Assessment of Zooplankton Population in the Keshopur Chhumb Wetland- A Ramsar Site Community Reserve in Punjab (India)

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ABSTRACT: Keshopur Chhumb wetland, 850-acre community reserve in Gurdaspur, Punjab, is a mosaic of natural marshes, covering numerous villages and added to the Ramsar site list in 2019. Zooplanktons are considered the best fish food organisms for various fish species' growth and survival during spawn, fry, and fingerling stages among aquatic biota. The study of zooplankton in Keshopur wetland examined various species, including Rotifers, Cladocera, Copepods, Ostracods, Oligochaete, and Dipteran populations. Rotifer populations varied from 11.0 to 40.0 individuals per liter, with the highest recorded population in December. Cladoceran populations ranged from 5.0 to 18.0 no. L^{-1}, with the highest in July and lowest in November and January. Copepod populations ranged from 3.0 to 18.0 no. L^{-1}, with the highest in July and lowest in December. Ostracod populations varied from 0.0 to 8.0 no. L^{-1}, with the highest in July, November, and December. Oligochaete populations varied from 1.0 to 12.0 no. L^{-1}, with the highest in August. Dipteran populations varied from 0.0 to 6.0 no. L^{-1}, with the highest density in August. The zooplankton abundance in Keshopur wetland follows a sequence of Rotifera, Cladocera, Copepoda, Oligochaeta, Ostracoda, and Diptera. The study reveals that water temperature and dissolved oxygen negatively impact Rotifer abundance, while positively affecting Cladocera, Copepoda, Ostracods, and Oligocheates. These factors also influence the abundance of other organisms, such as Diptera. The wetland's ecological and morphological characteristics significantly influence its faunal diversity distribution. This study is crucial for understanding bioindicators of water quality, ecosystem health, trophic dynamics, energy transfer, nutrient cycling, and productivity, aiding in wetland conservation and resource utilization.

Keywords: Keshopur Wetland, Ramsar Site, Community Reserve, Assessment, Zooplankton population.

Abbreviation: No. L^{-1} = Individual number per litre.

INTRODUCTION

Humans and environmental changes are straining wetland habitats. Indian wetland areas have declined, degraded, or changed in recent decades. Some became artificial wetlands including paddy fields, aquacultural ponds, reservoirs, and irrigation canals, while others were polluted. Some vanished owing to agricultural reclamation and settlement growth. Some bird or waterfowl populations can use man-made wetlands due to the massive degradation of wetland habitats in recent decades (Hassan, 2016). Plankton plays an important role in the productivity of wetland. Kadiri (2010) suggests that plankton organisms indicate water body cleanliness. Heterotrophic zooplanktons are crucial in aquatic food webs, transferring energy from producers to consumers and facilitating the decomposition of dead organic matter (Steinberg and Robert 2009). They are essential for the health of aquatic ecosystems and can serve as early warning systems for water quality declines

due to pollution or eutrophication (Mahajan, 1981). Zooplanktons are useful indicator of changes in water quality due to their rapid response to environmental changes (Contreras *et al.,* 2009). Ekwu and Sikoki (2006) found that planktons transmit energy in aquatic ecosystems, making their wellbeing vital for the health of wetland ecosystem. Ekwu and Udo (2013) found that reduced river discharge and increased water stagnation rates boost zooplankton and phytoplankton taxonomic diversity during the dry season. These circumstances increase plankton biomass, making prevalence of rotifers within zooplankton communities. The occurrence and distribution of plankton fauna are affected by various parameters, including physicochemical habitat qualities, biotic factors, and climatic change (Ekwu and Sikoki 2005; Richardson, 2008; Rajagopal *et al*., 2010; Ahmad *et al.,* 2011; Alexander, 2012). Water temperature is one example of an important environmental factor that affects the growth and development of organisms and, in turn, their mortality rate (Hall and Burns 2001;

Andrulewicz *et al.,* 2008; Tunowski, 2009). Lawrence *et al.* (2004) also highlighted the effect of salinity and its concentration on the body of organisms. Water temperature, salinity, and factors like surface water warming and freshwater inflow are important environmental factors that influence the diversity and abundance of zooplankton by influencing their reproductive success (Greenwood *et al.,* 2001). The present work aimed to determine the availability of zooplankton abundance in Keshopur wetland in Punjab.

MATERIALS AND METHODS

Study area. Keshopur Chhumb Wetland is a mosaic patchwork of natural marshes, quite low lying and encompasses a large number of villages in district Gurdaspur (Fig. 1). Its coordinates are 32° 05′16° 3″ N and 75° 24′ 24° 2″ E and the wetland area have shallow water features (Fig. 1). The selected study sites are depicted in Fig. 2-4. This community reserve consists of the land between Gurdaspur Township and Behrampur village, on the Indo-Pakistani border, and includes the villages of Dalla (152 acres), Miani (400 acres), Matwa (51 acres), Dhalla, and Magarmudhian (111 acres). This Community Reserve is situated on the lowlands that were once inundated by the rivers Ravi and Beas. It's a mishmash of natural wetlands, aquaculture ponds, and farmland wetlands where things like lotus and chestnut are cultivated in bulk (Hassan, 2016). There are many migratory waterfowl including significant habitat for rare and threatened species who use this area as a stopover or staging area. This area of Punjab has a climate that is sub-moist or humid and relatively cooler than the rest of the area. Rainfall sustains this wetland and is surrounded by fields of rice, wheat, and sugarcane crops. The rural economy and community involvement of local people in Keshopur Chhumb Wetland are significantly impacted by anthropogenic activities such as constructed fish ponds and prolific growth of aquatic weeds such as lotus, trapa etc. The populations from surrounding villages are also dependent on the wetland for their livelihood (Hassan, 2016).
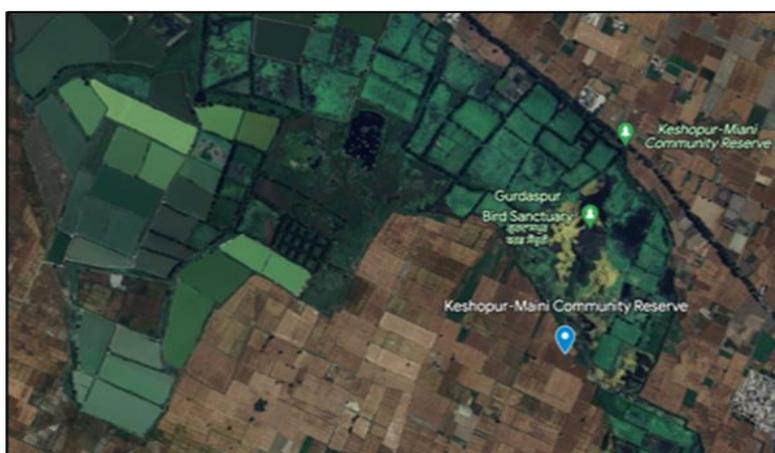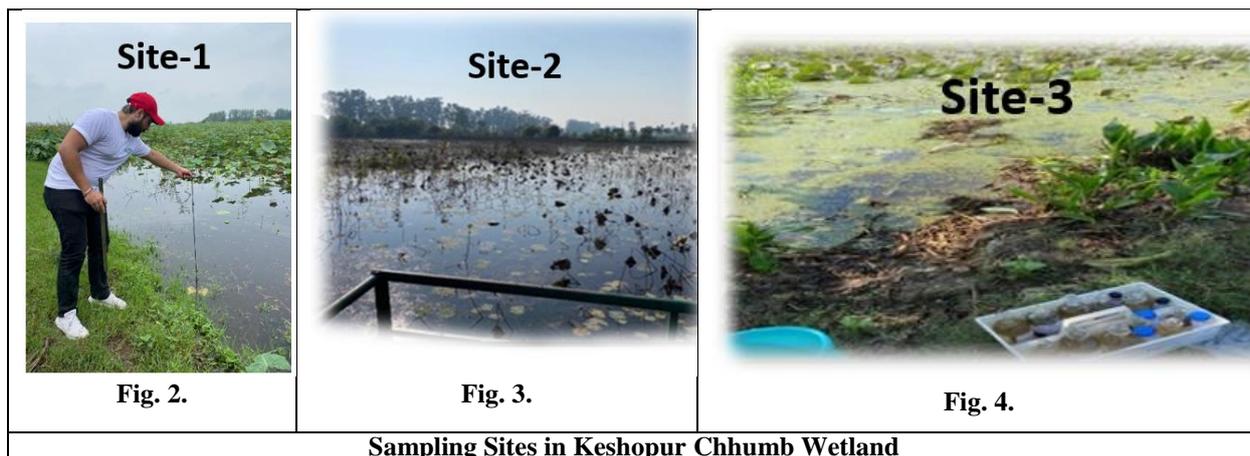

Fig. 1. Keshopur Chhumb Wetland.

Fig. 2.

Fig. 3.

Fig. 4.

Sampling Sites in Keshopur Chhumb Wetland

Collection, fixation, preservation and identification of zooplankton samples: Based on the diversity of Keshopur wetland's morphometry, microhabitat and hydrological characteristics, three sampling sites were selected (Fig. 2-4). In order to collect zooplankton samples of Keshopur Chhumb wetland, samples were collected on monthly basis. For collecting zooplankton, 50 litres of water were filtered through a conical shaped plankton net made of a ring and filtering cone made of bolting silk, nylon, or another synthetic material with a 150 μm mesh size. Each time the net was used to collect the samples (Plate 1 & 2). To stop bacterial action, cannibalism, and chemical deterioration from causing filtered zooplankton to degrade, the organisms were maintained in sterile plastic vials and immediately fixed and preserved by buffered formaldehyde solution (4–

5%). The samples were brought to the laboratory right away and kept upright to prevent spills before being stored in a dark, cool place for additional processing (Plate 1 & 2). After fixing, the sample was left undisturbed. The immobilised samples were centrifuged to obtain concentrated zooplankton, then placed into the Sedgwick Rafter Cell and observed under a microscope in ten randomly selected fields (Plate 2). However, following the protocols laid out by American Public Health Association (2017); Trivedy and Goel (1986), collected and preserved samples were used for further processing. Slides of plankton were developed in the laboratory for identification. Zooplankton were identified and counted using a light microscope and binoculars. The Sedgwick Rafter Counting Chamber (Welch, 1948) was used to calculate the density. Genus level identifications of planktonic organisms were made using the criteria established by Edmondson (1959), Needham and Needham (1962 and 1966), Pennak (1978), and Tonapi (1980), Kodakar (1992), Edmondson (1992), Gupta (2012), and APHA (2017).

Collection and fixation of sample – The sample was collected with the help of zooplankton net (mesh size 150 μm) by filtering 50 litres of river water through it.

The sample thus collected was poured into a vial and fixed with few drops of formaldehyde solution (37-41% w/v). After fixing, the sample was left undisturbed.

Enumeration:

(i) The fixed samples were centrifuged to make a known volume of zooplankton concentrate.

(ii) 1 ml of sample was taken in the Sedgwick rafter Cell (SRC).

(iii) Number of zooplankton in 10 randomly selected fields was recorded under microscope power 10x.

(iv) Number of zooplanktons per litre of sample was calculated as follows:

$$\text{No. of zooplankton/ml} = \frac{C \times \text{Area of SRC (1000 mm2)}}{A \times D \times E} = N$$

Where,

C = Number of organisms recorded/10 fields

A = Area of one microscope field

D = Depth of field/S.R.C. depth (1mm)

E = Number of fields counted

Number of zooplankton/litre of water =

$$\frac{N \times \text{Volume of concentrate (ml)}}{\text{Volume of water filtered (l)}}$$
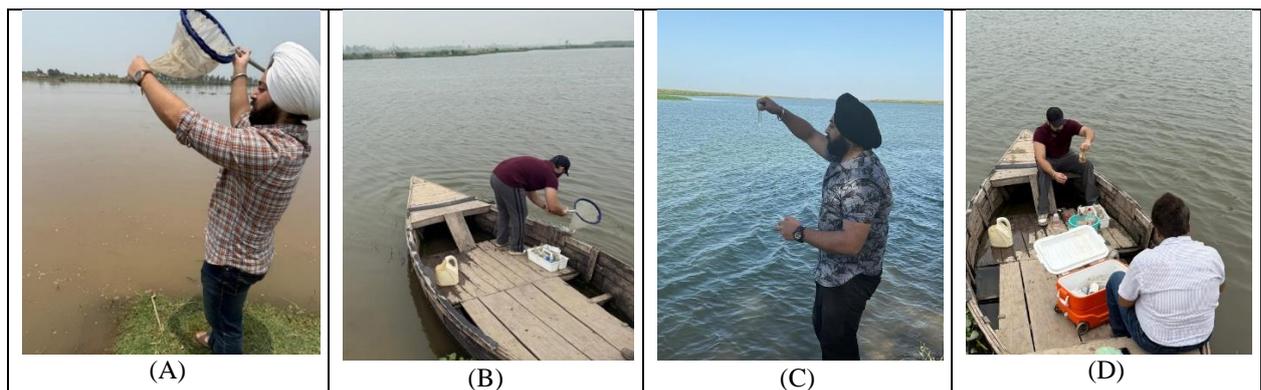

Plate 1: Sampling of Plankton from Keshopur Chhumb Wetland (A) Assembling the net, (B) Sample collection, (C) Examining the sample, (D) Labelling and storage of samples)
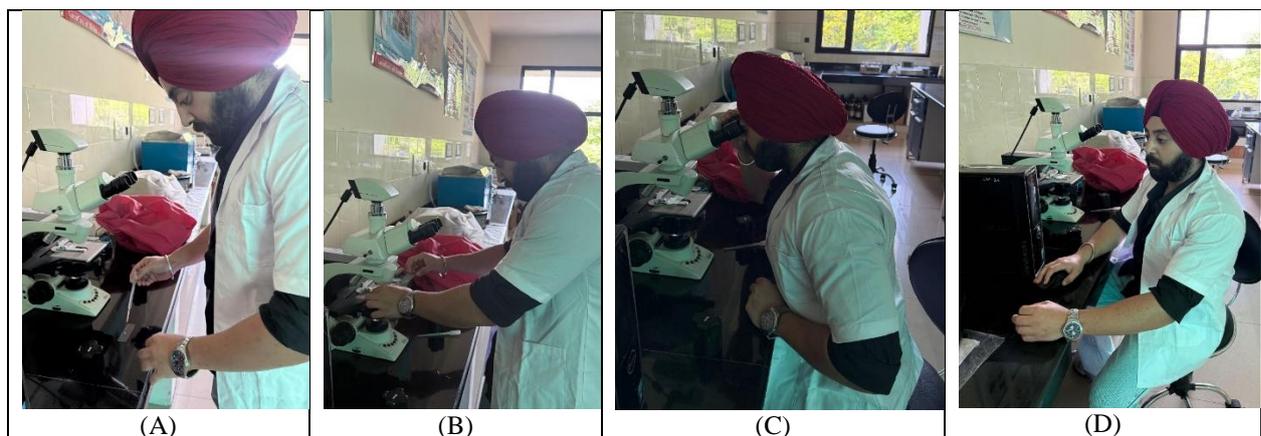

Plate 2 : Laboratory Analysis of Plankton Samples (A) Slide preparation, (B) Slide Mounting, (C) Microscopic examination, (D) Documentation of Plankton).

RESULT AND DISCUSSION

Zooplankton

During the investigation, Rotifera, Cladocera, Copepoda, Ostracoda, Oligochaeta, and Diptera were found in Keshopur wetland at various abundances. In aquatic ecosystems, zooplankton control algal and bacterial populations and feed higher trophic levels. Zooplankton connects aquatic food chains' trophic levels and drives energy flow. It spans the aquatic nutrient cycle and serve as bio-indicators of pollution. Zooplanktonic community structure, species composition, distribution, and relative abundance across time is an aquatic environment index. Zooplanktons are sensitive to environmental changes and significant markers of ecosystem health (Magadza, 1994). They also boost freshwater ecosystem biological production (Wetzel, 2001).

Rotifer

Rotifers, microscopic fauna typically found in freshwater (Plate 1), with an anterior wheel-like revolving structure called a "Corona". Rotifers are the most significant soft-bodied invertebrates (Hutchinson, 1957). In the present investigation, the population of rotifers at selected sites of the Keshopur wetland ranged from 11.0 to 40.0 individuals per liter. The average maximum (38.0 no. L⁻¹) rotifer population was observed in the month of December whereas minimum (12.33 no. L⁻¹) in August at Keshopur wetland (Table 1 and Fig. 5). The average population of rotifers exhibited seasonal variations, with the maximum recorded population (34.66 individuals per liter) observed during the winter season. This was followed by the post-monsoon season, where an average population of 23.33 individuals per litre was recorded. The lowest average population of rotifers (18.45 individuals per liter) was observed during the monsoon season in the water of Keshopur wetland. The overall trend of site-wise abundance of Rotifera population was observed as site-2 > site-1 > site-3. Significant seasonal variations in rotifer population were observed at all sites ($p<0.05$). However, the correlation analyses revealed that water temperature and dissolved oxygen is significantly negatively correlated with Rotifer ($r = -0.531$, $p = 0.176$ and $r = -0.423$, $p = 0.296$), suggesting that as water temperature and dissolved oxygen increases, the abundance of Rotifer tends to decrease (Table 3). Despite the fact that Rotifer show a significant positive correlation with Ostracods, suggesting that as the abundance of Ostracods increases, so does the abundance of Rotifer (Table 3). Antal *et al.* (2020) recorded minimum rotifer population were during monsoon months in both the Lakes (Lake Mansar and Lake Surinsar) of Jammu region. The present work is also in conformity with Antal *et al*. (2020). Sharma and Sharma (2019) observed variation of rotifer population, plankton and semi-plankton collections from floodplains of the Barak valley of south Assam. Jindal and Vasisht (1981) obtained similar results in Sirhind canal hydrobiological research. Site-1, site-2, and site-3 showed Rotifera population abundance trends. Khanna *et al*. (2012) found the highest Rotifera diversity in December and the lowest in July in Ganga, while Kolhe *et al*. (2013) found similar density in Godawari. Rotifers were also observed throughout the study period, but they showed maximum in December and winter season, in agreement with Jindal and Vasisht (1981); Gurumayum *et al*. (2002), who found the same results in hydrobiological studies of Sirhind canal and some selected Meghalayan rivers.

Table 1 : Monthly variations in Zooplankton (Rotifera, Cladocera, Copepoda) populations (no. L⁻¹) at Keshopur Wetland.

Month	Rotifera	Cladocera	Copepoda
July	24.58±1.08[c]	16.00±1.15[a]	16.00±1.15[a]
August	12.33±0.88[e]	12.00±1.15[b]	10.00±1.15[bc]
September	18.00±1.15[d]	10.00±1.15[b]	6.00±1.15[de]
October	22.00±1.15[c]	10.00±1.15[b]	12.00±1.15[b]
November	30.00±1.15[b]	6.33±1.15[c]	6.00±1.15[de]
December	38.00±1.15[a]	10.33±1.15[b]	4.00±1.15[e]
January	30.00±1.15[b]	6.33±1.15[c]	5.33±1.15[de]
February	36.00±1.15[a]	10.00±1.15[b]	8.00±1.15[cd]

*Values (mean ± standard error) with different alphabetical superscripts (a, b, c...) differ significantly between the sites (in a row) and within the site (in the column)

Table 2 : Monthly variations in Zooplankton (Ostracods, Oligochaetes, Diptera) populations (no. L⁻¹) at Keshopur Wetland.

Month	Ostracods	Oligochaetes	Diptera
July	6.33±0.881[a]	7.67±0.333[bc]	1.67±0.881[c]
August	0.00±0[c]	10.00±1.154[a]	5.33±0.666[a]
September	0.00±0[c]	9.00±0.577[ab]	4.33±0.333[ab]
October	5.00±0.577[ab]	6.33±0.881[c]	4.67±0.881[ab]
November	6.33±0.881[a]	4.00±0.577[d]	1.33±0.881c
December	6.33±0.881[a]	3.67±0.881[d]	3.00±0.577[bc]
January	3.00±0.577[b]	2.33±0.666[d]	1.00±0.577[c]
February	4.67±0.881[ab]	2.33±0.333[d]	2.00±0.577[c]

*Values (mean ± standard error) with different alphabetical superscripts (a, b, c...) differ significantly between the sites (in a row) and within the site (in the column)
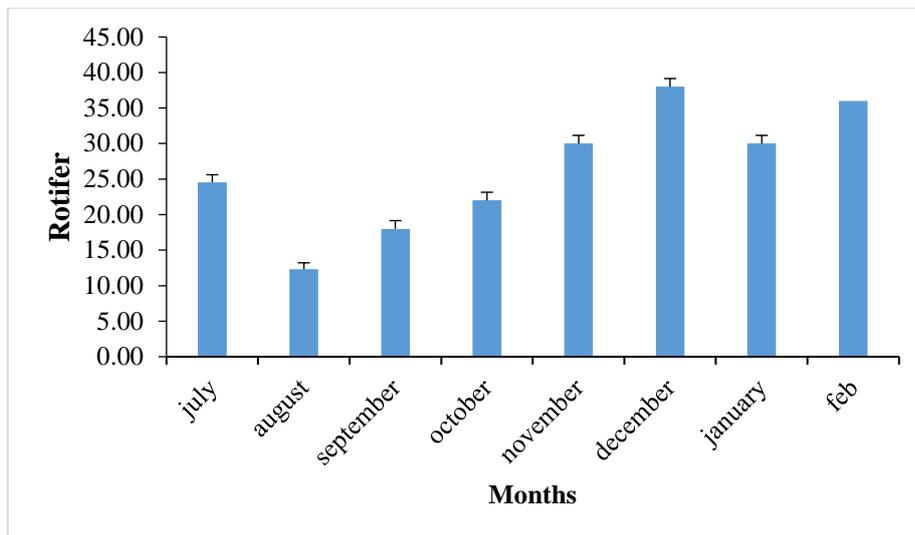
Fig. 5. Monthly variations in Rotifer populations (no. L^{-1}) at different sites of Keshopur Wetland.

Cladocera. Cladocera, sometimes known as "water fleas," are crustaceans that are commonly found in deep water and are an important food source for fish (Plate 1). They play an essential role in the chain of life and the transformation of energy (Uttangi, 2001). In the current study, the abundance of Cladocera populations at different selected sites within Keshopur wetland varied between 5.0 and 18.0 individuals per litre. The average maximum (16.0 no. L^{-1}) cladocera population was observed in the month of July whereas minimum (6.33 no. L^{-1}) in November and January at Keshopur wetland (Table 1 and Fig. 6). Seasonally, average Cladoceran population was recorded to be highest (14.0 no. L^{-1}) in monsoon followed by winter (8.88 no. L^{-1}) and post-monsoon (8.77 no. L^{-1}) in the water of Keshopur wetland. The overall trend of site-wise abundance of Cladoceran population was observed as site-2 > site-1 > site-3. Significant seasonal variations in Cladocera population were observed at all selected sites (p<0.05). However, the correlation analyses revealed that water temperature and dissolved oxygen are significantly positively correlated with Cladocera (r = 0.786, p = 0.021 and r = 0.810, p = 0.015), indicating that as water temperature and dissolved oxygen increases, the abundance of the Cladoceran organisms tends to increase (Table-3). It is also noteworthy, that Cladocera is significantly positively correlated with Copepoda (r = 0.772, p = 0.025), indicating a positive association between these two organisms (Table 3). Miah *et al.* (2013) evaluated Cladocerans specially Daphnia and Moina in freshwater environments. Pandey *et al.* (1994) also recorded highest number of Cladocerans during the month of July, and revealed that it may be due to high nitrate, phosphate, and chloride concentrations. According to Ray *et al.* (1966), hydrological and water quality parameters may have caused the lowest Cladocera count. According to Hassan (1999) Cladocera population was lowest in the river Ganga near Patna during Post-monsoon. During the present study, winter and post-monsoon Cladocera populations were lower than monsoon levels, possibly because of high water flow and turbidity stunting growth. These findings are in conformity with Hassan (1999). Michels *et al.* (2001); Pandey *et al.* (2004); Khanna *et al.* (2012) also observed similar results in aquatic ecosystem in Kishanganj and in Uttarakhand region. Frisch *et al.* (2004) recorded many Cladoceran species from five wetland zones within Donana, south-west Spain, whereas Sharma and Sharma (2014) observed significant Cladoceran population from Majuli wetland, Assam.
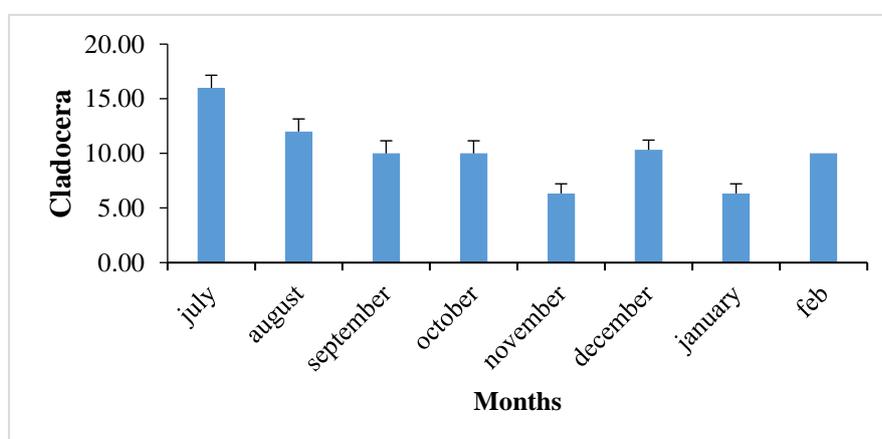

Fig. 6. Monthly variations in Cladocera populations (no. L^{-1}) at different sites of Keshopur Wetland.

Copepod. Copepods are a taxonomic group of little crustaceans (Plate 1) that inhabit marine environments as well as practically all freshwater habitats (Kalff, 2002). In the present study, the number of Copepod population ranged from 3.0 to 18.0 no. L^{-1} at selected sites of the Keshopur wetland. The average maximum (16.0 no. L^{-1}) Copepod population was observed in the month of July whereas minimum (4.0 no. L^{-1}) in December at Keshopur wetland (Table 1 and Fig. 7). Seasonally, average Copepod population was recorded to be highest (13.0 no. L^{-1}) in monsoon followed by post-monsoon (8.0 no. L^{-1}) and winter (5.776 no. L^{-1}) in the water of Keshopur wetland. The overall trend of site-wise abundance of copepod population was observed as site-1 > site-2 > site-3. Significant seasonal variations in Copepoda population were observed at all selected sites (p<0.05). However, the correlation analyses revealed that water temperature and dissolved oxygen are significantly positively correlated with Copepoda (r = 0.815, p = 0.014 and r = 0.600, p = 0.116) indicating that as water temperature and dissolved oxygen increases, the abundance of the Copepod organisms tends to increase (Table 3). It is also noteworthy, that Copepoda is significantly positively correlated with Cladocera (r = 0.772, p = 0.025), indicating a positive association between these two organisms (Table 3). Meanwhile,

copepod numbers varied greatly between monsoon and post-monsoon months within sites. Seenayya (1973) also recorded maximum Copepod population during monsoon. Winter Copepod populations were lower than post-monsoon and monsoon levels, possibly due to moderate water flow and turbidity limiting copepod growth. In freshwater ecosystem, Copepods (cyclops) were assessed by Miah *et al.* (2013). Hassan (1999) found less Copepods in Ganga at Patna during post-monsoon. Ray *et al.* (1966) also pointed turbidity and other hydrological factors caused the lowest Copepod count during winter. The present findings also corroborated with the work of Hassan (1999). Cyclops sp. and nauplii larvae dominated the copepod population, enriching natural water. Verma *et al.* (1984); Ahmad *et al.* (2011) found Cyclops sp. and nauplii larvae susceptible to pollution and increasing with water body nutrients. Frisch *et al.* (2004) recorded many Copepod species from five wetland zones within Donana, south-west Spain. Chauhan (1993) found similar results in Renuka Lake at Himachal Pradesh. Lawrence *et al.* (2004) found *E. affinis* and copepod nauplii, did not experience changes in abundance with varying salinity levels, while *A. hudsonica, A. tonsa,* and *C. hamatus* were more prevalent in saltier subestuaries.
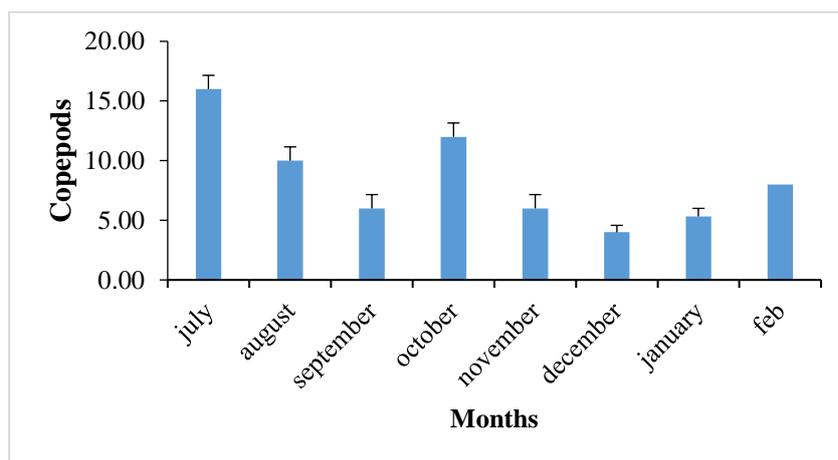

Fig. 7. Monthly variations in Copepod populations (no. L^{-1}) at different sites of Keshopur Wetland.

Ostracods. Ostracods are bivalves that resemble tiny seeds due to their morphology. They can be found in saltwater and freshwater ecosystems. Rivers, lakes, tanks, pools, marshes, streams, and even contaminated waterways are all suitable habitats for freshwater Ostracods. As a result of their high numbers, aquatic species have access to nutritious food. In the present study, the number of Ostracod population ranged from 0.0 to 8.0 no. L^{-1} at selected sites of the Keshopur wetland. The average maximum (6.33 no. L^{-1}) Ostracod population was observed in the month of July, November and December whereas nil (0.0) in the month of August and September at Keshopur wetland (Table 2 and Fig. 8). Seasonally, average Ostracod populations were recorded to be highest (4.66 no. L^{-1}) in winter followed by post-monsoon (3.77 no. L^{-1}) and monsoon (3.165 no. L^{-1}) at Keshopur wetland. The average populations of

Ostracods were seen to exhibit seasonal variations. At Keshopur wetland, winter Ostracod populations averaged 4.66 individuals per liter, followed by post-monsoon (3.77 individuals per liter) and monsoon (3.165 individuals per liter). The overall trend of site-wise abundance of Ostracods population was observed as site-1 > site-2 > site-3. Post-monsoon Ostracod populations were lower than monsoon, possibly due to moderate water flow and turbidity limiting growth. Bera *et al.* (2014) found Ostracoda in a reservoir in west Bengal, but Mezquita *et al.* (1999) found them in moderately contaminated and clear waters. Significant seasonal fluctuations in Ostracod population were observed at all sites (p<0.05). However, Ostracods show a significant positive correlation with Rotifer (r = 0.718, p = 0.045), suggesting that as the abundance of Ostracods increases, so does the abundance of Rotifer (Table 3).

Oligochaeta. The Oligochaeta taxonomic group holds significant ecological importance as a constituent of the zooplankton community found in the sedimentary habitats of flowing freshwater ecosystems. The aquatic ecology relies on it for the cycling of matter and transfer of energy, making it a crucial component. The present study found that the Oligochaete population varied from 1.0 to 12.0 individuals per liter at different selected sites in the Keshopur wetland. The average maximum (10.0 no. L^{-1}) Oligochaete population was observed in the month of August whereas minimum (2.33 no. L^{-1}) in the month of January and February at Keshopur wetland (Table 2 and Fig. 9). Seasonally, average oligochaetes were recorded to be highest (8.835 no. L^{-1}) in monsoon followed by post-monsoon (6.44 no. L^{-1}) and winter (2.77 no. L^{-1}) at Keshopur wetland. The overall trend of site-wise abundance of Oligochaete population was observed as site-1 and site-2 > site-3. Post-monsoon Oligochaeta population was lower than winter, possibly due to moderate water flow and turbidity limiting its growth. Significant seasonal variations in Oligocheate population were observed at all sites ($p<0.05$). However, Oligocheates have a significant positive correlation with Diptera ($r = 0.694$, $p = 0.056$), suggesting a positive association between these two organisms (Table 3).

Arslan *et al.* (2007) investigated research work on the Balikdami Wetland, an impoundment on the upper course of the Sakarya River in Turkey, and found abundant Oligochaete species. In Balikdami Wetland, the Oligochaete fauna was dominated by tubificid taxa because of its widespread distribution.
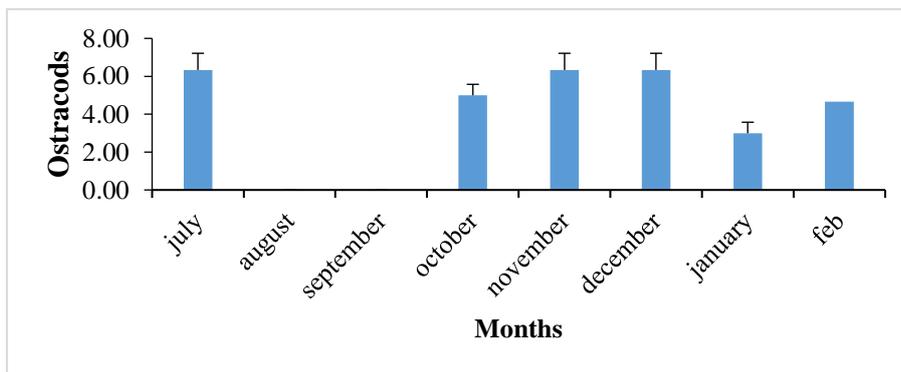

Fig. 8. Monthly variations in Ostracod populations (no. L^{-1}) at different sites of Keshopur Wetland.
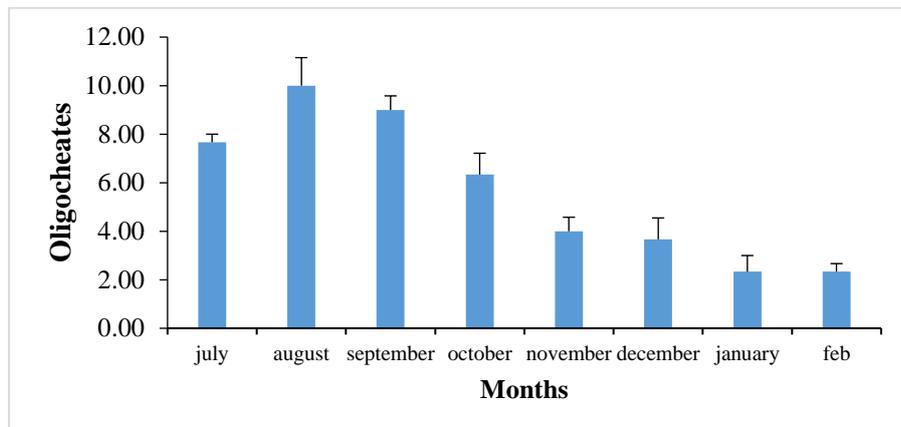

Fig. 9. Monthly variations in Oligochaete populations (no. L^{-1}) at different sites of Keshopur Wetland.
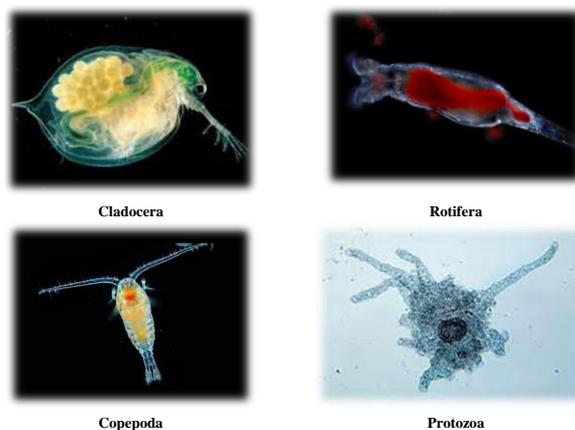

Plate 3. Zooplankton species.

Diptera. Dipteran larvae live in tree holes, saturated soil, mud puddles, streams, ponds, huge lakes, rivers, and even the marine rocky intertidal zone. Aquatic Diptera are one of the most important indicator organisms since they live in numerous ecological niches in clean and contaminated water and many species are extremely selective. In the current investigation, the Dipteran population exhibited a range of 0.0 to 6.0 individuals per liter at selected sites inside the Keshopur wetland. The average maximum (5.33 no. L^{-1}) Dipteran population was observed in the month of August whereas minimum (1.0 no. L^{-1}) in the month of January at Keshopur wetland (Table 2 and Fig. 10). The Dipteran population at Keshopur wetland exhibited seasonal variations, with the highest average population density (3.5 individuals per liter) observed during the monsoon season. This was followed by the post-monsoon season, which had an average population density of 3.44 individuals per liter. The winter season had the lowest average population density, with 2.0 individuals per liter at Keshopur wetland. The overall trend of site-wise abundance of Diptera population was observed as site-2 > site-1 > site-3. However, Diptera have a significant positive correlation with Oligocheates, suggesting a positive association between these two organisms (Table 3). Maan (2021) conducted research in River Beas and found seasonal average value of Diptera population was less during winter as compared to monsoon and postmonsoon which may be due to moderate water flow and turbidity impeded its growth. The present findings also corroborated with the work of Maan (2021).
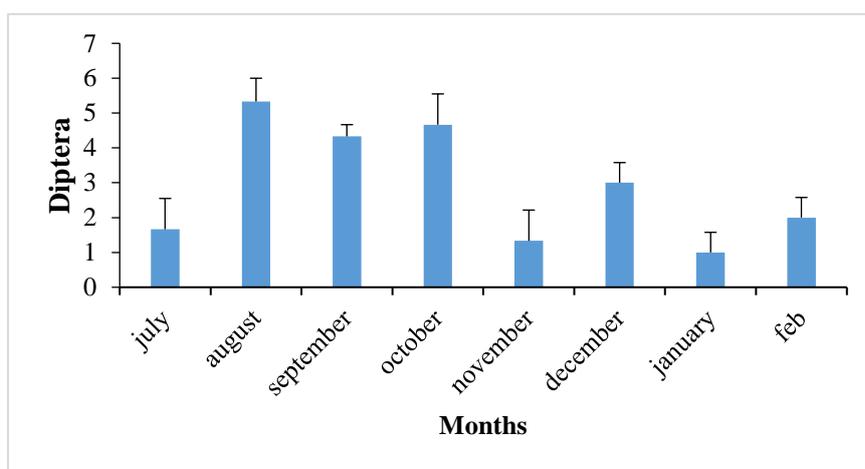

Fig. 10. Monthly variations in Dipteran populations (no. L^{-1}) at different sites of Keshopur Wetland.

Relative Abundance of Zooplankton. Seasonal variations in the presence or absence of ideal water quality characteristics can have a direct or indirect impact on the prevalence of zooplankton in various Keshopur wetland sample locations. According to Pennak (1946), zooplankton's seasonal cycle is quite unpredictable in the natural world. The expansion of the phytoplankton community constantly outpaces that of the zooplankton community, and even abundant populations of zooplankton can vanish and become quite rare (Pennak,1978). Higher trophic level creatures grazing on zooplankton is also associated with a reduction in the zooplankton community (Chakraborty *et al.,* 1959). Zooplankton were also recorded by Pandey *et al.* (2009) in the swamps of Kishanganj, the overall zooplankton density was higher in the summer and lower during the rainy season. In this study, Rotifera was found to be the leading group at site-2 (34.17%), followed by site-1 (33.0%) and site-3 (32.91%) in terms of site-wise relative abundance (no. L^{-1}) of the zooplankton population. The highest percent population of Rotifera in Keshopur wetland was recorded as 45.89% followed by Cladocera (17.84%), Copepoda (14.65%), Oligochaeta (9.86%), Ostracoda (6.89%), and Diptera (5.08%) (Fig. 11). The overall abundance trend of zooplankton in Keshopur wetland was recorded in the order of Rotifera > Cladocera > Copepoda > Oligochaeta > Ostracoda > Diptera. According to Pandey *et al.* (2009), Rotifera > Cladocera > Copepoda was the quantitative connection among the zooplankton category) in the swamps of Kishanganj. Lower copepod availability was observed by Parmar *et al.* (2016), who used cyclops as an indication of nutrient abundance; this finding is also corroborated by zone-based markers of pollution. In the Kumaun region's Bhimtal Lake, Panwar and Malik (2016) investigated the species richness, diversity, and distribution pattern of zooplankton and recorded Rotifera group was the most prevalent of the three categories.

Aquatic biodiversity and fisheries productivity are greatly impacted by zooplankton dynamics, which are closely associated with hydrological fluctuations, nutrient availability, and physico-chemical features of the trophogenic zone (Hassan *et al*., 1998a, b; Sehgal *et al.,* 2011; Hassan and Sinha 2015; Hassan, 2015). It has been demonstrated that plankton abundance and succession patterns are regulated by seasonal nutrient fluctuations in the epilimnion (Hassan *et al.,* 2015). Additionally, organic inputs and management interventions may alter water quality and biological productivity (Sharma and Hassan 2016; Sharma *et al.,* 2019). Research from comparable wetlands in north India, such as Nigeen Lake and Harike Wetland, highlights the significance of plankton populations as markers of fish growth potential and trophic status (Kaur *et al.,* 2018; Priyanka *et al.,* 2018). Furthermore, worries

about microbial contamination and heavy metal buildup in Punjab wetlands and rivers underscore the need to combine zooplankton assessment with more extensive environmental monitoring in order to assess the sustainability and health of ecosystems (Kaur *et al.,* 2019a, b, c; Kumar *et al.,* 2020; Maan and Hassan 2021). As a result, zooplankton population analysis in Keshopur Chhumb Wetland is a crucial ecological tool for the preservation of biodiversity and the sustainable management of fisheries in the area.

According to Sharma and Sharma (2011), zooplankton exhibited an annual peak abundance throughout the winter and constituted a large quantitative component of net plankton in Loktak Lake, Manipur. They went on to explain that Copepoda > Rhizopoda are sub-dominant groups, whereas Rotifera > Cladocera are dominant quantitative groups. Jindal and Singh (2006) observed Rotifera as most abundant zooplankton in the river Beas followed by Copepods and Cladocera. The present results are consistent with those of Jindal and Singh (2006), who likewise found that rotifers were the most common kind of organism.
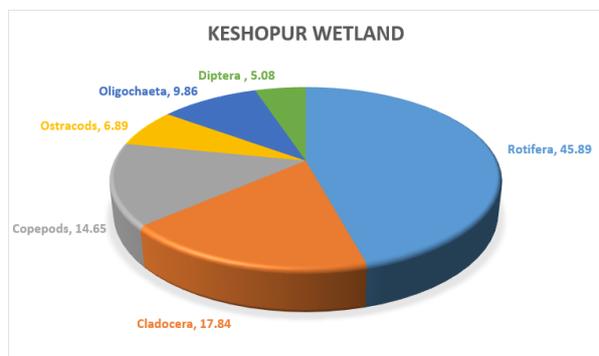

Fig. 11. Relative abundance (%) of Zooplankton population at Keshopur Wetland.

CONCLUSIONS

Based on the results of this study, zooplankton varieties are crucial for gauging the degree of pollution in this body of water. Rotifer abundance decreased as water temperature and dissolved oxygen increased as per the present findings. They are favourably correlated with Cladocera, Copepoda, ostracods, and Oligocheates. As water temperature and dissolved oxygen rise, these creatures multiply. Additionally, Copepoda and Cladocera are favourably connected. Ostracods correlate positively with Rotifer, and Oligocheates with Diptera. Overall, the study demonstrates these factors can affect organism abundance. It is also important that macrophyte and water quality variations had a significant impact on zooplankton populations. Assessing the ecological and fishery status of freshwater wetlands requires knowledge of zooplankton populations. It would also provide some insight about the wetland's diversity and productivity. Planning, exploitation, anti-pollution, and conservation initiatives all benefit from this.

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