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Time scale changes of plankton in the river Ganga at Kanpur

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Abstract
The present study analyses the long term seasonal changes in the Ganga river plankton communities at Kanpur during the period of 2002-2020. River Ganga at Kanpur is passing through multiple stressors like pollution, climate change, habitat alteration, eutrophication and various anthropogenic activities, since a long period. This was reflected by the abundant growth of various taxonomic groups of phytoplankton and zooplankton. Degradation of plankton quality was noticed by the reduction in Bacillariophyceae and increase in Chlorophyceae, with the lapse of time from 2002-2017 and 2018-2020 improvement in water quality was observed. A sudden increase in Myxophyceae was recorded after the construction of barrage in above Kanpur area during 2014 and 2015. A comparison with 1966 data indicated that river depth, temperature, Chloride, Silica, hardness and turbidity exhibited major differences in the past fifty years and impacted plankton community structures. Species shift was observed from time to time as *Synedra, Melosira, Cyclotella, Fragilaria, Nitzschia, Asterionella* were dominant diatoms but their order of dominance varied. Similarly, in Green algae, the present dominance of Chloroccoccales (*Ankistrodesmus, Scenedesmus, and Pediastrum*), replaced the dominance of Zygnemales (*Spirogyra, Mougeotia*-in 1966). In recent years (2018-2020) improvement in plankton, quality is evidenced by a gradual increase of Bacillariophyceae and reduction in Chlorophyceae.

Keywords: Abundance, composition, diversity, Ganga, plankton, time scale changes

Introduction
Kanpur is an industrial city of Uttar Pradesh (India) and Ganga at Kanpur is passing through multiple stressors like pollution, climate change, habitat alteration, eutrophication and various anthropogenic activities, since a long period. Various chemicals/nutrients released by the factory effluents, industrial waste etc. had also accumulated at the river bed of Kanpur eco-regions. Domestic sewage, effluents from the tannery, distillery, organic waste etc. although complicates the ecosystem of the river Ganga, by upsetting the oxygen balance through the disintegration of biodegradable material, have tremendous capacity in fertilizing the water which in turn helps in enriching aquatic biomass. Phytoplankton communities of river Ganga [1, 2] and River Yamuna [3-6] have been investigated regularly. This investigation of phytoplankton and zooplankton are focused on the time scale changes of plankton of the river Ganga at Kanpur, which may be useful to infer past environmental conditions. An improved understanding of the inherent natural variability of phytoplankton is therefore important for forecasting the extent of global change impact on aquatic ecosystem functioning. The extent of physical changes and potential for species to adapt to changing environmental conditions will greatly influence food web dynamics as the future climate warms and becomes more variable. In this backdrop present investigation of phytoplankton and zooplankton are focused on the time scale changes of plankton of the river Ganga at Kanpur, which may be useful to infer past environmental conditions.

Materials and Methods
Study area
Ganga is a perennial river, originated from Gangotri glacier, 3129.12 meters above the sea level. After the covering of 220 km in the Himalayas, it enters the plains at Haridwar and ultimately joins the Bay of Bengal, after meandering over a distance of about 2290 km in the Indo-Gangetic plains of Uttar Pradesh, Bihar and West Bengal. The Ganga is highly variable, often changing its course. It swells up enormously during the monsoon, and in the summer, it

gets reduced to a few narrow and shallow stream. The observation reported here were made at Shekhpur Centre on the river Ganga, as this centre received industrial waste of various factories directly or indirectly.

Sample Collection and Plankton analysis

Samples were collected quarterly (summer, monsoon and winter of each year) from the Shekhpur (Lat 26024'53" N, Long 80026'79" E) centre of the river Ganga at Kanpur, as this centre was highly polluted by various industrial discharges. During the period of studies (2002-2020) a total of 39 samples were collected for plankton analysis. Plankton samples were collected using bolting silk net no. 25 by filtering 50 litres water and fixed in 4 % formalin solution in 50 ml tubes for qualitative and quantitative analysis in the laboratory. Samples were analysed using the methodology proposed by [7]. After keeping the samples for about one day for sedimentation, the filtrate was made to 10 ml by removing the supernatant water from the tube using a fine pipette. The residual portion containing plankton was thoroughly mixed and 1 ml of it was transferred to a Sedgwick-Rafter plankton counting cell for differential numerical analysis. The organisms were identified up to genera in most cases. The quantity of each genus was then calculated in numbers per litre of river water by Welch's formula-

$N = (a\ 1000)\ c\ /\ l$

Where N denotes the number of planktons per litre, and a is the average number of planktons in all counts in a counting cell of 1 cu mm capacity, c the volume of original concentrate in ml, and l the volume of original filtered, expressed in litters.

Water quality analysis

Analysis of water quality parameters was performed by using [8]. Temperature is measured by mercury thermometer. Transparency is measured with help of Sacchi-dish. Alkalinity Measured by titration method. Dissolved oxygen by Winkler's method. pH, Specific Conductivity & total dissolved solids (TDS) is measured by the digital multi-parameter. The argentometric method is used to measure the chloride. Total Hardness & calcium were Measured with help of EDTA titration method, and Phosphorus by spectrophotometer.

Results and Discussion

Plankton abundance (average of summer, winter and monsoon) in the river Ganga at Kanpur is depicted in (Table 1). The increasing trend of plankton abundance from 2002 to 2016 was observed but after 2017 plankton abundance revealed a declining trend in Ganga at Kanpur over time (Fig.1). Plankton population were contributed by 147 taxa, which belonged to all major groups of phytoplankton (110) and zooplankton (37) like Bacillariophyceae (26), Chlorophyceae, (67) Myxophyceae (12), Euglenophyceae (3), Dianophyceae (2), Rotifera (19) Crustecea (9) and Protozoa (9). Phytoplankton dominated and contributed 82.6% (2005) to 94.2% (2017). Bacillariophyceae was the second-highest group (after Chlorophyceae) concerning algal diversity. Reduction in percentage contribution of Bacillariophyceae (Fig2) was noticed, as it ranged from 77.2% (2002) to 15.1% (2012) at Kanpur. Dominant taxa were *Synedra*, *Melosira* and *Cyclotella*, yet their order of abundance varied from time to time. Chlorophyceae contributed between 13.1% (2002) to 76.4% (2012) at Kanpur. A gradual increasing trend of Chlorophyceae is presented in Fig.2. Members of Chloroccocales like *Ankistrodesmus, Scenedesmus, Pediastrum, Actinastrum and Coelestrum* were found to be dominant. In the previous studies [6] taxa of Zygnemales like species of *Spirogyra, Zygnema and Mougeotia* were dominant. Now pollution load and global warming changed the scenario of algal communities. Myxophyceae ranged from 1.33% (2002) to 29.4% (2015) and dominated by *Phormidium*, *Merismopedia* and *Anabaena*. Increase in Myxophyceae in 2015, after the construction of Barrage at Bithoor, (above Kanpur) was noticed (Fig.2). The decline in Myxophyceae in 2016 and 2017 may be attributed to the action taken for Clean Ganga mission (NMCG). Euglenophyceae ranged from 10.3% (2003) to 0.8% (2017) and were dominated by *Euglena* sp. Presence of Dianophyceae was a unique feature of the river Ganga at Kanpur. It ranged from 4.9 % (2005) to 0.45% (2016) and presented by 2 taxa *Peridinium* and *Ceratium.*

The numerical contribution of zooplanktons to the total plankton population ranged from 17.41% (2005) to 0.19% (2012) and represented by Rotifera, Crustecea and Protozoa. Zooplankton was dominated by Rotifers which contributed from 0.19% (2012) to 8.36% (2015) and represented by 19 taxa with an abundance of *Brachionus* species. In 1966 Rotifers contribution was 3.7% at Kanpur and was dominated by *Keratella* and *Brachionus* spp. thought the year. But in present study, Rotifers population were higher in summer in comparison to winters. No definite trend of Rotifer population was noticed. Therefore, higher abundance in 2014 and 2015 may be attributed to the increased pollution due to the construction of a barrage at above Kanpur and rotifers population reduced gradually in 2016 and 2017, again increased in 2018. Myxophyceae and Rotifers both were maximum in 2015 indicating higher organic pollution at Kanpur. Rotifers are also considered as an indicator of pollution [9]. Reduction in Crustaceans population was recorded and ranged from 14.9 % (2005) to 0.4% (2017) represented by 15 taxa and dominated by *Ceriodaphnia* and *Bosmina.* While previously (1966) their contribution was 0.4% and was dominated by *Cyclops* and *Diaptomus* species. Again from 2018-2020 crustacean population could not be recorded. The protozoan population increased slightly, ranged from 0.9% (2004) to 2.1% (2017), and dominated by *Chlamydomonas*, *Paramoecium* and *Epistylis.* Some dominant and important taxa are given in Plate 1 (Figs. A-R).

A comparative account of some water quality parameters with that of 1966 is given in (Table-2). Rise in temperature (4^0C), a slight change in pH (7.5-8.8 in 1966, 7.8-8.0 in 2017), and Dissolved Oxygen (5-10 ppm in 1966, 6.0-9.6 ppm in 2017), increase in TDS (100-120 ppm in 1966, 160-252 ppm in 2017) and Chloride (2.5-16 ppm in 1966, 251-318 ppm in 2017) were noticed. Increase in Chloride and TDS both indicated an increase in the pollution status of the river Ganga at Kanpur. Hence, rise in temperature, change in nutrients due to pollutants/ chemicals or factory discharge developed a complex ecosystem which resulted in altered floral and faunal communities in the river Ganga at Kanpur.

Plankton composition and abundance revealed that Ganga at Kanpur is facing eutrophication by a gradual accumulation of nutrients and habitat alteration after the construction of many dams, from Gangotri to Kanpur, as observed by an increase in planktonic abundance from 2002 to 2016 and then declined gradually. In 2013, Kedarnath flood disturbed the river ecology and plankton trend exceptionally. This may be attributed to the frequent changes in water level brought about by rains and heat which affect the concentration of dissolved salts as these were the most important factors which determined the flora of freshwaters. In 2002-2006, total plankton ranged from 30 u/l to 800 u/l, with dominant taxa *Melosira, Synedra* and *Fragilaria* (Bacillariophyceae), *Pediastrum* and *Ankistrodesmus* (Chlorophyceae.) while in 2013-2017 it ranged from 230 u/l (2004) to 3780 u/ l (2012) with the dominance of *Melosira, Synedra,* and *Cyclotella* (Bacillariophyceae), *Ankistrodesmus and Scenedesmus* (Chlorophyceae), With an increasing level of pollution and temperature, the diatom dominance is replaced by that of green and blue-green algae. These general trends are confirmed by studies of several rivers [1, 3, 10]. The dominance of green algae, especially Chloroccocales (*Ankistrodesmus, Pediastrum* and *Scenedesmus*) depicted the impact of global warming, and they are characteristics of water with high organic content also [11]. Majority of Chloroccocales can tolerate varying degree of salinity and temperature as high as 50-62 ^{0}C. As a general rule, Cyanophyceae, Euglenophyceae, Centric diatoms (*Melosira* sp.) and members of Chlorococcales are characteristics of polluted waters [12]. A comparison of plankton composition in 1966 and 2020 are presented in Fig 3&4. The total number of taxa recorded in 1966 were 76 (Bacill.17, Chlorophyceae. 15, Myxophyceae 10, Dianophyceae 2, Rotifera 16, Crustecea 11, Protozoa 4) and from 2002 to 2020 increase in taxa (total 147) may be attributed to eutrophication as it causes an increase in density and diversity both. An abundance of Myxophyceae suggested organic waste accumulation over time. [13] Recorded *Euglena* sp, *Oscillatoria* sp, *Microsystis* sp, *Chlorella* sp, *Ankistrodesmus* sp, *Scenedesmus* sp, *Synedra ulna, Nitzschia* and *Navicula* sp from the sewage polluted sites from the river Ganga between Patna to Farakka. According [14] organic pollution tends to influence the algal flora more than any other factors in the aquatic environment. Sometimes higher nutrients in an aquatic system may produce a giant algal cell [15]. *Spirulina* important and useful blue-green algae appeared in the river Ganga, after a long time. The change was noticed in river depth (from 5-6 m in 1966 to 1.3-1.1 m in 2019), temperature, Chloride, Silica, hardness and turbidity, which may be the responsible for changing scenario of plankton of the river Ganga at Kanpur. Change in the balance of TDS drive by these environmental factors was the cause of latest change in plankton community structure, which in turn could have affected the fish community of the river Ganga, as major carp fisheries were declining and exotic carp was increasing in the middle stretch of the river Ganga [16]. Monitoring the components of plankton community structure may provide important information about diversity dynamics and process that modify ecosystem.

Table 1: Abundance (u/l) and composition (%) of plankton from 2002 to 2020 in the river Ganga at Kanpur.

Plankton/year	2002	2003	2004	2005	2012	2013	2014	2015	2016	2017	2018	2019	2020
Bacillariophyceae %	77.2	25.6	38.8	19.90	15.13	90.40	30.20	30.20	36.7	38.3	65.2	47.1	59.8
Chlorophyceae%	13.1	44.6	43.1	51.20	76.4	3.30	32.20	27.60	40.4	48	18.6	38.3	27.7
Myxophyceae %	1.33	10.3	9.2	6.50	8.3	1.00	25.90	29.40	12.7	6.2	6.1	3.2	7.4
Dianophyceae%	0	2.67	0.48	4.98	0	0.00	1.55	1.15	0.45	0.9	1.7	1.4	0
Euglenophyceae %	0	10.30	0	0	0	0	0	0	1.86	0.8	0	2.6	0.6
Rotifers%	2.65	6.49	4.75	2.49	0.19	0.00	6.87	8.36	5.49	4.5	2.7	7.4	3.7
Crustecea%	5.6	0	1.6	14.9	0	0.00	2.3	3.17	0.72	0.4	0	0	0
Protozoa %	0	0	2.1	0	0	0.00	0.9	0	1.6	0.9	0	0	0
Total plankton (u/l)	452	262	631	201	1566	700	1747	1735	3770	2560	2445	1095	1560

Table 2: Comparative water quality parameters at Kanpur (1966 and 2020)

Parameters	Kanpur 1965 (June-Dec.)	Kanpur2020 (winter)	Kanpur2020 (summer)
Temperature water (ºC)	16-30	15.3	26.8
Transparency (cm)	-	72	62
PH	7.5-8.3	8.8	8.2
Dissolved Oxygen (ppm)	5.0-10.	8	6.6
Free CO_2 (ppm)	5.0-10.0	0	0
CO_3 (ppm)	-	18	6
Carbonate (ppm)	-	10	6
Bicarbonate (ppm)	81-216	172	198
Chloride (ppm)	2.5-16	17.5	39
Specific conductivity	-	277	295
Turbidity/TDS (ppm)	100-120	180	192
Total hardness (ppm)	-	136	150
Silicate (ppm)	8.2-20.3	0.039	0.584
Nitrate (ppm)	0.08-19	0.565	2.036
Phosphate ppm	0.07-0.21	0.074	0.188
Calcium (ppm)	-	22.44	16.03
Mg (ppm)	-	12.6	32
River Depth (meter)	05-6met	1.32	1.1
BOD (ppm)	-	3.8	3.9
COD (ppm)	-	40.9	31.5

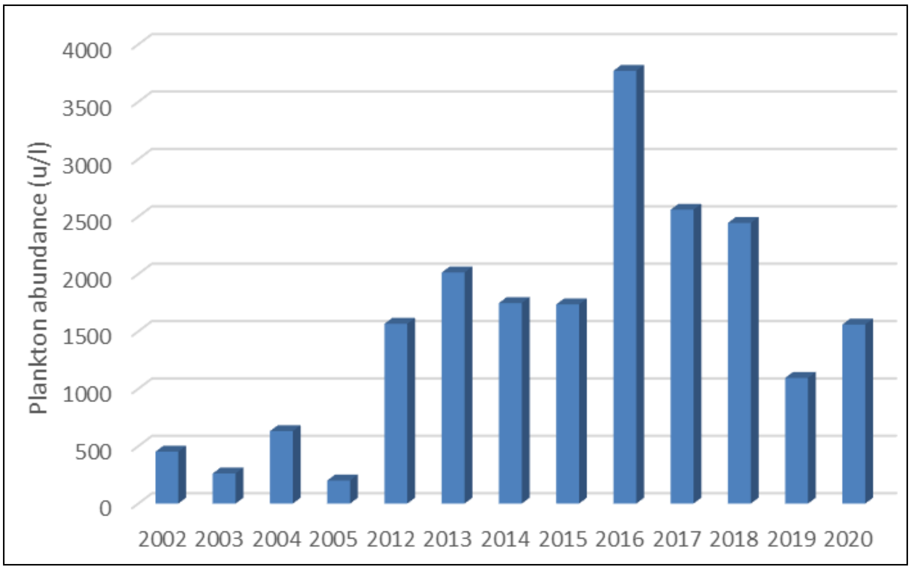


Fig 1: Plankton abundance (u/l) during different years at Kanpur

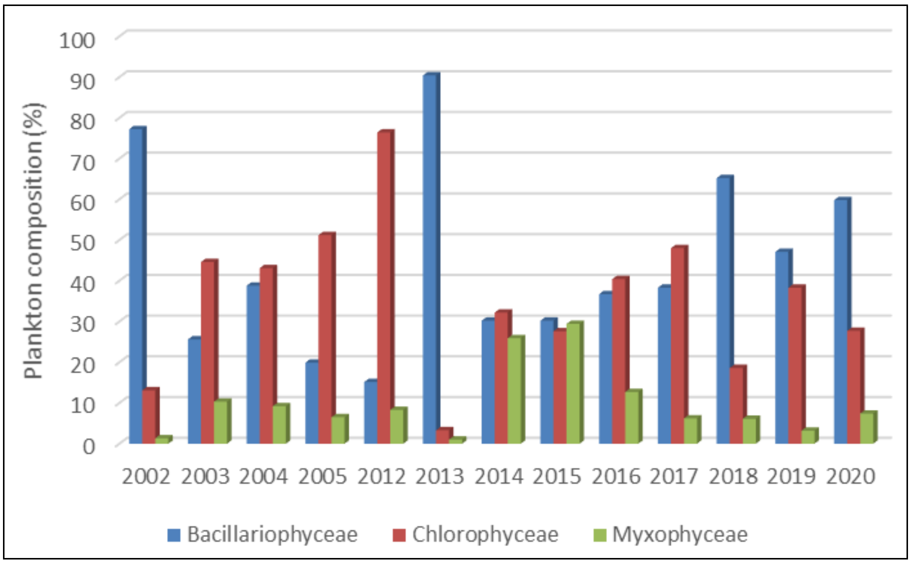


Fig 2: Graph showing increasing trend of Chlorophyceae and decreasing trend of Bacillariophyceae

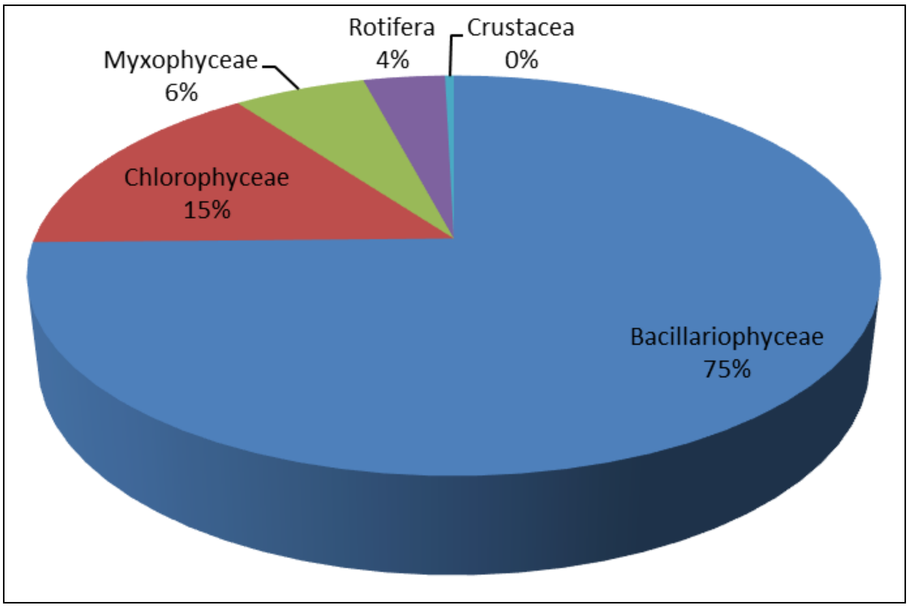


Fig 3: Plankton composition (%) in 1966

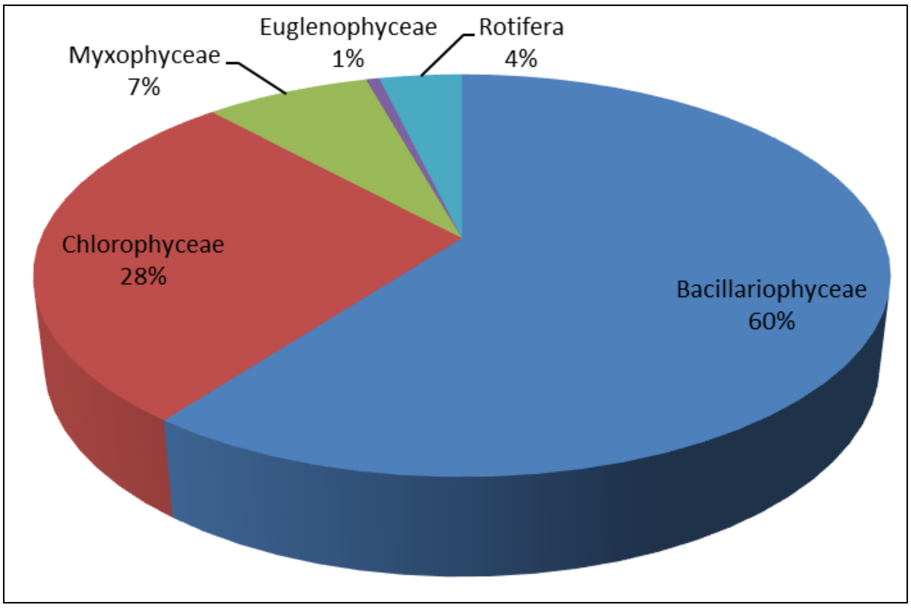
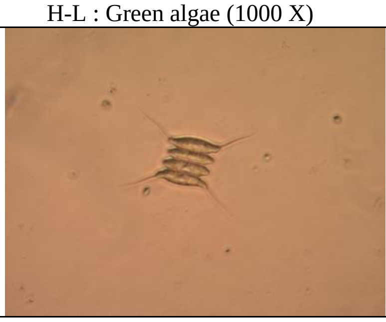
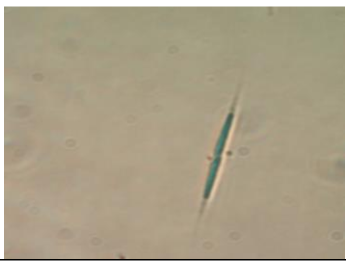
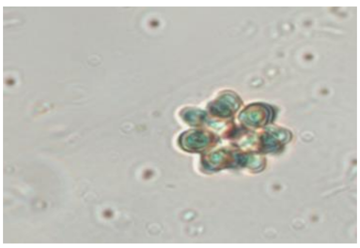
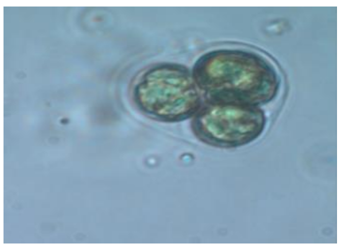


Fig 4: Plankton composition (%) in 2020

A-F : Diatoms (1000 X)		
		
Melosira	*Nitzschia*	*Surirella*
		
Stephnodiscuss	*Synedra*	*Rhopalodea*
H-L : Green algae (1000 X)		
		
Pediastrum	*Scenedesmus*	*Actinastrum*
		
Ankistrodesmus	*Coelestrum*	*Chlorella*

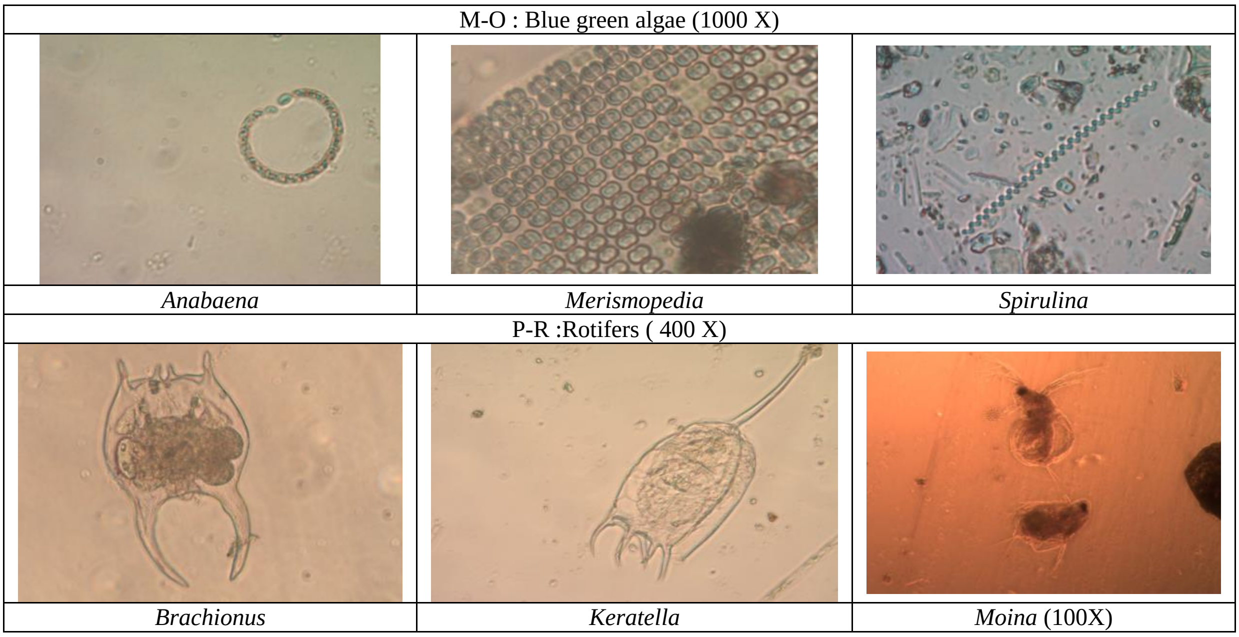


Plate 1: Some dominant planktonic taxa at Kanpur (A-R)

Conclusion

Studies of time scale changes of plankton of the river Ganga depicted that increase in percentage contribution of Chlorophyceae, Myxophyceae, Rotifera and Protozoa were noticed, while Bacillariophyceae, Euglenophyceae, Dianophyceae and Crustecea revealed a reduction in percentage contribution of planktonic composition. Presently dominant diatoms are *Melosira*, *Synedra*, and *Asterionella* (Bacillariophyceae), *Ankistrodesmus*, *Scenedesmus*, *Pediastrum*, *Chlorella* (Chlorophyceae), *Merismopedia* and *Phormidium* (Myxophyceae), *Brachionus, Asplanchna and Keratella* (Rotifera). A shift in dominant species suggested that *Melosira* sp. (Diatom), *Scenedesmus* sp. (green algae), *Merismopedia* (blue-green algae), and *Brachionus* (Rotifer) sp. are resistant planktonic taxa towards changing climatic conditions and will occupy strong abundance in the Ganga river ecosystem. The changes were noticed in river depth, temperature, Chloride, Silica, hardness and turbidity, which may be responsible for changing the scenario of plankton of the river Ganga at Kanpur.

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