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Phytoplankton Diversity Related to Pollution from Mula River at Pune City

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ABSTRACT

Water samples were collected monthly (during October 2007 to September 2008) at three selected sampling stations (station I: Wakad; station II: Aundh; station III: Dapodi) from Mula River, Pune City. Collected water samples were analyzed qualitatively and quantitatively for their algal population. A total of 162 algal species belonging to 75 genera were recorded at selected sampling stations at Mula River throughout the study period. Among the different groups, Chlorophyceae was the most abundant followed by Bacillariophyceae, Cyanophyceae and Euglenophyceae. The greatest algal population was recorded at station III followed by stations II and I. Maximum abundance of *Scenedesmus quadricauda*, *Chlorella vulgaris*, *Oscillatoria limosa* and *Melosira granulata* at stations II and III throughout the year showed that these algal species could be considered as bioindicators of organic pollution. Algal monitors showed that water at stations II and III are highly polluted with organic pollutants in the Mula River. Highest algal populations were observed in April, May and June, i.e., summer, and fewest in winter and the monsoon season.

Keywords: algae, algal population, water pollution, indicator

INTRODUCTION

Rivers are one of humankind's most valuable resources. Millions of people all over the world live on the banks of rivers and depend on them for their survival. Rivers have provided water for populations and industries as a navigation route for materials and commerce (Neal *et al*. 2006). Over the last century rivers throughout the world have become increasingly pollution due to increasing pressure from human activities which affects their ecological equilibrium, inevitably affecting the flora and fauna of water bodies.

The increasing population of India has resulted in an increase in waste matter generation, which in turn leads to the pollution of aquatic ecosystems. The River Mula is one of the major rivers that originates in the Western Ghats region and runs through the Pune area and Pune City, receiving treated and untreated effluents, resulting in eutrophication. A huge quantity of untreated domestic sewage significantly alters the physico-chemical properties of its water (Kshirsagar and Gunale 2011). This influences the biological imbalance both qualitatively and quantitatively. Algae are the most ubiquitous natural inhabitants of water and typically inhabit aquatic environments (Mohan *et al*. 2002). Algae tend to be directly affected by physical, chemical and environmental factors of water bodies. Algae have very short life cycles and rapid reproduction (McCormick and Cairns 1994; Hu *et al*. 2007); therefore, they respond rapidly to a wide range of pollutants and are potentially useful as early warning signals of deteriorating conditions and possible causes (McCormick and Cairns 1994; Francoeur *et al*. 1999; Ekelund and Aronsson 2007; Hu *et al*. 2007). An abundance of algae is indicative of nutrient pollution (Palmer 1959) and are widely used for river quality assessments (Prygiel *et al*. 1999; Whitton and Kelly 1995; Rott *et al*. 2003). A great deal of research has been done mainly with physico-chemical parameters and the correlation between algal growth in polluted and non-polluted water (Gunale and Balkrishanan 1981; Reddy and Venkateswarlu 1986; Tripathy 1989; Mohapatra and Mohanty 1992; Nandan and Aher 2005; Sharma *et al*. 2009).

Increasing urbanization and industrialization in Pune City over the last two to three decades has strongly impacted the level of pollution of the river water. Therefore, the present study aimed to assess the status of water quality at different sampling stations located on the Mula River in Pune City using algal diversity in relation to pollution.

MATERIALS AND METHODS

Study area and sampling stations

Pune is located 560 m above mean sea level (180 31' N, 730 51' E) and lies on the western margin of the Deccan Plateau that spreads out on the banks of the Mula and Mutha Rivers. The Mula River originates in Western Ghats of Maharashtra State, India and enters into the Pune metropolitan area near Wakad and merges with the Mutha River in Pune City. For the present study, Mula River water was collected monthly from three sampling stations between upstream at Wakad (station I); Aundh (station II) and downstream at Dapodi (station III) before it merges with the Mutha River on the basis of drainage pattern and activities in its catchment area (**Fig. 1**).

Collection and analysis of algal samples

The water samples for algal analysis were collected monthly from October 2007 - September 2008 at selected sampling stations I, II and III. Water samples were collected in the morning from 9.00 am to 12.30 pm. Algal collection was done by using a plankton net made of bolting silk cloth of 80 mesh/cm. A qualitative and quantitative study of four groups of algae, viz. Bacillariophyceae, Cyanophyceae, Chlorophyceae and Euglenophyceae, was carried out. The diversity of algae was studied for the qualitative analysis of algae. Algal taxa were identified by referring to relevant standard monographs and keys (Smith 1950; Prescott 1951; Desika-

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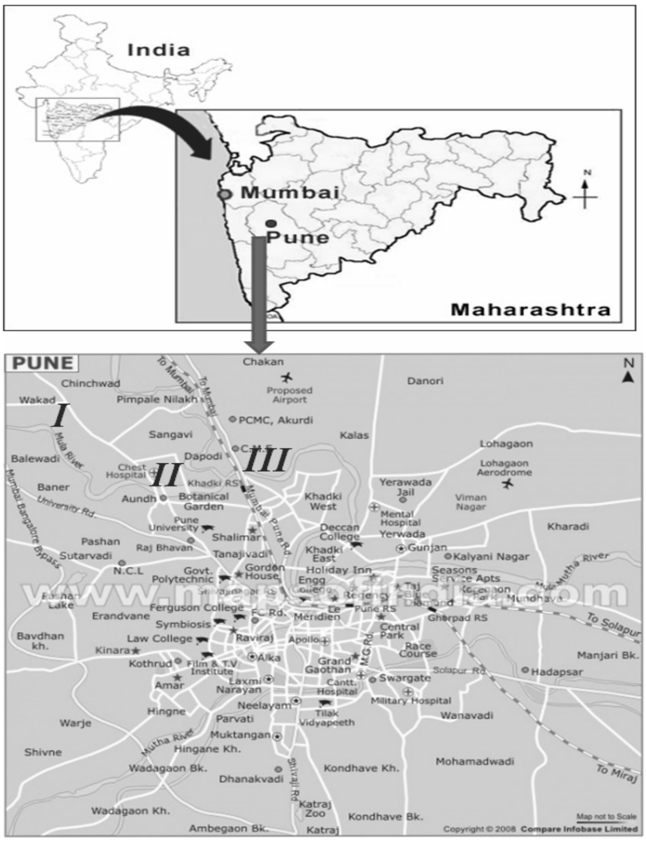

Fig. 1 Map showing geographical localities of sampling stations (station I, II and III). Map is only representative and distances are not to the scale.

chary 1959; Randhawa 1959; Ramnathan 1964; Sarode and Kamat 1984). Phytoplankton was counted by the drop count method or Lackey's drop method as mentioned in APHA (1998).

RESULTS AND DISCUSSION

Algal samples were collected monthly between October 2007 and September 2008 from the Mula River at sampling stations I, II and III in Pune City. The collected algal samples were analyzed qualitatively and quantitatively. Monthly and seasonal variations in algae were studied. During monsoon months, particularly in September, water flow in the river was fast and the river water was turbid. Therefore, algal growth was very low in the monsoon season. During the winter months (October to January), water flow in the river was reduced and during these months algal growth was visible while in the summer months (February to May), higher algal growth was observed.

A qualitative analysis of algae in the water samples throughout the study period showed high algal diversity. A total of 75 genera and 162 species of algae were recorded from three sampling stations of the Mula River throughout the study period (**Table 1**). Four groups of algae (Chlorophyceae, Bacillariophyceae, Cyanophyceae and Euglenophyceae) were recorded during the study (**Figs. 2A-D, 3**). The algal population was more abundant at stations II and III than at station I which is upstream; there are significant anthropogenic activities in the former two stations. In addition, the water continued to flow throughout the study period at station I. The range of these four algal groups fluctuated throughout the study period, varying from station to station and month to month, possibly due to discharge of waste into the river. The Chlorophyceae were dominant throughout the study period followed by Bacillariophyceae and Cyanophyceae. Members of the Euglenophyceae had the least population at all stations during the study period. Of these, 37 genera and 75 species belong to the Chlorophyceae, 19 genera and 39 species to the Bacillariophyceae,

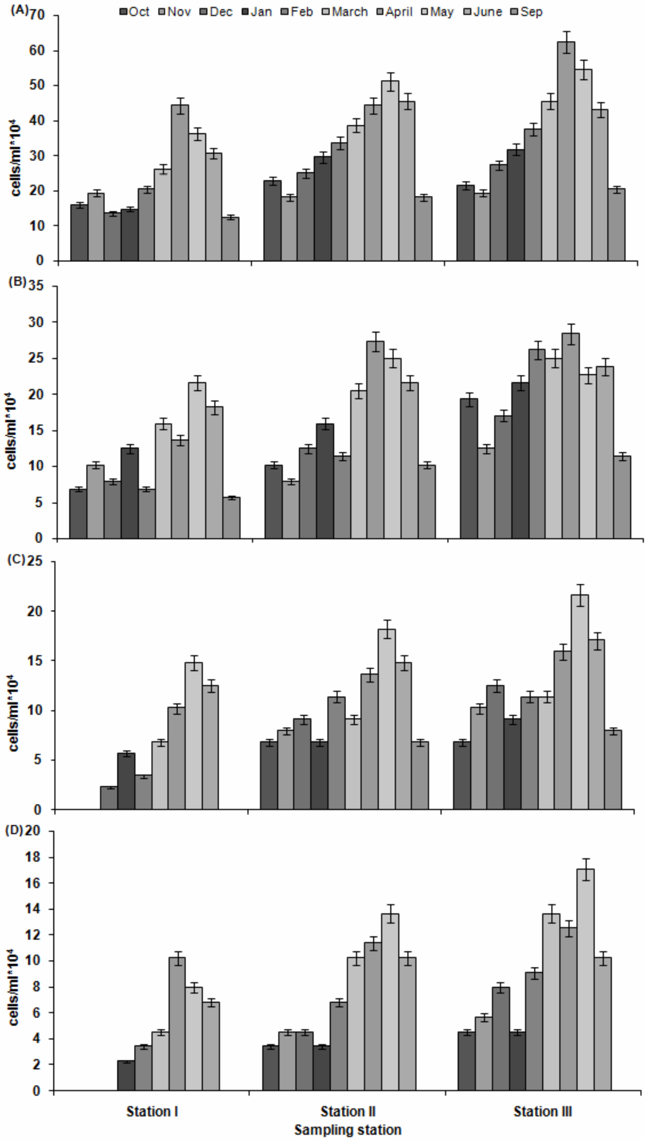

Fig. 2 Monthly variation in quantitative analysis (cells/ml*10[4]) of different algal (A: Chlorophyceae; B: Bacillariophyceae; C: Cyanophyceae; D: Euglenophyceae) groups at selected sampling station of Mula river for the period of October 2007 to September 2008.

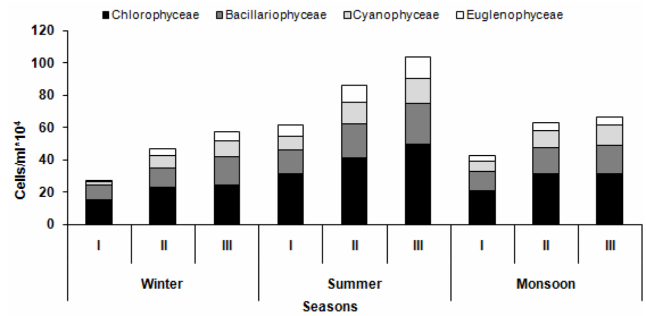

Fig. 3 Seasonal variation in quantitative analysis (cells/ml*10[4]) of four groups of algae at selected sampling station of the Mula River for the period of October 2007 to September 2008.

14 genera and 34 species belong to Cyanophyceae and 5 genera comprises 14 species belong to Euglenophyceae. Earlier, Kshirsagar and Gunale (2011) reported an increase in temperature, free CO_2, COD, BOD, chloride, nitrate, phosphate, total hardness and total alkalinity but a decrease in concentration of DO at stations II and III relative to station I. As the Mula River gradually flows downstream, it receives large inputs of nutrients/pollutants such as phos-

phates and nitrates (Kshirsagar and Gunale 2011).

Chlorophyceae was the dominant and most diversified group at all stations (**Table 1; Figs. 2A, 3**). Chlorophyceae was represented by the orders Volvocales, Tetrasporales, Oedogonials, Ulothrichales, Desmidiales, Chaetophorales, Cladophorales, Chlorococcales and Zygnematales. Genera such as *Scenedesmus*, *Pandorina*, *Pediastrum*, *Coelastrum*, *Chlorella*, *Ankistrodesmus*, *Micractinium*, *Spirogyra*, *Closterium*, *Staurastrum*, *Cosmarium*, *Closterium*, and *Actinastrum* were common. *Scenedesmus quadricauda*, *Chlorella vulgaris* and *Pediastrum duplex* were abundant at stations II and III. The Chlorophyceae was the dominant group with highest density during April and May at stations II and III which are polluted with organic pollutants and least in September at station I, which is less polluted. Similar observations were recorded by Pandey *et al*. (1995) in the Kosi River. According to Round (1957), the presence of Chlorophyceae in eutrophic water is due to its high nutrient content. Rama Rao *et al*. (1978) observed green algae to be indicators of highly polluted water. Prasad and Singh (1982) found that sewage contamination favored the growth of Chlorophyceae.

As the water temperature increases species like *Chlorella*, *Scenedesmus*, *Pediastrum*, *Ankistrodesmus*, *Coelastrum*, *Cosmarium* and *Dictyosphaerium* became more abundant. Chlorophyceae was dominant at all stations during the study period, being higher in summer. Sedamker and Angadi (2003) showed that higher alkalinity, nitrate, phosphate and BOD increased the growth of Chlorophyceae. Our results are similar to those of Sharma and Lyngdon (2003), and Sheeba and Ramanujan (2005). *Scenedesmus*, *Chlorella* and *Pediastrum* grew well at stations II and III, showing the polluted nature of the river. Palmer (1980) stated that *Scenedesmus* indicates eutrophic water. *Hydrodictyon*, *Zygnema*, *Tetraspora* and desmids were dominant at station I showing the unpolluted nature of the river. Generally *Cosmarium*, *Euastrum*, *Staurastrum* are recorded when the DO level is high (Ngearnpat and Peerapornpisal 2007). *Cosmarium* and *Closterium* indicate the mesotropic nature of water (Khan 1991). Coesel (1996) noticed desmids to be highly diverse and sensitive unicellular green algae that serve as biological indicators of the health of water bodies. Venkateshwarlu (1983) revealed that the dominance of desmids indicates the oligotrophic nature of the water body.

Bacillariophyceae was the second largest group encountered during the study period. *Gomphonema*, *Melosira*, *Cymbella* and *Fragilaria* found frequently and abundantly at all stations. *Melosira granulata*, *Synedra ulna*, *Cymbella affinis*, *Nitzschia palea* and *Cyclotella meneghiniana* were frequently found at stations II and III, which are organically polluted. *Diatomella*, *Cocconeis*, and *Caloneis* were found at station I which is less polluted than stations II and III. High BOD and a low level of DO favor the growth of diatoms. Venkateshwarlu (1983) stated that a decrease in levels of DO and high BOD raised the values of chlorides, nitrate and phosphate, favoring the growth of diatoms like *Nitzschia*, *Navicula*, *Melosira*, *Synedra*, *Fragilaria*, *Cyclotella* and *Gomphonema*. From sampling stations II and III pollution-tolerant genera that were recorded were *Melosira*, *Gomphonema*, *Nitzschia*, *Synedra*, *Navicula*. More *et al*. (2005) made similar observation in the Panzara River from Maharashtra.

At stations II and III, *Nitzschia palea*, *Synedra ulna*, *Cyclotella meneghiniana*, *Melosira granulate*, and *Navicula viridula* were recorded as these stations are organically polluted (Kshirsagar and Gunale 2011) which favors the growth of diatoms. Growth of *Nitzschia palea* is a typical example of phosphate-enriched or organically polluted waters (Fore and Grafe 2002).

Low occurrence of Cyanophyceae was recorded during the monsoon season, possibly because of a dilution of nutrients due to rain. *Merismopedia* and *Arthrospira* were recorded from station I which was least polluted. Members of *Oscillatoria* showed more diversity among Cyanophyceae members. *Oscillatoria limosa*, *Oscillatoria tenuis*, *Oscillatoria princeps*, *Microcystis aeruginosa* were found at station II and III frequently during summer which were organically polluted stations. *Merismopedia glauca*, *Merismopedia elegans*, *Merismopedia minima*, *Arthrospira massartii* which were recorded from station I. In summer months like April and May blooms of *Microcystis* were observed at stations II and III. During summer more number was recorded might be due to availability of free CO_2, phosphate and nitrate concentration (Kshirsagar and Gunale 2011). Our results correlated with the results obtained by More *et al*. (2005) in the case of Panzara River. Our result correlates with Rai (1978) who observed a Cyanophyceae peak during summer and low during monsoon seasons. Prescott (1951) and Singh (1953) showed *Microcystis aeruginosa* to be the best indicator of organic pollution. The abundance of Cyanophyceae was attributed to favorable contents of oxidizable organic matter and less DO observations also showed by Vijaykumar *et al*. (2005).

In the month of April and May the number was remarkable while in September fewer or no Euglenophyceae were recorded. Euglenophyceae consist mainly species of *Euglena*, *Phacus*, *Trachelomonas*, *Lepocinclis*, *Petalomonas*. *Trachelomonas* represented by *T. volvocina*, *T. horrid*, *T. dubia*. *Trachelomonas volvocina* is mainly found at station I and *Euglena oxyuris*, *E. acus*, *Phacus acuminatus* recorded from station II and III. *Phacus* and *Euglena* are pollution indicator genus which shows organically polluted water. During study station II and III that favors the growth and population of Euglenophyceae. Saxsena *et al*. (1959) reported that Euglenophyceae prefers the lower oxygen. Our results also showed more number of Euglenophyceae member in summer season when temperature was raised, high organic matter and DO was low (Kumar *et al*. 1974; Pawar *et al*. 2006). During summer *Euglena* and *Phacus* were recorded at station II and III. At these station pollution tolerant genera were recorded indicate the organic pollution. Members of the Euglenophyceae were completely absent during September at all station while Cyanophyceae completely absent in the month of October, November and September at station I. At station II and III maximum population of Chlorophyceae during summer season followed by monsoon and winter season. A similar trend was earlier observed by Sakhre and Joshi (2003).

CONCLUSION

The effect of pollution can be evaluated by studying the diversity and composition of algal flora and can be used for indicators of pollution. High polluted water has some tolerant phytoplankton species such as *Scenedesmus*, *Chlorella*, *Euglena*, *Oscillatoria*, *Melosira*, *Nitzschia*, *Fragilaria* which were recorded from downstream stations. Similar observation recorded by Goel *et al*. (1986). The occurrence of certain pollution tolerant species such as *Microcystis*, *Oscillatoria*, *Chlorella*, *Scenedesmus*, *Ankistrodesmus*, *Fragilaria*, *Euglena* and *Phacus* clearly indicates organic pollution (Palmer 1969; Tiwari and Shukla 2007). The algae from station II and III which were polluted water showed the dominance of *Scenedesmus quadricauda*, *Chlorella vulgaris*, *Oscillatoria limosa* and *Melosira granulata* throughout the year, which are considered to be indicators of organic pollution.

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Table 1 Qualitative analysis of algal species encountered during study period at three sampling stations of Mula River, Pune (October 2007-September 2008).

Name of algal species	Stations		
	I	II	III
CHLOROPHYCEAE			
Actinastrum hantzschii Lagerheim	+	+	-
Ankistrodesmus falcatus (Corda) Ralfs.	-	+	+
Ankistrodesmus convolutes Corda	-	-	+
Characium orissicum Philipose	-	+	+
Chlamydomonas angulosa Dill	-	-	+
Chlorella vulgaris Beijerinck	+	+	+
Chlorella pyrenoidosa Chick.	-	+	+
Chlorococcum humicola (Naegeli) Rabenhorst	-	-	+
Chlorococcum infusionum (Schrank) Meneghini	-	-	+
Closterium moniliferum (Bory) Ehr.	-	+	+
Closterium parvulum Nag.	+	-	-
Closterium lanceolatum (Kuetzing)	-	+	-
Closteriopsis longissima Lemm.	-	-	+
Coelastrum microporum Naegeli	-	-	+
Coelastrum sphaericum Naegeli	+	+	-
Coelastrum cambricum Archer.	+	-	+
Cosmarium constractum Kirchn.	-	+	-
Cosmarium granatum Breb.	+	+	-
Cosmarium speciosissimum Schmidle	-	+	-
Cosmarium pseudoprotuberans var. *tumidum* Borge	+	-	-
Cosmarium formosulum Hoffman.	-	+	+
Cosmarium gostyniease (Racid) Gronbl. var. *umbonatum* (Turn.) Krieger & Gerloff	+	-	+
Cosmarium sexangulare Lund.	-	+	+
Cosmarium hammeri Reinsch. var. *protubrans* West and G. S. West	+	-	-
Crucigenia lauterbornii Schmidle	-	-	+
Crucigenia crucifera (Wolle) Collins	-	-	+
Cylindrocystis brebissonii Menegh.	-	-	+
Dictyospharium pulchellum Wood	-	-	+
Eudorina elegans Ehrenberg	-	-	+
Eudorina indica Iyengar	-	+	+
Euastrum spinulosum Delponle. var. bellum Scott and Prescott	+	-	-
Euastrum verrucosum Ehr.	+	-	-
Euastrum sp.	+	-	-
Golenkinia paucispspina West and West	-	-	+
Hydrodictyo reticulatum (L.) Lagerheim	+	-	-
Kirchneriella contorta (Schmidle) Bohlin	-	+	-
Lagerheimia sp	-	-	+
Monoraphidium contortum (Thru.) Kom. Legn.	-	+	+
Micractinium pusillum Frescenius	-	+	+
Oedogonium formosum Kam.	-	+	+
Oocystis pusilla Hansgirg	-	-	+
Oocystis sp.	-	-	+
Pandorina morum (Muellre) Bory	+	+	+
Pandorina sp.	-	+	+
Pediastrum boryanum (Turpin) Meneghini	-	+	+
Pediastrum ovatum (Ehr.) A. Braun	-	+	+
Pediastrum simplex var. deodenarium Bailey	+	+	-
Pediastrum simplex Meyen var. deodenarium (Bailey) Rabenhorst	+	+	+
Pediastrum duplex Meyen	+	-	-
Pediastrum tetras (Ehr.) Ralfs	-	-	+
Pediastrum sp.	+	-	+
Rhizoclonium crassipellitum West and West	+	+	-
Scenedesmus bijugatus (Turpin) Kuetz.	-	-	+
Scenedesmus obliquus(Turpin) Kuetz.	+	+	-
Scenedesmus quadricauda (Turpin) Brbisson var. quadrispina (Chodat) G. M. Smith	-	+	+
Scenedesmus acuminatus (Lagerheim) Chodat	+	-	+
Scenedesmus arcuatus (Lemm.)	-	+	+
Scenedesmus dimorphus (Turpin) Kuetzing	+	-	-
Scenedesmus bijugatus var. *graevenitzii* (Bernard) comb. Nov.	-	+	+
Scenedesmus longus Meyen var. dispar (Brebisson) G. M. Smith	+	-	-
Scenedesmus hystrix Lagerheim	-	+	-
Selenastrum minutum (Naegeli) Collins	-	+	+
Spirogyra singularis Nordstedt.	+	-	-
Spirogyra grevilleana (Hassall) Kuetzing	-	+	-
Staurastrum gracile Ralfs.	+	+	-
Staurastrum chaetoceras (schrod.) G.M. Smith	+	-	-
Staurastrum sebeldi Reinsch.	+	-	-
Stigeoclonium tenue (C. A. Ag.) Kuetz.	-	-	+
Schoroederia indica Philipose	-	+	-

Table 1 (Cont.)

Name of algal species	Stations		
	I	II	III
CHLOROPHYCEAE (Cont.)			
Tetraedron minimum (A. Braun) Hansgirg	-	-	+
Tetraedron sp.	-	-	+
Tetrastrum elegans Playfair	-	-	+
Tetraspora lubrica (Roth)	+	-	-
Ulothrix zonata Weber et Mohr. Kuetzing	-	-	+
Zygnema pectinatum (Vauch.) C. A. Agardh	+	-	-
BACILLARIOPHYCAEAE			
Asterionella formosa Hass.	-	+	-
Achnanthe sminutissima (Kuetzing) Cleve	-	-	+
Amphora acutiuscula Kuetz.	-	-	+
Caloneis silicula (Ehr)	+	-	-
Cocconeis placentula Ehrenb.	+	-	-
Cocconeis sp.	+	-	
Cyclotella meneghiniana Kuetz.	-	+	+
Cyclotella glomerata Bachmann	-	-	+
Cymbella affinis Kuetzing	+	+	+
Cymbella sp.	+	-	+
Diatomella sp.	+	-	-
Fragilaria intermedia Grun	+	+	-
Fragilaria brevistriata Grun	+	+	+
Fragilaria virescens Ralfs.	-	+	+
Fragilaria construens (Ehr.)	-	-	+
Gomphonema constrictum var. *capitula* Cleve	+	+	+
Gomphonema angustatum Kuetz.	-	+	-
Gomphonema intricatum Kuetz.	-	+	+
Grysosigma kuetzingii (Grun) Cleve	-	-	+
Hantschia amphioxys (Ehrenberg) Grunoro	-	+	+
Mastogloia smithii Thwaites	-	+	+
Mastogloia baltica Grun.	-	+	-
Melosira granulata (Ehr.) Ralf.	+	+	+
Melosira sp.	+	+	+
Navicula cuspidata var. *ambigua* (Ehr.) Cleve	-	+	+
Navicula grimmi Krasske	+	+	-
Navicula viridula Kuetz.	-	+	-
Navicula placentula (Ehr) Grun.	+	-	-
Nitzschia palea (Kuetz.) W.M. Smith	-	+	+
Nitzschia thermalis Kuetz.	-	-	+
Nitzschia mediocris Hustedt	-	+	-
Nitzschia sublinearis Hustedt.	-	+	+
Nitzschia regula Husdet var. *fennica* A. Cl.	-	-	+
Pinnularia dolosa Gandhi	-	+	-
Pinnularia sp.	-	-	+
Synedra ulna (Nitzch) Ehrenb.	-	+	+
Synedra acus Kuetz.	-	-	+
Synedra affinis Kuetz. var. *fasciculata*	-	+	+
Surirella robusta Ehrenb.	-	+	+
CYANOPHYCEAE			
Anabaena spiroides Klebahn	-	-	+
Anabaena sp.	-	-	+
Aphanocapsa pulchra (Kutz) Rabenh	-	+	-
Aphanocapsa biformis A. Br.	-	+	-
Aphanothece clathra W.et G.S.West	-	+	+
Arthrospira massartii Kuffareth	+	-	-
Chroococcus giganteus W. West	-	+	+
Chroococcus minor (Kutz.) Nag.	-	-	+
Chroococcus turgidus (Kuetz.) Nag	-	+	-
Calothrix marchica Lemm.	-	-	+
Gleocapsa luteofusca Martens	-	+	+
Gleocapsa atrata (Turp.) Kuetz.	-	+	-
Lyngbya contorta Lemm.	-	+	-
Lyngbya connectens Bruhlet Biwas	-	-	+
Lyngbya borgerti Lemmermann	-	+	+
Merismopedia minima Beck.	+	-	-
Merismopedia elegans A. Br.	+	-	-
Merismopedia glauca (Ehrenberg) Kuetz	+	-	-
Myxosarcina spectabilis Geitler (Orig)	-	+	-
Microcystis robusta (Clark) Nygaard	-	+	+
Microcystis aeruginosa Kuetz	-	-	+
Oscillatoria chalybea (Mertens)	+	+	+
Oscillatoria animalis Ag	-	-	+

Table 1 (Cont.)

Name of algal species	**Stations**		
	I	**II**	**III**
CYANOPHYCEAE (Cont.)			
Oscillatoria princeps Vaucher (orig)	-	+	+
Oscillatoria princeps Vaucher (after Fremy)	-	+	+
Oscillatoria limosa Ag. *ex*. Gomont	-	+	+
Oscillatoria tenuis C.A.Agardh	-	+	+
Oscillatoria agardhii Gomont	+	-	-
Oscillatoria sancta Kuetz.	+	-	-
Oscillatoria subtilissima Kuetz.	+	-	-
Oscillatoria curviceps C.A. Agardh	-	+	-
Phormidium tenue (Menegh) Gom.	-	+	-
Phormidium calcicola Gardner	-	-	+
Spirulina major Kuetz.	-	+	+
EUGLENOPHYCEAE			
Euglena acus Ehr.	-	+	+
Euglena oxyuris Klebs	-	-	+
Euglena minuta Prescott	-	+	+
Euglena sp.	-	+	-
Euglena caudata Huebener	-	-	+
Lepocinclis ovum (Ehrenberg) Lemmermann	-	+	+
Phacus undulatum (Skv.) Pochm.	-	+	+
Phacus candatus Hubn.	-	+	+
Phacus acuminatus Stoccker	-	+	+
Phacus tortus (Lemm.) Skv.	-	-	+
Trachelomonas volvocina Playfair	+	-	-
Trachelomonas dubia Swirem.	+	-	-
Trachelomonas horrid Palmer	+	+	-
Petalomonas sp.	+	-	+

+ = present; - = absent

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