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Effect of anthropogenic activities on algal community in Ganol River, West Garo Hills, Meghalaya

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ABSTRACT
The study deals with the effect of anthropogenic activities on algal community in Ganol River, West Garo Hills, Meghalaya. Ganol river is the main source of water supply in Tura town but some part of the river is undergoing degradation due to anthropogenic activities. Water samples were collected from November 2015 to October 2016 in three selected sites. Algal communities in relation to physico-chemical parameters were studied. A total 140 algal species belonging to 7 classes were recorded from Ganol River. Bacillariophyceae, Chlorophyceae and Zygnematophyceae were recorded maximum from site 1 which is a undisturbed area, Euglenophyceae, Cyanobacteria and Chrysophyceae were found maximum from site 3, which is an anthropogenically affected area. Physico-chemical parameters like transparency, turbidity, temperature, dissolved oxygen, conductivity, nitrate, nitrite and phosphate varied significantly among the sites. There was a strong significant difference in species composition among the three different sites which was revealed by non-metric multidimensional scaling. Canonical corresponding analysis clearly revealed that only pollution indicator species showed positive correlation with phosphate, nitrate, nitrite, temperature, pH, conductivity and turbidity in anthropogenically affected area, which is adversely effected by the anthropogenic activities.
Keywords: Algal community, Physico-chemical parameters, anthropogenic activities

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INTRODUCTION

Discharge of wastes into water bodies is a common practice globally. Most of the rivers of the world receive millions of liters of sewage, domestic waste, industrial and agricultural effluents containing substances varying in characteristic from simple nutrients to highly toxic substances. Increase in population and consequent urbanizations are the most significant cause of pollution of aquatic ecosystem due to diverse kind of wastes produced by them (26) Algae which form the most important component of aquatic ecosystems as primary producer, are very sensitive to the changing environment and respond accordingly. The occurrence of algae in any aquatic ecosystem in relation to the prevailing environmental conditions particularly the physico-chemical factors of the medium in which they grow reflect the status of that water system (8). The presence of different algal groups in different proportions provides a precise idea about the health of the ecosystem and thus has been used as mean to detect the anthropogenic impact in an aquatic system. It is clearly demonstrated that there is predictable changes in algal growth and taxonomic composition in response to changes in pH, conductivity and nutrient enrichment (24). A good amount of work has been done all over the world to establish the fact that the algal community structures are very susceptible to different anthropogenic disturbances and thus algal community structure has been used as a common criterion to characterize the status of water bodies (19, 7 & 4).

Meghalaya is one of the important states of North Eastern region of India. It is a biodiversity hot spot and very rich in aquatic resources. Aquatic resource of Garo Hills, in the western part of Meghalaya which is still remained unexplored is getting degraded at fast pace due to population pressure. Ganol River is very important river of the area supplying drinking water to its most parts. Due to various human activities mainly dumping of commercial and domestic waste is affecting directly the aquatic organisms, particularly algae. Therefore, the present work was carried out to check the effect of anthropogenic activities on algal community in relation to its physico- chemical parameters.

MATERIALS AND METHODS

Study sites

Ganol River is one of the important river of West Garo Hills in Meghalaya, India. The river starts from Tura peak, located at 872 m.s.l, latitude 25^{0}31’12’’N and longitude 90^{0}13’12” E and runs towards the west through Damalgre, Mukdangre, Garobadha before it enters Goalpara district (Assam).The water is used for drinking, domestic, washing and irrigation purposes. Three sites in the river were selected which represent three zones exposed to different activities (Fig 1).

Site 1- Located at an elevation of 349.91m.s.l, with geographical coordination of 25^{0}34’53’’N latitude and 90^{0}14’84” E longitude. This site is undisturbed, away from human activities.

Site 2- Located at an elevation of 43.89 m.s.l, with geographical coordination of 25^{0}33’92’’N latitude and 90^{0}04’99” E longitude. This site of the river water is mainly used for domestic purposes and it is a sand mining area.

Site 3- Located at an elevation of 29.26 m.s.l, with geographical coordination of 25^{0}34’66’’N latitude and 90^{0}01’27” E longitude. This site of the river water is heavily degraded due to deposition of commercial and domestic wastes.

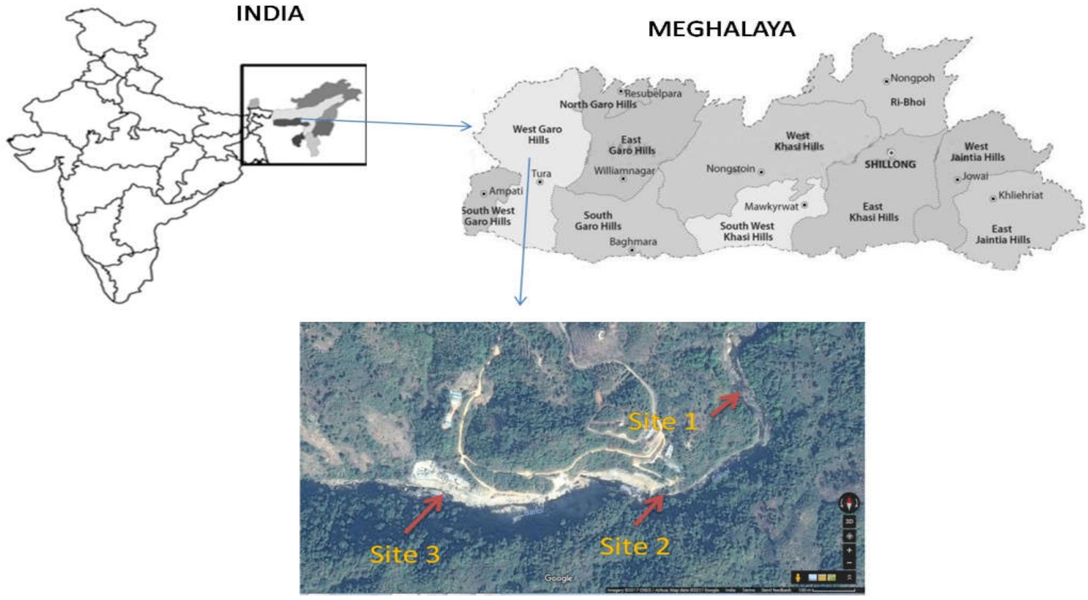

Fig 1: Three selected sites in Ganol river

Sample collection and analysis

Sampling was carried out in November 2015 to October 2016. Temperature, pH, turbidity, conductivity, transparency and water current were measured at the spot using mercury thermometer, digital pH meter, digital turbidity meter, conductivity meter, secchi disc method and float method respectively. Dissolved oxygen was analyzed by Winkler method. Collected water samples were brought to the laboratory for immediate estimation of phosphate, nitrate and nitrite (2).

Phytoplankton was collected from surface water by using plankton net (45 μm). Periphytic algae were collected from different substrata like stones, rocks, pebbles, dead leaves and sediments with help of scalpel and tooth brush. The algal samples were preserved in 4% formaldehyde and brought to the laboratory for further study. For extraction of diatoms, sediments samples were homogenised with acid (12). Algal samples were observed under a trinocular microscope, photographed (using Olympus B41 microscope). Taxonomic identification up to species level was carried out with the help of standard books and Monographs (21, 9, 10, 3 &14) and taxonomy was updated using the online Algae Base (1).

Statistical Analyses

nMDS (non-metric multidimensional scaling) ordination plot was used in order to illustrate the distribution of algal species composition in three different sites. Significance of differences in species composition among the three different sites was assessed by non parametric one way ANOSIM (Analysis of similarities) by using Bray-Curtis distance measure. SIMPER (similarity percentage) was used to detect the percentage contribution of each species to the observed dissimilarity amongst sites and the importance of each taxon in creating the observed pattern of dissimilarity. Canonical Correspondence Analysis (CCA) was employed in order to explain the correlation of species to specific environmental variables. For this analysis, algal taxa (relative abundance more than 3%) were log transformed and environmental variables were square root transformed. The Statistical analysis was carried out using PAST software.

RESULTS AND DISCUSSION

Different physico-chemical parameters in different selected sites in Ganol River and one way ANOVA performed are given in Table 1. The present study revealed that in site 1, transparency (14.23-27.75 cm) and dissolved oxygen (6.45-7.6 mg/l) were high and pH (6.2-7.6), conductivity (0.01-0.02 mS/cm), temperature (18-24^{0}C), turbidity (5.27-8.30 NTU), phosphate (0.12-0.24 mg/l), nitrite (0.04-0.10 mg/l) and nitrate (0.21-0.33 mg/l) were low, which could be the result of being located away from human activities. In site 2, depth of the river and water current was high (0.30-1.00 m and 0.18-0.28 m/sec respectively), which could be due to sand mining activities. In site 3, dissolved oxygen (4.67-6.41mg/l), transparency (10.35-12.50cm) and water current (0.16-0.28 m/sec) were low, while temperature (21-28^{0}C), pH (7.4-7.8), conductivity (0.04-0.07 mS/cm), turbidity (29.23-47.9 NTU), nitrite (0.04-0.20 mg/l), nitrate (0.48-2.63 mg/l) and phosphate (0.14-0.65 mg/l) concentration were very high compared to other sites, which could be due to the deposition of commercial and domestic wastes, increase in nutrients led to rise in temperature and pH which resulted in low dissolved oxygen.

Similar results were reported from Tungabhadra river where alkaline condition of the water and low dissolved oxygen throughout the study period (28). Alkaline pH has been attributed to be one of the major caused of eutrophication of mesotrophic lakes (29). Not only alkaline pH, low concentration of dissolved oxygen, high concentrations of nitrate, high phosphate content and high turbidity were considered to be indicator of organic pollution and eutrophication (13) from Uyyakondan channel of river cauvery. Anthropogenic activities led to increase in phosphate content and turbidity in Umiew river, Meghalaya (27).

A total of 140 species have been recorded from three selected sites in Ganol river, spreading over 7 classes, out of which 63 species from Bacillariophyceae, 35 species from Zygnematophyceae, 17 species from Chlorophyceae, 12 species from Euglenophyceae, 10 species from Cyanobacteria, 2 species from Chrysophyceae, 1species from Ulvophyceae (Table 2). Among the three sites, in site 1, total numbers of 98 species have been recorded. Dominant class was Bacillariophyceae (49 species) followed by Zygnematophyceae (29 species), Chlorophyceae (13 species), Cyanobacteria (3 species), Euglenophyceae (3 species) and Chrysophyceae (1 species). In site 2, total numbers of 81 species have been recorded, dominated by Bacillariophyceae (44 species) followed by Zygnematophyceae (19 species), Chlorophyceae (10 species), Euglenophyceae (5 species), Cyanobacteria (2 species) and Ulvophyceae (1species). In site 3, total numbers of 53 species have been recorded, dominated by Bacillariophyceae (24 species) followed by Euglenophyceae (12 species), Cyanobacteria (9 species), Chlorophyceae (5 species), Zygnematophyceae (2 species) and Chrysophyceae (1 species).

The distributional patterns of algae in fresh water system depend mainly on the physico-chemical features of the system (6). It is well known that diatoms are sensitive to a wide range of limnological and environmental variables and its community structure quickly respond to changing physical, chemical and biological conditions in the environment (5&18). The Bacillariophyceae (diatom) was found to be maximum in site 1(49 species) where the depth was less (0.30-0.75m). Diatoms are usually the most common elements of shallow communities (20 & 25). Presence of Zygnematophyceae members mainly desmids are used as indicator of water quality. Presence of many Zygnematophyceae members in site 1 (29 species) indicated the clear nature of that region of the river and presence of only few members in site 3 (2 species) indicated polluted nature of the river in that part. Low turbidity, temperature, pH and low nutrients in site 1 favoured the growth of many desmids whereas deposition of domestic and commercial wastes might have resulted in rise of water temperature, pH and nutrients which affected adversely the growth of desmids. High desmids population was recorded in the upstream of Bhadra reservoir where turbidity and phosphate concentration was low and desmids were absent in downstream of Bhadra river as the water was polluted by industrial effluents and domestic wastes (15). Chlorophyceae was recorded maximum in site 1 (13 species) which could be the result of high dissolved oxygen, low turbidity, low conductivity and low water temperature and low nutrient status. Chlorophyceae is an important group of fresh water green algae. Importance parameters like dissolved oxygen, pH and nutrients in distribution of Chlorophyceae members in freshwater zones have been reported by many workers (22 & 23). High dissolved oxygen resulted in abundant growth of phytoplankton (30). Abundance of Euglenophyceae members indicated increase in nutrient status and organic pollution (16 & 17). The occurrence of higher Cyanobacteria and Euglenophyceae members in site 3 could be attributed to higher level of nutrients (nitrate and phosphate) along with higher temperature, turbidity, slightly alkaline conditions (11).

The nMDS ordination (Fig 2) illustrated clustering of samples according to their sites by forming three different clusters which clearly indicated that the species composition differed in different sites that is Site 1(□), Site 2(△) and Site 3 (△). Comparing all the three sites showed variation in species composition. Significant difference observed in species composition on different sites was further substantiated by ANOSIM (mean rank within group = 177.7; mean rank between group = 378.7; R = 0.637 and p = 0.0001). SIMPER analysis revealed a high dissimilarity in species composition among the three sites with an overall dissimilarity of 84.89 % and the species like *Cymbella cistula* (Ehrenberg) Kirchner, *Cosmarium binum* Nordstedt, *Cosmarium constractum* Kirchner , *Closterium acutum* Brebisson, *Cocconeis placentula* Ehrenberg, *Closterium dianae* Ehrenberg ex Ralfs, *Closterium lineatum* Ehrenberg ex Ralfs, *Eunotia minor* (Kutzing) Grunow, *Ankistrodesmus spiralis* (W.B.Turner) Lemmermann, *Ankistrodesmus fusiformis* Corda ex Korshikov, *Fragilaria crotonensis* kitton, *Cosmarium pachydermum* P. Lundell, *Cymbella proxima* Reimer, *Achnanthes lemmemannii* Hustedt, *Cosmarium subcrenatum* Hantzsch and *Achnanthes inflate* (Kutzing) Grunow contributed high percentage for the observed pattern of dissimilarity.

Canonical corresponding analysis (CCA) was performed, which established the relationship between environmental variables and algal distributional pattern in three sites in Ganol river. Eigen values of axis 1 (0.4916),axis 2 (0.2348), axis 3 (0.1796) and axis 4 (0.1419) explained 71.47 % of the relation between species and environmental variables. The CCA biplot explained the correlations between algal assemblages and physico-chemical parameters of water (Fig 4). *Closterium navicula* (Brebisson) Lutkemuller, *Gomphonema parvulum* (Kutzing) Kutzing, *Cosmarium biretum* Brebisson ex Ralfs, *Closterium leibleinii* Kutzing ex Ralfs, *Achnanthes lemmemannii* Hustedt, *Closterium lineatum* Ehrenberg ex Ralfs, *Cosmarium binum* Nordstedt, *Scenedesmus serratus* (Corda) Bohlin, *Fragilaria biceps* Ehrenberg, *Scenedesmus abundans* (Kirchner) Chodat, *Cosmarium angulosum* Brebisson, *Cymbella cistula* (Ehrenberg) Kirchner and *Cosmarium subcrenatum* Hantzsch showed positive correlation with transparency and dissolved oxygen in site 1. *Cosmarium connatum* Brebisson ex Ralfs, *Ankistrodesmus spiralis* (W.B.Turner) Lemmermann, *Cosmarium constractum* Kirchner, *Navicula cryptocephala* Kuetzing, *Navicula gracilis* Ehrenberg, *Eunotia minor* (Kutzing) Grunow, *Eunotia bilunaris* (Ehrenberg) Schaarschmidt, *Penium margaritaceum* Brebisson, *Pinnularia melosepta* (Ehrenberg) W.Smith, *Navicula lanceolate* Ehrenberg, *Navicula cuspidata* (Kutzing) Kutzing, *Fragilaria crotonensis* kitton, *Scenedesmus aculeolatus* Reinsch, *Cymbella cuspidata* Kutzing showed positive correlation with depth and water current in site 2. *Aphanocapsa annulata* G.B.McGregor, *Fragillaria capucina* Desmazieres, *Scenedesmus dimorphus* (Turpin) Kutzing, *Euglena oxyuris* Schmarda, *Euglena proxima* P.A.Dangeard, *Euglena pascheri* Swir, *Anabaena constricta* (Szafer) Geitler, *Anabaena sphaerica* Bornet and Flahault, *Anabaena subcylindrica* Borge, *Nitzschia commutata* Grunow, *Trachelomonas volvocina* (Ehrenberg) Ehrenberg, *Trachelomonas intermedia* P.A.Dangeard, *Trachelomonas lacustris* Drezepolski showed positive correlation with pH, conductivity, turbidity, phosphate, nitrite and nitrate in site 3.

CONCLUSION

Distribution of Bacilariophyceae was found maximum in all the study sites. Chlorophyceae and Zygnematophyceae distribution were maximum in sites l and 2. Cyanobacteria and Euglenophyceae distributions were maximum in site 3. The maximum distribution of Cyanobacteria and Euglenophyceae in site 3 indicate nutrient rich condition favoring their growth which was also confirmed by CCA analysis. This finding confirms that the algal communities vary with the changes in water parameters. Anthropogenic activities i.e. dumping of commercial and domestic wastes in site 3 adversely effected algal community.

Table 1: Physico-chemical parameter of Ganol river with one way ANOVA

Parameter	**Site 1**	**Site 2**	**Site 3**	**P-value**
Depth (m)	0.30-0.75	0.30-1.00	0.20-0.56	0.09
Water current (m/sec)	0.21-0.24	0.18-0.28	0.16-0.21	0.88
Transparency (cm)	14.23-27.75	13.0-25.12	10.35-12.50	4.62×10^{-5}*
Turbidity (NTU)	5.27-8.30	11.35-17.27	29.23-47.9	6.27×10^{-13}*
Conductivity (mS/cm)	0.01-0.02	0.02-0.04	0.04-0.07	3.25×10^{-6}*
Temperature (^{0}C)	18-24	19-25	21-28	0.50
pH	6.2-7.6	7.1-7.5	7.4-7.8	0.51
Dissolved oxygen (mg/l)	6.45-7.60	6.03-7.24	4.67-6.41	0.002*
Nitrate (mg/l)	0.21-0.33	0.45-0.57	0.48-2.63	0.0001*
Nitrite (mg/l)	0.04-0.10	0.03-0.16	0.04-0.20	0.0006*
Phosphate (mg/l)	0.12-0.24	0.15-0.27	0.14-0.65	1.82×10^{-7}*

* significant difference at p<0.05

Table 2: List of Algal species recorded from three sites of Ganol river.

Chlorophyceae	Species code	Site 1	Site 2	Site 3
Ankistrodesmus fusiformis Corda ex Korshikov	Ank fus	+	+	
Ankistrodesmus spiralis (W.B.Turner) Lemmermann	Ank spi		+	
Chlorococcum infusionum (Schrank) Meneghini	Chlor infu	+		
Coelastrum astroideum De Notaris	Coel astro	+		+
Coelastrum cambricum W. Archer	Coel cam	+	+	
*Golenkinia radiata*Chodat	Golen rad	+		
Kirchneriella aperta Teiling	Kir aper	+		
Kirchneriella contorta (Schmidle) Bohlin	Kir cont		+	+
Kirchneriella lunaris (Kirchner) Mobius	Kir lun	+		
Scenedesmus abundans (Kirchner) Chodat	Scen abun	+	+	
Scenedesmus aculeolatus Reinsch	Scen acul	+	+	
Scenedesmus acutus (Meyen)	Scen acut	+	+	+
Scenedesmus dimorphus (Turpin) Kutzing	Scen dim	+		+
Scenedesmus obliquus (Turpin) Kutzing	Scen obli		+	
Scenedesmus quadricauda (Turpin) Brebisson	Scen qua	+	+	
Scenedesmus serratus (Corda) Bohlin	Scen ser	+		+
Selenastrum gracile Reinsch	Selen gra		+	
Bacillariophyceae				
Achnanthes inflata (Kutzing) Grunow	Ach inf	+	+	
Achnanthes lemmemannii Hustedt	Ach lem	+	+	
Achnanthes minuscule Hustedt	Ach minu	+		
Achnanthidum minutissimum (Kutzing) Czarnecki	Ach min	+	+	
Amphora ovalis Kutzing	Amp ova	+	+	
Cocconeis placentula Ehrenberg	Coco pla		+	+
Cymatopleura solea (Brebisson) W. Smith	Cym sol	+		
Cymbella affinis Kutzing	Cym affi	+	+	+
Cymbella amphicephala Naegeli	Cym amp	+	+	
Cymbella cistula (Ehrenberg) Kirchner	Cym cis	+		+
Cymbella cuspidate Kutzing	Cym cus	+	+	
Cymbella microcephala Grunow	Cymmic		+	

Cymbella proxima Reimer	Cymprox	+		+
Cymbella tumida (Brebisson) Van Heurck	Cym tumi	+	+	
Cymbella turgidula Grunow	Cym tur	+	+	
*Cymbellaventricosa*C.Agardh	Cymven	+	+	
Eunotia bilunaris (Ehrenberg) Schaarschmidt	Eun bil	+	+	
Eunotia flexuosa (Brebisson) Kutzing	Eun flex		+	
Eunotia microcephala Krasske	Eun mic	+		
Eunotia minor (Kutzing) Grunow	Eun min		+	
Fragilaria biceps Ehrenberg	Frag bicp	+	+	+
Fragillaria capucina Desmazieres	Frag cap	+	+	+
Fragilaria crotonensis kitton	Frag crot	+	+	
Fragilaria virescens Ralfs	Frag vir	+	+	+
Frustulia rhomboids (Ehrenberg) De Toni	Frust rhom	+		
Gomphonema angustatum (Kutzing) Rabenhorst	Gom ang	+	+	
Gomphonema augur Ehrenberg	Gam aug		+	+
Gomphonema constrictum Ehrenberg	Gom con	+		
Gomphonema gracile Ehrenberg	Gom gra	+	+	
Gomphonema olivaceum (Hornemann) Brebisson	Gomoliv	+	+	+
Gomphonema parvulum (Kutzing) Kutzing	Gom par	+	+	+
Gomphonema sphaerophorum Ehrenberg	Gom spha		+	
Gyrosigma exilis (Grunow) C.W.Reimer	Gyros exl	+		
Gyrosigma scalproides (Rabenhorst) Cleve	Gyros scal	+	+	
Hantzschia amphioxys (Ehrenberg) Grunow	Han amp	+		
Melosiragranulata (Ehrenberg) Ralfs	Melo gran		+	
Melosira varians C.Agardh	Melo varn	+		+
Naviculaampliatum (Ehrenberg) Krammer	Nav amp		+	

Navicula cryptocephala Kutzing	Nav cryt	+	+	
Navicula cuspidata (Kutzing) Kutzing	Nav cusp	+	+	+
Navicula dicephala Ehrenberg	Nav dicep	+		+
Navicula gracilis Ehrenberg	Nav gra	+	+	+
Navicula lanceolate Ehrenberg	Nav lan	+	+	+
Navicula radiosa Kutzing	Nav rad	+	+	+
Navicula salinarum Grunow	Nav saln			+
Navicula secreta Krasske ex Hustedt	Nav scre	+		
Neidium productum (W. Smith) Cleve	Neid prod	+		
Nitzschia commutate Grunow	Nitz com			+
Nitzschia intermedia Hantzsch	Nitz inter	+	+	
Nitzschia linearis W. Smith	Nitz lin		+	+
Nitzschia palea (Kutzing) W.Smith	Nitz pale	+	+	+
Pinnularia braunii Cleve	Pin brau	+		
Pinnularia brebissonii (Kutzing) Rabenhorst	Pin breb		+	
Pinnularia gibba (Ehrenberg) Ehrenberg	Pin gib	+		
*Pinnulariainterrupta*W.Smith	Pin inter		+	+
Pinnularia mesolepta (Ehrenberg) W.Smith	Pin melo	+	+	+
Pinnularia viridis (Nitzsch) Ehrenberg	Pin virid	+	+	
Sellaphora bacillum (Ehrenberg) D.G.Mann	Sell bac	+	+	
Surirella apiculata W. Smith	Suri api			+
Surirella elegans Ehrenberg	Suri elng	+		
Surirella robusta Ehrenberg	Suri rob	+	+	+
Surirella splendid (Ehrenberg) Kutzing	Suri spln	+	+	
Synerda ulna (Nitzsch) Ehrenberg	Syn ulna	+	+	
Zygnematophyceae				
Closterium acutum Brebisson	Clos acut			+

Closterium dianae Ehrenberg ex Ralfs	Clos dia	+		
Closterium leibleinii Kutzing ex Ralfs	Clos lei	+	+	
Closterium lineatum Ehrenberg ex Ralfs	Clos lin	+	+	
Closterium navicula (Brebisson) Lutkemuller	Clos nav	+		
Cosmarium angulosum Brebisson	Clos ang	+	+	
Cosmarium bidentatum W.B.Turner	Cos bid	+		
Cosmarium binum Nordstedt	Cos bin	+		
Cosmarium biretum Brebisson ex Ralfs	Cos bir	+		
Cosmarium connatum Brebisson ex Ralfs	Cos con	+	+	
Cosmarium constractum Kirchner	Cos const	+	+	
Cosmarium cucumis Corda ex Ralfs	Cos cuc	+	+	
Cosmarium formosulum Hoff	Cos for	+		
Cosmarium jaoi Kouwets	Cos jao	+		
Cosmarium leave Rabenhorst	Cos lae		+	
Cosmarium meneghinii Brebisson ex Ralfs	Cos men	+		
Cosmarium pachydermum P. Lundell	Cos pac		+	
Cosmarium perforatum P.Lundell	Cos per	+	+	
Cosmarium portianum W.Archer	Cos por	+		
Cosmarium pseudoconnatum Nordstedt	Cos pseu	+	+	
Cosmarium quadrifarium P. Lundell	Cos qua	+		
Cosmarium quadrum P.Lundell	Cos quad	+	+	
Cosmarium quinarium P.Lundell	Cos quin		+	
Cosmarium subcrenatum Hantzsch	Cos sub	+	+	
Euastrum binale Ehrenberg ex Ralfs	Eua bin	+	+	+

Euastrum denticulatum F.Gay	Eua den		+	
Hyalotheca dissiliens Brebisson ex Ralfs	Hya dis	+		
Penium cylindrus Brebisson ex Ralfs	Pen cylin	+	+	
Penium margaritaceum Brebisson	Pen mar	+	+	
Pleurotaenium ehrenbergii (Ralfs) De Bary	Pleu mar	+		
Pleurotaenium trabecula Nageli	Pleu tra	+		
Roya obtuse (Brebisson) West et G.S.West	Roy obt	+		
Spirogyra flavescens (Hassall) Kutzing	Spiro fla		+	
Staurastrum connatum (P.Lundell) J.Roy and	Staur con	+	+	
Staurastrum margaritaceum Meneghini ex Ralfs	Staur mar	+		
Chrysophyceae				
Mallomonas acaroids Perty	Mall acar	+		
Mallomonas caudate Iwanoff	Mall cau			+
Ulvophyceae				
Ulothrix variabilis Kutzing	Ulo var		+	
Cyanobacteria				
Anabaena constricta (Szafer) Geitler	Ana con			+
Anabaena sphaerica Bornet and Flahault	Ana sph	+		+
Anabaena subcylindrica Borge	Ana sub	+		+
Aphanocapsa annulata G.B.McGregor	Apha ann		+	+
Merismopedia glauca (Ehrenberg) Kutzing	Mer gla			+
Merismopedia minima G. Beck	Mer min			+
Oscillatoria curviceps C.Agardh ex Gomont	Osci cur			+
*Oscillatorialimosa*C.Agardh ex Gomont	Osci lim			+
*Oscillatoriaprinceps*Vaucher ex Gomont	Osci prin			+
*Oscillatoriatenuis*C.Agardh ex Gomont	Osci ten	+	+	
Euglenonphyceae				
Euglena acus (O.F.Muller) Ehrenberg	Eug acus		+	+
Euglena ehrenbergii G.A.Klebs	Eug ehren			+
Euglena oxyuris Schmarda	Eug oxy	+		+
Euglena pascheri Swir	Eug pas			+
Euglena proxima P.A.Dangeard	Eug prox		+	+
Lepocinclis fusiformis (H.J.Carter) Lemmermann	Lep fusi			+
Lepocinclis playfairiana (Deflandre) Deflandre	Lep play		+	+
Phacus caudatus Hubner	Phac cau	+		+

*Phacuscurvicauda*Svirenko	Phac cur		+	+
Trachelomonas intermedia P.A.Dangeard	Trac inter			+
Trachelomonas lacustris Drezepolski	Trac lac			+
Trachelomonas volvocina (Ehrenberg) Ehrenberg	Trac vol	+	+	+

+ Indicates presence of species

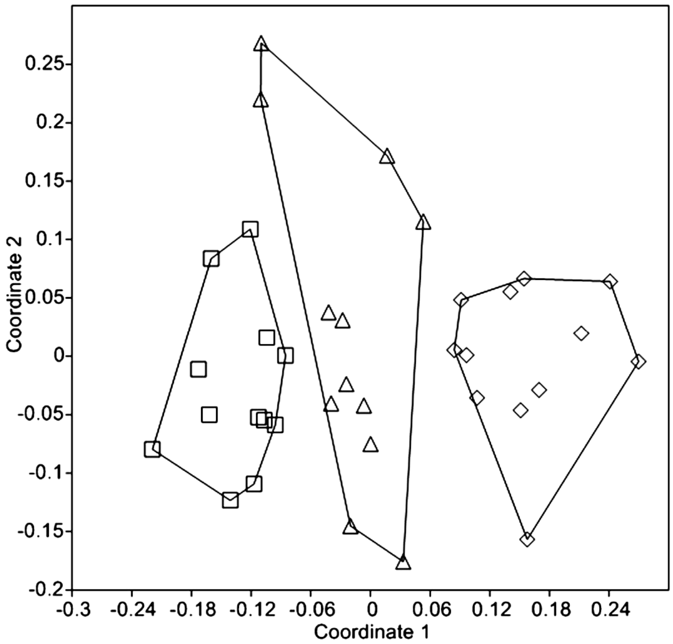

Fig 2: The non- metric multidimensional scaling (nMDS) ordination diagram of algal composition in three different study sites [Site 1(□), Site 2(△), Site 3(◇)].

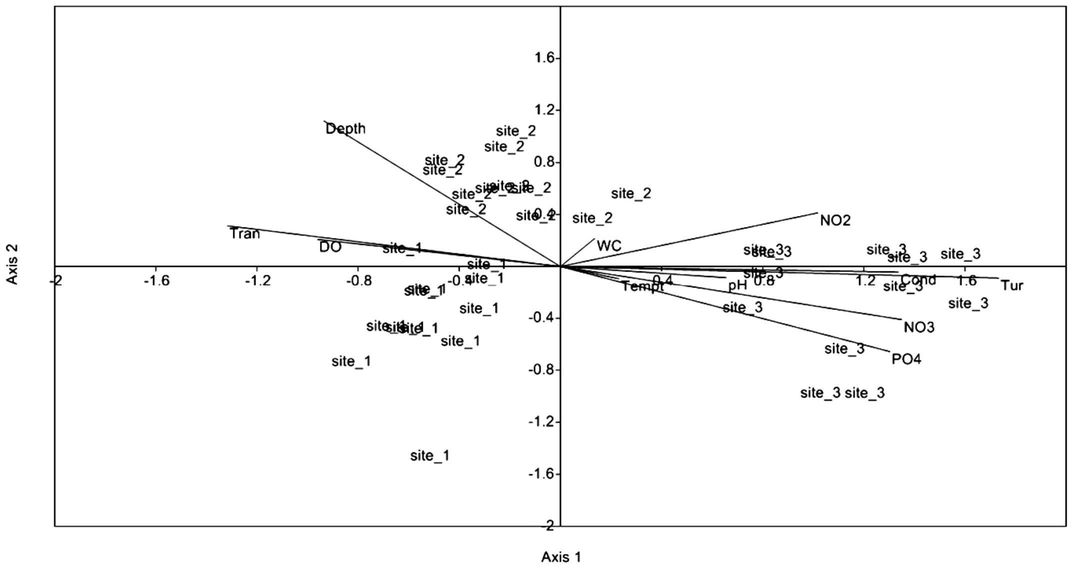

Fig 3: CCA (Canonical Corresponding Analysis) ordination diagram of selected environmental gradients Depth, water current (WC), transparency (Tran), dissolved oxygen (DO), temperature (Tempt), pH, Conductivity (Cond), turbidity (Tur), nitrite (NO_2), nitrate (NO_3) and phosphate (PO_4) correlated with different sites in Ganol river.

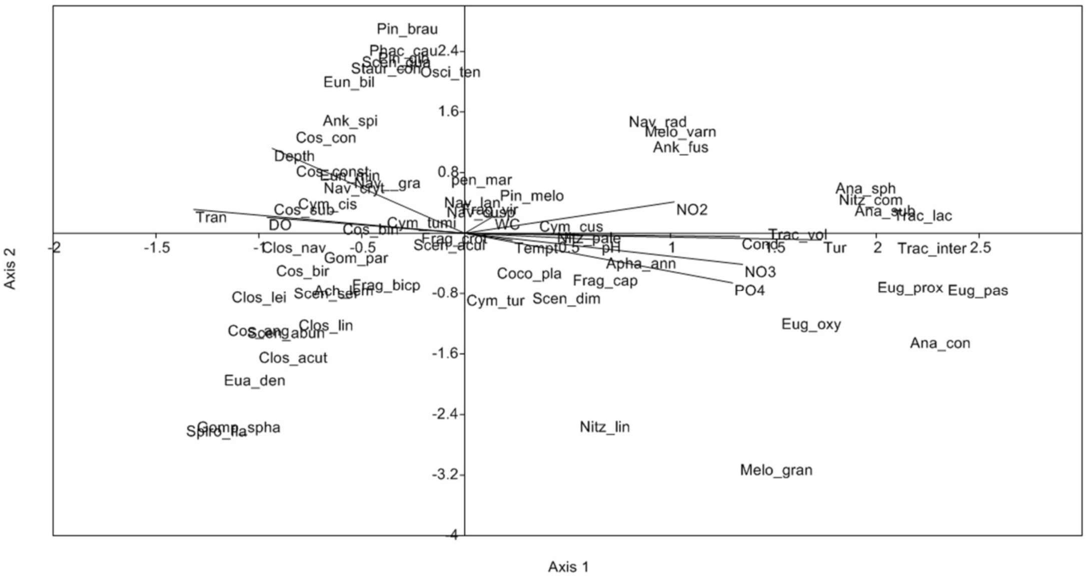

Fig 4: Canonical Corresponding Analysis (CCA) ordination diagram of selected environmental gradients Depth, water current (WC), transparency (Tran), dissolved oxygen (DO), temperature (Tempt), pH, Conductivity (Cond), turbidity (Tur), nitrite (NO_2), nitrate (NO_3) and phosphate (PO_4) correlated with algal assemblages in Ganol river. Species code is given in Table 2.

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