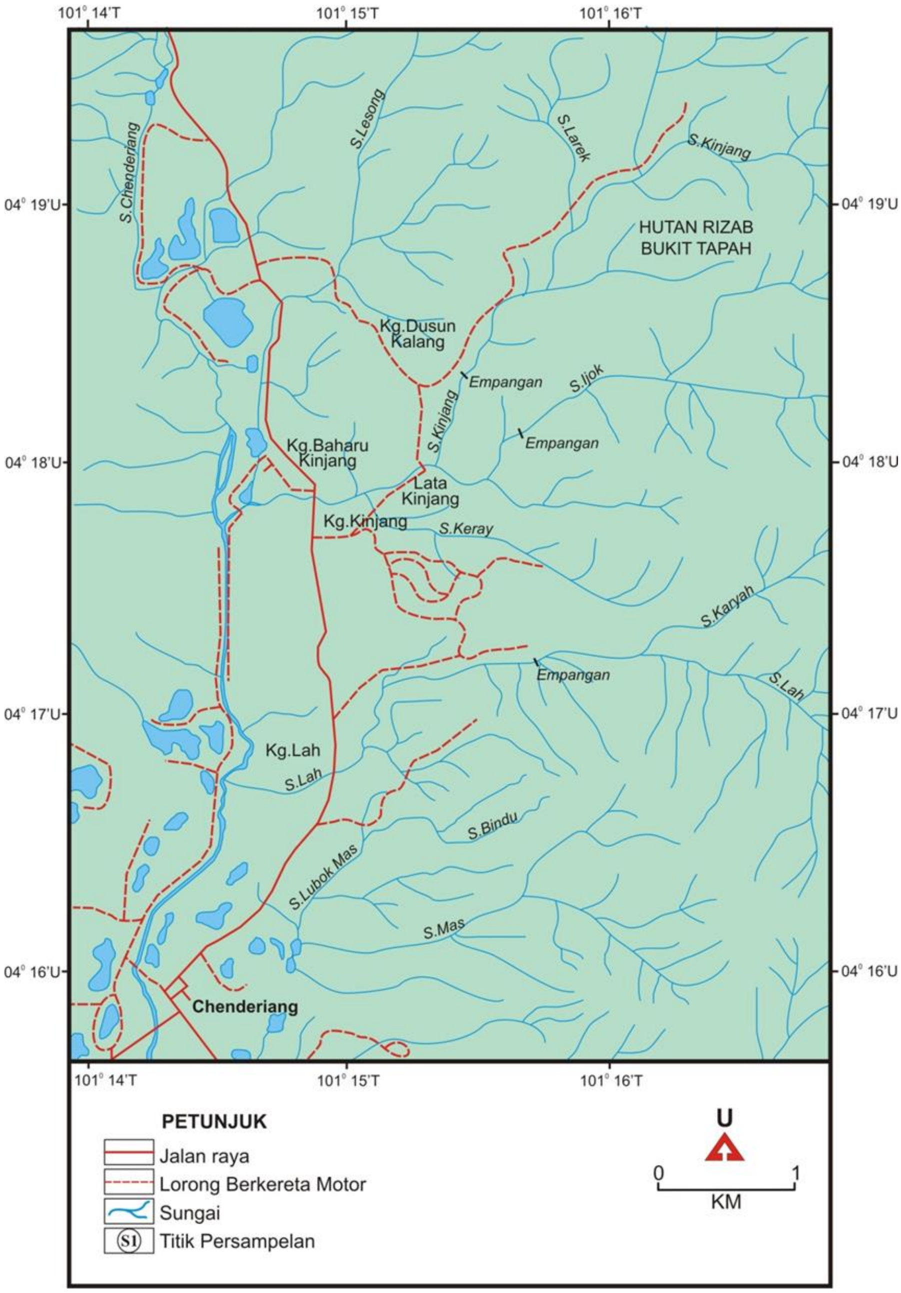


Figure 1 Map of Air Terjun Lata Kinjang, Chenderiang, Perak.

Water Quality Parameters

There are six parameters which were emphasized in this study 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 Malaysian Water Quality Index (WQI). The *in situ* measurements for water quality parameter namely temperature, pH, dissolved oxygen and conductivity were undertaken using YSI Pro Series multisensor probe. The biological oxygen demand (BOD_5), chemical oxygen demand (COD), ammoniacal nitrogen (NH_3-N) and total suspended solid (TSS) were analysed in the laboratory. All samples were preserved with ice (<4 °C) prior to analysis. The COD was measured using digestion method, and ammoniacal nitrogen was analysed using Nessler's Method (HACH 2007). The TSS was analysed using gravimetric method (APHA 1995).

Benthic Macroinvertebrates

A Surber net was used to sample invertebrates. Three replications of benthic macroinvertebrates were taken randomly for each of the stations. Samples were then 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 bottom tray. Collected invertebrates were then preserved in universal bottles containing 70% ethanol. The identification of benthic macroinvertebrates was done using Merritt and Cummins (1998), Throp & Covich (1991), Yule & Yong (1996) and Sangpradub & Boonsoong (2010).

Water Quality Index and Ecology Indices

The WQI index was calculated according to Department of Environment (2010) and the formulation is shown below.

WQI = 0.22(SIDO) + 0.19(SIBOD) + 0.16(SICOD) + 0.15(SIAN) + 0.16 (SITSS) + 0.12(SIpH)
SI = subindex

The ecological indices were performed were based on two types of indices, biotic indices and diversity indices. The biotic indices are Biological Monitoring Working Party (BMWP), and Family Biotic Index (FBI). For the diversity indices, Shannon Diversity Index, *H'*, Pielou Evenness Index, *J'*, and Margaleff Richness Index, D_{Mg} were calculated. Water quality data, ecological data and substrate type data were analysed using canonical correspondent analysis (CCA) to determine environmental influence to the invertebrates.

RESULTS AND DISCUSSION

Water Quality

The average value of *in situ* and *ex situ* water quality parameters are shown in Table 1. The average value of temperature is 24.49 ± 0.34˚C and average value of DO is 7.25 ± 0.59 mg/L. Both parameters exhibit very constant readings. Any changes in temperatures could effects dissolved oxygen in water body (Ahmad et al. 2013) and increase BOD values (Agarwal 2002). Conductivity is a good performance indicator because it is sensitive to changes in water quality (Nolte & Loose 2004) and the lower the conductivity the better (Schwoerbel 1984). Average conductivity value recorded in this study is 81.89 ± 4.92 μS/m which is considered low. According to National Water Quality Standards (NWQS), average value for pH classify studied river in class IIA. According to Ahmad et al (2015), benthic macroinvertebrates can live well within the range of 6.0 to 8.5. The average value of the flow is 0.29 ± 0.25 m/s. The *ex situ* parameters indicate that Air Terjun Lata Kinjang is in clean condition (class I). The average COD value is 2.31 ± 0.83 mg/L whereas BOD_5 is 0.45 ± 0.35 mg/L. According to Ahmad et al. (2015), COD is closely related to BOD_5 because of the use of DO for the decomposition of non-organic and organic materials. Therefore, if the BOD_5 value is low, the COD value is decrease. Air Terjun Lata Kinjang is classified as class I based on NH_3N (0.02 ± 0.01 mg/L). Low NH_3N values indicate no inclusion of non-organic nutrient elements into the river (Ahmad et al. 2013). The average value of the five stations for the TSS parameter is 6.07 ± 1.48 mg/L. the one-way ANOVA test shows that all the parameters were not significant difference between the sampling stations ($p > 0.05$, $\alpha = 0.05$). Based on the WQI, Air Terjun Lata Kinjang is categorised in class I with WQI value of 96.

Table 1 Average value of physico-chemical parameters in Air Terjun Lata Kinjang.

Station	DO (mg/L)	pH	NH_3-N (mg/L)	COD (mg/L)	BOD_5 (mg/L)	TSS (mg/L)	Conductivity (µS/m)	Flow (m/s)	Temperature (˚C)	WQI	CLASS	WQ STATUS
1	6.75±0.17	6.50±0.00	0.03±0.01	2.33±0.67	0.70±0.67	5.70±0.43	89.60±0.17	0.36±0.46	24.1±0.00	94.83	I	C
2	6.45±0.37	6.31±0.09	0.02±0.02	2.80±1.71	0.29±0.05	6.67±0.81	84.30±0.21	0.16±0.25	24.1±0.00	95.58	I	C
3	7.6±0.25	6.44±0.12	0.01±0.01	2.20±0.69	0.51±0.50	5.67±0.78	81.50±0.72	0.27±0.21	24.6±0.06	97.01	I	C
4	7.78±0.02	6.35±0.05	0.02±0.02	2.10±0.53	0.40±0.08	5.00±0.53	76.60±0.10	0.37±0.24	24.9±0.06	97.50	I	C
5	7.67±0.06	6.28±0.01	0.02±0.01	2.10±0.46	0.35±0.06	7.33±2.93	77.50±0.26	0.31±0.17	24.8±0.00	97.23	I	C

Note: C = clean

Table 2 Composition and distribution benthic macroinvertebrates.

Phylum	Class	Order	Family	Station 1	Station 2	Station 3	Station 4	Station 5	Total
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	0	1	1	0	2	**4**
			Leptophlebiidae	8	14	3	9	11	**45**
			Baetidae	73	91	37	47	79	**327**
			Caenidae	16	26	2	5	2	**51**
			Ephemeridae	3	0	0	0	0	**3**
		Trichoptera	Hydropsychidae	27	33	0	4	7	**71**
			Helicopysychidae	1	0	1	0	1	**3**
			Leptoceridae	6	10	0	0	6	**22**
			Philipotamidae	0	8	0	1	3	**12**
			Hydroptilidae	2	1	0	0	0	**3**
			Odontoceridae	0	3	0	1	1	**5**
		Plecoptera	Perlidae	21	20	13	3	22	**79**
		Coleoptera	Elmidae	3	11	15	7	18	**54**
			Scirtidae	1	5	11	0	25	**42**
			Psephenidae	3	0	0	1	4	**8**

			Hydrophilidae	0	4	1	0	2	**7**
			Lampyridae	1	0	0	0	0	**1**
			Dytiscidae	0	0	0	3	0	**3**
			Eulichadidae	0	0	0	0	2	**2**
		Diptera	Tipulidae	0	3	0	0	4	**7**
			Chironomidae	59	76	18	39	82	**274**
			Simuliidae	79	23	8	15	7	**132**
			Ceratopogonidae	1	0	0	0	2	**3**
			Tabanidae	0	0	0	0	1	**1**
		Odonata	Gomphidae	1	1	1	3	4	**10**
			Euphaeidae	0	0	1	0	1	**2**
			Amphipterygidae	1	1	0	0	0	**2**
	Malacostraca	Decapoda	Atyidae	0	0	1	1	0	**2**
			Palaemonidae	0	0	1	0	0	**1**
Annelida	Oligochaeta	Lumbriculida	Lumbriculidae	0	0	1	0	0	**1**
			Total	**306**	**331**	**115**	**139**	**286**	**1177**

Benthic Macroinvertebrate Diversity and Distribution

A total of 1177 benthic macroinvertebrate individuals were sampled consisting of two phyla, three classes, eight orders and 30 families (Table 2). Insecta dominates each station with highest number of taxa and abundance. The Malacostraca and Oligochaeta classes are only recorded at very low composition compared to the Insecta (Table 2). Ephemeroptera (37 %) and Diptera (35 %) dominating the overall sample with 847 individuals (72 % from total sample).

Domination of Ephemeroptera is attributed to their morphological features that are in line with the stony substrates and fast-moving habitats (Ahmad et al. 2013) and its universal properties and adaptation of stream flow from slackwaters to fast-flowing riffle zone of streams (Che Salmah et al. 2001). Most families of Ephemeroptera are well known with the taxanomy and tolerances (Nurhafizah-Azwa & Ahmad 2016) which are very useful in environmental assessment (John & Edward 2002). Table 2 shows Air Terjun Lata Kinjang is dominated by Baetidae (28 %) from 30 families. Baetidae inhabit consistently in five sampling stations due to their capability to adapt to fast flowing water (Ahmad et al. 2015; Gooderham & Tsyrlin 2002) and live within stony substrate areas and fast-flowing water (William Bouchard 2004).

Chironomidae was recorded as the second most dominant family. In this study, Chironomidae were present at all sampling stations and was the highest in station 5. Although Chironomidae is a tolerant family and referred to as a polluted ecosystem indicator (Spellman & Drain, 2001), previous studies showed Chironomidae also recorded abundance in clean rivers (Ahmad et al. 1999; Ahmad et al. 2013; Ahmad et al. 2015; Azrina et al. 2006; Nurhafizah-Azwa & Ahmad 2016; Siti Hafizah 2017). Therefore, studies at lower taxonomic levels should be conducted to identify specific biological indicator.

Relationship between WQI and Ecology Indices

Table 3 shows WQI and all other ecological indices calculated from existing data. Air Terjun Lata Kinjang is classified as moderately clean from the biotic indices data. Shannon Index evaluated all stations as fair to moderate stress. However, this study only underestimates the true value since taxonomic was only conducted up to family level (Nurhafizah-Azwa & Ahmad 2016) and calculated values are lower in actual value (Ahmad et al. 2015). As for Pielou Index, when the value is getting closer to 1, the individuals are distributed evenly (Turkmen & Kazanci 2010). Therefore, this result also demonstrates fair distribution. Margaleff Index has no limit and is applicable for comparison of sites (Kocatas 1992). Station 5 recorded the highest value of Air Terjun Lata Kinjang and station 4 is the lowest.

Similar results were demonstrated by biotic indices. The BMWP index classify study site between moderate to good conditions, except the FBI index classify as good to very good. Generally, these indices exhibit some degree of agreement in term of river water quality assessment using invertebrates as biological indicator agents. As regards to the WQI result, the FBI index produce the closest result followed by the BMWP and diversity indices.

Since biotic and diversity indices demonstrate that Air Terjun Lata Kinjang water quality is in good condition, next attempt is to identify which invertebrates families contribute to this result significantly. Therefore, Canonical Correspondence Analysis (CCA) was conducted to examine environmental factors that determine benthic macroinvertebrate population. Figure 2 shows none of environment factor controlling the invertebrates population significantly. Therefore, as this study area has excellent water quality and dominated by boulder and sand, these factors related invertebrates are concerned. The CCA plot shows that

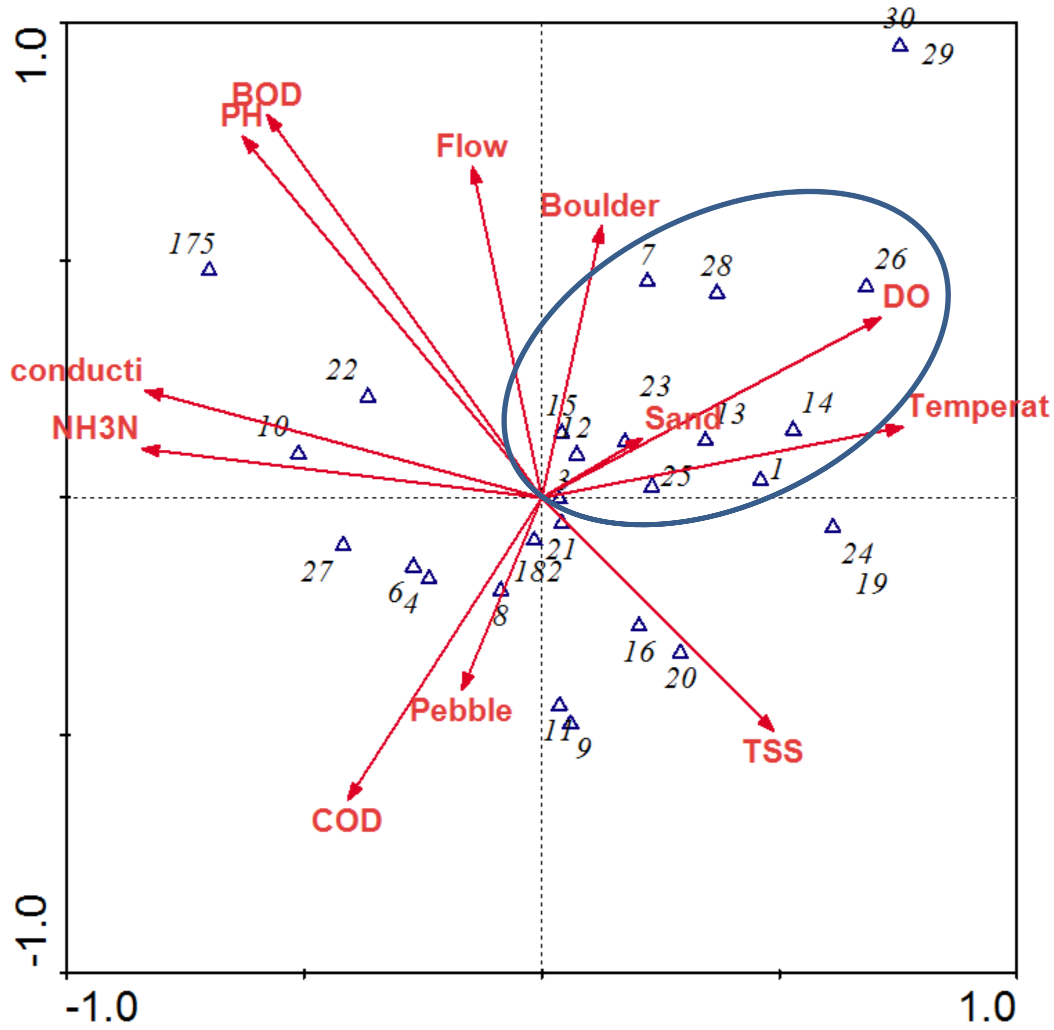
Baetidae, and Perlidae are amongst most distributed invertebrates in this study area. Baetidae reported most sensitive to temperature and dissolved oxygen change. Temperature is the main influence of Baetidae nymphs life cycle (Ward 1992), and Ahmad et al. (2013) mentioned fluctuation of temperature will affect dissolved oxygen in water. Thus, low oxygen concentration is limiting to the survival of certain Baetidae (Brittain 1982). The CCA test shows a clear connection between physico-chemical parameters towards benthic macroinvertebrates, especially Baetidae, and Perlidae.

Perlidae present uniformly in each sampling station. Ahmad et al. (2013) mentioned that Perlidae inhabit high flow stream with rocky substrate and also present within debris and sandy substrate. As Perlidae in order Plecoptera, Plecoptera are among the most intolerant insects occurring in aquatic habitats. The restrictive ecological requirements and poor dispersal abilities of Plecoptera often results in their elimination from aquatic systems before any other group of insects (Beaty, 2015). Therefore, the presence or absence of Plecoptera especially Perlidae in this study site play an important role as important indicator taxa.

This study exhibits that Baetidae and Perlidae is the most reliable as good bio-indicator. This family has constant distribution along the study area and present with good composition.

Table 3 Results for WQI and Ecological Indices.

Indices	**Station 1**	**Station 2**	**Station 3**	**Station 4**	**Station 5**	**Average**
WQI	94.83	95.58	97.01	97.50	97.23	96.43 ± 1.16
	I	I	I	I	I	I
Shannon (*H'*)	2.02	2.19	2.07	1.90	2.17	2.07 ± 0.12
	fair	fair	fair	Moderate stress	Moderate stress	Fair
Pielou *(J)*	0.42	0.50	0.50	0.48	0.40	0.46 ± 0.05
Margaleff (D_{Mg})	2.97	2.93	3.12	2.64	3.71	3.08 ± 0.40
BMWP	90	108	86	90	112	97.2 ± 11.9
	moderate	good	moderate	moderate	good	moderate
FBI	5.14	4.82	3.90	5.08	4.43	4.67 ± 0.23
	good	good	very good	good	very good	good



1.Heptageniidae, 2.Leptophlebiidae, 3.Baetidae, 4.Caenidae, 5.Ephemeridae, 6.Hydropsychidae, 7.Helicopsychidae, 8.Leptoceridae, 9.Philipotamidae, 10.Hydroptilidae, 11.Odontoceridae, 12.Perlidae, 13.Elmidae, 14.Scirtidae, 15.Psephenidae, 16.Hydrophilidae, 17.Lampyridae, 18.Dytiscidae, 19.Eulichadidae, 20.Tipulidae, 21.Chironomidae, 22.Simuliidae, 23.Ceratopogonidae, 24.Tabanidae, 25.Gomphidae, 26.Euphaeidae, 27.Amphipterygidae, 28.Atyidae, 29.Palaemonidae, 30.Lumbriculidae.

Figure 2 Effect of physico-chemical parameters and substrate types benthic macroinvertebrates.

CONCLUSION

Based on WQI, Air Terjun Lata Kinjang is classified as clean and in class I. As a clean recreational stream, Air Terjun Lata Kinjang is supporting a large diversity of benthic macroinvertebrates. In this study, Baetidae is found as an important bioindicator.

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