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Full Length Research Paper

Seasonal variation in the diversity and abundance of phytoplankton in a small African tropical reservoir

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Phytoplankton species composition and seasonal changes were investigated in the shallow reservoir of Adzopé. Taxonomic composition, diversity and abundance of phytoplankton were studied at 4 stations from May 2008 to February 2009, in relation to physical and chemical factors (temperature, conductivity, dissolved oxygen, transparency, pH, nutrients) and climatic factor (rainfall). The phytoplankton comprised 144 taxa, mainly Chlorophyta (29.45% of taxa), Euglenophyta (29.45%) Bacillariophyta (23.97%) and Cyanobacteria (10.27%). Phytoplankton density values were greatest during the transition season (short rainy season), lower during the dry seasons, and extremely lower during the long rainy season (mean value 356 10^5 cells/l, 44 10^5 cells/l and 35 10^5 cells/l respectively). Abundance was dominated by *Anabaena constricta* Szafer (Geitler) and *Microcystis aeruginosa* (Kütz.) Kütz. The diversity index varied between 2.1 bits/cells in long rainy season and 4.6 bits/cells in short dry season. The redundancy analysis (RDA) demonstrated a separation between the long rainy season and the other seasons due to the influence of the flood pulse.

Key words: Phytoplankton, shallow reservoir, species dominance, West Africa.

INTRODUCTION

Phytoplankton is usually at the base of aquatic food web and is the most important factor for production of organic matter in aquatic ecosystem. Most reservoirs will require significant amount of phytoplankton to have productive and sustainable fisheries. The interplay of physical, chemical and biological properties of water most often lead to the production of phytoplankton, while their assemblage (composition, distribution, diversity and abundance) is also structured by these factors. The importance of phytoplankton in tropical reservoir eco-systems include its use in estimating potential fish yield (Hecky and Kling, 1981), productivity (Park et al., 2003), water quality (Walsh et al., 2001), energy flow (Simciv, 2005), trophic status (Reynolds, 1999) and management (Beyruth, 2000). These reservoirs are increasingly threatened by human activities (Cecchi, 2007; Descy and Sarmento, 2008).

In Côte d'Ivoire, about 500 small reservoirs have been constructed on most river systems for water supplies and are presently considered to be threatened (Aka et al., 2000). In spite of this, little is known about the ecology of small reservoirs in Côte d'Ivoire, even though many aquatic habitats are being degraded by pollution, siltation and other human activities (Cecchi, 2007). Water resources in these reservoirs are utilized for drinking, washing, bathing, and irrigation purposes. They receive run-off and wastewater discharges from agriculture and domestic uses. The only published account of Ivorian small reservoirs, a survey of the reservoir of Agboville, clearly showed the impact of river regulation, pollution and emphasized the need for further investigations (Gone et al., 2010). Therefore, the present investigation has attempted to study the water quality in relation to the phytoplankton in the reservoir of Adzopé. This reservoir was selected because it is surrounded by Adzopé city and there are major activities in the vicinity on its catchment.

The seasonal fluctuations in phytoplankton abundance and species composition in any water body is due to differential response of different species to changing

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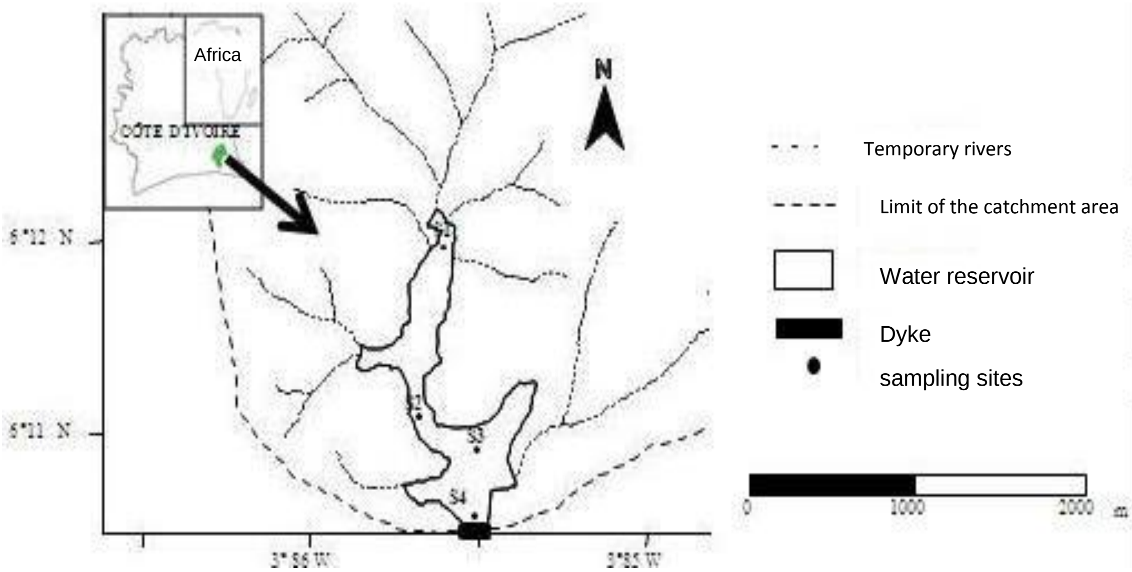

Figure 1. Adzopé reservoir showing the sampling sites (Universal transverse mercator, (UTM))

levels of light, temperature, nutrients, grazing pressure, onset of parasitic infection, extracellular metabolites of plants and animals with a change in season during a course of year (Agrawal, 1999). The seasonal fluctuations in number and kind of phytoplankton are more pronounce in temperate or polar lakes and reservoirs than those in tropical regions (Reynolds, 1988). According to several studies (Abbas, 2009; Figueredo and Giani, 2009), the tropical lakes and reservoirs do not experience marked seasonal fluctuations and thus do not exhibit variations in stocks of phytoplankton species composition. The phytoplankton abundance is regulated by fairly equal influences of any factor like nutrients supply, water turbulence, grazing pressure etc. throughout year.

The aim of this study was to examine the phytoplankton variability throughout year in terms of distribution, abundance and diversity in relation with the physico-chemical variables in Adzopé's reservoir.

MATERIALS AND METHODS

Study area and sampling stations

Adzopé Reservoir (6°10'52" and 6°12'15" N and 3°85'65" and 3°86'73" W) is located in the south-east of Côte d'Ivoire that belongs to the subequatorial zone (Iltis and Lévêque, 1982), characterized by four climatic seasons: long rainy season (April to July); short dry season (August to September); short rainy season (October to November); long dry season (December to March). It is led by the temporary rivers inflow and direct run-off during the rainy season. The dwelling sewage flows though permanently into the reservoir. The total area of the reservoir is estimated at 61.44 ha. The reservoir has a mean depth of 4.91 m and a length of about 2 km. Bank around the reservoir is often occupied by dwelling and market gardening. The hydrological regime of this reservoir depends on precipitations.

Four representative stations (S1, S2, S3, S4) were sampled according to the longitudinal gradient (Figure 1). S1 was located in the upper zone of the reservoir (close to 2.7 m average depth), S2 (4.1 m) and S3 (6.3 m) in the central zone, and S4 (6.5 m) in a down zone, near the dyke.

Sampling and study of phytoplankton community

At each station, four samplings were carried out in order to represent the four climatic seasons: May 2008 for long rainy season (LRS), September 2008 for short dry season (SDS), November 2008 for short rainy season (SRS) and February 2009 for long dry season (LDS) (Figure 2).

Water samples were taken between 06:00 and 09:00 am with 2.5 L Van Dorn bottle from the surface of water. For each sample, the Aqualitic CD24 was used to assess water temperature and conductivity. Dissolved oxygen was measured with the Aqualitic OX24, and pH with the Aqualitic, pH24. For nutrients (nitrates and soluble reactive phosphorus), subsamples of 30 ml were collected and refrigerated for later analysis following the spectrometric method (AFNOR, 2005). The transparency of the water was estimated by Secchi disk.

For phytoplankton analysis, sub-samples of 50 ml were gathered and preserved with 200 µl Lugol's solution. These samples were examined in the laboratory using an Olympus BX40 microscope equipped with tracing and measuring devices. Before microscopic identifications, organic substances on the samples were removed using HNO_3^- for diatoms (Leclercq and Maquet, 1987). The species were identified under microscope Olympus BX40 and classification was done with standard works (Compère, 1989; Ouattara et al., 2000) and more specific literature (Couté and Iltis, 1981; Komárek and Fott 1983; Compère 1986; Krammer and Lange-Bertalot, 1991; Uherkovich, 1995; Da et al., 1997; Komárek et al., 2003; Komárek and Anagnostidis, 2005). Aliquots were settled in 5 or 10 ml settling chambers and density of phytoplankton was estimated using the Utermöhl (1958) method as modified by Laplace-Treyture et al.

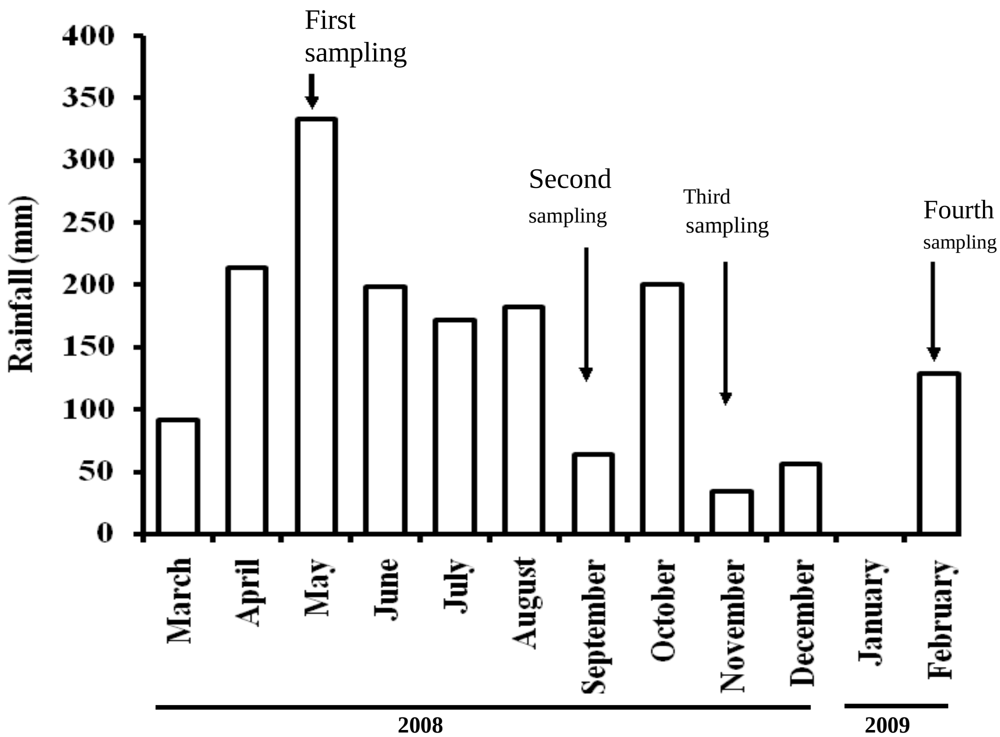

Figure 2. Monthly rainfall data from May 2008 to March 2009 recorded at the study area obtained from the SODEXAM. The arrows indicate the sampling periods

(2007), with a DIAVERT inverted microscope. To analyze phytoplankton community structure, species richness (total number of species recorded after counts), population density (cells.l^{-1}), Shannon-Wiener diversity index (Shannon and Weaver, 1949) and Pielou evenness (Pielou, 1966) were used. Both evenness and diversity (bits/cell) were based on abundance data.

Statistical analyses

Differences of physical-chemical parameters, phytoplankton density, Shannon diversity and evenness among sampling seasons and stations were tested using ANOVA Kruskal-Wallis (significance level 0.05). However, means and standard deviation of all measurements were recorded for each parameter. The coefficient of variation (CV%) was computed according to Zar (1999):

$$CV(\%) = \frac{\sigma}{\mu} \times 100$$

Where σ is the standard deviation and μ is the mean of the measurements of each parameter.

To investigate the phytoplankton community environment relationship, a ReDundancy analysis (RDA) (ter Braak and Smilauer, 2002) was performed on the dominant species (contribution > 2%) and on eight environmental variables: temperature; conductivity; pH; dissolved oxygen; nitrate; soluble reactive phosphorus (SRP); transparency and depth. In this analysis, we used a linear model, because the gradient length of the first axis obtained by detrended correspondence analysis was 0.39. The significance of the first four axes was tested using a Monte Carlo analysis with 499 permutations. ReDundancy analysis was computed with the program CANOCO for Windows 4.5 (ter Braak and Smilauer, 2002). The others were performed with STATISTICA software 7.1 (StatSoft, 2005).

RESULTS

Physical and chemical variables

Physical and chemical variables at all four sampling sites are presented in Table 1. Average values of the conductivity (182.68 µS/cm) and dissolved oxygen (6.40 mg/l) were slightly higher at the site 2, located at the middle stretch of the reservoir, than those at the others sites and Secchi transparency depth presented the highest values at site 4 (62.50 cm), close to the dyke of the reservoir. Dissolved oxygen and transparency showed high coefficient of variation values (CV > 25%). Concerning conductivity, only station S2 presented high variability. In such variables as water temperature, pH, nitrate and SRP, the four sampling sites were similar. Their coefficients of variation values were relatively low (CV < 25%) except nitrate that displayed a high variability (CV > 68%). No significant differences in physical and chemical variables occurred between the four sampling sites (Kruskal-Wallis test; p > 0.05).

Precipitation data showed the characteristic of local seasonal patterns (Figure 1), with four periods during this study: long rainy season (March to August), transition period rainy to short: short dry season (September), short

Table 1. Means and coefficient of variation (CV) of physical and chemical variables in Adzopé impoundment at different stations (S1 to S4). SRP: soluble reactive phosphorus, ns = non significant.

Variables	Units	S1		S2		S3		S4		Kruskal-Wallis test
		Mean	CV (%)	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)	
Conductivity	µS/cm	166.78	11.31	182.68	25.65	176.40	15.38	178.35	17.97	ns
Temperature	°C	28.65	10.22	28.45	10.60	25.95	6.93	26.93	11.80	ns
Dissolved oxygen	mg/L	5.63	36.17	6.40	37.91	4.69	33.84	4.79	50.35	ns
pH		7.07	8.95	6.86	13.07	6.84	13.15	7.10	12.45	ns
Nitrate	mg/L	0.15	98.55	0.11	68.58	0.32	113.65	0.17	148.04	ns
SRP	mg/L	1.17	0.06	1.17	0.02	1.17	0.06	1.17	0.02	ns
Transparency	cm	52.75	26.92	56.25	33.99	50.50	42.98	62.50	31.53	ns

rainy season (October to November) and long dry season (December to February). Water temperature showed a variation within a small amplitude (Table 2). Water transparency was higher at the beginning of the short season. Nitrate and soluble reactive phosphorus presented higher values during the transition period from the rainy to the short season and lower concentrations during the long rain season for soluble reactive phosphorus and during the short rainy and long dry seasons for nitrate. Conductivity decreased during long rainy season, increased during the transition period, decreasing again during the next rainy season and reaching higher values during the long dry period. Values of dissolved oxygen increased regularly from long rainy to short rainy season and decreased during long dry season. pH values oscillated abruptly from long rainy to short rainy season and were higher during the last period, with clear seasonal pattern.

In this study, there were significant differences in conductivity between the long dry season and the others seasons ($p < 0.05$). Water temperature showed significant seasonal variation between long rainy season and short rainy season, between long rainy season and long dry season and between short rainy season and short dry season ($p < 0.05$). Dissolved oxygen concentrations, pH, soluble reactive phosphorus concentrations and water transparency also showed significant differences between the long rainy season and the others seasons ($p < 0.05$). For nitrate concentrations, significant variation was observed between short dry season and long dry season.

Phytoplankton community

A total of 144 phytoplankton taxa were identified belonging to 6 phylums. The chlorophyta and euglenophyta were the most diversified with 29.45% of total species, followed by the bacillariophyta (23.97%) and the cyanobacteria (10.27%). The xanthophyta and the pyrrhophyta were the least diversified group with 4.11% and 2.74% of total taxa, respectively.

Overall, species richness not differed signify-cantly between sampling sites. S1 (95 taxa) and S3 (92 taxa) were similar, but S2 (88 taxa) and S4 (117 taxa) have lower and higher total richness respectively than the two sites.

There are marked seasonal differences in the quantitative and qualitative composition of the phytoplankton communities at each site (Figure 3). In terms of total cellule numbers for each species in all the algal groups, the highest maxi-mum counts were recorded in S1 (332 10^5 cells/l), S2 (221 10^5 cells/l) and S4 (356 10^5 cells/l) during the short rainy season whereas the lowest densities occurred during the long rainy season and long dry season in S1 (35 and 48 10^5 cells/l, respectively), S2 (23 and 104 10^5 cells/l, respectively) and S4 (89 and 44 10^5 cells/l, res-pectively). Contrary to these sampling sites, the highest maximums cells counts were observed during the long rainy season (171 10^5 cells/l) and long dry season (214 10^5 cells/l) at site 3.

Most of the abundance was represented by only 3 of the 6 phylums: the cyanobacteria, the chlorophyta and the euglenophyta (Figure 4).
Phytoplankton analysis indicates that cyanobacteria were dominant in 56.25% of the samples, whereas chlorophyta and euglenophyta were dominant in 31.25% and 12.5% of them, respectively. In samples where the latter were dominant, cyanobacteria were generally subdominant.

Table 2. Means of physical and chemical variables and their coefficient of variation (CV) in Adzopé impoundment at different periods. CV: variation of coefficient; SRP: soluble reactive phosphorus. The letters indicate the significant difference between variables (Tukey test, p <0.05). There is no significant difference between the mean having an alphabetical letter in common along the same row (Tukey test, p > 0.05); LRS: long rainy season; SDS: short dry season; SRS: short rainy season; LDS: long dry season.

Variables	Units	LRS		SDS		SRS		LRS	
		Mean	CV (%)	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)
Conductivity	µS/cm	157.50^{a}	3.79	179.65^{a}	2.42	148.50^{a}	1.17	217.05^{b}	13.13
Temperature	°C	24.68^{a}	7.66	26.23^{a}	1.37	31.70^{b}	3.19	28.83^{ba}	4.35
Dissolved oxygen	mg/L	2.60^{a}	36.52	5.73^{b}	5.02	8.04^{b}	24.23	6.17^{b}	15.61
pH		8.10^{a}	1.17	6.40^{b}	1.43	6.66^{b}	2.93	6.86^{b}	8.55
Nitrate	mg/L	0.15^{ab}	81.91	0.44^{a}	68.55	0.02^{ab}	40.0	0.05^{b}	35.35
SRP	mg/L	1.170^{a}	0.05	1.171^{b}	0.009	1.171^{b}	0.01	1.171^{b}	0.06
Transparency	cm	28.75^{a}	27.44	66.75^{b}	19.28	64.75^{b}	5.26	61.50^{b}	4.30

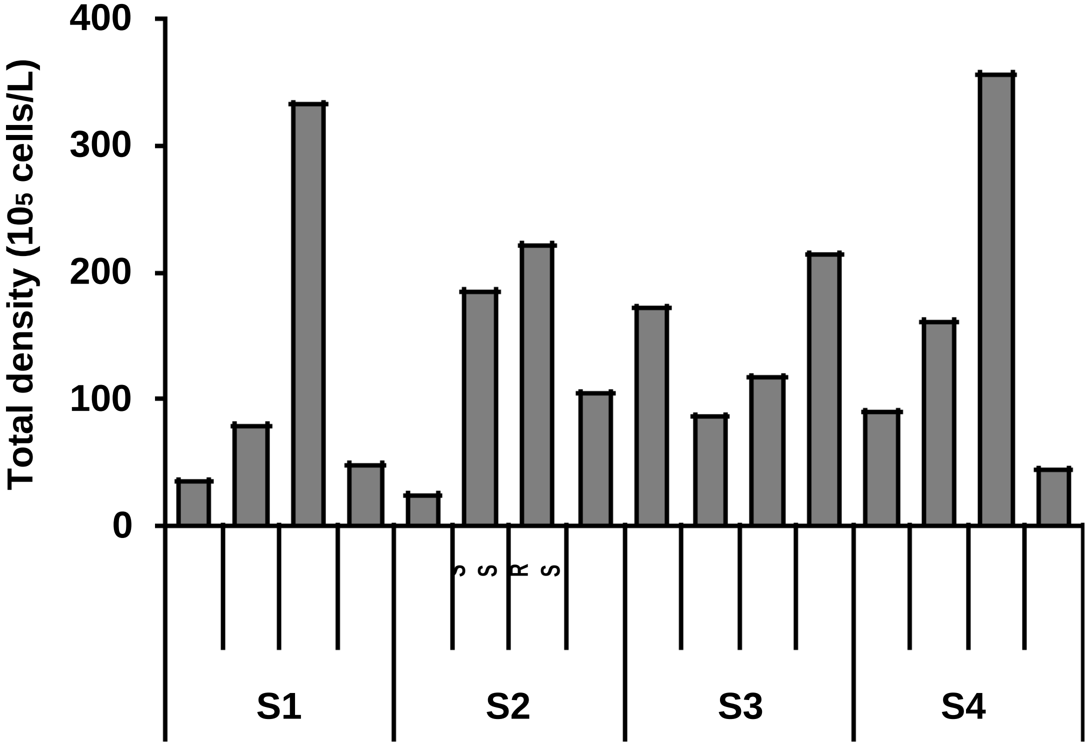

Figure 3. Temporal patterns of total density in four stations of Adzopé Reservoir. LRS: long rainy season; SDS: short dry season; SRS: short rainy season; LDS: long dry season.

Seasonally variation of phytoplankton density in Adzopé reservoir is comprised between 35 10^5 cells/l and 356 10^5 cells/l (Figure 5). Minimum and maximum of phytoplankton density were recorded during long rainy season and short rainy season respectively.

Table 3 shows that cyanobacteria were more frequent than the other groups. Altogether, the 17 dominant taxa composed up to 78% of total phytoplankton abundance. In terms of taxa relative abundance, Cyanobacteria dominated most of sampling periods throughout the impoundment and comprised between 51 to 75% of total phytoplankton by a high contribution of the filamentous *Anabeana constricta* Szafer (Geitler) and the colonial form *Microcystis aeruginosa* (Kütz.) Kütz.. Cyanobacteria dominated community of the impoundment declined to less than 27.93% during the long dry season at all sites, with significant decrease of 9.58% at site 1 (short dry season) and 12.99% at site 4 (long dry season) and replacement by a chlorophycean (33.04 to 34.1%) and an euglenophycean (51.1 to 38.96%) dominated community. *Dictyosphaerium pulchellum* Wood, *Oocystis borgei* Snow and *Crucigeniella crucifera* (Wolle) Kom.

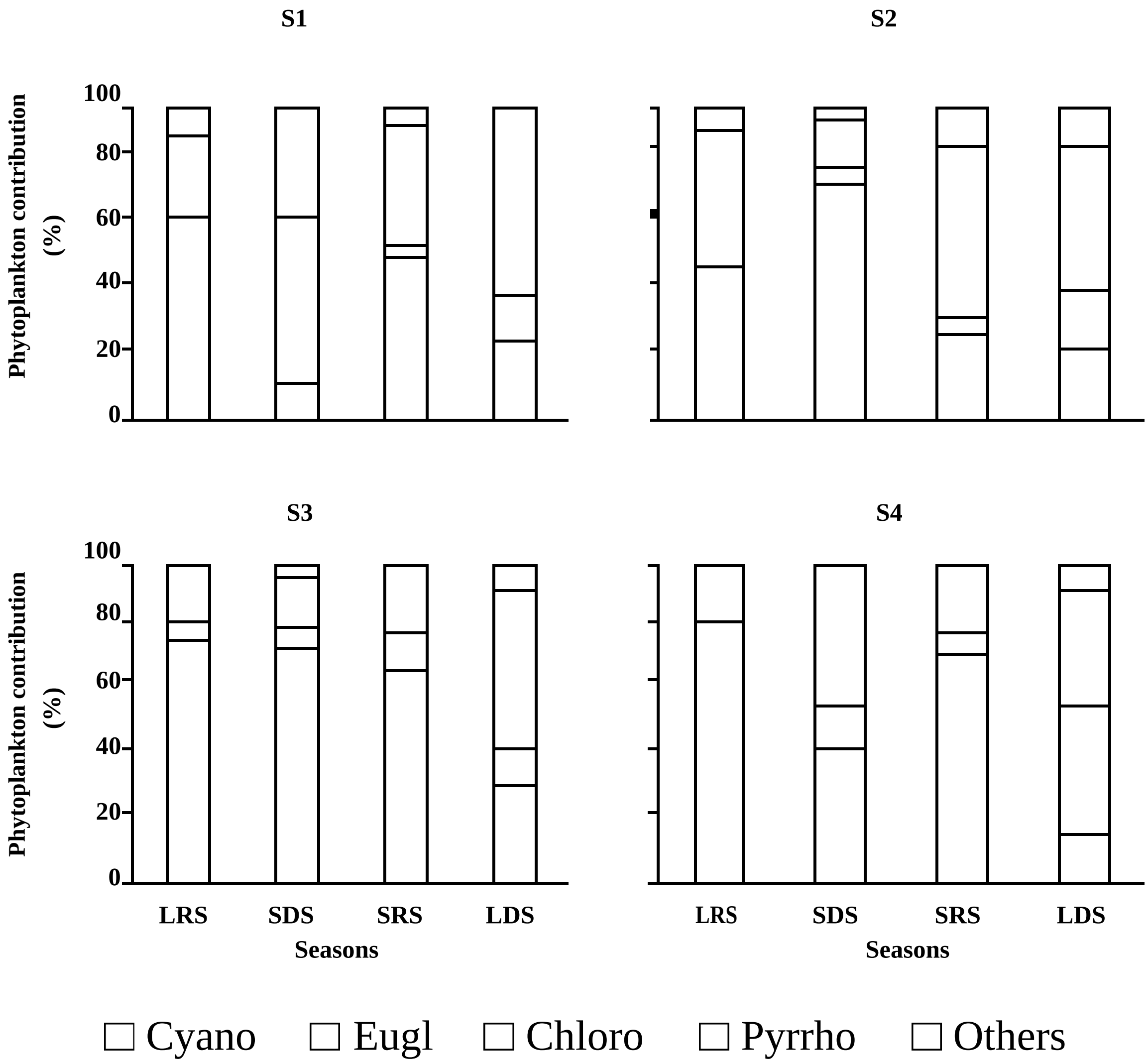

Figure 4. Community succession in Adzopé Reservoir. S1; S2; S3; S4: samplings stations. Cyano: Cyanobacteria; Eugl: Euglenophyta; Chloro: Chlorophyta; Pyrrho: Pyrrhophyta; LRS: long rainy season; SDS: short dry season; SRS: short rainy season; LDS: long dry season.

contributed the largest proportion to chlorophyta abundance in the impoundment. Other important phytoplankton species observed in sampling sites were the euglenophyta *Trachelomonas volvocina* Ehrenbg. and the Pyrrhophyta *Peridinium cinctum* (Müller) Ehrenbg*.*

There was no statistically significant differences in phytoplankton abundance among sampling sites (ANOVA; $p = 0.962$). In the impoundment, total density showed statistically significant differences between long rainy season and short rainy season (Tukey test; $p = 0.039$). Values of diversity (H') and evenness (E) indexes are shown in Figure 6. Their seasonal and spatial variations did not show a defined pattern. During SRS, H' and E values increased in S1 and S3, whereas in S2 they diminished; during SDS and LDS they increased in S2 and in S4. Values of E index varied between 0.4 and 0.82; minimum value was registered in S4 during LRS, when the taxa *Coelomoron* sp.*, A. constricta* and *C. crucifera* reached the 81% of total cells; the maximum value was registered in the same site (S4), during LDS. The diversity index showed the same trend with E index, with high values observed during the SRS (4.39 bits/cells) at S1and SDS and LDS in S4 (4.63 and 4.60 bits/cells, respectively) and lowest values at S1 (2.1 bits/cells) and S4 (2.2 bits/cells) during the LRS.

Significant differences in Shannon-Wiener's diversity index were recorded between LRS and LDS (Tukey test; $p < 0.05$) whereas evenness index was not significantly different between the seasons. Both diversity and evenness indexes were not statistically significant different among sampling sites (Kruskal-Wallis test; $p > 0.05$).

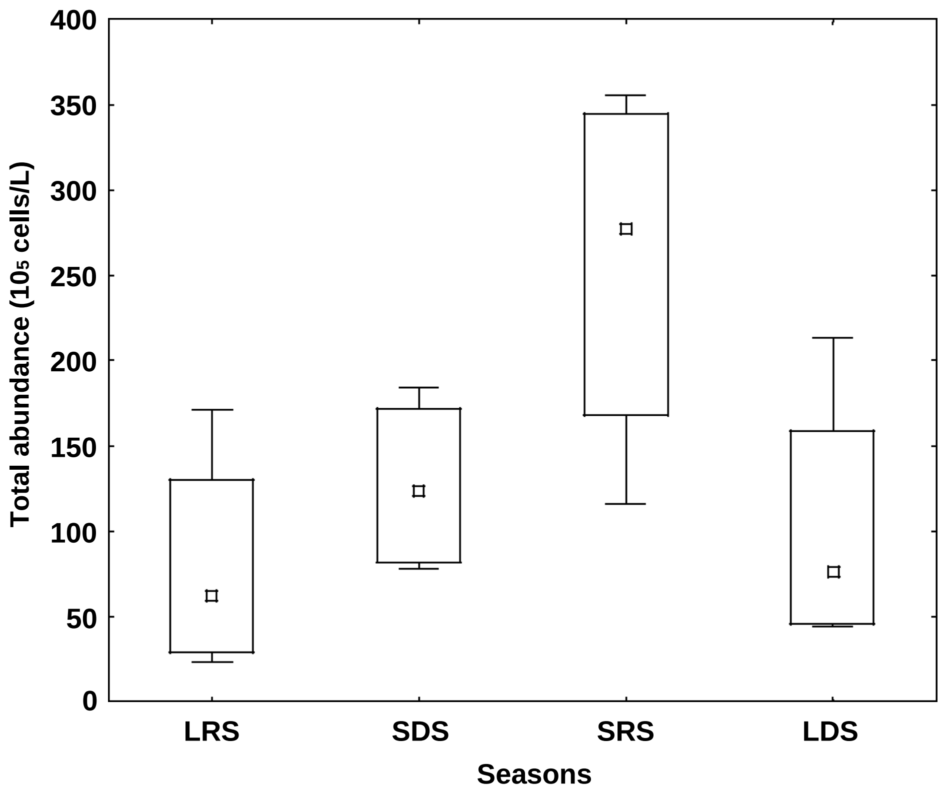

Figure 5. Seasonal patterns of total abundance in of Adzopé Reservoir. LRS: long rainy season; SDS: short dry season; SRS: short rainy season; LDS: long dry season

Relationship of phytoplankton with environmental variables: Redundancy analysis (RDA)

A RDA tested phytoplankton variations in relation to physical and chemical variables in the impoundment. The first two components accounted for 51.1% of the variance. Figure 7 shows that the first axis (31.1% of the variance) was positively correlated with rainfall and pH and negatively correlated to water transparency and soluble reactive phosphorus. In sample ordering according to the first two axes, no completely homogeneous groups were found.

A general gradient from right to left, starting from samples from long rainy season towards those from the other seasons was observed. High water transparency values and soluble reactive phosphorus concentrations during the periods of low rainfall, especially during the transition period from the long rainy to the long dry season, coincided with the dominance of majority of phytoplankton taxa, such as *Aphanothece* sp.*, C. crucifera, Scenedesmus acutiformis* Schröd., *D. pulchellum*, *Karenia* sp. *Merismopedia punctata* Lemm. and *Komvophoron* sp.

The second axis (20% of the variance) is characterized by variables that determine the algal metabolism with high oxygen production. According to this axis, high abundances occurred, in general, during higher water temperature.

DISCUSSION

Analysis of the phytoplankton community in the small reservoir of Adzopé reveals some similarities with the situation observed in reservoirs in Central and North Côte d'Ivoire (Bouvy et al., 1998; Arfi et al., 2001), Lake Guiers in Senegal (Bouvy et al., 2006) and Lake Tana in Ethiopia (Wondie et al., 2007). These authors described the occurrence of many species of cyanobacteria. This group is commonly encountered in nutrient-rich shallow reservoirs (Pearl, 1988; Komárek and Anagnostidis, 2005). The absence of relationships between abundances of these dominant cyanobacteria and dissolved nutrient levels is notable. Most environmental variables (water transparency, dissolved oxygen, temperature, conductivity and nutrient concentrations) were similar between seasons, except for the rainfall and pH. According to the catchment's morphology and the characteristics of the surrounding area it can be assumed that Adzopé reservoir receives a high nutrient input. Despite the high external nutrient loads, nitrate was present in much lower concentrations than phosphorus

Table 3. Dominant phytoplankton species (contribution > 2% to total density) in Adzopé reservoir at each station during study period. F: percentage of occurrence, P: proportion in terms of abundance of the species in the community.

Taxa	Acronymes	S1		S2		S3		S4	
		F (%)	P (%)	F (%)	P (%)	F (%)	P (%)	F (%)	P (%)
Cyanobacteria									
Aphanothece sp.	Aphp	100	1.09	100	3.81	0	4.34	0	0
Microcystis aeruginosa (Kütz.) Kütz.	Mism	0	0	50	12.46	75	3.53	75	9.45
Aphanocapsa sp.	Apsp	25	4.23	25	1.08	0	0	25	4.63
Merismopedia punctata Lemm.	Mepu	0	0	0	0	50	7.42	25	8.74
Coelomoron sp.	Cosp	25	1.31	0	0	0	0	75	7.69
Pseudanabaena cf. *limnetica* (Lemm.) Kom.	Psli	25	1.37	25	4.21	75	10.05	50	4.84
Komvophoron sp.	Kosp	25	4.72	25	0.70	0	0	0	0
Anabaena constricta Szafer (Geitler)	Anco	100	26.04	75	15.04	75	28.14	75	20.71
Euglenophyta									
Trachelomonas volvocina Ehrenbg.	Trvo	100	7.61	75	0.92	100	4.26	100	2.53
Chlorophyta									
Pediastrum biradiatum var. *longecornutum* Gutw.	Pebl	75	3.98	25	0.38	50	0.31	50	1.30
Dictyosphaerium pulchellum Wood	Dipu	75	11.25	50	4.90	75	3.79	50	3.08
Oocystis borgei Snow	Oobo	0	0.00	25	13.98	25	0.05	0	0
Crucigeniella crucifera (Wolle) Kom.	Crcr	75	7.27	75	7.81	100	12.07	100	11.03
Crucigenia quadrata Morr.	Crqu	50	2.36	50	1.15	100	1.87	25	0.26
Scenedesmus acutiformis Schröd.	Scac	75	2.11	75	1.17	100	2.23	100	1.70
Pyrrophyta									
Karenia sp.	Kasp	0	0	75	0.89	100	3.79	75	1.12
Peridinium cinctum (O.F.Müller) Ehrenbg.	Peci	50	6.90	100	15.04	100	1.90	75	1.10

and might have a limited effect on phytoplankton total densities.

Furthermore, results showed no significant phosphorus decrease in either during the rainy or the dry seasons, probably because of the prevailing high nutrient concentrations and the low phosphorous requirements of the cyanobacteria species dominating the phytoplankton community. The capacity of some dominating cyanobacteria (for example, *Anabaena constricta*) to fix atmospheric nitrogen and the presence of terminal heterocystes is also a determining factor for their proliferation in various aquatic systems (Padisák, 1997; Walsby, 2001; Oberholster et al., 2004).

All the sampling sites were quite similar in community composition and were dominated by species like *A. constricta* and *M. aeruginosa*. An important reason for the absence of difference between sites is probably that this reservoir examined in this study is too shallow to stratify thermally and is all well mixed system. Furthermore, the small amplitude changes occurring in the reservoir is probably due to the fact that sampling sites are connected to small rivers

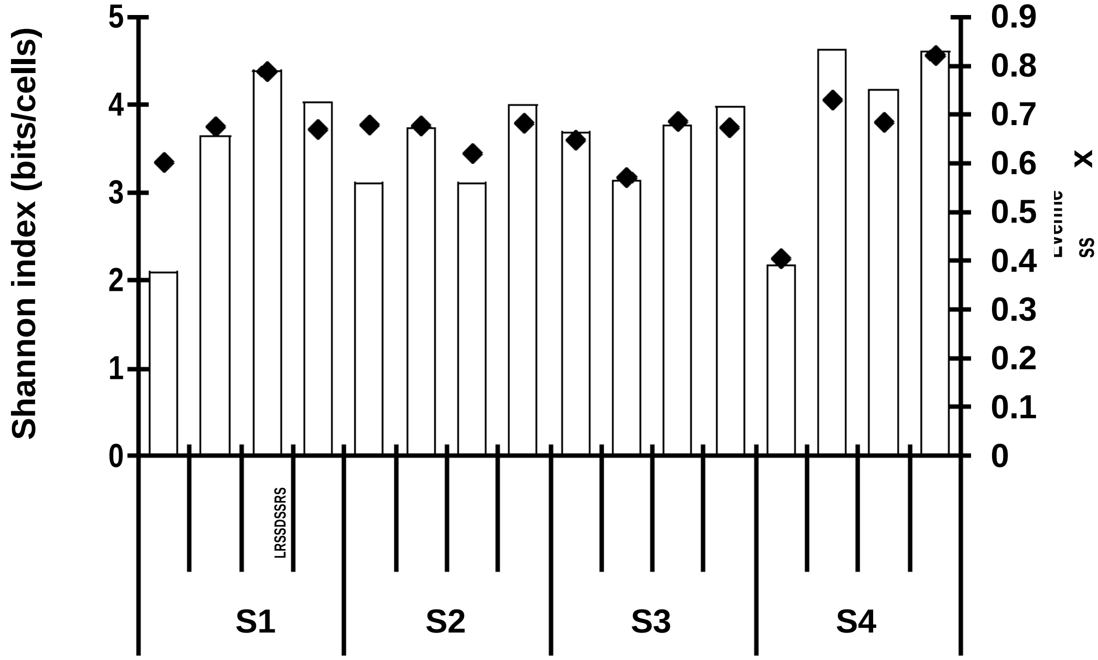

Figure 6. Temporal variation of Shannon and evenness index in the four stations of Adzopé reservoir. H': Shannon index; E: Evenness index; LRS: long rainy season; SDS: short dry season; SRS: short rainy season; LDS: long dry season.

which regularly contribute to mixing and to homogeneous water quality. The development of the dominating cyanobacteria during the short rainy season in the reservoir increases the phytoplankton abundances. The colonial and filamentous cyanobacterium were present during this period, characterised by conditions transitory from short dry season to short rainy season, thus exploiting the homogenization of the water column to grow quickly. Some species have gas vacuoles (*A. constricta* and *M. aeruginosa*), giving them an excellent capacity for vertical migration (Walsby, 1994; Brookes and Ganf, 2001; Komárek and Anagnostidis, 2005).

There is little relationship between nutrients and phytoplankton abundances. All the variables in this data set are not significantly correlated. It is likely that phytoplankton densities at this reservoir is limited by a combination of variables, involving light and possibly grazing, but rainfall seems to be most important to explain the seasonal variation observed, acting as a possible disturbing factor.

According to Talling (1986) more generally in Africa, annual patterns of phytoplankton seasonality are usually either dominated by hydrological features (water input-output) or by hydrographic ones (water column structure and circulation), which influences the chemical dynamics of the water column and ultimately their biota. Changes in the community structure through the association of precipitation events and general hydrological budget is one of the characteristics key of shallow lakes (Garcia de Emiliani, 1997). These changes are not only a result of the water level changes owing to the lakes' filling and drying phases, but also the accompanying input of allochthonous nutrients and suspended solids.

Data obtained in the present study also point to the importance of the small reservoirs' hydrology for structuring the phytoplankton community. However, the effect of grazing, one of the main factors shaping phytoplankton structure was not tackled in this study. Probably, grazing by zooplankton on phytoplankton was not significant because of filamentous cyanobacteria species dominating the phytoplankton community which are inedible for the abundance of rotifers dominating the zooplankton community in this impoundment (Ahizi, 2010).

According to Bouvy et al. (2006) eutrophic tropical systems are often characterised by opportunist piscivores and planktivores; predominant rotifers are considered to be inefficient grazers but the phytoplankton population could be regulated by fish, especially by tilapias, regularly captured by fishermen in this impoundment. Diversity index (H') showed similar mean values in all sampling sites (between 2.1 and 4.6 bits/cells) although a reductional tendency was observed during the long rainy season. Low diversity values were strongly affected by the most abundant species. Very low richness values were detected during the development of cyanobacteria. Other phytoplanktons, such as the 3 chlorophytes species (*D. pulchellum*, *O. borgei* and *C. crucifera*) were only observed when densities of total phytoplankton community were low. Conversely, Figueredo and Giani

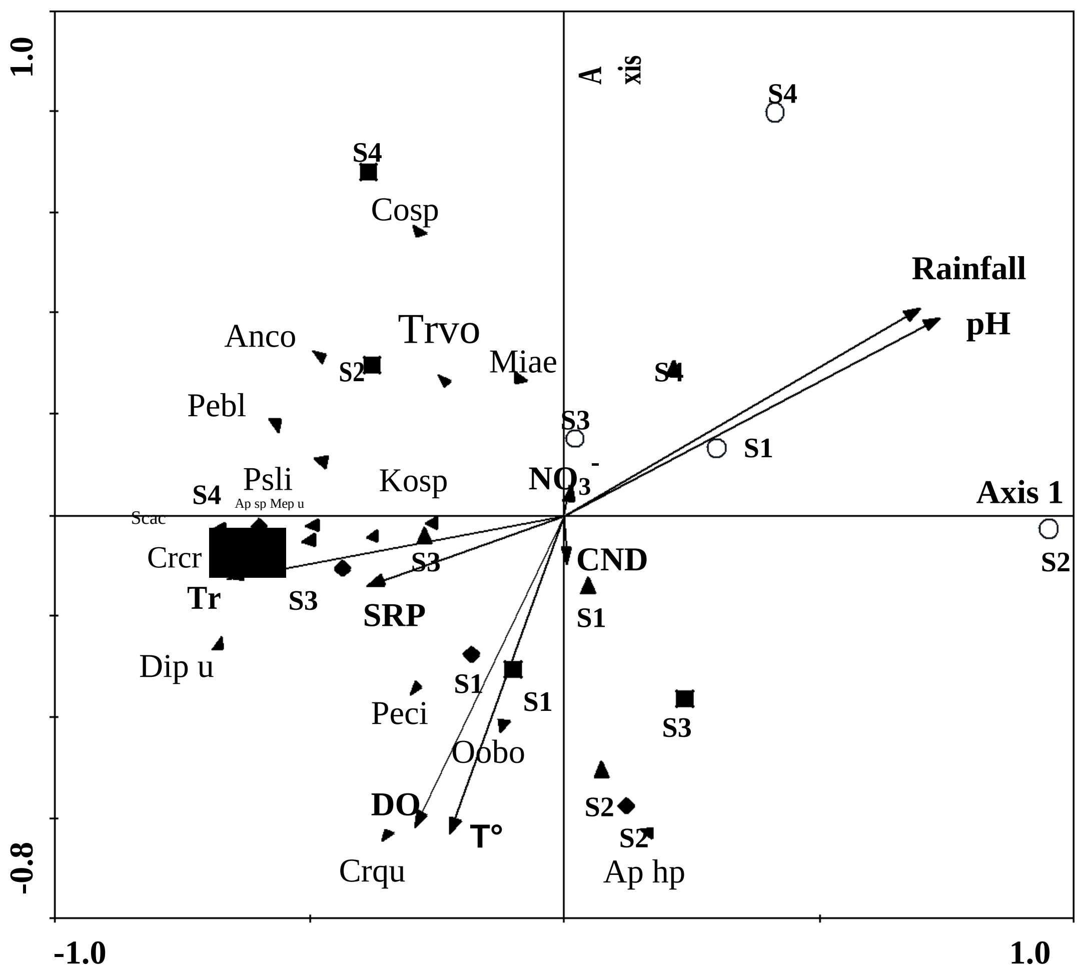

Figure 7. Scores derived from the ReDundancy analysis (RDA axis 1 and 2) applied to the dominant species and environment data. For the acronyms (Table 3). T: temperature, CND: conductivity; DO: dissolved oxygen; NO_3^-: nitrate; SRP: soluble reactive phosphorus; Tr: transparency; station (S).

(2001) and Kemka et al. (2004) in their study of Pampulha Reservoir in Brazil and Yaoundé municipal Lake (Cameroon) respectively reported higher phytoplankton diversity during the rainy seasons. They argued that the onset of rainfall destabilises the hitherto established conditions, creating a new environment conducive to other phytoplankton for exploitation.

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