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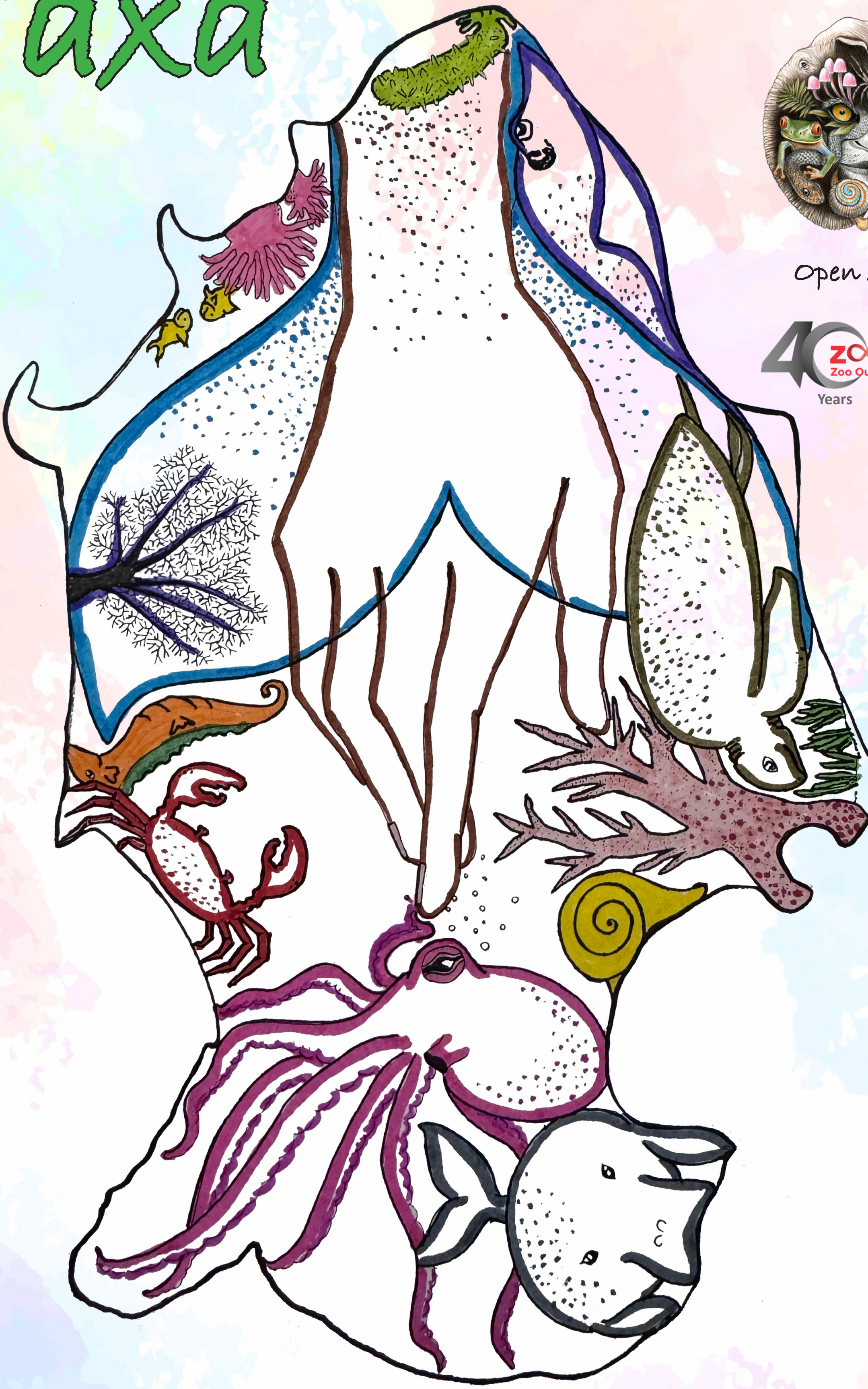

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continued on the back inside cover

Cover: Little Andaman is part of the island chain with incredible biodiversity, but these amazing species are threatened by development projects, and need our support. Pen and ink artwork by Priyanka Iyer.

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ARTICLE

Environmental drivers of zooplankton diversity and composition of Pargwal Wetland, Jammu & Kashmir, India

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Abstract: This study investigates temporal and spatial variability in zooplankton abundance within Pargwal wetland, the largest wetland in the Jammu region. Water samples were collected from three strategically selected stations and analyzed for physico-chemical parameters including temperature, pH, dissolved oxygen, carbonates, nutrients, and ions. A total of 27 zooplankton species spanning five groups were recorded. Rotifera dominated in terms of abundance and diversity with 15 species, followed by Cladocera with five species, Protozoa with three, and two species each of Ostracoda and Copepoda. Key environmental factors contributing to the dominance of rotifers and cladocerans were high levels of nutrients (nitrates and phosphates), water transparency, and light penetration (due to shallow water depth), and resilience to pollution-induced stress. Rotifers are also known to outcompete other groups when resources are limited or of poor quality. The abundance of pollution-tolerant species indicated overall degradation of this important wetland driven by anthropogenic pressures. This highlights the need for integrated management strategies to safeguard biodiversity for future generations.

Keywords: Abundance, degradation, revival efforts, spatial, temporal, variability, wetland.

Hindi: यह अध्ययन जम्मू क्षेत्र की सबसे बड़ी आर्द्रभूमि परगवाल आर्द्रभूमि के भीतर ज़ूप्लांकटन की प्रचुरता में अस्थायी और स्थानिक परिवर्तनशीलता की जांच करता है। तीन रणनीतिक रूप से चयनित स्टेशनों से पानी के नमूने एकत्र किए गए और तापमान, पीएच, घुलित ऑक्सीजन, कार्बोनेट, पोषक तत्व और आयनों सहित भौतिक-रासायनिक मापदंडों के लिए विश्लेषण किया गया। पांच समूहों में फैली कुल 27 ज़ूप्लैंक्टन प्रजातियों को दर्ज किया गया था। 15 प्रजातियों के साथ प्रचुरता और विविधता के मामले में रोटिफेरा का वर्चस्व रहा, इसके बाद पांच प्रजातियों के साथ क्लाडोसेरा, तीन के साथ प्रोटोजोआ और ओस्ट्राकोडा और कोपेपोडा की दो-दो प्रजातियों का स्थान रहा। रोटिफर्स और क्लैडोसेरेंस के प्रभुत्व में योगदान देने वाले प्रमुख पर्यावरणीय कारक उच्च स्तर के पोषक तत्व (नाइट्रेट और फॉस्फेट) जल पारदर्शिता, और प्रकाश प्रवेश (उथले पानी की गहराई के कारण) और प्रदूषण-प्रेरित तनाव के प्रति लचीलापन थे। रोटिफर्स को अन्य समूहों को पछाड़ने के लिए भी जाना जाता है जब संसाधन सीमित होते हैं या खराब गुणवत्ता के होते हैं। प्रदूषण-सहिष्णु प्रजातियों की प्रचुरता मानवजनित दबावों द्वारा संचालित इस महत्वपूर्ण आर्द्रभूमि के समग्र क्षरण का संकेत देती है। यह भावी पीढ़ियों के लिए जैव विविधता की रक्षा के लिए एकीकृत प्रबंधन रणनीतियों की आवश्यकता पर प्रकाश डालता है।

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Competing interests: The authors declare no competing interests.

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Author contributions: Neha Jamwal- carried out the fieldwork, sampling, species identification, data collection, analysis & interpretation and manuscript writing. Arti Sharma- study design, supervision and guidance in sample collection, careful examination and final approval to the manuscript.

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INTRODUCTION

Zooplankton play vital roles in the aquatic food chain making them essential elements of the aquatic ecosystem. They serve as natural water purifiers, energy transferrers from lower to higher trophic levels (Steinberg & Condon 2009), recyclers of nutrients and energy in their surroundings, and the primary natural fish food source, which is directly related to fish survival and growth (Miah et al. 2013). They also serve as crucial determiners of water quality as they are influenced by the constantly shifting environmental conditions; and subsequently, their distribution, and diversity is influenced by seasonal changes in the physicochemical characteristics of the water (Saba & Sadhu 2015). They are also known to play a handy role in determining the status of pollution in any water body (Contreras et al. 2009).

Discrete ecological niches are found in wetlands, which contribute significantly to the biological variety. Every freshwater ecosystem on earth is home to zooplankton, and within the population, their density, and variety vary widely (Golmarvi et al. 2018). Among zooplanktons, Copepoda, Cladocera, and Rotifera are better suited to examine the community structure of these organisms in relation to environmental heterogeneity (Toruan 2021). Due to their sensitivity to any unfavourable environmental change, zooplankton population composition, and abundance are negatively impacted by continuously declining water quality (Razak & Sharip 2019). Most zooplankton move away from direct sunlight in a pronounced vertical diurnal migration. In response to angular light distributions, copepods exhibit migration away from littoral areas through behavioural swimming while the spatial horizontal distribution of cladocerans sometimes seems patchy, and uneven (Wetzel 2001). Conversely, ostracods are bottom-dwelling animals that mostly consume dead & detritus phytoplankton, which in turn provide food for fish, and other macroinvertebrates. Because of their ease of identification, ability to adapt to environmental gradients, and important function in the food web, cladocerans may be considered the best indicators of biodiversity (Jeppesen et al. 2011). The capacity of certain crustacean zooplankton, such as copepods, to restrict mosquito larvae makes them extremely important. Alekseev (2002) also recognized copepods as the intermediary host for a variety of parasitic diseases, including worms.

Ecology, diversity, and distribution patterns of zooplankton has been reviewed from India by Sreenivasan (1967) in Madras, Sivakumar & Altaff (2004) in Tamil Nadu, Mathivanan et al. (2007) in Cauvery River, Manickam et al. (2012, 2014) in Goa and southern India, while globally by Ezz et al. (2014) from Mediterranean Sea, de Puelles et al. (2014) from Baleares archipelago & Ziadi et al. (2015) from a Mediterranean lagoon. Although, from Jammu region of J&K, many lentic, and lotic waterbodies have been exploited for the zooplankton diversity but among wetlands, this largest Pargwal wetland has remained unexplored.

Due to the ecological significance, short life cycles, and susceptibility to the environmental changes, zooplankton community structure (which includes diversity indices, species richness and dominance pattern) is anticipated to differ greatly depending upon the water quality factors of Pargwal Wetland, hence, revealing the water quality, and ecological well-being of this wetland due to region's continuous anthropogenic disturbances, including waste discharge, sand mining, and agricultural runoff. This will make them an efficient tool for tracking the wetland's ecological status and restoration potential.

MATERIAL AND METHODS

Study area

The present study encompasses Pargwal Wetland located at 32.87°N & 75.03°E in tehsil Akhnoor of Jammu District, J&K, India. This wetland is a humid subtropical riverine type and is surrounded by human habitation, and agricultural fields on one side, and mighty river Chenab on the other side (Image 1) covering a total area of 12,154 acres making it the largest wetland in terms of area. Since this wetland is of riverine kind, three study sites were identified based on anthropogenic activities, and accessibility around the area which are about 1–2.5 km apart from one another (Image 2a–c). All the three sampling stations were equally positioned by the humans but station I (Image 2a) and station III (Image 2c) are highly impacted by the ease of disposing, and adulterating the water body. The main occupation of the inhabitants includes farming and cattle rearing. Station II (Image 2b) is least impacted by human intervention.

Methods

Seasonal sampling of water quality (in triplicates from each station per season) and zooplankton diversity was done quarterly for a period of one year (2021–2022) that included Spring (February–April), Summer (May–June), Monsoon (July–September), and Winter (November–

Image 1. The satellite view of study stations (Inset: Jammu & Kashmir; Location of Pargwal). Source: Google Maps.

Image 2. Study stations: a—Station | b—Station | c—Station III. © Neha Jamwal

January). Water quality parameters, i.e., air & water temperature (using mercury bulb thermometer), pH (Hanna digital pH meter), dissolved oxygen (modified Winkler method), free carbon dioxide (titrimetric method), bicarbonates, chloride (Argentometric method using potassium chromate as indicator was used for determination of chlorides), calcium & magnesium (EDTA-titrimetric method), nitrates (Phenoldisulphonic acid method), phosphates (Stannous chloride method), and sulphates (Turbiditimetric method), were assessed as prescribed by A.P.H.A. (2017), and Adoni (1985). Zooplankton samples were collected by filtering 50 L of water from the study stations using a plankton net having mesh size 40 µm. The filtrate was then preserved by adding 10% formalin. The samples were analyzed using light microscope Magnus MLX under 40x magnification.

Quantitative estimation of zooplankton

Quantitative analysis was done using drop count method and calculated using below mentioned formula:

$$\text{Individuals / litre} = A \times 1/L \times n/v$$

Where, A = number of organisms per drop.

L = volume of original sample (l).

N = total volume of concentrated sample (ml).

V = volume of one drop (ml).

The identification was done using keys by Ward & Whipple (1959), Edmondson & Winberg (1971), Pennak (1978), and Adoni (1985).

Data Analysis

Community structure was assessed using various diversity indices like Shannon-Wiener index (H), evenness index (E), and dominance (C) and calculated using PAST software while Pearson correlations and one-way ANOVA were done using SPSS 29.0.2.0 software.

RESULTS

Water Quality

The water quality parameters of selected study stations of Pargwal Wetland were assessed seasonally and their mean values have been depicted in Table 1 and Figure 1. The air temperature values in the study varied from the lowest value (13°C) recorded at station III during winter to the highest value (39°C) recorded at station II during summer while the water temperature values varied from (10°C) at station III during winter to the highest value of (36°C) observed at station I during summer. The annual mean values of air and water temperature were recorded as 26.83°C and 24.5°C, respectively. The water body remained neutral to moderately alkaline with minimum pH values ranging from 7.2 noted at station III during summer to maximum value of 8.0 recorded at station II during winter. The annual mean pH value was recorded as 7.71. The values of dissolved oxygen (DO) were relatively low having minimum value of 1.6 mg/l reported during summer to 9.6 mg/l during winter at station II, with annual mean 5.07 mg/l ± 0.6. Free carbondioxide (FCO_2) values were comparatively high varying spatially from a minimum 5.28 mg/l during winter to maximum 9.2 mg/l during summer at station II and station I respectively with annual mean value recorded as 6.99 mg/l ± 1.5. Bicarbonates (HCO_3-) were recorded high during entire period of investigation with values fluctuating from minimum 170.8 mg/l at station II during summer to maximum 488 mg/l during winter at station I. The annual mean value of bicarbonates was recorded 276.93 mg/l ± 35.19.

Lowest values of Cl^- (5.81 mg/l) were observed during spring at station II while highest (18.02 mg/l) at station I during summer. The annual mean Cl^- concentration was observed to be 10.91 ± 2.8. The present study showed that the highest values of calcium (84.11 mg/l) and magnesium (72.76 mg/l) were recorded from station I during winter, while the lowest values of calcium (48.78 mg/l) and magnesium (26.6 mg/l) were recorded at station II during summer. The annual mean concentration of Calcium and Magnesium was observed to be 62.41 ± 5.8, and 45.96 ± 6.3, respectively.

All the minerals were well within the permissible limits (as prescribed by WHO 1992; BIS 1998) but values of phosphates were dangerously high (WHO

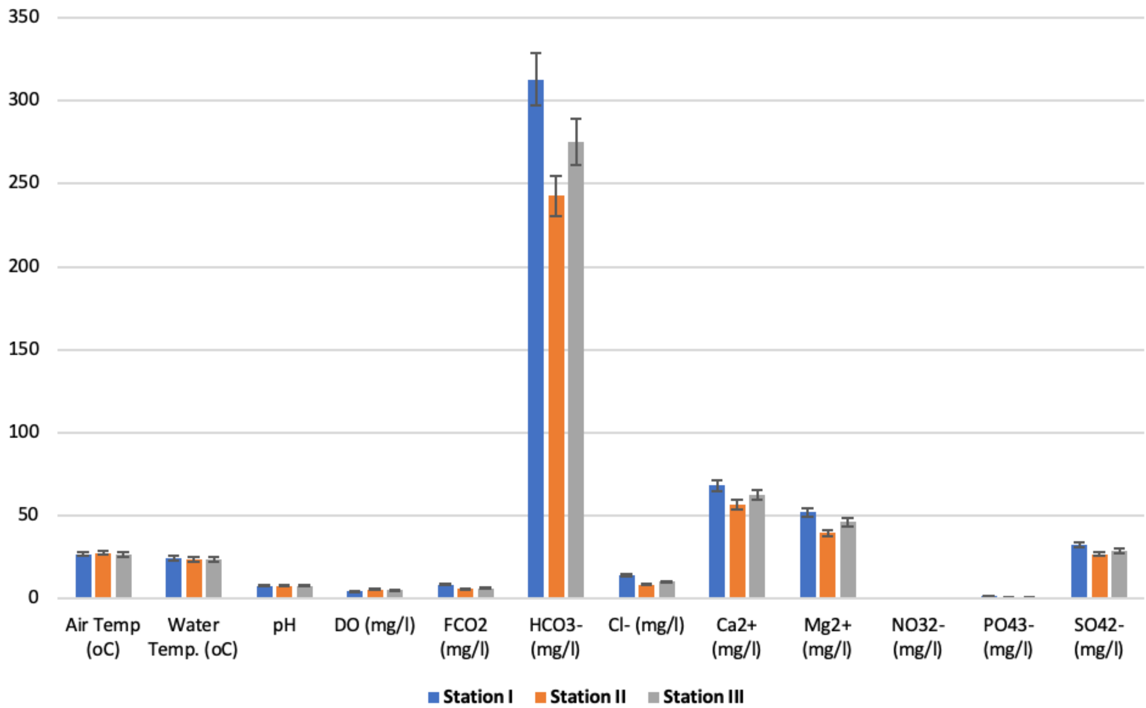

Figure 1. Variations in the physical and chemical parameters of Pargwal Wetland during 2021–2022.

Table 1. Physicochemical parameters of water at different stations of Pargwal Wetland (2021–2022).

Parameters		Station I	Station II	Station III	P-value
Air Temp. (^{O}C)	Min	15	15	13	0.994
	Max	38	39	38	
	Mean ± S.D.	27 ± 9.4	27.25 ± 9.8	26.5 ± 10.5	
Water Temp. (^{O}C)	Min	13	14	10	0.500
	Max	36	35	35	
	Mean ± S.D.	24.5 ± 9.5	23.75 ± 8.8	23.75 ± 10.3	
pH	Min	7.6	7.4	7.2	0.860
	Max	7.9	8.0	7.9	
	Mean ± S.D.	7.73 ± 0.2	7.73 ± 0.3	7.68 ± 0.3	
DO (mg/l)	Min	2.0	1.6	2.6	0.986
	Max	7.2	9.6	9.6	
	Mean ± S.D.	4.48 ± 2.5	5.6 ± 4.2	5.15 ± 3.1	
FCO2 (mg/l)	Min	7.5	5.28	5.4	0.923
	Max	9.2	7	7.2	
	Mean ± S.D.	8.66 ± 0.8	5.87 ± 0.8	6.45 ± 0.8	
HCO_3^- (mg/l)	Min	244	170.8	187.9	
	Max	488	336	430	0.968
	Mean ± S.D.	312.9 ± 116.9	242.6 ± 68.6	275.3 ± 106.2	
Cl^- (mg/l)	Min	9.15	5.81	7.61	0.633
	Max	18.02	10.01	12.01	
	Mean ± S.D.	14.05 ± 3.7	8.52 ± 1.9	10.17 ± 1.9	
Ca^{2+} (mg/l)	Min	60.56	48.78	57.19	0.914
	Max	84.11	60.56	66.52	
	Mean ± S.D.	68.13 ± 10.8	56.62 ± 5.6	62.47 ± 3.9	
Mg^{2+} (mg/l)	Min	35.5	26.6	30.43	0.815
	Max	72.76	50.46	63.92	
	Mean ± S.D.	52.15 ± 15.4	39.59 ± 9.8	46.15 ± 13.8	
$NO3^{2-}$ (mg/l)	Min	0.13	0.096	0.31	
	Max	1.17	0.42	0.58	0.509
	Mean ± S.D.	0.48 ± 0.5	0.19 ± 0.2	0.45 ± 0.1	
$PO4^{3-}$ (mg/l)	Min	0.79	0.72	0.78	0.084
	Max	2.43	1.74	1.36	
	Mean ± S.D.	1.55 ± 0.8	1.23 ± 0.5	1.24 ± 0.4	
$SO4^{2-}$ (mg/l)	Min	18.27	12.77	15.31	0.796
	Max	46.29	41.65	41.79	
	Mean ± S.D.	32.71 ± 13.3	26.92 ± 16.2	28.87 ± 14.5	

1992) except for station I where the value was above permissible limit. The annual mean value of nitrates was 0.4 mg/l ± 0.2 which varied between a minimum of 0.096 mg/l during winter at station II to a maximum 1.17 mg/l during summer at station I, while annual mean phosphate values was 1.34 mg/l ± 0.2, that ranged from lowest value of 0.72 mg/l during summer at station II to highest value of 2.43 mg/l during winter at station I. Sulphates ranged from a minimum 12.77 mg/l during winter at station II to a maximum 46.29 mg/l during summer at station I.

Zooplankton Composition and Abundance

A total of 27 zooplankton species were collected

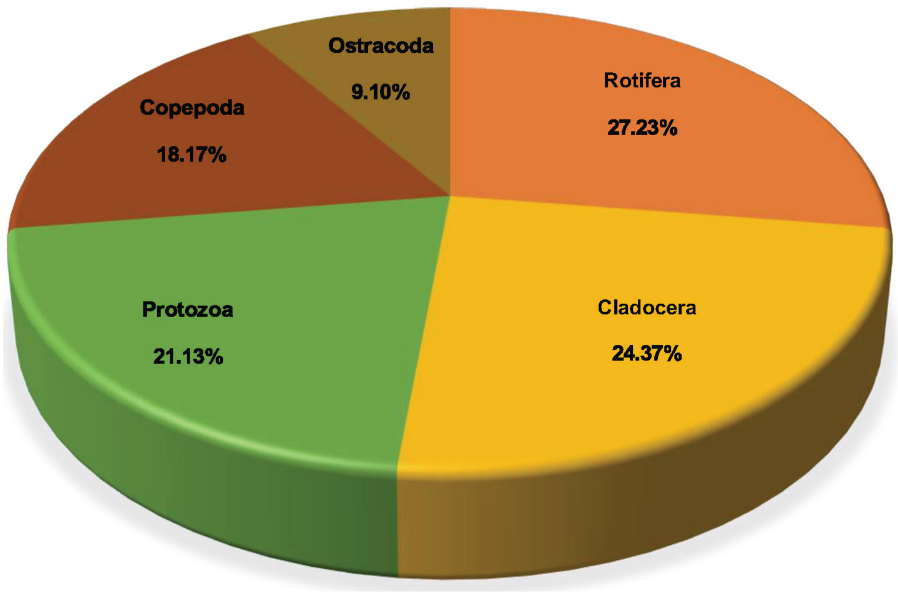

Figure 2. Relative abundance of different zooplankton groups in Pargwal Wetland.

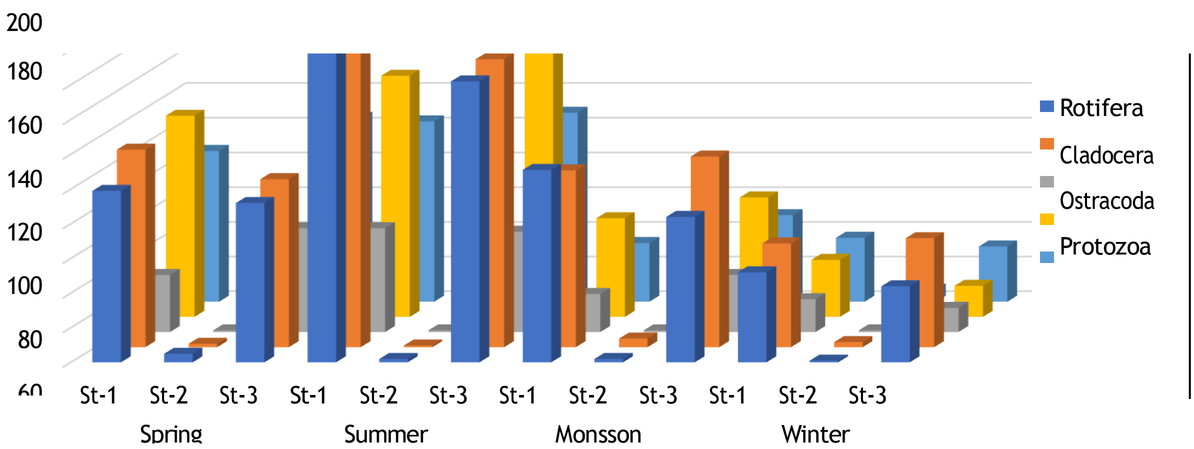

Figure 3. Variations in species richness of zooplankton in Pargwal Wetland.

from the study stations (Table 2, Image 3) and divided into six groups: Rotifera, Cladocera, Ostracoda, Amoebozoa, Copepoda, and Ciliophora. Rotifera topped the table with 15 species (102.7 ind./L; 27.23%) out of all the groupings, followed by Cladocera with five species (91.9 ind./L; 24.37%), Protozoa with three species (79.7 ind./L; 21.13%), Copepoda with two species (68.5 ind./L; 18.17%), and Ostracoda with two species (34.3 ind./L; 9.10%) (Table 3; Figure 2).

The overall temporal abundance of zooplankton followed the following trend:

Summer (42.33%) > Spring (29.14%) > Monsoon (20.68%) > Winter (7.85%)

The summer peak and the winter decline can also be clearly seen in the Table 3. The values of various diversity indices have been depicted in Table 4. Figure 3 depicts Rotifera as the highly diversified group with high abundance of *Euchlanis dilatata*, *Lepadella ovalis*, *Asplanchna* sp., *Brachionus calyciflorus*, *Brachionus quadridentatus*, *Cephalodella* sp., and *Platiyas platulus* which indicates its pollution status.

The review of Table 3 also highlights various dominant species of the zooplankton found in the wetland area which include, Brachionus *calyciflorus*, *Brachionus quadridentatus*, *Arcella discoides*, *Mesocyclops leukarti*, *Cyclops* sp., *Stenocypris* sp., and *Eucypris* species at

Table 2. List of zooplankton reported from all the study stations of Pargwal Wetland (2021–2022).

Phylum	Name of the species
Rotifera	*Euchlanis dilatata* (Ehrenberg, 1830)
	Keratella tropica (Apstein, 1907)
	Lepadella ovalis (Muller, 1786)
	Asplanchna sp.
	Brachionus calyciflorus (Pallas, 1776)
	Brachionus quadridentatus (Hermann, 1783)
	Trichocerca longiseta (Schrank, 1802)
	Trichocerca porcellus (Gosse, 1851)
	Trichotria sp.
	Cephalodella sp.
	Colurella adriatica (Ehrenberg, 1831)
	Monostyla bulla (Gosse, 1851)
	Monostyla hamata (Stokes, 1896)
	Philodina sp.
	Platyias platulus (Muller, 1786)
Arthropoda (Cladocera)	*Macrothrix* sp.
	Pleuroxus sp.
	Simocephalus sp.
	Alona costata (Sars, 1862)
	Alonella sp.
	Stenocypris sp.
Arthropoda (Ostracoda)	*Oncocypris pustulosa* (Vavra, 1891)
Amoebozoa (Protozoa)	*Arcella discoides* (Ehrenberg, 1832)
	Centropyxis aculeata (Ehrenberg, 1832)
Ciliophora (Protozoa)	*Epistylis* sp.
Copepoda	*Mesocyclops leukarti* (Claus, 1857)
	Cyclops sp.

station III, while *Macrothrix* sp., *Simocephalus* sp., and *Alona costata* at station I. Station II was the least species rich among all the stations, with little to no diversity at all, because this area was extremely disturbed by the constant anthropogenic activities.

DISCUSSIONS

High values of air and water temperatures were recorded during summer due to elongated photoperiod, and abundant vegetation cover the surface of water which traps the heat (Sharma 2018; Singh 2022), while lower temperatures during winters result from less diffusion of heat from air to water. The limited range of pH values seen in all study stations in this investigation is explained by the high alkalinity of water which regulates hardness (Goldman & Horne 1983). It is possible to explain the low DO values in summer because high temperature reduces DO solubility in water, therefore, decreasing oxygen carrying capacity (Dallas 2008; Sahni & Yadav 2012). Also, the wetland is frequently filled by waste products, such as household and agricultural runoff, which results in nutrient enrichment and lower DO, elevating BOD. High DO values were observed during winter as low temperature leads to elevated oxygen holding capacity (Sharma 2018). High FCO2 levels during summer may be due to high decomposition rate which consumes more DO (Harney et al. 2013) while its low value during winter may be due to consumption of FCO2 that exceeds its production (Sharma 2018). High HCO3 levels during winter may be because bicarbonate ions accumulate when not taken up by macrophytes, while its low value during summer may be assigned to utilization by macrophytes, and phytoplankton during photosynthesis (Singh 2022). The elevation in bicarbonates could also be attributed to the ease of access to wetland water by people for carrying out their daily chores like bathing, cleaning, and washing.

According to the present findings, values of chlorides were maximum during summer which may be accorded to higher chloride solubility discharged from catchment area (Umamaheshwari & Sarvanan 2009) and due to increased rate of decomposition of organic matter while minimum values during spring were recorded which may be due to its uptake by growing macrophytic biomass (Singh 2004, 2022). High nitrate values during summer may be accredited to evaporation, leading to more nitrate build-up and bacteria causing aerobic decomposition of organic matter (Mustapha et al. 2013) while low values of nitrates during winter may be because of slow decomposition rate at low temperature (Tamot & Sharma 2006). Less phosphate values in summer can be attributed to intense phytoplankton blooms that readily take up phosphate ions (Nassar et al. 2014; Abdulwahab & Rabee 2015), while highest level during winter can be because of low mineralization of organic matter at reduced temperature (Mushtaq et al. 2016). Summer maxima in the values of sulphates may be attributed to biogenic inputs, increased microbial activity (Munawar 1970; Hill-Falkenthal et al. 2013).

In the present studies, Zooplankton peaked in summer which may probably be due to the encouraging environmental conditions (Sharma 2018), increased organic matter content due to higher rate of decomposition in warmer temperatures (Holcik & Olah

Table 3. Seasonal population density (ind./litre) of the zooplankton species reported from Pargwal Wetland, Jammu, J&K.

Phylum	Species		Spring			Summer			Monsoon			Winter	
		St-1	St-2	St-3	St-1	St-2	St-3	St-1	St-2	St-3	St-1	St-2	St-3
Rotifera	*Euchlanis dilatata.*	1.1	-	0.6	2.1	-	1.4	0.6	-	-	0.6	-	-
	Keratella tropica	0.2	-	-	1.0	-	0.9	-	-	-	-	-	-
	Lepadella ovalis	1.7	-	0.9	3.1	-	2.9	1.7	-	0.6	0.3	-	-
	Asplanchna sp.	0.2	0.2	0.1	1.6	-	0.8	0.7	-	0.1	0.1	-	-
	Brachionus calyciflorus	2.1	0.3	3.2	2.9	-	4.3	3.4	-	3.2	0.3	-	0.4
	Brachionus quadridentatus	1.4	-	1.7	2.2	-	2.9	1.7	-	2.2	0.7	-	0.4
	Trichocerca longiseta	1.1	-	2.1	2.1	-	0.3	0.9	-	1.4	0.1	-	0.1
	Trichocerca porcellus	-	-	0.3	0.3	-	0.6	-	-	-	-	-	-
	Trichotria sp.	0.3	-	0.1	0.1	-	-	-	-	-	-	-	-
	Cephalodella sp.	4.2	-	1.5	5.1	0.2	4.6	0.5	0.2	0.2	0.2	-	0.2
	Colurella adriatica	-	-	0.3	-	-	-	-	-	-	-	-	-
	Monostyla bulla	0.6	-	-	0.3	-	0.1	0.7	-	-	0.6	-	0.4
	Monostyla hamata	1.1	-	0.5	1.7	-	2.1	1.4	-	0.5	0.4	-	0.3
	Philodina sp.	0.3	-	-	1.1	-	0.6	0.2	-	0.6	0.2	-	-
	Platyias platulus	0.6	-	0.1	1.1	-	0.3	0.9	-	0.9	0.8	-	0.5
Total Rotifera		**14.9**	**0.5**	**11.4**	**24.7**	**0.2**	**21.8**	**12.7**	**0.2**	**9.7**	**4.3**	**-**	**2.3**
Arthropoda	*Macrothrix* sp.	3.1	0.1	1.5	3.3	-	3.6	3.2	0.2	2.1	0.1	0.1	0.3
(Cladocera)	*Pleuroxus* sp.	0.6	0.1	1.3	0.9	-	0.5	0.6	0.1	0.7	0.5	0.1	-
	Simocephalus sp.	3.3	0.3	1.9	6.4	1.4	5.6	1.5	0.2	2.2	1.1	0.1	0.1
	Alona costata	3.6	-	3.7	5.1	-	4.9	3.5	-	3.4	0.4	-	0.5
	Alonella sp.	2.2	-	2.5	3.2	0.1	3.4	2.9	-	3.2	0.7	-	0.6
Total Cladocera		**12.8**	**0.4**	**10.9**	**18.9**	**1.5**	**18.0**	**11.7**	**0.5**	**12.6**	**2.8**	**0.3**	**1.5**
Arthropoda	*Stenocypris* sp.	1.7	-	3.9	3.9	-	2.9	2.2	-	1.3	1.3	-	1.6
(Ostracoda)	*Eucypris* sp.	2.1	-	3.4	3.4	-	3.8	1.0	-	0.9	0.9	-	-
Total Ostracoda		**3.8**	**-**	**7.3**	**7.3**	**-**	**6.7**	**3.2**	**-**	**2.2**	**2.2**	**-**	**1.6**
Amoebozoa	*Arcella discoides*	3.7	-	5.1	3.4	-	5.4	3.1	-	5.0	1.3	-	-
(Protozoa)	*Centropyxis aculeata*	1.9	-	2.3	2.2	0.1	2.7	1.4	0.1	1.1	0.7	0.1	-

Table 4. The species diversity indices of zooplankton observed in Pargwal Wetland, Akhnoor, Jammu.

Group	Indices	Spring			Summer			Monsson			Winter		
		St-1	St-2	St-3	St-1	St-2	St-3	St-1	St-2	St-3	St-1	St-2	St-3
Rotifera	Taxa_S	13	2	12	14	1	13	11	1	9	11	1	7
	Individuals	99	5	92	181	2	162	111	2	84	52	1	44
	Dominance_D	0.1016	0.4	0.1663	0.09159	1	0.1275	0.1333	1	0.1922	0.1139	-	0.1892
	Simpson_1-D	0.8984	0.6	0.8337	0.9084	-	0.8725	0.8667	-	0.8078	0.8861	-	0.8108
	Shannon_H	2.408	0.773	2.073	2.476	-	2.262	2.206	-	1.875	2.267	-	1.768
	Evenness_e^H/S	0.8546	1.083	0.6622	0.8498	1	0.7385	0.8257	1	0.7242	0.8776	1	0.8371
Cladocera	Taxa_S	5	2	5	5	1	5	5	3	5	5	3	4
	Individuals	114	2	97	182	1	166	102	5	110	60	3	63
	Dominance_D	0.2383	-	0.2489	0.2384	-	0.241	0.239	0.2	0.2252	0.2475	0	0.2401
	Simpson_1-D	0.7617	1	0.7511	0.7616	-	0.759	0.761	0.8	0.7748	0.7525	1	0.7599
	Shannon_H	1.493	0.9431	1.456	1.49	-	1.464	1.491	1.255	1.528	1.5	1.432	1.406
	Evenness_e^H/S	0.8904	1.284	0.8576	0.8874	1	0.8646	0.8887	1.169	0.9214	0.8959	1.396	1.02
Ostracoda	Taxa_S	2	1	2	2	1	2	2	1	2	2	1	1
	Individuals	33	1	60	60	1	58	22	1	33	19	1	14
	Dominance_D	0.4886	-	0.4938	0.4938	-	0.5009	0.4935	-	0.4886	0.4854	-	1
	Simpson_1-D	0.5114	-	0.5062	0.5062	-	0.4991	0.5065	-	0.5114	0.5146	-	-
	Shannon_H	0.7042	-	0.6993	0.6993	-	0.6922	0.6993	-	0.7042	0.7069	-	-
	Evenness_e^H/S	1.011	1	1.006	1.006	1	0.9991	1.006	1	1.011	1.014	1	1
Protozoa	Taxa_S	3	1	3	3	1	3	3	1	3	3	1	1
	Individuals	116	1	96	139	1	166	57	1	69	33	1	18
	Dominance_D	0.4262	-	0.3607	0.4808	-	0.4251	0.3571	-	0.4672	0.3598	-	1
	Simpson_1-D	0.5738	-	0.6393	0.5192	-	0.5749	0.6429	-	0.5328	0.6402	-	-
	Shannon_H	0.9624	-	1.057	0.8916	-	0.9623	1.064	-	0.9131	1.057	-	-
	Evenness_e^H/S	0.8726	1	0.9596	0.813	1	0.8726	0.9655	1	0.8307	0.9597	1	1
Copepoda	Taxa_S	2	2	2	2	2	2	2	2	2	2	2	2
	Individuals	87	15	106	104	11	109	34	7	50	37	7	32
	Dominance_D	0.4948	0.5238	0.4997	0.4968	0.6727	0.4964	0.492	0.4286	0.4931	0.4895	0.4286	0.4859
	Simpson_1-D	0.5052	0.4762	0.5003	0.5032	0.3273	0.5036	0.508	0.5714	0.5069	0.5105	0.5714	0.5141
	Shannon_H	0.6983	0.6698	0.6934	0.6963	0.5196	0.6967	0.7009	0.7543	0.6999	0.7034	0.7543	0.7068
	Evenness_e^H/S	1.005	0.977	1	1.003	0.8407	1.004	1.008	1.063	1.007	1.01	1.063	1.014
	Confidence Intervals	6.95	1.28	3.31	8.00	1.21	9.04	6.14	0.79	6.92	1.46	0.57	1.54

1992; Hans & Anj 2007; Mishra et al. 2009; Golmarvi et al. 2018; Sharma 2018), thereby increasing food availability, increased productivity of phytoplankton owing to elevated concentrations of nutrients like nitrates (Breitburg et al. 1999). Similar upsurging trend of zooplankton during summers was observed by El-Sherbiny et al. (2011), Pradhan (2014), Vasanthkumar et al. (2015), Golmarvi et al. (2018), Sharma (2018). Decline in zooplankton abundance was witnessed during winters probably due to low temperature and high pH which reduces the overall zooplankton abundance (El-Sherbiny et al. 2011; Liu et al. 2023), increased predatory pressure (Shchapov & Ozersky 2023), weak water column stratification, and reduced phytoplankton biomass, and dilution in mineral & salt concentration in the wetland water (Hoyer & Jones 1983; Sivakami et al. 2013; Sharma & Kour 2021).

The number of species in the sample and the distribution of individuals within these species are indicated by biodiversity indices, therefore differences in biodiversity are a sign of changes in the characteristics of the water. A high Shannon-Weiner index value denotes

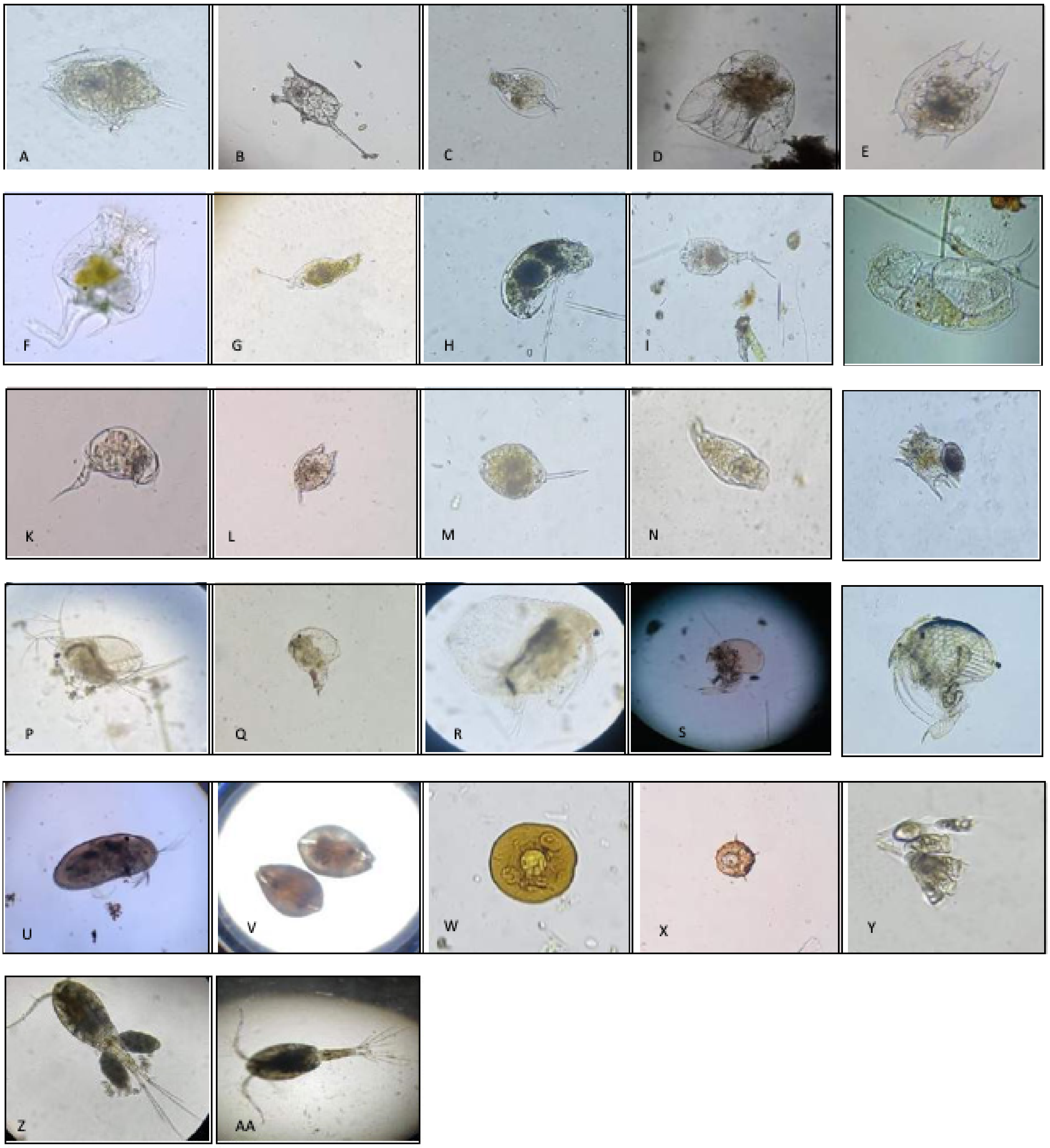

Image 3 (A–AA). Zooplankton species recorded from Pargwal wetland: A—*Euchlanis dilatata* | B—*Keratella tropica* | C—*Lepadella ovalis* | D—*Asplanchna* sp. | E—*Brachionus calyciflorus* | F—*Brachionus quadridentatus* | G—*Trichocerca longiseta* | H—*Trichocerca porcellus* I—*Trichotria* sp. | J—*Cephalodella* sp. | K—*Colurella adriatica* | L—*Monostyla bulla* | M—*Monostyla hamata* | N—*Philodina* sp. | O—*Platiyas platulus* | P—*Macrothrix* sp. | Q—*Pleuroxus* sp. | R—*Simocephalus* sp. | S—*Alona costata* | T—*Alonella* sp. | U—*Stenocypris* sp. | V—*Oncocypris pustulosa* | W—*Arcella discoides* | X—*Centropyxis aculeata* | Y—*Epistylis* sp. | Z—*Mesocyclops leukarti* | AA—*Cyclops* sp. © Neha Jamwal.

a higher level of diversity while a diversity score of three or higher denotes pure water, and between one–three imply significant pollution (Abdulwahab & Rabee 2015). Since rotifers thrive better in organic matter rich environment and thus are recognized as effective indicators of organic pollution (Karabin 1985; Paleolog et al. 1997; El-Sherbiny et al. 2011). Therefore, on applying the diversity indices, high mean value of Shannon-Wiener index (H) was recorded which follows, Rotifera (1.509) > Cladocera (1.288) > Copepoda (0.691) > Protozoa

Table 5. Pearson's correlation coefficient values between various physico-chemical parameters of water and zooplankton community.

Parameters	Rotifera	Cladocera	Copepoda	Protozoa	Ostracoda
AT	-0.794	**-0.843***	-0.922	-0.871	**-0.941***
WT	0.608	0.537	0.387	0.491	0.338
PH	-0.383	-0.462	-0.605	-0.509	-0.645
DO	-0.875	-0.829	-0.723	-0.798	-0.686
FCO2	0.753	0.693	0.561	0.653	0.517
HCO_3^-	**0.908***	0.868	0.771	**0.840***	0.737
Cl^-	0.813	0.759	0.639	0.723	0.594
Ca^{2+}	0.927	0.891	0.802	**0.866***	0.769
Mg^{2+}	0.933	0.899	0.812	0.874	0.780
NO_3^{2-}	**0.999***	**0.999***	0.976	0.995	0.363
$PO4^{3-}$	0.630	0.560	0.412	0.515	0.365
$SO4^{2-}$	0.837	0.786	0.671	0.752	0.630

*Correlation is significant at the 0.05 level (2-tailed).

(0.576) > Ostracoda (0.409) while Simpson index (1-D) followed the order as Rotifera > Cladocera > Protozoa > Ostracoda > Copepoda. The high number of Rotifers, i.e., *Euchlanis dilatata*, *Lepadella ovalis*, *Asplanchna* sp., *Brachionus calyciflorus*, *Brachionus quadridentatus*, *Cephalodella* sp., and *Platiyas platulus* reported in the presently studied wetland indicates mesosaprobity that clearly depicts their presence in moderate oxygenated conditions with considerable organic matter, and bacteria while the presence of less number of other rotifers like, *Keratella tropica*, *Trichocerca longiseta*, *Trichocerca porcellus*, *Colurella adriatica*, *Monostyla bulla*, *Monostyla hamata*, and *Philodina* sp. indicate them as oligosaprobic, which indicates the organisms live in highly oxygenated condition in which little organic matter is present (Slâdeček 1983). High abundance of cladocerans reported in the wetland clearly indicate pollution caused majorly by accumulation of phosphorus but low concentration of contaminants like, heavy metal ions (Aslam et al. 2012; Hosmani 2013. Abundance of *Mesocyclops leuckarti* (Copepod) and *Eucypris* sp. (Ostracod) also indicate slight to moderate pollution in Pargwal Wetland.

Based on Pearson's correlations (Table 5), temperature, pH, and DO remain prime factors that restricted the abundance, and diversity of zooplankton communities in Pargwal Wetland. Correlations were significantly positive for phosphates as follows: Rotifer ($r = 0.999^*$), Cladocera ($r = 0.999^*$), Copepoda ($r = 0.976$), Protozoa ($r = 0.995$), and Ostracoda ($r = 0.963$). The results of one-way ANOVA showed a less significant difference in the physicochemical parameters ($p > 0.05$; 0.960) and with zooplankton diversity ($p > 0.05$; 0.451).

When compared with other internationally important wetlands/reservoirs in Jammu and Kashmir like from Dal Lake, authors like Jeelani & Kour (2014), deciphered 40 zooplankton species (27 rotifers and 13 crustaceans). Pargwal Wetland along with many other important wetlands like Gharana wetland (an International Bird Area, recognized by Birdlife International UK and Bombay Natural History Society) in the Jammu province, crave attention for their revival, and replenishment. No significant work has been done on the wetlands of Jammu province due to the inadvertent neglect and immaculate anthropogenic influence that have turned these important sources into wastelands. Although recent government interventions on the upliftment of Gharana Wetland has led to its substantial revival, others desperately fight for their existence.

It is a universal fact that zooplankton are the driving force which propel an aquatic food chain. They play a crucial role in the transmission of energy from lower to higher trophic levels because of a variety of characteristics, including stress resistance, enormous diversity, density, and drifting behavior (Dutta & Mondal 2020). Because of their brief lifespan, they frequently show abrupt and dramatic changes in reaction to changes in the physicochemical characteristics of water, which greatly enhances the freshwater ecosystem's biological production (Sultana et al. 2023). With a strong association between zooplankton dynamics and important physical & chemical properties of water, this study highlights the critical importance of zooplankton conservation within the setting of this very important wetland. The study deciphered that even minor changes in water quality can have a big impact on zooplankton populations and consequently, the larger aquatic food web, by looking at factors like pH, temperature, and nutrient concentrations. Conservation of zooplankton is important for maintaining water quality and ecosystem resilience as well as for safeguarding aquatic life since they are sensitive bioindicators that offer early warning indications of ecological stress.

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