

Aquatic Insects as Indicator in Water Quality Assessment of Recreational Rivers

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Abstract: In order to attain the certainty that aquatic insects interact with water changes caused by human recreational activities, a sampling was conducted in Kedah and Penang, northern state of peninsular Malaysia. Sampling of aquatic insects and water parameters measurement were carried out on three periods of time; before school holiday, during school holiday and after school holiday at eight recreational rivers. Before school holiday, the abundance of aquatic insects dominated by order Ephemeroptera, while during school holiday, it was dominated by order Diptera, whereas order Trichoptera dominated the abundance of aquatic insect after school holiday season. The abundance of aquatic insect was the greatest during school holiday and it was dominated by the order Diptera. During school holiday, the season offered the least suitable habitat for aquatic insects especially the intolerant group such as Ephemeroptera, Plecoptera and Trichoptera (EPT). All biological indices described the river in all seasons as clean except for FBI which described the water quality during school holiday season as fair.

1 INTRODUCTION

The aquatic insect community can give reliable information as they spent most of their life cycle in water especially during their immature stage. Compared to other organism, insects are able to impart a practical assessment of sustainability. Aquatic insects have beaucoup of advantages to be used as biological indicator and therefore, by studying the diversity, population, behavior and taxonomy of species, we can estimate the current degradation rate and estimate the future consequences of the water body. It is well understood that aquatic ecosystems has received disturbances from human beings since few decades. According to Hodkinson and Jackson (2005), there is a strong relationship between disturbances of the aquatic habitats with human activities. Malaysian loves to do recreational activities near the river bank. The recreational activities such as camping, picnicking and swimming is usually held in the upstream rivers because the water is clean and cool. Thus, recreational rivers are expected to have a moderate level of water quality. High increase of recreational activities in rivers probably degrade the assemblages of aquatic insects. Therefore, this study was undertaken to determine the

composition and diversity of aquatic insects in recreational rivers and the status of the water quality of the recreational rivers.

2 MATERIAL AND METHODS

2.1 Study Areas

Bukit Hijau River is located within the Gunung Inas Forest Reserve. The second river chosen for this study was Sedim River that runs down from Gunung Bintang. The sampling also was conducted in Titi Hayun River and Batu Hampar River that flows from Gunung Jerai Forest Reserve. All selected rivers were famous recreational rivers in Kedah state and were always visited by people observed during sampling sessions. Bukit Mertajam River is located in Bukit Mertajam Forest Reserve, Penang. The river was too small for swimming, thus the management renovated few part of the river into pool which allowed visitors to swim. Teluk Bahang River located in Teluk Bahang Forest Reserve, Penang. Teluk Bahang River is one of the famous recreational river in Penang for picnic, camping, swimming and team building activities due to its well-managed facilities.

2.2 Aquatic Insects Sampling and Identification

Ten samples of aquatic insects were collected at each river at riffle habitats using kick sampling technique followed by Merritt et al. (2008) using the D-pond net. Three sets of sampling period was designed comprised of three periods; before school holiday, during school holiday and after school holiday with two weeks gap between each period. The sample from the net was transferred into a labeled plastic bag, brought to the laboratory, sorted on a tray and was identified to the family level using taxonomic keys by several authors Yule and Yong (2004), Morse et al (1994) and Orr (2005).

2.3 Hydrological Parameters

Concurrently with insects sampling, water samples were collected at each sites and parameters tested for water samples were dissolved oxygen (DO), biochemical oxygen demand (BOD₅), chemical oxygen demand (COD), ammonia-nitrogen, pH, total suspended solids (TSS), and total coliform test. Total coliforms, *E.coli* and enterococci counts for each river were carried out immediately in laboratory using standard kit IDEXX Colilert Test Kit (total coliforms and *E.coli*) and Enterolert Test Kit (enterococci) (IDEXX, USA) following the standard procedures provided by IDEXX.

2.4 Statistical Analyses

Non-parametric analyses was applied as the abundance of aquatic insects was not normally distributed. Kruskal-Wallis test (at $p < 0.05$) was conducted using Statistical Package for the Social Science (SPSS) version 22.0 for Windows®. Biological indices were calculated to describe the condition of selected rivers from biological perspective.

During school holiday (DSH) season, the individuals of aquatic insects were skyrocketing increased to 9304 individuals from 8 orders comprised of 62 families. The composition of aquatic insects in DSH season was dominated by order Diptera with 37.4% and followed by order Ephemeroptera (32.2%). Meanwhile, after school holiday (ASH) season, the number of aquatic insects individuals decreased to 7810 individuals from 9 orders that comprised of 66 families. Order Ephemeroptera (40.4%) dominating the composition of aquatic insects in BSH season followed by Diptera (27.4%) and Trichoptera (17.5%). Among the aquatic insects collected, Ephemeroptera was the major insects order inhabiting selected recreational rivers (Table 2). In BMJ, Baetidae was found the most followed by Heptageniidae. However, in TBH family Caenidae was found the most abundant. Ephemeroptera was more diverse in BSH and lesser diversity of Ephemeroptera was recorded in TBH. There was a significant different (Kruskal-Wallis test, $\chi^2 = 37.204$, $df = 2$, $P = 0.00$) abundance of aquatic insect between seasons. The Family Biotic Index (FBI) index gave a reflection that both water quality in BSH and ASH seasons were moderately good compared to DSH season which was considered as moderate water quality (Table 3). However, other biological indices such as BMWP, ASPT and EPT, described the water quality for all seasons as very good, good and not impacted, respectively.

3.2 Water Quality of Recreational Rivers based on School Holiday Seasons

The mean value of hydrological parameters recorded during school holiday (DSH) season were slightly decreased compared to before school holiday (BSH) and after school holiday (ASH) seasons except for total coliform, *E.coli* and enterococci (Table 4).

3 RESULTS

3.1 Assemblage of Aquatic Insects at Selected Recreational Rivers

Number of aquatic insects in most of the selected rivers were greater during school holiday compared to before and after school holiday (Table 1). Before school holiday (BSH), a total of 5958 aquatic insect was recorded from 9 orders comprised of 61 families.

Table 1: Distribution of aquatic insects in all selected rivers based on school holiday season.

	BEFORE			DURING			AFTER		
	No.	No.	%	No.	No.	%	No.	No.	%
	Fami ly	Indiv idual		Fami ly	Indivi dual		Fami ly	Indivi dual	
Ephemeroptera	11	2407	40.4	12	3000	32.2	14	2218	28.4
Odonata	8	126	2.1	7	153	1.6	9	176	2.3
Plecoptera	4	179	3.0	3	138	1.5	3	248	3.2
Hemiptera	8	280	4.7	6	488	5.2	7	326	4.2
Coleoptera	9	261	4.4	9	308	3.3	8	270	3.5
Megaloptera	1	5	0.1	0	0	0.0	1	1	0.0
Lepidoptera	1	26	0.4	1	8	0.1	1	12	0.2
Trichoptera	12	1040	17.5	15	1727	18.6	14	2331	29.8
Diptera	7	1634	27.4	9	3482	37.4	9	2228	28.5

Table 2: List of taxa and their assemblages of aquatic insects at selected recreational rivers.

Order	Family	Recreational River						
		BH	TH	SD	BM	TB		
		P	Y	BHJM	J	H		
Ephemeroptera	Baetidae	1	1	1	1	1	1	
	Caenidae	1	1	1	1	1	1	
	Ephemerellidae	0	0	1	1	0	0	
	Heptageniidae	1	1	1	1	1	1	
	Isonychiidae	1	1	1	1	1	1	
	Leptophlebiidae	1	1	1	1	1	1	
	Neophemeridae	0	1	1	1	0	0	
	Potamanthidae	0	0	1	1	0	0	
	Tricorythidae	1	1	1	1	1	1	
	Odonata	Amphipterygidae	1	0	0	0	1	0
Calopterygidae		1	0	1	1	0	0	
Coenagrionidae		1	0	0	1	0	0	
Cordulegastridae		0	0	0	0	0	1	
Cordulidae		0	1	1	1	0	1	
Chlorocyphidae		1	1	1	1	1	1	
Euphaeidae		1	1	1	1	0	1	
Gomphidae		0	0	0	1	0	0	
Libellulidae		1	0	0	0	0	1	
Platystictidae		0	0	1	1	1	0	
Plecoptera	Perlidae	1	1	1	1	1	1	
	Peltoperlidae	1	0	1	1	0	0	
	Nemouridae	1	1	0	1	0	1	
	Leuctridae	1	0	0	0	0	0	
Hemiptera	Aphelocheiridae	0	0	1	1	0	0	
	Corixidae	0	0	1	0	0	0	
	Gerridae	0	0	0	1	0	0	

	Helotrephidae	0	0	1	1	0	0
	Hebridae	1	0	0	1	0	0
	Naucoridae	1	1	1	1	0	1
	Pleidae	1	0	1	1	0	0
	Veliidae	0	0	0	1	0	0
Coleoptera	Dytiscidae	1	1	1	1	1	0
	Dryopidae	0	0	1	1	0	0
	Eulichadidae	1	1	1	1	1	1
	Elmidae	1	0	1	1	1	1
Order	Family	BH P	TH Y	SD BHJM	BM J	TB H	
Coleoptera	Gyrinidae	0	0	1	0	0	0
	Hydrochidae	0	0	0	0	1	0
	Hydrophilidae	1	1	1	1	1	1
	Lampyridae	1	1	1	1	0	0
	Psephenidae	1	1	1	1	1	1
	Scirtidae	1	1	1	1	1	1
	Megaloptera	Corydalidae	0	0	1	1	0
Lepidoptera	Pyralidae	1	1	1	1	1	1
Trichoptera	Calamoceratidae	1	0	0	0	0	1
	Ecnomidae	0	0	1	0	0	0
	Glossosomatidae	1	1	1	1	0	1
	Hydropsychidae	1	1	1	1	1	1
	Hydroptilidae	0	0	1	1	0	0
	Lepidostomatidae	1	1	1	1	0	0
	Leptoceridae	0	0	1	1	0	0
	Limnephilidae	1	1	1	0	0	1
	Molannidae	1	1	1	0	0	1
	Odontoceridae	0	0	0	0	0	1
	Philopotamidae	1	1	1	1	1	1
	Phryganopsychidae	1	0	0	1	0	0
	Polycentropodidae	1	1	0	1	1	1
Psychomyiidae	1	1	1	1	1	1	
Rhyacophilidae	0	0	1	1	0	0	
Sericostomatidae	1	1	1	1	0	1	
Stenopsychidae	1	0	1	1	0	0	
Diptera	Athericidae	1	1	1	1	1	0
	Ceratopogonidae	1	1	1	1	1	1
	Chaoboridae	1	1	1	0	0	1
	Chironomidae	1	1	1	1	1	1
	Dixidae	0	0	0	0	1	0
	Psychodidae	1	1	1	1	0	0
	Simuliidae	1	1	1	1	1	1
	Tabanidae	0	1	1	1	1	1
	Tipulidae	1	1	1	1	1	1

*BHP=Batu Hampar River; THY= Titi Hayun River; BHJ=Bukit Hijau River; SDM= Sedim River, BMJ= Bukit Mertajam River, TBH= Teluk Bahang River (1= present; 0= absent).

Table 3: Scores of biological indices of the recreational rivers based on school holiday seasons.

Season	Indicats	BM	Indicati	ASP	Indic	EP	Indicati	
	FBI	ion	WP	on	T	ation	T on	
Before	4.7	Good	152	Very good	6.28	Good	34	Not impacted
During	5.3	Fair	157	Very good	6.38	Good	39	Not impacted
After	4.7	Good	151	Very good	6.38	Good	31	Not impacted

Table 4: Seasonal variations of water parameters (mean±SE) at selected recreational rivers.

Parameters	Before	During	After
Temperature (°C)	24.8 ± 0.11	21.97 ± 1.08	24.48 ± 0.15
pH	7.1 ± 0.07	6.33 ± 0.31	7.12 ± 0.10
DO (mg/L)	7.4 ± 0.12	6.9 ± 0.35	7.98 ± 0.07
AN (mg/L)	2.5 ± 0.25	2.75 ± 0.28	4.27 ± 0.40
BOD5 (mg/L)	0.3 ± 0.03	0.29 ± 0.04	0.34 ± 0.04
COD (mg/L)	23.4 ± 1.90	35.35 ± 3.73	58.56 ± 6.66
TSS (mg/L)	3.0 ± 0.34	3.91 ± 0.42	4.56 ± 0.30
T. Coliform (MPN)	878.24 ± 2.7	1529.24 ± 6.16	1259.1 ± 8.4
E. coli (MPN)	2.90	457.77 ± 4.63	254.44 ± 2.07
Enterococci (MPN)	864.6 ± 2.69	1042.9 ± 9.7	920.79 ± 0.39

4 DISCUSSION

This study revealed that the aquatic insect community was affected by human recreational activities especially DSH season as the diversity was found greatest before school holiday (BSH) and after school holiday (ASH) seasons. BSH season, the composition of aquatic insect was dominated by order Ephemeroptera followed by order Diptera. The domination of order Ephemeroptera at the recreational rivers was undeniable as previous study conducted by Flannagan *et al.* (1990) and Suhaila *et al.* (2014) showed 80% of the composition of aquatic insects was dominated by Ephemeroptera. Great number of Ephemeroptera collected BSH season

might be due to its ability to exploit various kind of habitat of extensive range from running to standing freshwater, thus it also known as cosmopolitan aquatic insects (Che Salmah *et al.*, 2001). Less human contact to river also part of the factors affecting the composition of aquatic insects at selected rivers since there were not much visitors in BSH season. The quality of water in BSH season was indicated as good and not impacted by the biological indices such as FBI, BMWP, ASPT and EPT index. The composition of aquatic insects DSH season was dominated by order Diptera from family Simuliidae and Chironomidae. In general, dipteran was the most advance aquatic insects as it able to survive under harsh condition of water (Al-Sahmi *et al.*, 2010) which perpendicular to the biological index of Family Biotic Index (FBI) of recreational rivers DSH considered as fair compared to BSH and ASH which were categorized as good. Relatively great abundance of Trichoptera in ASH season probably due to the restoration of the river due to human disturbance in the river. During picnicking or swimming, people tend to lift up the cobbles which were the microhabitat for the aquatic insect and release these insects into water from its case. So when sampling was carried out at this time, a lot of aquatic insect can be trapped. After school holiday season, the substrates are stable and were less disturbed because the recreational river was seldom visited by the people. The stable substrates were preferred by the Psychomyiidae and Hydropsychidae from order Trichoptera as their habitat (Yule and Yong, 2004).

During school holiday season, a slight deterioration of DO concentration and pH were observed. The least DO content in recreational rivers DSH season might be due to the water related activities such as swimming and picnic during this season because many visitors were observed in this season compared to other season. Although DSH recorded the greatest number of individuals of aquatic insects collected, it was dominated by order Diptera. The fecal coliform including *E. coli* count and enterococci count in this study discovered to be increased in DSH due to human activities at selected recreational rivers and it is reported that fecal coliform levels were higher at river with poorer water quality (Dawn-Arlene *et al.*, 2009 and Craig *et al.*, 2002). In addition, study conducted by Dawn-Arlene *et al.* (2009) also found faecal coliform, *E. coli*, and enterococci counts increased at recreational rivers when there were recreational users (Al-Sabahi, 2007; Eisakhani and Malakahmad, 2009).

5 CONCLUSION

Ephemeroptera was found the most abundant followed by order Diptera in all selected river. In respect to biological perspective, all selected river averagely considered as good quality and non-impacted river. Great diversity of aquatic insects collected after school holiday (ASH) season but low during the school holiday (DSH) due to the quality of water caused by the human recreational activities.

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