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Structure and Diversity of Phytoplankton Community in Taabo lake, Côte d'Ivoire

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ABSTRACT

Phytoplankton communities are widely used as indicators of trophic status and eutrophication in freshwater ecosystems. This is particularly true for tropical reservoirs, which are strongly influenced by seasonal and human activities. The present study examined the structure, diversity, and spatial and temporal dynamics of phytoplankton communities in Taabo lake (Côte d'Ivoire). Sampling was conducted over a one-year period, from November 2017 to October 2018. Five sampling sites were monitored during contrasting four seasons. Phytoplankton composition, abundance, and environmental variables were simultaneously assessed. A total of 242 phytoplankton taxa belonging to seven phyla were identified. Chlorophyta represented the most taxonomically diverse phyla. Despite the high taxonomic richness, phytoplankton composition showed strong similarity among sites. In contrast, phytoplankton abundance was largely dominated by Cyanoprokaryota throughout the study period. The most abundant species were *Pseudanabaena limnetica* and *Microcystis aeruginosa*. Phytoplankton densities increased markedly during the rainy seasons, coinciding with higher concentrations of nitrogen and phosphorus. Diversity and evenness indices were significantly lower at sites (S1 and S2) affected by fish farming activities. This pattern reflected the dominance of a few opportunistic Cyanoprokaryota species under nutrient-enriched conditions. ReDundancy Analysis demonstrated that seasonal variations in nutrient availability, conductivity, lake depth, and water transparency were the main factors structuring phytoplankton communities. Overall, the results indicate that Taabo lake exhibits clear symptoms of eutrophication. Nutrient enrichment, combined with seasonal hydrological dynamics, strongly controls phytoplankton structure and promotes Cyanoprokaryota dominance.

Keywords

Phytoplankton; Eutrophication; Nutrient enrichment; Cyanobacteria; Tropical reservoir

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Introduction

Phytoplankton represents the foundation of aquatic food webs and plays a key role in biogeochemical cycles and primary production in freshwater ecosystems (Naselli-Flores and Padisák, 2023). Because of their rapid growth rates and sensitivity to changes in nutrient availability, phytoplankton communities are widely recognized as reliable indicators of trophic status and eutrophication processes (Van Meerssche and Pinckney, 2019). Variations in phytoplankton composition, abondance, and diversity are closely associated with nutrient enrichment, particularly nitrogen and phosphorus inputs, which can lead to shifts in community structure and the dominance of opportunistic or bloom-forming taxa (Zhou *et al*., 2018).

In tropical reservoirs, eutrophication is often exacerbated by intense seasonal rainfall, high temperatures, and prolonged water residence times, which together enhance nutrient loading and internal recycling (Kouassi *et al*., 2007; Winton *et al*., 2019). Agricultural runoff, domestic wastewater, and erosion from surrounding catchments contribute substantial amounts of dissolved and particulate nutrients, promoting phytoplankton proliferation and, in some cases, harmful algal blooms (Wurtsbaugh *et al*., 2019). These processes may result in reduced water transparency, oxygen depletion, and alterations of ecosystem functioning, ultimately affecting fisheries and water uses (Kim *et al*., 2023).

Taabo lake, located in central Côte d'Ivoire, is a multipurpose artificial lake of major socio-economic importance. However, the reservoir is subjected to increasing nutrient inputs from agricultural activities, urban settlements, and riverine inflows within its watershed (Aliko *et al*., 2010**;** N'guessan *et al*., 2022). Previous investigations in West African reservoirs have highlighted strong relationships between nutrient concentrations and phytoplankton dominance patterns, often characterized by the proliferation of cyanobacteria and other eutrophication-tolerant groups (Adon *et al*., 2011; Attoungbre *et al*., 2019; Groga *et al*., 2019). Nevertheless, existing information on the influence of nutrient enrichment on phytoplankton structure and diversity in the Taabo lake warrants re-evaluation more than a decade after the study conducted by Groga *et al*. (2014).

The present study aims to assess the structure, diversity, and spatial and temporal dynamics of the phytoplankton community in Taabo lake. Specifically, this study aims to: (i) characterize the waters of the Taabo Reservoir based on physico-chemical parameters; (ii) analyze phytoplankton communities in terms of composition and abundance; and (iii) determine the influence of environmental factors on these phytoplankton communities.

Materials and Methods

Study area and sampling sites

Located in central Côte d'Ivoire (6°25'-6°56' N; 5°07'-5°33' W), Taabo Lake (Figure .1) covers an area of 69 km², has an average depth of 16 m (maximum depth 30 m), and exhibits a water residence time of approximately 49.2 days (Kouassi *et al*., 2007). The climate is characterized by four seasons (two rainy seasons and two dry seasons). The rainy seasons are represented by a long rainy season (LRS) from April to July and a short rainy season (SRS) from October to November. The two dry seasons are represented by a long dry season (LDS) from December to March and a short dry season (SDS) from August to September (Kouassi *et al*., 2013). The mean annual precipitation varies from 1100 to 1600 mm, and the mean annual air temperature ranges between 24.5 °C and 34 °C (Aliko *et al*., 2010).

Table.1 Coordinates and characteristics of the sampling sites in Taabo lake (2017-2018, Côte d'Ivoire)

Sampling sites	Latitude (N)	Longitude (W)	Mean Depth (m)	Characteristics of the sampling sites
St1	06°15'46.6"	05°04'57.4"	2.8	Urban area of the reservoir, cattle farming on the bank, agriculture, bathing and washing activities
St2	06°15'42.5"	05°04'59.3	8	Fish farming operation into the reservoir
St3	06°15'06.3"	05°05'11.2"	19	Fishing area
St4	06°13'00.8"	05°06'13.7"	8.5	Fishing area
St5	06°12'59.2"	05°06'14.6"	3.2	Rural zone of the reservoir, fishing area, agriculture

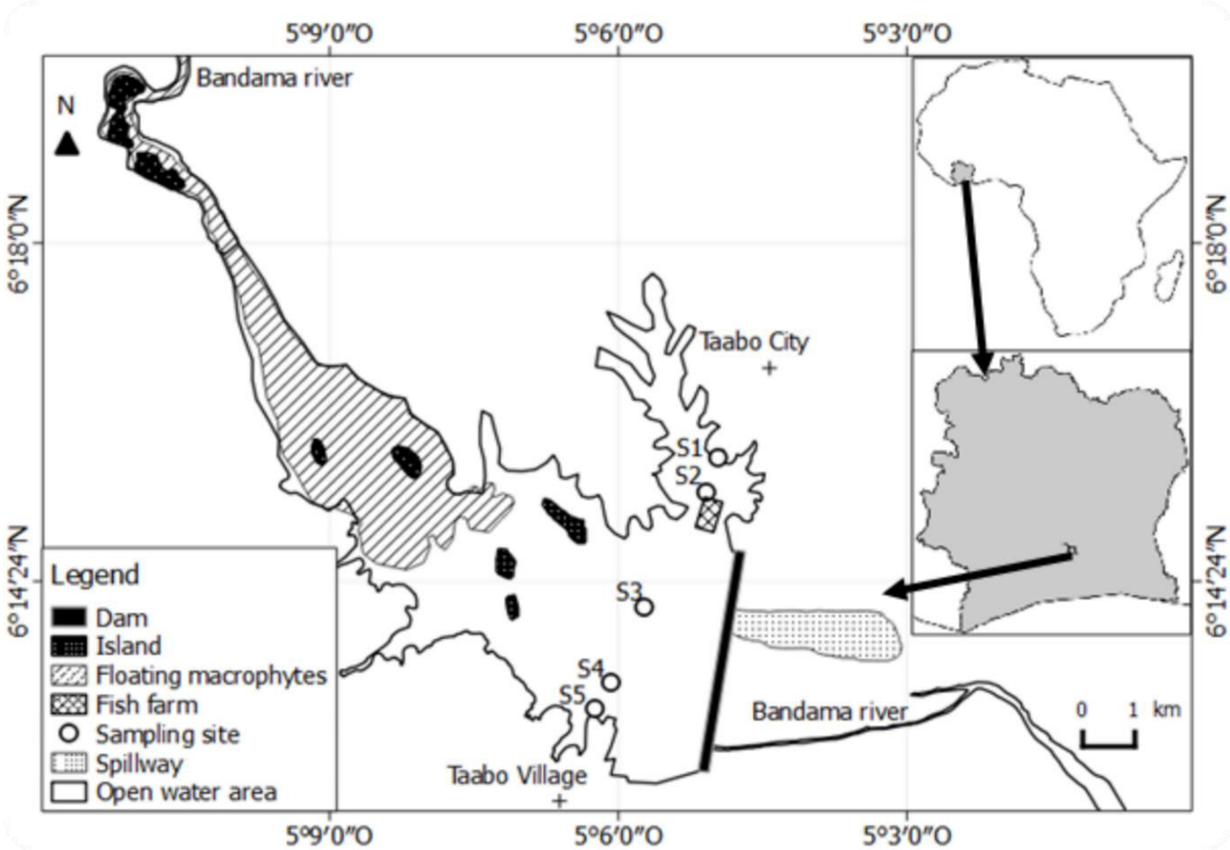


Figure.1 Map showing the location of sampling sites in Taabo lake (Côte d'Ivoire): S1-S5 = sampling sites

A year long survey was carried out from November 2017 to October 2018 at five sampling sites distributed along a seven kilometre transect in the open waters of the reservoir. Sampling site characteristics are summarized in Table.1. Samples were collected every 45 days.

Phytoplankton sampling

Phytoplankton samples were obtained by taking two vertical hauls (0.5 m and 1 m) using a Van Dorn bottle at each sampling point. Samples were fixed with solution formaldehyde at 5%. Estimation of species composition of phytoplankton samples was carried out by examining several small fractions of the samples under microscope (Zeiss). The component organisms were identified as far as possible using identification manuals (Ouattara *et al*. 2000, John *et al*. 2002; Cocquyt, 1998; Ten-Hage *et al*., 2007; Zongo *et al*., 2011, ….). Additionally, all species names were checked for current status and names in the database of AlgaeBase (Guiry and Guiry, 2016).

Phytoplankton were counted (cell) according to Utermöhl (1958) using an inverted microscope (OPTIKA) at 200X/400X magnification by following the standard NF EN 15204 (2006).

Environmental variables

Selected physical and chemical parameters (temperature, conductivity, pH, dissolved oxygen, transparency, nutrients) were measured in order to characterize the water quality of this limited geographical sampling area together with the phytoplankton at each site. Water parameters were followed at two depths (0.5 and 1 m). Water temperature and conductivity were measured using a conductivity meter, WTW COND 340-i model and pH with a pHmeter, HANNA, Hi 991001 model. Dissolved oxygen, water depth and water transparency were measured with respectively an oximeter HANNA (Hi 9146) model, a portable sounder ECHOTEST model and a 20 cm diameter black and white Secchi disk.

Water nutrient concentrations were measured with a spectrophotometer Model HACH DR 2010. Samples for

Total nitrogen (TN) and Total phosphorus (TP) analysis were determined using standard method NF EN ISO 10304-1 (2009).

Data analysis

Phytoplankton community structure was described through taxonomic richness, frequency of occurrence, Sorensen similarity index, Shannon-Weaver diversity index, and Pielou evenness index. The Sorensen similarity index was used to assess phytoplankton taxonomic similarity between sampling sites. The frequency of occurrence (FO) of each specie was calculated using the following formula: $FO = (Ni/Nts) \times 100$; with Ni = number of samples containing a given specie i and Nts = total number of samples collected. The FO was used to classify taxa following Dajoz (2000): $FO > 50$ (common taxa); $25 < FO < 50$ (occasional taxa); $FO \leq 25$ (rare taxa).

Differences in phytoplankton abundance, Shannon-Weaver diversity index, Pielou evenness index and environmental parameters between sampling sites and sampling months were evaluated using Kruskal-Wallis test, a non parametric analysis of variance, followed by Mann-Whitney test. Before performing comparison test, normality of data was checked by Shapiro test ($p > 0.05$ at all sampling sites). Analyses were conducted using Rstudio R 3.1.3 (R Core Team, 2013). Statistical analyses were performed at a level of significance of $p < 0.05$.

In order to assess relationships between phytoplankton community and environmental variables, ReDundancy Analysis (RDA) was performed based on the data matrix of phytoplankton densities. Phytoplankton densities and environmental variables were log10 (X+1) transformed prior to analysis. Monte Carlo permutation test (499 permutations) were done so as to identify a subset of measured environmental variables, which exerted significant and independent influences on phytoplankton distribution at $p < 0.05$ (Van Tongeren *et al*., 1992). RDA was performed using CANOCO 4.5.

Results and Discussion

Environmental variables

The spatio-temporal variations of the environmental parameters recorded in this study are shown in Figure. 2. Water depth fluctuated between the dry (LDS: Jan-Feb; SDS: Sep) and rainy seasons (LRS: Apr, Jun, Jul; SRS: Oct-Nov). It reached a maximum of 22 m at S3. Water temperature peaked in January (31 °C) and declined to 26.9 °C by October. Conductivity ranged from 71.9 µS cm^{-1} (S4, LDS) to 134 µS cm^{-1} (S2, SRS). Dissolved oxygen varied inversely, from 3.7 mg L^{-1} (S1, LRS) to 7.1 mg L^{-1} (S3, SRS). pH exceeded 9 in the littoral zones of S1 and S2 during the SDS. It dropped to 6.5 in the SRS, corresponding with minimal transparency (0.2 m). Nutrient concentrations increased during the rainy season. Total nitrogen (TN) and total phosphorus (TP) peaked at 0.38 mg L^{-1} and 0.84 mg L^{-1}, respectively, at S2 in October. Despite slight variations in depth, no significant differences were observed among sites (Kruskal-Wallis test, $P > 0.05$), whereas all parameters showed significant seasonal variations (Mann-Whitney test, $P < 0.05$).

Qualitative analysis of phytoplankton populations in Taabo Lake

A total of 242 phytoplankton taxa were identified in Lake Taabo (Table.2). These taxa belong to 104 genera, 49 families, 26 orders, 14 classes, and seven phyla (Cyanoprokaryota, Euglenophyta, Chlorophyta, Bacillariophyta, Dinophyta, Chrysophyta, and Xanthophyta). Chlorophyta was the most diverse phylum, with 114 taxa, representing over 47% of the phytoplankton community. It was followed by Euglenophyta (54 taxa), Cyanoprokaryota (38 taxa), and Bacillariophyta (24 taxa). Xanthophyta (6 taxa), Dinophyta (4 taxa), and Chrysophyta (2 taxa) were poorly represented. Chlorophyta comprised six orders: Desmidiales (2 families), Chlamydomonadales (1 family), Chlorellales (2 families), Sphaeropleales (9 families), Spirogyrales (1 family), and Ulotrichales (1 family). The most diverse families were Desmidiaceae and Scenedesmaceae, each with 30 taxa.

Phytoplankton composition was similar across sites. Species richness varied among sites, ranging from 205 taxa at S3 to 216 taxa at S5. Many taxa (178) were common to all sites. The phytoplankton community inventory in Lake Taabo revealed a high taxonomic similarity among sites. A total of 178 taxa were found to be common across the surveyed sites. Several phytoplankton species were restricted to specific sites. *Pediastrum simplex*, *Tetradesmus obliquus*, *Selenodictyum brasiliensis*, and *Spondylosium tetragonum* occurred only at the coastal sites (S1 and S5). *Euastrum platycerum*, *Euglena gaumei*, and *Closterium* *jenneri var. cynthia* were confined to S4 and S5. *Monoraphidium convuluptum* and *Trachelomonas acanthophora* were exclusive to S4, while *Tetraedron tumidulum*, *Oedogonium* sp., *Trachelomonas pulchra*, and *Euglena rubra* occurred only at S2. *Spirogyra* sp., *Cosmarium vexatum, Micrasterias ceylanica*, and *Pleurotaenium cylindricum* were characteristic of S5. Some taxa, including *Mallomonas* sp. (S1 and S2), *Trachelomonas dastuguei* var. *dastuguei* f. *africana* (S3 and S4), and *Trachelomonas bernardinensis* var. *africana* (S2 and S5), were common to multiple sites. Phytoplankton composition across the sites indicated that Chlorophyta phyla was the most abundant group, representing 44 - 47% of the community. This was followed by Euglenophyta phyla, with proportions ranging from 20% to 23%. Bacillariophyta (10-12%) and Cyanoprokaryota (16-17%) were less abundant. Other phyla collectively accounted for only 5 - 6% of the diversity.

The proportion of common taxa (FO > 50 %) are the most numerous at all the sites with percentages ranging between 44.3% (S1) and 65.9% (S3) (Table.3). For the occasional taxa (25 < FO < 50 %), the highest proportion (27.3%) was observed at site S4 and S5, whereas the lowest proportion (18.5 %) was noted at site S3. Regarding the rare taxa (FO ≤ 25 %), the highest proportion was noted at site S1 (29.5 %), and the lowest proportion was observed at site S3 (15.6 %).

The highest values (more than 80 %) of Sorensen similarity index between all the sampled sites highlight the great homogeneity in phytoplankton community among the sites (Table.4).

Quantitative analysis of phytoplankton populations in Taabo lake

Spatio-temporal variations of densities showed a similar trend at all sites during this study (Figure. 3). Phytoplankton abundance was low at all sites between January and February, below 250 × 10^5 cells L^{-1}. It gradually increased to higher densities in July. Values ranged from 300 × 10^5 cells L^{-1} at S5 to 650 × 10^5 cells L^{-1} at S2. A slight decrease was observed in September, with values below 450 × 10^5 cells L^{-1}. Densities then increased until October, reaching their annual maximum. They ranged from 650 × 10^5 cells L^{-1} at S3 to 2.000 × 10^5 cells L^{-1} at S2. No significant differences were observed between sites S1, S3, S4, and S5 (Mann-Whitney test; $p > 0.05$). However, the abundances observed at site S2 were significantly higher (Mann-Whitney test; $p = 0.004$). The Mann-Whitney test ($p = 0.003$) shows that phytoplankton densities are significantly higher during the rainy season (GSP; PSP) than during the long dry season.

The relative abundances of the phytoplankton phyla (Figure. 4) showed that Cyanoprokaryota were the most dominant at all sites. They accounted for over 60% of the total density during the sampling periods. Across sites, *Pseudanabaena limnetica* (41-79%) and *Microcystis aeruginosa* (7-22%) were the numerically dominant species each month.

Spatial variations in the Shannon diversity index and the Piélou equitability index

Figure. 5 shows the diversity and evenness indices of phytoplankton communities at the five sites in Lake Taabo. Median diversity values ranged from 1.1 bits.cell^{-1} at S1 to 1.7 bits.cell^{-1} at S4. Evenness values also varied among sites, ranging from 0.26 at S2 to 0.37 at S4. Diversity and evenness indices at S1 and S2 were significantly lower than those at S3, S4, and S5 (Mann–Whitney test; $p = 0.025$).

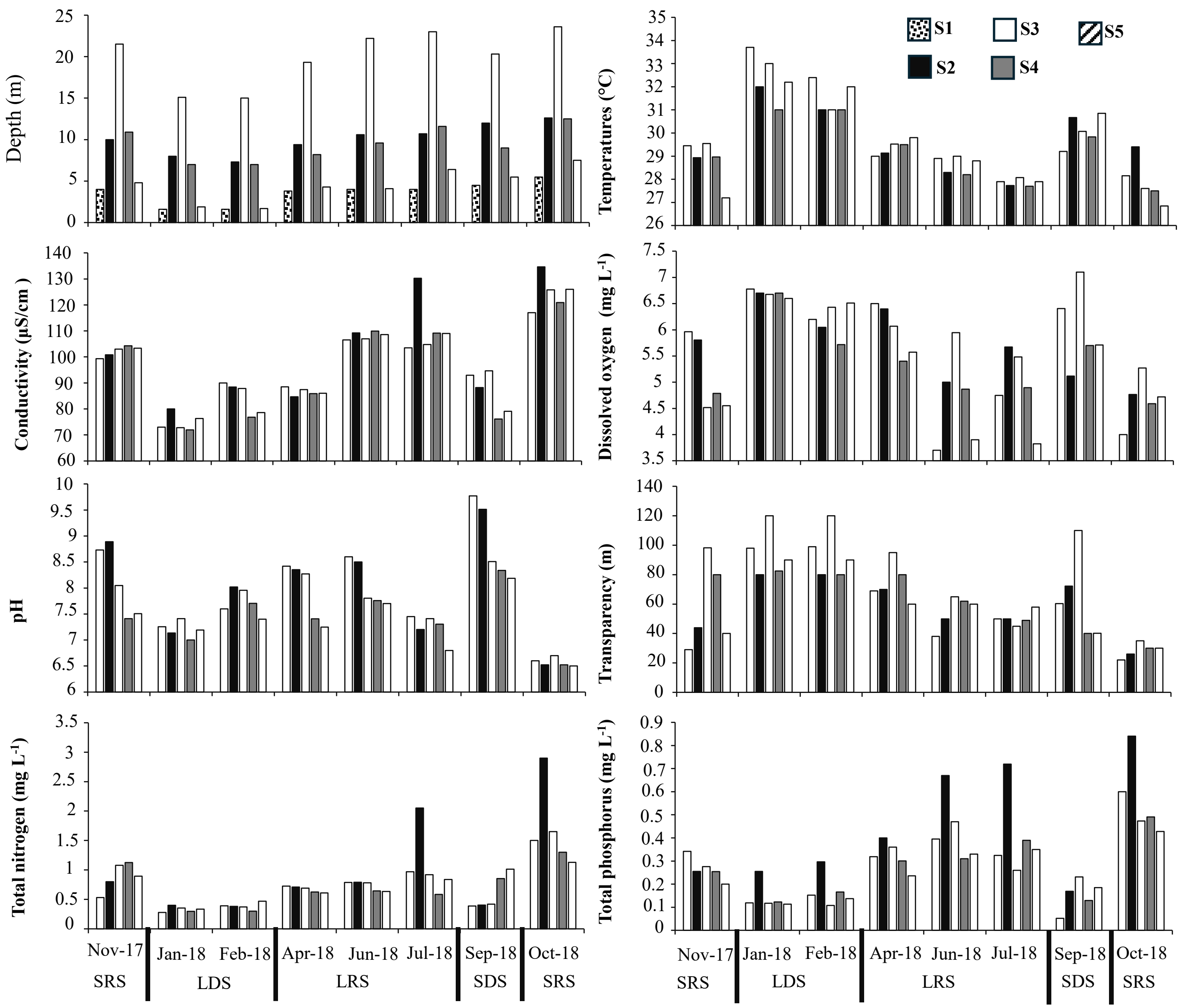
Taxa relationships with environmental variables

The relationships between environmental variables and the abundance of the main phytoplankton taxa were examined using redundancy analysis (RDA). Sixteen (16) phytoplankton taxa accounting for more than 5% of the total phytoplankton abundance were included in the analysis. The RDA explained 77% of the total variance in the data along the first two ordination axes (Figure. 6).

The first axis, which accounted for 65% of the variance, reflected a clear seasonal gradient, with samples from the rainy seasons clustering on the positive side and those from the dry seasons on the negative side. Several phytoplankton taxa were strongly and positively correlated with this axis, including *Aulacoseira granulata* var. *angustissima*, *Aulacoseira granulata* f. *spiralis*, *Aulacoseira granulata*, *Cosmarium baileyi*, *Eudorina elegans*, *Eudorina unicocca*, *Peridiniopsis armebeensis*, *Microcystis aeruginosa*, *Peridinium cinctum*, and *Pseudanabaena limnetica*. The proliferation of these taxa was associated with increased lake depth, total phosphorus, total nitrogen, and conductivity, together with decreased dissolved oxygen, temperature, and water transparency.

The second axis explained 12% of the variance and was positively correlated with *Coelastrum indicum*, *Glenodinium* sp., *Pandorina morum*, *Phormidium* sp., *Nitzschia* sp., *Ulnaria acus*, and *Ulnaria ulna*. The proliferation of these taxa was favored by elevated pH values. In contrast, the positioning of samples near the origin of the ordination axes indicates that none of the measured abiotic parameters significantly discriminated the samples within this group.

Figure.2 Spatio-temporal variations in physical and chemical variables of Taabo lake (2017-2018):



Apr: April; Jun: June; Sept: September; Oct: October; Nov: November; LRS: long rainy season; SDS: short dry season; SRS: short rainy season; LDS: long dry season

Table.2 Taxonomic composition and the frequency of occurrence (FO) of phytoplankton recorded in Taabo lake from November 2017 to October 2018 (Côte d'Ivoire): * = rare taxa ; $*^2$ = Occasional taxa ; $*^3$ = Common taxa ; Acro = Acronyms

Phytoplankton taxa	Acro	Sampling sites					Phytoplankton taxa	Acro	Sampling sites				
		S1	S2	S3	S4	S5			S1	S2	S3	S4	S5
Bacillariophyta							**Bacillariophyta (Next)**						
Bacillariophyceae							**Rhopalodiaceae**						
Bacillariales							*Epithemia turgida* (Ehrenberg) Kützing	Eptu	*	$*^3$	$*^2$	*	$*^2$
Bacillariaceae							**Surirellales**						
***Nitzschia* sp. 1**	Nsp1	$*^3$	$*^3$	$*^3$	$*^3$	$*^3$	**Surirellaceae**						
***Nitzschia* sp. 2**	Nsp2	$*^3$	$*^3$	$*^3$	$*^3$	$*^3$	*Surirella* sp.	Susp	*	*	*	*	$*^2$
***Ntizchia* sp. 3**	Nsp3	*	$*^3$	$*^3$	$*^2$	$*^3$	**Thalassiophysales**						
***Tryblionella victoriae* Grunow**	Trvi	$*^2$	*	$*^2$	*	*	**Catenulaceae**						
Cymbellales							*Amphora commutata* Grunow	Amco	$*^2$	*	*	*	*
Cymbellaceae							**Coscinodiscophyceae**						
***Cymbella cucumis* Schmidt**	Cycu		$*^2$	$*^3$	$*^2$	$*^2$	**Aulacoseirales**						
Gomphonemataceae							**Aulacoseiraceae**						
***Encyonema silesiacum* (Bleisch) Mann**	Ensi	$*^2$	$*^2$	$*^3$	*	$*^2$	*Aulacoseira granulata* (Ehrenberg) Simonsen	Augr	$*^3$	$*^3$	$*^3$	$*^3$	$*^3$
***Gomphonema gracile* Ehrenberg**	Gogr	$*^3$	$*^2$	$*^3$	$*^2$	*	*Aulacoseira granulata* f. *spiralis* (Hustedt) Czarnecki	Augs	$*^3$	$*^3$	$*^3$	$*^3$	$*^3$
Eunotiales							*Aulacoseira granulata* var. *angustissima* (Müller) Simonsen	Auga	$*^3$	$*^3$	$*^3$	$*^3$	$*^3$
Eunotiaceae							**Mediophyceae**						
***Eunotia* sp.**	Eusp	$*^3$	$*^3$	$*^3$	$*^3$	$*^3$	**Chaetocerotales**						
Licmophorales							**Chaetocerotaceae**						
Ulnariaceae							*Acanthoceras zachariasii* (Brun) Simonsen	Acza	*	$*^2$	*		
***Ulnaria acus* (Kützing) Aboal**	Ulac	$*^3$	$*^3$	$*^3$	$*^3$	$*^3$	**Chlorophyta**						
***Ulnaria ulna* (Nitzsch) Compère**	Ulul	$*^3$	$*^3$	$*^3$	$*^3$	$*^3$	**Chlorophyceae**						
Naviculales							**Chlamydomonadales**						
Naviculaceae							**Volvocaceae**						
***Gyrosigma acuminatum* (Kützing) Rabenhorst**	Gyac	*	*	$*^2$	$*^2$	$*^2$	*Eudorina elegans* Ehrenberg	Euel	$*^3$	$*^3$	$*^3$	$*^3$	$*^3$
***Navicula* sp.**	Nasp	$*^3$	$*^2$	$*^2$	*	$*^3$	*Eudorina unicocca* Smith	Euun	$*^2$	$*^3$	$*^3$	$*^3$	$*^2$
Pinnulariaceae							*Pandorina morum* (Müller) Bory	Pamo	$*^3$	$*^3$	$*^3$	$*^3$	$*^3$
***Pinnularia brauniana* (Grunow) Studnicka**	Pibr	$*^3$	$*^3$	*	*	$*^2$	*Volvox africana* West	voaf	$*^2$	*	$*^2$	*	*
***Pinnularia divergens* Smith**	Pidi	*	$*^2$	$*^2$	$*^2$	$*^2$	*Volvox aureus* Ehrenberg	voau	$*^3$	$*^3$	$*^3$	$*^2$	$*^3$
***Pinnularia mesolepta* (Ehrenberg) Smith**	Pime	$*^2$	$*^3$	$*^3$	*	$*^3$	**Sphaeropleales**						
***Pinnularia* sp.**	Pips	$*^2$	$*^3$	$*^3$	$*^2$	$*^3$	**Cylindrocapsaceae**						
Sellaphoraceae							*Fusola viridis* Snow	Fuvi	$*^2$	$*^3$	$*^3$	$*^2$	$*^2$
***Sellaphora pupula* (Kützing) Mereschkovsky**	Sepu	$*^2$	$*^2$	$*^2$	$*^2$	$*^2$	**Hydrodictyaceae**						
Rhopalodiales							*Lacunastrum gracillimum* (West & West) Mc-Manus	Lagr	$*^3$	$*^3$	$*^3$	$*^3$	$*^3$
							*Monactinus simplex (*Meyen) Corda	Mosi	$*^3$	$*^3$	$*^3$	$*^3$	$*^3$
							Parapediastrum biradiatum (Meyen) Hegewald	Pabi	$*^3$	$*^3$	$*^3$	$*^3$	$*^3$

Table.2 Continued

Phytoplankton taxa	Acro	Sampling sites					Phytoplankton taxa	Acro	Sampling sites				
		S1	S2	S3	S4	S5			S1	S2	S3	S4	S5
Chlorophyta (Next)							**Chlorophyta (Next)**						
***Pediastrum duplex* Meyen**	Pedu	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	*Desmodesmus spinulatus* (Biswas) Hegewald	Desp	$*^{2}$	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$
***Pediastrum simplex* Meyen**	Pesi	*				$*^{2}$	*Dimorphococcus lunatus* Braun	Dilu	$*^{2}$	$*^{2}$	$*^{3}$	$*^{2}$	$*^{2}$
***Sorastrum americanum* (Bohlin) Schmidle**	Soam	*	$*^{2}$	*	*		*Hariotina reticulata* Dangeard	Hare	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$
***Stauridium tetras* (Ehrenberg) Hegewald**	Sttt	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	*Pectinodesmus regularis* (Svirenko) Hegewald, Wolf, Friedl et Krienitz	Pere	$*^{3}$	$*^{3}$	$*^{3}$	*	$*^{3}$
***Tetraedron arthrodesmiforme* Woloszynska**	Tear	$*^{3}$	$*^{2}$	$*^{2}$	$*^{2}$	$*^{2}$	*Scenedesmus bicaudatus* (Hansgirg) Chodat	Scbi	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$
***Tetraedron gracile* (Reinsch) Hansgirg**	Tegr	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	*Scenedesmus communis* Hegewald	Scco	$*^{3}$	$*^{3}$	$*^{3}$	*	$*^{3}$
***Tetraedron minimun* cf. *apiculatum* (Reinsch) De-Toni**	Temi	*	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	*Scenedesmus naegelii* Brébisson	sena	*		*	$*^{3}$	*
***Tetraedron triangulare* Korshikov**	Tetr	*	$*^{3}$	$*^{3}$	$*^{3}$	$*^{2}$	*Scenedesmus obtusus* Meyen	Scob	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$
***Tetraedron tumidulum* (Reinsch) Hansgirg**	Tetu		*				*Scenedesmus obtusus* f. *disciformis* (Chodat) Compère	Scod	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$
Neochloridaceae							*Selenodictyum brasiliensis* Uherkovich & Schmidt	Sebr	*				$*^{2}$
***Golenkinia radiata* Chodat**	Gora	$*^{2}$	$*^{3}$	$*^{3}$	$*^{2}$	$*^{2}$	*Tetradesmus bernardii* (Smith) Wynne	Tebe	$*^{2}$	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$
***Golenkinia* sp.**	Gosp	$*^{2}$		*		$*^{2}$	*Tetradesmus dimorphus* (Turpin) Wynne	Tedi	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$
Nephrocytiaceae							*Tetradesmus lagerheimii* Wynne & Guiry	Tela	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$
***Nephrocytium agardhianum* Nägeli**	Neag	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	*Tetradesmus obliquus* (Turpin) Wynne	Teob	$*^{2}$				*
***Nephrocytium lunatun* West**	Nelu	*	$*^{2}$	*	*	$*^{2}$	*Tetrastrum elegans* Playfair	Teel		*	*	*	
Schroederiaceae							*Tetrastrum heteracanthum* (Nordstedt) Chodat	Tehe	$*^{2}$	$*^{2}$	$*^{2}$	$*^{3}$	$*^{2}$
***Schroederia nitzschioides* (West) Korchikov**	Scni	*	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	*Tetrastrum triangulare* (Chodat) Bock & Krienitz	Tetr	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$
***Schroederia setigera* (Schröder) Lemmermann**	Scse	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	*Westella* sp.	Wesp	$*^{2}$	*	*	*	$*^{2}$
Scenedesmaceae							*Willea crucifera* (Wolle) John, Wynne & Tsarenko	Wicr	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$
***Acutodesmus acutiformis* (Schröder) Tsarenko et John**	Acac	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	*Willea rectangularis* (Braun) John, Wynne & Tsarenko	Wire	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$
***Coelastrum cambricum* Archer**	Coca	*	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	**Selanastraceae**						
***Coelastrum indicum* Turner**	Coin			*		*	*Ankistrodesmus arcuatus* Korshikov	Anar	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$
***Coelastrum microporum* Näegeli**	Comi	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	*Ankistrodesmus bernadii* Komàrek	Anbe	*	$*^{2}$	$*^{2}$	$*^{2}$	*
***Desmodesmus abundans* (Kirchner) Hegewald**	Deab	$*^{3}$	$*^{3}$	$*^{3}$	*	$*^{3}$	*Ankistrodesmus falcatus* (Cordat) Ralfs	Anfa	*		*		*
***Desmodesmus armatus* var. *longispina* (Chodat) Hegewald**	Dear					*	*Ankistrodesmus fusiformis* Cordat	Anfu	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$
***Desmodesmus brasiliensis* (Bohlin) Hegewald**	Debr	$*^{2}$	$*^{3}$	$*^{2}$	$*^{2}$	$*^{2}$	*Ankistrodesmus spiralis* (Turner) Lemmermann	Ansr	$*^{3}$	*	$*^{3}$	$*^{2}$	$*^{3}$
***Desmodesmus denticulatus* (Lagerheim) An, Friedl & Hegewald**	Dede	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	*Kirchneriella lunaris* (Kirchner) Mobius	Kilu	$*^{2}$	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$
***Desmodesmus opoliensis* (Richter) Hegewald**	Deop	$*^{3}$	$*^{3}$	$*^{3}$	*	$*^{3}$	*Kirchneriella obesa* (West) West & West	Kiob	*	$*^{2}$		*	*

Table.2 Continued

Phytoplankton taxa	Acro	Sampling sites					Phytoplankton taxa	Acro	Sites				
		S1	S2	S3	S4	S5			S1	S2	S3	S4	S5
Chlorophyta (Next)							**Chlorophyta (Next)**						
Messastrum gracile **(Reinsch) Garcia**	Megr	*	$*^{3}$	$*^{3}$	$*^{3}$		*Closterium jenneri* var. *cynthia* (De-Notaris) Petlovany	Clej				*	*
Monoraphidium convoluptum **(Corda) Komàrkovà & Legnerovà**	Moco				*		*Cloterium kuetzingii* Brébisson	Clku	*	*	*	*	*
Monoraphidium griffithii **(Berkeley) Komàrkovà & Legnerovà**	Mogr	$*^{2}$	$*^{3}$	$*^{2}$	$*^{2}$	$*^{2}$	*Closterium leibleinii* Kützing ex Ralfs	Clle				*	*
Selenastrum bibraianum **Reinsch**	Sebi	$*^{2}$	$*^{2}$	$*^{3}$	$*^{2}$		*Closterium lineatum* Ehrenberg ex Ralfs	Clli	*	$*^{2}$	$*^{3}$	$*^{3}$	$*^{2}$
Sphaeropleaceae							*Closterium strigosum* Brébisson	Clst	$*^{2}$	*	*	$*^{2}$	$*^{2}$
Polyedriopsis spinulosa **(Schmidle) Schmidle**	Posp	$*^{2}$	$*^{2}$	$*^{3}$	*	$*^{3}$	*Closterium subulatum* (Kützing) Kützing Brébisson	Clsu	*		$*^{2}$	*	*
Radiococcaceae							**Desmidiaceae**						
Gloeocystis **sp.**	Gcsp	*	$*^{3}$	$*^{3}$	$*^{3}$	*	*Actinotaenium capax* (Joshua) Teiling	Acca	*	*			*
Oedogoniales							*Cosmarium Baileyi* Wolle	Coba	*	$*^{3}$		*	$*^{2}$
Oedogoniaceae							*Cosmarium brebissonii* Meneghini ex Ralfs	Cobr	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$
Oedogonium **sp.**	Oesp		$*^{2}$			*	*Cosmarium contractum* Kirchner	Coco	$*^{3}$	*	$*^{3}$	$*^{3}$	$*^{3}$
Trebouxiophyceae							*Cosmarium granatum* var. *pyramidale* Schmilde	Cogp	*			*	*
Crucigenia tetrapedia **(Kirchner) Kuntze**	Crte	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	*Cosmarium lundellii* var. *ellipticum* West & West	Colu	*	$*^{2}$	$*^{2}$		*
Chlorellales							*Cosmarium quadrum* Lundell	Coqu	$*^{2}$		*	$*^{2}$	
Chlorellaceae							*Cosmarium spinuliferum* West & West	Cosp	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$
Actinastrum gracillimun **Smith**	Acgr	$*^{2}$	$*^{2}$	*	*	*	*Cosmarium vexatum* West	Cove					*
Actinastrum hantzschii **Lagerheim**	Acha	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	*Euastrum binale* Ehrenberg ex. Ralfs	Eubi	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$
Golenkiniopsis **sp.**	Gosp			*		*	*Euastrum denticulatum* Gay	Eude	*	*	*		
Hindakia tetrachotoma **(Printz) Bock, Pröschold & Krienitz**	Hite	$*^{2}$	$*^{3}$	$*^{2}$	$*^{3}$	$*^{3}$	*Euastrum platycerum* Reinsch	Eupl				*	*
Mucidosphaerium puchellum **(Wood) Bock, Proschold & Krienitz**	Mupu	$*^{3}$	$*^{3}$	*	$*^{3}$	$*^{3}$	*Micrasterias ceylanica* Fritsch	Mice					*
Oocystaceae							*Pleurotaenium cylindricum* (Turner) Schmidle	Plcy					*
Oocystis borgei **Snow**	Oobo	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	*Sphaerozosma laeve* (Nordstedt) Thomasson	Spla	$*^{2}$			$*^{2}$	
Oocystis elliptica **West**	Ooel	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	*Spondylosium tetragonum* West & West	Spte	*				*
Ulvophyceae							*Staurastrum barbaricum* West & West	stba	$*^{2}$	$*^{2}$	$*^{3}$	$*^{2}$	$*^{2}$
Ulotrichales							*Staurastrum brachioprominens* Borgesen	Stbr	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$
Ulotrichaceae							*Staurastrum forficulatum* var. *minus* (Fritsch & Rich) Grönblad et Scott	Stfo	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$
Ulothix **sp.**	Ulsp	*					*Staurastrum gracile* var. *elongatum* West & West	Stgr	$*^{2}$	*	$*^{2}$	$*^{2}$	$*^{2}$
Zygnematophyceae							*Staurastrum leptocladum* var. *cornutum* Wille	Stle	*	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$
Desmidiales							*Staurastrum polymorphum* Brébisson	Stpo	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$	$*^{3}$
Closteriaceae													
Closterium acutum **Brébisson**	Clac	*	$*^{3}$	$*^{3}$	$*^{2}$	$*^{2}$							

Table.2 Continued

Phytoplankton taxons	Acro	Sampling sites					Phytoplankton taxa	Acro	Sampling sites				
		S1	S2	S3	S4	S5			S1	S2	S3	S4	S5
Chlorophyta (Next)							**Cyanoprokaryota (Next)**						
***Staurastrum pseudotetracerum* (Nordstedt) West & West**	Stps	*	*	*	*	*	*Chroococcus minutus* (Kützing) Nägeli	Chmn	*	$*^2$		*	*
***Staurastrum subcornutum* De-Toni**	Stsu	$*^3$	$*^3$	$*^3$	$*^2$	$*^2$	*Chroococcus turgidus* (Kützing) Nägeli	Chtu	$*^3$	$*^3$	$*^3$	$*^3$	$*^3$
***Staurastrum subgracillimum* West & West**	Stsg	$*^3$	$*^3$	$*^3$	$*^3$	$*^2$	**Microcystaceae**						
***Staurastrum teliferum* var. *gladiosum* (Turner) Coesel et Meesters**	Sttg	$*^2$	$*^3$	*	$*^2$	$*^3$	*Anacystis* sp.	Ansp	$*^2$	*	$*^2$		
***Staurastrum tetracerum* Raifs ex Ralfs**	Stte	$*^2$	$*^3$	$*^3$	$*^2$	$*^2$	*Microcystis aeruginosa* (Kützing) Kützing	Miae	*	$*^3$	$*^3$	$*^3$	$*^3$
***Staurastrum volans* West & West**	Stvo	$*^3$	$*^3$	$*^3$	$*^3$	$*^3$	*Microcystis wesenbergii* (Komàrek) Komàrek ex Komàrek	Miwe	*	$*^3$	$*^3$	$*^3$	$*^3$
***Staurodesmus subulatus* (Kützing) Croasdale**	Stsu	$*^2$	$*^3$	$*^3$	$*^2$		**Nostocales**						
***Staurodesmus triangularis* (Lagerheim) Teiling**	Stti	$*^3$	$*^3$	$*^3$	$*^3$		**Aphanizomenonaceae**						
Spirogyrales							*Cylindrospermopsis raciborskii* (Woloszyska) Seenayya & Subbu Raju	Cyra	$*^3$	$*^3$	$*^3$	$*^3$	*
Spirogyraceae							*Dolichospermun affine* (Lemmermann) Wacklin et Komàrek	Doaf	*			*	*
***Spirogyra* sp.**	Spsp					*	*Dolichospermun circinale* (Rabenhorst ex Bornet & Flashault) Wacklin, Hoffmann & Komàrek	Doci	$*^2$	$*^2$	$*^2$	$*^2$	$*^2$
Chrysophyta							*Dolichospermun flos aquae* (Rabenhorst ex Bornet & Flashault) Wacklin & Komàrek	Dofl	$*^3$	$*^3$	$*^3$	$*^3$	$*^3$
Chrysophyceae							**Nostocaceae**						
Chromulinales							*Anabaena planctonica* Brunnthaler	Anpl	*	$*^3$	$*^3$	$*^2$	$*^2$
Dinobryaceae							*Anabaena sphaerica* Bornet & Flashault	Ansh	$*^3$	$*^3$	$*^3$	$*^3$	$*^3$
***Dinobryon sertularia* Ehrenberg**	Dise		$*^2$	$*^2$	$*^2$	*	*Anabaena spiroides* (Woronichin) Elenkin-	Ansi	*	$*^2$	$*^2$	$*^2$	$*^2$
Synurophyceae							*Nostoc* sp.	Nosp	*	*	*		*
Synurales							**Oscillatoriales**						
Mallomonadaceae							**Oscillatoriaceae**						
***Mallomonas* sp.**	Masp	$*^2$	*				*Oscillatoria limosa* Agardh ex Gomont	Osli		*		*	$*^2$
Cyanoprokaryota							*Oscillatoria princeps* Vaucher ex Gomont	Ospr				$*^2$	
Cyanophyceae							*Oscillatoria simplicissima* Gomont	Ossi	*				
Chroococcales							*Oscillatoria* sp. 1	Osp1	*	$*^2$	$*^3$	$*^2$	*
Aphanothecaceae							*Oscillatoria* sp. 2	Osp2	$*^2$	$*^2$	$*^2$	$*^2$	$*^2$
***Aphanothece* sp.**	Apsp		$*^2$	*	*	*	**Phormidiaceae**						
Chroococcaceae							*Arthrospira* sp.	Arsp	*	$*^2$	$*^3$	$*^2$	$*^2$
***Chroococcus dispersus* (Keissier) Lemmermann**	Chdi	*		*		$*^2$	*Phormidium* sp. 1	Psp1	$*^3$	$*^3$	$*^3$	$*^3$	$*^3$
							Phormidium sp. 2	Psp2	$*^3$	$*^3$	$*^3$	$*^3$	$*^3$

Table.2 Continued

Phytoplankton taxa	Acro	Sampling sites					Phytoplankton taxa	Acro	Sampling sites				
		S1	S2	S3	S4	S5			S1	S2	S3	S4	S5
Cyanoprokaryota (Next)							**Dinophyta**						
Synechococcales							**Peridiniopsidaceae**						
Coelosphaeriacea							*Peridiniopsis armebeensis* Ten-Hage, Da & Couté	Pear	*^{3}	*^{3}	*^{3}	*^{3}	*^{3}
***Coelomoron* sp.**	Cosp	*^{3}	*^{3}	*^{3}	*^{3}	*^{3}	**Euglenophyta**						
***Coelosphaerium kuetzingianum* Nägeli**	Coku	*^{3}	*^{3}	*^{3}	*^{3}	*^{3}	**Euglenophyceae**						
***Snowella lacustris* (Chodat) Komárek & Hindák**	Snla	*^{3}	*^{3}	*^{3}	*^{3}	*^{3}	**Euglenales**						
Merismopediaceae							**Euglenaceae**						
***Aphanocapsa elachista* West & West**	Apel	*^{3}	*^{3}	*^{2}	*^{3}	*^{3}	*Euglena gaumei* Allorge & Lefevre	Euga			*	*^{2}	
***Aphanocapsa grevillei* (Berkeley) Rabenhorst**	Apgr	*^{3}	*^{3}	*^{2}	*^{2}	*^{3}	*Euglena proxima* (Dangeard) Bennett & Triemer	Eupr	*^{3}	*^{3}	*^{3}	*^{3}	*^{3}
***Aphanocapsa holsatica* (Lemmermann) Cronberg & Komàrek**	Apho	*^{3}	*^{3}	*^{3}	*^{3}	*^{3}	*Euglena rubra* Hardy	Euru		*			
***Aphanocapsa incerta* (Lemmermann) Cronberg & Komàrek**	Apin	*^{3}	*^{3}	*^{3}	*^{3}	*^{3}	*Euglena texta* (Dujardin) Hübner	Eute	*^{3}	*^{3}	*^{3}	*^{3}	*^{3}
***Limnococcus limneticus* (Lemmermann) Komàrkovà, Komàrek & Zap**	Lili	*^{3}	*^{3}	*^{3}	*^{3}	*^{3}	*Strombomonas acuminata* var. *deflandreana* Conrad	Stac	*^{3}	*^{3}	*^{3}	*^{3}	*^{3}
***Merismopedia elegans* Braun ex Kützing**	Meel	*^{2}	*^{2}	*	*^{2}	*^{2}	*Strombomonas ensifera* (Daday) Deflandre	Sten	*			*^{2}	*^{2}
***Merismopedia glauca* (Ehrenberg) Kützing**	Megl	*	*^{3}	*^{3}	*^{3}	*^{3}	*Strombomonas gibberosa* (Playfair) Deflandre	Stgi	*	*^{2}		*^{2}	
***Merismopedia* sp.**	Mesp	*^{2}	*^{2}	*^{3}	*^{3}	*^{2}	*Strombomonas maxima* (Skvortzov) Deflandre	Stma	*		*		*^{2}
***Merismopedia tenuissima* Lemmermann**	Mete	*^{3}	*^{3}	*^{3}	*^{2}	*^{2}	*Strombomonas* sp.	Stsp		*	*^{2}	*	*
***Synechocystis* sp.**	Sysp	*		*		*	*Strombomonas triquetra* (Playfair) Deflandre	Sttr	*^{2}	*^{2}	*^{3}	*^{3}	*^{2}
Pseudanabaenaceae							*Strombomonas verrucosa* (Daday) Deflandre	Stve	*^{3}	*^{3}	*^{3}	*^{3}	*^{3}
***Pseudanabaena limnetica* (Lemmermann) Komàrek**	Psli	*	*^{3}	*^{3}	*^{3}	*^{3}	*Trachelomonas acanthophora* Stokes	Trac				*^{2}	
Synechococcaceae							*Trachelomonas armata* (Ehrenberg) Stein	Trar		*	*	*	
***Synechococcus elongatus* (Nägeli) Nägeli**	Syel	*^{2}	*^{3}	*^{2}	*^{2}	*^{2}	*Trachelomonas bernardinensis* var. *africana* Deflandre	Trbe		*			*
Dinophyta							*Trachelomonas* cf. *allorgei* Deflandre	Trcf		*^{2}	*^{2}	*^{2}	*^{2}
Dinophyceae							*Trachelomonas conica* Playfair	Trco	*^{2}	*	*	*	*^{2}
Peridiniales							*Trachelomonas crebea* var. *spinosa* Kellicott	Trcr					*
Peridiniaceae							*Trachelomonas curta* Cunha	Trcu	*	*^{3}	*^{2}	*^{2}	*^{3}
***Bagredinium crenulatum* (Couté & Iltis) Da, Zongo, Mascarell & Couté**	Bacr	*^{3}	*^{3}	*^{3}	*^{3}	*^{3}	*Trachelomonas dastuguei* var. *dastuguei* f. *africana* Couté & Iltis	Trda			*	*	
***Glenodinium* sp.**	Glsp	*^{3}	*^{3}	*^{3}	*^{3}	*^{3}	*Trachelomonas dubia* Svirenko	Trdu	*	*^{3}	*^{3}	*^{3}	*^{3}
***Peridinium cinctum* (Müller) Ehrenberg**	Peci	*^{3}	*^{3}	*^{3}	*^{3}	*^{3}	*Trachelomonas duplex* (Deflandre) Couté & Tell	Trdp	*	*	*	*	
							Trachelomonas dybowskii Drezepolski	Trdy	*^{2}	*^{2}	*^{2}	*^{2}	*^{2}

Table.2 end

Phytoplankton taxa	Acro	Sampling sites					Phytoplankton taxa	Acro	Sampling sites				
		S1	S2	S3	S4	S5			S1	S2	S3	S4	S5
Euglenophyta (Next)							**Euglenophyta (Next)**						
***Trachelomonas hispida* var. *coronata* Lemmermann**	Trhc	*	*3	*3	*3	*3	*Phacus longicauda* (Ehrenberg) Dujardin	Phlo	*3	*3	*3	*	*3
***Trachelomonas hispida* (Perty) Stein**	Trhi	*3	*3	*3	*	*3	*Phacus onyx* Pochmann	Phon	*2	*2	*2	*2	*
***Trachelomonas hispida* var. *duplex* Deflandre**	Trhd	*	*3	*3	*2	*3	*Phacus orbicularis* Hübner	Phor	*3	*3	*3	*	*3
***Trachelomonas hispida* var. *hispida* Deflandre**	Trhh	*2	*2	*3	*	*3	*Phacus pleuronectes* (Müller) Nitzsch ex Dujardin	Phpl	*2	*2	*2	*2	*2
***Trachelomonas lefevrei* Deflandre**	Trle	*2	*2	*2	*2	*2	*Phacus ranula* Pochmann	Phra	*3	*3	*3	*	*3
***Trachelomonas planctonica* Svirenko**	Trpl	*3	*3	*3	*3	*3	*Phacus* sp.	Phsp		*	*2	*2	*
***Trachelomonas pulchra* Svirenko**	Trpu		*				*Phacus suecicus* Lemmermann	Phsu	*3	*2	*3	*2	*
***Trachelomonas similis* Stokes**	Trsi	*3	*3	*3	*3	*3	*Phacus tortus* (Lemmermann) Skvorstzov	Phto	*	*3	*3	*	*3
***Trachelomonas superba* Svirenko**	Trsu	*2	*3	*3	*3	*3	**Xanthophyta**						
***Trachelomonas sydneyensis* Playfair**	Trsy	*	*	*		*2	**Eustigmatophyceae**						
***Trachelomonas volvocina* (Ehrenberg) Ehrenberg**	Trvo	*3	*3	*3	*3	*3	**Goniochloridales**						
***Trachelomonas volvocinopsis* Svirenko**	Trvl	*3	*3	*3	*3	*3	**Goniochloridaceae**						
***Trachemomona pisciformis* var. *bicoronata* Couté & Iltis**	Trpi		*		*2	*	*Speudostaurastrum gracile* (Reinsch) Chodat	Spgr	*2	*3	*2	*2	*2
Phacaceae							*Speudostaurastrum lobulatum* (Nägeli) Bourrely	Splo	*2	*2	*2	*2	*2
***Lepocinclis acus* (Müller) Marin & Melkonian**	Leac	*2	*3	*2	*2	*	*Speudostaurastrum* sp.	Sesp	*3	*3	*3	*3	*3
***Lepocinclis fusiformis* (Carter) Lemmermann**	Lefu	*2	*	*2	*2	*2	*Tetraedriella regularis* (Kützing) Fott	Tere	*	*3	*3	*3	*3
***Lepocinclis ovum* (Ehrenberg) Lemmermann**	Leov	*3	*3	*3	*3	*3	**Xanthophyceae**						
***Lepocinclis oxyuris* (Schmarda) Marin & Melkonian**	Leox	*2	*3	*3	*3	*3	**Mischococcales**						
***Lepocinclis* sp.**	Lsp1	*	*	*	*	*	**Centritactaceae**						
***Lepocinclis tripteris* (Dujardin) Marin & Melkonian**	Letr	*	*3	*3	*2	*	*Centritractus belonophorus* (Schmidle) Lemmermann	Cebe	*	*3	*3	*3	*2
***Monomorphina pyrum* (Ehrenberg) Meresschkowsky**	Mopy	*					**Ophiocytiaceae**						
***Phacus acuminatus* Stokes**	Phac	*3	*3	*3	*3	*3	*Ophiocytium capitatum* Wolle	Opca	*2	*2	*3	*	*2
***Phacus glaber* Pochmann**	Phgl	*	*3	*3	*	*2	**Total**	**242**	**210**	**207**	**205**	**209**	**216**
***Phacus hamatus* Pochmann**	Phha		*		*	*							
***Phacus limnophilus* Linton & Karnkwska-Ishikawa**	Phli	*2	*	*2	*	*2							

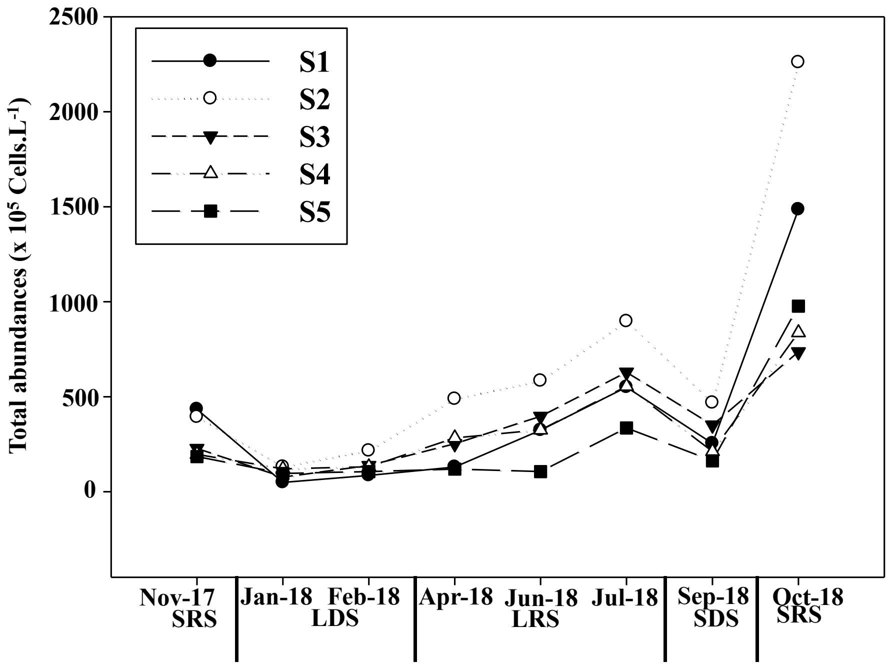
Table.3 Proportion of common (***), occasional (**) and rare (*) of phytoplankton taxa at five sampling sites (S1-S5) in the Taabo lake from November 2017 to October 2018 (Côte d'Ivoire)

Sites	Common taxa (%)	Occasional taxa (%)	Rare taxa (%)
S1	44.30	26.20	29.50
S2	63.80	20.30	15.90
S3	65.90	18.50	15.60
S4	49.30	27.30	23.40
S5	51.90	27.30	20.80

Table.4 Proportions of the Sorensen similarity index between the five sampling sites (S1 – S5) of phytoplankton in Taabo lake from November 2017 to October 2018 (Côte d'Ivoire)

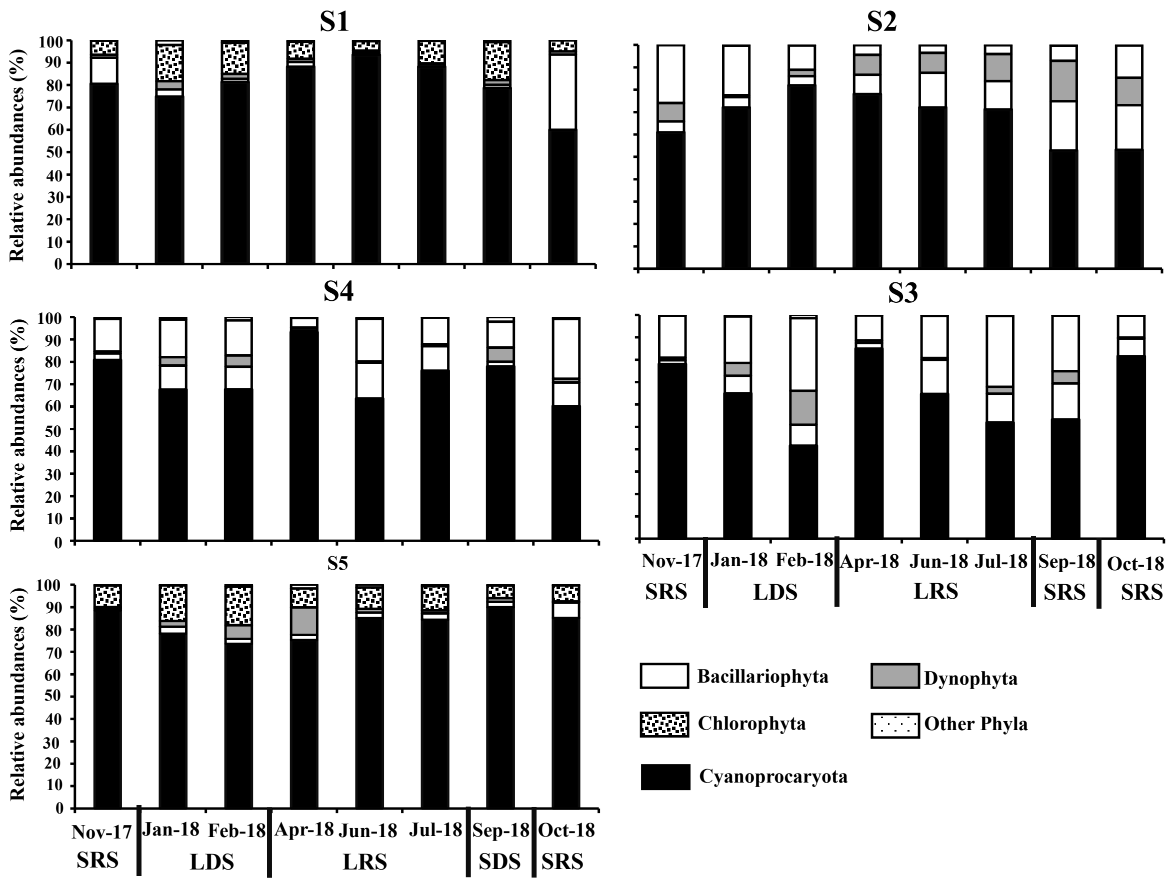
Sites	S1	S2	S3	S4
S2	98%			
S3	84%	81%		
S4	83%	81 %	91%	
S5	90 %	81%	90%	95%

Figure.3 Spatio-temporal variations in total phytoplankton abundances recorded in Taabo Lake from November 2017 to October 2018 (Côte d'Ivoire)



S1 - S5 = sampling sites; LDS = long dry season; LRS = long rainy season; SDS = short dry season; SRS = short rainy season; Nov = November, Jan = January, Feb = February, Apr = April, Jun = June, Jul = July, Sep = September, Oct = October

Figure.4 Spatio-temporal variations in the relative abundances of phytoplankton groups recorded in Lake Taabo from November 2017 to October 2018 (Côte d'Ivoire)



S1 - S5 = sampling sites; LDS = long dry season; LRS = long rainy season; SDS = short dry season; SRS = short rainy season; Nov = November, Jan = January, Feb = February, Apr = April, Jun = June, Jul = July, Sep = September, Oct = October

Figure.5 Boxplots showing spatial variations of Shannon index and Pielou's Evenness index of Taabo lake (Côte d'Ivoire) S1-S5: sampling sites, different letters denote significant differences between sampling sites ($p < 0.05$; Kruskal-Wallis test)

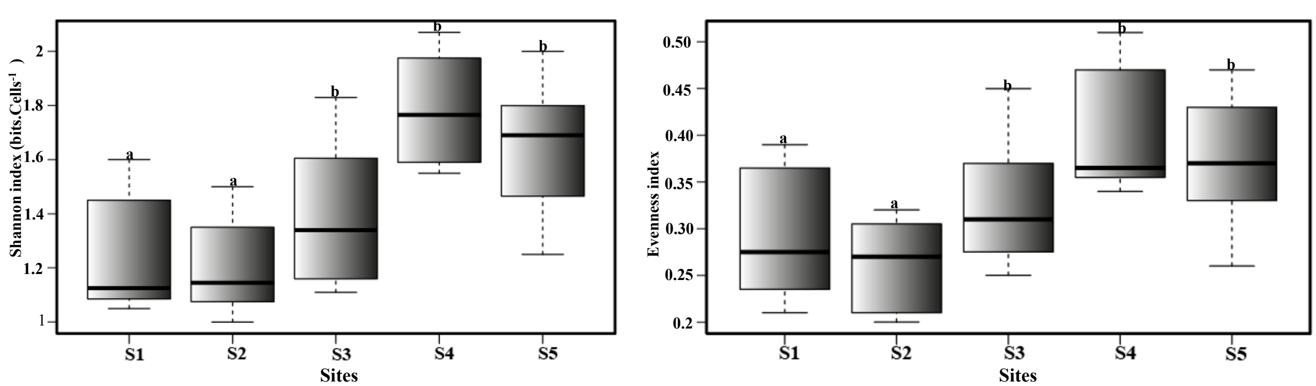
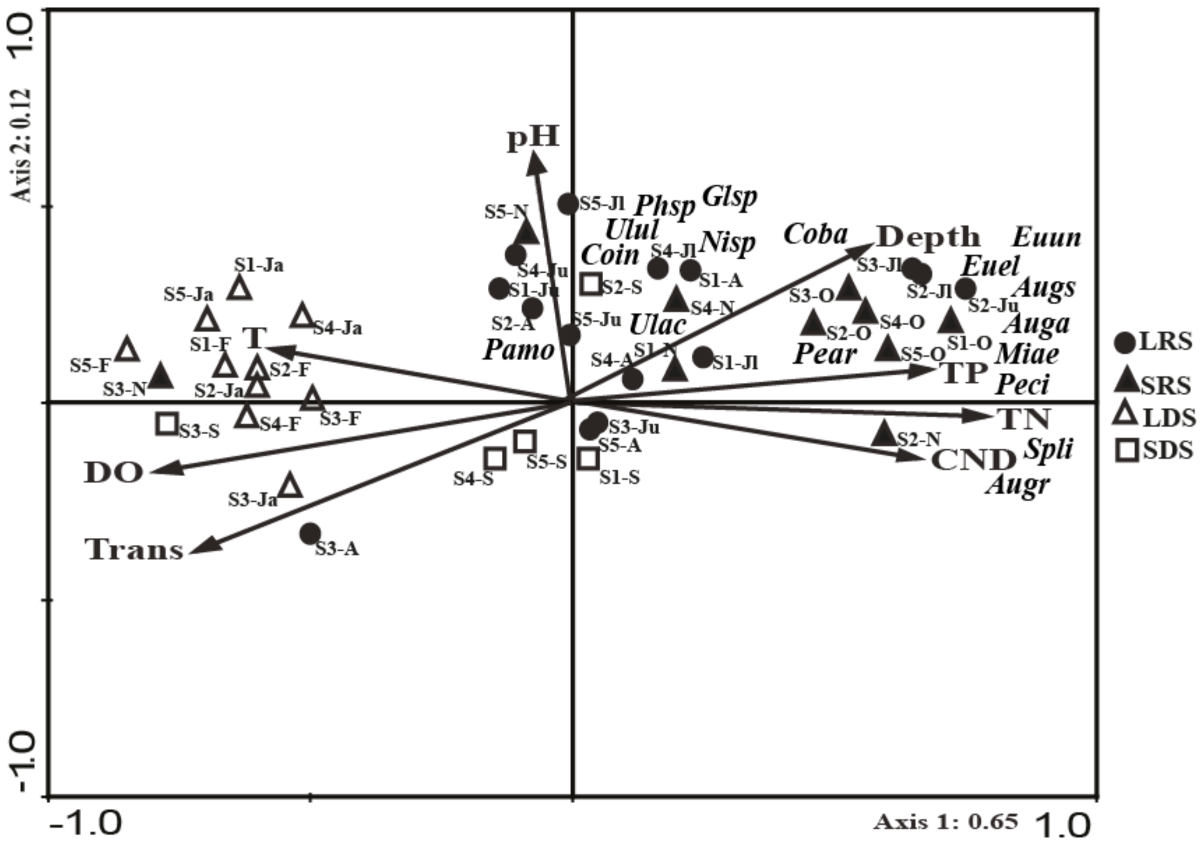


Figure.6 ReDundancy Analysis triplot showing phytoplankton species and sampling sites, and seasons in relation to environmental variables in Taabo lake (Côte d'Ivoire)



T = temperature; CND = conductivity; DO = dissolved oxygen ; TRANS = Transparency; sampling sites = S1 - S5; Nov = November, Jan = January, Feb = February, Apr = April, Jun = June, Jul = July, Sep = September, Oct = October ; LDS = long dry season; LRS = long rainy season; SDS = short dry season; SRS = short rainy season; Auga*: Aulacoseira granulata* var. *angustissima*, Augs: *Aulacoseira granulata* f. *spiralis*, Augr: *Aulacoseira granulata*, Coba: *Cosmarium ; Coin: Coelastrum indicum baileyi*, Euel: *Eudorina elegans*, Euun: *Eudorina unicocca*, Glsp: *Glenodinium* sp., Miae: *Microcystis aeruginosa*, Pamo: *Pandorina morum*, Pear: *Peridiniopsis armebeensis*, Peci: *Peridinium cinctum*, Phsp: *Phormidium* sp., Psli: *Pseudanabaena limnetica;*, Nisp: *Nitzschia* sp., Ulac: *Ulnaria acus*, Ulul: *Ulnaria ulna*.

The qualitative results showed a high taxonomic richness (242 taxa) in the phytoplankton community. Phytoplankton compositions showed less variability from one site to another. This low spatial variation in phytoplankton compositions suggests that Lake Taabo is a more or less homogeneous environment. The high taxonomic richness of phytoplankton in the lake is thought to be linked to the stagnant nature of its waters and the relative spatial stability of abiotic parameters such as temperature, dissolved oxygen, conductivity, and nutrient salts. According to Ouattara *et al*. (2007), the development of phytoplankton communities is closely linked to the stability of the water column and environmental parameters. This stability of abiotic parameters in the water column promotes biological processes such as the complete cycle of algae reproduction (Ouattara *et al*., 2007; Attoungbre *et al*., 2019). The species richness of Lake Taabo is lower than that obtained by Ouattara *et al*. (2007) in the Ayamé reservoir (262 taxa), but higher than that obtained by Adon *et al*. (2011) in the Adzopé reservoir (190 taxa) in Côte d'Ivoire. The difference in taxonomic richness observed between these different studies could be related to the size of the hydrosystems explored. Indeed, the Ayamé reservoir, with an area of 180 km², is larger than the Taabo lake (69 km²), which is larger than the Adzopé reservoir, which has an area of 3 km². Roland *et al*. (2010) showed that phytoplankton richness increases with reservoir size and sampling effort. Phytoplankton is characterized by a predominance of Chlorophyta. These were the most diverse group, with a strong representation of the Scenedesmaceae and Desmidiaceae families (30 taxa each). These two families are known to be very species-rich in freshwater, especially stagnant waters (Anyanwu *et al*., 2021). The dominance of Chlorophyta in phytoplankton communities has been highlighted in numerous studies on lakes in Côte d'Ivoire (Adon *et al*., 2011; Attoungbré *et al*., 2019; Kouassi *et al*., 2021). This predominance of Chlorophyta and Euglenophyta has also been highlighted by Bouvy *et al*. (2006) in Lake Guiers in Senegal and by Matsumura-Tundisi *et al*. (1989) in the Samuel reservoir in Brazil. According to Attoungbré *et al*. (2019) and Ouattara *et al*. (2007), the great diversity of Chlorophyta in lake environments is due to the fact that this phylum includes a large number of thermophilic and photophilic taxa.

In terms of quantity, Cyanoprokaryota (Cyanobacteria) were dominant at all sites and during all periods of the study. The dominance of Cyanoprocaryopta indicates that the lake environment is very favorable to their development. The dominance of Cyanoprocaryopta is due in part to the enrichment of the lake with nutrients. According to Vaquer *et al*. (1997), this community is typical of turbid tropical environments. Similar results were obtained by Salazar-Torres *et al*. (2016) in the Funil reservoir in Brazil. On the other hand, Cyanoprocaryopta also have a competitive advantage over other phytoplankton groups, particularly because they can regulate their vertical position in the water column, produce toxins to prevent or mitigate the proliferation of other groups, and fix atmospheric nitrogen (Schindler *et al*., 2020).

In terms of spatial distribution, phytoplankton densities are high at sites S1 and S2. These high values at these two sites are thought to be linked to their proximity to fish farming structures (floating cages in situ), which means they are richer in organic matter and nutrients. This organic matter and nutrients come from fish feed and excrement, promoting strong phytoplankton growth compared to other sites. The degradation of this exogenous organic matter enriches the environment with nutrients, promoting algal proliferation. Our observations are consistent with those of Groga *et al*. (2019), who observed algal proliferation linked to fish farming activities on the Kossou reservoir in Côte d'Ivoire.

In contrast to abundances, Shannon diversity and Pielou equitability indices are significantly lower at sites S1 and S2. These low values are thought to be due to the dominance of a few Cyanoprokaryota species. Reynolds (1984) and Chorus and Bartram (1999) explain the dominance of Cyanoprokaryota by the fact that they have a competitive advantage over other phytoplankton groups, as they have the ability to regulate their vertical position in the water column in addition to their ability to fix atmospheric nitrogen. This ability improves their chances of survival compared to other groups in conditions of nutrient scarcity (Mwaura *et al*., 2002).

The influence of abiotic factors on phytoplankton abundance was assessed using Canonical ReDundancy Analysis (RDA). This analysis revealed a clear seasonal separation of the samples. During the short rainy season (SRS), parameters such as lake depth, conductivity, and nutrient concentrations were elevated. According to the hydrological regime of Lake Taabo, the highest water inputs occur between September and October. This period corresponds to the end of the short dry season and the beginning of the short rainy season (Kouassi *et al*., 2007). The observed pattern may result from the substantial inflow of water from tributaries and surface runoff rich in minerals and nutrients. The densities of *Aulacoseira granulata* var. *angustissima*, *A. granulata* f. *spiralis*, *A. granulata*, *Cosmarium baileyi*, *Eudorina elegans*, *E. unicocca*, *Peridiniopsis armebeensis*, *Microcystis aeruginosa*, *Peridinium cinctum*, and *Pseudanabaena limnetica* were positively associated with the short rainy season (SRS). The environmental conditions during this season favored their proliferation. According to Reynolds *et al*. (2002) and Padisák *et al*. (2009), these phytoplankton taxa are typical of nutrient-rich, eutrophic environments, such as eutrophic lakes.

In conclusion, phytoplankton community is characterized by high taxonomic richness but low spatial variability, reflecting the relative environmental homogeneity of the reservoir. While Chlorophyta and Euglenophyta dominate in terms of species richness, Cyanoprokaryota largely control phytoplankton abundances throughout the year, particularly during the rainy seasons.

Seasonal nutrient enrichment, driven by hydrological inputs and anthropogenic pressures, notably agriculture and fish farming, plays a central role in shaping phytoplankton dynamics. Elevated nitrogen and phosphorus concentrations during rainy periods favor the proliferation of eutrophication-tolerant and bloom-forming taxa, such as *Microcystis aeruginosa* and

Pseudanabaena limnetica. The reduced diversity and evenness observed at sites influenced by aquaculture activities further highlight the ecological consequences of localized nutrient inputs.

Overall, the findings confirm that Taabo lake is undergoing eutrophication, with potential implications for water quality, ecosystem functioning, and resource use. These results underscore the need for improved watershed management and nutrient load control to mitigate further degradation of this socio-economically important lake.

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Data availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Author contributions

CAMARA Maboundou : Conceived the original idea and designed the model and wrote the manuscript. NANGOH Kouame Martin: Analysed the data, KOUASSI Blé Alexis Tardy: Review & Editing, NIAMIEN-EBROTTIE Julie Estelle: Methodology, DOUMBIA Lassina: Supervision, OUATTARA Allassane: Supervision.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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