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WATER QUALITY ASSESSMENT WITH BIOTIC INDEX BASED ON ABUNDANCE AND DIVERSITY OF AQUATIC INSECTS IN A HILLY STREAM, BANGLADESH

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ABSTRACT

Study of stream insect fauna provide valuable insights into aspects of the stream channel ecosystem. The present study was conducted to investigate the aquatic stream living insect community, abundance and diversity in a hilly stream, Balukhali chora of Chittagong University campus to determine the water quality. The insects were collected with bottom dredge net from the edge and benthic regions of the Riffle zone and the Pool zone of the stream from January 2018 to December 2018. Insects were sampled using standard entomological method and determined their tolerance value. A total of 2535 insects were recorded, belonging to six insect orders, 30 families and 45 genera. The abundance ratio was higher in all the months in the Pool zone excepting the months of April, May, June and October. The orders Ephemeroptera, Odonata and Diptera were abundant in the Pool zone, while Hemiptera, Coleoptera and Lepidoptera were abundant in the Riffle zone. On the basis of Biotic Index, the most dominating orders Odonata and Hemiptera indicated good water quality, though the dipteran genus *Chironomus* spp. indicated poor quality in some of the months. The stream insect community structure of the two zones indicated that the overall water quality of the stream water was very good. Both manmade and natural interruption occurred in the stream channel due to human settlement, agricultural runoff and natural disasters. The study was conducted to know the abundance and diversity of aquatic insect community which indicated the water quality of the stream.

Keywords: Water quality, Biotic Index, Abundance, Aquatic insects, Hilly stream

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INTRODUCTION

In a lotic ecosystem, the flow of water from upstream to downstream and include biotic interactions amongst plants, animals and microorganisms as well as abiotic physical and chemical interactions. Streams and rivers are the most prominent features of landscape and a great example of lotic water system. There are two main zones in lotic ecosystems, rapids and pools. Rapids are fast flowing water zone which is also known as Riffle zone, whereas pools are slow running water zone. Aquatic biodiversity is the fundamental characteristics, which maintains the stability of aquatic ecosystem (Vinson and Hawkins, 1998). Tachet *et al*. (2003) stated that various kinds of disturbances were the main causes for increasing pressure of an aquatic ecosystem, which arises the threat to both aquatic living resources and human population. Biodiversity loss in freshwater ecosystem is an increasing phenomenon that occurs mainly due to human activities (Abell, 2002). Saunders *et al.* (2002) reported some main causes, such as the habitat destruction and defragmentation, exotic species introduction and global climate change impacts. Certain nutrients which are used in the agricultural and urban lands are mixed into river water by means of runoff or with the wash water of rain (Hynes, 1970; Smart *et al*., 1981) and influence the distribution and abundance of whole biotic community of the entire ecosystem (Townsend *et al*., 1997). The greatest threats comprising freshwater biodiversity are overexploitation, water pollution and eutrophication, flow modification, habitat degradation and invasive species (Dudgeon *et al*., 2006). The restoration costs for freshwater ecosystems, such as streams, have been substantial (Palmer *et al*., 2005) and, thus, thorough knowledge of these ecosystems is of utmost importance. Conservation of freshwater biodiversity and ecosystems is a great challenge under increasing human demands and activities (Vorosmarty *et al*., 2010). In this regard, pollution status of a tropical forest river based on the diverse composition of aquatic insect community was reported by Ohiokhioya *et al*. (2009). Bhatt and Pandit (2010) proposed a macro-invertebrate based new biotic index to evaluate the water quality in freshwater rivers. Whist, water quality assessment based on aquatic insect communities in a hilly stream was reported by Nasiruddin *et al*. (2013), whereby they calculated the Biotic Index value to find out the water quality of the stream.

As no previous study had been done on the hilly stream, the study was aimed to study the composition of aquatic insects of the stream, identification and their distribution pattern to provide more information for monitoring this ecosystem, to analyze their diversity patterns existing among the sampling sites in the two different zones, the Pool zone and the Riffle zone and to evaluate the quality of stream water on the basis of Biotic Index based on aquatic

insect abundance and diversity, as some insects indicated the water quality of the water body by showing their pollution tolerance as evaluated by Hilsenhoff (1987) and to know the impact of manmade and natural disturbance on the stream channel.

METHODOLOGY

The present study was carried out on a stream namely "Balukhali Chora" at Chittagong University (CU) campus, located between latitude 22º287'35.0" North and longitude 91º47'18.9" East. The stream was originated from Sonaichori approximately 3 km away from CU campus. From its source, the stream flows along North East direction through the CU campus and finally meets the Halda River. Two different zones were selected for the study from this stream, varied greatly in their water flow and underlying geology which created a wide range of habitats. Three different study sites were selected at each of the two different zones. Thus, six different study sites from the two different zones were surveyed for twelve-month duration from January to December 2018 in order to monitor the abundance and diversity of insect of these zones. During the survey, three sites from fast moving rapid zone (Riffle zone) was selected which was situated behind Botanical garden of CU campus. The location was 22º28'21.52" N and 91º46'44.25" E. The slow-moving lotic ecosystem of the stream was selected (Pool zone) for the survey, situated behind the "Masterda Surjo Sen" Hall, Institute of Forestry and Environmental Sciences in the CU campus, and the location was 22º28'53.16" N and 91º47'7.93" E. During the study period sampling was done once in each month and the insects were collected both from the edge and bottom of the stream with a bottom dredge net. Collected aquatic insects were identified up to genus or species level using taxonomic keys of Fraser (1933-1936), Ward and Whipple (1959), Needham and Needham (1962), Dean and Suter (1996), Dudgeon (1999), Dean (1999, 2000), Hawking and Theischinger (1999), Theischinger (2000), Heckman (2002), Bouchard (2004), and Kawai and Tanida (2005).

Abundance: The total numbers of insects in the two zones were recorded month wise and order wise, thus abundance of insects in two zones were ascertained.

Community dominance: Dominant species are those which are highly successful ecologically and which determine to a substantial extent, the conditions under which the associated species must grow. The simple community dominance index, i.e. percentage of abundance contributed by two most abundant species, put forth by Mc Naughton (1968) was used.

$$DC\ (\%) = \frac{y1+y2}{y} \times 100$$

Where, y1=number of individuals of most dominant species or the rank-1 species.

y2=number of individuals of the 2nd dominant species or the rank-2 species.

y=Total number of individuals of all species.

Abundance is closely associated with dominance but emphasize the relative proportions of various species in a community. The abundance was measured by calculating community dominance, Shannon-Wiener's Species diversity index (H or H') (Lloyd and Ghelard, 1964), Species richness (SR) (Gleason, 1922), and Species Evenness (J') (Pielou, 1966).

Shannon-Wiener's Species Diversity index (H or H'):

$$H' = -\sum_{i-1}^{s} (pi\ ln\ pi\ )$$

Species Richness (SR):

$$SR = S-1/\ logN$$

Where, S= Total number of species in a sample

N= Number of logs of total no. of individuals of all species.

Species Evenness (J'):

$$J' = H' / \log_2 S$$

Where, J'= Species Evenness

H'= Species Diversity

S= Number of the species

Biotic Index value:

In 1987, Hilsenhoff reevaluated the pollution tolerance scores and expanded the range from 0 to 10. The value is based on field and laboratory responses of these organisms toward organic pollution. One of the most comprehensive formula proposed by the Hilsenhoff (1987) was:

$$BI = \frac{\sum niai}{N}$$

Where, ni is the number of specimens in each taxonomic group,

ai is the pollution tolerance score for that taxonomic group

N is the total number of organisms in sample.

RESULT AND DISCUSSION

In this study aquatic insects were represented by 6 orders, 30 families, 45 genera and 55 species (Table-1). A total of 2535 insect individuals were collected from two different zones, Riffle zone and Pool zone of the stream. The collected six orders were: Ephemeroptera, Odonata, Hemiptera, Coleoptera, Diptera and Lepidoptera.

Table 1: List of aquatic insects collected during the study period from the Riffle zone and Pool zone of Balukhali Chora at Chittagong University campus.

Family	Genus/ Species	Family	Genus/ Species
Order: Ephemeroptera		**Order: Hemiptera**	
Ameletidae	*Ameletus* spp.	Mesoveliidae	*Mesovelia* spp.
Caenidae	*Brachycercus harrisella*		*Mesovelia mulsanti*
Leptophlebiidae	*Atalophlebia* spp.	Micronectide	*Micronecta* spp.
	Thraulus spp.	Notonectidae	*Notonecta* spp.
Order: Odonata (Zygoptera)		Nepidae	*Nepa cinerea*
Chlorocyphidae	*Chlorocypha* spp.		*Ranatra elongata*
Coenagrionidae	*Enallagma* spp.		*Ranatra filiformes*
	Ischnura spp.	Veliidae	*Rhagovelia* spp.
	Pseudagrion spp.		*Rhagovelia sumatrensis*
Lestidae	*Lestes sponsa*		*Rhagovelia singaporensis*
Platycnemididae	*Platycnemis* spp.	Belostomatiae	*Sphaerodema annulatum*
Order: Odonata (Anisoptera)			*Sphaerodema rusticum*
Cordulegastridae	*Cordulegaster* spp.	**Order: Coleoptera**	
Gomphidae	*Dromogomphus spinosus*	Hydrophilide	*Berosus* spp.
	Gomphus spp.		*Derallus* spp.
	Progomphus spp.		*Enochrus* spp.
Corduliidae	*Hemicordulia*		*Hydrochara* spp.
Libellulidae	*Libellula* spp.		*Hydrophillus* spp.
	Libellula quadrimaculata	Chrysomelide	*Chrysochus* spp.
Macromiidae	*Macromia* spp.		*Donacia* spp.
Order: Hemiptera		Noteridae	*Hydrocanthus* spp.
Gerridae	*Amemboa cambodiana*	**Order: Diptera**	
	Amemboa burmensis	Culicidae	*Culex* spp.
	Gerris spp.	Chironmidae	*Chironomus* spp.
	Gerris costae	Tabanidae	*Chrysops* spp.
	Gerris lacustris		*Simulium* spp.
	Gerris thoracicus		*Tabanus* spp.
Corixidae	*Corixa* spp.	**Order: Lepidoptera**	
Hydrometridae	*Hydrometra* spp.	Pyralidae	*Cadra cautella*
			Plodia interpunctella
		Noctuidae	*Trichoplusia* spp.
		Crambidae	*Hygraula* spp.

During the study, representatives of the Order Ephemeroptera was moderately found. Three families (Ameletidae, Caenidae and Leptophlebiidae) and four genera from the Order Ephemeroptera were identified. Of the total odonate collection, six genera under four families of suborder Zygoptera (Chlorocypidae, Coenagrionidae, Lestidae and Platycnemididae) and eight genera under five families (Cordulegastridae, Gomphidae, Cordulidae, Libellulidae and Macromiidae) of suborder Anisoptera were identified. Anisopteran larvae were easily distinguished from the Zygoptera by the absence of caudal gills, as well as general characteristics which included a rather squat body. Hemipteran insects were the most diversified, which included 20 species under nine families (Gerridae, Corixidae, Hydrometridae, Mesoveliidae, Micronectidae, Notonectidae, Nepidae, Veliidae and Belostomatidae). Three families (Hydrophilidae, Chrysomelidae, and Noteridae) and eight genera were identified under the order Coleoptera. The Nematocera are by far the most

diverse aquatic Diptera and within this suborder, the Chironomidae were the richest and most abundant family of stream living insects which was identified during this study along with one genera of Culicidae and three of Tabanidae families. Four genera with two species belonging to three families (Pyralidae, Noctuidae and Crambidae) of the order Lepidoptera were identified. Monthly abundance and abundance ratio of the insects collected from the Riffle zone and Pool zone are shown in Table-2.

Table 2: Total number and % composition of the aquatic insects collected from the two zones of Balukhali Chora and their abundance ratio during January-December 2018.

Month	Riffle zone		Pool zone		Abundance Ratio
	Total Number	%	Total Number	%	
Jan	182	16.09	183	13.03	1:1.01
Feb	153	13.53	465	33.12	1:3.04
Mar	198	17.51	220	15.67	1:1.11
Apr	233	20.60	79	5.63	1:0.34
May	55	4.86	35	2.49	1:0.64
Jun	73	6.45	19	1.35	1:0.26
Jul	25	2.21	95	6.77	1:3.80
Aug	7	0.62	42	2.99	1:6.00
Sep	5	0.44	15	1.07	1:3.00
Oct	77	6.81	60	4.27	1:0.78
Nov	45	3.98	79	5.63	1:1.76
Dec	78	6.90	112	7.98	1:1.44

Maximum number of insects were collected from the Riffle zone in April (20.60%) and from the Pool zone in February (33.12%) and lowest number was collected in the month of September from both Riffle zone (0.44%) and Pool zone (1.07%). Month wise, the dominance hierarchy of insects for the Riffle zone was in the order: April (20.60%) > March (17.51%) > January (16.09%) > February (13.53%) > December (6.90%) > October (6.81%) > June (6.45%) > May (4.86%) > November (3.98%) > July (2.21%) > August (0.62%) > September (0.44%) and for the Pool zone was in the order: February (33.12%) > March (15.67%) > January (13.03%) > December (7.98%) > July (6.77%) > April & November (5.63%) > October (4.27%) > August (2.99%) > May (2.49%) > June (1.35%) > September (1.07%). Abundance ratio was higher for the Pool zone in almost all the months excepting in the months of April, May, June and October when the ratio was (1:0.34), (1:0.64), (1:0.26) and (1:0.78) respectively. In the Riffle zone highest number of insect communities was found in the month of April, while in the Pool zone the insect community was highest in February. During the month of March, the second highest numbers of insect communities were found in both the zones, which indicated that dry season is favorable for stream insect communities.

The climate (precipitation), the regular annual variation (monsoon), and other meteorological conditions significantly affect the abundance of stream insects. Studies conducted in different rivers show that both the composition and richness of macro invertebrates increased from the head water to the mouth of a river, but also the width, depth, temperature and also the production, which directly influenced the composition and distribution of macroinvertebrates (Vane *et al*., 1980; Jacobsen, 2004). Most of the specimens were found in the months from November to April. The temperature was low (12-13ºC) in both the zones in the month of January, but the number of insects were comparatively low in the rainy months (May to September) probably due to the wash out from the surrounding through the water channel. The experimental stream had a narrow channel and was mostly interrupted by human irrigation activities and in the months of June to September landslides occurred due to heavy rainfall. Hence the abundance of insect individuals was interrupted both due to manmade and natural disasters. A comparative account of the representatives of the six orders occurring in the Riffle zone and Pool zone is given in Table-3. The total numbers of insects collected in the Pool zone was slightly higher than that of the Riffle zone (1:1.24). The orders Hemiptera and Odonata were the most dominant orders both in the Riffle zone and in the Pool zone. The orders Hemiptera and Odonata comprised 41.38% and 28.29% in the Riffle zone while 31.62% and 30.63% in the Pool zone respectively of the total sample. The Lepidoptera was the least dominant Order in both the zones comprising 0.97% and 0.21% of the total collection in the Riffle zone and the Pool zone respectively. In the Pool zone, the representatives of the Order Ephemeroptera were greater in number than in the Riffle zone. Out of the two zones, the representatives of Ephemeroptera, Odonata and Diptera were higher in the Pool zone than in the Riffle zone, while the representatives of Hemiptera, coleoptera and Lepidoptera were higher in the Riffle zone than in the Pool zone.

Table 3: Total number, % of aquatic insects and their abundance ratio in each Order collected from the Riffle zone and Pool zone of Balukhali Chora during January-December 2018.

Order	Riffle zone		Pool zone		Abundance Ratio
	Number	%	Number	%	
Ephemeroptera	70	6.19	142	10.11	1:2.03
Odonata	320	28.29	430	30.63	1:1.34
Hemiptera	468	41.38	444	31.62	1:0.95
Coleoptera	55	4.86	19	1.35	1:0.35
Diptera	207	18.30	366	26.07	1:1.77
Lepidoptera	11	0.97	3	0.21	1:0.27
Total	1131	100	1404	100	1:1.24

The percentage composition of the orders of aquatic insects collected from the two zones during the twelve-month study period is given in Table-4. Ephemeroptera represented by four

genera was the slightly moderate abundant order of insects among the total collection comprising 6.19% in Riffle zone and 10.11% in Pool Zone. The group reached its peak of abundance during March (31.43%) and was moderately abundant in January and February (24.29%) in Riffle zone. In the Pool zone highest (46.48%) and near to highest (42.25%) numbers were collected during February and March respectively from the Pool zone. It might be due to the fact that dry season was favorable for reproduction and development of ephemeropteran insects. The Abundance of ephemeropteran insects decreased during rainy season and attained minor peak of abundance during October (1.43%) and June (2.86%) in the Riffle zone and remained absent in the other months.

Table 4: Percentage composition of the orders of aquatic insects collected during January-December, 2018 from the Riffle zone and Pool zone of Balukhali Chora.

Order	% Composition of insects in Riffle zone											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ephemeroptera	24.29	24.29	31.43	0.00	0.00	2.86	0.00	0.00	0.00	1.43	0.00	15.72
Odonata	10.93	10.31	14.06	16.56	11.25	10.93	5.93	1.56	0.00	8.75	6.56	3.12
Hemiptera	25.00	8.33	12.61	21.15	1.92	4.49	0.43	0.21	0.43	9.62	4.49	11.32
Coleoptera	10.91	14.55	0.00	23.64	18.18	3.64	7.27	1.82	5.45	5.45	5.45	3.64
Diptera	2.42	27.05	30.92	32.85	0.00	6.28	0.00	0.00	0.00	0.00	0.00	0.49
Lepidoptera	18.18	0.00	72.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.09
Order	**% Composition of insects in Pool zone**											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Ephemeroptera	42.25	46.48	11.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Odonata	3.72	21.60	21.80	8.84	5.30	4.40	22.00	3.70	3.40	0.70	0.47	3.72
Hemiptera	7.43	18.24	14.64	7.43	0.00	0.00	0.00	5.68	0.00	12.84	11.94	21.62
Coleoptera	42.11	0.00	47.37	10.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diptera	17.21	61.48	9.84	1.64	3.28	0.00	0.00	0.00	0.00	0.00	6.56	0.00
Lepidoptera	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Odonata ranked second in abundance among the orders collected from Riffle zone (28.29%) and Pool zone (30.63%). This group was most diverse with 13 genera and was found in both the zones throughout the year and reached maximum abundance in April (16.56%) in the Riffle zone and July (22.00%) in the Pool zone and low abundance during August (1.56%) in the Riffle zone and November (0.47%) in the Pool zone. Hemiptera was the most abundant Order among the six other orders represented by 11 genera and comprising 41.38% in the Riffle zone and 31.62% in the Pool zone. The group reached its peak of abundance during January (25.00%) in the Riffle zone and December (21.62%) in the Pool zone, indicating the group favoring cold season. Abundance of hemipteran insects was lowest during July and September (0.43%) in Riffle zone and in August (5.68%) in Pool zone. The group was absent in September in both the zones and in May to July in the Pool zone probably due to landslides and cutting of the stream edge by the farmers. Coleoptera was represented by eight genera, was not so abundant comprising 4.86% in Riffle zone and 1.35% in Pool zone, reached its peak of abundance during April (23.64%) in Riffle zone and in March (47.37%) in Pool zone.

Lowest abundance was seen in August (1.82%) in Riffle zone and during April (10.53%) in Pool zone. Insects of this order was absent in March in the Riffle zone and in February and May to December in the Pool zone. Hence, in the Pool zone coleopteran insects was abundant in dry season, or otherwise were absent throughout the year. But in Riffle zone the coleopterans were found in almost throughout the year except in March. Diptera represented by five genus was third in abundance in Riffle zone (18.30%) and in Pool zone (26.07%) was most abundant in Riffle zone during April (32.85%) and was absent in May and July to November. In the Pool zone the group was most abundant during February (61.48%) and absent in June to October and December. The group showed lowest abundance during December (0.49%) in the Riffle zone and April (1.64%) in the Pool zone. The Lepidoptera was represented by three families and four genera. In the Riffle zone insects of this order was present mostly in March (72.73%), to some extent in January (18.18%), rarely in December (9.09%) and absent in rest of the months. In the Pool zone only one genus *Trichoplusia* spp. was found in the month of January. The Lepidoptera comprised 0.97% in the Riffle zone and 0.21% in the Pool zone of the total collection.

The diversity and community composition changed in the two zones. Higher number of aquatic insect fauna was found in the Pool zone and lower in the Riffle zone. Only specific and adaptive organisms can survive in the Riffle zone. In both zones, Hemiptera was the most dominant order. But in the Riffle zone the Hemiptera and Coleoptera was higher, while the Ephemeroptera, Odonata and Diptera was lower than in the Pool zone. The lowest abundant order in both the zones was Lepidoptera. In the Pool zone odonates were the most abundant and were found in almost all the months from March to August. In the months of August, and October to December the hemipteran insects dominated while the Dipterans dominated in the months of January and February. The Riffle zone was completely dominated by hemipteran insects in the months of January to April, September, October and December, and by odonates in the rest of the months. The monthly Community Dominance index of aquatic insect species was calculated in the Riffle zone and Pool zone given in Table-5 and it was observed from monthly variations that the dominance index (δ) of aquatic insects varied from month to month.

Table 5: Monthly % Community Dominance (DC) of aquatic insects in the Riffle zone and Pool zone of Balukhali Chora collected from January-December 2018.

Riffle Zone		
Month	**Most dominating species**	**DC (%)**
Jan	*Rhagovelia singaporensis, Notonecta* spp.	22.53
Feb	*Chironomus* spp., *Sphaerodema rusticum*	45.10

Mar	*Chironomus* spp., *Amemboa cambodiana*	42.42
Apr	*Chironomus* spp., *Lestes sponsa*	42.49
May	*Dromogomphus spinosus, Macromia* spp.	38.18
Jun	*Lestes sponsa, Chironomus* spp.	45.21
Jul	*Lestes sponsa, Libellula* spp.	76.00
Aug	*Ischnura* spp., *Rantra filiformes, Berosus* spp.	100.00
Sep	*Chrysochus* spp., *Gerris costae*	100.00
Oct	*Rhagovelia singaporensis, Gerris* spp.	46.75
Nov	*Rhagovelia singaporensis, Gerris* spp.	31.11
Dec	*Rhagovelia singaporensis, Sphaerodema rusticum*	42.31
Pool Zone		
Month	**Most dominating species**	**DC (%)**
Jan	*Ameletus spp., Chironomus* spp.	54.64
Feb	*Chironomus* spp., *Culex* spp.	48.39
Mar	*Lestes sponsa, Gerris* spp.	44.09
Apr	*Lestes sponsa, Dromogomphus spinosus, Gerris* spp.	46.84
May	*Dromogomphus spinosus, Chironomus* spp.	91.43
Jun	*Lestes sponsa*	100
Jul	*Lestes sponsa*	100
Aug	*Rhagovelia singaporensis, Chlorocypha* spp.	88.10
Sep	*Gomphus* spp., *Lestes sponsa*	100
Oct	*Rhagovelia singaporensis, Gerris Lacustris*	90
Nov	*Chironomus* spp., *Rhagovelia singaporensis, Gerris* spp.	63.29
Dec	*Gerris* spp., *Rhagovelia singaporensis*	55.36

The community dominance value was 100.00% in the Riffle zone in August and September, which was recorded as the highest value of the year. *Ischnura* spp., *Ranatra filiformes* and *Berosus* spp. were found in August and *Chrysochus* spp. and *Gerris costae* were found in September. The second dominant species *Ranatra filiformes* and *Berosus* spp. both had the same rank throughout the year, so, both species were used to calculate the community dominance value in the month August. In January, in the Riffle zone, the most dominating insects were *Rhagovelia singaporensis* and *Notonecta* spp. and the community dominance value was 22.53%, which was the lowest value in the Riffle zone. The lowest value of community dominance indicated the diversity of species in the respective month. In the Pool zone only *Lestes sponsa* was found in the months of June and July, and the dominance value was 100%. The value was 100% also in the month September, when the dominant and only found species were *Gomphus* spp. and *Lestes sponsa*. The community dominance was low i.e., 44.09% in March. So, the most diversified month was March in the Pool zone. In the Riffle zone, the most dominating species were *Gerris* spp. and *Rhagovelia singaporensis.* The second most dominating species was the *Chironomus* spp. The *Sphaerodema* spp. was found also higher in number than the other species. On the other hand, in the Pool zone the most dominating species was *Chironomus* spp. and *Gerris* spp. The second most dominating species was *Lestes sponsa*. From the community dominance table, it can be seen that *Gerris* spp. was highly dominant over all other species in the both zones.

Species diversity is a measure of both the number of species (species richness) and the relative contribution of each of these species to the total number of individuals in a community. The species diversity, species richness and species evenness of stream living insects showed that, the species diversity decreased in Riffle zone in the month of September (0.68) with lowest insect abundance (5). In February the species diversity was highest (1.44) in the Riffle zone with moderately high insect abundance (153), indicating that the water quality was good in that month (Table-6). In the Pool zone the species diversity was within 0-1.50 and did not fluctuate greatly which indicated that water quality was almost same in all the months. Due to the good water quality, the species diversity was good. In the Pool zone, the highest monthly species diversity value (1.47) with comparatively high abundance (183) was observed in January and the lowest (0.20) with comparatively low abundance (60) in October (Table-6). The value of species diversity was 0 in the months of June, July and September. Lowest number of species was found in Riffle zone during September among the total survey. Higher number of species was also found in Riffle zone during April. In Riffle zone highest species richness was observed in September (7.15) with low insect abundance (5) and lowest in April (2.11) with high insect abundance (233). Species Richness was highest in September (4.25) with low insect abundance (5), and lowest in February (1.87) with second highest abundance (220) in Pool zone (Table-6). In the Riffle zone species evenness was highest (0.56) with moderately high abundance (153) in February and lowest in September (0.26) with low abundance (5). The Species evenness was 0 in the month of June, July and September and was lowest in October (0.08) with comparatively low abundance (60) and highest in January (0.57) with moderately high abundance (153) in Pool zone (Table-6).

Table 6: Monthly fluctuation in Species diversity (H'), Species richness (SR), and Species evenness (J') of the total aquatic insects collected from the Riffle zone and Pool zone of Balukhali Chora.

Zone	Diver. Index	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Riffle Zone	H'	1.08	1.44	1.43	1.22	0.89	1.22	0.70	0.80	0.68	0.87	0.90	1.01
	SR	2.21	2.29	2.18	2.11	2.87	2.68	3.58	5.92	7.15	2.65	3.02	2.64
	J'	0.42	0.56	0.55	0.47	0.34	0.47	0.27	0.31	0.26	0.34	0.35	0.39
Pool Zone	H'	1.47	1.25	1.34	1.00	0.65	0.00	0.00	0.65	0.00	0.20	0.72	0.41
	SR	2.21	1.87	2.13	2.63	3.24	3.91	2.53	3.08	4.25	2.81	2.63	2.44
	J'	0.57	0.48	0.52	0.39	0.25	0.00	0.00	0.25	0.00	0.08	0.28	0.16

Species Diversity was higher in Riffle zone than the Pool zone except in the month of January when the species diversity was lower in the Riffle zone in comparison with Pool zone. Species Richness was also higher in Riffle zone except the month of January, when the species richness of both zones was equal and April to June and October, when species richness was lower in the Riffle zone than in the Pool zone. Species Evenness was higher in

Riffle zone excepting the months of January and November. Hence, the insect species were not so well diversified in both the Riffle zone and the Pool zone, probably due to natural disaster and human interruption like cutting the stream edge and damming the stream channel in winter. Furthermore, the comparative study of the insect abundance and the species diversity indices showed that the species diversity and species evenness were positively correlated and species richness was negatively correlated with the insect abundance.

For detecting the quality of stream water, biotic index was calculated. Samples obtained from January to December 2018 gave the most reliable values of biotic index and water quality of stream was evaluated following Hilsenhoff (1987). The result of Hilsenhoff's Biotic Index (HBI) indicated that, the stream water quality of the Pool zone varied from very poor to excellent in different months (Table-7). The stream water quality of Riffle zone varied from fair to excellent in different months. The number of insects could have influenced the results for each site.

The HBI value was within 1.64-3.50 and indicating excellent water quality in January, May and October in the both the zones. Besides, the Riffle zone had excellent water quality in September while in Pool zone in August, November and December. Excellent water quality refers to no apparent organic pollution in the water. Very good water quality was found in February, March, July, August, November and December in the Riffle zone and the HBI score varied from 3.61-4.38 in the Riffle zone which indicated possible slight organic pollution occurred. On the contrary the Pool zone showed very good water quality only in February with the HBI value 4.1. The Riffle zone showed good water quality with some organic pollution in April when the Biotic Index score was 4.54 and fair water quality with fairly significant organic pollution with HBI score 5.88 in June. The Pool zone showed good water quality with some organic pollution in March, April and September, when the HBI value varied from 4.60 to 5.30. In June and July the water quality was very poor with score 9.00 in the Pool zone with severe organic pollution. After the total survey of twelve months, it was found that the average HBI score of the Riffle zone was 3.68 and of the Pool zone was 4.47 which refers that the both the zones had very good water quality with possible slight organic pollution.

Table 7: Evaluation of water quality using Hilsenhoff's Biotic Index (HBI) values of samples collected from January-December 2018 from Riffle zone and Pool zone of Balukhali Chora.

Riffle Zone													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean $\pm SE$
HBI Value	3.33	4.19	3.78	4.54	1.64	5.88	3.74	4.00	2.00	3.09	4.38	3.61	3.68 $\pm$1.12
Water quality	Excellent	Very Good	Very Good	Good	Excellent	Fair	Very Good	Very Good	Excellent	Excellent	Very Good	Very Good	Very Good
Comments	No apparent organic pollution	Possible slight organic pollution	Possible slight organic pollution	Some organic pollution	No apparent organic pollution	Fairly significant organic pollution	Possible slight organic pollution	Possible slight organic pollution	No apparent organic pollution	No apparent organic pollution	Possible slight organic pollution	Possible slight organic pollution	Slight organic pollution
Pool Zone													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean $\pm SE$
HBI Value	2.5	4.1	5.2	4.6	2.9	9.0	9.0	3.5	5.3	2.0	3.5	2.0	4.47 $\pm$2.39
Water quality	Excellent	Very Good	Good	Good	Excellent	Very Poor	Very Poor	Excellent	Good	Excellent	Excellent	Excellent	Very Good
Comments	No apparent organic pollution	Possible slight organic pollution	Some organic pollution	Some organic pollution	No apparent organic pollution	Severe organic pollution	Severe organic pollution	No apparent organic pollution	Some organic pollution	No apparent organic pollution	No apparent organic pollution	No apparent organic pollution	Slight organic pollution

CONCLUSION

Water quality of the natural water bodies not only help to ascertain the pollution control measures but also indicates its impact on aquatic ecosystem. Benthic macro invertebrates are good indicators of water quality of water bodies and fluctuations in aquatic insect communities give information on water quality as revealed by Biotic Index. Human interruption should be taken under control or to be limited, otherwise the overall aquatic ecosystem will be interrupted and thus can cause a great negative impact on the entire stream, Balukhali Chora.

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