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Original Research Paper

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This study evaluated some parameters of Water quality and phytoplankton growth in order to ascertain its seasonality in the lake Taabo (South East of Côte d'Ivoire). Seasonality was mainly due to significant variations in parameters such as conductivity, turbidity, transparency and nutrients (mean values of nitrate and orthophosphate were respectively equal to 1.62 and 10 mg/L). The lake downstream presented some features: oxygenation and mineralization were higher than upstream, at the time. Chlorophyll a ranged from 4.8 to 16.5 mg/L. For algal species composition, 118 taxa distributed into 5 main groups and 45 genera were identified. The algal assemblage was dominated by Chlorophyceae (30.5%), followed by cyanobacteria (27.1%). Conditions prevailing in this biotope favoured a massive phytoplankton growth, dominated by Chlorophyta and Cyanobacteria. Spatial and temporal analysis of nutrient and the composition of phytoplankton community revealed a seasonal variability in the ecosystem of the lake of Taabo which was under anthropogenic stress. This hydro system is growing towards a dystrophic state, thus implies an urgent need for restoration, followed by rehabilitation and process of elimination of solid materials in the lake catchment.

Key words: Phytoplankton community, diversity, structure, nutrient, environmental factors, pollution.

INTRODUCTION

Lake ecosystems are not only fresh water, but they are also tourist attractions and fish can stimulate regional economies (Burton 1997). Given the current population explosion, we realize that fresh water resources are finite, and human activities are one of the major causes of stress in aquatic ecosystems (Vasquez and Favila, 1998; Dokulil et al., 2000; Tazi et al., 2001). Around the world, many water bodies are thus irreversibly damaged by pollution and/or eutrophication, the most vulnerable are those located nearby large human settlements (Zohary et al., 1996).

The consensus seems to emerge on the role played in the process of eutrophication by phosphorus (Lacaze 1996), but the vulnerability of established tropical lake ecosystems calls for greater vigilance and hydrobiological investigations investigations in that region to look for factors that may be specific.

Phytoplankton communities consist of assemblages of species with different morphological (size, shape) and physiological (nutrition mode, reproduction) characteristics and whose organization is a key thing in the understanding of the dynamic of any ecosystem.

During a seasonal cycle, the phytoplankton composition follows the general trends, as described by Sommer et al., (1986). These trends vary in response to changes in environmental conditions such as temperature, light, and nutrients (Reynolds 1997; Grover and Chrzanowski 2005); and various biological interactions namely grazing, parasitism, viral lyses (Griffin and Rippingale 2001;

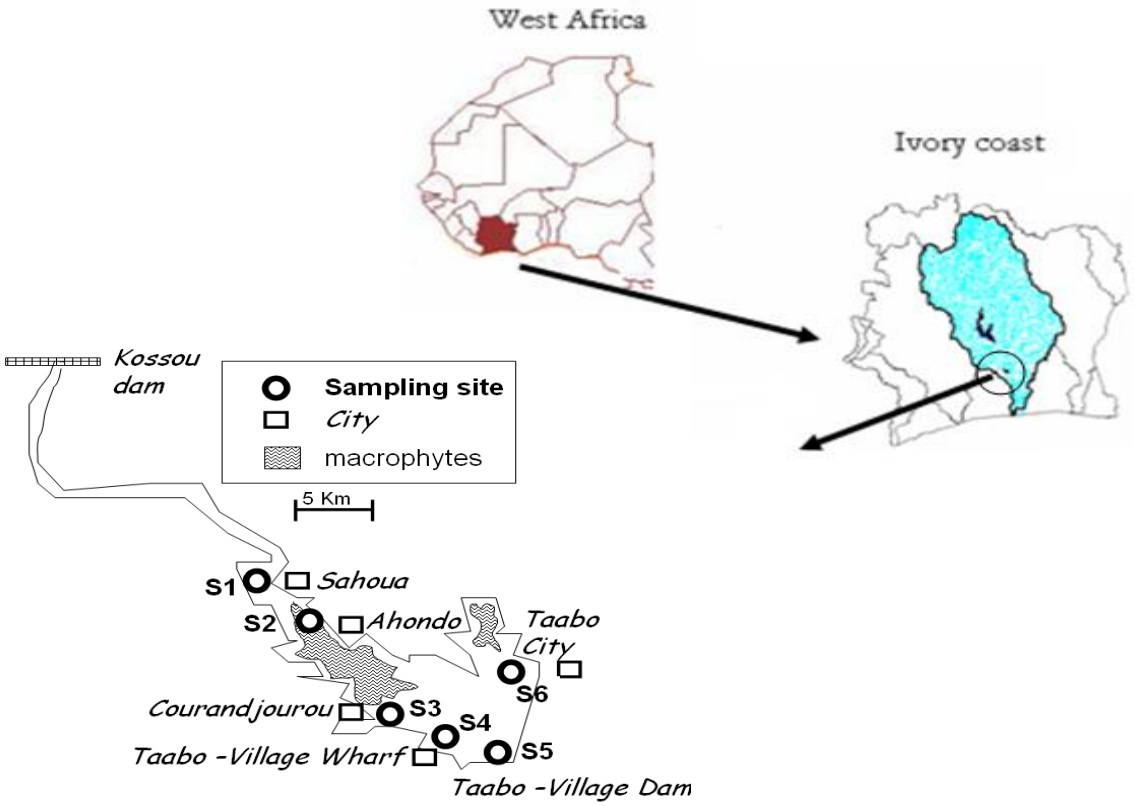

Figure 1: Location of the sampling stations of Taabo reservoir (S1, S2, S3, S4, S5, S6)

Brussaard 2004, Gleason et al., 2008). At tropical lake reservoir scale, a main variable may be important for hydrological seasonal variations. That is likely to play a major role in the stability of the water column, which can have a significant impact on the composition of the phytoplankton community.

Wind is also an environmental factor that can significantly alter the physical structure and form of the reservoir and by the same exerts forcing on the control of phytoplankton dynamics (Pannard et al., 2007). Wind speed and direction that induce movements of water mass and the current that is generated by the arrival of water in the inlet channels may also be responsible for the horizontal heterogeneous distribution of phytoplankton (Moreno-Ostos et al., 2008). The human activities is dominated by agriculture and the influence of anthropogenic activities on phytoplankton was studied in the characteristic zone of Côte d'Ivoire near the Lamto region (Koulibaly et al., 2010), the Taabo region where, the invasion of water hyacinth has resulted in the progressive eutrophication of the lake, leading to major problems for water use during the last ten years. Véi 2005 revealed the invasion of the lake of Taabo by Macrophytes which was described by Kouamé et al., 2011.

The aim of this study was to investigate the influence of anthropogenic nutrient inputs, both on water quality and phytoplankton community in the Lake of Taabo, which is located in a tropical climate characterized by two rainy seasons and two dry seasons; and relatively high temperatures throughout the year. This study pointed out the species composition and spatial and temporal variations of phytoplankton with respect to environmental physicochemical variables, which may account for the level of degradation of the hydro system.

METHODS

Study site

The lake of Taabo (6° 25'-56' N and 5° 07'-33'W; Figure 1) is the regulating lake of the Kossou dam. It is located downstream from the confluence of the White Bandama and the Marahoué (or Red Bandama). The lake of Taabo has a catchment area of 58.700 km^2. The lake covers an area about 80 km^2, and is generally subjected to a daily

Table 1. Morphometric and hydrographic characteristics of the reservoir hydroelectric Taabo

Geography coordinates		5°07'6°40'N
Date of construction		1975-1979
Date of impoundment		1978
Date of commissioning		1979
Hydrology	Catchment area	58700km^2
	Annual medium flow	278m^3/^{S}
	Coast of normal reserve	124m
	Surface at the coast 124m	69km^2
	Minimal level of exploitation	121m
Reservoir	Volume of the useful section	185×10^{6}m^3
	Coast of maximum rising	124.8m
	Volume with the maximum rising	163×10^{6}m^3
	Minimum rating of exploitation	120m
	Type of water retention	Earth and rock fill
Dam	Coast of the peak	127m
	Maximum height	34m
	Length of the peak	7.5m
Hydrant	Height of the hydrant	35m
	Width of the catch	35m
	A number of valves(coach)	3
	Diameters of valves force	6.6m
	Side of the lower edge of the penstock	99.4m
	Types of vannes	Segmented valve
Spillways	Numbers	5
	Capacity of evaluation	4460m$^{3/s}$
	Side of the lower edge of the penstock	113m
Power and Energy	Working installed capacity	210MW
	Annual productivity	1050GWH

fluctuation of the water level about 3 meters depending on the functioning of Kossou dam and wind stress. A hydroelectric reservoir was installed on the lake since 1975 (Table 1) what explains the presence of inhabitants in the vicinity of the lake which is estimated to 140.000 inhabitants. The main activity in the region is agriculture occupying 85% of the land in the catchment area of the lake reservoir, and it uses large amounts of agrochemicals.

Sampling

Water samples were collected during five campaigns from July 2006 to June 2007, using an opaque PVC Van Dorn-type bottle with a capacity of 2.5 L, mounted horizontally in order to maintain the sampling depth. Samples were collected through the water column at depths as follow: subsurface 40 cm, 1 m, 2 m, 3 m, and 4 m. Six stations were defined taking into account the succession of aquatic habitats and human activities from upstream to downstream (Figure. 2): furthest upstream, the reference station Sahoua (S1), the upper flow at Ahondo (S2), the deep segment of the left bank of the lake at Courandjourou (S3), an agricultural zone at Taabo-village wharf (S4), an urban zone on the right bank at Taabo-City (S6), and finally the furthest downstream at the Taabo-village (S5). A GPS MLR SP 12X satellite navigator was used for the location of the stations. Water transparency was measured *in situ*, from the depth (Zs) at which the Secchi disk disappeared. Since 15% of the incident light reached this depth, the depth of the euphotic layer (Zeu) could then be evaluated using the following equation: Zeu = 2.43 x Zs (Wetzel and Likens 1995). Measurement of temperature (°C), conductivity (µS.cm^{-1}), total dissolved solids (TDS; mg.L^{-1}), dissolved oxygen (DO; mg/L), pH and the turbidity (NTU) of water were carried out on the field, using a multiparameter WTW 340i instrument.

Nutrients analysis

Water samples were analysed in the laboratory in order to determine the concentrations of ammonia (mg/L of NH_4^+), nitrate (mg/L of $N\text{-}NO_3$), nitrites (mg/L of $N\text{-}NO_2$), phosphate (mg/L of PO_4^{3-}) and silica (mg/L of SiO_2^-) (Wetzel RG, and Likens GE, 1995). Samples were filtered through Whatman GF/C fibreglass filters (25 mm diameter). Then, in accordance with standard operating procedures (APHA, American Public Health Association, 1989), the concentrations of these parameters were

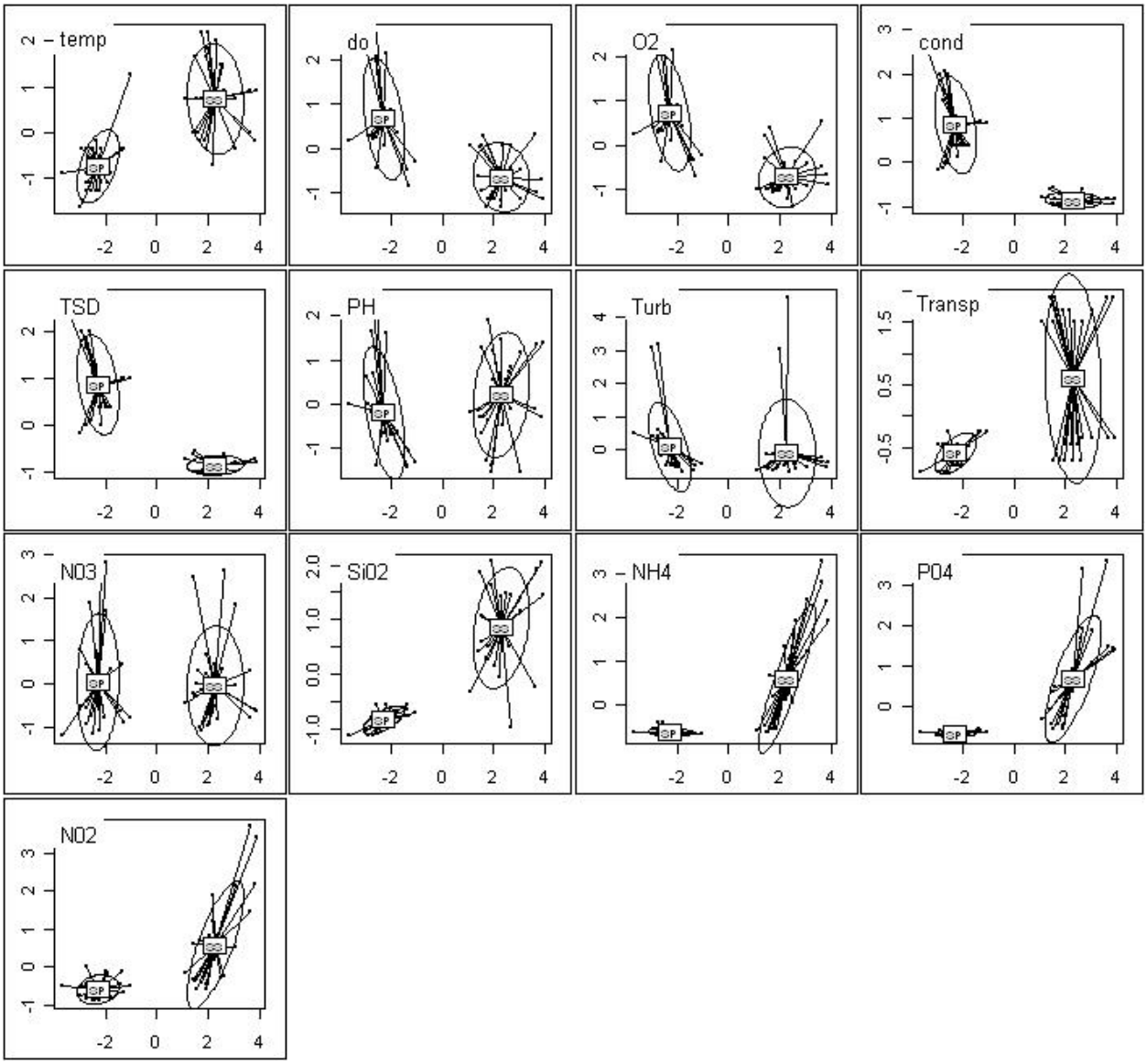

Figure 2: Seasonal variations of physical and chemical parameters in different stations. (SP): rainy season and (SS): dry season

determined using a HACH DR 2000 model spectrophotometer at specified wavelengths of 665 and 750 nm.

Biological analysis

For Chl a concentration measurement, 250 ml of each river water sample was passed through glass fibre filters of 0.7 µm size (Whatman GF/C, diameter of 25 µm) no later than 10 hours after collection. Because sampling was carried over 2 days time, filters were stored at -80°C for 48h, following which, chl a was extracted in 97% methanol at 75°C. The extinction of extracts was measured at 665 nm and 750 nm before and after HCL addition. The chl a content was calculed according to Herbland et al. (1985).

Samples for the determination and counting of phytoplankton were collected near the surface and at the different depths. These samples were fixed in formalin 5% (neutralized with borax). These samples previously agitated, settled in sedimentation chambers of 25 ml capacity. Microscopic observation was then performed on an Olympus AX70 microscope, using the method developed by Utermöhl (1958). The counting was performed using an inverted microscope. Counts were conducted on two orthogonal bands using the objective (X40). The number of counted cells was reported to the whole surface of the

chamber.

Phytoplankton composition and structure were assessed by the taxonomic richness (the number of taxa), diversity (the Shannon-Wiener index, Ish = -Σ ((ni/N) × log2 (ni/N))), uniformity (Pielou index, E '= H'/log $_2$ S) (Magurran 1988) and abundance. However, our analyses were carried out on the standardized data. To obtain such results, data were compiled and passed to the density using the formula of the total number N of phytoplankton cells contained in one liter of sample:

N = (n * S/s) x (1000/V)

n: Number of cells counted in the two bands,

S: total area of the settling chamber,

s: surface of the two bands,

V: volume of the settling chamber.

Taxa identification was possible by using keys, monographs and books (Bourrelly, 1966, 1968, 1970; Streble and Krauter, 1988; Carter-Lund and Lund, 1995; Ouattara, 2000; Desikachary, 1959; Hendey, 1964; Compere, 1967. and Krammer and Lange-Bertalot; 1986. 1988, 1991a, 1991b.

Data analysis

R package available at the following address: http://cran.r project.org was run for statically analysis. Variations of physical, chemical and biological parameters were tested by both Kruskal-Wallis and Wilcoxon tests for significant differences between the selected stations with respect to depth of the water and seasons. The spatial and temporal analysis were carried out through a normalized principal component analysis (PCA) processing analyzes between the groups (Doledec and Chessel 1987) to test the significance of the effects of three factors on the multidimensional model. The test procedure was based on 9999 random permutations of the rows of data file (Manly 1991).

RESULTS

Physical and chemical features of the Lake of Taabo

Physical and chemical parameters of water quality of the lake of Taabo varied significantly from the surface of the water to depth (Wilcoxon test, $p < 0.05$). Thus, water transparency ranged from 0.56 to 2.1 m. The lowest values of transparency were measured during the rainy season (June 2007 and July 2006) and the highest in dry seasons (December 2006 and March 2007).

Water temperature ranged from 26 to 32°C. The spatial and temporal fluctuations of water temperature showed a slight cooling near the lake floor. However, no remarkable thermal stratification was noted during the study time even if that cooling was important throughout the water column in October 2006 and March 2007. The pH values were measured between 6.55 and 7.85, indicating slightly acid waters and alkaline temporarily. Conductivity as a whole was measured between 73 and 143 µS.cm^{-1}. These values varied slightly from the surface of the water to 2 m of depth. Then, there were significant elevated values, leading to an accumulation of conductive elements in the deep water masses. Vertical profile of dissolved oxygen decreased throughout the year. Unlikely the surface water bodies which showed well marked super saturations. Deep waters instead exhibited strong deficit in dissolved oxygen so that the rate of oxygen saturation that characterizes the critical biological was reached at a depth of 2 m. During the dry seasons, it was not uncommon to meet anoxia at 3 m of depth. Only sporadically heavy rains cause slight elevation of dissolved oxygen concentrations at that depth. Concentrations of ammonia had undergone large temporal variations and increase with depth (0.03 a 3.05 mg.L-1). Vertically, relatively poor surface layer (up to 2 m) could be distinguished from a deep richer zone (4 m). This distinction was rarely noticeable during the rainy season when the lowest values were generally measured. Its occurrence was mainly regulated by changes in dissolved oxygen levels at these depths, which displayed the significant negative correlations ($p < 0.05$) between ammonia and the percentage of oxygen saturation. In raw water (unfiltered), concentrations of total dissolved phosphorus ranged from 0.01 to 54 mg/L. The highest levels were encountered during the rainy seasons (June and July). Their vertical distribution showed negative trend which was more pronounced during the rainy seasons. This would denote its dilution in the lake at the sediment-water interface. Nitrate concentrations were measured between 0.12 and 3.81 mg/L. The levels of nitrite (NO_2^-) fluctuated between 0.02 and 2.19 mg/L. Elevated levels of that variable were recorded during the rainy season. Its vertical distribution presented an orthograde profile. Silica concentrations ranged from 3.41 to 46.81 mg/L. The high nutrient concentrations were measured at stations S4, S6, and S5 located in the enclosing channel of the lake, while low values were noted at S1 and S2 which are upstream of the lake. Intermediate values recorded at station S3 of the lake showed the purifying role played by the water. These values varied slightly from the surface to depths. Chlorophyll a concentrations were generally quite high and ranged between 0.84 and 16.52 µg/L. Spatial and temporal variations of Chlorophyll a concentrations revealed that the highest values were located at 0.5 m depth, while the lowest values were measured at 4 m depth. That feature revealed two periods of high concentrations in chlorophyll a in the lake ecosystem. The first occurred from December 2006 to January 2007 and the second period started in March to end in May 2007. These high chlorophyll growths were consecutive to intense multiplication of volvocales *Eudorina elegans* and *Pandorina sp*. The start of the rainy season significantly reduced their biomass.

Table 2. Wilcoxon test (effect of season) and Kruskal-Wallis (stations and depth effect) applied to each descriptor.). DO: dissolved oxygen. Bold values significantly different ($p < 0.05$)

Descriptor	Season effect		Station effect		Depth effect	
	wilcoxon	*P*	χ^2	*P*	χ^2	*P*
Turbidity(NTU)	369.0	0.005	43.3	<0.001	2.3	0.687
Transparency	0.0	<0.001	31.1	<0.001	0.0	1.000
Temperature (°C)	13.0	<0.001	6.7	0.247	1.1	0.901
pH	85.5	0.003	46.9	<0.001	0.8	0.940
Conductivity($\mu S.cm^{-1}$)	465.0	<0.001	6.1	0.295	0.7	0.950
Dissolved oxygen($mg.L^{-1}$)	464.0	<0.001	12.0	0.035	1.2	0.884
(%)O_2	464.0	<0.001	16.4	0.006	1.4	0.851
NH_4-N($mg.L^{-1}$)	5.0	<0.001	6.5	0.261	1.5	0.832
NO_3- N($mg.L^{-1}$)	298.0	0.176	11.4	0.044	6.1	0.194
NO_2- N($mg.L^{-1}$)	20.0	<0.001	3.0	0.707	3.0	0.563
PO_4- P($mg.L^{-1}$)	0.0	<0.001	2.3	0.809	1.6	0.809
SiO_2($mg.L^{-1}$)	1.0	<0.001	6.7	0.243	1.7	0.798

Thus, physical and chemical features firstly appeared to be strongly influenced by seasons, and secondarily, accordingly to stations (Table 2 and Figure. 2). Variations recorded in depths showed minor heterogeneity of the water column.

Analyses of phytoplankton concentrations

Qualitative analysis

Analyses of composition of the lake water revealed the identification of 118 taxa distributed in 45 genera from which only some were periodically and particularly dominant at certain stations. Taxa were divided into the five following classes: 36 Chlorophyta (Chlorophyceae, and Conjugatophyceae), 30 Cyanophyceae, 28 Diatoms, 17 Euglenophyceae, 6 Dinoflagellates, 1 Chrysophyte (Table 3). The percentage of the latter group did not exceed 1% of the total density recorded at each station, thus was neglected in the different graphs representation.

Chlorophyta were dominated by the subclass of Desmids (over 15% of total species), mainly *Closterium strigosum* species, *Closterium gracile* and *Staurastum volans*. However, these species represented an important part of the phytoplankton biomass. On the contrary, the Centrophycideae were always more abundant despite the low number of observed taxa, among the species that have most marked the various developments of Chlorophyta, we quoted:

-*Eudorina elegans*, with exceptional growth in October, was regularly present in the waters of Lake of Taabo, but at relatively low densities. Its growth primarily occurred during the campaign in December and March, when it reached approximately 30% of the total density (80.10^6 cells/L) at station S4 (Figure. 3).

Staurodesmus subulatus is being common species in the neritic plankton and freshwater environments. *S. Subulatus* bloom primarily occurred in December, with a maximum at station S6 and S4 in March, with a rate exceeding 35% of the total density. Cyanophyceae showed high species richness, compared to that of Chlorophyta, and was always expressed as the dominant group in the lake. The genus *Scenedesmus*, in particular *Scenedesmus quadricauda*, was detected in 60% of sampling stations (Figure. 3).

Cyanophyceae (Chroococcales), represented by five species of *Microcystis*, never appeared as a dominant class. However, the genus *Microcystis aeruginosa* was present in elevated numbers within 75% of samples of the annual campaign. On the contrary, the Hormogonales like *Anabaena spiroides* and *Anabaena affinis* were mainly present in October 2006 (rainy season) and December 2006 (dry season). The other classes, smaller, such as Euglenophyceae and mainly represented by *Strombomonas, Euglena* and *Trachelomonas* were very rare for *Phacus* taxa.

Chromophyta (Diatoms) were essentially dominated by the subclass of Pennatophycid (over 30% of total taxa), including species as *Pinullaria acrosphaeria*, *Pinullaria brebissonii*, *Fragilaria crotonensis, Navicula placentula,* and *Gomphonema augur var. turris*. However, these perennials were never significant portions of phytoplankton biomass. The Centrophycideae despite the low number of observed taxa, were always more abundant. Among the species that have most marked the various developments of diatoms, we mainly observed *Acanthoceras sp, Lyngbya granulata* and *Fragilaria virescens*.

Pyrrhophyta, represented by six species, had never appeared as a dominant class. They were counted within 55% of samples during the campaigns in December 2006 and March 2007 (dry season) as showed on figure 4. The Chrysophyceae, mainly represented by *Dinobryon*, were sporadically observed in the samples collected in July 2006,

Table 3. Frequencies of phytoplankton taxa

code	Taxa	Present(%)
	cyanobacteria	
	chroococcales	
Apho	Aphanoc aspa ho Isatica (lemm) Cron berg & Komarek.	0.41
Apin	Aphanoc aspa Incerta (lemm) Cron berg & Komarek.	0.37
Clim	Chroococcus Limneticus Lemm	0.49
Cmin	Chroococcus Minicus (Kutz) Nag.	0.31
Ctur	Chroococcus turgidus (Kutz) Nag. Var. Maximus Nyg.	1.02
Cpus	Coelomoron pusillum (Van Goor) Kom.	0.52
Cosp	Coelosphaerium sp.	1.01
Mele	Merismopedia elegans A. Br. ex kutz. var. elegans	0.41
Mgla	Merismopedia gluaca (Ehr.) Nag.	1.97
Mpun	Merismopedia punctata Meyen.	0.88
Mten	Merismopedia tenuissina Lemm.	2.59
Maer	Microcystis aeruginosa (Kutz) Kutz.	2.52
Mden	Microcystis densa W. & G. West.	1.28
Mflo	Microcystis flos-acquae (Wittr.) Kirchan.	1.09
Mrob	Microcystis robusta (Clark) Nyg.	0.42
Mwes	Microcystis wesenbergii. Kom.	0.78
Syca	Synechococcus capitatus A, E, Bailey-Watt & J, Komarek,	0.52
Wosp	Woronichinia sp,	1.27
	Hormogonales	
Aaff	Anabaena affinis Lemm.	1.10
Acta	Anabaena c atenula. var. affinis (Lemm) Geitler.	0.57
Aflo	Anabaena aflos-aquae Breb. Ex. Born. & fl. var. aflos-aquae	1.49
Aspi	Anabaena spiroides Kleb.	0.33
Crac	Cylindrospermopsis raciborskii (Wolosz) Seena and Raju	0.20
Lgra	Lyngbya granulata (Ehrenb.) Simonsen.	0.36
Lgra	Lyngbya granulata (Ehrenb.) Simonsen.var.angustissinaf spirallis	0.85
Lmag	Lyngbya magnifica Gardner.	0.15
Opri	Oscillatoria princeps Vaucher ex Gom	0.31
Porn	Phormidium omatum (Kutz) Anagnostidis & Komarek.	0.35
Pcon	Plantolyngbya contoria (Lemm) Anagostidis & Komarek.	0.31
Plsp	Plantolyngbya sp.	1.02
Pgra	Plectonema graccilimun Hansg.	0.55
Rhsp	Rhabdoderma sp.	0.24
	Euglenophyta, Euglenophyceae	
	Euglenales	
	Chlophyta, Conjugatophyceae	
	Desmidiales	
Clac	Closterium acutum Breb.	1.37
Clacu	Closterium acutum Breb. Var. Variable (Lemm.) Krieger	1.81
Clgr	Closterium gracile Breb.ex. Rafls.	2.07
Cllin	Closterium lineatum Ehrenb.ex Rafls.	1.25
Clpa	Closterium parvulum Nag.	0.98
Clps	Closterium pseudolunula Borge.	1.07
Clsu	Closterium subulatum (Kutz.) Breb. Var. Subulatum	1.07
Clst	Closterium strigosum Breb.	1.43
Cobr	Cosmarium brebissonii Rafls.	1 .1
Ccon	Cosmarium contractor Kirchn.	1.47
Corps	Cosmarium psuedodecoratum Schmidle.	0.92
Eude	Euastrum dentriculatum F. Gay.	1.18
Euel	Euastrum elegans (Turp.) Rafls.	0.7
Stbr	Staurastrum brachiopromines Borg. var acherianum Bohl.	0.71
Stpo	Staurastrum polymorphum Breb. ex Rafls.	0.55
Stvo	Staurastrum volans W. & G. S. West.	0.81
Stsu	Staurastrum subulatus (Ehrenb.ex Rafls) Teil.	0.92
Xasu	Xanthidium subtrilobum W. & G.S West var. inornatum	0.48

Table 3. Cont.

	Chlorophyceae	
	Chloroccocales	
Ahib	Ankistrodesmus bibraianus (Reunch) Korsch.	0.66
Afal	Ankistrodesmus falcatus (Corda) Rafls var. falcatus	0.63
Agra	Ankistrodesmus gracilis (Reinch) Korsch.	0.87
Coin	Coelastrum indicum Turn.	1.54
Cosp	Coelastrum sp.	0.7
Dpul	Dictyosphaerium pulchellum Wood.	0.77
Grad	Golenkinia radiate (Chod) Wille.	0.98
Kcon	Kirchneriella contorta (Schmidle) Bohl.	1.96
Pdup	Pediastum duplex Meyen var. duplex.	1.5
Pgra	Pediastum duplex Meyen var. gracillimum W. & G. S. West.	1.53
Psim	Pediastum simplex.	1.76
Sbic	Scenedesmus bicaudatus (Hansg.) Chod.	0.99
Sper	Scenedesmus perforatus Lemm.	0.44
Scua	Scenedesmus quadricauda (Turp.) Breb sensu Chod	0.45
Sspi	Scenedesmus quadrispina Chod.	0.86
Tmin	Tetraedron minimum (A. Br.) Hansa f tetralobulatum (Reinsch.)	0.78
	Chlorophyceae	
	Volvocales	
Euel	Eudorina elegans Ehrenb.	1.57
Pspe	Pandorina sp	1.41
	Pyrrhophyta, Dinophyceae	
	Peridiniales	
Peac	Peridinium aciculiferum Lemm.	0.54
Peci	Peridinium cinctum (O.F.Mull.)Ehrenb.	0.56
Pein	Peridinium inconspicuum Lemm.	0.54
Peum	Peridinium umbonatum F. Stein	0.43
Pevo	Peridinium volzii Woloszynska.	0.61
Pesp	Peridinium sp.	0.7
	Chromophyta, Bacillariophyceae, Diatomophyceae	
	Centrales	
Cyme	Cyclotella menaghhiniana Kutz.	0.26
Cysp	Cyclotella sp.	0.21
Temu	Terpsinoe musica Ehrenb.	0.18
	Pennales	
Acsp	Acanthoc eras sp.	0.61
Eupe	Eunotia pectinalis (Dyll.) Rabenh.var. pectinalis	1.02
Fcap	Fragilaria capucina Desm azies.	0.85
Fcro	Fragilaria crotonens is kitton.	0.12
Fuln	Fragilaria ulna (Nitzsch.) Lange-Bert.	0.28
Fvir	Fragilaria virescens Rafls.	0.43
Guag	Gomphonema augur Ehrenb .var. turis (Ehrenb.) Lange –Bert.	0.23
Ggra	Gomphonema gracile Ehrenb.	0.42
Goli	Gomphonema olivaceum (Hom.) Breb. var olivaceum	0.34
Gosp	Gomphonema sp.	0.22
Mesp	Melosira sp.	0.38
Ncus	Navilcula cuspidata Kutz . Gomphonema sp.	0.23
Npla	Navilcula placentula (Ehrenb.) Grun.	0.31
Npup	Navilcula pupulla var. pupulla Kutz.	0.42
Nisc	Nitzchia scalar is (Ehrenb.) W. Smith.	0.28
Nisp	Nitzschia sp.	0.37
Piac	Pinnularia acrosphaeria Rabenh.	0.16
Pbra	Pinnularia brauniana (Grun.) Kram.	0.21
Pbre	Pinnularia brebissonii (Kutz) Rabenh.	0.51
Pdiv	Pinnularia divergens W. Smith.	0.43
Pigi	Pinnularia gibba Ehrenb.	0.17
Pieo	Pinnularia neomajor Kram.	0.28
Pivi	Pinnularia viridis (Nitzsch.) Ehrenb.	0.32

Table 3. Cont.

	Chromophyta, Chrysophyceae, Ochromonadales	
Dser	Dinobryon sertularia Ehrenb.	0.13

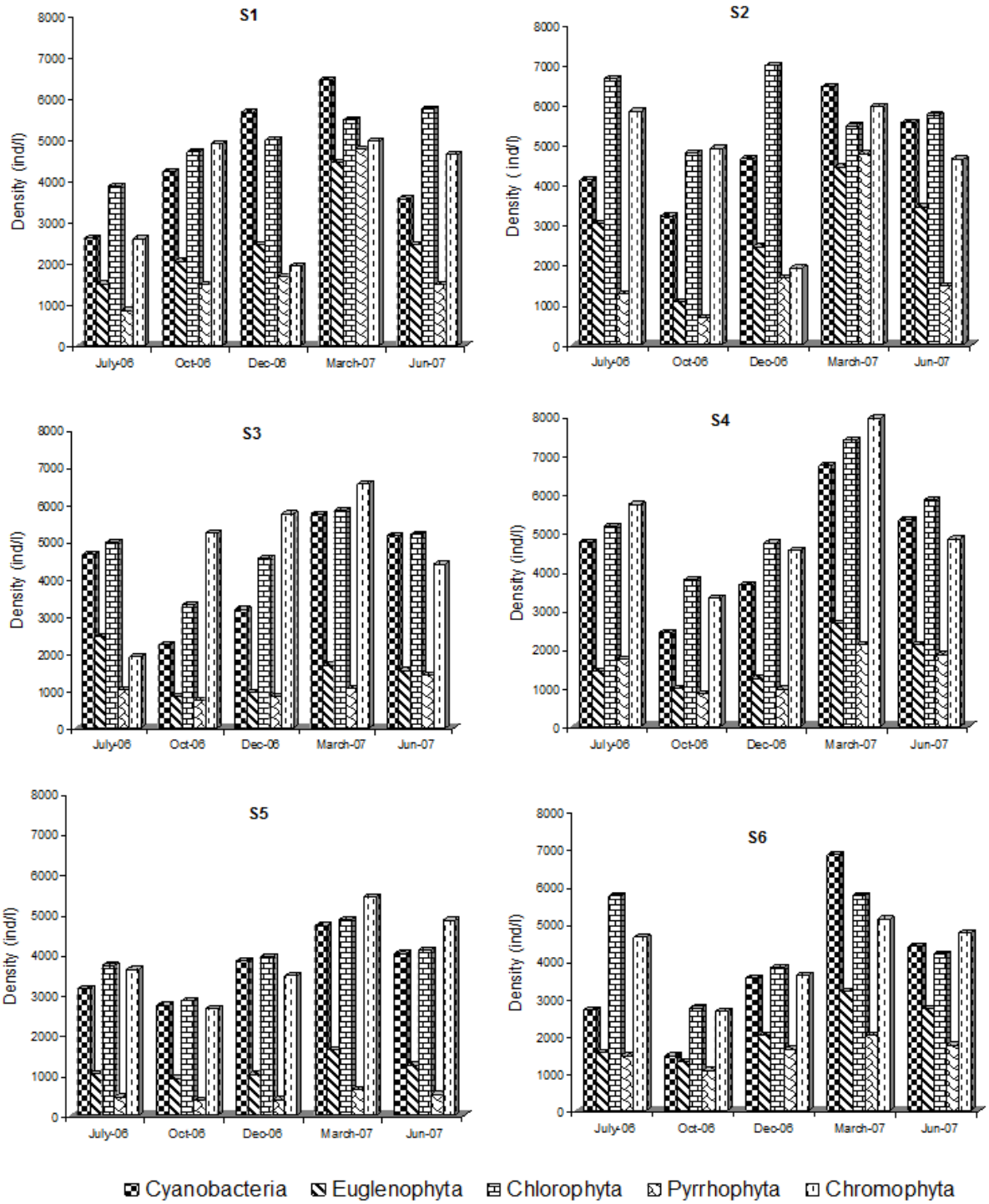

Figure 3 : Distribution of the phytoplankton density in different stations

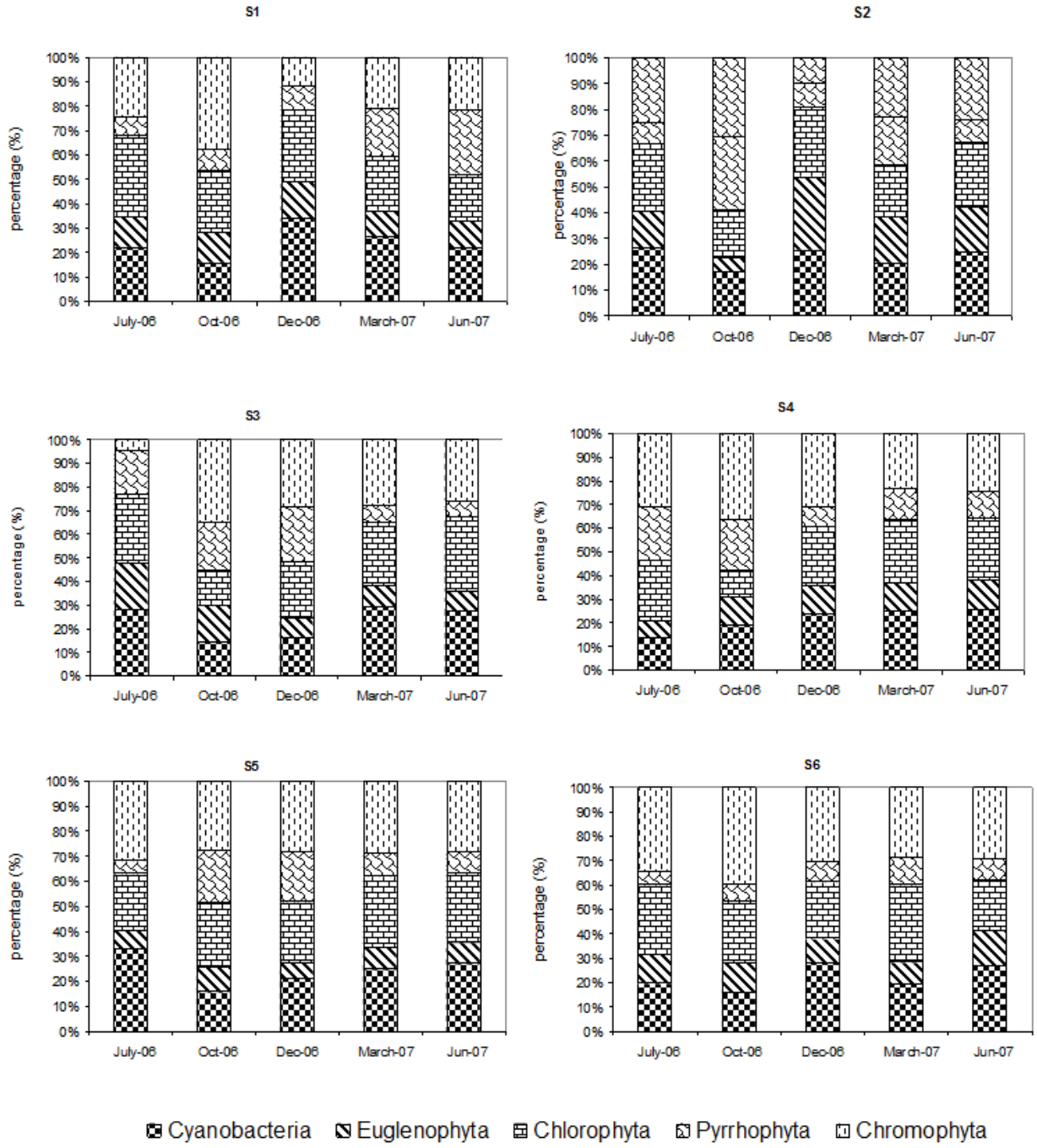

Figure 4: Seasonal variations with relative density of dominant phytoplankton groups in different stations

and always with a rate below 1%. This class had never been counted in higher values of density. It was found that the low phytoplankton densities were recorded during the campaigns in October 2006 (rainy season) and December 2006 and March 2007 (dry season). High densities were observed in July 2006 and especially in June 2007. During the campaigns of December and March, Diatoms were the largest group of the examined settlements. During that same time, Cyanophyceae concentrations were low. But they were well represented in March 2007 and June 2007. The same observation was done for Chlorophyta but with a lower rate.

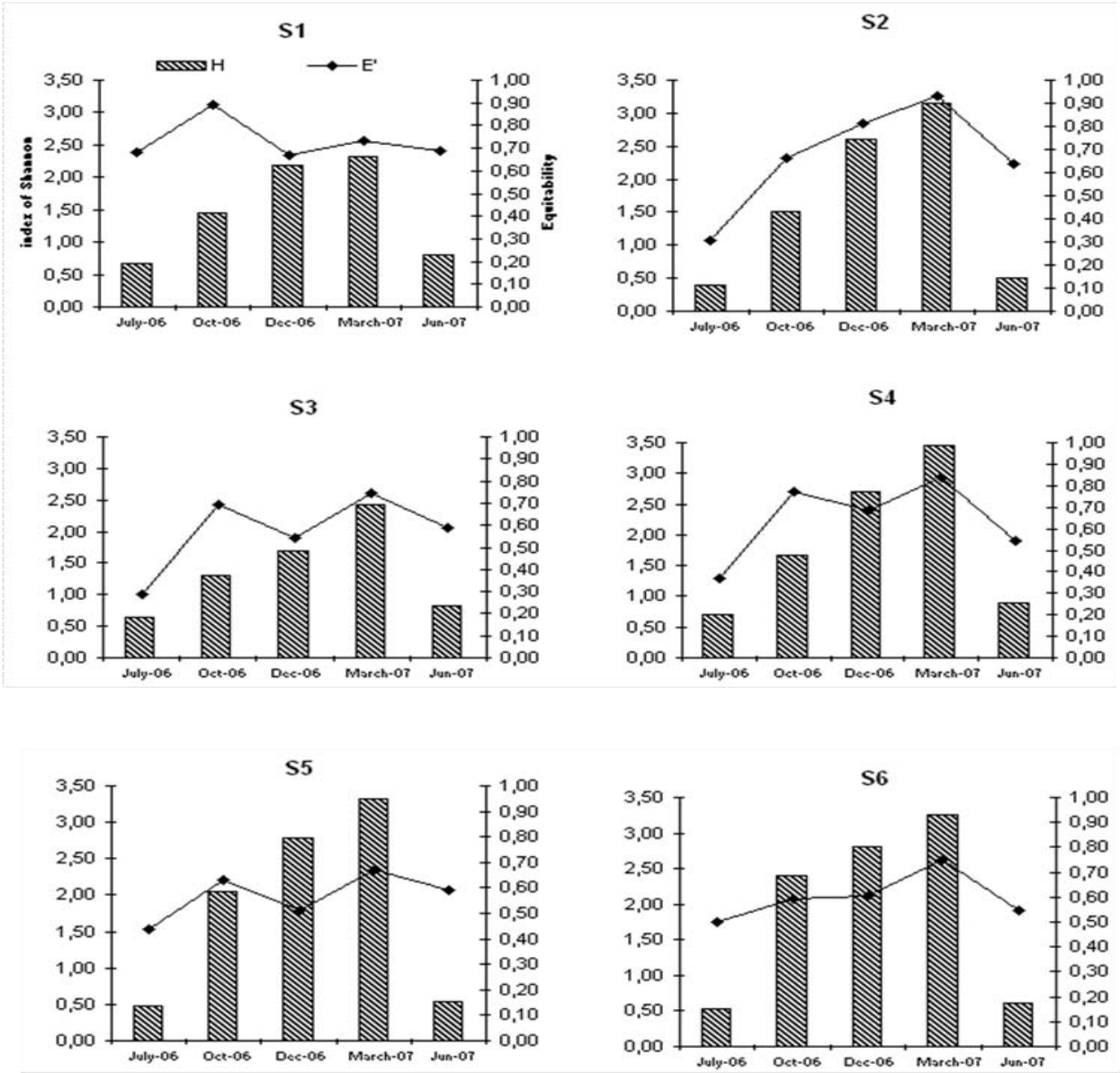

Figure 5. Average diversity index of Shannon (H) and equitability (E) at sites S1, S2, S3, S4, S5 and S6

The lowest densities of phytoplankton were recorded in October 2006 (rainy season) and the highest in March 2007 (dry season).

Phytoplankton in the Lake of Taabo was characterized by significant species richness of 118 taxa. We noted an average of 41 species per station, with a maximum richness of 57 taxa at Station S4 in the dry season. The maximum richness (32 taxa) was observed at 1 m depth at S5. Below 2 m depth, richness was significantly lower (Wilcoxon test, $p = 0.001$). However, no significant differences in species richness were observed between stations and seasons (Wilcoxon test, $p = 0.163$ and $p = 0.230$ respectively). The Shannon index (H) and equitability (E) are based on the proportions of observed species. In the Lake of Taabo, the yearly average values were respectively: S1 ($H = 1.48$, $E = 0.60$), S2 ($H = 0.39$, $E = 0.31$), S3 ($H = 1.72$, $E = 0.61$), S4 ($H = 3.46$, $E = 0.78$), S5 ($H = 1.83$, $E = 0.66$), S6 ($H = 1.99$; $E = 0.67$). The minimum values of H and E were observed at station S2 ($H = 0.39$, $E = 0.31$) while the maximum was obtained at S4 ($H = 3.46$, $E = 0.78$). The variability index was high at stations S4, S5 and S6 unlikely stations S1 and S3 which presented relatively low variability (Figure. 5).

The Shannon index and equitability reached the lowest values in June and July. In October, the diversity increased

rapidly due to the development of several Chlorophyceae, Diatoms and Euglenophyceae species. In March, communities presented their maximum diversity. Changes in diversity indices and Shannon equitability between the stations of study were not significant (Kruskal-Wallis, p> 0.05). The principal component analysis showed the Eigen values A, B, C as follow: axis 1 (40.95%) and 2 (6.37%); axis 1 showed the depth gradient. D, E, F: axis 1 and 3 (4.90%), Axis 2 showed the season/depth interaction, the effect being marked at surface and disappeared at depth (Figure. 7). That graph shows the large dispersion of taxa in the medium area.

Quantitative analysis

The seasonal peak in phytoplankton growth occurred in March with a large share of small species (nanoplankton) belonging mainly to the centric Diatoms. That was followed in June by a collapse as samples displayed large presence in zooplankton. Sharp increase in transparency was observed as result of a phase of clear water. In December, phytoplankton exhibited low growth again which was mainly consisted of large species easily consumed by zooplankton. Grazing can be considered as a decisive factor in the decline or collapse of the phytoplankton populations. Thus, phytoplankton growth in the Lake Taabo started in October, ending in the rainy season. When thermal stratification shapes the surface layer of the lake in july, algae already take advantage of intense lighting and high nutrient concentrations. Algae migrate to the euphotic zone during the vertical water mixing which takes place in December. Transparency in turn is very low (0.65 m).

In July, Cyanobacteria were weakly represented in the lake (Figure 4). On the contrary, we observed their important presence from December to March (25%). Maximum growth was observed for Chlorophyceae in June (30%), Euglenophyceae in December (11%) and Dinoflagellates in October (8%). Regarding the phytoplankton dynamic, the stations of that study in the Lake of Taabo were divided into two major groups of phytoplankton densities as follow: S4, S3, S6 and S1, S2, S5 (Figure. 4).

The average biomass in chlorophyll a concentration was 10.7 $\mu g.L^{-1}$. Peaks were observed in October, December and March with respective chlorophyll a concentrations of 16.4, 16.02 and 16.52 $\mu g.L^{-1}$. These concentrations were consecutive of intense growth of volvocales *Eudorina elegans* and *Pandorina sp*, which coincided with rains. The lowest concentrations in phytoplankton biomass were measured in July (4.84 $\mu g.L^{-1}$). Those concentrations resulted of water clarification leading to a much higher transparency (2.01 m) (Figure. 6).

Phytoplankton community of the Reservoir of the Lake Taabo presented a taxonomic spectrum dominated by Chlorophyta, Cyanobacteria and Euglenophyta. Those phytoplankton communities are characteristic of rich and polluted environments in putrescible organic substances.

The continuous nutrient input in the environment is causing the instability of phytoplankton populations. In addition, the development of large Euglenophyceae that dominated the number of species which were restrained to the middle by their biomass and the extent of areas of the lake overgrown with macrophytes, are signs of advanced functional degradation of the ecosystem.

DISCUSSION

Apparent changes in the lake ecosystem could be related to natural causes, anthropogenic activities and management issues. Natural influences such as climatic variations in the West African region had caused changes in levels of the lake. Regulations of the lake outflow for hydroelectric power generation at the Taabo dam located downstream may also contribute to changes in the lake levels. Inundation of farmlands that occur during such periods may contribute to large loads of sediments and nutrients to the lake, whereas, decrease in water levels can modify near-shore habitats and change breeding areas available to many fish species.

Overall, Phytoplankton communities consist of assemblages of species with morphological and physiological characteristics with different ecological organizations. The Phytoplankton diversity in lake of Taabo was dominated by Chlorophyta, against Diatoms when the site is small and severely disturbed (Moshood, 2009; El Haouati 2013). Their densities were relatively high in Lake Taabo, low both downstream and upstream. Accordingly to the longitudinal gradient upstream-downstream, phytoplankton was differently distributed at each station. Indeed, the population mainly changed with respect to the number of species extinction, at least in the cashing of the lake. That is an essential component to the understanding of ecosystem functioning (Klug and Tiedje 1993). Thus, knowledge of community taxonomic compositions, such as Diatom indices, is a source of key information concerning pollution (Descy and Coste 1990; Karr 1991). In the case of this study Diatoms (22%) indicated that the changes in environmental conditions have to be considered in regard to the other studies in Africa (Moshood, 2009; El Haouati 2013).

In terms of structure, the phytoplankton community was not different between stations. Changes in phytoplankton biocoenosis could be explained by the hydrological changes that occurred and the influence of surrounding anthropogenic inputs. Indeed, phytoplankton densities were relatively higher downstream the Lake of Taabo than upstream. In that river-lake system, flows were more or less rapid and turbulent, and phytoplankton communities were very scarce. On the contrary, phytoplankton densities

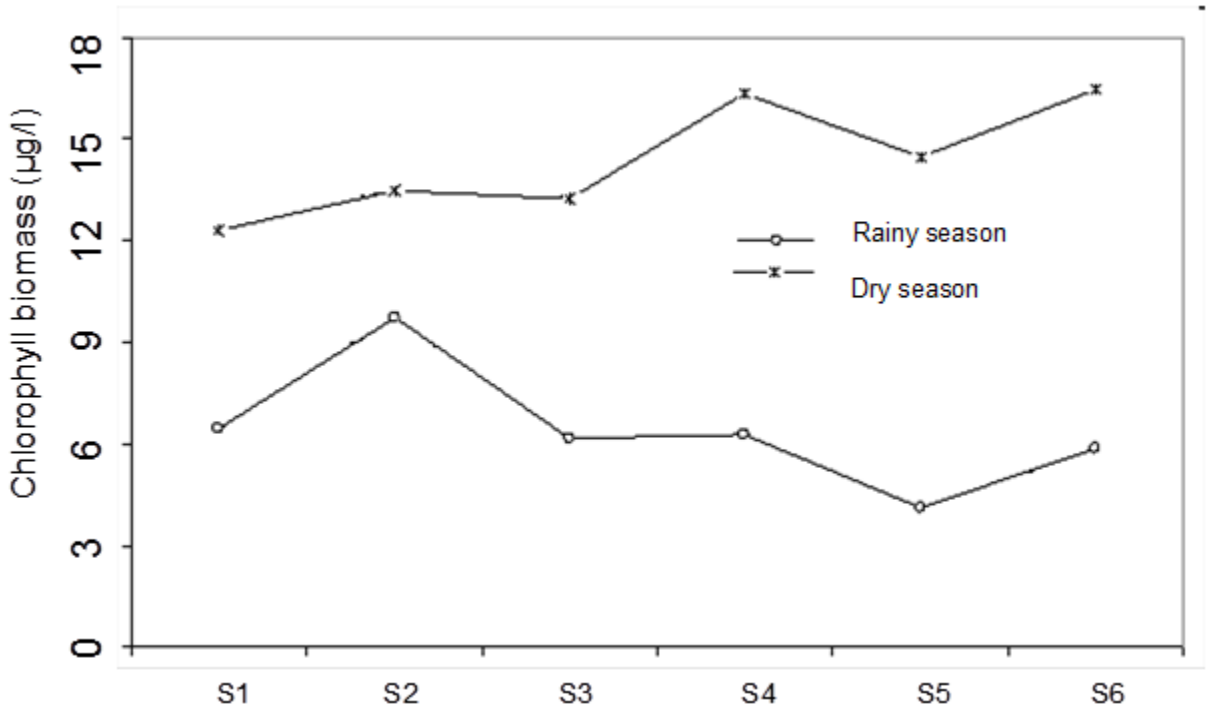

Figure 6: Annual change in total biomass Chlorophyll (µg / l) in the six stations of Lake Taabo for flood periods (= rainy season from June to October) and low water (= dry season from December to March).

were relatively high in the lacustrine system of Taabo. Indeed, phytoplankton communities found many favorable conditions for their development in relation with a stagnant state and urging water transparency of 0.56 m to 2.01 m.

Gradient in dissolved oxygen concentrations resulted from the organic matter oxidization. Indeed, high concentrations of ammonia recorded at the bottom of water bodies reflected an incomplete mineralization of organic substances. Nitrifying bacteria are aerobic and cannot influence the conditions of the site because nitrogen in its ammonium form predominates (Guilford *et al.,* 2000). Highly eutrophic environments are characteristic of organic substance rich environments (Moss, 1998), in which deoxygenated deep waters are produced by biological means. These low levels in oxygen concentration were due to suspended solids overload, and photosynthetic activity at the Lake surface was weak to offset the consumption of dissolved oxygen. On the contrary, phosphorus predominated in some stations (S4, S5, and S6) during the rainy season. Most of the initial detritus are incompletely mineralized. Therefore, those detritus sink and accumulates on the lake bottom, resulting in the extension of areas of anoxia in the water column through the entire ecosystem. Release into the ecosystem of large amounts of untreated domestic sewage lead to the growth of taxonomy dominated by Chlorophyta, the Cyanobacteria and euglena. Those genera are characteristic of polluted and organic substances rich environments (Akpan et al*.,* 2004). Representatives groups, including the genera *Scenedesmus, Microcystis* and *Lepocinclis*, are known for their preference for eutrophic sensu lato (Reynolds et al.,2000). Algal bloom occurred 1-2 months after heavy rainfall which sluices inputs in phosphorus from surrounding farms and lands, and also causes complete mixing of the lake. Phytoplankton communities had experienced significant changes in biomass as well as in their composition. Episodic phytoplankton blooms were regularly reported in the middle of the lake on calm and sunny water (Cogels et al., 1993). Those authors reported that these blooms were mainly composed of Cyanobacteria including *Anabaena spiroides*, *Woronichinia sp* and *Microcystis aeruginosa*, typical algae of eutrophic waters. These species were previously identified by Dia and Reynaud (1982). The occurrence of these algal blooms in these periods of the annual cycle is therefore related to the tropical climate and highlights the regulatory action of rain on the photosynthetic activity within the water body. Besides the supply in organic matter from the bottom, the rain action leaded larger flow discharges, and backlash by more efficient solids transport.

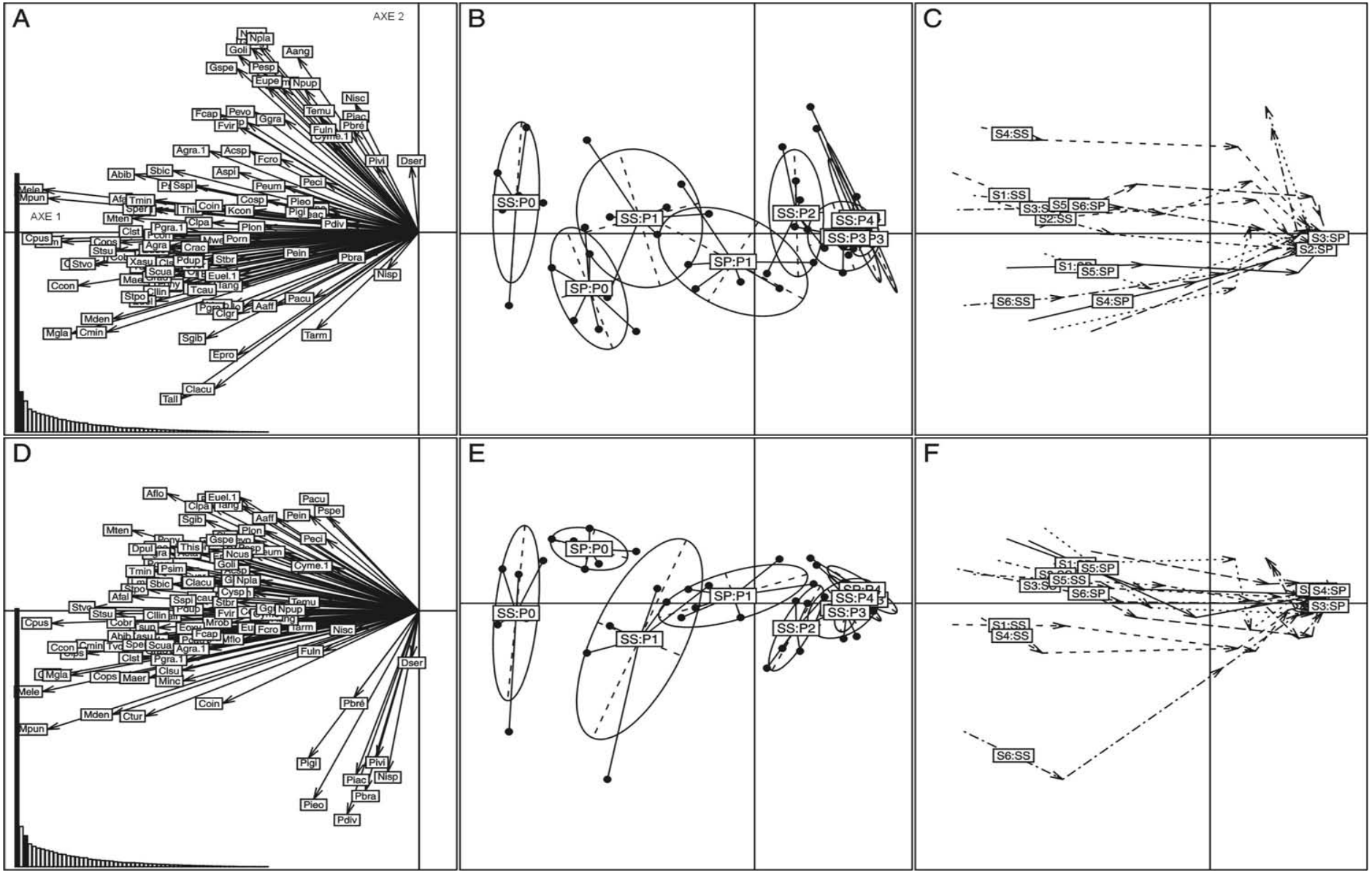

Figure 7: Principal Component Analysis of phytoplankton taxa at various depths, stations and seasons F1 (40.95%), F2 (6.37%) and F3 (4.90%)

The structure of the phytoplankton community is partly characterized by a small number of species of Bacillariophyceae, also noted by Carl Bro (1999). Therefore, the predominance of green algae and higher number of species of cyanobacteria showed changes occurring in the phytoplankton community. Analysis of vertical structure also indicated that this lake was not actually in green estate according to Margalef (1960). That was with phases of rapid and ephemera growth of various species. The constant nutrient enrichments from the watershed and sediment following high frequency of episodic mixing water (Dokulil et al., 2000), and the shallowness of the water, favor the maintenance of this type of community.

Conclusion

This paper is based on a recent field study, and includes various data available about Lake Taabo. The physicochemical analysis of water and the study of the phytoplankton populations based upon sampling performed during an annual cycle were used to determine trophic status of the lake Taabo. The effects of environmental pressure and subsequent impacts are evident in the Lake of Taabo. This Lake is under a disturbance of its ecosystem at physical chemistry and phytoplankton diversity levels, due to the anthropological influence at its proximity. This water body is engaged in an eutrophication process. The imbalance of the ecosystem from a continuous nutrient inputs and domestic untreated discharges is causing the instability of phytoplankton communities, the extent of flooded areas of the lake by macrophytes. These observations are signs of advanced functional degradation of the ecosystem. Therefore, the results of this study could help in pollution management and project for preservation of the Lake of Taabo. The rapid evolution of phytoplancton communities related to the environmental changes increase the interest of their ecological follow-up. Next studies should allow a precise approach which will take into account the interactions between the diversity of phytoplankton, the levels of the trophic network and the physico-chemical parameters of these sites that are uses for multipurpose.

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