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Comparision and Relationship Between Abundance of Aquatic Insects and Water Parameters of Sagar Lake, Madhya Pradesh, India

Zoology

KEYWORDS : Aquatic insects, Physiochemical parameters, Hemiptera, Coleoptera.

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ABSTRACT

An investigation was done to study the diversity of aquatic insect community and physico-chemical parameters in Sagar Lake, India. The aquatic insects were collected by using insects net from the study area during the month of November 2013 to October 2014. The aquatic insect community was represented by 10 species, 10 genus, 12 families and 4 orders. The most abundant order was Hemiptera, followed by Coleoptera during study period. Physico-chemical parameters studied were Temperature, pH, DO, COD, BOD, Total Alkalinity, Total Hardness, Chloride, Phosphate and Nitrate.

1. INTRODUCTION:

Aquatic insects are important components in food chain of aquatic ecosystem. There are about 45,000 insect species known to inhabit diverse freshwater ecosystem (Balaram, 2005). To maintiain the stability of aquatic ecosystem its aquatic biodiversity is very essential (Vinson and Hawkins, 1998; Sharma et al., 2004). Water body's pollution status usually expressed as biological and physico-chemical parameters (Lenat, et al., 1980). Improper anthropogenic activities in water body such as washing clothes, bathing; agricultural runoff, sewage etc. may cause the disturbance of water quality. This affects the diversity and distribution of aquatic insect community. Some insects are very sensitive to pollution and prefer good water quality (Rasdi, et al., 2012), which serves them as reliable indicator of ecological characteristics of water. The development of new biomonitoring tools using aquatic insects are of great effort among the aquatic entomologist (Carter and Resh, 2001). The aquatic entomofauna of this part of India is rather poorly documented. Some works are those by (Srivastava, 1956; Krishnamurthy 1966, Mandal and Moitra 1975, Oomachan and Belsar, 1985; Pahwa, 1979; Jaiswal and Singh, 1994; Singhal, 1991). The aims and objectives of present study were to find the diversity and distribution of aquatic insects. Their abundance was correlated with water parameters to find the significant value.

2 MATERIALS AND METHODS:

2.1. Study Area

Study was conducted in Sagar Lake which is situated in the middle of the Sagar city, it is a district of Madhya Pradesh. Sagar city falls a few kilometres to the North of tropic of cancer at an altitude of 517m and at the latitude of 23°50' N and longitude of 78°45' East. The lake popularly known as "Lakha Banjara" is divided into two parts, the main lake with spread area of 1.1848 ha. and small lake with water spread area of 0.4046 ha. The catchment area of the lake basin is 1817 ha. out of which the total water spread area is 145 ha.

2.2. Experimental Design

Eight sampling sites were identified from the Lake as sampling areas consisting of two parts namely main lake and small wetland. Four sites were selected from each part. Survey of aquatic entomofauna was conducted from November 2013 to October 2014. Insects were collected at 8.00 am to 11.00 am local time in 3rd week of every month.

2.2. Collection of Samples

Samples were taken from four corners of each part of lake within an area of $10m^2$ in three replications. Insect collection were made by dipping a sweep net by sweeping method made of finely meshed polyester mosquito curtain cloth of 1mm mesh size. Dragging of sweeping net was done about one meter, in water. Insects were randomly collected and preserve in 70% ethyl alcohol at sites. Water samples were collected and took to the laboratory for water analysis in three replications for each test.

2.3. Sample Analysis

All the samples of the insects were bought to the laboratory for sorting, classifying and counting. In the laboratory insects were identified up to lowest taxonomic level either by dissecting microscope or a compound microscope. Identification of the insects samples were done by using standard keys. The family level identification was done following the manual of (Subramanian and Sivaramkrishnan, 2007a). Identification of species was confirmed in the laboratory of Zoological Survey of India, Jabalpur (Madhya Pradesh). The water parameters namely Temperature, pH, DO, COD, BOD, Total Alkalinity, Total Hardness, Chloride, Phosphate and Nitrate was analysed in the laboratory using titrimetric method.

2.4. Data Analysis

Diversity and abundance of insects were calculated. The relationship between insects and water parameters was determined. Multiple regression analysis was done to find the effects of water parameters on abundance of insects by using Origin pro 8.6.

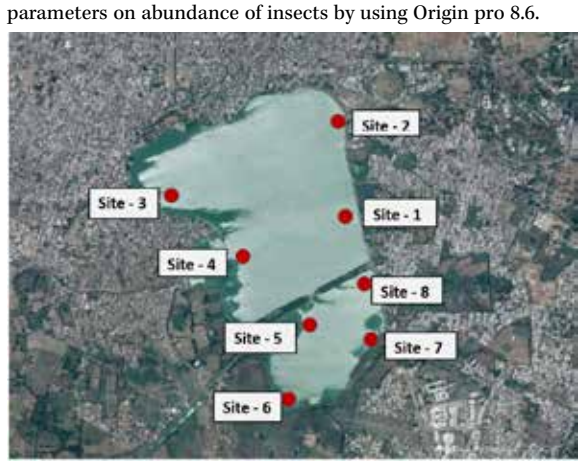

Fig 1: Satelite image of Sagar Lake showing sampling areas

3. RESULTS:

The study was carried for a period of 12 months from November 2013 to October 2014. Monthly data was collected, but results were represented season wise. Four month make one season (March to June –**'summer season'**; July to October –**'rainy season'**;and November to February –**'winter Season'**).

3.1. Composition of Aquatic insects

A total of 6,186 individuals of insects were successfully counted and classified. Collected insects classified into 4 orders, which were Hemiptera, Coleoptera, Odonata and Diptera. Hemiptera

contains three families, namely Belostomatidae, Nepidae and Gerridae. Coleoptera were classified into two families, Dytiscidae and Hydrophilidae. Furthermore, there were two suborders of insects found from order Odonata which were Anisoptera and Zygoptera. The suborder, Anisoptera contains families, Gomphidae, Aeshnidae and Lebullidae. The suborder, Zygoptera contains family Coenagriidae, Order Diptera has only one family namely Chironomidae. The Chironomidae larva is pest on aquatic plants.

Table 1: shows the mean of insect composition.

	Dr	Aniso	Zygop	Agabs	Cybstr	Hydrpls	Lacco	Rntra	Chirns	Limno
WINTER	40.03	2.84	3.41	0.28	0.43	0.43	0.21	1.25	0.43	0.37
SUMMER	37.84	3.28	2.03	0.65	4.12	0.81	0.5	1.28	1.0	0.96
RAINY	31.96	2.18	1.09	0.75	4.25	0.68	0.62	1.28	0.9	1.40

Dr= *Diplonycus rusticus*, Aniso= Anisoptera, Zygop= Zygoptera, Cybstr= *Cybister limbatus*, Hydrpls= *Hydrophilus aquaticus*, Lacco= *Laccotrepes ruber*, Rntra= *Ranatra sp*., Chirns= *Chironimus sp*., Limno= *Limnovetra flavinum*.

3.2. Relationship between Abundance of Aquatic Insects and Water Parameters

Diplonycus rusticus had recorded significant relationship with several water parameters throughout the sampling seasons. The highest correlation coefficient r value recorded for *Diplonycus rusticus* was TDS (r= 0.999, p=0.10) in winter season. However, *Diplonycus rusticus* shows the significant positive correlation with Temperature (r=0.950, p=0.04*) and DO (r=0.997, p=0.002**). *Diplonycus rusticus* had significant negative correlation with chloride (r=-0.989, p=0.01*) in rainy season. The result indicates that Anisoptera shows no significant correlation between any water parameter during winter and summer season. However, during rainy season Anisoptera had recorded significant negative correlation with DO (r=-0.969, p=0.03*). Zygoptera shows positive correlation with DO(r=0.378, p=0.62) and COD (r=0.387, p=0.61) during winter season. While, in summer season Zygoptera had positive correlation with DO (r=0.878, p=0.12), BOD (r= 0.641, p=0.35) and Alkalinity (r=0.785, p=0.21). However, in rainy season Zygoptera shows positive correlation with pH (r=0.614, p=0.38), Temperature (r=0.724, p=0.27), DO (r=0.929, p=0.07), Hardness (r=0.614, p=0.38) and Nitrate (r=0.354, p=0.64). During winter season *Agabus sp*. had recorded significant positive correlation with pH (r=0.991, p=0.008**) and TDS (r=0.951, p=0.04*). However, *Agabus sp*. shows no significant correlation between any water parameter during summer and rainy season. *Cybister limbatus* shows the significant positive correlation with Chloride (r=0.967, p=0.03*) and Hardness (r=0.992, p=0.007**) in winter season. *Cybister limbatus* show no significant correlation with any water parameter during summer season. *Cybister limbatus* had significant positive correlation with Chloride (r=0.965, p=0.03*) and significant negative correlation with DO (r=-0.973, p=0.02*) in rainy season. *Hydrophilus aquaticus* shows positive correlation with DO(r=0.470, p=0.52), Alkalinity (r=0.776, p=0.22), Nitrate (r=0.775, p=0.22) and Phosphate (r=0.577, p=0.42) during winter season. While, in summer season *Hydrophilus aquaticus* had positive correlation with Temperature (r=0.017, p=0.98), TDS (r= 0.553, p=0.44), COD (r=0.181, p=0.81), Hardness (r=0.561, p=0.43) and Phosphate (r=0.161, p=0.83). However, in rainy season *Hydrophilus aquaticus* shows positive correlation with TDS (r=0.728, p=0.27), BOD (r=0.212, p=0.78), COD (r=0.866, p=0.13), Chloride (r=0.881, p=0.11), Alkalinity (r=0.597, p=0.40), Hardness (r=0.139, p=0.86) and Phosphate (r=0.560, p=0.43). *Laccotrephes ruber* shows no significant correlation with any water parameter during winter and summer season. *Laccotrephes ruber* had significant positive correlation with TDS (r=0.946, p=0.05*) and significant negative correlation with Temperature (r=-0.962, p=0.03*) and DO (r=-0.992, p=0.007**) in rainy season. *Ranatra sp.* shows no significant correlation with any water parameter during winter, summer and rainy season. *Ranatra sp*. had significant negative correlation with pH (r=-0.983, p=0.01*) in winter season. *Chironimus sp.* shows positive correlation with pH (r=0.859, p=0.140), TDS (r=0.896, p=0.10), DO (r=0.819, p=0.18), Chloride (r=0.775, p=0.22), Alkalinity (r=0.026, p=0.97), Hardness (r=0.663, p=0.33) and Phosphate (r=0.803, p=0.19) during winter season. While, in summer season *Chironimus sp*. had positive correlation with pH (r=0.403, p=0.59), Temperature (r=0.275, p=0.72), DO (r= 0.337, p=0.66), COD (r=0.100, p=0.89), Chloride (r=0.400, p=0.59), Alkalinity (r=0.268, p=0.73 and Nitrate (r=0.310, p=0.68). However, in rainy season *Chironimus sp*. shows positive correlation with Temperature (r=0.834, p=0.16), DO (r=0.584, p=0.41) and Hardness (r=0.549, p=0.45). *Limnovetra flavinum* had recorded significant positive correlation with Phosphate (r=0.996, p=0.003**) in summer season. However, *Limnovetra flavinum* shows no significant correlation between any water parameter during winter and rainy season.

Table 2: showing relationship between aquatic insects and water parameters in winter season

	Dr	Drfly	Dmfly	Agbs	Cybstr	Hydrpls	Lacco	Rntra	Chirns	Limno
pH	r=0.939 p=0.060	r=0.244 p=0.755	r=-0.02 p=0.977	r=0.991 p=0.008**	r=0.536 p=0.463	r=-0.48 p=0.512	r=0.201 p=0.798	r=-0.98 p=0.016*	r=0.859 p=0.140	r=0.116 p=0.883
Temp	r=-0.50 p=0.490	r=-0.54 p=0.450	r=-0.32 p=0.678	r=-0.41 p=0.586	r=-0.14 p=0.851	r=-0.50 p=0.490	r=-0.35 p=0.642	r=0.345 p=0.654	r=-0.82 p=0.179	r=0.183 p=0.816
TDS	r=0.999 p=0.102	r=-0.06 p=0.930	r=-0.13 p=0.647	r=0.952 p=0.047*	r=0.802 p=0.197	r=-0.39 p=0.608	r=0.540 p=0.459	r=-0.93 p=0.065	r=0.896 p=0.103	r=0.453 p=0.546
DO	r=0.511 p=0.488	r=0.604 p=0.395	r=0.378 p=0.621	r=0.437 p=0.562	r=0.107 p=0.892	r=0.470 p=0.529	r=0.291 p=0.708	r=-0.37 p=0.627	r=0.819 p=0.180	r=-0.24 p=0.758
BOD	r=-0.54 p=0.451	r=-0.49 p=0.501	r=-0.26 p=0.738	r=-0.44 p=0.558	r=-0.21 p=0.789	r=-0.49 p=0.508	r=-0.41 p=0.588	r=0.373 p=0.626	r=-0.84 p=0.153	r=0.120 p=0.879
COD	r=-0.41 p=0.586	r=0.208 p=0.791	r=0.387 p=0.612	r=-0.15 p=0.849	r=-0.57 p=0.427	r=-0.60 p=0.397	r=-0.89 p=0.106	r=0.081 p=0.918	r=-0.61 p=0.387	r=-0.49 p=0.503
Chlo	r=0.876 p=0.123	r=-0.42 p=0.570	r=-0.67 p=0.321	r=0.715 p=0.284	r=0.967 p=0.032*	r=-0.18 p=0.818	r=0.852 p=0.148	r=-0.68 p=0.311	r=0.775 p=0.224	r=0.770 p=0.229
Alkal	r=-0.16 p=0.835	r=-0.41 p=0.580	r=-0.42 p=0.578	r=-0.43 p=0.561	r=0.261 p=0.738	r=0.776 p=0.223	r=0.723 p=0.276	r=0.491 p=0.508	r=0.026 p=0.973	r=0.458 p=0.541

Hard	r=0.797 p=0.202	r=-0.57 p=0.429	r=-0.78 p=0.210	r=0.620 p=0.379	r=0.992 p=0.007**	r=-0.18 p=0.811	r=0.887 p=0.112	r=-0.59 p=0.402	r=0.663 p=0.336	r=0.864 p=0.135
Nitrat	r=-0.53 p=0.464	r=-0.40 p=0.593	r=-0.28 p=0.710	r=-0.75 p=0.245	r=-0.05 p=0.947	r=0.775 p=0.224	r=0.428 p=0.571	r=0.789 p=0.210	r=-0.36 p=0.639	r=0.274 p=0.725
Phosp	r=0.535 p=0.464	r=0.175 p=0.824	r=-0.05 p=0.946	r=0.341 p=0.658	r=0.421 p=0.578	r=0.577 p=0.422	r=0.693 p=0.306	r=-0.26 p=0.732	r=0.803 p=0.196	r=0.189 p=0.810

Note: Correlation is significant at the 0.01 level (2-tailed) and 0.05 level (2-tailed); r = Pearson's correlation; p = significance (2-tailed)

Dr= *Diplonycus rusticus*, Aniso= Anisoptera, Zygop= Zygoptera, Cybstr= *Cybister limbatus*, Hydrpls= *Hydrophilus aquaticus*, Lacco= *Laccotrepes ruber*, Rntra= *Ranatra sp*., Chirns= *Chironimus sp*., Limno= *Limnovetra flavinum.*

pH= pH, Temp=Temperature, TDS= Total Dissolved Solids, DO=Dissolved Oxygen, BOD= Biochemical Oxygen

Demand, COD= Chemical Oxygen Demand, Chlo= Chloride, Alkal= Alkalinity, Hard= Hardness, Nitrat= Nitrate, Phosp= Phosphate.

Table 3: showing relationship between aquatic insects and water parameters in summer season

	Dr	Drfly	Dmfly	Agabs	Cybstr	Hydrpls	Lacco	Rntra	Chirns	Limno
pH	r=-0.29 p=0.701	r=0.697 p=0.308	r=-0.18 p=0.81	r=-0.10 p=0.891	r=0.242 p=0.757	r=-0.17 p=0.823	r=0.431 p=0.568	r=0.062 p=0.937	r=0.403 p=0.596	r=0.868 p=0.131
Temp	r=-0.46 p=0.539	r=0.741 p=0.258	r=-0.37 p=0.626	r=-0.09 p=0.904	r=0.406 p=0.592	r=0.017 p=0.982	r=0.590 p=0.409	r=0.192 p=0.807	r=0.275 p=0.724	r=0.835 p=0.164
TDS	r=-0.76 p=0.239	r=0.005 p=0.994	r=-0.66 p=0.335	r=0.680 p=0.319	r=0.758 p=0.241	r=0.553 p=0.446	r=0.796 p=0.203	r=0.759 p=0.240	r=-0.40 p=0.590	r=0.911 p=0.088
DO	r=0.883 p=0.116	r=-0.50 p=0.499	r=0.878 p=0.121	r=-0.11 p=0.889	r=-0.84 p=0.154	r=-0.58 p=0.414	r=-0.92 p=0.077	r=-0.63 p=0.366	r=0.337 p=0.662	r=-0.46 p=0.539
BOD	r=0.671 p=0.328	r=-0.77 p=0.225	r=0.641 p=0.358	r=-0.16 p=0.832	r=-0.61 p=0.388	r=-0.24 p=0.757	r=-0.76 p=0.239	r=-0.34 p=0.659	r=-0.03 p=0.962	r=-0.54 p=0.453
COD	r=-0.62 p=0.376	r=0.811 p=0.188	r=-0.59 p=0.408	r=-0.21 p=0.780	r=0.561 p=0.438	r=0.181 p=0.818	r=0.719 p=0.280	r=0.282 p=0.717	r=0.100 p=0.899	r=0.542 p=0457
Chlo	r=-0.33 p=0.661	r=0.773 p=0.226	r=-0.24 p=0.759	r=-0.17 p=0.820	r=0.277 p=0.722	r=-0.15 p=0.845	r=0.472 p=0.527	r=0.063 p=0.936	r=0.400 p=0.599	r=0.816 p=0.183
Alkal	r=0.853 p=0.146	r=-0.40 p=0.591	r=0.785 p=0.214	r=-0.33 p=0.666	r=-0.82 p=0.178	r=-0.50 p=0.492	r=-0.91 p=0.081	r=-0.67 p=0.325	r=0.268 p=0.731	r=-0.82 p=0.175
Hard	r=-0.72 p=0.278	r=0.429 p=0.570	r=-0.78 p=0.261	r=-0.96 p=0.903	r=0.690 p=0.309	r=0.561 p=0.438	r=0.719 p=0.280	r=0.476 p=0.523	r=-0.37 p=0.628	r=-0.01 p=0.981
Nitrat	r=-0.40 p=0.594	r=0.693 p=0.306	r=-0.30 p=0.699	r=-0.58 p=0.941	r=0.349 p=0.650	r=-0.06 p=0.930	r=0.532 p=0.467	r=0.161 p=0.838	r=0.310 p=0.689	r=0.879 p=0.120
Phosp	r=-0.46 p=0.534	r=0.194 p=0.805	r=-0.33 p=0.662	r=0.441 p=0.558	r=0.447 p=0.552	r=0.161 p=0.838	r=0.547 p=0.452	r=0.425 p=0.574	r=-0.01 p=0.9850	r=0.996 p=0.003**

Note: Correlation is significant at the 0.01 level (2-tailed) and 0.05 level (2-tailed); r = Pearson's correlation; p = significance (2-tailed)

Table 4: showing relationship between aquatic insects and water parameters in rainy season

	Dr	Drfly	Dmfly	Agabs	Cybstr	Hydrpls	Lacco	Rntra	Chirns	Limno
pH	r=-0.17 p=0.820	r=0.222 p=0.777	r=0.048 p=0.951	r=-0.18 p=0.812	r=0.110 p=0.889	r=-0.12 p=0.272	r=0.265 p=0.734	r=0.503 p=0.496	r=-0.25 p=0.746	r=-0.45 p=0.542
Temp	r=0.950 p=0.049*	r=-0.82 p=0.172	r=0.724 p=0.275	r=-0.70 p=0.296	r=-0.81 p=0.181	r=-0.88 p=0.111	r=-0.96 p=0.037*	r=-0.52 p=0.471	r=0.834 p=0.165	r=0.533 p=0.466
TDS	r=-0.91 p=0.084	r=0.856 p=0.143	r=-0.70 p=0.295	r=0.641 p=0.358	r=0.818 p=0.181	r=0.728 p=0.271	r=0.946 p=0.053*	r=0.695 p=0.304	r=-0.72 p=0.276	r=-0.51 p=0.489
DO	r=0.997 p=0.002**	r=-0.96 p=0.030*	r=0.929 p=0.070	r=-0.90 p=0.931	r=-0.97 p=0.026*	r=-0.83 p=0.163	r=-0.99 p=0.007**	r=-0.71 p=0.288	r=0.584 p=0.415	r=0.808 p=0.191
BOD	r=-0.50 p=0.499	r=0.503 p=0.496	r=-0.24 p=0.753	r=0.121 p=0.878	r=0.407 p=0.592	r=0.212 p=0.787	r=0.574 p=0.425	r=-0.63 p=0.363	r=-0.48 p=0.514	r=-0.05 p=0.949
COD	r=-0.86 p=0.14	r=0.685 p=0.314	r=-0.55 p=0.443	r=0.540 p=0.459	r=0.672 p=0.327	r=0.866 p=0.133	r=0.879 p=0.120	r=0.374 p=0.625	r=-0.92 p=0.071	r=-0.33 p=0.662
Chlo	r=-0.98 p=0.010	r=0.944 p=0.055*	r=-0.93 p=0.061	r=0.936 p=0.063	r=0.965 p=0.034*	r=0.881 p=0.118	r=0.973 p=0.261	r=0.634 p=0.365	r=-0.58 p=0.413	r=-0.83 p=0.167
Alkal	r=-0.88 p=0.115	r=0.895 p=0.104	r=-0.74 p=0.259	r=0.654 p=0.345	r=0.846 p=0.153	r=0.597 p=0.402	r=0.920 p=0.079	r=0.833 p=0.166	r=-0.55 p=0.444	r=-0.57 p=0.424
Hard	r=0.274 p=0.725	r=-0.55 p=0.440	r=0.614 p=0.385	r=-0.54 p=0.450	r=-0.54 p=0.453	r=0.139 p=0.860	r=-0.26 p=0.734	r=-0.77 p=0.220	r=0.549 p=0.450	r=0.735 p=0.264
Nitrat	r=0.006 p=0.993	r=-0.86 p=0.913	r=0.354 p=0.645	r=-0.45 p=0.547	r=-0.18 p=0.815	r=-0.09 p=0.901	r=0.756 p=0.924	r=0.089 p=0.910	r=-0.43 p=0.567	r=0.546 p=0.453
Phosp	r=-083 p=0.165	r=0.826 p=0.172	r=-0.64 p=0.357	r=0.550 p=0.449	r=0.767 p=0.232	r=0.560 p=0.439	r=0.879 p=0.120	r=0.784 p=0.215	r=-0.59 p=0.400	r=-0.45 p=0.542

Note: Correlation is significant at the 0.01 level (2-tailed) and 0.05 level (2-tailed); r = Pearson's correlation; p = significance (2-tailed)

3.3. Effects of Water Parameters on Abundance of Aquatic Insects

The R^2 values for the winter season Table 5 shows that 97.1% of abundance of the *Diplonycus rusticus* in the Lake is explained by the water parameters. In the summer season the R^2 values of the multiple regression models for *Diplonycus rusticus* was 89.7% Table 6. However, the R^2 values for the rainy season Table 7 was 0.881. Therefore, about 88.1% *Diplonycus rusticus* abundance was explained by water parameters. The multiple regression models to predict the effects of water parameters on abundance of *Cybister limbatus* were only significance for winter season. The R^2 values of the multiple regression models for winter season for *Cybister limbatus* was 0.999 Table 5 Therefore, about 99.9 % water paramaters influenced the abundance of *Cybister limbatus*. Among the water parameters, pH (0.010) and Alkalinity (0.009) showed significant difference with abundance of *Cybister limbatus*. In the summer season the R^2 values of the multiple regression models for *Cybister limbatus* was 0.979 Table 6. However, the R^2 values for the rainy season Table 7 was 0.975 it means that 97.5% of *Cybister limbatus* abundance was explained by water parameters. The significance of the regression model between *Chironimus sp.* and water parameter was 0.009 in rainy season. The water parameter that more influenced and well predict to the abundance of *Chironimus sp*. was Temperature and DO in rainy season. The R^2 value of this season for *Chironimus sp*. was 0.999. The R^2 value of the regression model for *Chironimus sp*. in winter and summer season was low 0.998 and 0.927 respectively. The multiple regression model for *Limnovetra flavinum* in different season of the lake was not authentic to predict the effects of water parameters on abundance of the *Limnovetra flavinum*. In overall, the significance of the regression model for winter, summer and rainy season were 0.179, 0.384 and 0.113 ($p > 0.05$) respectively. Table 5,6 and 7 showed that TDS, BOD, COD, Chloride and Hardness were excluded in all analysis since the variable was failed to meet the selection criteria as indicate by non-significant t-value; $p>0.05$.

Table 5: multiple regression analysis between aquatic insects and water parameters in winter season

			pH	Temp	DO	Alkalinity	Nitrate	Phosphate
Diplonychus Rusticus	Coefficient t value P value R^2	0.971	-392.641 -1.706 0.337	-193.092 -3.266 0.189	30.876 1.615 0.352	-2.723 -0.363 0.778	108.12 1.494 0.375	-1663.15 -4.530 0.138
Dragonfly Nymph	Coefficient t value P value R^2	0.992	-133.18 -4.544 0.137	-136.995 -4.913 0.127	4.998 2.053 0.288	5.675 5.940 0.106	67.112 7.284 0.086	-396.50 -8.479 0.074
Damselfly nymph	Coefficient t value P value R^2	0.872	-61.979 -0.647 0.634	-38.593 -1.568 0.361	9.233 1.160 0.452	1.198 0.383 0.766	23.851 0.792 0.573	-249.70 -1.634 0.349
Agabus sp.	Coefficient t value P value R^2	0.982	4.941 0.619 0.647	-2.518 -1.228 0.435	-0.451 -0.681 0.619	--1.064 -4.089 0.152	-3.728 -1.485 0.377	-32.911 -2.583 0.235
Cybister limbatus	Coefficient t value P value R^2	0.999*	23.678 61.459 0.010*	2.895 29.245 0.021*	2.002 62.577 0.010*	0.859 68.397 0.009**	3.762 31.063 0.0204*	4.688 7.626 0.083
Hydrophillus aquaticus	Coefficient t value P value R^2	0.814	-24.704 -0.757 0.587	-8.406 -1.003 0.498	1.126 0.415 0.749	-0.186 -0.175 0.889	2.393 0.233 0.853	-54.500 -1.047 0.485
Laccotrepes ruber	Coefficient t value P value R^2	0.904	-27.720 -1.665 0.344	-4.605 -1.077 0.476	1.904 1.377 0.399	0.242 0.447 0.732	3.553 0.679 0.620	-14.841 -0.558 0.675
Ranatra sp.	Coefficient t value P value R^2	0.968	-22.156 -0.610 0.650	-2.798 -0.300 0.814	5.568 1.847 0.315	3.093 2.614 0.232	25.874 2.268 0.264	-66.209 -1.143 0.457
Chironimus sp.	Coefficient t value P value R^2	0.998	-0.125 -0.086 0.945	1.348 3.591 0.172	0.459 3.784 0.164	-0.156 -3.286 0.188	-3.764 -8.194 0.077	11.165 4.789 0.131
Limnovetra flavinum	Coefficient t value P value R^2	0.975	-46.358 -3.454 0.179	-7.962 -2.309 0.260	2.494 2.237 0.267	0.197 0.452 0.729	3.753 0.889 0.537	-24259 -1.132 0.460

Note: * significance at p<0.05 (2 tailed), ** significance at p<0.01 (2 tailed)

Table 6: multiple regression analysis between aquatic insects and water parameters in summer season

			pH	Temp	DO	Alkalinity	Nitrate	Phosphate
Diplonychus Rusticus	Coefficient t value P value R^2	0.897	-99.734 -0.564 0.672	-34.871 -0.781 0.577	60.058 0.743 0.593	7.197 0.719 0.602	-29.145 -1.009 0.497	117.510 0.120 0.923
Dragonfly Nymph	Coefficient t value P value R^2	0.610	-39.607 -0.637 0.638	13.792 0.878 0.541	-23.843 -0.838 0.555	0.382 0.108 0.931	3.141 0.309 0.809	82.786 0.241 0.849
Damselfly nymph	Coefficient t value P value R^2	0.968	6.824 1.565 0.361	0.622 0.565 0.672	-0.445 -0.223 0.860	0.106 0.432 0.740	0.288 0.404 0.755	-104.69 -4.349 0.143

Agabus sp.	Coefficient t value P value R^2	0.944	-6.663 -0.488 0.710	6.856 1.988 0.296	-14.078 -2.253 0.265	0.268 0.348 0.786	-2.323 -1.041 0.487	283.03 3.756 0.165
Cybister limbatus	Coefficient t value P value R^2	0.979	8.840 0.645 0.634	10.652 -3.080 0.199	22.507 3.593 0.174	1.620 2.091 0.283	3.338 1.491 0.376	-56.981 -0.754 0.588
Hydrophillus aquaticus	Coefficient t value P value R^2	0.998*	-9.205 -8.931 0.070	-3.125 -12.00 0.052*	6.845 14.515 0.043*	-0.719 -12.331 0.051*	-0.579 -3.436 0.180	-36.00 -6.328 0.997
Laccotrepes ruber	Coefficient t value P value R^2	0.815	16.749 1.309 0.415	-2.097 -0.649 0.633	5.557 0.949 0.516	0.548 0.757 0.587	-0.261 -0.124 0.920	-88.058 -1.247 0.430
Ranatra sp.	Coefficient t value P value R^2	0.658	-44.252 -0.897 0.534	-5.042 -0.404 0.755	7.404 0.328 0.798	-0.811 -0.290 0.819	0.849 0.105 0.933	1.515 0.005 0.996
Chironimus sp.	Coefficient t value P value R^2	0.927	-17.846 -1.793 0.323	-3.067 -1.220 0.437	4.129 0.906 0.531	0.142 0.252 0.842	1.575 0.968 0.510	52.709 0.959 0.513
Limnovetra flavinum	Coefficient t value P value R^2	0.817	-10.111 -0.544 0.682	-5.370 -1.144 0.457	12.309 1.448 0.384	-0.644 -0.613 0.649	1.991 0.655 0.630	-95.17 -0.928 0.523

Note: * significance at p<0.05 (2 tailed), ** significance at p<0.01 (2 tailed)

Table 7: multiple regression analysis between aquatic insects and water parameters in rainy season

			pH	Temp	DO	Alkalinity	Nitrate	Phosphate
Diplonychus Rusticus	Coefficient t value P value R^2	0.881	94.407 0.523 0.693	20.150 1.293 0.419	8.961 0.527 0.691	-1.209 -0.241 0.849	-4.990 -0.222 0.860	1559.3 2.098 0.283
Dragonfly Nymph	Coefficient t value P value R^2	0.879	20.498 0.426 0.743	2.367 0.570 0.670	-3.0804 -0.680 0.619	-3.214 -2.405 0.250	-3.735 -0.625 0.644	114.63 0.579 0.665
Damselfly nymph	Coefficient t value P value R^2	0.702	3.932 0.117 0.925	-1.389 -0.482 0.713	2.828 0.899 0.533	0.175 0.189 0.880	2.716 0.655 0.630	32.26 0.234 0.853
Agabus sp.	Coefficient t value P value R^2	0.981	4.456 0.465 0.722	2.173 2.626 0.231	0.014 0.015 0.990	0.503 1.890 0.309	-3.645 -3.062 0.200	123.65 3.134 0.196
Cybister limbatus	Coefficient t value P value R^2	0.975	47.326 2.355 0.255	-2.146 -1.236 0.432	-0.432 -0.228 0.856	-2.975 -5.325 0.118	-2.441 -0.977 0.507	145.78 1.761 0.328
Hydrophillus aquaticus	Coefficient t value P value R^2	0.925	-13.240 -1.214 0.438	-2.473 -2.626 0.231	-1.018 -0.991 0.502	0.0506 0.166 0.894	-3.480 -2.568 0.236	-58.85 -1.310 0.414
Laccotrepes ruber	Coefficient t value P value R^2	0.980	13.333 2.182 0.273	0.546 1.035 0.488	0.395 0.686 0.616	-0.468 -2.756 0.221	-0.514 -0.678 0.620	139.39 5.540 0.113
Ranatra sp.	Coefficient t value P value R^2	0.739	5.781 0.139 0.911	-3.094 -0.866 0.545	-0.118 -0.030 0.980	-0.032 -0.028 0.981	-0.624 -0.121 0.923	-183.63 -1.078 0.475
Chironimus sp.	Coefficient t value P value R^2	0.999*	-4.317 -6.104 0.103	-4.273 -69.94 0.009**	-4.064 -60.97 0.010*	-0.542 -27.57 0.023*	-1.573 -17.89 0.035*	6.355 2.182 0.273
Limnovetra flavinum	Coefficient t value P value R^2	0.985	103.84 5.563 0.113	-6.654 -4.127 0.151	-4.921 -2.797 0.218	-2.198 -4.235 0.147	3.579 1.542 0.366	145.34 1.890 0.309

Note: * significance at p<0.05 (2 tailed), ** significance at p<0.01 (2 tailed)

4. DISCUSSION:

4.1. Composition of the Aquatic Insects

Aquatic insects are found associated with water for the most part of their lifecycle, any change in their number and composition in the population at a given time and space may indicate a change in the water quality. They also act as an indicator of trophic structure, water quality and eutrophication of the aquatic ecosystems (Varma and Pratap, 2006). First sampling of aquatic entomofauna was conducted in winter season (November 2013 to February 2014) where there is occasionally rainfall, whereas second sampling was done in summer season (March to June 2014) where there is little rainfall and third sampling was done in rainy season (July to October 2014) when there is relatively high rainfall. According to (Basset, 1999), abundance of aquatic insects during a particular sampling period was considerably influenced by rainfall and surrounding vegetation. (Norazliza, et al.,) had determined the effect of water parameter on abundance of beneficial insects in the paddy field of Sungai Burong at two seasons of sampling periods and found that water parameters such as Water Temperature, DO, BOD and COD were good predictors for abundance of beneficial insects which were Anisoptera, Zygoptera, Gerridae and Coccinellidae. Odonates are characterized as an excellent habitat indicator of present and past (long term) environmental conditions in aquatic habitats (Watson, et al., 1982; Steward and Samway, 1988). A feature of the odonate species is that they prefer to live in freshwater, non-contaminated and well oxygenated habitats. Hence, they can serve as valuable bio-indicators for environmental contamination studies (Needham, et al., 2000; Morin, 1984). Diptera prefer lentic habitats as breeding ground and early life stages (Majumder, Goswami and Agarwala, 2011). Aquatic Hemiptera have an intermediate place in the food chain, apart from being eaten, are often important predators too (Runck and Blinn, 1994). Insecticide run-off could be damaging to the population of predatory aquatic bugs of superfamily Nepoidea, including families Belostomatidae and Nepidae (Vasuki, 1996). Predators such as *Dytiscus* reduce the number of other invertebrates and help to keep the balance among the different kinds of organisms and the food that is available in the freshwater ecosystem. Family Dytiscidae generally inhabits leaf of bottom macrophytes of the clean freshwater and are predacious in nature. Hydrophylidae family are water scanvenger beetles and generally occur in shallower regions of the wetland with abundant macrophytes particularly emergent ones and feed mainly on detritus, algae and decaying vegetative matter (Khan and Ghosh, 2001). In this way, aquatic insects may consider as model organisms in analyzing the structure and function of the freshwater ecosystem because of their high abundance, large biomass and rapid colonization of freshwater habitats.

4.2. Relationship and Effects of Water Parameters on Abundance of Aquatic Insects

The results of Pearson's correlation indicate that *Agabus sp.* had significant correlation with both pH and TDS with probability value of 0.008 with 1% significant level and 0.04 with 5% significant level respectively. pH is important environment factors which affect the life process of animals inhabiting the water. The increase rate of decomposition of organic matters, influx of CO_2, source of high water temperature, mixing of domestic sewage caused low pH value, (Dubey, et al., 2006). The *Cybister limbatus* show significant correlation with Chloride with probability value of 0.03 at 5% significant level and Hardness with probability value of 0.007 with 1% significant level respectively, in winter season. There is significant correlation between *Limnovetra flavinum* and phosphate with probability value of 0.003 at 1% significant level during summer. There is Phosphate contamination when fertilizer is used in nearby agricultural field and detergent is widely used. Phosphate concentration together with Nitrate indicates eutrophic nature of water body (Ahmad, et al., 2011). During rainy season *Diplonycus rusticus* show significant correlation with Temperature with probality value of 0.04. Water Temperature affects the numbers of aquatic insects since each species requires in a specific range of water temperature to live in because of different respiratory rate metabolism (Devi, 2013). *Laccotrephes ruber* show significant correlation with TDS with probability value of 0.05 at 5% significant level. Both Anisoptera and *Cybister limbatus* show significant correlation with Chloride with probability value of 0.05 and 0.03 respectively at 5% significant level. *Cybister limbatus* and *Laccotrephes ruber* show significant negative correlation with DO during rainy season with probability value of 0.02 at 5% significant level and 0.007 with 1% significant level. Negative relationship of DO with rainfall might be an indication that surface runoff transported sewage, fertilizer etc into the Lake which lowered the DO value by bacterial respiration (Laskar and Gupta, 2009).

The results of multiple regression models showed that these models could predict the effects of selected water parameters on abundance of aquatic insects in Sagar Lake as the R^2 value is high. The results of multiple regression models showed that there is a relation, at the 95% confidence level, between the effects of water parameters and the abundance of aquatic insects in Sagar Lake (significance values of overall regression models were below $p < 0.05$). There was inter-relationship between different physico-chemical parameters which affect the diversity and distribution of aquatic insects in particular water body. However, there is limited information related to abundance and distribution of aquatic insects in lentic water body in Madhya Pradesh. Therefore, it is important to continue study on aquatic insects so that it is accessible for scientists who are attentive in proper organisation of aquatic resources.

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