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Research Article

Plankton Composition in Relation to Physio-Chemical Parameters of Yamuna River at Three Different Cities of India

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Abstract

To evaluate plankton diversity in relation to physico-chemical parameters of the Yamuna river, the present study was conducted from March 2019 to February 2020. Three sites along the Yamuna River were chosen for regular sampling: Delhi (B_1), Mathura (B_2) and Agra (B_3). 11 species of phytoplankton and 9 species of zooplankton were recorded from site B_1 with a concentration of 15,517 individual L^{-1}. At site B_2 14 species of phytoplankton and 5 species of zooplankton with a concentration of 15,329 individual L^{-1} was observed. At site B_3 a total 15 species of phytoplankton and 5 species of zooplankton were recorded with a concentration of 19,453 individual L^{-1}. The highest abundance of group Cynophyceae in phytoplankton and Rotifera in zooplankton was observed during the study period at sites B_1, B_2 and B_3. Physico-chemical parameters were found suitable for plankton growth at site B_3.

Keywords: Delhi, Phytoplankton, River, Yamuna, Zooplankton

Introduction

Our natural heritage, like rivers, seas, and oceans, has been exploited, mistreated, and contaminated. Water is one of the basic needs of mankind and is a vital resource used for various activities. The Yamuna, sometimes called Jamuna or Jumna, is the largest tributary river of the Ganges (Ganga) in Northern India. It is perennial in nature as it receives all the three types of water inputs, *i.e.*, snowmelt runoff, rainfall runoff and groundwater (Mane *et al.,* 2005). Rivers are the most important freshwater resource for man. Social, economic and political developments have been largely related to the availability and distribution of freshwater contained in riverine systems. Water quality parameters provide current information about the concentration of various solutes at a given place and time (Khanna and Singh, 2000). Phytoplankton is the primary producer and plays an important role in the material circulation and energy flow in the aquatic ecosystem. Its presence often controls the growth, reproduction capacity and population characteristics of other aquatic organisms (Ariyadej *et al.,* 2008). The presence of plankton in the body of water directly affects the productivity of any aquatic system. Estimation of the plankton composition and diversity has often been used to evaluate the overall health of a river ecosystem. The physio-chemical parameters also affect plankton distribution, sequential occurrence and species diversity. Due to irrational fishing practices and environmental aberrations like reduction in water volume, increased sedimentation, water abstraction and pollution over the years, this diversity is on the decline and a few species have been lost from the freshwater ecosystem of India and some are listed under the endemic, endangered and threatened categories. According to research on fish and plankton assemblages, abiotic factors like temperature, current speed, and substrate can affect both the distribution and abundance of particular species as well as community-level traits like species richness, production, and guild composition (Gorman and Karr, 1978; Matthews, 1985).

Article History

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Materials and Methods

Sampling Location

The study was conducted from March 2019 to February 2020 for a period of one year. The flexibility within the river stretch, taking into account differences in the hydrological regimes, pollutants, and biodiversity features, served as the foundation for the selection of sampling locations. The Yamuna River was chosen for one site in Union territory Delhi (Yamuna Bridge) and two sites in Uttar Pradesh districts, Mathura (near Reti Ghat) and Agra (near Mokshdham).

Sample Collection and Analysis

Monthly samples were taken for the examination of phytoplankton and zooplankton by filtering 100 litres of water through a plankton net made of bolting silk number 25. The samples were then stored in a formol-alcohol solution, which is composed of an equal mixture of 5% formalin and 70% alcohol. Phytoplankton and zooplankton were identified using 10x and 40x objective lenses of a compound microscope (Labomed). Standard reference books (Edmondson, 1959; Needham and Needham, 1962; Pennak, 1978; Tonapi, 1980) were consulted for the identification of zooplankton.

The dissolved oxygen content of the water was determined by Winkler's titrimetric method (APHA, 2012). Free carbon dioxide was estimated by the standard titrimetric method using phenolphthalein as an indicator (APHA, 2012). A standard mercury thermometer (Borosil) with a range of 0 to 50 °C marked at the interval of 0.5 °C was used to measure the water temperature. pH and electrical conductivity were measured by using a portable 'HANNA' digital meter.

Results and Discussion

Physio-Chemical Parameters

At station B_1, the least amount of dissolved oxygen was recorded in the month of June, at a value of 2.1 and the highest amount was recorded in the month of January, at a value of 6.5. At site B_1, a mean value of 4.53 with an SD of 1.58 was recorded. The smallest value at station B_2 was 3.4 in April, while the highest value was 7.4 in January. At station B_2, a mean value of 5.4 with an SD of 1.38 was recorded. The smallest value at station B_3 was 3.8 in April, while the highest value was 7.3 in January. At station B_3, a mean value of 5.62 and an SD of 1.26 were recorded. Figure 1 shows the monthly fluctuations in dissolved oxygen. The dissolved oxygen in the river was at its maximum during the winter seasons and at its minimum during the pre-monsoon or summer seasons. The increased concentration in winter might be due to the increased rate of photosynthesis activity and the decrease in water temperature and minimum might be due to the high metabolic rate of organisms in the water body. Similarly, (Khanna and Bhutiani, 2003) noted a tendency in the Ganga near Haridwar. Dissolved oxygen is crucial and frequently acts as a critical missing component in the regulation of aquatic life. In the Kosi River, Almora, (Babita and Rao, 2015) found maximum dissolved oxygen readings of 10.5 mg l^{-1} in the month of January and a minimum of 8 mg l^{-1} in August during his investigation.

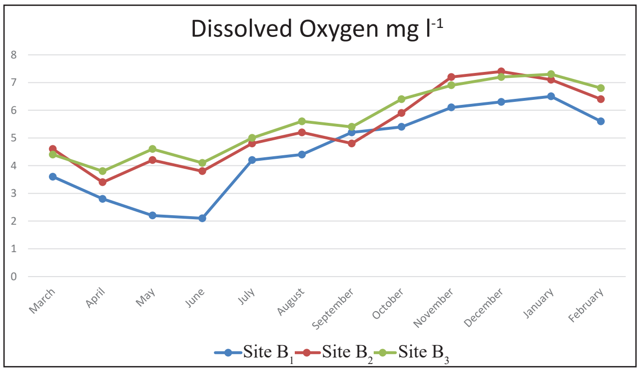

Figure 1: Monthly variation in dissolved oxygen (mg l^{-1}) at different sites of Yamuna River

At station B_1, the free CO_2 (mg l^{-1}) value ranged from 4.8 in the month of February to 15.3 in the month of June. At site B_1, a mean value of 9.58 with an SD of 3.35 was recorded. The smallest value at station B_2 was 5.5 in December, while the highest value was 12.1 in June. At station B_2, an average of 8.32 with a standard deviation of 2.03 was recorded. The smallest value at station B_3 was 4.8 in January, while the highest value was 11.2 in June. At station B_3, an average of 7.95 with a standard deviation of 2.08 was recorded. Figure 2 displays the monthly fluctuations in free CO_2. Pramod *et al.* (2014) reported a comparable free CO_2 result from the Kali River in Pithoragarh, Uttarakhand. According to (Badola and Singh, 1981), the Alaknanda River had its highest levels of free CO_2 during the rainy season as a result of a small phytoplankton population using it and a lack of sunlight. Dutta *et al.,* (2001) noted that the free carbon dioxide fluctuated from 1.69 to 3.62 ml^{-1} in the Jammu River Basanter.

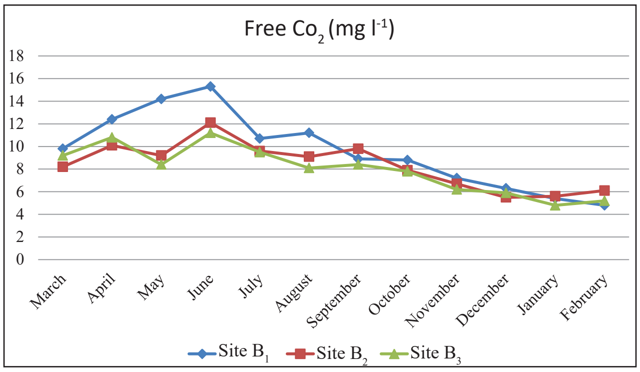

Figure 2: Monthly variation in free carbon-dioxide (mg l^{-1}) at different sites of Yamuna River

At station B_1, the minimum value of water temperature (°C) was 18.8 in the month of January and a maximum of 32 in the month of June. At site B_1, a mean value of 24.67 with an SD of 4.10 was recorded. At station B_2, the minimum value in January was 20.3 and the maximum value in July was 32.6. At station B_2, a mean value of 26.67 with an SD of 4.13 was recorded. The minimum value at station B_3 was 21.8 in January, while the highest value was 32.8 in May. At station B_3, a mean value of 28.01 with an SD of 3.40 was recorded. Figure 3 displays monthly fluctuations in water temperature (°C). It was found that the fluctuations in the river water

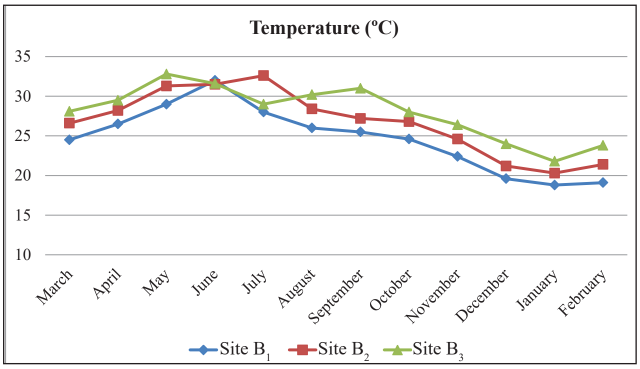

Figure 3: Monthly variation in Temperature (°C) at different sites of Yamuna River

temperature usually depend on the season, sampling time, as well as the temperature of the effluents pouring into the river from various anthropogenic sources (Koshy and Nayar, 1999). Khanna *et al.* (2005) observed a similar trend in water temperature at various bathing ghats on the River Ganga at Bulandshahar and the River Panvdhoi at Saharanpur. The variation in the water temperature may be due to different timing of sample collection and observation and the influence of the season (Parashar *et al.,* 2006).

The minimum and maximum pH values for pH station B_1 were 7.3 in July and 8.2 in January, respectively. At site B_1, a mean value of 7.77 with an SD of 0.28 was recorded. The minimum value at station B_2 was 7.6 in March, while the highest value was 8.3 in December. At station B_2, a mean value of 7.96 with an SD of 0.21 was recorded. The minimum value at station B_3 was 7.5 in June, while the highest value was 8.3 in January. At station B_3, a mean value of 7.85 with an SD of 0.24 was recorded. Figure 4 displays the pH variations by month. pH is a measure of the acidity or basicity of a solution. In the present study, the higher pH values were observed during the monsoon period and lower pH values during the summer seasons in both the rivers. Khanna *et al.* (2005) discovered lower pH levels in the winter and higher pH values during the monsoon season in their study on the Ganga River, which may be related to the river's increased chemical load during that time. Similar results were made by Giri and Singh (2015) in the Subarnarekha River; Mishra and Yadav (2020) in the Betwa River; and Meher *et al.* (2015) in the Ganga River. Environmental elements including pressure, salinity, and temperature have an impact on it. It was found that the pH

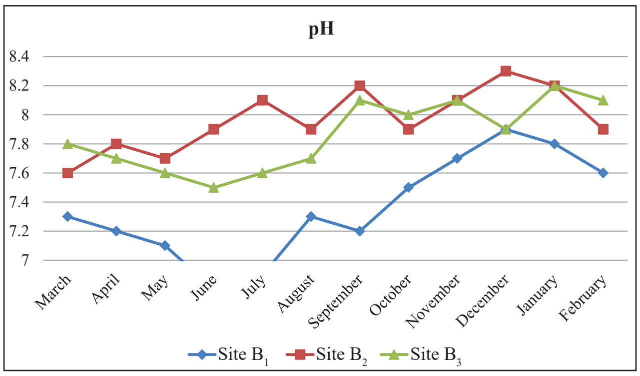

Figure 4: Monthly variation in pH at different sites of Yamuna River

had a direct link with carbonate and an inverse relationship with carbon dioxide (Dutta *et al.,* 2001).

The electrical conductivity (µS cm^{-1}) in the Yamuna River at station B_1 was 269 in the month of January and 529 in the month of September. At site B_1, the average value was 403.33 with a standard deviation of 81.07. The minimum value at station B_2 was 628 in January, while the highest value was 958 in September. At station B_2, a mean value of 783.41 with a standard deviation of 112.25 was recorded. The minimum value at station B_3 was 1065 in December, while the highest value was 1326 in September. At station B_3, a mean value of 1189.08 with a standard deviation of 81.52 was recorded. Figure 5 shows the monthly fluctuations in electrical conductivity. The electrical conductivity (µS cm^{-1}) of an aqueous solution is a measure of the ability to carry out an electric current (Parashuram and Singh, 2007). The monsoon season had the highest EC in both rivers, while the winter saw the lowest EC. A similar trend in conductivity was also observed by (Khanna *et al.,* 2005) in the River Panvdhoi at Saharanpur. Because of the abundance of salts, silts, and higher ionic concentration inflow flows transported by the river during the monsoon season, higher values may be observed (Jha and Barat, 2003). A measurement of total dissolved solids and salinity, conductivity in water is caused by the ionisation of dissolved inorganic particles (Bhatt *et al.,* 1999).

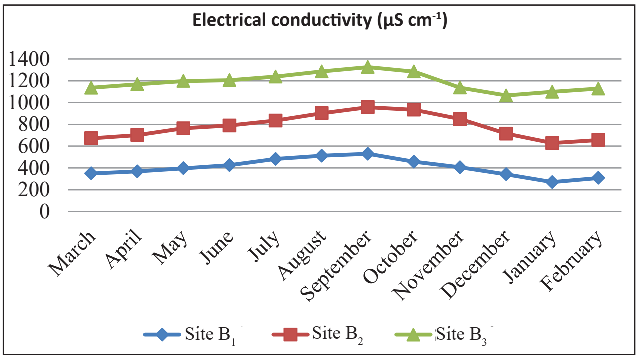

Figure 5: Monthly variation in Electrical conductivity (µS cm^{-1}) at different sites of Yamuna River

Biodiversity of Plankton in River

In the Yamuna River at site B_1, 11 species of phytoplankton containing Chlorophyceae (*Sphaerocytis* sp. and *Chlamydomonas* sp.), Cynophyceae (*Spirulina* sp., *Merismopedia* sp., *Microcystis* sp., *Psedoanabaena* sp., *Oscillatoria* sp.), Bacillariphyceae (*Melosira* sp. and *Navicula* sp.), Euglinophyceae (*Euglena* sp.) and Ulvophyceae (*Cladophora* sp.) were found during the study period. The highest abundance of group Cynophyceae and a minimum of Euglinophyceae were observed at site B_1, which is presented in table 1. The order of occurrence of phytoplankton was Cynophyceae (46%), Chlorophyceae (18%), Bacillariphyceae (18%), Ulvophyceae (9%) and Euglinophyceae (9%). At site B_1, 9 species of zooplankton from 5 groups were observed during the study period. Rotifera (34%) (*Asplanchna* sp., *Brachionus* sp., *Testudinella* sp.), Protozoa (22%) (*Actinophrys* sp. and *Verticella* sp.), Cladocera (22%) (*Daphnia* sp. and *Bosmina*

Table 1: Phytoplankton composition observed at site B_1 of Yamuna River

Phytoplankton	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
Chlorophyceae												
Sphaerocytis sp.	++	+++	+	+	+	+	-	+	++	++	+++	+
Chlamydomonas sp.	-	-	+	+	+	-	-	-	+	+	+	-
Cynophyceae												
Spirulina sp.	+	+	+	+	+	-	-	-	-	+	+	+
Merismopedia sp.	+	+	+	+	+	-	+	+	-	-	-	+
Microcystis sp.	+	+	+	+	-	-	+	-	+	++	+++	++
Psedoanabaena sp.	+	-	-	+	+	-	-	-	-	-	+	+
Oscillatoria sp.	+	-	+	+	-	-	-	+	+	+	-	+
Bacillariphyceae												
Melosira sp.	++	+++	+	+	+	-	+	-	++	++	+	-
Navicula sp.	+	+	+	-	+	+	-	+	-	-	+	+
Euglinophyceae												
Euglena sp.	-	+	+	++	+	-	-	-	-	+	-	+
Ulvophyceae												
Cladophora sp.	++	+	+	+	-	-	-	+	++	-	+	-

Note: - (Absence); + (Presence); ++ (Moderate); +++ (Abundance)

sp.), Copepoda (11%) (*Cyclops* sp.) and Ostracoda (11%) (*Cyclops* sp.). Rotifera were the dominant group found at site B_1, which is presented in table 2. The mean concentration at site B_1 was 15,517 individuals L^{-1}.

At site B_2, 14 species of phytoplankton within 3 groups containing Chlorophyceae (*Eudorina* sp., *Volvox* sp., *Spirogyra* sp. and *Zygnema* sp.), Cynophyceae (*Merismopedia* sp., *Anabaena* sp., *Nostoc* sp., *Spirulina* sp. and *Microcystis* sp.) and Bacillariphyceae (*Cyclotella* sp., *Frustularia* sp., *Syndora* sp., *Navicula* sp. and *Nilocera* sp.) were found during the study period. The highest abundance of group Cynophyceae and a minimum of Chlorophyceae were observed at site B_2, which is presented in table 3. The order of occurrence of phytoplankton was Cynophyceae (36%), Bacillariphyceae (36%) and Chlorophyceae (28%). At site B_2, 5 species of zooplankton from 4 groups were observed during the study period. Rotifera (40%) (*Filina* sp. and *Brachionus* sp.), Protozoa (20%) (*Euglena* sp.), Cladocera (20%) (*Bosmina* sp.)

Table 2: Zooplankton composition observed at site B_1 of Yamuna River

Zooplankton	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
Rotifera												
Asplanchna sp.	-	+++	+	-	++	+	+	+	+	-	-	+
Brachionus sp.	+	+	+	++	+	+	-	-	+	-	+	+
Testudinella sp.	+	-	++	+	+	-	-	-	-	-	+	-
Copepoda												
Cyclops sp.	+	+	+	+	+	+	-	+	+	-	-	+
Cladocera												
Daphnia sp.	++	+	++	+	-	+	-	-	+	-	+	+++
Bosmina sp.	+	+	-	-	+	+	+	-	-	-	-	+
Ostracoda												
Cypris sp.	++	+++	+	++	++	+	-	+	-	-	+	-
Protozoa												
Actinophrys sp.	++	+	++	+	+	+	-	-	-	+	++	+
Verticella sp.	-	+	+	+	-	-	+	+	+	++	+++	+

Note: - (Absence); + (Presence); ++ (Moderate); +++ (Abundance)

Table 3: Phytoplankton composition observed at site B_2 of Yamuna River

Phytoplankton	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
Chlorophyceae												
Eudorina sp.	+	++	+	+	+	-	+	+	+	-	-	++
Volvox sp.	++	+	+	+	+	-	+	+	-	+++	+	+++
Spirogyra sp.	+	+	-	+	+	+	-	-	+	-	+	+
Zygnema sp.	-	+	+	+	+	+	-	+	+	+	+	-
Cynophyceae												
Merismopedia sp.	+	-	-	-	+	-	-	+	-	+	++	-
Anabaena sp.	+	+	-	++	+++	+	+	+	++	++	+	+
Nostoc sp.	-	-	+	+	+	-	-	+	+	-	-	+
Spirulina sp.	-	+	-	+	+	-	+	+	++	++	+	-
Microcystis sp.	+	+	++	+	+	-	-	+	+	-	+	++
Bacillariphyceae												
Cyclotella sp.	+	-	-	+	+	-	-	-	+	-	+	-
Frustularia sp.	+++	++	+	+	+	-	-	+	-	+	++	+
Navicula sp.	++	+	+	+	+	+	-	+	++	++	-	+
Syndora sp.	++	+	-	-	-	-	-	+	+	+	+++	++
Milocera sp.	+	+	+	+	+	-	+	-	+	++	++	+

Note: - (Absence); + (Presence); ++ (Moderate); +++ (Abundance)

and Ostracoda (20%) (*Cypris* sp.). Rotifera were the dominant group found at site B_2, which is presented in table 4. The mean concentration at site B_2 was 15,329 individual L^{-1}.

At site B_3, 15 species belonging to 3 groups containing Chlorophyceae (*Eudorina* sp., *Volvox* sp., *Spirogyra* sp., *Zygnema* sp., *Pediastrum* sp., *Scenedesmus* sp. and *Closterium* sp.), Cynophyceae (*Anabaena* sp., *Spirulina* sp., *Microcystis* sp. and *Ocillatoria* sp.) and Bacillariphyceae (*Gomphonema* sp., *Frustularia* sp., *Navicula* sp. and *Nitzschia* sp.) were found during the study period. The highest abundance of group Chlorophyceae and a minimum of Bacillariphyceae were observed at site B_3, which is presented in table 5. The order of occurrence of phytoplankton was Chlorophyceae (46%), Bacillariphyceae (27%) and Cynophyceae (27%). At site B_3, 5 species of zooplankton belonging to 5 groups were observed during the study period. Rotifera (46%) (*Filina* sp., *Testudinella* sp. and *Brachionus* sp.), Protozoa (25%) (*Euglena* sp. and *Arcella* sp.), Cladocera (13%) (*Bosmina* sp.), Copepoda (12%) (*Cyclops* sp.) and Ostracoda (13%) (*Cypris* sp.). Rotifera were the dominant group found at site B_3, which is presented in table 6. The mean concentration at site B_3 was 19,453 individual L^{-1}.

Table 4: Zooplankton composition observed at site B_2 of Yamuna River

Zooplankton	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
Rotifera												
Filina sp.	++	+	+	-	+	+	-	-	-	+	-	+++
Brachionus sp.	++	+	+	+	-	+	-	-	+	++	+++	+
Cladocera												
Bosmina sp.	+	+	-	-	+	+	+	-	-	-	-	+
Ostracoda												
Cypris sp.	+	-	+	+	+	-	+	-	-	-	-	-
Protozoa												
Euglena sp.	-	+	++	+++	+	+	-	-	+	++	+	-

Note: - (Absence); + (Presence); ++ (Moderate); +++ (Abundance)

Phytoplankton are regarded as the chief primary producers of any aquatic environment, which fix solar energy by the process of photosynthesis, assimilating carbon dioxide to

Table 5: Phytoplankton composition observed at site B_3 of Yamuna River

Phytoplankton	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
Chlorophyceae												
Eudorina sp.	++	+	+++	++	+	+	+	+	+	-	-	++
Volvox sp.	+	+	+	+	+	-	-	-	+	++	+++	+
Spirogyra sp.	+	-	+	++	+	-	-	+	+	+	+	+
Zygnema sp.	+	+	+	+	-	+	+	+	-	+	++	+
Pediastrum sp.	-	+	+	+	+	-	-	-	-	-	-	++
Scenedesmus sp.	+	++	+	++	+	-	-	-	-	+	-	+
Closterium sp.	+	+	-	+	-	-	-	+	+	+	+	+
Cynophyceae												
Anabaena sp.	-	-	+	++	+	+	-	-	+	-	-	-
Spirulina sp.	-	+	+	+	-	+	-	+	+	+	-	-
Microcystis sp.	-	+	++	++	+	+	+	-	+	+	+++	++
Ocillatoria sp.	-	+	-	-	-	+	-	+	-	-	+	-
Bacillariphyceae												
Gomphonema sp.	+	-	-	-	-	+	+	+	+	-	-	+
Frustularia sp.	+	-	-	-	+	+	+	-	+	+	-	+
Navicula sp.	++	+	+	+	+	-	-	+	-	+	++	-
Nitzschia sp.	-	+	+	+	-	-	-	-	+	+	+++	++

Note: - (Absence); + (Presence); ++ (Moderate); +++ (Abundance)

Table 6: Zooplankton composition observed at site B_3 of Yamuna River

Zooplankton	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
Rotifera												
Brachionus sp.	++	+	+	-	+	+	-	-	+	-	+++	+
Testudinella sp.	-	-	+	+	+	-	+	+	-	-	+	-
Filina sp.	++	+	+	-	+	+	-	-	-	-	-	++
Copepoda												
Cyclops sp.	+	+	+	+	-	+	-	+	+	-	-	+
Cladocera												
Bosmina sp.	++	+	-	-	+	+	+	-	-	-	+	++
Ostracoda												
Cypris sp.	++	++	+	+	-	+	+	+	-	-	+	-
Protozoa												
Euglena sp.	-	+	++	++	+	+	-	-	-	+	+++	++
Arcella sp.	-	+	+	+	-	-	+	+	++	++	-	+

Note: - (Absence); + (Presence); ++ (Moderate); +++ (Abundance)

produce carbohydrates, thus serving as an important link between the abiotic factors and the biota in the aquatic system (Choudhury *et al.,* 2000). They are more efficient in utilizing CO_2 at high pH levels and thus their abundance in the Yamuna River at sites B_1 and B_2 indicates the eutrophic nature of the studied water bodies. Cyanophyceae are considered to be highly adaptive and colonise even polluted waters at higher temperatures. Ingole *et al.* (2010), and Asimiea and Sam-Wobo (2011) discovered similar results in Majalgaon Dam in Maharashtra and Lower Brass River, Niger Delta, Nigeria, respectively. In the present study, phytoplankton was found to be dominant over zooplankton. The physico-chemical parameters affect the growth of algae in different seasons. The rainy season does not support the algal growth; higher water flow restricts it. Bhowmick and Singh (1985) observed the maximum density of phytoplankton during summer and a minimum in the monsoon months. Sharma *et al.* (2007) described changes in phytoplankton diversity caused by seasonal changes in the physicochemical characteristics of surface water in the Garhwal Himalaya hill stream Chandrabhaga. Rotifera abundance and dominance have been reported in several bodies of water (Kudari *et al.,* 2005). This pattern is common in many freshwater bodies like lakes, ponds, reservoirs, rivers, or streams (Neves *et al.*, 2003).

Conclusion

The physicochemical properties of surface water varied depending on the season. It is alarming that the pollution in the river Yamuna is escalating over the years in this stretch. The river is highly polluted at site B_1 because of high total dissolved solids containing domestic waste and tannery effluent discharged into the river as compared to other sites indicated by lower levels of DO. More detailed and systematic investigations of natural and anthropogenic variables that are contributing to changes in phytoplankton physiology and growth are to be conducted.

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