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Influence of Water Quality on Aquatic Insect Diversity of Lake Fateh Sagar, Udaipur, Rajasthan, India

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Abstract

This study evaluates the impact of physicochemical parameters on aquatic insect diversity of Fateh Sagar Lake by assessing water quality across five sampling sites. Physicochemical parameters such as temperature, pH, total hardness (TH), total dissolved solids (TDS), dissolved oxygen (DO), biochemical oxygen demand (BOD), and chemical oxygen demand (COD) were analyzed. The results indicated that while most physicochemical parameters remained within permissible BIS/ICMR standards, Site 5 exhibited signs of pollution with higher BOD and COD levels and lower DO. A total of 3668 aquatic insects from 65 species, categorized under 37 families and five orders, were recorded. The BMWP and ASPT indices were employed for biological assessment, revealing good water quality at Sites 1-3, moderate conditions at Site 4, and significant degradation at Site 5, where no aquatic insects were found. Statistical correlations highlighted the importance of DO in species composition and the influence of physicochemical factors on aquatic biodiversity. This study underscores the necessity of regular monitoring and conservation efforts to mitigate anthropogenic impacts on Fateh Sagar Lake.

Keywords: Aquatic Insects, BIS/ICMR, BMWP, Diversity, Lake, Physicochemical Parameters.

INTRODUCTION

Aquatic habitats have a wide variety of insect fauna living in it. The characteristic feature of aquatic insects is their diverse distribution in water bodies along with their adaptability to these environments. Aquatic insects play crucial role in ecological systems, functioning as key bio-indicators of water quality in various freshwater habitats, including lakes, ponds, wetlands, streams, and rivers. They play vital role as a food source for fish and other invertebrates, as well as acting as vectors for pathogens affecting both humans and animals (Chae *et al*., 2000). Because of their sensitivity to environmental conditions, aquatic insects are used in bio-monitoring to access the health and quality of freshwater habitat (Ashworth *et al*., 2004). The presence and absence of specific insect families can reveal the health or pollution status of a water body.

Worldwide human activities are increasing pollution loads in freshwater ecosystem, leading to change in the physicochemical characteristics such as temperature, pH, dissolved oxygen, COD, alkalinity, phosphates, nitrates, and metal concentrations. These changes can have effects on the diversity, distribution, and composition of aquatic insects (Bauernfeind & Moog, 2000; Chae *et al*., 2000). The pollution of freshwater bodies caused by domestic and industrial effluents is a common anthropogenic impact on watercourses globally, including freshwater lakes. Pollution modifies the physicochemical properties of water, affecting aquatic insect community distribution in a given water body.

India, a global mega-biodiversity hotspot, holds the ninth position of freshwater biodiversity (Mittermeier *et al*., 1997). However, despite this richness, there has been limited research on the aquatic insect diversity of freshwater lakes of Udaipur, Rajasthan, Northwestern India. This study represents the first quantitative assessment of aquatic insect diversity and provides insight into their distribution and relative abundance in the urban freshwater lake Fateh Sagar, Udaipur Rajasthan, which is the part of inland freshwater resources, and under increasing pressure due to rising human populations.

MATERIALS AND METHODS

Study Area:

Fateh Sagar is an artificial lake, in Udaipur city of Rajasthan state, located 1.8 km away from the southwest of Udaipur at 73^0 61' E Longitude and 24^0 58' N latitude. It has an overall length of 2.4 km, shore length 8.5 km, 1.6 km width and 11.5 meter in depth. The lake is rain-fed and receives water from three inlet channels (Pichhola Lake, Madar and Badi Lake), along with an overflow section on the eastern side in Masonry Dam. The catchment area is approximately 54 km^2. The geo-coordinates and sites of this lake are provided in Table 1.

Sampling Regime:

Survey for aquatic entomo-fauna was conducted from January 2019 to Dec. 2019. Water and insect samples were collected monthly from five sites from Fateh Sagar Lake. Water temperature and pH were measured on site using thermometer and pH meter. Physico-chemical parameters such as total dissolved solids (TDS), total alkalinity (TA), total hardness (TH), dissolved oxygen (DO), chemical oxygen demand (COD and biological oxygen demand (BOD), were analyzed in the laboratory following standard methods (APHA, 2012;Trivedy & Goel, 1984). The results were compared with the prescribed limits for potable water given by the Bureau of Indian Standards (BIS, 2012) and the Indian Council of Medical Research (ICMR, 1975). Field work was conducted 5 days in each month and selection of days was not chronological but clear, windless, and sunny days were selected. Sampling was done between 10.00 am to 05.00 pm, when insect activities were found in peak to regulate their body temperature in sunlight (Das *et al*., 2013).

Adult stages of aerial insects were collected using a long-handled wide mesh net. A small mesh net and pond net was used for collecting adult and premature aquatic insect stages in the lentic zones and near the shore, as well as from floating aquatic plants. Aquatic insects on water surface were sampled with a nylon pond net. The insects were collected by submerging the net and sweeping it through water column. Identification was done following the keys and manuals (Jonathan *et al*., 1986; Merritt, 2008; K. A. Subramanian & Gadgil, 2009; K. Subramanian & Sivaramakrishnan, 2007; Turkamen & Kazanci, 2013).

Data Analysis:

All the collected data were analyzed by using statistical tools in Microsoft Office Excel 365 and diversity indices (Shannon - Weiner Index (H), Simpson's diversity Index (1-D), Margalef's Index (***d***), Pielou's evenness Index (e), and relative abundance) were worked using PAST (Paleontological Statistics) software.

Table 1: Site-wise Geo-coordinates of Fateh Sagar Lake

Fateh Sagar lake		
Site no	**Name**	**Location**
1	Near Sanjay Gandhi park	24°35'43" N 73°39'52" E
2	Rani Road, near Rajiv Gandhi park	24°35'56" N 73°39'43" E
3	Church Road, Block E	24°35'24" N 73°40'0" E
4	Dewali Road	24°35'40" N 73°39'46" E
5	Pal Area	24°35'58" N 73°40'43" E

RESULTS AND DISCUSSION

A total of 3668 insects representing 65 Species categorized under 23 families and 5 orders were collected from all the sampling sites in the present study. The aquatic entomo-fauna of Site 1, 2, 3 and 4 constituted 65 species, 23 families and 5 orders, were recorded. No insects were found at Site 5. The site-wise abundance of aquatic insects in Fateh Sagar Lake revealed maximum insects (1450) at Site 1 and minimum (395) at Site 4. Site 1 and Site 2 showed somewhat equal distribution of fauna throughout the sampling periods (Table 2).

The relative abundance of species of various insect orders collected from Fateh Sagar Lake is shown in Figure 1. Among the entomofauna collected, the order Odonata was most diverse in number of genera (17) comprising 43.62% of the total insect fauna. It was represented by 4 families viz., Coenagriondae, Libellulidae, Aeshnidae, Gomphidae. Of these, family Libellulidae was the most common family in all sites contributed by species (Table 2) and was most individualized (863 insects) family accounting for 21.70% of the total individuals recorded in the study. Family Coenagriondae (633 individuals, 8 species) accounted for 19.22% of the total individuals. Members of Dytiscidae (7 species, 321 individuals), Nepidae (4 species, 223 individuals), Corixidae (4 species, 206 individuals), Gerridae (4 species, 206 individuals), Culicidae (4 species, 171 individuals), Halipidae (3 Species 118 individuals), Hydrophilidae (2 Species 74 individuals), Belostomatidae (2 species, 122 individuals), Mesoveliidae (2 species, 91 individuals), and Notonectidae (2 species, 96 individuals) occurred in decreasing order. Rest of the 11 families were recorded by 1 species each representing 30 to 67 individuals (Table 2).

The biological assessment of the lakes was conducted using the Biological Monitoring Working

Party (BMWP) score and the Average Score Per Taxon (ASPT). The BMWP score is calculated by summing the individual scores assigned to each family, with these scores reflecting their tolerance to pollution (Table 2). Higher BMWP scores indicate better water quality, as they are associated with the presence of more pollution-sensitive families, whereas lower scores suggest poorer water quality, dominated by pollution-tolerant families. The ASPT is derived by dividing the BMWP score by the total number of families present in the sample. This value represents the average tolerance score of all taxa within the aquatic community, providing insight into the overall health of the ecosystem ((Armitage *et al*., 1983; Hynes, 1998; Mandaville, 2002). Fateh Sagar Lake was found to be slightly impacted by pollution with a BMWP score (of 100) and an ASPT value of 5.09 (Mandaville, 2002). Sites 1, 2, and 3 showed good water quality, as indicated by their high BMWP score (of 100) and ASPT score. Site 3 has the highest ASPT (5.29), indicating the good ecological condition.

Site 4 has slightly lower ASPT (4.92), indicating moderate water quality and potential pollution. According to BMWP and ASPT Site 5 is severely impacted, with no aquatic insect diversity, suggesting extreme pollution and habitat degradation. While BMWP and ASPT scores are commonly used to assess water quality based on the presence of aquatic insect families, a score of zero does not always indicate pollution.

The absence of aquatic insects at Site 5 is not due to severe pollution but is instead a result of physical and ecological limitations. Reduced shoreline vegetation, deeper water levels, increased human disturbance, and habitat unsuitability have created conditions that do not support insect colonization. Unlike other sites where insects can thrive in shallow, well-vegetated waters, Site 5 lacks key habitat features required for the survival of most aquatic insect families.

In the present investigation, different diversity indices demonstrated distinct patterns (Table 3). Highest Shannon diversity index (H´) was recorded at site 1 (4.14) and lowest was observed at site 4 (4.06). A Shannon diversity index of less than 1 indicates extremely polluted water, whereas 1-3 suggests moderate pollution, and greater than 4 indicates clean water (Wilhm & Dorris, 1968). An Evenness value of 1 indicates equal distribution of individuals (Türkmen & Kazanci, 2010). The Evenness value (J´) was maximum for site 1 (0.964) and minimum for site 4 (0.906) which were close to 1 suggesting equal distribution of individuals. The Margalef's richness index was maximum for Site 4 (10.54) followed by site 3, 2 and 1(9.67, 9.17 and 8.79 respectively). Clean conditions are indicated by Margalef's richness index values greater than 3, values less than 1 indicate severe pollution, and intermediate values indicate moderate pollution (Lenat *et al.*, 1980). This is substantiated by a higher BMWP score, which was 100 at each site except site 5 (Table 2). A BMWP score of 100 or higher indicates that the environment is unaffected (Class I), 71-100 indicates slightly polluted (Class II), 41-60 indicates that the environment is moderately impacted (Class III), and less than 40 indicates poor or polluted environment (Class IV) (Armitage *et al.*, 1983; Kazanci *et al.*, 2013). The ASPT value also indicates water quality. A score of 6 or >6 implies very good quality, a score of less than 4 indicates poor quality, and an intermediate value implies moderate quality (Armitage *et al*., 1983; Mandaville, 2002). In the present investigation, the ASPT values were 5.29, 5.09, 5.03 and 4.92 for site 3, 2, 1, and site 4 respectively, suggesting moderate water quality.

The physicochemical water parameters of all five sites were within acceptable limits for drinking water as per BIS/ICMR standards, except for TDS, pH and TH (Table 4). The pH levels (6.8–7.9) remained within the permissible range of 6.5–8.5, indicating a neutral to slightly alkaline nature of the water. The Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) remained below critical levels**,** indicating a moderate organic load in the water.

Mean values of selected physicochemical parameters of water quality of Fateh Sagar Lake are presented in Table 4. The chemical and biological properties of surface water are affected by temperature. There was little temperature fluctuation at all sites. Across the sites temperature ranged between 18.5°C and 22.9°C, within the natural variability of freshwater bodies. Temperature showed significant positive correlation with COD and negative correlation with Order Ephemeroptera. The pH values varied between 6.8 and 7.9**,** remaining within the acceptable BIS/ICMR limit (6.5-8.5) except for Site 5**,** which had a slightly lower pH (6.8), indicating mild acidity. All sites exhibited total hardness values well below the permissible limit of 300 mg/L, indicating moderate hardness. TDS values for all sites were within the permissible limit of 500 mg/L**,** ensuring good water quality. Concentration of dissolved oxygen is one of the most important indicators of water quality and a key determinant of the distribution of aquatic insect groups (Wahizatul *et al*., 2011). Sites 4 and 5 showed the lowest DO level (6.2 and 6.6 mg/L, respectively) than other sites. There was a strong positive correlation between DO and order Odonata and negative correlation with order Diptera in the lake highlighting the importance of DO in species composition. In the present investigation, the DO concentration of site 4 and 5 was lower than other sites. These sites receive sewage waste, which raises the water's biological oxygen demand. The Dissolved Oxygen (DO) values (6.2–9.2 mg/L) were adequate**,** supporting aquatic life. BOD values were below the permissible limit of 5 mg/L, indicating relatively low level of organic matter. However, Site 5 showed a slightly higher BOD

compared to other sites. The higher BOD (3.6 mg/L) at Site 5 suggests slightly higher organic pollution, likely due to external sources such as runoff and human activity. Site 5 had the highest COD value, suggesting higher pollution levels compared to other sites. Sites 4 and 5 showed the lowest DO level (6.2 and 6.6 mg/L, respectively), indicating potential stress on aquatic life. The total alkalinity was within the acceptable range for all sites, indicating sufficient buffering capacity. The overall water quality across the sampling sites remains within acceptable limits, making it suitable for drinking and aquatic life, except for Site 5, which showed some concerning trends, including a lower pH, higher BOD, COD, and lower DO levels, suggesting an increase in organic pollution, possibly due to anthropogenic activities. Site 4 also exhibited lower DO, while other sites exhibited stable water quality. In Fateh Sagar Lake correlation coefficient analysis (Table 5) revealed a significant positive relationship of water temperature with pH and COD. pH also showed significant positive relationship with COD. A significant negative correlation of water temperature with BOD, and water temperature with Ephemeroptera was observed. DO showed strong positive relationship with Odonata and a significant negative relationship with Diptera (Table 5), highlighting the importance of DO in species compostion.

Table 2: Family-wise distribution of aquatic insect species

Order	Family	No. of species	Site 1	Site 2	Site 3	Site 4	Site 5	Individual (% occurence)	BMWP Score
Odonata	Coenagriondae	8	233	195	136	69	0	633 (19.22%)	6
	Libellulidae	12	315	258	212	78	0	863 (21.70%)	8
	Aeshnidae	1	26	13	12	2	0	53(1.44%)	8
	Gomphidae	1	18	14	10	4	0	46(1.25%)	8
Coleoptera	Dytiscidae	7	139	87	56	39	0	321 (8.75%)	5
	Elmidae	1	20	9	5	3	0	37(1.01%)	5
	Halipidae	3	49	34	21	14	0	118(3.21%)	4
	Hydrophilidae	2	36	20	11	7	0	74(2.02%)	3
Ephemeroptera	Baetidae	1	25	12	9	5	0	51(1.39%)	4
	Ephemeridae	1	24	13	8	6	0	51 (1.39%)	10
Hemiptera	Belostomatidae	2	50	33	25	14	0	122(3.33%)	3
	Nepidae	4	99	66	46	12	0	223(6.08%)	3
	Corixidae	4	91	62	35	18	0	206 (5.61%)	3
	Micronectidae	1	23	16	10	8	0	57 (1.55%)	3
	Pleidae	1	25	12	9	2	0	48(1.31%)	3
	Gerridae	4	80	72	34	20	0	206 (5.61%)	3
	Mesoveliidae	2	36	24	18	13	0	91 (2.48%)	3
	Hydrometridae	1	21	15	11	13	0	60 (1.64%)	3
	Notonectidae	2	38	30	16	12	0	96 (2.61%)	3
Diptera	Ceratopogonidae	1	12	10	11	6	0	39 (1.06%)	4
	Chironomidae	1	26	16	15	10	0	67(1.83%)	2
	Culicidae	4	58	53	33	27	0	171 (4.66%)	2
	Dixidae	1	6	9	7	8	0	30 (0.81%)	4
	Total individuals		1450	1073	750	395	0	3668	100
		BMWP	100	100	100	100	0	100	
		ASPT	5.03	5.09	5.29	4.92	0	5.09	

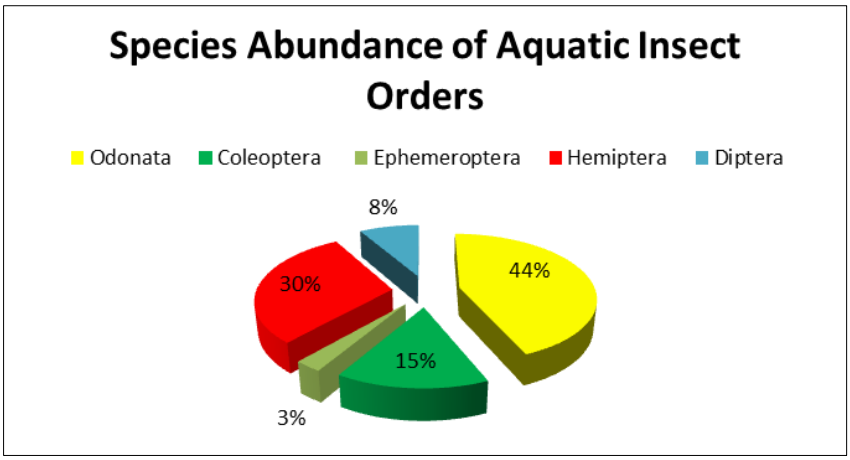

Figure 1: Composition of insect orders of Fateh Sagar Lake during a period study

Table 3: Diversity of aquatic insects in five sites of Fateh Sagar Lake

Fateh Sagar Lake	Site 1	Site 2	Site 3	Site 4	Site 5
Species	65	65	65	64	0
Number of Individuals	1450	1073	750	395	0
Dominance_D	0.016	0.017	0.018	0.019	0
Simpson_1-D	0.9835	0.9829	0.9816	0.9814	0
Shannon_H	4.14	4.12	4.08	4.06	0
Evenness_e^H/S	0.964	0.948	0.910	0.906	0
Margalef	8.79	9.17	9.67	10.54	0

Table 4: Mean values of physico-chemical parameters of selected sites of Fateh Sagar Lake

Variables	Range value	Site 1	Site 2	Site 3	Site 4	Site 5	Drinking water standard
		Mean	Mean	Mean	Mean	Mean	BIS/ICMR limit
Temperature	17.5-29.2	20.9	21.8	18.5	21.4	22.9	NA
pH	7-8.2	7.8	7.6	7.7	7.9	6.8	6.5-8.5
Total hardness (mg/l)	76-190	115.8	117.5	120.4	118.8	121.08	< 300 mg/L
TDS (mg/l)	540-700	228.42	224	231.91	228.11	194.66	< 500 mg/L
BOD (mg/l)	1.3-3.5	2.06	2.19	2.30	2.18	3.6	< 5 mg/L
COD (mg/l)	19.1-41.2	29.43	31.4	30.7	30.7	36.7	NA
DO (mg/l)	6.7-9.9	9.2	7.5	7.2	6.2	6.6	< 200 mg/L
TA(mg/l)	107-149	136.83	136.21	139.31	137.58	137.5	≥ 5.0 mg/l

Table 5: Pearson's correlation between physicochemical parameters and aquatic insect fauna

	Temp.	pH	TH	TDS	DO	COD	BOD	TA	Odonata	Coleoptera	Ephemeroptera	Hemiptera	Diptera
Temp.	1												
pH	0.909*	1											
TH	0.036	-0.389	1										
TDS	-0.119	-0.460	0.749	1									
DO	-0.425	0.146	-0.502	-0.603	1								
COD	0.900*	0.921*	-0.123	-0.429	-0.008	1							
BOD	-0.888*	-0.733	0.283	0.196	0.478	-0.713	1						
TA	0.276	-0.022	-0.108	-0.441	-0.347	0.216	-0.370	1					
Odonata	-0.451	0.143	-0.734	-0.652	0.943**	-0.095	0.347	-0.293	1				
Coleoptera	-0.438	0.135	-0.844	-0.575	0.807	-0.175	0.214	-0.305	0.955	1			
Ephemeroptera	-0.396*	0.175	-0.843	-0.516	0.766	-0.161	0.162	-0.370	0.927	0.994	1		
Hemiptera	-0.430	0.151	-0.835	-0.640	0.856	-0.131	0.238	-0.259	0.979	0.994	0.977	1	
Diptera	0.651	0.098	0.654	0.536	-0.905*	-0.327	0.518	-0.296	0.970	0.935	0.899	0.953	1

Level of significance * $p<0.05$ and ** $p<0.01$

CONCLUSION

This is the first study on the aquatic insect diversity of Fateh Sagar Lake, Udaipur, providing crucial insights into its ecological health. Biological assessments using BMWP and ASPT scores confirm that Sites 1, 2, and 3 have relatively healthy ecological conditions, whereas Site 4 has moderate pollution levels. Site 5, however, is characterized by extreme habitat degradation, with no recorded aquatic insects, primarily due to physical and ecological limitations rather than severe chemical contamination. Diversity indices further corroborate these findings, with the highest species richness and evenness observed at Site 1. The correlation analysis highlights the strong influence of DO levels on species composition, emphasizing the need to maintain adequate oxygen levels to support aquatic biodiversity. While the water quality of Fateh Sagar Lake remains within acceptable limits for drinking and aquatic life, there is a clear need for targeted conservation and pollution mitigation measures, particularly at the disturbed sites. Regular monitoring and management efforts should be implemented to prevent further deterioration and ensure the long-term sustainability of the lake ecosystem.

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