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Research Article

STRUCTURE AND SPATIAL DISTRIBUTION OF PHYTOPLANKTON FROM THE BOUAKE'S RESEARCH STATION FISHPONDS (CENTRAL, CÔTE D'IVOIRE)

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ABSTRACT

This study was carried out to evaluate phytoplankton structure from farmed environments at Bouaké's Fisheries and Aquaculture Research Station (SRPAC). Measure of physical-chemical and phytoplankton flora sampling were realized from December, 2015 to March, 2016. Conductivity, water transparency and temperature were measured *in situ*. Phytoplankton was sampled in fishpond using a plankton net mesh-size 20 µm between 7 to 9 am. The results showed that conductivity varied from 19, 37 mS/cm ± 0, 21 to 23, 88 mS/cm ± 1, 20. Therefore, water transparency is relatively ranging from 16 cm ± 0,2 to 57 cm ± 0,5. The pond water temperature fluctuated between 28, 34 °C ± 0, 88 and 30, 20 °C ± 1, 27. Phytoplankton flora is spatially heterogeneous and is made up of 197 taxa divided into 7 branches. These are Chlorophyta (36,04%), Euglenophyta (24,87%), Bacillariophyta (14,72%), Cyanobacteria (13,71%), Charophyta (7,11%), Ochrophyta (2,54%) and Miozoa (1,02%).This phytoplankton study confirmed the existence of potential toxigenic microalgae identified in genus *Anabaena, Anabaenopsis, Cylindrospermopsis, Lyngbya, Microcystis, Oscillatoria* and *Peridinium* that could interfere with fish production. This study showed the main phytoplankton communities which dominate in the fish ponds of the Bouaké Research Station.

Keywords: Bouaké's Fisheries and Aquaculture Research Station, Phytoplankton flora, Fishpond, Toxigenic microalgae.

INTRODUCTION

A good knowledge of phytoplankton that exists in an ecosystem allows an assessment of the fertility of this ecosystem and its degree of productivity. Also, the characterization of phytoplankton population of an aquatic habitat permits to identify potential disruptions (Komoé, 2010).Although, phytoplankton plays an important role in aquatic ecosystems by producing oxygen through photosynthesis, necessary for the survival of heterotrophic organisms (fishes, zooplankton, crustaceans) it is also the source of food for animal (Fauchot, 2006; Haberkorn, 2009) particularly for the fishes. In addition, phytoplankton contributes to the purification of the environment by the possibility that it has to absorb the dissolved minerals (Adon, 2013). However, the formation of blooms of some species of algae can be one of the causes of poor growth or death of fish and other aquatic organisms(Fauchot, 2006; Haberkorn, 2009; Kempf, Merceron, & Nezan, 1995; Roset *et al*., 2002).Experts agree that these microorganisms represent one of the main threats of the millennium for humans and more generally for the biological balance of aquatic systems (Ouellet, 2012). Otherwise, there is little information on phytoplankton populations of ivorian small sizes reservoirs. Most of the studies in Ivory Coast on phytoplankton freshwater concern natural lakes or large hydroelectric reservoirs. The little we know of the composition of phytoplankton populations of small reservoirs comes from many ponds or fishponds (Da, 1992) and Adzopé's small reservoir (Adon, 2013). The flora of these aquatic environments thus remains poorly understood and more particularly that of fishponds. The objective of this study is to determine the composition of phytoplankton

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communities and to search for potential toxic taxa whose proliferation and consumption would be harmful to the health of fish species.

MATERIAL AND METHODS

Description of the study area

The Research Station of Fisheries and Continental Aquaculture (SRPAC) (7º37'58,919"N and 5º2'34,051"W at 296 m of altitud), is located in the forest of Kongodékroat about 6 km from Bouaké in the center of the Ivory Coast (Figure 1). It covers an area of 114 hectares, including 2,6 hectares of water. The fishponds are rectangular with depth between 0,5 m to1,5 and water extended from 50 to 1000 m^2. These devices are supplied with water by gravity from two feeder canals from Kan dam situated at 1 kilometer upstream and underground pipe from three wells with a pumping system. The ponds are arranged in series (A to G); each series being designed to a specific farming activity (breeding, conservation, growth). The study environment is subject to a humid tropical climate. The area is under the influence of two rainy seasons (March - June and September-October) and two dry seasons November-February and July - August) with an annual air temperature oscillating between 25 and 38 ºC.

Choice of sampling sites

For this study, five sampling sites were selected taking into account the piscicultural activities (which may enrich the environment) carried out there and their water availability. This choice is also based on the hypothesis of a gradient in the distribution of phytoplankton from the water inlet until it leaves the Station. Site 1: it is located furthest upstream from the others and receives water directly from the two water sources. It is used for the storage of *Oreochromis niloticus* broodstock whose food intake is 3% of the biomass. Site 2: it is intended for the reproduction of *O. niloticus*. The parents receive an exogenous food ration equivalent to 5% of their biomass. Site 3: it is used for the storage of the *O. niloticus* gene pool. The daily ration is 10% of their biomass. Site 4: other species of fish are stored there with variable food rations. Site 5: this site was used for magnification tests during the period of our sampling. The rationing rate for fish was 5%.

Sampling procedure

Conductivity, temperature and water transparency were measured *in situ* twice a day, two days a week with HACH conduct meter. The Secchi disk was used to assess pond water transparency. Phytoplankton was sampled in thirteen ponds spread over five (5) sites (along a longitudinal gradient S1 to S5) between 7 and 9 AM with plankton net with manifold. Sixty (60) liters of water were filtered into the net and then the filtrate is inserted into sample tube and fixed with four drops of formaldehyde 5%.Phytoplankton observation was made with photonic microscope BRESSER included micro - camera. Diatoms have undergone a specific preparation following (Rumeau & Coste, 1988) before being observed. Specific identification guide of (Förster, 1964; Iltis & Doebley, 1980)and the inventory works of (Adon, 2013; Komoé, 2010; Konan, 2014; Kouassi-Blé, 2013; Ouattara, 2000)have used to identify the phytoplankton taxa.

Data analysis

Jaccard index was used to determine the similarity between two sites by comparison two by two based on the presence and absence of taxa. This index varies from 0 (absence of similarity) to 1 (Dajoz, 1982). Its formula is as follow:

$$Sj = \frac{\mathrm{a}}{\mathrm{a+b+c}}$$

a: number of taxa common to sites A and Bb: number of taxa specific to site Ac: number of taxa specific to site B. An ascending hierarchical classification made it possible to regroup these sites according to their taxonomic similarity. Factor Correspondence Analysis (CFA) was performed in order to characterize the sampling sites by relating them to the taxa. The data obtained were processed using STATISTICA software version 7.1 and PAST software version 2.17c.

RESULTS AND DISCUSSION

Table I shows the results of physicochemical parameters measures. Conductivity varied from 19,37 ± 0,21 to 23,88 ± 1,20 mS/cm. These high conductivity values could be justified with strong mineralization of organic matter dissolved in water of ponds. Therefore, water transparency is relatively low on all sites ranging from 16 ± 0,2 to 57 ± 0,5 cm due to suspended nutrients (rest of food). The temperature of the pond water was high. It fluctuated between 28, 34 °C ± 0,88 and 30,2 °C ± 1,2 and is in the range of variation of the temperature of the ambient air. This may be due to the fact that the measurements were taken at shallow (less than 10 cm) and the small size of the ponds.

The taxonomic richness of the sites is given by Table II. The number of phytoplankton taxa sampled was 197 comprised of 72 genera, 38 families, 25 orders, for a total of 7 phyla. These are Chlorophyta (36, 04 %), Euglenophyta (24,87 %), Bacillariophyta (14,72 %), the Cyanobacteria (13,70 %), Ochrophyta (2,54 %), Charophyta (7,11 %) and Miozoa (1,02%) (Table III).This diversity of phytoplankton flora can be justified by the fact that the ponds are daily enriched by nutrients from food losses during the fish feeding. According to (Blé *et al.*, 2007), exogenous nutrients in fish farming stimulate the pelagic food pathways by promoting development of planktonic organisms. Moreover, the dominance of Chlorophyta and Euglenophyta is characteristic of eutrophic environment (Adon, 2013).

The result of Factor Analysis of Correspondences (FAC) conducted on presence / absence matrix of taxa in 25 orders and 5 sampling sites is presented by the factorial map in figure 2A. The axes 1 and 2 express 5.11% and

11.32% respectively and contribute to 86.43% of the information in the matrix. The hierarchical classification represented by the cluster of similarity (Figure 1) comprises two distinct groups. The first group (I) formed by the sites 4 and 5, is characterized by taxa in order of the Oscillatoriales, Zygnematales, Cymbellales, Chlamydomonadales, Mastogloiales, Melosirales, Naviculales, Bacillariales and Thalassiophysales. The second group (II) formed by the sites 1, 2 and 3, is characterized by taxa in orders of the Euglenales, Eustigmatales, Trebouxiophyceae ordo incertae sedis, Nostocales, Sphaeropleales and Anaulales.

There is a longitudinal gradientin the distribution of phytoplankton flora that would be linked to the activities associated with each site. The phytoplankton flora is spatially heterogeneous. The genus *Anabaena*, *Anabaenopsis*, *Cylindrospermopsis*, *Lyngbya*, *Microcystis*, *Oscillatoria* and *Peridinium* include potentially toxic taxa whose proliferation and consumption would be a health risk. The relative abundance of these taxa is recorded in (Table IV) According to Bernard (2011), chronic exposure to toxins from algae could affect the life traits (fertility, growth, survival) and therefore on growth performance of fishes.

Table 1. Physico-chemical parameters measured.

Station	Conductivity (mS/cm)	Temperature (◦C)	Transparency (cm)
Site 1	$20.04^{a} \pm 0.49$	$29.64^{ab} \pm 0.72$	$25^{a} \pm 0.2$
Site 2	$19.58^{a} \pm 0.21$	$30.02^{ab} \pm 0.91$	$20^{a} \pm 0.1$
Site 3	$19.37^{a} \pm 0.21$	$30.20^{a} \pm 1.27$	$16^{a} \pm 0.2$
Site 4	$22.65^{bc} \pm 1.33$	$29.89^{ab} \pm 0.75$	$55^{b} \pm 0.6$
Site 5	$23.88^{c} \pm 1.20$	$28.34^{b} \pm 0.88$	$57^{b} \pm 0.5$
Minimal value	19.37 ± 0.21	28.34 ± 0.88	16 ± 0.2
Maximal value	23.88 ± 1.20	$30.20^{a} \pm 1.27$	57 ± 0.5

There is a significant difference between sites for parameter values with different letters ($p < 0.05$), the same letter otherwise.

Table 2. Composition and distribution of phytoplankton in fishponds.

Phylum	Orders	Families	Taxa	Sites 1	2	3	4	5
Chlorophyta	Chlamydomonadales	Cylindrocapsaceae	*Fusola viridis*	*				
		Spondylomoraceae	*Spondylomorum caudatum*			*		
		Treubariaceae	*Treubaria triappendiculata*				*	*
			Treubaria sp.				*	
		Volvocaceae	*Pandorina morum*			*		*
	Chlorellales	Chlorellaceae	*Actinastrum aciculare* cf. *africanum*	*		*	*	*
			Actinastrum hantzschii	*				*
			Actinastrum gracillimum	*	*	*		*
			Actinastrum minimum	*				*
			Dictyosphaerium pulchellum	*	*	*	*	
			Dictyosphaerium cf. *tetrachotomum*	*		*		
			Dictyosphaerium sp.			*		
			Dictyosphaerium sp.1			*		
			Keratococcus bicaudatus	*	*	*		
		Oocystaceae	*Chlorella vulgaris*	*		*	*	
			Oocystis borgei	*		*		
			Oocystis lacustris	*	*	*	*	
			Oocystis sp.		*	*		
			Oocystis sp.1			*		
			Lagerheimia wratislaviensis				*	*
	Sphaeropleales	Hydrodictyaceae	*Monactinus simplex*	*	*	*		
			Pediastrum duplex	*	*	*		
			Pediastrum duplex var. *gracillimum*	*	*	*		
			Pediastrum simplex var.	*	*	*		

Phylum	Orders	Families	Taxa	Sites 1	2	3	4	5
			echinulatum					
			Stauridium tetras	*	*	*	*	
			Tetraedron arthrodesmiforme			*		
			Tetraedron incus	*	*	*		
			Tetraedron minimum	*	*	*	*	
			Tetraedron regulare var. *torsum*	*		*		
			Tetraedron triangulare	*	*	*	*	*
			Tetraedron trigonum	*	*	*		
			Acutodesmus acuminatus	*	*	*		
			Acutodesmus acutiformis	*	*	*	*	
			Coelastrum microporum var. *octaedricum*			*		
			Coelastrum quadricellulare	*		*	*	
			Coelastrum sp.	*	*	*		
			Desmodesmus bicaudatus	*	*	*	*	*
			Desmodesmus insignis		*	*	*	*
			Desmodesmus opoliensis	*	*	*	*	*
			Desmodesmus sp.	*	*	*		
			Scenedesmus acutus var. *acutus*	*	*	*		
			Scenedesmus indicus	*	*	*		
		Scenedesmaceae	*Scenedesmus naegelii*			*	*	
			Scenedesmus obtusus cf. *disciformis*	*	*	*		
			Scenedesmus obtusus var. *alternans*	*	*	*		
			Scenedesmus pseudoquadricauda	*	*	*		
			Scenedesmus quadricauda	*	*	*	*	*
			Scenedesmus quadrispina	*	*	*		
			Scenedesmus smithii	*	*	*		*
			Scenedesmus sp.		*	*		
			Tetradesmus bernardii	*	*	*		
			Tetradesmus dimorphus	*	*	*		
			Tetradesmus obliquus	*	*	*		
			Willea apiculata	*	*	*		
			Willea crucifera		*	*		
			Willea sp.	*	*	*		
			Ankistrodesmus bibraianus		*	*		
			Ankistrodesmus falcatus		*	*	*	
			Ankistrodesmus fusiformis	*		*	*	
			Ankistrodesmus gracilis		*		*	
			Ankistrodesmus sp.		*		*	
		Selenastraceae	*Ankistrodesmus spiralis*	*	*	*	*	
			Kirchneriella obesa	*	*			
			Kirchneriella sp.		*			
			Monoraphidium arcuatum	*		*		
			Monoraphidium griffithii		*	*		
			Selenastrum bibraianum	*	*	*		
			Crucigenia fenestrata		*	*		
	Trebouxiophyceae ordo incertae sedis	Trebouxiophyceae incertae sedis	*Crucigenia quadrata*			*		
			Crucigenia tetrapedia	*	*	*		
			Crucigeniella rectangularis	*		*		
			Closterium lineatum		*			
		Closteriaceae	*Closterium pritchardianum*	*	*			
Charophyta	Desmidiales		*Closterium venus*	*				
			Closterium sp.					*
		Desmidiaceae	*Cosmarium granatum*					*

Phylum	Orders	Families	Taxa	Sites 1	2	3	4	5
			Cosmarium rectangulare var. *hexagonum*	*	*			
			Cosmarium sp.		*			
			Cosmarium sp.1			*		*
			Spondylosium sp.			*		
			Staurastrum volans		*	*		
			Mougeotia sp.				*	*
	Zygnematales	Zygnemataceae	*Spirogyra* sp.				*	*
			Spirogyra sp.1				*	*
			Spirogyra sp.2	*			*	*
	Eustigmatales	Eustigmataceae	*Pseudostaurastrum gracile*			*		
			Pseudostaurastrum lobulatum			*		
Ochrophyta			*Goniochloris mutica*		*	*		
	Mischococcales	Pleurochloridaceae	*Tetraëdriella regularis*	*	*	*	*	*
			Tetraplektron trigonum	*				
Miozoa	Peridiniales	Peridiniaceae	*Peridinium* sp.				*	
			Peridinium sp.1				*	
			Euglena deses			*		
			Euglena grisoli			*		
			Euglena polymorpha	*		*		
			Euglena purpurea	*	*	*		
			Euglena sp.	*				
			Euglena sp.1	*	*			
			Euglena texta	*	*	*		
			Euglenaformis proxima	*	*	*		
			Strombomonas sp.			*		
		Euglenaceae	*Trachelomonas armata*	*				
			Trachelomonas hispida var. *coronata*	*			*	
			Trachelomonas lefevrei	*				
			Trachelomonas planctonica	*	*			
			Trachelomonas raciborskii				*	*
			Trachelomonas sp.			*		
			Trachelomonas sp.1	*	*			
			Trachelomonas splendidissima	*		*		
			Trachelomonas volvocina	*	*	*	*	*
Euglenophyta	Euglenales		*Lepocinclis acus*	*	*	*		
			Lepocinclis caudata		*	*		
			Lepocinclis fusiformis			*		
			Lepocinclis globulus	*	*	*	*	
			Lepocinclis ovum var. *gracillicauda*			*		
			Lepocinclis oxyuris var. *minor*		*			
			Lepocinclis sp.		*	*		
			Lepocinclis tripteris			*		
		Phacaceae	*Monomorphina arnoldii*			*		
			Phacus acuminatus	*	*	*		
			Phacus angulatus	*	*	*		
			Phacus hamelii			*		
			Phacus helikoides			*		
			Phacus lefevrei			*		
			Phacus longicauda var. *rotunda*	*	*	*		
			Phacus longicauda	*	*	*	*	
			Phacus onyx		*			
			Phacus orbicularis	*	*	*		
			Phacus orbicularis var. *undulata*	*				

Phylum	Orders	Families	Taxa	Sites 1	2	3	4	5
			Phacus platalea		*			
			Phacus pleuronectes	*	*	*		
			Phacus rotunda			*		
			Phacus tortus			*		
			Phacus sp.			*		
			Phacus sp.1				*	
			Phacus sp.2		*			
			Phacus sp.3			*		
			Phacus sp.4		*	*		
			Phacus sp.5	*				
			Phacus sp.6	*	*			
			Phacus sp.7		*			
Cyanobacteria	Chroococcales	Microcystaceae	*Microcystis novacekii*	*		*		
			Microcystis aeruginosa	*	*	*		*
	Synechococcales	Merismopediaceae	*Merismopedia* sp.				*	
		Pseudanabaenaceae	*Pseudanabaena* sp.			*	*	
		Cyanothecaceae	*Cyanothece aeruginosus*			*		
		Gomontiellaceae	*Crinalium endophyticum*			*		
	Oscillatoriales	Oscillatoriaceae	*Lyngbya* cf. *contorta*					*
			Oscillatoria limosa				*	
			Oscillatoria margaritifera				*	*
			Oscillatoria simplicissima				*	*
			Oscillatoria sp.				*	*
			Oscillatoria tenuis				*	*
			Phormidium cf. *simplicissimum*					*
			Phormidium cortianum				*	*
			Phormidium breve				*	*
			Phormidium ornatum				*	*
			Phormidium sp.				*	
			Phormidium sp.1					*
	Nostocales	Aphanizomenonaceae	*Raphidiopsis curvata*	*	*	*	*	
			Cylindrospermopsis raciborskii			*		
			Cylindrospermopsis sp.		*	*		
			Anabaenopsis circularis var. *javanica*			*		
			Anabaenopsis circularis		*	*	*	
			Anabaenopsis arnoldii	*	*	*		
			Anabaenopsis tanganyikae			*		
		Nostocaceae	*Anabaena circinalis*	*		*		
			Anabaena cf. *spiroides*	*		*		
Bacillariophyta	Anaulales	Anaulaceae	*Terpsinoe musica*	*				
	Bacillariales	Bacillariaceae	*Nitzschia tryblionella* var. *victoriae*		*		*	
			Nitzschia sp.	*		*	*	
			Gomphonitzschia sp.	*				*
	Cymbellales	Gomphonemataceae	*Gomphonema intricatum*			*		*
			Gomphonema acuminatum				*	*
			Gomphonema sp.				*	
	Fragilariales	Fragilariaceae	*Ulnaria ulna*				*	*
			Synedra pulchella				*	*
	Mastogloiales	Mastogloiaceae	*Mastogloia baltica*					*
			Mastogloia smithii var. *lacustris*	*			*	
	Naviculales	Naviculaceae	*Caloneis* sp.	*				
			Gyrosigma attenuatum				*	*
			Navicula elegans	*			*	
			Navicula globosa		*			*
			Navicula sp.	*		*		

Phylum	Orders	Families	Taxa	Sites 1	2	3	4	5
		Pinnulariaceae	*Diatomella* sp.	*			*	
	Rhopalodiales	Rhopalodiaceae	*Rhopalodia gibba*		*			
	Stephanodiscales	Stephanodiscaceae	*Cyclotella meneghiniana*	*	*	*	*	*
			Cyclotella sp.		*		*	
			Cyclotella sp.1	*				
	Surirellales	Surirellaceae	*Surirella capronii*		*	*		
			Surirella robusta					*
	Melosirales	Melosiraceae	*Melosira arenaria*	*			*	
			Melosira italica	*		*	*	*
	Thalassiophysales	Catenulaceae	*Amphora commutata*	*	*	*	*	*
			Amphora lineolata					*
			Amphora ovalis				*	*
			Amphora sp.				*	*
		Total	197	97	90	121	65	49

*Presence of taxa on the corresponding site

Table 3. Distribution of phytoplankton in fish ponds.

Branches	Number of orders	Number of families	Number of genus	Number of taxa	Specific proportion (%)
Chlorophyta	4	10	26	71	36.04
Euglenophyta	1	2	7	49	24.87
Bacillariophyta	11	12	16	29	14.72
Cyanobacteria	4	8	12	27	13.70
Charophyta	2	3	6	14	7.11
Ochrophyta	2	2	4	5	2.54
Miozoa	1	1	1	2	1.02
Total	25	38	72	197	100

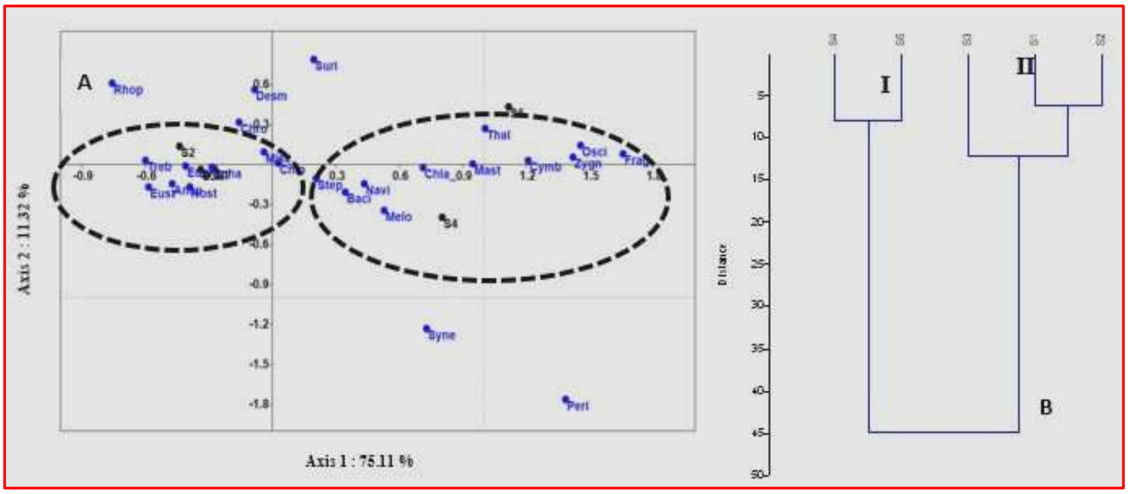

Figure 1. Correspondence Analysis showing the distribution of phytoplankton orders on sampling sites (A) and dendrogram (B) showing the taxonomic similarity between sites.

Spha: Sphaeropleales; **Chla**: Chlamydomonadales; **Chlo**: Chlorellales; **Treb**: Trebouxiophyceae ordo incertae sedis; **Desm**: Desmidiales; **Zygn**: Zygnematales; **Peri**: Peridiniales; **Eust**: Eustigmatales; **Misc**: Mischococcales; **Eugl**: Euglenales; **Chro**: Chroococcales; **Syne**: Synechococcales; **Osci**: Oscillatoriales; **Nost**: Nostocales; **Melo**: Melosirales; **Anau**: Anaulales; **Step**: Stephanodiscales; **Suri**: Surirellales; **Mast**: Mastegloiales; **Thal**: Thalassiophysales; **Rhop**: Rhopalodiales; **Cymb**: Cymbellales; **Navi**: Naviculales; **Baci**: Bacillariales; **Frag**: Fagilariales. **I** and**II** : Groups,**S1**, **S2**, **S3**, **S4**and**S5** : sites Code.

Table 4. Inventory of taxa with toxic potential in fish ponds.

		Toxins produced		
Inventoried taxa	Density (Cells /mL)	Hepatoxin	Neurotoxin	Dermatoxin
Oscillatoria sp.	--	x		
Microcystis aeruginosa	1000	x		
Microcystis novacekii	--	x		
Anabaena circinalis	2000	x		
Anabaena cf. *spiroides*	--	x		
Anabaenopsis circularis	2000	x		
Anabaenopsis arnoldii	3000	x		
Anabaenopsis circularis var. *javanica*	--	x		
Anabaenopsis tanganyikae	2000	x		
Cylindrospermopsis raciborskii	1000	x		
Lyngbya sp.	1000		x	x
Peridinium sp.1	--		x	
Peridinium sp.2	5000		x	

--:Unassisted densityX:Toxin produced by the corresponding taxon.

CONCLUSION

This study showed the spatial heterogeneity and diversity of phytoplankton flora in Bouake Research Station fishponds. The composition of the phytoplankton flora is dominated by Chlorophyta and Euglenophyta. Furthermore, the presence of potentially toxic taxa harmful to the growth of fish was notedin phyla of Cyanobacteria and Miozoa. Impact of these harmful taxa should be checked for future studies.

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