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Original Research Paper

Impact of Anthropogenic Activities on the Phytoplankton Diversity of Rajaram Reservoir, Kolhapur, Maharashtra, India

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ABSTRACT

The present investigation was undertaken to study the impact of anthropogenic activities such as Ganesh idol immersion and mattresses washing during the Navaratra festival on the phytoplankton diversity of Rajaram reservoir. The total number of phytoplankton recorded during this investigation is 120. Several of these algal species belong to the pollution tolerant genera. A few biological and diversity indices were also calculated, which indicate high level of pollution of the Rajaram reservoir. Therefore, it is an urgent need to conserve this reservoir for the future water resource.

INTRODUCTION

Reservoirs are recognized an aquatic ecosystems that harbour high biological diversity, provide sustenance for millions of people and face ongoing threats as a result of human activities throughout the world (Gopal & Chauhan 2001). The reservoirs are most important resources of water for the local people, mainly for drinking and domestic purposes. Thus the rural and urban people are mostly dependent on reservoir water, hence the environmental monitoring and conservation of freshwater environment has got a prime importance.

The water quality of reservoir depends on its physico-chemical and biological characteristics. Millions of idols are immersed as a religious activity each year since ancient times in different lotic and lentic water bodies such as lakes, reservoirs and rivers in India (Reddy & Kumar 2001), which greatly affects the quality of water.

The anthropogenic activities such as Ganesh idol immersion and mattresses washing during the Navaratra festival are common since long in Maharashtra. In Rajaram reservoir, thousands of Ganesh idols are immersed every year and also tremendous washing of the mattresses is being done in month of September before 'Navaratra' festival by the people from surrounding areas. The idols are made up of plaster of Paris (gypsum), clay, hay, paper, wood, thermocol, jute, adhesives and clothes supported by small iron rods and diverse paints such as varnish and water colours. They also contain heavy metals, especially nickel, lead and mercury, which find their way into fishes and birds inhabiting the lake, and finally reach the humans through food chains. During the washing tremendous amount of detergents are mixed into the reservoir which contain mineral, phosphorus and nitrogenous compounds. These compounds are binding agents that suspend dirt into water. The nitrogenous and phosphorus compounds are nutrients for algae and other plant life. So, all these anthropogenic activities have potential to create short and long term impacts on water quality (Geesen 2006). The phytoplanktons are photosynthesizing, microscopic organisms which are main primary producers of aquatic ecosystems, and a slight change in water quality can affect their diversity. Thus, the present attempt has to be undertaken to study the effect of anthropogenic activities on phytoplankton diversity with the help of pollution indices.

MATERIALS AND METHODS

Study area: Rajaram lake is situated near Shivaji University campus, Kolhapur, at the south east edge of Kolhapur city (latitude 16°42' east; longitude 74°14' north).

Water sampling: The phytoplankton samples were collected from the Rajaram reservoir before and after the anthropogenic activities. They were brought to laboratory, preserved by adding 1mL of 0.4 % formalin and analysed under microscope. The photographs were taken, and the phytoplankton were identified by using books, monographs and research articles (West & West 1907, Prescott 1982, Fritsch 1935, Cox 1996, Sarode & Kamat 1984, Bhosale et al. 2010, 2010a, 2010b).

RESULTS AND DISCUSSION

The diversity of phytoplankton species observed during the present study is given in Table 1, and microphotographs of some important species are shown in Fig. 5. A total number of 120 species of phytoplankton were identified belonging to six major classes of algae. Chlorophyceae (64) was dominant followed by Bacillariophyceae (34), Cyanophyceae (14), Euglenophyceae (4), Crysophyceae (2) and Dinophyceae (2). It was observed that the number of phytoplankton increased after anthropogenic activities (Table 1). This is mainly due to Ganesh idols immersion and mattresses washing, that add nutrients to the water, thus, resulting in increasing the phytoplankton.

Table 2 depicts the class-wise diversity of phytoplankton. There were 38 species observed before the activities which were absent after the activities i.e., they are sensitive to the change in characteristics of reservoir water. On the other hand, 51 species were observed after the anthropogenic activities, which were absent before the activities. These were tolerant to pollution, and can be considered as pollution indicator species. The number of similar species observed during, before and after the anthropogenic activities is 31 and dissimilar species is 90 (Table 2) which also indicates the effect of anthropogenic activities on phytoplankton composition.

Form the several past decades various indices have been used to monitor the water pollution. The indices are a sign of an overall stress caused by various factors that causes pollution. It also serves as a good indicator of the overall pollution of water. The results of pollution diversity indices as well as similarity and dissimilarity indices are given in Tables 3 to 6 are as follows.

Odum's Species Index (Odum 1971): It is an excellent index used to determine the water pollution level in both flowing and standing water bodies. The Cyanophyceae, Chlorophyceae and Bacillariophyceae are the important pollution indicator classes (Zargar & Ghosh 2006). The Odum's Species indices of classes Cyanophyceae, Chlorophyceae and Bacillariophyceae have increased after anthropogenic activities indicating increase in the level of pollution (Table 4 and Fig. 1).

Similarity and Dissimilarity indices: The class-wise similarity and dissimilarity indices were studied (Table 4 and Fig. 2). Only the class Cyanophyceae shows more similar species during before and after anthropogenic activities, while the classes Euglenophyceae, Chrysophyceae, Dinophyceae, Bacillariophyceae and Chlorophyceae show high values of dissimilarity index. This indicates that the species compositions of these classes is not same at before and after the activities. The increase in the number of species from these classes composed of pollution indicators species, indicates increase in pollution, which is due to the festival activities.

Nygaard's algal indices (Nygaard 1949): Nygaard prepared organic pollution indices of trophic state of major classes of algae (Myxophyceaen, Chlorophycean, Diatom, Euglenophycean and Compound). He assumed that Cyanophyta, Euglenophyta, Centric diatoms and Chlorococcales are found in eutrophic waters, whereas Desmids and pinnate diatoms generally found in oligotrophic waters (Table 5 and Fig. 3).

The present study reports the Nygaard's algal pollution indices and reveal the presence of species belonging to class Cyanophyceae, Chlorophyceae and Euglenophyceae before anthropogenic activities indicating that the Rajaram reservoir has eutrophic water. These indices increased after anthropogenic activities resulting in the high values of class

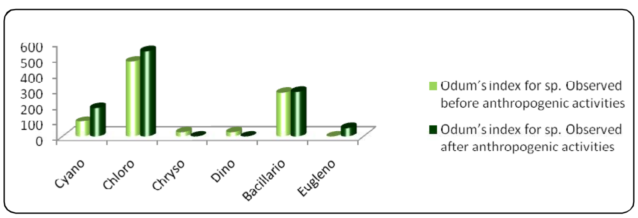

Fig. 1: Odum's Species index.

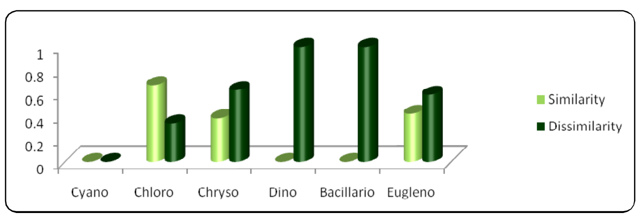

Fig. 2: Similarity and Dissimilarity index.

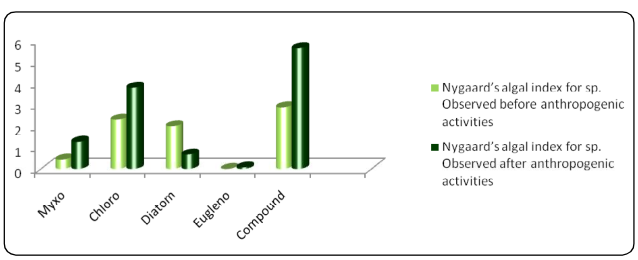

Fig. 3: Nygaard's algal indices for species.

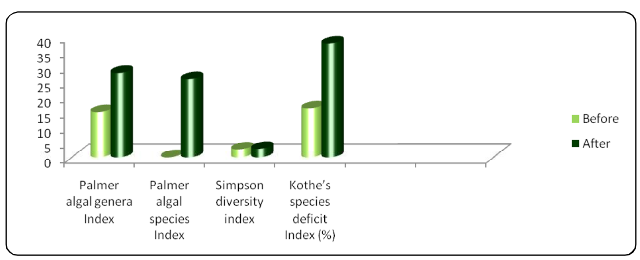

Fig. 4: Palmer genera index, Palmer species index, Simpson diversity index and Kothe's species deficit index.

Table 1: Phytoplankton species observed before and after the anthropogenic activities in Rajaram reservoir.

Sr. No	Name of species	R_B	R_A
A.	**Class: Cyanophyceae**		
1.	*Chroococcus turgidus* (Kuetz) Naegeli	1	1
2.	*Lyngbya* sp.	1	1
3.	*Lyngbya martensiana* Meneghini	0	1
4.	*Microcystis aeruginosa* Kuetz. emend, Elenkin.	1	1
5.	*Microcystis incerta* Lemmermann	1	1
6.	*Merismopedia glauca* (Ehrenb) Naegeli	1	1
7.	*Merismopedia elegans* var. major	1	1
8.	*Nostock muscorum* C. A. Agardh	0	1
9.	*Oscillatoria tenuis* C. A. Agardh, Algarum Decades	0	1
10.	*Oscillatoria angustissima* West and West	1	1
11.	*Oscillatoria subbrevis* Schmidle	0	1
12.	*Oocystis gigas* Archer	0	1
13.	*Rivularia haematities* (D.C.) C. A. Agardhs	0	1
14.	*Scytonema* sp.	0	1
B.	**Class: Chlorophyceae**		
15.	*Ankistrodesmus fusiformis* Corda	1	1
16.	*Ankistrodesmus falcats* (Corda) Ralfs	0	1
17.	*Botryococcus* sp.	0	1
18.	*Bulbochaete* sp.	0	1
19.	*Closterium acutum* Brebisson	1	0
20.	*Closterium aciculare* T. West	1	0
21.	*Closterium navicula*	1	0
22.	*Closterium parvulum* Naegeli	0	1
23.	*Closterium ehrenbergii* Meneghini ex Ralfs	1	0
24.	*Closteriopsis longissima* var. *tropica* West & West	0	1
25.	*Cosmarium undulatum* Corda ex Ralfs	0	1
26.	*Cosmarium tinctum* Ralfs	0	1
27.	*Cosmarium subtumidum* Nordstedt	0	1
28.	*Cosmarium bioculatum* var. *hians*	0	1
29.	*Cosmarium raniforme* (Ralfs) W. Archer	0	1
30.	*Cosmarium moniliforme* Ralfs	0	1
31.	*Cosmarium venustrum* (Brebisson) W. Archer	0	1
32.	*Coelastrum spharicum* Naegeli	1	0
33.	*Coelastrum microporum* Naegeli in Braun	0	1
34.	*Coleochaete pulvinata* A. Braun in Kuetzin	1	0
35.	*Crucigenia truncata* G. M. Smith	1	0
36.	*Crucigenia irregularis* Wille	1	0
37.	*Crucigenia rectangularis* (A. Broun) Gay	0	1
38.	*Cerasterias staurastroides* West & West	0	1
39.	*Desmidium swartzii* C. Agardh ex Ralfs	1	0
40.	*Eudorina elegans* Ehrenbserg	0	1
41.	*Euastrum inermius* (Nordstedt) W.B.Turner	1	1
42.	*Euastrum spinulosum* Delponte	1	1
43.	*Lagerheimia quadriseta* (Lemm) G. M. Smith	1	0
44.	*Mougeotia scalaris* Hassall	0	1
45.	*Micrasterias zeilanica* Fritsch	0	1
46.	*Oedogonium pretense* Transeau	0	1
47.	*Pediastrum simplex* (Meyen) Lemmermann	1	1
48.	*Pediastrum simplex var.duodenarium* (Bailey) Rob.	1	1
49.	*Pediastrum tetras* (Ehrenb.) Ralfs	1	0
50.	*Pediastrum duplex* var. *reticulatum*	0	1
51.	*Pediastrum ovatum* (Ehr.) A. Braun	1	0
52.	*Pediastrum clathratum* var. *baileyanum*	1	0
53.	*Pediastrum biradiatum* Meyen	1	0
54.	*Pandorina morum* (Muell.) Bory	0	1
55.	*Scenedesmus opoliensis* Richter	1	1
56.	*Scenedesmus quadricauda* var. *minutum*	1	1
57.	*Scenedesmus acutiformis* Schroeder	0	1
58.	*Scenedesmus quadricauda* var. *maximum*	0	1
59.	*Spirogyra condensate* (Vauch.) Kuetzing	1	1
60.	*Spirogyra ellipsopora* Transeau	1	1
61.	*Spirogyra pratensis* Transeau	1	1
62.	*Spirogyra Weberi* Kuetzing	1	1
63.	*Spirogyra aquinoctialis* G. S. West	0	1
64.	*Staurastrum manfeldtii* Delponte	1	0
65.	*Staurastrum sebaldii* Reinsch	1	1
66.	*Staurastrum anaticum* Cook & Wills	0	1
67.	*Staurastrum glabrum* var. *depressum*	1	0
68.	*Staurastrum uniseriatum*	1	0
69.	*Tetraedron minimum*(A. Braun) Hansgirg	1	0
70.	*Tetraedron muticum*(A. Braun) Hansgirg	0	1
71.	*Tetraedron incus* (Teling) G. M. Smith	1	1
72.	*Tetraedron regulare* Kuetzing	1	0
73.	*Tetraedron limneticum* Borge	1	0
74.	*Tetrastrum triangulare* Korsh	1	0
75.	*Trachaelomonas volvocina* Ehrenberg	1	1
76.	*Trachaelomonas hispida* var. *papillata* Skvortzow	1	1
77.	*Trachelomonas* sp.	0	1
78.	*Zygnema pectinatum* (Vauch.) C. A. Agardh	1	0
C.	**Class: Chrysophyceae**		
79.	*Dinobryon sociale* Ehenberg	1	0
80.	*Dinobryon divergens* Imhof	1	0
D.	**Class: Dinophyceae**		
81.	*Peridinium ciculiferum* Lemmermann	1	0
82.	*Gymnodinium palustre* Schilling	1	0
E.	**Class: Bacillariophyceae**		
83.	*Amphora ovalis* Kuetzing	1	1
84.	*Asterionella formosa* Hassall	1	1
85.	*Cymbella affinis* Kuetz.	1	0
86.	*Cymbella lanceolata* Kirchner	1	0
87.	*Cymbella tumida* (Berb.) V. H.	0	1
88.	*Cyclotella meneghiniana* Kuthz.	0	1
89.	*Cyclotella striata* (Kutz.) Grun.	1	0
90.	*Coscinodiscus ecentricus* Erhenberg	1	0
91.	*Diploneis puella* (Schu.) Cl. Pascher	1	0
92.	*Diatoma vulgares* Bory de Saint-Vincent	0	1
93.	*Eunotia minuta* F. W. Hilse	0	1
94.	*Gomphonema parvulum* (Kuetzing) Kuetzing	0	1
95.	*Gomphonema subventricosum* F. Hustedt	1	1
96.	*Gomphonema intricatum* var. *bohemicum*	0	1
97.	*Gyrosigma acuminatum* (Kützing) Rabenhorst	1	0
98.	*Licmophora abbreviate* C. Agardh	1	0
99.	*Melosira granulate* (Ehrenberg) Ralfs	0	1
100.	*Melosira islandica* O. Mull.	1	0
101.	*Navicula capitatoradiata* Germain	1	0
102.	*Navicula papula* A.W.F. Schmidt	1	1
103.	*Navicula radiosa* Kuetzing	1	1
104.	*Navicula trivialis* Lange-Bertalot	1	0
105.	*Navicula viridis* Ehrenberg	1	0
106.	*Navicula minuta* (Cleve.) A. Cl.	1	1
107.	*Nitzschia archibaldii* Lange-Bertalot	0	1
108.	*Nitzashia closterium* W. Smith	0	1
109.	*Nitzschia palea* (Kutz.) W. Smith	0	1
110.	*Pinnularia viridis* (Nitzsch) Ehrenberg	1	1
111.	*Pinnularia nobilis* (Ehrenberg) Ehrenberg	1	1
112.	*Pinnularia debesii* Hustedt	1	0
113.	*Rhopalodia gibba* (Ehr.) O. Miill, G.M. Smith	1	1

Table 1 cont....

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114.	*Surirella tenuissima* Hustedt	0	1
115.	*Synedra ulna* (Nitzsch) Ehrenberg	0	1
116.	*Synedra acus* Kuetzing	0	1
F.	**Class: Euglenophyceae**		
117.	*Euglena acus* Ehrenberg	0	1
118.	*Euglena gracilis* Klebs	0	1
119.	*Phacus orbicularis* Huebner	0	1
120.	*Phacus pyrum* (Ehrenb.) Stein	0	1
	Total	**69**	**82**

R_B - Phytoplankton before anthropogenic activity of Rajaram reservoir.
R_A - Phytoplankton after anthropogenic activity of Rajaram reservoir.

and this is also supported by Gunale & Balakrishnan (1981). According to Palmer, 60 genera and 80 species are most tolerant to organic pollution, which provided algal genus and species indices for the evaluation of organic pollution of water bodies. These species also indicate nutrient enrichment of aquatic bodies (Kumar 1990, Zargar & Ghosh 2006). Same genera were recorded in the present investigation. Table 3 shows the list of most pollution tolerant phytoplankton species according to Palmer, and these species are absent before anthropogenic activities but found after the activities. The presence of these species after festival activities is an indication of water pollution due to nutrient enrichment.

Table 2: Class-wise observed phytoplankton.

Sr. No	Observed Classes	Total no. of species observed before anthropogenic activities	Total no. of species observed after anthropogenic activities	Species observed only before anthropogenic activities	Species observed only after anthropogenic activities	No. of similar species	No. of dissimilar species
A.	Cyanophyceae	07	14	00	07	07	07
B.	Chlorophyceae	37	42	23	26	15	49
C.	Chrysophyceae	02	00	02	00	00	02
D.	Dinophyceae	02	00	02	00	00	02
E.	Bacillariophyceae	21	22	12	13	09	25
F.	Euglenophyceae	00	04	00	04	00	04
	Total	69	82	38	51	31	89

Table 3: Most pollution tolerant species as per Palmer (1969), observed after anthropogenic activities.

Sr. No	Name of species
1.	*Nitzschia palea*
2.	*Scenedesmus quadricauda* var. *minutum*
3.	*Oscillatoria tenuis*
4.	*Synedra ulna*
5.	*Ankistrodesmus falcats*
6.	*Pandorina morum*
7.	*Cyclotella meneghiniana*
8.	*Euglena gracilis*
9.	*Gomphonema parvulum*
10.	*Eudorina elegans*
11.	*Euglena acus*
12.	*Phacus pyrum*
13.	*Melosira granulate*
14.	*Diatoma vulgares*
15.	*Synedra acus*
16.	*Coelastrum microporum*
17.	*Pediastrum duplex* var. *reticulatum*
18.	*Tetraedron muticum*

Cyanophyceae, Chlorophyceae and Euglenophyceae making a fear that the day is not far that will extinct the Rajaram reservoir.

Palmer's algal pollution indices: Palmer (1969) has shown that the genera like *Oscillatoria*, *Euglena*, *Scenedesmus*, *Chlamydomonas*, *Navicula*, *Nitzschia*, and *Ankistrodesmus* are the species generally found in organically polluted waters, and this is also supported by Gunale & Balakrishnan (1981).

Table 6 and Fig. 4 show Palmer's algal genus and species indices. It is concluded that number of pollution tolerant algal genera and species are getting increased after anthropogenic activities. The Palmer's algal genus index value gets doubled after festival activities and Palmer's algal species index, which is zero before festival activities, shows high value after the activities. The increased genera and species belong to the list of pollution tolerant genera and species of Palmer. Thus, on account of anthropogenic activities, the Rajaram reservoir's organic pollution level gets vastly elevated.

Simpson diversity index: It is another important index, widely used in determining the water quality and its monitoring. The present investigation indicates that the Simpson diversity index is increased after the anthropogenic activities (Table 6 and Fig. 4). This shows that how rapidly deterioration of the quality of reservoir water is going on per year due to these activities.

Kothe's species deficit index (1962): The index is based on the principle i.e., in an ecosystem the number of species decreases after they are exposed to pollution. The index is mostly related to addition of organic matter, idol immersion and mattress washing, which increase the nitrogen and phosphorous contents in waters. It affects the composition of existing species and replaced by new species which are

Table 4: Diversity indices according to class.

Sr.No.	Observed Classes	Odum's index for sp. observed before anthropogenic activities	Odum's index for sp. observed after anthropogenic activities	Similarity index	Dissimilarity index
A.	Cyanophyceae	93.33	181.82	0.666	0.334
B.	Chlorophyceae	480.52	545.45	0.379	0.621
C.	Chrysophyceae	26.67	0	0	01
D.	Dinophyceae	26.67	0	0	01
E.	Bacillariophyceae	280	285.71	0.418	0.582
F.	Euglenophyceae	0	51.95	0	01

Table 5: Diversity indices according to Nygaard (1949).

Sr.No.	Observed Classes	Calculations	Oligotrophic	Eutrophic	Nygaard's algal index for sp. observed before anthropogenic activities	Nygaard's algal index for sp. observed after anthropogenic activities
A.	Myxophycean	Myxophyceae / Desmideae	0.0 - 0.4	0.1 - 3.0	0.43	1.27
B.	Chlorophyceae	Chlorococcales / Desmideae	0.0 - 0.7	0.2 - 9.0	2.31	3.81
C.	Diatom	Centric Diatoms / PinnateDiatoms	0.0 - 0.3	0.0 - 1.75	2.00	0.66
D.	Euglenophyceae	Euglenophyte / Myxophyceae + Chlorococcales	0.0 - 0.7	0.01 - 0.1	0.00	0.07
E.	Compound	Myxo. + Chloro. + Centric diatoms + Euglenophyceae / Desmideae	0.01 - 1.0	1.2 - 2.5	2.87	5.63

pollution tolerant. The species number gets increased after increase in pollution, so after anthropogenic activities the Kothe's species deficit index is high (Table 6 and Fig. 4).

A number of workers have reported many algal species as indicators of water quality (Naik et al. 2005, Nandan & Aher 2005, Zargar & Ghosh 2006). The algal genera like *Euglena, Oscillatoria, Scenedesmus, Navicula, Nitzschia* and *Microcystis*, are the taxa found in organically polluted waters (Nandan & Aher 2005). Similar genera were also recorded in the present study. The epilithic and epiphytic algae are excellent indicators of water pollution (Round 1965). In this study, occurrence of *Oscillatoria* as epilithic and *Gomphonema* as epiphytic algae were recorded. The algae like *Microcystis aeruginosa* was used as the best single indicator of pollution and it was associated with the highest degree of organic pollution (Nandan & Aher 2005). In the present study, similar phytoplankton were recorded mostly after the anthropogenic activities.

CONCLUSION

Phytoplankton communities are sensitive to changes in their environment and, therefore, many phytoplankton species are used as an indicator of water quality. The study on assessment of idol immersion and mattresses washing on phytoplankton diversity revealed that these activities cause a negative impact on water quality of the reservoir. The inputs of biodegradable and nonbiodegradable substances during idol immersion and mattresses washing at Navratra festival caused deterioration of water quality, which affects phytoplankton composition and diversity. Thus, the present study gives warning sign about not only Rajaram reservoir but also similar type of anthropogenic activities on other reservoirs. If these activities cannot stop, the day is not long when the Rajaram reservoir will be converted into land.

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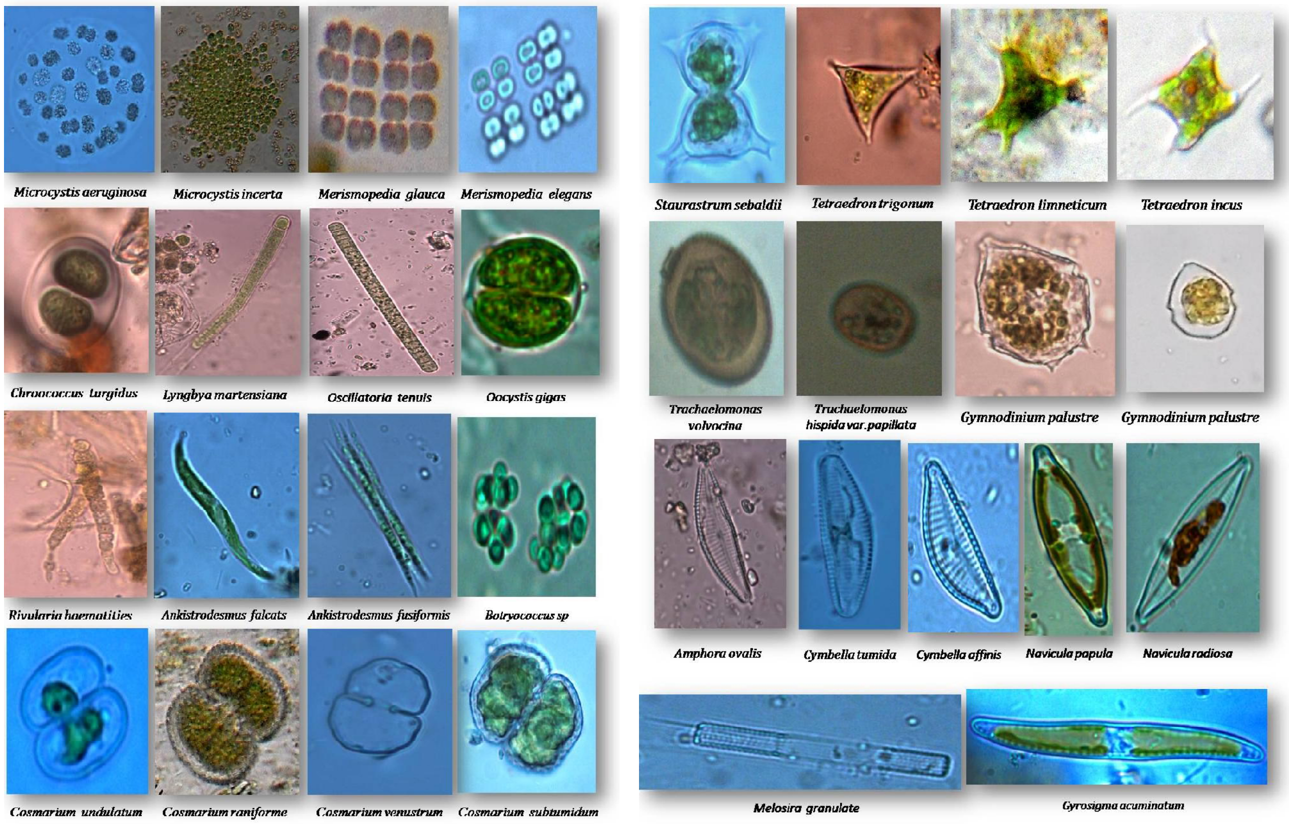

Fig. 5: Photomicrographs of common algal species in Rajaram reservoir.

Table 6: Genera, species and diversity indices.

Sr. No.	Name of Index	Before	After
1.	Palmer algal genera index	15	28
2.	Palmer algal species index	00	26
3.	Simpson diversity index	2.6095	2.7931
4.	Kothe's species deficit index (%)	16.216	37.805

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