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RESEARCH PAPER

Zooplankton Diversity with Special Reference to Water Quality of Yamuna River at Delhi

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ABSTRACT

Present investigation was conducted to study the relationship between physico-chemical characteristics and seasonal variation on the diversity of zooplanktons of river Yamuna in the stretch of Delhi. For this purpose samples were collected for one year during Feb 2024 to March 2025 from three different Locations i.e. SW1-Near Wazirabad bridge (Upstream and entry point of Yamuna river in Delhi), SW2-Near ITO (Mid-stream and located in middle of stretch of Yamuna river in Delhi) and SW3-Near Okhla barrage From Kalindi Kunj (Downstream and exit point of Yamuna river from Delhi). These samples were tested for various physicochemical parameters like Temperature, pH, Turbidity, Electrical conductivity, Total dissolved solid, Total Suspended solid, Total hardness, Total alkalinity, Dissolved oxygen, Biological oxygen Demand, Free CO_2, Nitrate, Phosphate and Chloride etc. Zooplankton analysis was also carried out during whole sampling period. The Values of the physicochemical parameters varied at all the three locations because of discharge of the huge quantity of sewage and industrial effluent in this stretch of river. Four groups of zooplanktons were reported i.e. Rotifers, Cladocera, Copepods and Ostracodes. The density of zooplankton was found to be very low at all the three locations. The lowest density is recorded at location SW2 because it is situated in centre of the city and receive very large amount of sewage and untreated effluent from the whole city. Among all the group of the zooplankton Rotifers were found to be most dominant at all location followed by Cladocera, Copepoda and Ostracoda. The overall population of were recorded maximum during pre-monsoon season.

HIGHLIGHTS

- Zooplankton diversity in the Yamuna River was studied over one year across three locations in Delhi, revealing low overall density due to pollution.
- Rotifers emerged as the most dominant group, especially during the pre-monsoon season when populations peaked.
- Midstream site SW2 showed the lowest zooplankton density, heavily impacted by sewage and industrial effluent discharge.

Keywords: Zooplanktons, Physicochemical Parameters, Yamuna River, Seasonal Variation

The presence of biota provides and insight of existing condition of an ecosystem. Change in the structure and function of biological systems are induced by environmental disturbances. In natural and unpolluted streams the flora and fauna is represented by higher no of taxa, most of them with relatively small populations. A progressive decrease in number of individuals of each taxa is generally observed with an increase in pollution level. Zooplanktons is known not only to form an integral part of lotic community but also contribute significantly to the biological productivity of fresh water ecosystems (Sellner *et al.* 1993 and Hassan *et al.* 2009). Zooplanktons are microscopic, free-

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floating animals which plays a vital role in aquatic ecosystem (Priya *et al.* 2024). They link the primary producers, phytoplankton with higher trophic level organisms. Zooplankton communities respond to a wide variety of disturbance including nutrient load and also plays a key role in aquatic food chain (Murugan, Murugavel and Koderkar, 1998). The zooplanktons play an integral role and serves as bioindicator (Mathivonum, 2007) and it is a well suited tool for understanding water pollution status (Ahmed, 1996; Contreras *et al.* 2009). Odum (1971)observed that zooplanktons are sensitive to their environment and a change in zooplanktons concentration can indicate a specific environmental change. The diversity of species, amount of biomass and abundance of zooplankton communities can be used to determine the health of an ecosystem (Senthilkumar *et al.* 2016; Pooja Jakhar, 2013). Sladecek, V. 1983 and Saksena *et al.* 2006 reported that among zooplankton Crustaceans, Cladocerons and Copepods can be used as indicator of aquatic environment. Zooplankton community structure has significant potential for assessing aquatic ecosystem health. Zooplankton density has also been reported to vary depending on the availability of nutrients and the other water characteristics. Higher diversity means longer food chain and more cases of associations which further increases stability (Bhatnagar *et al.* 2013).

Rivers are important systems of biodiversity and are among the most productive ecosystems on the earth because they receive nutrients and other materials from vast area and flow in varied environmental conditions that support number of flora and fauna (Emeka Donald Anyanwu *et al.* 2022). They Play a vital role in the productivity as they are beset with varieties of Flora and Fauna including planktons (Vijayan, P. *et al.* 2018). River Yamuna locally known as Jamuna is the longest tributary of the Ganga riverin north India. The Yamuna originates at "Yamunotri in Uttarakhand". The total length of the river from YamunotriGlaciers to the sangam at Allahabad is about 1300 km. The river Yamuna flows the Uttarakhand, Himanchal Pradesh,Haryana, NCT of Delhi and Uttar Pradesh stats of India (Upadhyay *et al.* 2010). The river stretch for 22 kms along the city of Delhi. It enters at Wazirabad in North to Okhla barrage in South and is major source of water for drinking, irrigation & other uses. It has significant impact on the human settlement pattern witnessed by the city. Delhi being the biggest consumer of Yamuna's water resources has also become the biggest polluters by contributing 80-90% of the total sewage discharge to the Yamuna deteriorating the water quality and also the possibility impacting survival of biodiversity. The river has been subjected to immense degradation and pollution due to huge amount of domestic waste water entering the river (Sharma and Kansal, 2011 & Anil Kumar Mishra, 2010). The river Yamuna is described as the "River of grief" and dirty river in Delhi due to seepage of untreated waste water (Sarkar *et al.* 2021; Yadav & Yadav, 2024). A healthy aquatic environment is largely governed by its physicochemical characteristics and stability (Rajni, 2023). Biological production in any water body is directly correlated with its physicochemical status (Sharma *et al.* 2013). The physical and chemical properties of freshwater bodies are characterized by climatic, geochemical, geomorphologic condition and pollution level, it is very important to study the physico-chemical factors influencing the biological productivity in water bodies (Sahni and Yadav, 2012), The quality of water affects the species composition, abundance, productivity and physiological condition especially, the indigenous population of aquatic organisms (Wetzel, 2001). Zooplankton communities are sensitive to anthropogenic impacts and their study may be useful in the prediction of long term change in the water bodies as these communities are highly sensitive to environment fluctuations (Ferrara *et al.* 2002; Kehayias *et al.* 2014). Change in zooplankton abundance, species diversity and community composition can indicate the change or disturbance of the environment; it has been reported by several studies that zooplankton can serve as indicator of change in trophic dynamics and the ecological state of water bodies related to change in nutrient load and climate (Kehayias *et al.* 2014). Zooplankton community structure (species density and species composition) is potentially affected by chemistry of water body, its morphology and changes due to anthropogenic activities (An *et al.* 2012; Dodson *et al.* 2000). A change in physicochemical parameters in aquatic ecosystem brings a corresponding change in relative composition and abundance of organism thriving in the water; therefore they can be used as a tool in monitoring aquatic ecosystems;

zooplankton have been considered as ecological important organism (Jose *et al.* 2015). The present paper highlights the basic structure and dynamics of zooplankton communities of river Yamuna in Delhi stretch, with emphasis on highlighting the interrelationships of water quality change with zooplankton communities.

MATERIALS AND METHODS

Study Area

The study was carried out at Delhi stretch of the Yamuna river. Yamuna in Delhi, is severely polluted due to discharge of sewage and effluent by more than 20 drains. Delhi stretch counts only 2% of the total length of the river however 80% of its pollution contributed by this stretch. Yamuna river enters in Delhi after crossing the Wazirabad barrage. It travels for 22 kilometres (13.7 miles) through the northwest, north, northeast, east and south Delhi regions. It finally leaves Delhi at the Okhla Barrage Delhi. The following locations were chosen for sampling in order to study the physicochemical properties of river water and for study of distribution of zooplanktons of Yamuna river. Water samples were collected in sterile containers and maintained in an icebox on the site. A total of 3 surface water samples were collected in triplicate from 3 sites representing different environmental conditions. Information of the sampling sites with their latitude and longitude are provided below:

Location 1: SW1 (Wazirabad) - Near Wazirabad bridge (28º 43′ 8.88″ N, 77º 14′ 27.36″ E) (Upstream and entry point of Yamuna river in Delhi).

Location 2: SW2 (ITO) -Near ITO (28º 37′ 39.18″ N, 77º 15′ 30.00″ E) (Mid-stream and located in middle of stretch of Yamuna river in Delhi).

Location 3: SW3 (Kalindi Kunj) - Near Okhla barrage From Kalindi Kunj (28º 32′ 9.84″ N, 77º 19′ 29.16″ E) (Downstream and exit point of Yamuna river from Delhi).

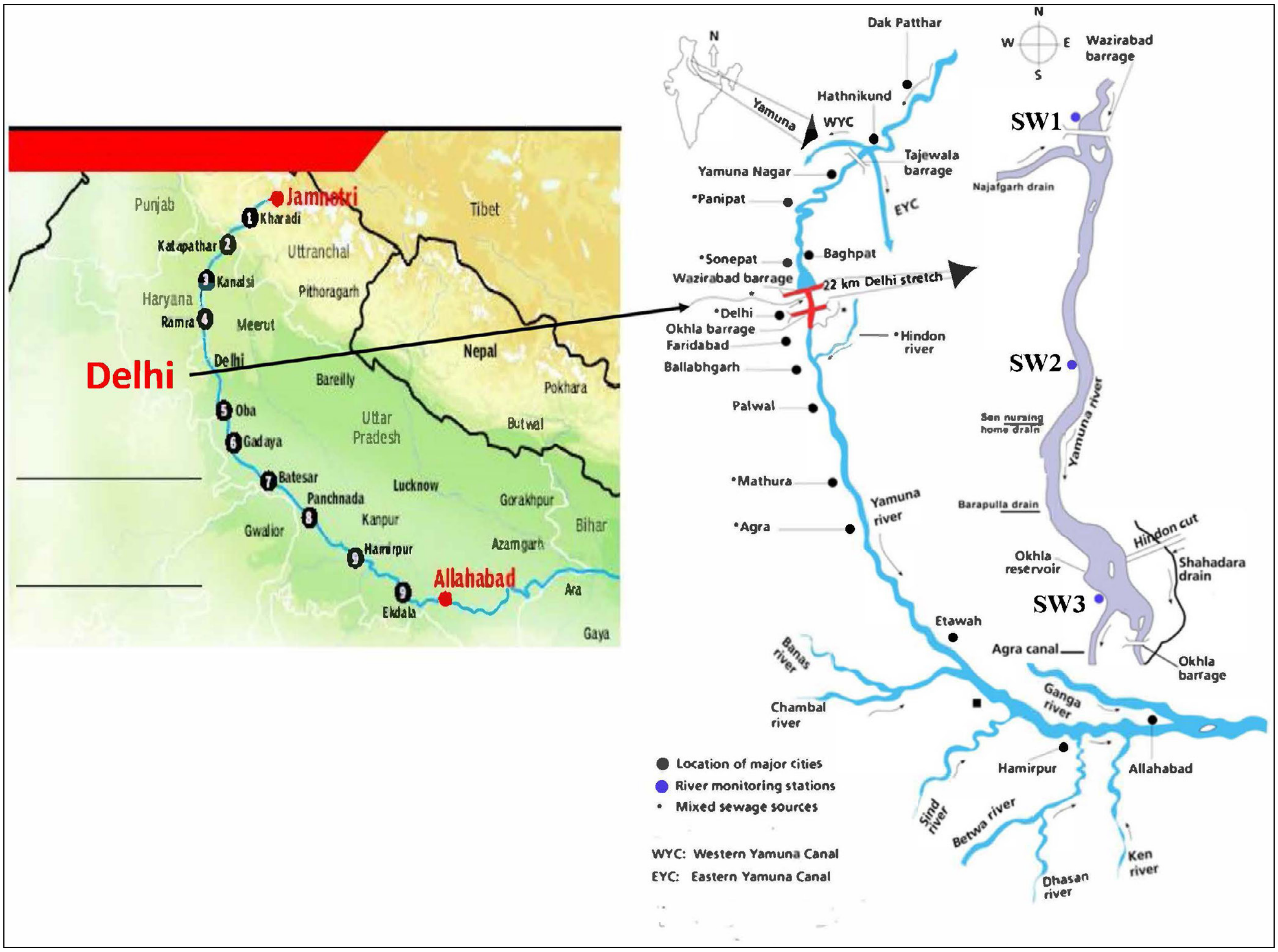

Fig. 1: Yamuna Stretch & Location of Sampling Sites

Water Sampling

Physico-Chemical parameters

For investigation, monthly water samples were collected in triplicate from three different i.e., SW1 (Wazirabad Barrage), SW2 (ITO) & SW3 (Kalindi Kunj) spanning from month of Feb 2024 to Jan 2025. The samples were collected on 15th day of every month in morning hours. Surface-grab samples (Martin *et al.* 1992; Nollet & De Gelder, 2014) were collected from all the three sites. Water samples were collected in plastic bottles of two litre capacity. In order to prevent contamination due to surface scum, debris and bottom deposits. Samples were collected not closer than 30 cm to surface or bottom of the river. After collection, samples were properly packed, stored in icebox and transported to laboratory on the same day to avoid any biochemical change. Separate BOD bottles were used for sample collection for DO and BOD analysis. Water samples were kept in dark at 4°C for analysis in laboratory. Water temperature and pH was measured by at sampling site. Other parameters like Electrical Conductivity (EC), Turbidity, Total Dissolved Solid (TDS), Total Hardness (TH), Total Alkalinity (TA), Chloride (Cl), Sulphate(SO_4), Phosphate (PO_4), Nitrate (NO_3), Dissolved Oxygen (D.O.), Biochemical Oxygen Demand (B.O.D.). And Chemical Oxygen Demand (C.O.D.), Free Carbon-di-Oxide (Free CO_2) were analysed in the laboratory according to the standard methods (APHA, 2005; & IS, 3025).

Zooplankton Sampling & Analysis

A horizontal quantitative sample was taken at each site. Zooplankton sampling from river obtained by filtering 50 L of water through a small standard plankton net (mesh size 55 micron) using a 10 L plastic container. The collected samples preserved directly with 4% neutral formalin solution in 250 mL polyethylene bottles. The volume of all samples concentrated to 100 mL, and the whole sample examined in a Petri dish under a research binocular microscope. For quantitative assessment of zooplankton 1 ml of sample is taken and placed on Sedgwick-Rafter counter and the number of individuals of every species was enumerated as the number of organisms per cubic meter. The organisms were identified and counted. The total number of zooplankton present in a cubic meter (m^3) of water sample was calculated according to the following equation:

$$N = n\,(v/V) - 1000 \qquad \ldots(1)$$

Where N = total number of zooplankton per cubic meter of filtered water; n = average number of zooplankton in 1 ml of zooplankton sample, v = volume of zooplankton concentrates (ml), V = volume of total water filtered (L). The identification of zooplanktons was carried out with help of taxonomic keys and standard literature by Michael (1986); Kodarkar (1992) and Dhanapathi (2000).

RESULTS AND DISCUSSION

The Result of water quality & Zooplankton are mentioned in the table 1 & table 2 respectively.

The physicochemical characteristics parameters of Yamuna river was measured in three different Seasons i.e., Summer (Pre-monsoon), Monsoon and Winter (Post-monsoon). The samples were collected on monthly basis from Feb 2024 to Jan 2025 to know the variations. The Temperature was recorded maximum during June (31.4°C), moderate during August (25.4 °C) and minimum during Jan (16.8 °C), The temperature is known to be affected by several factor such as air temperature, solar radiation, cloud cover, wind speed etc. (Pletterbauer *et al.* 2018). The water temperature showed an upward trend from winter to summer followed by downward trend from monsoon onwards. pH of the water varied in all the three seasons, in summer seasons it ranges from (7.85-.7.96) for location 1, (6.20-6.50) for location 2, and (7.78-7.92) for location 3, in monsoon seasons it ranges from (7.61-7.96) for location 1, (6.36-6.45) for location 2, and (7.50-7.56) for location 3 and in Winter seasons it ranges from (7.87-8.15) for location 1, (6.38-6.62) for location 2, and (7.81-8.06) for location 3. Showing that the water from SW1 and SW3 are alkaline in nature and SW2 is somewhat acidic because of mixing of effluent and sewage at this point. However pH of water body tend to be somewhat lower during summer season in comparison to winters. The lower pH during summer is because of increased temperature and biological activities, leading to increased production of dissolved carbon dioxide. Similar results was also reported by Simarjeet, Kaur and Indu Singh (2012)

Table 1: Physico-Chemical Characteristics of Yamuna River during Year Feb 2024-Jan 2025

Parameters	Sampling locations	Months											
		Summer (Pre monsoon)				Monsoon				Winter (Post monsoon)			
		FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN
Temp	SW1	20.6(±0.56)	23.2(±0.54)	26.1(±0.60)	29.8(±0.58)	31.2(±0.62)	27.6(±0.59)	25.2(±0.57)	26.4(±0.60)	25.1(±0.58)	22.2(±0.59)	19.4(±0.56)	16.8(±0.54)
	SW2	20.4(±0.55)	23.1(±0.51)	26.2(±0.55)	29.7(±0.61)	31.2(±0.59)	27.5(±0.57)	25.3(±0.63)	26.2(±0.59)	25.2(±0.62)	22.4(±0.60)	19.5(±0.58)	16.5(±0.61)
	SW3	20.8(±0.52)	23.3(±0.58)	26.4(±0.59)	29.6(±0.57)	31.4(±0.56)	27.4(±0.60)	25.4(±0.61)	26.6(±0.55)	25.4(±0.60)	22.3(±0.58)	19.3(±0.59)	16.6(±0.56)
pH	SW1	7.94(±0.21)	7.96(±0.22)	7.85(±0.21)	7.86(±0.19)	7.61(±0.22)	7.96(±0.19)	7.93(±0.22)	7.92(±0.22)	8.12(±0.21)	8.15(±0.24)	8.10(±0.24)	7.87(±0.23)
	SW2	6.20(±0.20)	6.31(±0.20)	6.50(±0.19)	6.33(±0.20)	6.40(±0.18)	6.45(±0.20)	6.36(±0.17)	6.45(±0.19)	6.38(±0.19)	6.48(±0.19)	6.50(±0.21)	6.62(±0.17)
	SW3	7.92(±0.21)	7.91(±0.22)	7.80(±0.23)	7.78(±0.20)	7.55(±0.18)	7.51(±0.19)	7.56(±0.21)	7.50(±0.21)	8.06(±0.24)	7.92(±0.23)	7.90(±0.23)	7.81(±0.23)
EC	SW1	986(±19.7)	1030(±20.6)	1070(±21.4)	1112(±22.2)	978(±18.5)	896(±16.1)	926(±17.5)	945(±17.0)	986(±17.2)	974(±17.5)	948(±17.0)	965(±16.4)
	SW2	1402(±32.2)	1474(±34.0)	1462(±33.4)	1508(±34.6)	1463(±32.1)	1430(±31.4)	1450(±30.6)	1492(±31.4)	1510(±26.4)	1385(±29.8)	1348(±28.1)	1374(±31.4)
	SW3	1148(±24.1)	1198(±23.9)	1240(±24.6)	1280(±26.6)	1178(±23.5)	1120(±22.0)	1140(±23.8)	1156(±24.2)	1176(±23.5)	1136(±23.6)	1124(±22.2)	1126(±21.2)
Turbidity	SW1	8.5(±0.12)	7.2(±0.08)	8.2(±0.10)	9.0(±0.14)	8.1(±0.09)	6.2(±0.08)	9.1(±0.15)	5.5(±0.07)	8.0(±0.08)	8.4(±0.16)	9.0(±0.13)	7.2(±0.10)
	SW2	10.6(±0.16)	10.2(±0.14)	12.0(±0.20)	12.0(±0.21)	9.6(±0.15)	9.0(±0.13)	11.5(±0.19)	10.6(±0.15)	12.0(±0.23)	10.2(±0.15)	11.2(±0.18)	9.4(±0.16)
	SW3	9.2(±0.13)	8.5(±0.11)	11.5(±0.18)	10.2(±0.15)	9.4(±0.14)	8.0(±0.10)	9.6(±0.17)	9.5(±0.12)	10.5(±0.13)	9.3(±0.14)	10.6(±0.16)	8.7(±0.09)
TDS	SW1	630(±18.2)	654(±19.4)	682(±20.4)	710(±19.0)	620(±16.2)	570(±16.4)	588(±17.6)	602(±18.0)	624(±16.5)	620(±15.2)	602(±18.6)	612(±17.4)
	SW2	894(±24.4)	940(±25.1)	932(±24.2)	960(±24.4)	932(±22.0)	910(±26.2)	924(±20.2)	950(±24.1)	962(±27.2)	882(±25.1)	860(±24.2)	876(±24.0)
	SW3	732(±21.1)	762(±22.0)	790(±23.0)	816(±23.4)	750(±12.2)	712(±20.6)	724(±21.4)	736(±22.4)	750(±21.4)	724(±20.6)	714(±20.4)	718(±20.4)
TSS	SW1	56.0(±2.1)	64.0(±2.2)	66.0(±2.0)	68.0(±1.9)	64.0(±1.8)	60.0(±1.7)	58.0(±1.9)	63.0(±1.6)	66.0(±1.8)	56.0(±2.2)	68.0(±1.6)	64.0(±2.0)
	SW2	94.0(±2.8)	102.0(±2.1)	106.0(±2.3)	98.0(±2.5)	102.0(±2.4)	100.0(±2.3)	108.0(±2.6)	94.0(±1.7)	98.0(±2.5)	104.0(±2.4)	96.0(±2.3)	92.0(±2.1)
	SW3	70.0(±2.5)	86.0(±1.8)	78.0(±1.9)	82.0(±2.3)	88.0(±2.2)	76.0(±1.8)	70.0(±2.4)	78.0(±1.9)	71.0(±2.3)	89.0(±2.1)	84.0(±2.2)	78.0(±2.3)
Hardness	SW1	216.0(±6.0)	209.0(±4.5)	223.2(±5.1)	210.0(±5.5)	202.0(±6.0)	205.2(±5.8)	212.4(±7.2)	219.6(±8.0)	194.4(±5.6)	191.0(±5.0)	191.0(±4.6)	198.0(±5.3)
	SW2	324.0(±9.0)	317.0(±8.6)	324.0(±8.5)	310.0(±6.4)	309.6(±9.5)	317.0(±10.2)	327.6(±10.0)	331.2(±10.5)	313.2(±7.6)	306.0(±6.4)	310.0(±7.0)	320.4(±8.4)
	SW3	238.0(±7.0)	226.0(±4.2)	234.0(±6.4)	232.0(±6.0)	223.2(±6.6)	227.0(±6.4)	237.6(±7.2)	241.2(±8.2)	216.0(±6.2)	209.0(±5.6)	219.0(±6.2)	227.0(±6.5)

Total Alkalinity	SW1	210.0(±10.5)	216.0(±10.4)	216.0(±9.0)	220.0(±9.2)	188.0(±9.0)	180.0(±8.2)	202.0(±7.4)	206.0(±8.6)	204.0(±7.3)	205.0(±8.3)	210.0(±8.3)	214.0(±9.5)
	SW2	294.0(±13.2)	302.0(±14.6)	306.0(±13.0)	310.0(±13.4)	306.0(±15.2)	276.0(±11.5)	290.0(±12.4)	300.0(±12.6)	310.0(±11.4)	306.0(±9.4)	304.0(±9.3)	308.0(±10.4)
	SW3	218.0(±10.2)	228.0(±11.4)	234.0(±10.2)	237.0(±9.4)	230.0(±10.2)	202.0(±8.0)	210.0(±8.6)	228.0(±9.4)	220.0(±9.0)	228.0(±8.6)	226.0(±8.0)	229.0(±8.3)
DO	SW1	2.8(±0.11)	2.2(±0.11)	1.8(±0.13)	2.1(±0.12)	2.7(±0.10)	2.5(±0.15)	2.8(±0.14)	2.2(±0.12)	2.3(±0.14)	2.5(±0.10)	2.5(±0.189)	2.9(±0.16)
(mg/l)	SW2	1.5(±0.12)	1.3(±0.16)	0.8(±0.08)	1.1(±0.10)	1.8(±0.11)	1.6(±0.10)	1.7(±0.11)	1.5(±0.13)	1.3(±0.15)	1.4(±0.17)	1.6(±0.12)	1.5(±0.15)
	SW3	2.5(±0.10)	2.0(±0.12)	1.6(±0.14)	1.8(±0.15)	2.4(±0.13)	2.2(±0.14)	2.5(±0.14)	2.3(±0.10)	1.9(±0.10)	2.0(±0.13)	2.2(±0.13)	2.9(±0.18)
BOD	SW1	12.0(±0.24)	14.0(±0.30)	15.0(±0.34)	16.0(±0.38)	12.0(±0.25)	16.0(±0.21)	8.0(±0.18)	6.0(±0.11)	12.0(±0.22)	10.0(±0.17)	12.0(±0.15)	14.0(±0.17)
	SW2	28.0(±0.61)	32.0(±0.64)	40.0(±0.71)	46.0(±0.84)	26.0(±0.54)	30.0(±0.61)	30.0(±0.60)	24.0(±0.54)	26.0(±0.52)	30.0(±0.47)	40.0(±0.77)	36.0(±0.53)
	SW3	16.0(±0.36)	18.0(±0.41)	19.0(±0.45)	22.0(±0.52)	16.0(±0.37)	18.0(±0.42)	11.0(±0.21)	8.0(±0.20)	18.0(±0.41)	16.0(±0.36)	14.0(±0.22)	17.0(±0.23)
COD	SW1	84.0(±4.0)	90.0(±4.4)	94.0(±4.6)	102.0(±5.3)	40.0(±2.54)	44.0(±2.62)	30.0(±2.4)	28.0(±2.2)	80.0(±4.42)	62.0(±3.61)	70.0(±3.6)	80.0(±4.61)
	SW2	220.0(±8.2)	230.0(±8.8)	242.0(±9.4)	250.0(±10.0)	182.0(±8.4)	190.0(±9.12)	174.0(±8.26)	160.0(±8.0)	224.0(±10.0)	194.0(±9.6)	216.0(±8.2)	202.0(±7.66)
	SW3	96.0(±4.6)	112.0(±5.16)	120.0(±5.5)	130.0(±6.2)	50.0(±2.6)	62.0(±3.6)	60.0(±3.22)	52.0(±2.77)	110.0(±5.21)	80.0(±4.3)	90.0(±4.6)	110.0(±5.02)
Phosphate	SW1	0.12(±0.01)	0.15(±0.01)	0.17(±0.02)	0.21(±0.02)	0.10(±0.01)	0.13(±0.02)	0.15(±0.01)	0.19(±0.02)	0.06(±0.01)	0.08(±0.01)	0.12(±0.01)	0.15(±0.01)
	SW2	0.28(±0.02)	0.35(±0.03)	0.42(±0.03)	0.50(±0.04)	0.26(±0.02)	0.31(±0.04)	0.36(±0.02)	0.41(±0.04)	0.17(±0.03)	0.22(±0.02)	0.25(±0.02)	0.36(±0.03)
	SW3	0.22(±0.02)	0.26(±0.02)	0.30(±0.02)	0.36(±0.03)	0.15(±0.01)	0.22(±0.02)	0.27(±0.02)	0.32(±0.03)	0.11(±0.02)	0.14(±0.01)	0.18(±0.02)	0.24(±0.03)
Nitrate	SW1	0.11(±0.02)	0.12(±0.01)	0.14(±0.01)	0.16(±0.01)	0.25(±0.02)	0.29(±0.02)	0.24(±0.02)	0.28(±0.02)	0.16(±0.01)	0.18(±0.01)	0.14(±0.02)	0.15(±0.01)
	SW2	0.34(±0.03)	0.36(±0.02)	0.42(±0.04)	0.46(±0.04)	0.55(±0.05)	0.66(±0.05)	0.54(±0.04)	0.62(±0.05)	0.36(±0.01)	0.42(±0.03)	0.36(±0.03)	0.40(±0.03)
	SW3	0.14(±0.03)	0.15(±0.03)	0.16(±0.01)	0.22(±0.02)	0.42(±0.02)	0.34(±0.03)	0.30(±0.03)	0.40(±0.04)	0.21(±0.02)	0.26(±0.02)	0.18(±0.02)	0.20(±0.02)
Chloride	SW1	82.0(±1.64)	90.6(±1.80)	96.2(±1.84)	102.0(±2.12)	70.0(±1.26)	76.0(±1.40)	68.2(±1.22)	64.0(±1.30)	70.2(±1.42)	74.0(±1.42)	80.0(±1.54)	82.0(±1.64)
	SW2	216.0(±4.26)	222.0(±4.40)	228.0(±4.28)	236.0(±4.54)	202.0(±4.02)	210.0(±4.11)	205.0(±4.10)	196.0(±3.62)	218.0(±4.19)	206.0(±4.15)	210.0(±4.25)	214.0(±4.33)
	SW3	94.0(±1.84)	102.0(±2.11)	110.0(±1.96)	114.0(±2.02)	72.0(±1.35)	80.0(±1.62)	76.0(±1.66)	82.0(±1.28)	86.0(±1.68)	90.0(±1.52)	96.0(±1.61)	86.0(±1.60)
Bicarbon-ate	SW1	210.0(±10.5)	216.0(±10.4)	216.0(±9.0)	220.0(±9.2)	188.0(±9.0)	180.0(±8.2)	202.0(±7.4)	206.0(±8.6)	204.0(±7.3)	205.0(±8.3)	210.0(±8.3)	214.0(±9.5)
	SW2	294.0(±13.2)	302.0(±14.6)	306.0(±13.0)	310.0(±13.4)	306.0(±15.2)	276.0(±11.5)	290.0(±12.4)	300.0(±12.6)	310.0(±11.4)	306.0(±9.4)	304.0(±9.3)	308.0(±10.4)
	SW3	218.0(±10.2)	228.0(±11.4)	234.0(±10.2)	237.0(±9.4)	230.0(±10.2)	202.0(±8.0)	210.0(±8.6)	228.0(±9.4)	220.0(±9.0)	228.0(±8.6)	226.0(±8.0)	229.0(±8.3)
Free CO2	SW1	5.18(±0.36)	5.84(±0.42)	5.96(±0.45)	5.90(±0.42)	5.10(±0.40)	5.72(±0.40)	5.80(±0.46)	5.85(±0.53)	3.65(±0.28)	3.50(±0.31)	3.22(±0.32)	3.36(±0.36)
	SW2	6.53(±0.46)	6.76(±0.51)	6.82(±0.56)	6.90(±0.60)	6.58(±0.56)	6.70(±0.54)	6.80(±0.72)	6.93(±0.85)	4.02(±0.28)	4.26(±0.31)	4.65(±0.33)	4.74(±0.41)
	SW3	5.41(±0.38)	6.01(±0.42)	6.11(±0.52)	6.02(±0.44)	5.36(±0.35)	5.84(±0.41)	6.12(±0.60)	6.01(±0.45)	3.80(±0.34)	3.77(±0.35)	3.46(±0.31)	3.54(±0.35)

for Yamuna River. The EC was recorded maximum during summer period ranging from (986-1112 μs/cm) for location 1, (1402-1508 μs/cm) for location 2 and (1148-1280 μs/cm) for location 3, and minimum during monsoon period ranging from (896-978 μs/cm) for location 1, (1430-1492 μs/cm) for location 2 and (1120-1178 μs/cm) for location 3. The findings are similar to finding of Devika *et al.* (2006) and Mishra *et al.* (2007). High EC during summer may be due to more solubility of ions at higher temperature & higher evaporation rate from surface water body. While the lower EC during monsoon season is due to high surface runoff and dilution of dissolved ion. Similar trend was also recorded for TDS values as it is also recorded maximum during summer season ranging from (630-710 mg/l) for location 1, (894-960 mg/l) for location 2 and (732-816 mg/l) for location 3, and minimum during Winter ranging from (602-624 mg/l) for location 1, (860-962 mg/l) for location 2 and (714-750 mg/l) for location 3. Total Suspended Solid is considered as significant factor in observing water clarity, they are typically larger than 2.0 microns (μm) and can be retained by a standard glass-fiber filter. TSS can include a wide range of materials, such as silt, sand, sediment, decaying organic matter, and even algae and bacteria (Bukaveckas P.A. 2010 & Li, D, Liu, S. 2019). TSS values range from (56-68 mg/l) for location 1, (94-106 mg/l)for location 2, (70-86 mg/l) for location 3 in summer season, For Location 1 from (58-64 mg/l), Location 2 (94-108 mg/l), Location 3 (70-88mg/l), in monsoon season and For Location 1 from (56-68 mg/l), Location 2 (92-104 mg/l), Location 3 (71-89 mg/l), in winter season. The total hardness of water is mainly due to presence of various salts of Calcium and magnesium. Hardness values is recorded maximum during summer ranging from (209-223 mg/l) for location 1, (310-324 mg/l) for location 2 and (226-238 mg/l) for location 3, and minimum during winter period ranging from (191-198 mg/l) for location 1, (306-320.4 mg/l) for location 2 and (209-227 mg/l) for location 3. The high value of hardness in summer season is due to the temperature which increases with the concentrations of salts by more evaporation may increase the hardness of water in this season Dey, S. *et al.* (2021). Alkalinity is the capacity of water to neutralize the strong acid. The total alkalinity was found to minimum during Monsoon period and ranges from (180-206 mg/l) for location 1, (276-306 mg/l) for location 2 and (202-230 mg/l) for location 3.while during summer it is recorded Maximum and ranges from (210-220 mg/l) for location 1, (294-310 mg/l) for location 2 and (218-237 mg/l) for location 3. This is due to high temperature there is more decomposition of organic matter and high microbial activity. Dissolved oxygen is one of the most important parameter governing the aquatic life it is important for survival of organism in water in the Present study Maximum Value of DO for all the station has been recorded during winter season (2.3-2.9 mg/l) for location 1, (1.3-1.6 mg/l) for location 2 and (1.9-2.9 mg/l) for location 3 and minimum Value of DO were observed during summer (1.8-2.8 mg/l) for location 1, (0.8-1.5 mg/l) for location 2 and (1.6-2.5 mg/l) for location 3. The low value of DO during summer is due to less oxygen holding capacity of water at higher temperature and increased DO assimilation by microorganism. The Lower DO value of the river is also due to discharge of untreated sewage (Khaiwal *et al.* 2003). As Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) are inversely related to each other so the maximum Value of BOD was recorded during Summer ranging from (12-16 mg/l) for location 1, (28-46 mg/l) for location 2 and (16-22 mg/l) for location 3. And minimum Value of BOD were observed during winter (10-14 mg/l) for location 1, (26-40 mg/l) for location 2 and (14-18 mg/l) for location 3. The High BOD and DO values was recorded at all the three station is due to various domestic as well as industrial unit which directly release their untreated or partially treated sewage directly into river (Rawat *et al.* 2010; Mishra and Malik, 2013). The COD is widely used as a measure of the susceptibility to oxidation of organic and inorganic materials present in water bodies, it is also one of the detrimental factors for the amount of oxygen dissolved in the water body. The maximum COD was recorded during summer ranging from for location 1, (84-102 mg/l) for location 2 and (220-250 mg/l) for location 3 (96-130 mg/l) and minimum Value of COD were observed during winter (62-80 mg/l) for location 1, (194-224 mg/l) for location 2 and (80-110 mg/l) for location 3. The higher value of COD is due to water pollution caused by high organic and significant chemical load of Fertilizers, Pesticides etc carried out by drain from industrial and domestic sewage. Bicarbonate and Chloride also shows higher trends during summer followed by winter and Monsoon at all three location. As

Table 2: Monthly and seasonal variation in density (No./Litre) of zooplankton (Group Wise) Yamuna river during Feb 2024 to Jan 2025

zooplanktonic Group	SW1 (Upstream Near Wazirabad Bridge)												Total
	Summer (Pre-monsoon)				Monsoon				Winter (Post-monsoon)				
	FEB	MAR	APR	MAY	JUNE	JUL	AUG	SEPT	OCT	NOV	DEC	JAN	
Rotifers	18	13	16	21	12	7	8	9	12	10	13	15	154
CLADOCERA	9	11	5	7	6	8	5	4	9	5	6	7	82
COPEPODS	10	9	3	8	5	0	4	3	8	6	4	6	66
OSTRACODA	7	9	6	4	2	3	0	6	7	4	4	3	55
TOTAL	44	42	30	40	25	18	17	22	36	25	27	31	357
Seasonal Variation	156				82				119				357
zooplanktonic Group	**SW2 (Near ITO)**												**Total**
	Summer (Pre-monsoon)				**Monsoon**				**Winter (Post-monsoon)**				
	FEB	**MAR**	**APR**	**MAY**	**JUNE**	**JUL**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**	**JAN**	
Rotifers	10	7	8	10	5	2	2	4	6	7	2	9	72
Cladocera	7	3	4	2	2	1	1	2	4	5	3	3	37
Copepods	3	3	3	2	3	0	0	1	3	2	1	1	22
Ostracoda	4	2	2	1	1	2	1	3	1	2	3	2	24
Total	24	15	17	15	11	5	4	10	14	16	9	15	155
Seasonal Variation	71				30				54				155
Zooplanktonic Group	**SW3 (Near Kalindi Kunj)**												**Total**
	Summer (Pre-monsoon)				**Monsoon**				**Winter (Post-monsoon)**				
	FEB	**MAR**	**APR**	**MAY**	**JUNE**	**JUL**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**	**JAN**	
Rotifers	15	12	14	20	9	4	5	6	8	12	14	17	136
Cladocera	9	8	8	12	7	2	4	3	7	6	5	5	76
Copepods	9	7	5	6	6	1	2	4	5	4	1	3	53
Ostracoda	7	4	3	2	6	1	0	2	2	3	5	3	38
Total	40	31	30	40	28	8	14	15	22	25	25	25	303
Seasonal Variation	141				65				97				303

far as phosphate and nitrate are concerned the maximum value of both parameters are recorded during monsoon seasons at all the three stations and minimum was recorded during winter seasons High values of phosphate and nitrate in monsoon season is due to excessive entry of runoff water from agriculture fields, decayed vegetables,domestic sewage, industrial discharge and leachable from refuse dumps. Excess presence of nitrate and phosphate in water is major cause of eutrophication and depletion of oxygen in water bodies. All the physicochemical parameters are found to be higher at all the three stations indicating the increasing level of pollution in Yamuna River which is directly linked with the growth of zooplanktons.

Zooplankton diversity

Zooplanktonconstitute necessary part of aquatic biological community they are the major link in the energy transfer at secondary level in aquatic food webs between autotroph and heterotroph (Deivanai *et al.* 2004).Zooplanktons communities responds to wide variety of disturbance including nutrient loading, acidification and pollution loading. Zooplankton diversity and their abundance are directly affected by seasonal variation as well as physicochemical factors of the environment (Poongodi *et al.* 2009 & Saba and Sadhu, 2015). Identification and counting of different zooplankton species had been done regularly during study

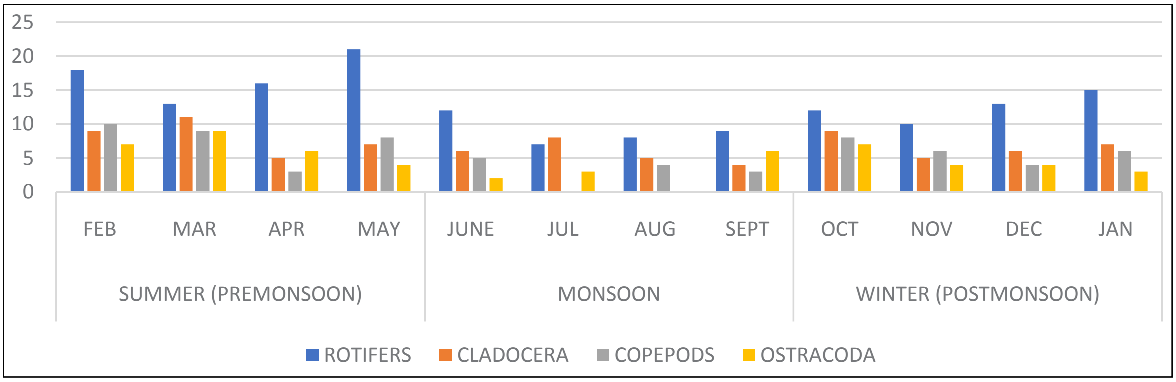

Fig. 1: Monthly Varition in Zooplankton Population during Feb 2024 to Jan 2025 at Monitoring Location (SW1)

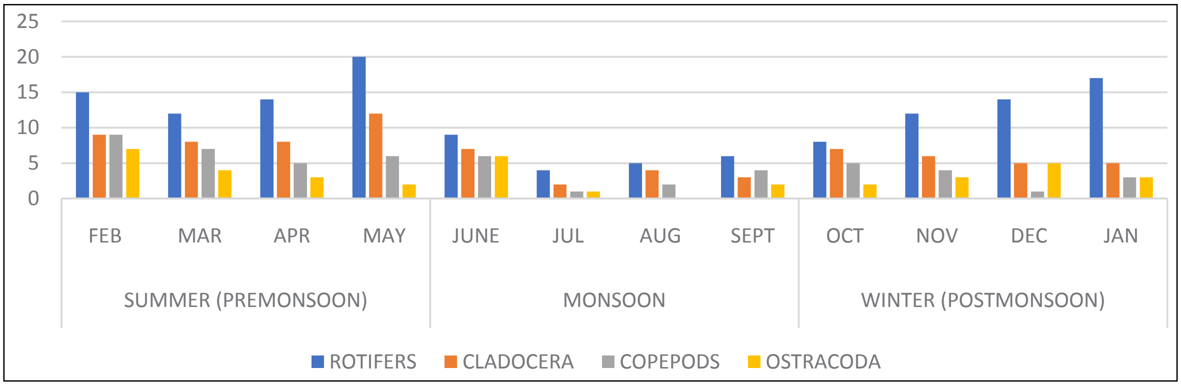

Fig. 2: Monthly Varition in Zooplankton Population during Feb 2024 to Jan 2025 at Monitoring Location (SW2)

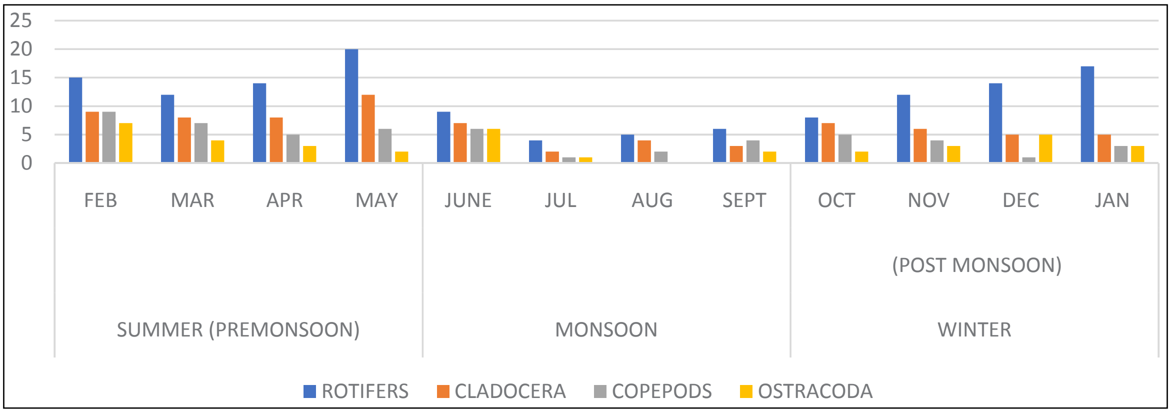

Fig. 3: Monthly Varition in Zooplankton Population during Feb 2024 to Jan 2025 at Monitoring Location (SW3)

period. In present study a total four groups of zooplankton were recorded which belongs to, Rotifera, Cladocera, Copepoda & Ostracoda. As far as the seasonal variations are concerned, the abundance of zooplankton population were recorded to be highest during summer season followed by winter and lowest in monsoon season at all the three stations Table 2 and Fig. 1,2,3. Similar results were reported by (Mehra and Arya, 2022 and Watker, 2013). It is pertinent to mention here that Yamuna river at its Delhi stretch has the worst water quality with Low Do, High BOD and COD due to several drains from different industries Due to Serval drain from different industries and sewage of Delhi as well as neighbouring state. At this Segment water quality is very poor at all the three sampling locations. However, among all the three sampling stations the population of zooplanktons were found to be lowest at SW2 in comparison to SW2 and SW3. The site ordinations based on water quality parameters and species richness and density indicate close relationship between zooplankton

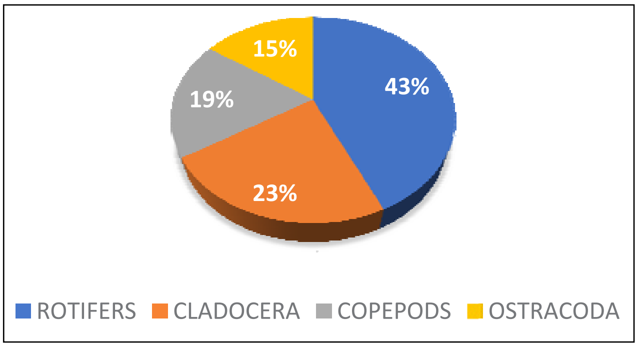

Fig. 4: Density Variation of Zooplankton at Monitoring Location SW1

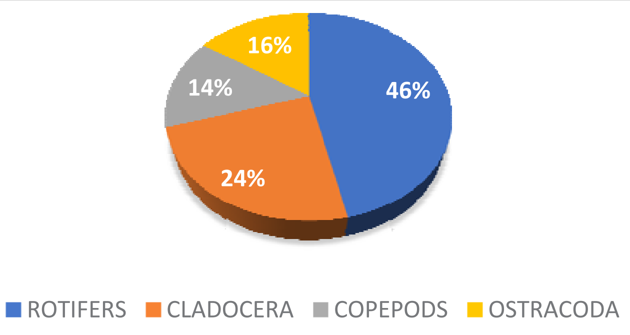

Fig. 5: Density Variation of Zooplankton at Monitoring Location SW2

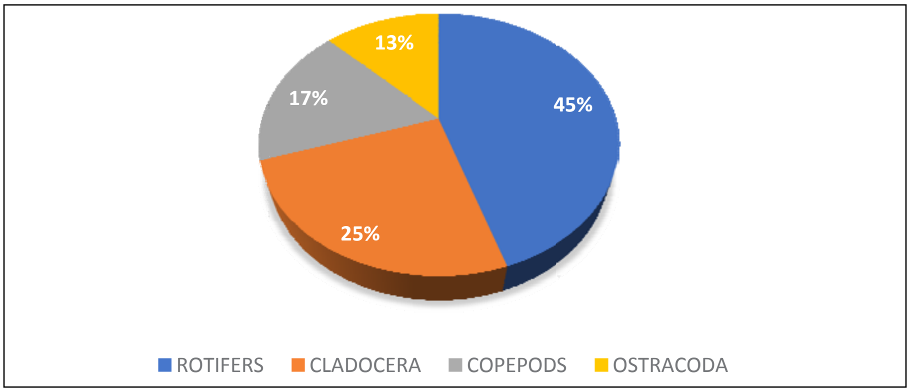

Fig. 6: Density Variation of Zooplankton at Monitoring Location SW3

communities and water quality. Comparatively larger assemblages of zooplankton found in the location SW1 and SW3 correspond to relatively better water quality conditions existing at these location. Lower number of co-existing species observed at SW2 are due to stress conditions created by heavy pollution load, this is due to the fact that this part of the river is situated in the centre of Delhi and receive large amount sewage and industrial waste throughout the whole city. During study period among all the four groups rotifers were found to be dominant followed by Cladocera, Copepoda and Ostracoda Fig. 4,5,6. This is because High temperature and nutrient concentration seems to be favouring growth of rotifers (Moitra and Mukherjee, 1972; Jyoti and Sehgal, 1979). The possible reason behind the abundance in summer may be due to favourable environmental conditions, maximum temperature during summer stimulates the rate of decomposition of organic matter, availability of more nutrient due to decomposition of organic matter, less predation pressure increase in nutrient load (nitrate and phosphate) which cause an increase in phytoplankton productivity and prolific growth of macrophytes during summer which may serve as a better refuge for zooplankton. The characteristic fall in zooplankton population during rainy season i.e. monsoon and winter could be attributed to dilution factors which destabilize the ecosystem, thereby affecting the habitat of zooplankton fauna, regular flush out of water during rains. Increased flow of water during rains reduces the detritus, which may disturb the feeding habitat of zooplankton high turbidity interferes with the photosynthesis of phytoplankton thus inhibiting their multiplication and ultimately reducing the zooplankton population due to food scarcity. Negative correlation has been observed between zooplankton population with BOD, hardness, turbidity etc and positive correlation with, DO, CO_2, and conductivity. Similar results were also reported by Priyanka Malhotra, (2014).

CONCLUSION

It is concluded from above discussion that physicochemical properties of Yamuna water varied depending on the season. The diversity and distribution of the zooplankton also Changes according to the variation in physicochemical parameters. Total four group of zooplanktons are reportedi, e-Rotifera, Cladocera, Copepoda & Ostracoda, the overall population of Zooplanktons are found to be maximum during Summer (Pre-monsoon Season) and minimum during monsoon season at all the three sampling locations. The Rotifers are found to be dominant at all locations followed by Cladocera, Copepods and Ostracods. Among the three locations sampled the water quality is found to be worst with low DO, pH, high BOD and COD at SW2 (Near ITO) in comparison to SW1 (Near Wazirabad) and SW2 (Near Kalindi Kunj). The SW2 (Near ITO) is found to be the most polluted one because it is situated in the mid of the city and receive huge amount of sewage and untreated industrial effluent from the whole city. The population of the zooplankton is found maximum at SW1 because it is entry point of river Yamuna into Delhi and is upstream of the main pollution sources in Delhi, dilution of river water by freshwater release from the Wazirabad barrage, and a minimal discharge of industrial effluents compared to the downstream areas like ITO Bridge while minimum at station SW2 or near ITO. The SW3 (Kalindi Kunj) is located downstream of the major pollution sources in Delhi, like industrial and sewage drains and is benefited from river flows carrying pollutants.

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