AQUATIC INSECTS ASSEMBLAGE IN PENANG BOTANIC GARDEN

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ABSTRACT

This study investigated the diversity of aquatic insects as well as the chemical parameters of Sungai Air Terjun that runs in Penang Botanic Garden. Aquatic insects and chemical parameters of river were studied from April 2013 until January 2014. A total of twenty specimens were collected monthly using D and rectangular net following kick-net sampling technique. A total of 2966 individuals from 48 families of seven orders of aquatic insects were collected. The most abundant aquatic insects were recorded in July 2013 with 566 individuals from 44 genera, while the least abundant was in May 2013 with 156 individuals from 31 genera. The Diptera (996 individuals), Trichoptera (689 individuals) and Ephemeroptera (327 individuals) were very rich and diverse in this river during all the sampling months. This study provides a current situation of aquatic insect's community and river condition of Sungai Air Terjun, Penang Botanic Garden.

Keywords: Abundance, Diversity, Aquatic Insects, Sungai Air Terjun.

ABSTRAK

Kajian ini mengkaji kepelbagaian serangga akuatik dan juga parameter kimia Sungai Air Terjun yang mengalir di Taman Botani Pulau Pinang. Serangga akuatik dan parameter kimia sungai telah dikaji dari April 2013 hingga Januari 2014. Sejumlah 20 spesimen telah dikumpulkan setiap bulan menggunakan jaring bingkai D dan segi empat berdasarkan teknik *kick-sampling*. Sebanyak 2966 individu daripada 63 famili dan tujuh order serangga akuatik telah diperolehi. Serangga paling banyak dicatatkan pada bulan Julai 2013 dengan 566 individu daripada 44 genus, manakala bulan Mei 2013 mencatatkan bilangan yang terendah dengan 156 individu daripada 31 genus. Diptera (996 individu), Trichoptera (689 individu) dan Ephemeroptera (327 individu) merupakan order yang paling tinggi kekayaan dan kepelbagaian genusnya di dalam sungai ini bagi semua bulan persampelan. Kajian ini menyediakan maklumat terkini status komuniti serangga akuatik di Sungai Air Terjun, Taman Botani Pulau Pinang.

Kata kunci: Kelimpahan, Kepelbagaian, Serangga Akuatik, Sungai Air Terjun

INTRODUCTION

Aquatic insects are the most successful group of organisms for their ability to adapt in a variety of habitats. Using aquatic insects in monitoring the quality of aquatic ecosystem have been proven useful because the distribution of organisms in the flowing stream is restricted to a specific environment due to their limited physiological tolerance such as water temperature and chemistry (Boyero et al. 2009). The aquatic insects reside in the water during their immature stages, thus exposed them to any changes in water quality or stressor that occur in the streams. According to Mitchell and Stapp (1996) and Ahmad et al. (2008), aquatic insects are often used as biological indicators to measure the quality of water because some aquatic insects are very sensitive to polluted environment. For example, mayflies or Ephemeroptera are rarely found in severely polluted stream which makes them a good indicator for quality of the ecosystem (Yule & Yong 2004).

Many studies have focused on the effect of pollution or disturbance on aquatic insect assemblages at polluted rivers, catchment area and state park but none in a garden. The garden is regarded as important area for many localized endemic invertebrate groups, particularly dragonflies, caddisflies and mayflies. Limited information on what exists in this habitat yet currently do not know the abundant and diversity of the aquatic insects, whether there are rare species is still to be found factors that may threaten the survival of existing rare species. In addition, the recreational activities in stream are likely to have altered the functioning of many aquatic habitats (particularly around garden areas) with unknown effects on species assemblages. Moreover, the use of aquatic insects as biological indicators is crucial when it comes to human activities.

Above and beyond, almost none of monitoring agencies in Malaysia have collected adequate data of aquatic insects to support analysis of temporal trends in biological condition at a given stream site. The temporal changes in biological condition need to be identified for the effective management of aquatic ecosystems. According to Jackson and Fureder (2006), monitoring programs involved a long-term study of water quality and biological parameters of streams. Thus, the present study highlights the ecological variations of temporal changes in stream water quality; and significant changes associated with aquatic insects assemblages to achieve the following objectives, (1) to investigate the composition of aquatic insects in Sungai Air Terjun using different sampling gear, and (2) to determine the physico-chemical parameters that influences the aquatic insect assemblages in this river.

MATERIALS AND METHODS

Insects and Water Samplings

Study was conducted in Sungai Air Terjun at N $5^0$26.424' E $100^0$16.944' [GPS map 76 CSX versatile navigator (Garmin®)] located in the Penang Botanical Garden. This river runs from Penang Hill where it cascades down to the Botanical Gardens, from which it derives its name of Air Terjun.

Twenty samples were collected randomly every month for 10 consecutive months from April 2013 to January 2014 using two types of aquatic nets; rectangular (0.5 m width and 0.5 m height) and D net (0.3 m width and 0.3 m height) following the method from Merritt and Cummins (1996). Ten replicates using each type of net were taken in every sampling effort. The sampling procedure was followed from Suhaila and Che Salmah (2011). Larval collections were sorted, preserved in 75% alcohol and later identified in the laboratory. In the laboratory,

larvae of the aquatic insects were identified under a dissecting microscope Olympus CX41 (Olympus, Tokyo, Japan) following various key such as Morse et al. (1994), Dudgeon (1999) and Yule and Yong (2004).

River physical characteristics such as water temperature and dissolved oxygen (DO) were recorded *in situ* at each sampling month by using an oxygen meter (YSI Model 550 A, YSI Inc., Ohio, USA) and the pH of the water was measured with pH meter (HACH Co., Loveland, USA). A portable Autoflow Watch (JDC Instrument, Arizona, USA) was used to measure the water velocity. For water chemistry analysis such as biochemical oxygen demand (BOD), ammoniacal nitrogen and total suspended solids (TSS), the analysis were carried out using standard procedures from HACH© (HACH Co., Loveland, USA).

Data Analysis

Data was analyzed using biological indices such as Family Biotic Index (FBI), Biological Monitoring Working Party (BMWP), Average Score Per Taxon (ASPT) and EPT taxa richness. The abundance of aquatic insects in Sungai Air Terjun were normally distributed among the sampling months prior to Kolmogorov-Smirnov test at $p>0.05$ thus parametric test (one-way ANOVA) was chosen to analyze the data using SPSS version 20. Pearson Correlation was run on the data to assess the correlation of aquatic insect abundance with water parameters.

RESULTS

Abundances and Distribution of Aquatic Insects Larvae.

A total of 2966 individuals from 38 families of eight orders were collected from Sungai Air Terjun (Table 1). The most abundant aquatic insects larvae was collected in July 2013 with 566 individuals from 44 genera while the least abundant and least diverse of aquatic insects larvae were recorded in May 2013 with 156 individuals from 31 genera. However, the most diverse aquatic insects larvae were collected in August 2013 with 59 genera. The most abundant taxa in this river were *Hydropsyche* spp. and *Simulium* spp. Trichoptera was the most common order, representing eight families with 16 genera. The dominant taxonomic groups found during all sampling months were from order Trichoptera, Ephemeroptera and Diptera (Table 2). There was a significant difference between the abundance of aquatic insect among month of sampling, (ANOVA, $F_{(8,9)} = 12.693$, $p<0.05$).

Based on Biological Monitoring Working Party (BMWP) index, this river fell into moderately good categories only due to the low value recorded in October, November and December (Table 3). Meanwhile, Family Biotic Index (FBI) and EPT index classified Sungai Air Terjun into excellent river while BMWP index classified it as good and Average Score Per Taxon (ASPT) index classified this river into moderately good categories.

Physico-chemical parameters of Sungai Air Terjun.

The mean physico-chemical parameters of the water in Sungai Air Terjun were summarized in Table 4. Water temperature during all the sampling months was not uniform and its value fluctuated. May 2013 had the highest temperature (25.6°C) compared to the other sampled months. The lowest temperature at Sungai Air Terjun was in October 2013 (24.23°C). The pH value was increasing from April 2013 to January 2014 while the highest amount of ammoniacal nitrogen was in September (0.08 mg/L). October, June and January 2014 had higher TSS value compared to other sampling months with 1.83 mg/L, 2.5 mg/L and 1.0 mg/L, respectively. The lowest DO value was recorded in June (6.79±0.08 mg/L). Biochemical oxygen demand displayed greater value in December 2013 (1.79±1.25mg/L). Pearson correlation test showed

the abundance of aquatic insects was not correlated with all parameters, except with dissolved oxygen ($r=0.215$, $p < 0.05$) and ammoniacal nitrogen ($r=0.287$, $p < 0.05$).

DISCUSSION

The dominance existence of Ephemeroptera and Trichoptera in Sungai Air Terjun showed this river was clean and unpolluted. Aquatic insects especially from order Ephemeroptera, Plecoptera and Trichoptera (EPT) are commonly used as biological indicators to determine the level of cleanliness of the river water. This is because EPT was very sensitive and they cannot tolerate polluted environment (Compin & Cereghino 2003; Gill 2000; Mitchell & Stapp 1995).

Sungai Air Terjun area was well-kept and clean thus provides a variety of habitats that allowed *Hydropsyche* from families Hydropsychidae live and breed (McCafferty 1983). Trichoptera are rarely found in severely polluted streams which makes them a good indicator for quality of the ecosystem (Yule & Yong 2004). There were few factors that affect the abundances of aquatic insects in Sungai Air Terjun for each sampling months. Sungai Air Terjun had partly open canopy cover and embedded with a variety of substrate type such as bedrock, boulder, cobble and gravel. This variety of substrate provided a favorable condition for the aquatic insects to inhabit and breed. The dominant aquatic insects found in May, August, December 2013 and January 2014 were from order Trichoptera with the dominant family of Hydropsychidae, *Hydropsyche*. According to Suhaila et al. (2012), Trichoptera preferred protruding rocks as oviposition sites and from observation, Sungai Air Terjun had plenty of protruding rocks and this may provide the high abundance of *Hydropsyche* larvae in this river. May 2013 had the lowest abundance of aquatic insects found at Sungai Air Terjun with 156 individuals followed by October 2013 (166 individuals), June 2013 (175 individuals) and January 2014 (177 individuals). Variations in the abundances and diversity of aquatic insects for each sampling months may be due to the rainy season in which the flow of the water current lead away the aquatic insects (Dudgeon 1999). Thus, the abundance of aquatic insects tends to be low. In addition, higher water level in the rainy season turned the riverbed less conducive for Trichoptera because certain genera of Trichoptera especially the free living cannot withstand the hydraulic stresses and may flushed away.

Besides Trichoptera, the abundances of other aquatic insects were found high in April, July and August 2013. Depth of Sungai Air Terjun in April, July and August 2013 were shallower due to low precipitation and the slow water current. According to Richardson (1992), low precipitation of rainfall data and the slow water current are the best condition for insect breeding. In addition, order Diptera was dominantly found in April, June, July, September, October and November 2013. Family Simuliidae and Chironomidae from this order were the highest individuals found from Diptera. The presence of both families was major dietary source of at least 19 families of fish (Armitage 1995). The differences in the abundances and diversity of aquatic insects for each month also might have connection with the relationship of symbiosis, parasitisme and predators (Dudgeon 1999). Insect of the order Diptera (Chironomidae) are also versatile biological indicators (Lindegaard 1995). Not all aquatic insects of the order Diptera shows the level of contaminants because some of them indicate clean water.

Among the orders, Odonata has the highest number of genera. In order Odonata, the genus of the family Libellulidae, Euphaeidae and Gomphidae was among the highest genus found using both net at the study site. Odonata from family Libellulidae can be found in almost all different types of habitat, as it is widely spread in the habitat and other habitats (Asahina

1993; Hamalainen 1994), while Euphaeidae and Gomphidae breed in running water in forest streams and make Sungai Air Terjun as a suitable habitat. Besides, Odonata insects are predators (Elzinga 2004). Therefore, the species diversity of aquatic insects such as the order of Diptera is a dietary source for Odonata species. Thus, Odonata insects spreading were high as there was a lot of food on the Sungai Air Terjun.

Accordingly, the pH value of the river did not influence the abundances and distributions of aquatic insects. Insects can adapt to changes in pH. For example, Odonata can survive in low pH of 3.25 (Bell 1990) even though Odonata live at pH range between 5 until 8. According to Murphy (2007), very high pH (pH>9.5) or very low pH (pH<4.5) can kill the aquatic insect. Therefore, some aquatic life can tolerate wide range of pH but some cannot. For example, Plecoptera were apparently less sensitive to the effects of acidity than Ephemeroptera and Trichoptera (Bell 1990). pH in Sungai Air Terjun ranged between 6.3 to 8.3, so it is suitable for the survival of the aquatic insect including Ephemeroptera, Plecoptera and Trichoptera. Furthermore, species adaptation towards environment and feeding strategy plays an important role in ecosystem function (Suhaila & Che Salmah 2014; Townsend & Hildrew 1994).

Ammoniacal nitrogen in the water was a waste from monkeys that can be found in numerous numbers in the Penang Botanical Garden. The range of ammonia concentration in Sungai Air Terjun is 0.03 to 0.08 mg/L that was far below the critical limit for the insects. Some Chironomidae (Diptera) can live in high amount of ammoniacal nitrogen. In particular, it has been noted that different taxa show variation in their ranges of tolerance to ammoniacal nitrogen levels (Beketov 2004).

Based on the correlation test, dissolved oxygen (DO) affected the abundance of aquatic insect in Sungai Air Terjun. Most of the Trichoptera was collected from this river. Some trichopterans are free living while some build cases from sand and leaves. All aquatic insect adapted to live in flowing water as their mechanism to obtain oxygen for respiration. They usually rely on gills, plastrons, or cuticular respiration to meet their metabolic demand for oxygen. Dissolved oxygen was found to have strongest correlation with benthic community in Chesapeake Bay watershed, US (Daeur et al. 2000). According to Ekness and Randhir (2007), organisms become stress and die if DO remains outside the range for a longer time. Water with consistently high dissolved oxygen is considered healthy and stable aquatic systems capable of supporting many different types of aquatic insects.

CONCLUSION

River physical of this river as well as variation in water quality did not influence the tolerance aquatic insects order such as Diptera and Odonata. The abundance of aquatic insect was highest on November and December 2013. This is because of the hot weather that influences the abundance of aquatic insects. In addition, this month is also ideal to be taken as a sampling month for having an abundance of many aquatic insects.

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APPENDICES

Table 1 Total genera and individuals number of aquatic insects collected in Sungai Air Terjun from April 2013 until January 2014.

Month	Total genus	Total individuals
April	52	507
May	31	156
June	32	175
July	44	566
August	59	412
September	36	313
October	21	166
November	25	232
December	27	262
January	25	177
Total		**2966**

Table 2 Aquatic insects composition found in Sungai Air Terjun, Penang Botanical Garden.

Order	Family	Genus	Total individual
Ephemeroptera	Baetidae	*Platybaetis*	113
		Baetis	136
	Heptageniidae	*Thalerosphyrus*	16
		Campsoneuria	41
	Caenidae	*Caenis*	6
Coleoptera	Elmidae	*Stenelmis*	25
		Zaitzevia	9
		Pseudomophilus	3
	Hydrophilidae	*Berosus*	14
		Hydrophilus	20
	Eulichadidae	*Eulichas*	4
	Psephenidae	*Eubrianax*	4
Plecoptera	Perlidae	*Phanoperla*	24
		Neoperla	22
	Peltoperlidae	*Cryptoperla*	28
Diptera	Ceratopogonidae	*Dasyhelea*	8
		Culicoides	3
	Simuliidae	*Simulium*	499
	Tipulidae	*Tipula*	18
	Blephariceridae	*Blepharicera*	6
	Chironomidae	*Chironomus*	73
	Athericidae	*Suragina*	16

Continuous in the next page

Lepidoptera	Acentopinae	*Paraponyx*	4
Hemiptera	Gerridae	*Ptilomera*	39
		Cryptobates	47
		Limnogonus	10
		Metrocoris	10
	Veliidae	*Rhagovelia*	185
	Aphelocheiridae	*Aphelocheirus*	11
	Naucoridae	*Naucoris*	7
Odonata	Euphaeidae	*Euphaea*	23
	Libellulidae	*Branchydiplax*	72
		Nannophya	1
	Chlorocyphidae	*Libellago*	9
	Coenagrionidae	*Pseudagrion*	10
	Gomphidae	*Burmagomphus*	16
		Megalogomphus	8
	Amphipterygidae	*Devadatta*	10
	Calopterygidae	*Vestalis*	8
	Platystictidae	*Drepanosticta*	1
	Coenagrionidae	*Agriocnemis*	1
	Corduliidae	*Macromia*	1
Trichoptera	Hydropsychidae	*Hydropsyche*	729
		Ceratopsyche	78
		Potamia	6
		Cheumatopsyche	105
		Macrostemum	37
		Diplectrona	224
		Potamyia	23
	Leptoceridae	*Trianodes*	35
		Oecetis	44
		Setodes	11
	Sericostomatidae	*Gumaga*	22
	Polycentropodidae	*Polycentropus*	47
	Philopotamidae	*Chimarra*	36
	Lepidostomatidae	*Lepidostoma*	3
	Goeridae	*Goera*	1
	Rhyacophilidae	*Rhyacophila*	4

Table 3 Biological indices of aquatic insects in Sungai Air Terjun for all sampling months.

Month	Indices				River Categories			
	FBI	**BMWP**	**ASPT**	**EPT**	**FBI**	**BMWP**	**ASPT**	**EPT**
April	4.40	226	4.35	20	Good	Very good	Moderately good	Excellent
May	2.81	102	3.29	11	Excellent	Good	Moderately good	Excellent
June	3.65	122	3.81	10	Excellent	Good	Moderately good	Good
July	4.05	190	4.32	18	Very good	Very good	Moderately good	Excellent
August	3.61	259	4.39	22	Excellent	Very good	Moderately good	Excellent
September	5.06	115	3.19	11	Fair	Good	Moderately good	Excellent
October	4.19	89	4.24	6	Very good	Moderately good	Moderately good	Good
November	3.82	81	3.24	8	Very good	Moderately good	Moderately good	Good
December	4.03	88	3.26	10	Very good	Moderately good	Moderately good	Good
January	3.35	112	4.48	12	Excellent	Good	Moderately good	Excellent

Table 4 Mean (± SE) of physico-chemical parameters in Sungai Air Terjun. SE = Standard Error.

Parameters	Months									
	April	May	June	July	August	September	October	November	December 2013	January 2014
Temperature (°C)	25.5±0.16	25.6±0.29	25.6±0.45	24.7±0.18	25.30±0.30	25.2±0.01	24.2±4.33	24.6±0.71	21.9±0.01	24.8±1.18
Dissolve Oxygen (mg/L)	7.48±0.09	7.11±0.09	6.79±0.08	7.25±0.14	6.90±0.06	7.15±0.14	8.03±0.24	8.03±1.10	8.08±0.58	7.97±0.36
pH	6.31±0.06	6.51±0.24	6.53±4.04	6.68±0.25	6.68±1.25	7.66±4.77	8.80±0.35	8.69±1.06	8.50±1.24	8.31±1.54
Velocity (m/s)	0.17±0.01	0.57±0.12	0.87±0.65	0.45±0.55	0.10±1.25	1.15±0.64	0.70±0.37	0.47±1.25	0.22±3.24	0.15±1.24
Total suspended solid (mg/L)	1.00±1.09	3.00±0.74	2.50±0.43	1.00±4.58	3.00±0.45	3.50±1.22	1.83±0.42	1.33±0.78	1.67±1.25	1.00±0.84
Ammoniacal nitrogen (mg/L)	0.01±0.01	0.02±.045	0.07±0.53	0.01±0.47	0.03±1.55	0.08±4.10	0.06±0.25	0.08±1.32	0.07±2.33	0.05±0.86
BOD (mg/L)	0.36±0.52	0.39±0.25	0.33±0.54	0.07±0.24	0.11±0.65	1.69±0.25	0.31±0.78	0.26±0.57	1.79±1.25	1.26±0.67