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Aquatic Insect Fauna and Diversity in Urban Fresh Water Lakes of Tripura, Northeast India

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Abstract: Freshwater lakes are integral part of urban ecosystem and provide numerous benefits to human beings directly or indirectly. An inventory was carried out to study the aquatic entomofauna, their diversity and distribution in three urban freshwater lakes of Tripura, northeast India during January to May, 2012. A total of 2159 individuals representing 31 species belonging to 23 genera, 15 families and 4 orders were recorded. Maximum of 30 species and 1191 individuals of aquatic insects were recorded in vegetation rich Maharaja Bir Bikram College Lake and minimum of 11 species and 215individuals were recorded in vegetation poor Laxminarayan Bari Lake. Insects belonging to the orders Hemiptera (32.26%) and Odonata (32.25%) showed higher species richness followed by those belonging to Coleoptera (25.81%) and Diptera (9.68%), respectively. Maximum diversity (H_s= 3.03) and least dominance (D_s= 0.06) and minimum diversity (H_s= 1.50) and maximum dominance (D_s= 0.06) of aquatic insects was recorded in Maharaja Bir Bikram College Lake and Laxminarayan Bari Lake, respectively. Richness estimators Chao 1 and Chao 2 provided the best predicted value of species richness. Three species are reported here for the first time from the state. Dominance of hemipteran and coleopteran insects suggested that urban lakes of Tripura are relatively less polluted.

Key words: Aquatic Entomofauna · Diversity · Urban Freshwater Lake · Richness Estimate · Tripura

INTRODUCTION

There are about 751,000 known species of insects, which is about three-fourths of all species of animals on the planet. While most insects live on land, their diversity also includes many species that are aquatic in habit [1]. Freshwater makes up only about 0.01% of world total water body and contains about 100000 species (8%) out of 1.3 million scientifically described species [2]. Aquatic insects are extremely important in ecological systems for many reasons [3] and are the primary bio-indicators of freshwater bodies such as lakes, ponds, wetland, streams and rivers. They serve various purposes such as food of fishes and other invertebrates, as vectors of pathogens to both humans and animals [4, 5]. Bio-monitoring pertains to the use of insects and/or their differential responses to stimuli in their aquatic habitat to determine the quality of that environment [3]. The presence or absence of certain families of aquatic insects can indicate whether a particular water body is healthy or polluted. Worldwide, due to over human explosions, most of the fresh water bodies are being subjected to increasing pollution loads. Consequently, changes the physico-chemical properties (temperature, dissolved oxygen, carbonates, alkalinity, phosphates, nitrates and metal concentrations) can adversely affect the diversity, distribution and composition of aquatic insects [4-6]. India is one of the megabiodiversity countries in the world and occupies the ninth position in terms of freshwater megabiodiversity [7]. Literature review suggested that this is the first study on the quantitative assessment of aquatic insect diversity of man-made urban freshwater lakes in the state of Tripura, northeast India. Except for preliminary study of insect community of water-filled tree hole ecosystems [8], there

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was no study on species richness and diversity of aquatic insects of lakes in urban areas of Tripura, northeast India which is part of the wet tropics having one of the largest inland resource of freshwater which are indirect conflict with rising human populations of tropical Asia.

MATERIALS AND METHODS

Study Area: Agartala city is spread out 7.20 km^2 area and is situated in the western part of Tripura state (latitude of 23°45′N, longitude of 91°45′E, elevation of 12.8 m above sea level). The study area experience tropical wet climate with an average annual rainfall of 2200 mm. Average minimum and maximum temperatures of 6.8°C in January and 37.8°C in June, respectively. Present study was carried out in three different man-made freshwater perennial lakes, Maharaja Bir Bikram College Lake (Lake 1), Jagannath Bari Lake (Lake 2) and Laxminarayan Bari Lake (Lake 3) (Fig. 1) having approximate area of 1020 m^2, 740 m^2 and 640 m^2, respectively. These lakes are infested with many aquatic weeds and are subject to varying degree of anthropogenic disturbances. The geo-coordinates and vegetation profile of the three lakes are provided in Table 1.

Sampling Regime: Survey for aquatic entomofauna was conducted from January 2012 to May 2012. Insects were collected at 15-day interval between 7.00 am to 9.00 am local time. Samples were taken from 4 corners of the lake within an area of 10 m^2. Collections were made by dipping a 40 cm diameter circular net with a mesh size of 60 µm (ACCO made, Ambala, India). The frequency of netting was 15 hauls/corner/ 30 minutes. Three lakes are sampled in 3 consecutive days. Adult flying insects of aquatic larvae were collected using sweep net of 30 cm diameter at respective sampling sites of each lake. Hard bodied sinsect specimens were desiccated, pinned and preserved in dry condition and soft bodied insect were preserved in 75% Ethanol. Only one or two specimens of each kind of insects were used for identification in the laboratory and the rests were returned to the respective sampling sites after counting. Stereo zoom microscope (Carl Zeiss, Stemi DV4) was used to examine insects and these were identified up to the lowest taxonomic category following the standard keys [9-13]. Some of the species which could not be identified are included as unidentified and given Arabic numerals for the purpose of quantitative determinations. All the specimens were photographed under Leica microscope (LEICA DFC 295).

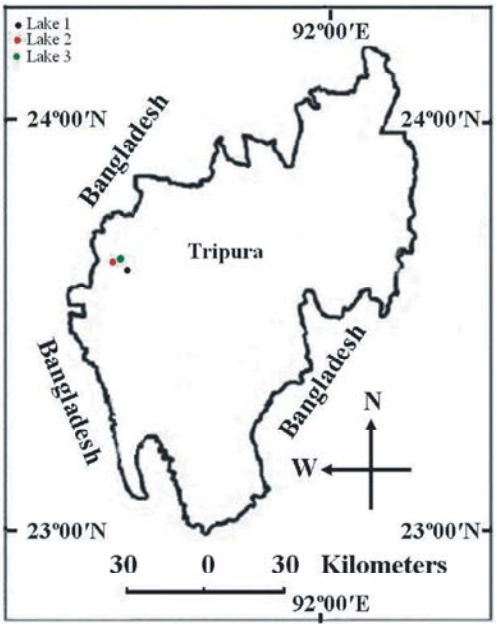

Fig. 1: Map of Tripura showing location of studied freshwater lakes

Data Analysis: Data collected from the study were tested for normality. Data which failed normality were not used for further analysis. Species diversity (Shannon-Weiner index), component of dominance (Simpson dominance index) and relative abundance of different species (Pielou's evenness index) were determined for each lake [14]. Comparison in species composition between different lakes was estimated using single linkage cluster analysis based on Bray-Curtis similarity [15]. Species recorded in this study were ranked on the basis of relative abundance of individual species. First order Chao (Chao 1) and second order Chao (Chao 2) species richness estimates were used to determine the expected number of species. Sampling completeness was calculated as ratio of observed species richness to the average species richness estimate value and expressed as percentage [16]. Data of species richness counts of five months from the three lakes were pooled to get rarefaction curves for comparison of estimated species richness between the lakes. Biodiversity Pro version 2 [17] was used to determine diversity indices, cluster analysis, rarefaction curves, species richness estimates. Rank abundance diagram and species richness index were determined by Origin version 5 [18] and PAST version 2 [19], respectively. Non-parametric test (Kruskal-Wallis) was used to compare species composition between the lakes.

Table 1: Geo-coordinates and vegetation profile of the studied freshwater lakes

Study sites	Geo-coordinate position	Aquatic vegetation
Lake 1	N 23°49'35.45", E 91°17'42.28" Ele: 17 m	The lake is full of aquatic weeds and the dominant vegetations were *Utrieularia* sp., *Nymphea, Cyperus rotandus*, *Enhydra fuctuta*, *Eichornia* sp., *Hrysopogon* sp., *Eurena globate*, *Mimosa pudica*, *Nymphea* sp., *Pistea, Melustonea* sp., *Mikenia* sp., *Colocasia* sp. and *Azolla* among many others.
Lake 2	N 23°50'05.43", E 91°16'53.70" Ele: 14 m	The lake experiences substantial weed load and the dominant vegetations were *Enhydra* sp., *Colocasia* sp., *Mikenia* sp., *Commelina* sp., *Pteris* sp. and *Pistea*.
Lake 3	N 23°50'04.52", E 91°17'01.11" Ele: 15 m	The lake has limited number of aquatic vegetations and these include *Colocasia* sp., *Enhydra* sp., *Pteris* sp., *Lowdogia* sp., *Mikenia* sp. and *Cypreous rotandus*.

Abbreviations: Lake 1 = Maharaja Bir Bikram College Lake, Lake 2 = Jagannath Bari Lake, Lake 3 = Laxminarayan Bari Lake

RESULTS

Insect Fauna: A total of 2159 individuals representing 31 species belonging to 23 genera, 15 families and 4 orders were recorded. Maximum of 30 species and 1191 individuals of aquatic insects were recorded in Maharaja Bir Bikram College Lake and minimum of 11 species and 215 individuals were recorded in Laxminarayan Bari Lake (Table 2). Jaganath Bari Lake was represented by 26 species. Among the three lakes, Lake 1 and Lake 2 showed significant differences with Lake 3 in terms of species composition (Kruskal-Wallis Test: Lake 1: $H = 29.24$, $p < 0.000$; Lake 2: $H = 22.00$, $p < 0.000$) but the recorded differences between Lake 1 and Lake 2 was not significant ($H = 3.42$, $p = 0.65$). Three species are reported here for the first time from the state. Another 4 species are recorded from one of the three lakes only, thus, treated as unique species. Nine of the 31 species are found to be common to all the sampling sites.

Species Richness and Diversity: Insects belonging to the orders Hemiptera (32.26%) and Odonata (32.25%) showed higher species richness followed by those belonging to Coleoptera (25.81%) and Diptera (9.68%), respectively (Table 3). However, abundance of different insect groups did not show the same trend. Members of the order Hemiptera dominated the collections (37.8%) followed by Diptera (29.74%), Odonata (17.78%) and Coleoptera (14.68%), respectively (Table 3).

Family-wise, members of the Libelullidae (Order: Odonata) were more species rich (8 species) and that of Culicidae was the most individualized (435 insects) family accounting for 20.15% of the total individuals recorded in the study. Members of Dytiscidae (6 species, 156 individuals), Nepidae (3 species, 286 individuals), Belostomatidae (2 species, 202 individuals) and Coenagrionidae (2 species, 163 individuals) occurred in decreasing order. Rests of the 10 families were recorded by 1 species each representing 3 to 172 individuals (Table 3).

Calculated diversity indices showed maximum diversity ($H_s = 3.03$) and least dominance ($D_s = 0.06$) of aquatic insects in Lake 1 and minimum diversity ($H_s = 1.50$) and highest dominance ($D_s = 0.06$) occurred in Lake 3. Evenness of distribution of aquatic insects in the three lakes ranged from 0.90 to 0.63. Species diversity in vegetation rich Lake 1 and Lake 2 were higher than vegetation poor Lake 3. The overall species diversity, dominance and evenness value for the three lakes were found to be 2.96, 0.08 and 0.86, respectively (Table 4).

Species Ranking: Ranking of 31 species according to their abundance showed that these are distributed into 28 ranks. *Culex* sp., *Chironomidae* sp. and *Corixa* sp. occupied ranks 1, 2 and 3, respectively, having relative abundance of 20.15%, 7.97% and 6.90%. Together these species shared 756 individuals (35.02%). Next 14 species are ranked between 4 and 16; each of these showed abundance in the range of 6.39% to 2.18% and together accounted 46.93% of the total individual abundance. Another 11 species are ranked between 17 and 25 and together accounted abundance of 10.93%. Remaining 3 species are ranked between 26 and 28 and together accounted 0.60% of the total abundance (Fig. 2).

Richness Estimates: Average value of estimation of species richness in the three studied lakes showed that expected richness are very close to the observed values. The sampling efficiency ranged from 73 % to 100 % between the lakes and showed an overall sampling completeness of 94 % (Table 4). Rarefaction curves from the three studied lakes showed quick rise at first and then level off (Fig. 3).

Species Composition Similarity Between Lakes: Bray-Curtis single linkage similarity analysis exhibited that vegetation poor Lake 3 stood out from the other two lakes and linked at 30.44% similarity to the vegetation rich Lake 1 and at 43.60% similarity to the moderate vegetation rich Lake 2 (Fig. 4).

Table 2: List of species and relative abundance of aquatic insects recorded in the three lakes

		Number of insects			
Order/Family	Zoological name	Lake 1	Lake 2	Lake 3	RA (%)
Coleoptera					
Dytiscidae					
Diving beetle	*Ciliatus* sp.	38	18	2	2.69
	Dineutus sp. [x]	26	0	0	1.20
	Laccophilus sp.	5	9	0	0.65
	Sandracottus sp.	8	6	0	0.65
	Unidentified sp1 [x]	0	0	1	0.05
Hydrphilidae					
Giant water scavenger beetle	*Hydrophilus triangularis* Say	23	20	0	1.99
Water scavenger beetle	*Berosus indicus* Sharp	83	55	0	6.39
Lampyridae					
Fire fly	*Photinus* sp.	21	2	0	1.07
Diptera					
Culicidae					
Mosquitoes	*Culex* sp.	181	131	123	20.15
Chironomidae					
Midges	*Chironomidae* sp.	80	64	28	7.97
Tipulidae					
Crane flies	*Tipula* sp.	32	0	3	1.62
Hemiptera					
Belostomatidae					
Giant water bug	*Lethocerus indicus* (Lepeletier and Serville)	66	30	0	4.45
Small water bug	*Diplonychus rusticus* (F.) *	73	33	0	4.91
Corixidae					
Water boat man	*Ccorixa* sp.	86	63	0	6.90
Gerridae					
Common pond skater	*Gerris lacustris* (L.) *	48	36	0	3.89
Hydrometridae					
Water measurer	*Hydromentra* sp. [x]	3	0	0	0.14
Mesoveliidae					
Water treaders	*Mesovelia vittigera* Horvath	11	16	0	1.25
Nepidae					
Giant water scorpion	*Ranatra elongata* F.	69	31	0	4.63
	Ranatra varipea Stal	66	32	0	4.54
Water scorpion	*Laccotrephes ruber* (L.)	51	37	0	4.08
Notonectidae					
Water back swimmer	*Notonecta* sp.	39	26	0	3.01
Odonata					
Coenagrionidae					
Golden dartllet	*Ischnura auroa* (Brauer)	46	36	14	4.45
Pigmy dartlet	*Agricnemis pygmaea* (Rambur)	24	27	16	3.10
Libellulidae					
Brown-backed red marsh hawk	*Orthetrum chrysis* (Selys) *	26	16	6	2.22
Blue-tailed forest hawk	*Orthetrum triangular* (Selys)	18	19	10	2.18
Blue marsh hawk	*Orthetrum glaucaum* (Brauer)	6	9	1	0.74
Green marsh hawk	*Orthetrum Sabina* (Drury)	35	17	11	2.92
Ground skimmer	*Diplocodus trivialis* (Rambur)	5	11	0	0.74
Pied paddy skimmer	*Neurothemis tullia* (Drury)	7	3	0	0.46
Fulvous forest skimmer	*Neurothemis fulvia* (Drury) [x]	6	0	0	0.56
Blue-tailed yellow skimmer	*Palpupleura sexmaculata* (F.)	9	6	0	0.42
--	Total species	30	26	11	--
--	Total individuals	1191	753	215	--

* denotes new record for the state, [x] denotes unique species, RA = Relative abundance

Table 3: Family-wise distribution of aquatic insects showing number of species and individuals

Order	Family	Species (% occurrence)	Individuals (% occurrence)
Coleoptera	Dytiscidae	6 (19.35)	156 (7.23)
	Hydrphilidae	1 (3.23)	138 (6.39)
	Lampyridae	1 (3.23)	23 (1.07)
Diptera	Culicidae	1 (3.23)	435 (20.15)
	Chironomidae	1 (3.23)	172 (7.97)
	Tipulidae	1 (3.23)	35 (1.62)
Hemiptera	Belostomatidae	2 (6.45)	202 (9.36)
	Corixidae	1 (3.23)	149 (6.90)
	Gerridae	1 (3.23)	84 (3.89)
	Hydrometridae	1 (3.23)	3 (0.14)
	Mesoveliidae	1 (3.23)	27 (1.25)
	Nepidae	3 (9.68)	286 (13.25)
	Notonectidae	1 (3.23)	65 (3.01)
Odonata	Coenagrionidae	2 (6.45)	163 (7.55)
	Libellulidae	8 (25.81)	221 (10.24)
Total	--	31	2159

Table 4: Diversity parameters and species richness estimates of aquatic insect communities in the three lakes

Lakes	Shannon (H_s)	Simpson's (D_s)	Pielou's (J')	Chao 1	Chao 2	Average of Chao 1 and Chao 2	Observed species richness	*Sampling completeness (%)
Lake 1	3.03	0.06	0.89	30	30	30	30	100
Lake 2	2.93	0.07	0.90	28	27	28	26	93
Lake 3	1.50	0.06	0.63	13	16	15	11	73
Overall	2.96	0.08	0.86	35	31	33	31	94

*Sampling completeness = [(Observed species no./Estimated species no.) 100]

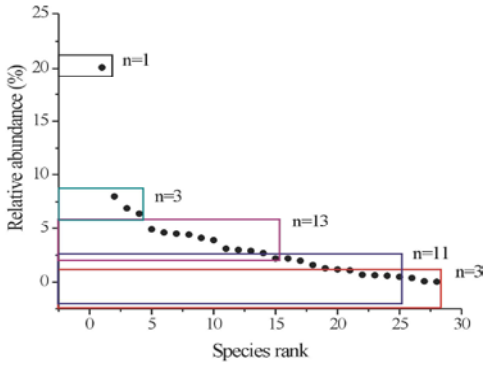

Fig. 2: Rank abundance diagram of aquatic insect species recorded from three lakes

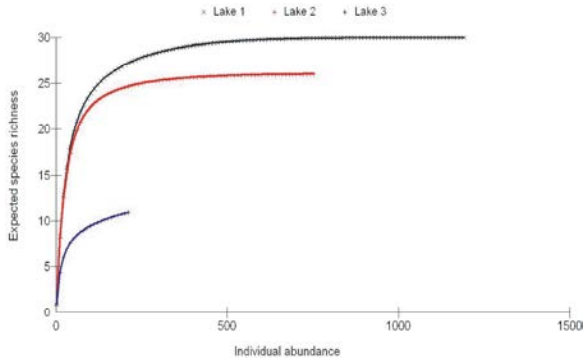

Fig. 3: Sample-based rarefaction curves of estimated species richness at three studied lakes

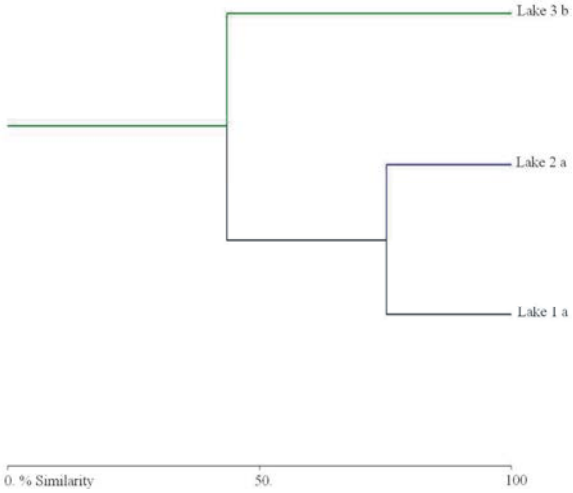

Fig. 4: Single linkage cluster analysis between studied lakes based on Bray-Curtis similarity; dissimilar letters following habitat types indicate significant differences by Kruskal-Wallis test ($P< 0.05$)

DISCUSSION

The major aquatic insect taxa of Ephemeroptera, Plecoptera and Trichoptera were completely absent in the studied lakes. In contrast, insects of the order Hemiptera, Diptera, Odonata and Coleoptera showed high species

richness and abundance. These results are similar to that recorded in the perennial Loktak lakes of Manipur (northeast India) [20]. Three species, *Dineutus* sp. (Dytiscidae), *Hydromenta* sp. (Hydromentidae) *Neurothemis fulvia* (Drury) (Libellulidae) were recorded exclusively from Lake 1 and another unidentified Dytiscidae beetle was recorded from Lake 3 only. Three species namely *Gerris lacustris* (L.), *Diplonychus rusticus* (F.) and *Orthetrum chrysis* (Selys) are reported here as new records for the state of Tripura.

Overall species abundance and richness revealed that insects of the order Hemiptera were the most dominant and that of Coleoptera was the least dominant in the urban freshwater lakes of Tripura. At family level, Libellulidae dominated the collections with maximum number of species and family Culicidae with maximum number of individuals. A similar pattern of dominance of Hemipteran insects was reported from Loktak Lake [20]. However, Jana *et al.* [21] in West Bengal and Sharma and Rai [22] in Bhagalpur, Bihar found insects of Odonata and Coleoptera to be the most common. In this study, Odonata was the second dominant order and Diptera was the least dominant order, which suggested that urban lakes of Tripura are less polluted and rich in aquatic vegetation [20, 23-24]. Insects of Dytiscidae and Hydrophilidae family together shared 92.74% of total Coleoptera (14.68%) insects. Prevalence of Dytiscidae is indicative of the ecological health of studied lakes. Dytiscidae insects generally prefer leaves of submerged aquatic vegetations in clean freshwater lakes and are predacious in nature. In contrast, Hydrophilidae beetles inhabit shallower regions of water bodies with abundant macrophytes and feed on detritus, algae, decaying vegetative matter [25]. Among the insect families, Culicidae dominated the fauna of aquatic insects represented by 20.15% of total insects collected. A similar pattern of dominance of Culicidae was also reported from other lentic ecosystems [26], because many of the dipterans prefer lentic habitats are breeding ground and early life stages [8].

Occurrence of more diverse and abundant insects in Lake 1 than Lake 2 and Lake 3 suggested the presence of luxuriant aquatic vegetation which is necessary for shelters, oviposition sites and foods [27]. Another possible cause of insect abundance and richness in Lake 1 may be the larger size and greater depth than the other two lakes. Absence of hemipteran insects in Lake 3 suggested that this Lake was less polluted.

Recent studies have widely used extrapolation methods in biodiversity studies to standardize the sample size of short term studies [28-29]. Individual based rarefaction curves denote β-diversity between studied habitats [29]. Rarefaction curves of Lake 1 and Lake 2 showed saturation of species richness at high individual abundance in comparison to Lake 3 which did not show asymptote at low abundance of different species. The incidence-based Chao 1 and Chao 2 estimators of species richness provided the most reliable estimate (33 estimated species against 31 observed species) in this study. Therefore, it can be concluded that over a period of five months long study, approximately, explored nearly 94% of the aquatic insect species present among the three studied fresh water lakes. Since short term sampling does not cover all the species which are active in different seasons of a year, therefore, the true number of species estimated for the three lakes might be higher than the present predicted value.

CONCLUSION

Man-made urban freshwater lakes provide numerous benefits to human beings directly or indirectly. In this study, a total of 31 species was recorded from three different freshwater lakes and the number of aquatic insect species and their abundance varied among the lakes. Dominance of hemipteran and coleopteran insects suggested that urban lakes of Tripura are relatively less polluted.

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