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A Seasonal Assessment of Water Quality Characteristics and Aquatic Insects Diversity in Ropar Wetland (Ramsar Site), Punjab, India

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ABSTRACT

Wetlands are vital freshwater ecosystems that support diverse aquatic life, including endangered and vulnerable species. The decrease in wetland water quality directly or indirectly influences the aquatic biodiversity, making continuous monitoring which is essential for sustainable management. The study focused on the seasonal variations of the physico-chemical water quality parameters and their influence on the aquatic insect diversity of the Ropar Wetland (Ramsar site), Punjab, India, from February, 2021 to January, 2023. Four sites were sampled across four seasons viz., winter (December to February), pre-monsoon (March to May), monsoon (June to August) and post-monsoon (September to November). Most of the parameters including alkalinity, hardness, calcium and chloride, peaked during the pre-monsoon and declined during winter, while dissolved oxygen showed inverse trend. In case of aquatic insect diversity, a total of 24 genera, 18 families and 7 insect orders were recorded, a strong correlation of insect diversity was also observed with water parameters. These findings highlight the ecological significance of aquatic insects as bioindicators and emphasize the need for sustainable management strategies to maintain wetland health.

Key words: Aquatic insects, physico-chemical parameters, Ropar Wetland, Ramsar site, seasonal variations, sustainable maintenance

INTRODUCTION

Wetlands are the most productive ecosystems in natural environment (Balwan and Kour, 2021). They meet numerous essential needs including water supply, protein synthesis, water purification, biodiversity maintenance, flood control, recreation, research and education. They also hold great cultural, social, ecological and economic significance (Ramachandra *et al*., 2024). Wetlands are characterized by four main types of services and functions: production of food, water, raw materials for building like clay and wood, regulation including the ecological processes of the wetland that support a healthy environment and information including research, education, aesthetic and spiritual values related to wetland (Banda and Banda, 2022; Mandishona and Knight, 2022).

Despite their importance, wetlands are facing a crisis due to critical decline in area and number, caused by population growth, high rates of urbanization, increased water consumption for irrigation and the use of dry land for agricultural activities. These factors exert negative impacts on the physico-chemical dynamics and biodiversity of wetland environments (Kumar and Singh, 2020). Surface runoff carries unwanted and toxic materials into the wetlands regularly, lowering the water quality (Scholz, 2023). Punjab (India) is home to several designated Ramsar sites, including Kanjli lake, Harike lake, Keshopur-Miani Reserve, Beas Conservation Reserve and Ropar Wetland.

The present study narrowed its focus on the Ropar wetland, which is surrounded by a thermal power plant, cement factory and some other running projects that result to the settlement of human population in this area in heavy number (Kumar and Singh, 2020). This growing population accelerates the deforestation, leading to the discharge of large amounts of silt. The silt, in turn, affects the abiotic features of the water, making it

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unsuitable for fish and many other aquatic insects to survive. Additionally, the water holding capacity and its depth have both been significantly diminished by the emergence of small islands in its reservoir area (Sheoran *et al.,* 2024). Insects play a crucial role in the aquatic and terrestrial ecosystems, especially like order Lepidoptera, and their diversity serves as an important bio-indicator of environmental health (Kirti *et al.,* 2019). Any change in the abiotic factors affects the flora and fauna of the water body in which water insects play significant role to maintain the ecological balance of the water body (Kaur *et al.,* 2023a, b).

Accordingly, the study was to evaluate the seasonal variations of physico-chemical parameters of Ropar wetland and their effects on the abundance of the aquatic insect diversity. The research highlighted the need for ongoing ecological monitoring to promote the conservation and sustainable management of this important Ramsar site.

MATERIALS AND METHODS

The study was conducted at Ropar Wetland, situated in the Sutlej River valley in the Rupnagar district of Punjab (India). It covers an area of 1365 ha, which includes 800 ha of reservoir and river area, 30 ha of forest around Sadavart and 30 ha area marshy land. The water sampling sites were chosen based on their exposure to natural and anthropogenic influences. The study was conducted through four separate seasons from February, 2021 to January, 2023; the winter season (December to February), Pre-monsoon season (March to May), Monsoon season (June to August) and the Post-monsoon season (September to November). The precise locations of the sampling sites: Site I (Ropar head: 30º59'31.9" N 76º30'57.5" E), Site II (Garh Bagha: 31º01'16.7" N 76º31'56.0" E), Site III (Chak Dhera: 31º02'28.0" N 76º31'28.9" E), and Site IV (Batarla: 31º04'17.7" N 76º33'22.0" E) were selected with the help of GPS (Fig. 1). These sites were selected due to presence of various industries in Himachal Pradesh which add some pollutants in the water which affect the biodiversity of animals especially the invertebrates like insects.

Water samples were collected seasonally from each site using 2 litre plastic bottles to ensure sample integrity. Physical parameters like Air Temperature (AT; ºC), Water Temperature (WT; ºC), pH and Electrical Conductivity (EC; µS/cm) were determined on site with the help of digital meters. Chemical parameters like Dissolved Oxygen (DO; mg/l), Free Carbon Dioxide (FCO_2; mg/l), Alkalinity (mg/l), Hardness (mg/l), Calcium (mg/l) and Chloride (mg/l) were analyzed in the laboratory by titrimetric methods using standard methodology (APHA, 2017).

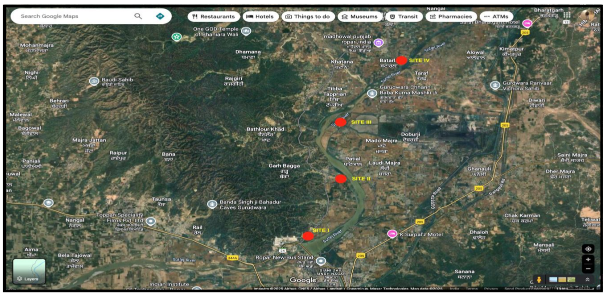

Fig. 1. Map of Ropar Wetland along with selected sites (*Source*: Google Maps).

All physical and chemical water parameters were expressed as mean±standard deviation (SD). The relationship between alteration in the physico-chemical parameters and their effects on the diversity of aquatic insects was measured by using correlation matrix.

Aquatic insects were collected using the Kick method with a plankton net (mesh size: 60 µm). Specimens were preserved either by wet preservation (70% ethyl alcohol) or by standard dry preservation techniques like pinning and stretching. The collected specimens were sorted out for further identification. The taxonomic identification of immature and adult stages of insects were examined under a magnoscope and various magnifications of Dewinter's advanced stereo-zoom microscope. Characterizations of specimen were done with the help of standard keys and relevant literature.

RESULTS AND DISCUSSION

At all sites, both AT and WT exhibited seasonal fluctuations consistent with climatic patterns. AT showed moderate negative correlations with DO and FCO_2 (Table 1), while strong positive correlations with alkalinity, hardness, calcium, chloride, EC (Tables 2 and 3). WT showed very strong negative correlations with DO and FCO_2 and moderate positive correlation

Table 1. Seasonal variations in the physico-chemical water parameters at site I, II, III and IV of the Ropar Wetland (February, 2021 to January, 2023)

Sites	Seasons	DO (mg/l)	FCO_2 (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	Calcium (mg/l)	Chloride (mg/l)	pH	EC (µS/cm)	AT (ºC)	WT (ºC)
Site I	Winter	8.57±0.13	2.25±0.02	76.73±9.87	169.81±7.08	25.44±0.29	19.28±0.18	6.81±0.01	244.67±10.31	19.90±0.18	18.01±0.85
	Pre-M	7.19±0.44	3.47±0.27	112.60±27.68	358.92±0.69	39.63±0.14	37.49±0.39	7.87±0.05	418.26±5.20	32.44±0.42	24.33±2.15
	Monsoon	6.16±0.11	2.89±0.03	98.69±13.13	244.62±5.40	26.93±0.09	23.83±1.12	7.37±0.03	329.64±6.56	30.64±1.01	27.62±0.40
	Post-M	7.57±0.40	3.18±0.05	80.19±11.57	216.21±8.33	29.92±0.24	22.42±1.65	7.22±0.04	322.58±3.41	25.82±0.59	23.40±0.73
Site II	Winter	8.53±0.09	2.28±0.03	95.67±30.71	193.26±11.77	24.36±0.22	18.37±0.20	6.44±0.03	240.33±3.50	19.16±0.90	18.21±0.71
	Pre- M	7.43±0.12	3.51±0.27	134.97±1.52	340.51±4.83	34.18±0.14	35.07±0.78	7.95±0.03	347.01±11.86	28.97±2.81	24.23±0.46
	Monsoon	6.40±0.15	2.91±0.03	114.59±17.79	234.12±5.02	24.98±0.09	18.39±0.59	7.18±0.01	326.96±6.33	27.92±0.30	24.18±0.50
	Post-M	7.91±0.03	3.19±0.02	102.78±24.54	224.90±4.45	27.61±0.30	22.95±1.17	7.43±0.03	298.29±0.71	24.18±0.75	22.40±0.22
Site III	Winter	8.65±0.13	2.29±0.02	92.28±6.24	170.08±0.66	24.19±0.14	16.68±0.11	6.60±0.07	252.15±13.33	19.80±0.54	17.21±1.96
	Pre- M	7.30±0.29	3.51±0.29	125.90±14.86	359.02±4.69	38.39±0.13	38.72±0.44	7.92±0.06	431.77±5.72	31.42±0.74	25.75±1.16
	Monsoon	6.40±0.06	2.94±0.04	108.74±0.75	252.23±4.95	26.99±0.09	25.17±0.65	7.31±0.06	347.86±6.34	30.92±0.89	26.73±0.29
	Post-M	7.91±0.03	3.19±0.03	94.28±4.94	227.29±5.03	29.79±0.43	23.46±1.34	7.41±0.09	331.36±1.52	25.91±0.40	22.88±0.65
Site IV	Winter	8.47±0.04	2.29±0.03	79.61±2.20	166.17±0.98	23.60±0.14	18.17±0.68	6.31±0.09	231.17±7.88	16.89±0.49	15.86±0.50
	Pre-M	7.50±0.17	3.50±0.27	112.75±20.92	337.21±5.13	33.92±0.17	34.31±0.24	7.91±0.02	341.66±6.76	29.42±3.40	23.40±0.46
	Monsoon	6.27±0.02	2.93±0.02	94.11±2.76	230.60±4.77	24.77±0.33	24.03±0.82	7.36±0.02	304.83±0.75	28.42±0.33	24.20±1.74
	Post-M	7.90±0.03	3.20±0.03	90.14±0.48	214.93±6.77	29.91±0.15	22.22±1.38	7.28±0.06	325.13±6.07	25.26±0.90	23.28±0.66

with alkalinity and weak positive correlation with hardness. The season, ambient temperature and the time of day the water was collected all affected the temperature of water. The higher WT during the summer may be due to the increased turbidity, as suspended particles absorb solar heat (Akhtar and Brraich, 2020; Sadauki *et al.* 2022; Birmachu *et al.* 2024).

pH values fluctuated slightly across seasons and sites, ranging from mildly acidic to slightly alkaline conditions (6.31 to 7.95). Weak positive correlation with DO and no correlation with FCO_2 were observed, while moderate positive correlations with alkalinity, hardness, calcium and chloride were noted. These results were nearly identical to the reported pH values for several seasons ranging from 6.5 to 8 by Yasmin *et al.* (2023). All research locations had slightly alkaline and mildly acidic pH values over the course of the investigation.

EC showed considerable seasonal fluctuations, ranging approximately from 231 to 432 µS/cm across sites, showing weak negative correlations with DO and FCO_2 and strong positive correlations with alkalinity, hardness, calcium, chloride and AT. These findings aligned to the EC range from 230 to 436 µS/cm (Sheoran *et al.*, 2024).

Dissolved oxygen ranged from approximately 6.16 to 8.65 mg/l across sites and seasons. Strong positive correlation with FCO_2 and weak positive correlation with hardness, while strong negative correlations with calcium, chloride, pH, EC, AT and WT was observed. The amount of oxygen in an aquatic water body is determined by dissolved oxygen (DO), which in turn influences the overall health of the ecosystems (Brraich *et al.*, 2021). Similar range of variations 5.9 - 8.9 mg/l was also observed by Sheoran *et al.,* (2024).

Seasonal fluctuations in Free Carbon Dioxide (mg/l), FCO, were noted, varying from 2.25 to 3.51 mg/l. FCO_2 showed strong positive correlation with DO and weak negative correlation with hardness. Additionally, strong negative correlations with alkalinity, calcium, chloride, EC, AT, and WT were observed. These results are similar to Bhagde *et al.* (2020).

Alkalinity ranged from 76.73 to 134.97 mg/l with moderate positive correlation with all parameters. According to Kamboj and Kamboj (2019), the presence of various

Table 2. Correlation matrix between various physico-chemical water parameters and aquatic abundance in site I (above the diagonal) and site II (below the diagonal) during the period of February, 2021- January, 2023

	DO	FCO_2	Alkalinity	Hardness	Calcium	Chloride	pH	EC	AT	WT	ABN
DO	1	-0.523	-0.649	-0.482	-0.184	-0.342	-0.605	-0.562	-0.843	-0.985	0.965
FCO_2	-0.421	1	0.697	0.836	0.838	0.792	0.9	0.935	0.832	0.641	-0.681
Alkalinity	-0.541	0.797	1	0.947	0.775	0.907	0.938	0.899	0.917	0.647	-0.816
Hardness	-0.331	0.832	0.969	1	0.934	0.988	0.983	0.974	0.874	0.53	-0.696
Calcium	-0.079	0.844	0.851	0.954	1	0.965	0.893	0.915	0.683	0.271	-0.432
Chloride	-0.035	0.807	0.84	0.948	0.998	1	0.945	0.941	0.787	0.391	-0.577
pH	-0.432	0.996	0.848	0.879	0.876	0.842	1	0.995	0.938	0.663	-0.791
EC	-0.767	0.887	0.894	0.817	0.687	0.648	0.904	1	0.916	0.636	-0.754
AT	-0.824	0.836	0.882	0.781	0.625	0.585	0.856	0.995	1	0.875	-0.954
WT	-0.834	0.851	0.789	0.689	0.553	0.504	0.854	0.98	0.982	1	-0.967
ABN	0.946	-0.68	-0.654	-0.499	-0.312	-0.259	-0.679	-0.904	-0.931	-0.962	1

Table 3. Correlation matrix between various physico-chemical water parameters and aquatic abundance in site III (above the diagonal) and site IV (below the diagonal) during the period of February, 2021- January, 2023

	DO	FCO_2	Alkalinity	Hardness	Calcium	Chloride	pH	EC	AT	WT	ABN
DO	1	-0.499	-0.599	-0.537	-0.265	-0.486	-0.556	-0.605	-0.888	-0.922	0.954
FCO_2	-0.36	1	0.722	0.88	0.895	0.884	0.989	0.937	0.824	0.795	-0.729
Alkalinity	-0.405	0.88	1	0.959	0.838	0.947	0.816	0.918	0.832	0.731	-0.671
Hardness	-0.346	0.865	0.998	1	0.946	0.998	0.938	0.986	0.849	0.761	-0.687
Calcium	0.035	0.906	0.841	0.855	1	0.963	0.921	0.928	0.675	0.578	-0.484
Chloride	-0.338	0.846	0.995	0.999	0.843	1	0.938	0.981	0.819	0.727	-0.648
pH	-0.554	0.965	0.936	0.913	0.813	0.899	1	0.978	0.872	0.828	-0.762
EC	-0.46	0.988	0.828	0.803	0.833	0.781	0.962	1	0.901	0.837	-0.771
AT	-0.752	0.884	0.843	0.805	0.629	0.789	0.962	0.92	1	0.987	-0.967
WT	-0.742	0.85	0.68	0.631	0.549	0.607	0.89	0.919	0.958	1	-0.994
ABN	0.988	-0.486	-0.541	-0.486	-0.114	-0.479	-0.671	-0.57	-0.838	-0.803	1

bicarbonates, hydroxides and carbonates in water which can neutralize strong acids is what causes alkalinity. Numerical (or mean) value of alkalinity reached its peak in the summer and fell in the winter was also supported by Akhtar and Brraich (2020).

Hardness ranged from 166.17 to 359.02 mg/l. Hardness showed weak positive correlation with DO and weak negative correlation with FCO_2, strong positive correlations with alkalinity, calcium, and EC. The primary cause of elevated hardness in water was due to anthropogenic activities (Bariki, 2017; Chinamalli and Vijaykumar, 2023).

Calcium concentrations fluctuated seasonally from 23.60 to 39.63 mg/l. Strong negative correlations with DO, FCO_2 and chloride, whereas strong positive correlations with alkalinity, hardness, EC and AT were recorded. These variations were likely due to the accumulation of silt, the influx of waste from industries and agricultural runoff. The observations of Zonunthari *et al.* (2023) and Mandloi and Gupta (2025) also corroborated our findings.

Chloride levels varied considerably from 16.68 to 38.72 mg/l. Moderate negative correlations with DO, FCO_2 and EC, while strong positive correlations with alkalinity, calcium and AT were observed. Increased chloride is likely a sign of sewage contamination from industrial runoff and home sewage. As a result, seasonal fluctuations in the chloride value indicated changes in the Ropar wetland's water quality, a finding also corroborated by Akhtar and Brraich (2020).

Across all four sites, the insect diversity (family, genus and number of individuals) was evaluated in relation with water quality parameters. A total of 18 families and 24 genus under 7 orders: Coleoptera, Diptera, Hemiptera, Ephemeroptera, Odonata, Placoptera and Trichoptera were identified. The details of insect diversity and their abundance in the selected sites are given in Tables 4 and 5, respectively.

CONCLUSION

The Present study revealed that variations in alkalinity, hardness, calcium and chloride, peak during the pre-monsoon season, attaining the lowest values during winter, whereas DO inversely related to the different

Table 4. Taxonomic description of aquatic insects in relation to their orders, families and genus

Order	No. of families	Family (Genus/Genera)
Coleoptera	3	Hydrophilidae (*Hydrophilus*), Tenebrionidae (*Blaps*), Dytiscidae (*Cybister*)
Diptera	2	Culicidae (*Culex*), Chironomidae (*Chironomus*)
Hemiptera	5	Gerridae (*Metrocoris*), Micronectidae (*Micronecta*), Nepidae (*Ranatra, Laccotrephes*), Belostomidae (*Lithocerus*), Corixidae (*Sigara*)
Ephemeroptera	1	Ephemiridae (*Ephemerella, Rhithrogenia*)
Odonata	3	Calopterygidae (*Neurobasis*), Libelluidae (*Trithmis, Rhyothemis, Neurothemis, Orthetrum, Crocothemis*), Gomphidae (*Onychogamus*)
Plecoptera	1	Perlididae (*Perla*)
Trichoptera	3	Hydropsychidae (*Hydropsyche*), Rhyacophilidae (*Rhyacophila*), Leptoceridae (*Mystacides*)

Table 5. Abundance of insect diversity across selected sites during different seasons

Season	Site	Orders	Families	Genera	No. of individuals
Winter	I	7	12	17	242
	II	7	12	17	219
	III	7	12	17	266
	IV	7	11	16	164
Pre monsoon	I	7	15	20	142
	II	7	18	23	160
	III	7	12	17	165
	IV	7	5	10	122
Monsoon	I	7	6	11	140
	II	7	13	18	141
	III	7	11	16	121
	IV	7	11	16	108
Postmonsoon	I	7	13	18	158
	II	7	10	15	168
	III	7	11	16	186
	IV	7	13	18	133

seasons indicated high levels of pollution from surrounding, which posed high risk to aquatic life and general wetland health. The patterns of aquatic insect diversity were strongly correlated with the studied parameters. The maximum aquatic insect diversity was found during winter and post-monsoon periods when water quality was relatively better, whereas minimum insect diversity was noticed during monsoon in some sites likely due to increased turbidity and habitat disturbance. The recorded 24 genera across 7 insect orders underlined the wetland's ecological richness but also its vulnerability related to physico-chemical stress.

Although DO levels remained within acceptable limits, their significant seasonal decreases, especially during summer, could negatively affect critical biological processes within the ecosystem. According to these findings, there is an urgent need to implement stringent pollution control measures, regulate industrial discharges and promote environmentally sustainable agricultural practices in the region. Public awareness campaigns, knowledge and active community participation will, in the long run, also play crucial role to protect the vulnerable wetland ecosystem.

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