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ASSESSING THE IMPACTS OF POND WATER QUALITIES ON ABUNDANCE OF AQUATIC INSECTS IN CHITTAGONG UNIVERSITY CAMPUS

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ABSTRACT

The physical and chemical properties of water are of great importance for the survival of aquatic organisms. Aquatic insect abundance depends on these physicochemical parameters of water. A faunistic survey of the aquatic insects from three ponds of Chittagong University Campus was made for a period of twelve months whereby a total at 2490 aquatic insects belonging to six insect orders were collected. Physicochemical parameters of water of the three experimental ponds were measured in terms of water depth, Secchi depth, air temperature, water temperature, conductivity, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), free Carbondioxide (fCO_2) and Calcium (Ca^{++}) for the same period. The abundance of the aquatic insects was influenced by the physical condition of the ponds as well as the physicochemical parameters of the water. In most cases the relationship between the total abundance of aquatic insect orders and the physicochemical properties of water of the three experimental ponds were positively correlated with Secchi depth, air and water temperature, pH, DO and Calcium but negatively correlated with water depth, conductivity, BOD and fCO_2.

Key words: Aquatic insect, abundance, physicochemical parameters, pond, correlation

Introduction

The presence of aquatic insects in the environment is correlated with diverse factors (Wetzel 1982). Temperature is a factor which is essential for growth of organisms. Depth of water body has also some influence in the community structure of wetland ecosystem. Turbidity is directly related with light and insects can live in optimum limit of turbidity. Conductivity is the presence of molecular electrolytes (acids, bases, and salts in solution) in water. DO indicate the concentration of oxygen content of natural waters. The pH is a measurement of the level of acid or alkali in a solution. Biochemical Oxygen Demand (BOD) refers to the amount of oxygen that would be consumed if all the organics in one liter of water were oxidized by bacteria and protozoa. Calcium is also an important limiting factor for abundance and growth of aquatic animals depending on the source and treatment of the water. Signs of water quality deterioration are evident in the result of the physicochemical analyses. In low conductivity water aquatic organisms dominate, as most organisms in low conductivity water bodies maintain high internal ion concentration relative to its surrounding medium. And also certain physiological effects on animals are affected by the number of available ions indicated by amount of TDS. DO concentration is also important, as beside the respiratory process of the organisms, the solubility and availability of nutrients also depend on DO concentration of an aquatic body, hence having direct effect on aquatic lives. Decrease of DO level of a water body below 5mg/l put aquatic life under stress. As BOD is an indication of pollution index, hence the higher the BOD values the greater will be its unsuitability for aquatic lives. Similarly, the lesser the free CO2 value of water the better will be the water quality for sustaining aquatic lives. pH influences many biological and chemical processes in organisms, hence lower pH puts aquatic lives under stress. A good number of scientific works are available on aquatic insects in different parts of the world. Hsu and Yang (1997, 2005), Wolf *et al.* (1999) and Traichaiyaporn (2000) studied on the relationship of macro-invertebrates especially aquatic insects with water quality. Chiangthong (2005) studied on water quality analysis in Chiang Rai province of Thailand and determined the insects as bioindicator of the water qualities. Thani and Phalaraksh (2008) studied on aquatic insect's diversity and water quality of Mekong river of Thailand. Purkayastha and Gupta (2012) studied on insect diversity and water quality parameters of two ponds of Chatla wetland, Barak valley of Assam. Gupta *et al.* (2013) studied on the use of aquatic insects and water quality assessment of ponds around two cement factories of Assam, India. Vasantkumar and Roopa (2014) and Payakka and Prommi (2014) reported on physicochemical and aquatic insect diversity of pond ecosystem in Karwar, India and receiving water body of Thailand.

In Bangladesh, the relationships between the aquatic insects and physicochemical factors of different ponds, lake and a stream were studied by Reza (2010), Ahad *et al.* (2012), and Nasiruddin *et al.* (2015) at Chittagong University Campus, which are still fewer and there is enough scope for more work in this aspect. This research is hence related to the occurrence and monthly variations of aquatic insects in the three experimental ponds in relation to some physicochemical parameters of those water bodies is being selected as one of the prior and important studies. It needs to be continued for further information's on aquatic insects in water bodies. The aim of this study was to investigate the abundance of aquatic insects in relation to physicochemical parameters of the three experimental ponds of Chittagong University Campus.

Materials and Methods

For the collection of aquatic insects, regular field trips were made at monthly intervals during the year 2012-2013. Aquatic insects were collected from nine sites of the three experimental ponds which were situated beside the Arts faculty and behind the Science faculty. The geographical location of Pond I was 22°39′29″ N and 95° 48′94″ E, of Pond II was 22°28′40″ N and 95°47′38″ E and Pond III was 22°38′79″ N 92°65′28″ E. Sampling was done mainly in the mid morning between 9.00-11.00 AM. Insect specimens were collected by insect drag net (1 mm mesh size). Net sweeping distance was 3-4 meters. Number of sweep per station was ten. Specimens were collected from the surface of the marginal zones and around the vegetations. The specimens along with debris and pond water were collected in plastic containers and taken to the laboratory for sorting. Collected aquatic insects were identified following Ward and Whipple (1959), Ross (1959), Macan (1959), Clegg (1974), Needham and Needham (1962), and Rahman and Hossain (1988). Abundance was expressed as percentage of fauna belonging to a particular order calculated from the total number of individuals of a monthly sample per station in each pond.

Physical parameters: The readings of water depths at collection sites of the three experimental ponds were taken with the help of a measuring tape at 1 m distance from the edge. Secchi depths were taken with the help of a black and white secchi disc following the technique of Almazan and Boyd (1978). The readings of air and water temperatures were taken with the help of a centigrade thermometer of minimum readability of 0.1°C. The conductivity of the water was estimated by a conductivity meter (T $ds^3 \times 10$ T 194, Model No. 3303, Made in Singapore) with sensitivity ±1 µs/cm.

Chemical parameters: Hydrogen ion concentration (pH) of water was measured by pH meter (Model-Hanna instrument, Portugal). Winkler's Azide modification method was the method for the determination of Dissolved Oxygen (DO) and Biological Oxygen Demand (BOD) approved by APHA (2005), whereby

$$\text{DO (mg/l)} = \frac{\text{Actual strength of titrant x ml of titrant}}{\text{standard stength of titrant}}.$$

The principal of Biological Oxygen Demand (BOD) involved the measuring of difference in oxygen concentration in the sample before and after incubating it for five days (BOD_5). Free Carbondioxide (fCO_2) was analyzed by alkalinity method (APHA 2005**)** that reacted with strong alkali (such as Sodium hydroxide) to form bicarbonates. Completion of the reaction was indicated by the development of a pink colour, characteristic for phenolphthalein indicator. The EDTA titrimetric method (APHA 2005) was the method used for Calcium ion (Ca^{++}) determination.

Pearson's Correlation coefficient (r) was used to determine the inter dependence of the parameters where insect abundance was correlated with the physicochemical parameters of pond waters.

Results

Abundance of aquatic insects: The monthly abundance of total aquatic insects collected from the three experimental ponds is given in Table 1. The overall ranking of the insect orders in Pond I was: Odonata (41.68%) > Hemiptera (28.32% > Trichoptera (16.08%) > Diptera (9.44%) > Ephemeroptera (3.83%) > Coleoptera (0.65%). In Pond II the ranking of the abundance of the insect orders was: Odonata (44.24%) > Hemiptera (35.13%) > Diptera (17.10%) > Ephemeroptera (1.86%) > Trichoptera (1.67%) > Coleoptera (0%). In Pond III the ranking of the abundance of the insect orders was in the order: Odonata (41.84%) > Hemiptera (27.55%) > Diptera (15.24%) > Trichoptera (12.93%) > Ephemeroptera (2.15%) > Coleoptera (0.11%).

Monthly comparison of physicochemical properties of water of the three experimental ponds

The mean±SE values of physicochemical parameters of the water of the three experimental ponds during the study period are given in Tables 2 and 3.

Physical parameters (Table 2): During the study period water depth ranged from 49.97±3.74 to 86.20±1.04 cm in Pond I, 36.20±3.19 to 65.43±3.19 cm in Pond II and 40.03±2.90 to 58.19±1.88 cm in Pond III, whilst secchi depth ranged from 22.00±1.67 to 50.41±7.40 cm in Pond I, 16.68±2.65 to 31.02±1.01 cm in P20.33±0.41 to 36.33±0.41 ºC, 19.44±0.54 to 35.00±0.00 ºC and 17.44±0.36 to 37.00±0.00 ºC in ponds I, II and III respectively, whilst water temperature ranged from 18.67±0.24 to 33.33±0.41ºC, 17.78±0.36 to 29.00±0.71 ºC and 15.00±0.71 to 32.67±1.63 ºC in ponds I, II, and III respectively. Conductivity ranged in Pond I from 25.67±2.16 to 169.33±6.72 µs/ cm, in Pond II from 29.33±0.41 to 203.33±0.82 µs/cm and in Pond III from 30.67±0.41to 53.33±0.41µs/cm.

Chemical parameters (Table 3): During the study period total pH (Hydrogen ion concentration) ranged from 6.57 to 8.60 in Pond I, 6.13 to 8.33 in Pond II and 7.03 to 8.58 in Pond III. The DO (Dissolved Oxygen) ranged from 1.73 to 11.20 mg/l, 1.70 to 11.78 mg/l and 2.50 to 9.98 mg/l in ponds I, II and III respectively, whilst BOD (Biological Oxygen Demand) ranged from 0.13 to 2.94 mg/l, 0.06 to 2.49 mg/l and 0.06 to 2.94 mg/l in ponds I, II and III respectively. Values of fCO_2 (free Carbon dioxide) ranged from 0.64 to 7.16 mg/l, 0.64 to 7.45 mg/l and 0.10 to 7.50 mg/l in ponds I, II and III respectively and Ca^{++} (Calcium ion) ranged from 0.08 to 2.60 mg/l, 0.08 to 4.61 mg/l and 0.33 to 3.17 mg/l in ponds I, II, and III respectively.

The abundance of aquatic insects with relation to physicochemical parameters of water

The correlation-coefficient (r) values of abundance of insect orders and the different physicochemical parameters are given in Tables 4 and 5.

Relationship between the monthly abundance of the orders of aquatic insects vs. the different physicochemical parameters of water (Table 4): In Pond I, there was no significant correlation between the abundance of ephemeropteran and dipteran insects and the studied parameters of water. In the order Odonata, abundance of various genera had significant correlations with air and water temperature at 0.01 level and Biological Oxygen Demand at 0.1 level. In the order Hemiptera, abundance of various genera had significant correlations with water depth and Biological Oxygen Demand at 0.1 level. In the order Trichoptera, abundance of various genera had significant correlations with secchi depth at 0.05 level and Dissolved Oxygen at 0.1 level. In the order Coleoptera, abundance of various genera had significant correlation with Dissolved Oxygen at 0.1 level only. In Pond II, the total ephemeropteran insect abundance had significant correlation with Biological Oxygen Demand at 0.1 level only. In the order Odonata, the abundance of various genera had significant correlation with air temperature at 0.05 level only. Both in the orders Hemiptera and Diptera the abundance of various genera had no significant correlations with the physicochemical parameters of the water body. In the order Trichoptera, the abundance of various genera had significant correlations with air temperature at 0.05 level and water temperature at 0.1 level. In the order Coleoptera, the individuals of various genera had zero correlations with the physicochemical parameters of the water body.

Table 1. Monthly abundance of the aquatic insects collected from the three experimental ponds during the year of 2012-2013

Pond	Order	Month													
		Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total	%
P-I	Ephemeroptera	1	0	0	0	1	0	4	9	0	10	6	10	41	3.83
	Odonata	23	22	18	34	42	25	13	46	62	50	41	70	446	41.68
	Hemiptera	44	31	30	12	35	30	29	29	0	17	6	40	303	28.32
	Diptera	9	0	0	1	1	1	29	4	10	15	3	8	101	9.44
	Trichoptera	82	25	14	6	0	0	0	0	0	0	25	20	172	16.08
	Coleoptera	0	1	0	1	1	0	0	0	0	0	2	2	7	0.65
	Total	159	79	62	54	80	56	75	88	72	92	83	170	1070	100
P-II	Ephemeroptera	1	2	0	0	1	1	0	5	0	0	0	0	10	1.86
	Odonata	9	19	10	9	16	20	18	34	28	20	15	40	238	44.24
	Hemiptera	22	17	14	15	11	15	14	8	18	15	10	30	189	35.13
	Diptera	62	2	6	1	0	2	3	6	0	5	5	0	92	17.10
	Trichoptera	4	3	0	0	0	0	0	0	0	0	2	0	9	1.67
	Coleoptera	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
	Total	98	43	30	25	28	38	35	53	46	40	32	70	538	100
P-III	Ephemeroptera	0	4	0	1	4	4	0	0	1	1	3	1	19	2.15
	Odonata	12	13	14	19	18	30	34	30	40	45	60	54	369	41.84
	Hemiptera	41	18	17	22	7	11	14	25	28	20	20	20	243	27.55
	Diptera	20	5	3	0	10	35	15	17	1	0	0	30	136	15.42
	Trichoptera	38	9	0	0	0	0	0	0	0	11	10	46	114	12.93
	Coleoptera	0	0	0	0	0	0	0	1	0	0	0	0	1	0.11
	Total	111	49	34	42	39	80	63	73	70	77	93	151	882	100

Table 2. Physical parameters of the water of three experimental ponds during the year of 2012-2013

Month	**Pond I**					**Pond II**					**Pond III**				
	Water depth cm ±SE	Secchi depth cm ±SE	Air temp ^{0}C ±SE	Water temp ^{0}C ±SE	Conduc. µS/cm ±SE	Water depth cm ±SE	Secchi depth cm ±SE	Air temp ^{0}C ±SE	Water depth cm ±SE	Conduc. µS/cm ±SE	Water depth cm ±SE	Secchi depth cm ±SE	Air temp ^{0}C ±SE	Water temp ^{0}C ±SE	Conduc. µS/cm ±SE
Nov	71.89 ± 5.33	50.41 ± 7.40	25.78 ± 0.13	21.67 ± 0.24	27.56 ± 0.98	45.49 ± 3.55	26.39 ± 5.00	21.78 ± 0.13	19.45 ± 0.49	31.56 ± 0.36	58.19 ± 1.88	32.43 ± 1.74	23.00 ± 0.00	18.89 ± 0.49	33.78 ± 1.11
Dec	63.26 ± 2.44	38.37 ± 1.83	20.33 ± 0.41	18.68 ± 0.25	25.67 ± 2.16	43.68 ± 2.51	30.75 ± 1.15	19.44 ± 0.54	17.78 ± 0.36	160.00 ± 8.34	55.51 ± 3.27	32.01 ± 1.67	17.44 ± 0.36	15.00 ± 0.71	42.67 ± 1.78
Jan	63.28 ± 1.86	33.21 ± 1.79	20.67 ± 0.41	18.67 ± 0.24	51.00 ± 0.71	42.79 ± 2.17	31.02 ± 1.01	21.22 ± 0.27	18.66 ± 0.41	60.78 ± 9.08	51.60 ± 4.39	27.54 ± 2.72	23.56 ± 0.29	21.11 ± 0.13	39.44 ± 3.21
Feb	61.17 ± 1.53	28.08 ± 1.74	27.33 ± 0.41	25.67 ± 0.41	169.33 ± 6.72	40.47 ± 1.71	19.47 ± 1.10	26.11 ± 0.13	22.89 ± 0.59	202.67 ± 1.08	48.20 ± 4.84	23.32 ± 1.86	26.67 ± 0.41	23.00 ± 1.19	34.33 ± 0.41
Mar	49.97 ± 3.74	22.00 ± 1.67	36.33 ± 0.41	33.33 ± 0.41	35.33 ± 4.55	36.20 ± 3.19	16.68 ± 2.65	33.00 ± 0.00	28.67 ± 0.82	203.33 ± 0.82	41.10 ± 3.11	17.87 ± 2.60	24.33 ± 0.41	30.67 ± 1.08	32.33 ± 1.47
Apr	65.59 ± 3.63	30.63 ± 2.95	28.00 ± 0.0	25.33 ± 0.41	34.67 ± 0.82	50.40 ± 3.99	26.73 ± 2.48	26.00 ± 0.00	21.33 ± 1.08	153.33 ± 2.48	42.07 ± 2.93	19.93 ± 3.74	30.00 ± 0.00	28.67 ± 0.41	53.33 ± 0.41
May	78.33 ± 1.88	37.70 ± 2.15	26.00 ± 0.0	23.00 ± 0.00	26.67 ± 0.41	63.50 ± 1.74	30.87 ± 2.79	23.00 ± 0.00	20.00 ± 0.00	139.00 ± 0.00	45.40 ± 3.22	25.83 ± 1.68	30.00 ± 0.00	24.33 ± 1.08	30.67 ± 0.41
June	76.53 ± 3.82	37.93 ± 2.00	30.00 ± 0.0	26.00 ±1.41	32.67 ± 1.47	65.43 ± 3.19	29.70 ± 2.62	28.00 ± 0.00	23.00 ± 0.00	29.33 ± 0.41	53.47 ± 1.81	22.69 ± 1.47	30.00 ± 0.00	26.33 ± 1.08	43.00 ± 0.71
July	75.17 ± 2.86	35.18 ± 2.10	30.00 ± 0.0	26.67 ± 1.63	38.00 ± 1.87	63.03 ± 1.79	28.17 ± 1.76	28.00 ± 0.00	22.00 ± 1.22	33.00 ± 1.87	46.77 ± 3.63	18.67 ± 2.33	30.00 ± 0.00	27.67 ± 1.08	38.67 ± 1.78
Aug	70.20 ± 4.26	32.80 ± 2.62	31.00 ± 0.0	27.33 ± 1.47	52.33 ± 1.47	56.63 ± 3.46	28.07 ± 2.26	32.00 ± 0.00	29.00 ± 0.71	142.67 ± 2.67	45.90 ± 3.51	18.70 ± 2.15	32.00 ± 0.00	30.33 ± 0.41	40.00 ± 0.71
Sep	86.20 ± 1.04	34.90 ± 2.75	24.00 ± 0.0	22.33 ± 1.47	54.69 ± 3.58	63.13 ± 1.82	21.77 ± 2.51	24.00 ± 0.00	18.33 ± 1.08	159.67 ± 6.72	46.27 ± 3.83	14.27 ± 1.06	30.00 ± 0.00	27.67 ± 1.08	39.00 ± 0.71
Oct	55.73 ± 3.57	25.57 ± 3.36	36.00 ± 0.0	32.00 ± 1.41	34.67 ± 3.19	44.90 ± 3.77	18.00 ± 2.29	35.00 ± 0.00	26.00 ± 1.22	55.33 ± 2.86	40.03 ± 2.90	15.17 ± 2.28	37.00 ± 0.00	32.67 ± 1.63	34.33 ± 1.47
Mean ±SE	68.11 ± 3.09	33.89 ± 2.19	27.95 ± 1.54	25.06 ± 1.38	48.55 ± 11.86	51.30 ± 3.16	25.64 ± 1.59	26.46 ± 1.49	22.26 ± 1.16	114.06 ± 20.34	47.88 ± 1.74	22.37 ± 1.83	27.83 ± 1.54	25.53 ± 1.58	38.46 ± 1.86

Conduc. = Conductivity

Table 3. Chemical parameters of the water of the three experimental ponds, during the year of 2012-2013

Month	**Pond I**					**Pond II**					**Pond III**				
	pH ±SE	DO ±SE (mg/L)	BOD ±SE (mg/L)	fCO_2 ±SE (mg/L)	Ca^{2+} ± SE (mg/L)	pH ±SE	DO ±SE (mg/L)	BOD ±SE (mg/L)	fCO_2 ±SE (mg/L)	Ca^{2+} ±SE (mg/L)	pH ±SE	DO ±SE (mg/L)	BOD ±SE (mg/L)	fCO_2 ±SE (mg/L)	Ca^{2+} ±SE (mg/L)
Nov	7.61 ± 0.11	9.59 ±0.40	1.53 ±0.37	1.12 ±5.72	1.60 ±6.28	8.14 ±7.22	9.34 ±0.54	1.45 ±0.45	1.26 ±0.12	3.37 ±0.47	8.51 ±0.13	9.17 ±0.38	1.16 ±0.27	0.88 ±0.24	0.63 ±0.31
Dec	8.21 ± 5.09	10.60 ±9.19	1.39 ±0.11	1.32 ±0.21	1.36 ±7.26	8.33 ±0.83	11.78 ±0.64	2.34 ±0.29	1.27 ±0.99	4.61 ±0.63	8.58 ±0.15	9.84 ±0.87	1.21 ±0.24	0.63 ±0.24	0.87 ±0.26
Jan	8.38 ± 0.96	7.74 ±1.12	0.51 ±0.20	0.64 ±0.11	0.25 ±0.15	8.26 ±0.11	8.59 ±0.57	0.49 ±0.16	0.64 ±0.12	4.06 ±0.31	8.12 ±0.21	7.98 ±0.12	0.20 ±0.11	1.09 ±0.22	0.79 ±0.24
Feb	8.20 ±0.71	11.02 ±0.16	0.50 ±0.41	0.86 ±0.25	1.84 ±0.57	8.27 ±0.41	10.18 ±0.94	0.30 ±0.71	1.14 ±0.36	3.91 ±0.72	8.33 ±0.11	9.98 ±0.14	0.18 ±0.76	1.51 ±0.72	0.77 ±0.57
Mar	7.90 ±0.19	7.40 ±0.29	0.77 ±0.83	1.40 ±0.25	0.27 ±0.11	7.33 ±0.41	7.94 ±0.11	0.17 ±0.41	1.14 ±0.36	4.50 ±1.32	7.60 ±0.71	6.30 ±0.71	0.12 ±0.29	0.10 ±0.00	1.53 ±0.18
Apr	7.10 ±0.14	2.94 ±0.64	2.94 ±0.64	3.88 ±0.61	0.30 ±0.71	7.07 ±0.11	2.49 ±0.39	2.49 ±0.39	4.03 ±0.54	0.17 ±0.41	7.23 ±0.41	2.94 ±0.36	2.94 ±0.36	4.41 ±0.39	0.34 ±0.36
May	6.77 ±0.41	1.73 ±0.15	1.73 ±0.15	7.16 ±0.18	0.08 ±0.14	6.93 ±0.11	1.73 ±0.18	1.73 ±0.18	7.27 ±0.22	0.08 ±0.12	7.20 ±0.19	3.67 ±0.98	0.06 ±0.41	5.11 ±0.43	2.41 ±0.35
June	6.80 ±0.71	2.26 ±0.12	2.26 ±0.12	6.53 ±0.11	1.92 ±0.72	6.73 ±0.41	1.70 ±0.71	1.70 ±0.71	7.45 ±0.36	0.20 ±0.71	7.07 ±0.11	2.50 ±0.37	0.06 ±0.41	7.50 ±0.43	1.00 ±0.25
July	7.13 ±0.15	4.35 ±1.28	0.13 ±0.11	4.08 ±1.09	0.93 ±0.32	6.63 ±0.15	2.59 ±0.32	0.06 ±0.41	5.11 ±0.43	1.11 ±0.20	7.07 ±0.11	3.83 ±0.82	0.10 ±0.00	4.94 ±0.53	0.33 ±0.41
Aug	7.07 ±0.25	4.97 ±0.76	0.23 ±0.11	4.60 ±0.53	0.43 ±0.29	7.37 ±0.27	6.17 ±0.45	0.30 ±0.71	3.80 ±0.25	1.27 ±0.11	7.17 ±0.16	6.13 ±0.18	0.27 ±0.41	2.57 ±0.54	0.61 ±0.15
Sep	6.57 ±0.15	5.00 ±0.56	0.18 ±0.94	4.37 ±0.47	2.66 ±0.46	6.13 ±0.12	4.57 ±0.29	0.20 ±0.70	6.17 ±0.18	0.43 ±0.18	7.03 ±0.82	5.24 ±0.25	0.20 ±0.71	3.97 ±0.15	3.17 ±0.50
Oct	8.60 ±0.19	10.63 ±0.17	0.36 ±0.41	1.37 ±0.15	0.80 ±0.07	7.60 ±0.19	9.54 ±0.14	0.17 ±0.41	1.53 ±0.11	2.68 ±0.44	8.53 ±0.25	9.90 ±0.32	0.23 ±0.11	1.33 ±0.11	0.57 ±0.15
Mean ±SE	7.53 ±0.21	6.52 ±1.03	1.04 ±0.28	3.11 ±0.69	1.04 ±0.25	7.40 ±0.22	6.39 ±1.09	0.95 ±0.28	3.40 ±0.78	2.20 ±0.55	7.70 ±0.20	6.46 ±0.86	0.56 ±0.25	2.84 ±0.69	1.08 ±0.26

Table 4. Correlation between the total monthly abundance of aquatic insects of the different orders with the physicochemical properties of water in the three experimental ponds (n=11)

Ponds	Order	Water depth	Secchi depth	Air Temp.	Water Temp.	Conduc-tivity	pH	DO	BOD	fCO_2	Ca^{2+}
Pond I	Ephemeroptera	0.227	-0.095	0.438	0.382	-0.181	-0.267	-0.234	-0.148	0.455	0.136
	Odonata	-0.114	-0.416	0.727 ***	0.719 ***	0.008	0.034	0.057	-0.495 *	0.034	0.146
	Hemiptera	-0.480 *	0.130	0.117	0.051	-0.433	0.424	0.279	0.479 *	-0.296	-0.325
	Diptera	0.124	0.024	0.372	0.302	-0.267	-0.089	-0.154	-0.122	0.367	-0.332
	Trichoptera	0.107	0.676 **	-0.288	-0.380	-0.162	0.202	0.497 *	0.010	-0.436	0.396
	Coleoptera	-0.207	-0.439	0.186	0.274	0.202	0.316	0.491 *	-0.446	-0.336	0.433
Pond II	Ephemeroptera	0.199	0.276	-0.062	-0.041	-0.265	-0.096	-0.204	0.524 **	0.294	-0.126
	Odonata	0.372	-0.054	0.590 **	0.353	-0.446	-0.396	-0.313	0.118	0.356	-0.386
	Hemiptera	-0.326	-0.224	0.221	0.087	-0.366	0.397	0.453	-0.115	-0.464	0.263
	Diptera	-0.117	0.118	-0.344	-0.265	-0.372	0.295	0.218	-0.107	-0.210	0.156
	Trichoptera	-0.137	0.129	-0.579 **	-0.539 *	-0.097	0.280	0.428	0.324	-0.234	0.292
	Coleoptera	0	0	0	0	0	0	0	0	0	0
Pond III	Ephemeroptera	-0.332	-0.242	-0.276	0.093	0.413	-0.044	-0.015	0.498 *	-0.261	0.133
	Odonata	-0.564 **	-0.805 ****	0.830 ****	0.699 ***	0.024	-0.497 *	-0.319	-0.237	0.415	0.354
	Hemiptera	0.663	0.362	-0.059	-0.353	-0.171	0.249	0.228	-0.089	0.063	-0.268
	Diptera	-0.251	-0.034	0.329	0.249	0.274	0.114	-0.150	0.585 **	0.138	-0.261
	Trichoptera	0.062	0.016	0.237	0.061	-0.286	0.560 **	0.554 **	0.044	-0.385	-0.179
	Coleoptera	0.306	0.017	0.133	0.048	0.232	-0.305	-0.436	-0.186	0.637 **	-0.031

Significance level *P < 0.10 (2 – tailed), ** P < 0.05 (2 – tailed), *** P < 0.01 (2 – tailed), **** P < 0.001 (2 – tailed)

Table 5. Correlation between the total number of aquatic insects with the physicochemical properties of water in experimental ponds (n=11)

		Water depth	Secchi depth	Air temp.	Water temp.	Conduc-tivity	pH	DO	BOD	f CO_2	Ca^{2+}
POND I	Total abundance of aquatic insects	-0.106	0.264	0.354	0.254	-0.348	0.250	0.385	-0.117	-0.221	0.130
POND II	Total abundance of aquatic insects	-0.010	0.039	0.009	-0.070	-0.678 **	0.183	0.176	-0.062	-0.132	0.033
POND III	Total abundance of aquatic insects	-0.179	-0.316	0.610 **	0.375	-0.046	0.125	0.107	0.118	-0.021	0.056

Significance level: * P < 0.10 (2 – tailed), ** P < 0.05 (2 – tailed)

In Pond III, the total ephemeropteran insect abundance had a significant correlation with Biological Oxygen Demand at 0.1 level only. In the order Odonata, abundance of various genera had significant correlations with water depth at 0.05 level, secchi depth and air temperature at 0.001 level, water temperature at 0.01 level and Hydrogen ion concentration at 0.1 level. In the order Hemiptera, the abundance of various genera had significant correlation with water depth at 0.05 level only. In the order Diptera, the abundance of various genera had a significant correlation with only the Biological Oxygen Demand at 0.05 level. In the order Trichoptera, the abundance of various genera had a significant correlation with Hydrogen ion concentration and Dissolved Oxygen at 0.05 level. In the order Coleoptera, the abundance of various genera had a significant correlation with free carbon dioxide at 0.05 level only.

Relationship between the total monthly abundance of aquatic insects vs. the different physicochemical parameters of water (Table 5): In Pond I, there was no significant correlation between the total monthly abundance of aquatic insects and different physicochemical parameters of the water body. In Pond II, the total monthly abundance of aquatic insects had a significant correlation with conductivity (-0.678) at 0.05 level only and in Pond III, the total monthly abundance of aquatic insects had a significant correlation with air temperature (0.610) at 0.05 level only.

Discussion

Physical parameters: In Pond I, the highest water depth was recorded in all the months with a mean water depth of 68.11±3.09 cm. In Pond II the recorded water depth was lower and mean water depth was 51.30±3.16 cm, whilst the water depth of Pond III was the lowest, the mean depth being 47.88±1.74 cm. Water depth is related to pond size as well as rainfall, as water depth was seen to increase in the rainy months in all the three ponds. In ponds I, II and III the mean secchi depths were 33.89±2.19, 25.64±1.59 and 22.37±1.83 cm respectively. Hence water of Pond I was most transparent and that of Pond III was least transparent. Secchi depths were more or less related to pond size and its surroundings as well as the turbid condition of the water bodies being caused by rainfall due to inflow of water carrying sediments from adjacent areas. The air and water temperature in the three ponds was more or less the same in all the months with a few exceptions and was related to environmental condition. In Pond I, the mean water conductivity was 48.55±11.86 µs/cm, but in Pond II, the conductivity increased, with mean conductivity of 114.06±20.34 µs/cm, whilst in Pond III the conductivity was always low and the mean conductivity was 38.46±1.86 µs/cm. The reasons for such fluctuation might be due to the changes in electrolytes and can also be explained on the basis of the reports given by Siddaramu and Puttaiah (2013) and Payakka and Prommi (2014) who reported that if the conductivity of a stream increases, it indicates that there is a source of dissolved ions in the vicinity and conductivity tended to increase in the dry season.

Chemical parameters: The pH values in the three experimental ponds were in the alkaline range and the mean pH value was highest in Pond III (7.70±0.20), followed by Pond I (7.53±0.21) and lastly in Pond II (7.40±0.22). The DO values in all the three ponds were more or less the same, 6.52±1.03 mg/l in Pond I, 6.39±1.09 mg/l in Pond II and 6.46±0.86 mg/l in Pond III. BOD in Pond III was the lowest (0.56±0.25 mg/l), whilst in Pond I (1.04±0.28 mg/l) and Pond II (0.95±0.28 mg/l) it was nearly the same. Free carbon dioxide was lowest in Pond III (2.84±0.69 mg/l) followed by Pond I (3.11±0.69 mg/l), then Pond II (3.40±0.78 mg/l). It is hence seen that pH of water is positively correlated with DO and negatively with fCO_2 as more carbonates make the water more acidic and again DO has negative correlation with BOD and fCO_2. Calcium ions indicated the hardness of water and it was highest in Pond II and that of Pond I and III was almost the same.

The pH of water can be treated as master parameter for determining the suitability of water for the survival of aquatic life as it influences many biological and chemical processes. DO concentration is also an important factor as the solubility and availability of the nutrients also depend on DO concentration of an aquatic body. BOD is an indication of organic load and it is also a pollution index (Ndimele 2012). BOD values indicated that the water quality of all the three experimental ponds was good and there was less demand of dissolved oxygen as decomposition by bacteria was less. Dubey *et al.* (2006) stated that the increasing rate of decomposition of organic matter, influx of carbondioxide, source of high temperature water, mixing of domestic sewage caused low pH values. Mandal (2014) noted that suspended particles in the water absorbed heat, thus they could increase water temperatures and could reduce the oxygen content of the water since warm water holds less dissolved oxygen than cold water.

Relationships between the monthly abundance of the orders of aquatic insects vs. different physicochemical parameters of water: In Pond I, it was observed that the total ephemeropteran insect abundance was not correlated with the different physicochemical parameters. With the order Odonata, air temperature and water temperature were positively and Biological Oxygen Demand was negatively correlated. With the order Hemiptera**,** water depth was negatively and Biological Oxygen Demand was positively correlated. With the order Diptera, individuals of various genera had no significant correlation with physicochemical parameters of water of the pond. Both secchi depth and Dissolved Oxygen were positively correlated with insect abundance of the order Trichoptera. With the order Coleoptera, Dissolved Oxygen was positively correlated. In Pond II, Biological Oxygen Demand was positively correlated with the ephemeropteran insects. With the order Odonata, air temperature was positively correlated. The orders Hemiptera, Diptera and Coleoptera had no significant correlations with the physicochemical parameters of the water body. With the order Trichoptera, air and water temperatures were negatively correlated. In Pond III, Biological Oxygen Demand was positively correlated with the Ephemeroptera order. With the order Odonata, water depth, secchi depth and pH were negatively and air and water temperatures were positively correlated. With the order Hemiptera, water depth; with the order Diptera, Biological Oxygen Demand; with the order Trichoptera, Hydrogen ion concentration and Dissolved Oxygen and with the order Coleoptera, free carbon dioxide was positively correlated. Reza (2010) found no significant correlation between the ephemeropteran, odonate, hemipteran, coleopteran and trichopteran abundance with the water parameters of the pond but significant correlation was observed in the abundance of dipteran insects with secchi depth and calcium. Purkayastha and Gupta (2012) reported that the diversity or density of aquatic insects showed positive correlation with transparency and fCO_2, which might be due to increased respiration by more number of insects. Payakka and Prommi (2014) also reported that alkalinity was positively correlated with Chironmidae (order Diptera), whereas dissolved oxygen was negatively correlated with Baetidae (order Ephemeroptera) and Hydrophilidae (order Coleoptera).

Relationship between the total monthly abundance of aquatic insects vs. the different physicochemical parameters of water: In Pond I**,** there was no significant correlation between the total monthly abundance of aquatic insects and different physicochemical parameters of the water body. In Pond II, conductivity was negatively correlated. In Pond III, air temperature was positively correlated. However, Reza (2010) observed that in the pond the total insect abundance had significance correlation with secchi depth and Calcium and in the lake the correlation of insect abundance was significant with DO and Calcium. Welch (1952) reported that the increase of fCO_2 decreased the population abundance. So, overall assumption was that when fCO_2 increased then DO decreased or vice verse. Low dissolved oxygen, high nitrate or phosphorous concentrations and low pH can also cause reduction in water quality (Payakka and Prommi 2014) and trichopterans are especially sensitive to decrease in water quality (Dohet 2002, Guilpart *et al.* 2012). Temperature, conductivity, pH, DO, BOD and free CO_2 are the most important phycochemical parameters of water which work as limiting factors for the survival of aquatic organisms (Elahi *et al.* 2015). Hence to ascertain whether a water body is suitable for aquatic organisms, it is necessary to test whether the physicochemical parameters of the water lies within the optimal range. From the present study it can be said that the various physicochemical parameters of water bodies are interrelated and these factors again in turn influence the abundance, diversity and distribution of aquatic insects in a water body.

The importance and influence of physicochemical factors of the water bodies on the aquatic insects is an important aspect in the life of the insects. There is no single factor whether chemical or physical which is responsible for the fluctuation of aquatic insects.

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