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Temporal dynamics of phytoplankton communities and their responses to environmental factors in Grand-Lahou Lagoon, Ivory Coast, West Africa

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Abstract

Variations in physical-chemical factors, species composition, abundance and biomass of phytoplankton assemblages, as well as their responses to environmental factors, were investigated in Grand-Lahou Lagoon from June 2006 to February 2007 (Ivory Coast, West Africa). The hydrosystem and the growth of anthropogenic activities on its hillsides particularly favored the high rate of soluble reactive phosphate concentration (0.32-2.1 mg/L) and nitrate concentration (0.09-7.93 mg/L). Consequently, high phytoplankton densities (56-156 10^6 cell/L), low transparency (0.45-0.90 m) and high suspended matters rate (3.60-22 mg/L) were observed. The 97 species were represented mainly by Diatom comprising 42 species (42.3%), Chlorophyceae with 23 species (23.7%), followed by Cyanobacteria, Euglenophyceae and Dinophyceae with 19 species (19.6%), 11 species (11.3%) and 3 species (3.1%) respectively. Species composition of phytoplankton was typical of eutrophic conditions. The occurrence of filamentous *Anabaena planctonica* Brunnthaler, *Oscillatoria limosa* C.Agardh ex Gomont, *Pseudanabaena* sp., *Oscillatoria princeps* Vaucher ex Gomont, *Planktothrix agardhii* (Gomont) Anagnostidis & Komárek and colonial *Microcystis aeruginosa* (Kützing) Kützing in high numbers may highlight pollution stress in the lagoon. The proliferation of the Cyanobacteria encountered was controlled by the nutrient level (nitrate) and transparency. The physico-chemical characteristics, Margalef, Shannon and Equitability indices indicated pollutions stress and dominance by a few species.

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Introduction

Lagoons are prominent hydrological features along the West African Coast (Onyema, 2008). They provide natural food resources rich in protein which includes an array of fish and fisheries. The functioning of these ecosystems is closely linked to freshwater and seawater inputs (Kouadio *et al.,* 2011). Lagoons also inadvertently serve as sinks for the disposal of domestic, municipal and industrial wastes in the region. Nowadays, many lagoons receive special attention because they are subject to intense anthropic action (Konan *et al.,* 2010). The Grand-Lahou Lagoon was ecologically and economically important aquatic ecosystem in south Ivory Coast (Seu-Anoï, 2012). This aquatic ecosystem is a habitat to a variety of biota which includes the plankton, nekton and benthos in a complex trophic interrelationship. And, habitat modification arising from anthropic pressure is one of the major ecological problems in the Ivory Coast coastal environment. There are two main types of modifications practiced. These include anthropogenic impacts in natural resources over exploitation, particularly through fisheries, mangrove firewood usage in changes in tidal dynamics, increase in turbidity and lowering of photosynthetic depth, loss of suitable substrate for benthic fauna and therefore a decline in biodiversity (Konan *et al*., 2008). The second type of modification is through pollution such as the introduction of biodegradable waste and creation of organically polluted zones. Indeed, as farming in the vicinity of this lagoon system, crops coconut, rubber and oil palms are the most frequently encountered. These agricultural activities around the lagoon complex may influence the quality and structure of the water by the use of pesticides and fertilizers (Seu-Anoï, 2012). Unfortunately, this sensitive environment serves as a sink for surrounding facilities and gradually is being transformed. The consequence of these actions is the loss of biodiversity in general and particularly in phytoplankton community (Pilkaitytė and Razinkovas, 2007). This investigation was designed to provide information on the phytoplankton structure of the Grand-Lahou Lagoon water and their relation with environmental factors.

Materials and methods

Description of study site

The Grand-Lahou lagoon system (Tagba, Niouzoumou, Mackey and Tadio lagoons) is located in the far west of the coast between 5° 11'- 5° 24'N and 5°- 5°42'W. The main characteristics of these lagoons and tributary rivers are listed in Table I. It receives freshwater from the Bandama river, and from the smaller Gô and Boubo rivers. The principal basin is elongated with an axis oriented E-W with 50 km long, parallel to the coast. The system is fringed by mangrove forests. The crabs, shrimps and fishes are very abundant in the Grand-Lahou lagoon system particularly from July to October. The average migration rate of the mouth of Bandama river about -10m per month was observed during our sampling period due to tide actions. Like all parts of South Ivory Coast, the Grand-Lahou Lagoon is exposed to four distinct seasons namely the short rainy season (October-November), the short dry season (April-September), the long dry season (December-March) and the long rainy season (April-July).

Collection of samples

Biological and water samples were collected monthly during four seasons (June, 2006 to March 2007). All samples were collected between 8:00 and 12:00 from four stations. Water samples for physico-chemical analysis were collected 0.50 m below the water surface in four liter plastic containers, properly labeled and stored in ice chests in the field. In the laboratory, the water samples were transferred into refrigerator (t = 4 °C) and analysed within 24 h of collection.

Plankton samples were collected using 20 µm mesh size plankton net and the net was dragged horizontally for 6 m in the surface water to obtain a sample of phytoplankton. The concentrated samples were stored in 200 ml well labeled containers with screw caps and preserved in 4% unbuffered formalin.

Physical and chemical parameters

The surface water temperature and salinity were measured with a WTW COND 340-i conductivity meter and transparency estimated with a 20 cm diameter white and black paused Secchi disc. The pH was determined using a ORION 230-A meter. The nutrient concentrations such as nitrates (NO_3^-), soluble reactive phosphate (SRP) and soluble reactive silicate (SRSi) were analyzed in a series of ten samples collected June 2006 to March 2007, considered representative for the different seasons of the year. Water samples for nutrient measurements were filtered through Sartorius cellulose acetate filters, re-filtered through 0.2 µm pore size polysulfone filters and preserved with $HgCl_2$ for NO_3^- and SRP, and with HCl for soluble reactive Si. NO_3^- concentrations were determined following the Auto Analyser II (Tréguer and Le Corre, 1975), with an estimated accuracy of ± 0.1 µmol L^{-1} and a minimum detection limit of 0.05 µmol L^{-1}. SRP and SRSi concentrations were analyzed according to the standard colorimetric methods (Grasshoff *et al.*, 1983), with an estimated accuracy of ± 0.01 µmol L^{-1} and ± 0.1 µmol L^{-1}, respectively.

Biological parameters

Phytoplankton analysis was done using an Olympus BX40 microscope equipped with a calibrated micrometer. The algal classification proposed by Van den Hoek *et al.* (1995) was followed. Identification of the main phytoplanktonic groups was made with reference to Desikachary (1959) and Komárek and Anagnostidis (2005) for Cyanobacteria, Huber-Pestalozzi (1955) for Euglenophyta, Komárek and Fott (1983) (Chlorophyta), Tomas (1995) and Bourrelly (1968) for Dinophyta, Krammer and Lange-Bertalot (1988, 1991), Tomas (1995) and Hartley *et al.* (1996) for Bacillariophyta.

The quantitative estimation of the phytoplankton was performed by counting with an inverted Diavert microscope, using the Utermöhl (1958) technique. Subsamples (25 ml) were settled in cylindrical chambers and left to sediment for at least 16 h. Phytoplankton community counts were made under phase contrast illumination at 400–1000× magnification. The counts of unicellular, colonial, or filamentous algae were expressed as cells l^{-1}. Three indices were used to obtain the estimate of species diversity. The species richness (d) was estimated according to Margalef (1951). The Shannon (1949) diversity index (H) and Pielou's (1966) evenness index (J) was calculated.

Statistical analyses

To test differences in physicochemical variables total phytoplankton abundance, Biomass, Shannon diversity index (H), evenness index (J) and Margalef's species richness (d) between the four seasons, the non-parametric Kruskal-Wallis test was used, because the data were not distributed normally (Zar, 1999). Significance level was defined as $p < 0.05$. All these analyses were carried out using STATISCA 7.1 software (StatSoft, n2005).

To evaluate the joint influence of several parameters on phytoplankton, a multivariate analysis was performed by ReDundancy Analysis (RDA) using the program CANOCO 4.5. The P-value was obtained by a Monte Carlo permutation test (499 permutations), carried out for all canonical axes. In this analysis, 11 phytoplankton taxa having a relative abundance >5% of total abundance (as shown in Table 1) and 8 environmental variables were taken into account. Abundance values were transformed by log ([100 * abundance] +1).

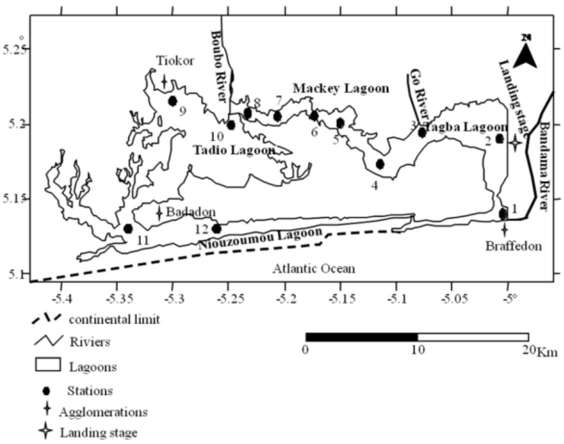

Fig. 1. Location of the study stations in Grand-Lahou lagoon system, Ivory Coast.

Table 1. Main morphometric characteristics of the Grand-Lahou system lagoon and of the main rivers (Mé, Comoé and Agnéby) flowing into this system lagoon (unpublished data from Koné, 2008 and Durand and Chantraine, 1982).

Grand-Lahou Lagoon	Area (km^2)	Mean depth (m)	Rivers
Tagba	57	3	Gô Bandama
Tadio	90	3	Boubo
Mackey	28	4.8	Gô
Niouzoumou	15	3	-

Results

Physical and chemical features

Data of the environment parameters at the Grand-Lahou Lagoon are presented in Table II. Transparency was generally low (≤ 0.8 m) all through the sampling period. The lowest transparency values (≤ 0.5 m) were recorded in long rain season (LRS). Surface water temperatures were relatively stable with a range of between 26.1 °C and 32.3 °C. Whereas the surface water salinity at Grand-Lahou Lagoon was relatively high and varied from 0 to 20.8. No differences were observed between seasons ($p > 0.05$). The pH was alkaline (> 7) all through the sampling period. The disolved oxygen (O_2) values were high during LDS (7.2 mg/L) while values were low at LRS (3.5 mg/L). There was a significant O_2 difference ($p < 0.05$) between the LRS and the other seasons. The soluble reactive phosphate (SRP) values were relatively higher in SRS (22 mg/L) than in LRS (3.6 mg/L). There was no significant difference ($P > 0.05$) in values of SRP during dry and wet seasons. Nitrate concentration (NO_3^-) values were significantly higher in the short dry season (7.93 mg/L). There was a decline in NO_3^- values to 0 mg/L in SRS and LDS. SRSi values decreased from wet (174.56 µmol/L) to dry seasons (65.93 µmol/L). Notable differences were observed between seasons ($p < 0.05$).

Table 2. The physico-chemical characteristics of surface water at Grand-Lahou Lagoon during the period of June, 2006-March, 2007.

Parameters		Seasons			
		LRS	SDS	SRS	LDS
Transparancy (m)	Min	0.50	0.45	0.6	0.51
	Max	0.7	0.9	0.95	0.9
	Mean ±σ	0.6± 0.07	0.66± 0.2	0.8± 0.12	0.72± 0.19
Temperature (°C)	Min	26.1	26.8	28.3	29.7
	Max	28.4	29.2	29.4	32.3
	Mean ±σ	26.75± 0.76	27.98± 1	29± 0.41	31.38± 1.11
Salinity	Min	0.3	0	6.3	7.3
	Max	1.7	8.6	12.5	20.8
	Mean ±σ	0.77± 0.46	5.45± 4.17	7.55± 3.59	17.1± 5.64
pH	Min	7.00	7.36	7.32	7.62
	Max	8.89	7.84	7.83	8.05
	Mean ±σ	7.31± 0.71	7.66± 0.2	7.66± 0.20	7.82± 0.15

SPM (mg L^{-1})	Min	3.60	6.4	6.0	6.0
	Max	8.4	20.0	22.0	21.6
	Mean ±σ	6.2±	12.4±	11.93±	13.13±
		1.69	5.33	5.61	5.79
O_2 (mg L^{-1})	Min	3.5	3.71	5.7	6.7
	Max	5.1	6.17	6.2	7.2
	Mean ±σ	4.35±	5.35±	6.0±	6.99±
		0.49	1.04	0.18	0.20
NO_3^- (µmol L^{-1})	Min	1	0.13	0.09	0.09
	Max	4.23	7.93	4.74	0.19
	Mean ±σ	2.3	3.44	1.70	0.06
		1.1±	3.5±	1.66±	0.1±
SRP (µmol L^{-1})	Min	1.30	0.63	0.34	0.32
	Max	2.1	0.94	0.80	0.81
	Mean ±σ	1.71±	0.77±	0.50±	0.68±
		0.3	0.13	0.18	0.19
SRSi (µmol L^{-1})	Min	142.04	88.16	59.40	65.93
	Max	174.56	156.46	89.57	99.59
	Mean ±σ	156.82±	131.18±	73.84±	78.72±
		12.60	27.73	9.63	15.10

Phytoplankton

Composition and Species diversity

A total of 97 phytoplankton taxa (Table III) were identified during the four seasons' survey, comprising five groups: Bacillariophyceae (42.3%), Chlorophyceae (23.7%), Cyanobacteria (19.6%), Euglenophyceae (11.3%) and Dinophyceae (3.1%). The Bacillariophyceae had the highest species diversity throughout (Table III) and Cyanobacteria had the highest relative abundance throughout the year (Table IV). Among the phytoplankton, 41 taxa were diatoms (centric-3; pennat-38), 24 belonged to the green algae (Chlorococcales-13, Desmidiales-8 Zygnematales-3, Euglenales-11) and the blue-green algae made up 19 taxa (Chrococcales- 7, hormogonales-12). Species composition of phytoplankton was typical of eutrophic conditions and was frequently characterized by the presence of Bacillariophyta. Diversity was comparatively lower (0.6) in the dry season than during the rainy (2.06) while equitability and Margalef index were higher (0.84, 0.74 respectively) in the dry months (Table V).The number of taxa (species and varieties) was higher in the rainy season than dry season. The compositions of phytoplankton were relatively similar at all the stations of the Grand-Lahou Lagoon.

Table 3. Taxa number and percentage compositions of the different Classes of phytoplankton species at Grand-Lahou Lagoon.

Algea classes	Taxa number	Pourcentage (%)
Bacillarophyceae	41	42.3
Chlorophyceae	23	23.7
Cyanobacteria	19	19.6
Euglenophyceae	11	11.3
Diniphyceae	3	3.1
Total	97	100

Seasonal variation in abundance and biomass

The range of phytoplankton abundance observed was high in the Grand-Lahou lagoon during the four seasons (56 and 156 x 10^6 cells l^{-1}) (Fig. 2). The lowest values were observed during the LDS and LRS (56 x 10^6 and 80 x 10^6 cellules/L respectively) while the highest values were recorded during the SDS (156 x 10^6 cellules) and SRS (151 x 10^6 cellules). Filamentous Cyanobacteria *Anabaena planctonica* Brunnthaler, *Oscillatoria limosa* C.Agardh ex Gomont, *Pseudanabaena* sp., *Oscillatoria princeps* Vaucher ex Gomont, *Planktothrix agardhii* (Gomont) Anagnostidis & Komárek and colonial *Microcystis aeruginosa* (Kützing) Kützing were the most important species in phytoplankton communities of all stations (Table IV). Analysis of variance indicated that significant differences ($p < 0.05$) in abundance were present between the LRS and LDS.

The values of biomass have the same seasonal pattern as the abundance and varied from 1.28 to 6.1 µg/L (Fig. 2). The highest values were obtained during SDS and SRS while the lower values were observed during LRS. Filamentous Cyanobacteria *Anabaena planctonica* Brunnthaler, *Oscillatoria limosa* C.Agardh ex Gomont, *Pseudanabaena* sp., *Oscillatoria princeps* Vaucher ex Gomont, *Planktothrix agardhii* (Gomont) Anagnostidis & Komárek and colonial *Microcystis aeruginosa* (Kützing) Kützing were responsible for the high biomass. No Notable differences were observed between seasons ($p > 0.05$).

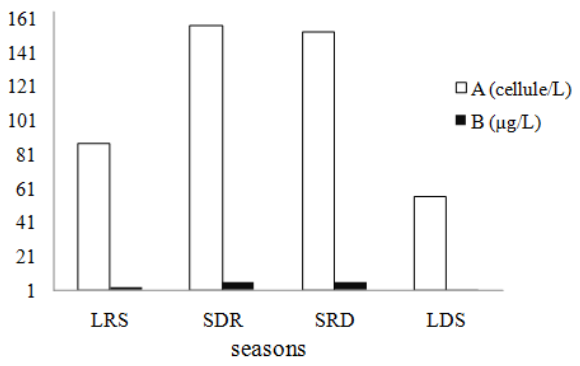

Fig. 2. Temporal variations in phytoplankton species number (A) abundance (B) Biomass (C) between June, 2006-March, 2007 at Grand-Lahou Lagoon.

Phytoplankton and environmental variables

Distribution according to the environmental variables, the characteristic taxa of the lagoon were determined on the basis of their dominance during the study. The Monte Carlo permutation tests (n = 499 permutations) indicated that the results of the redundancy analysis performed were significant ($p < 0.05$). The first and second axes of the RDA analysis performed with species and environmental variables explained 68% and 10%, respectively, of the total variance of the species matrix. The first axis was defined by the nutrients SRP and SRSi (Fig. 3). The second axis, principally defined by the nitrates and transparency, presented the strongest correlation between species and environmental variables. The direct ordination distinguished one taxa assemblage in Grand-Lahou Lagoon, characterized mainly by NO^-_3 and transparency gradients ($p < 0.05$ with the second axis). These parameters were generally higher during the SDS and SRS. This assemblage was mainly made up of *Anabaena planctonica* Brunnthaler, *Oscillatoria limosa* C.Agardh ex Gomont, *Pseudanabaena* sp., *Oscillatoria princeps* Vaucher ex Gomont, *Planktothrix agardhii* (Gomont) Anagnostidis & Komárek and *Microcystis aeruginosa* (Kützing) Kützing.

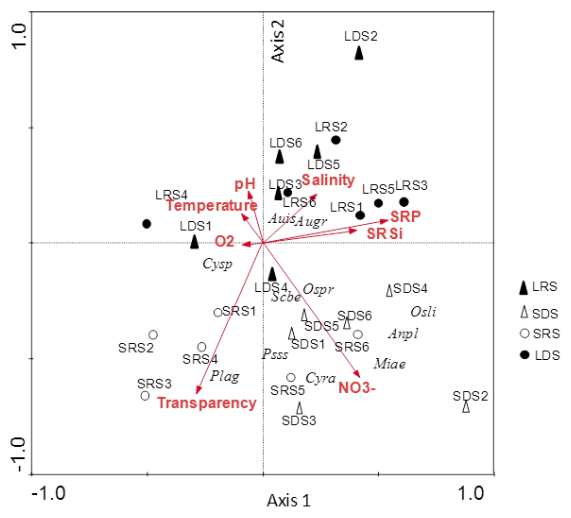

Fig. 3. Triplots obtained through the RDA of physico-chemical variables, seasons and phytoplanktonic abundance in Grand-Lahou Lagoon (see table IV for abbreviations).

Table 4. Phytoplankton taxa that represented >5% of total abundance, including abundance, in the Grand-Lahou Lagoon during the period of June, 2006-March, 2007.

Taxa	Acronym	LRS	SDS	SRS	LDS
Cyanoprocaryota					
Cyanobacteria					
Chroococcales					
Microcystis aeruginosa (Kützing) Kützing	Miae	5.32	2.18	17.02	6.33
Hormogonales					
Anabaena planctonica Brunnthaler	Anpl	7.03	8.48	0	7.03
Cylindrospermopsis raciborskii (Wołoszyńsk) Seenaya & Subbaraju	Cyra	0	1.17	5.86	0
Cylindrospermopsis sphaerica Prasad	Cysp	2.18	2.18	5.96	2.18
Pseudanabaena sp.	Psss	4.23	7.26	2.61	4.23
Oscillatoria limosa C.Agardh ex Gomont	Osli	4.29	9.81	2.31	5.59
Oscillatoria princeps Vaucher ex Gomont	Ospr	6.81	8.06	0	7.84
Planktothrix agardhii (Gomont) Anagnostidis & Komárek	Plag	4.50	9.68	13.41	4.50
Chlorophyta					
Chlorophyceae					
Volvocales					
Scenedesmus bernardii G.M.Smith	Scbe	1.69	4.94	0	1.69
Bacillariophyta					
Coscinodiscophyceae					
Coscinodiscales					
Aulacoseira islandica (O.F.Müller) Simonsen	Auis	0.01	0	0	0
Aulacoseira granulata var. *curvata* O.F.Müller	Augr	4.23	7.26	2.61	4.23

Table 5. Phytoplankton community structure indices during the period of June, 2006-March, 2007.

Indixes		Grand-Lahou Lagoon			
		LDS	LRS	SDS	SRS
Shannon index (H)	Min.	0.6	0.7	0.66	0.7
	Max.	1.3	2.06	2.4	1.32
	Mean ±σ	0.9± 0.22	1.3± 0.54	1.42± 0.74	0.98± 0.22
Equitability (j)	Min.	0.07	0.06	0.34	0.39
	Max.	0.84	0.8	0.8	0.79
	Mean ±σ	0.57± 0.27	0.56± 0.26	0.56± 1.18	0.63± 0.16
Margalef's species richness (d)	Min.	0.05	0.06	0.3	0.06
	Max.	0.74	0.71	0.71	0.13
	Mean ±σ	0.5± 0.2	0.5± 0.25	0.5± 1.16	0.1± 0.15

Discussions

The Grand-Lahou Lagoon ecosystem is extremely complex, partly due to the strong influence of many different sources of pollution (urban and agricultural) and the intensity of tidal inflow. The results presented above suggest that the temporal variability of the system is the result of the superposition of the seasonal changes in light, temperature, salinity, transparency, dissolved oxygen and dissolved nutrients which are discharged into the lagoon by the tributaries and other point sources. The lowest values of salinity, dissolved oxygen and transparency observed during the long rainy season (LRS) in the Grand-Lahou Lagoon were due to the influence of Bandama, Boubo and Gô Rivers. According to Durand and Chantraine (1982), the mixture of these coastal rivers and the lagoon water involves a decrease of salinity. In addition, the brown water of these rivers enriched the lagoon water in organic matter and thus reduced the transparency. The low transparency may cause the low algal cell counts and hence low values of oxygen into the lagoon. In contrast, during the LDS, the data revealed the highest values of salinity and transparency. According to Asmah (2010) and Oneyma (2013), this could be caused by the combined effects of high evaporation concentration especially during the dry season (associated with reduced cloud cover and increased solar insolation) and the reduction of freshwater inflow in the lagoon during this season. For instance, Nwankwo and Gaya (1996) reported that rainfall distribution determines salinity gradient in the Lagos lagoon. The pH values recorded during the study were alkaline in the dry months. Alkaline pH values recorded for the Grand-Lahou Lagoon were an indication of high amount of CO_2 stored as forms of Carbonates in seawater producing a buffering effect (Onyema, 2013). A similar inference was reported by Onyema *et al.* (2003, 2007) for the Lagos lagoon and Iyagbe lagoon, Asmah (2010) for the Sakumo Lagoon (Ghana). Concerning the variability of nutrients, except the NO3- (where the high value was observed during the SDS) the dissolved nutrient concentrations were relatively high in the lagoon during the LRS. Nutrient enrichment in lagoons, such as that observed in the Grand-Lahou Lagoon, has been found to be strongly related to polluted freshwater input from feeder streams, changes in water flow, and effective nutrient recycling between sediments and the water column (Lucena *et al.* 2002, Sylaios and Theocharis 2002). A similar observation was reported by Fianiko *et al.* (2013) in Kpeshi lagoon (Ghana).

The taxonomic composition of phytoplankton in Grand-Lahou Lagoon is characterized by Bacillariophyceae, Chlorophyceae, Cyanobacteria, Euglenophyceae and Dinophyceae. This taxonomic list is common to the traditional ones obtained in the lagoonal environment as suggested by Fonge *et al.* (2012) in Ndop wetland plain (Cameroon), Seu-Anoï *et al.* (2011) in the Aby lagoon (Ivory Coast), Onyema and Nwankwo (2010) in estuarine creeks (Nigeria), Healey *et al.* (1988) in Gambia River (Gambia), Iltis (1984) in Ebrié lagoon (Ivory Coast), Sevrin-Reyssac (1980) in bay water of Levrier (Mauritania) and Kwei (1977) in coastal Lagoon (Ghana). In comparison to the species richness of these lagoons, the Grand-Lahou Lagoon appears to be poor in phytoplankton probably because of its small surface area and the species composition of phytoplankton was typical of eutrophic conditions and was frequently characterized by the presence of Bacillariophyta. However, the number of phytoplankton taxa observed (97 specific and subspecific taxa) was not exhaustive because taxa under 20 µm were not collected in the plankton net. In general, phytoplankton species were dominated by freshwater species due to the fact that Grand-Lahou Lagoon is most influence by freshwater from rivers Bandama, Gô, Boubo allowed it to contain diverse organisms from freshwater. The seasonal distribution of phytoplankton communities in the Grand-Lahou Lagoon showed differences between the seasons. The differences observed in the present study may be due to the retarding influence of high dilution and turbidity during the wet season and increase in salt levels during the dry season. In fact, phytoplankton assemblages decreased in number of species at most of stations in the LDS and the LRS.

During the dry season, the increase in salinity due to sea intrusion could lead the disappearance of freshwater species not supporting high salinity range (Pilkaitytė and Razinkovas, 2007). Also, the total phytoplankton population in the Grand-Lahou Lagoon was lower in the wet season possibly due to the dilution effect of storm water which diluted the ion concentration in water and modified the water chemistry and high turbidity. This seasonal variability in the abundances of phytoplankton organisms that was attributed to temporal variability in environmental conditions that affect recruitment, survival and reproduction was shown by Khalifa and Add El-Hady (2010) and Panigrahi *et al.* (2009). However, the low phytoplankton abundances during the long rainy season in the Grand-Lahou Lagoon are contrasted to those generally observed in other tropical lagoons where phytoplankton abundances are positively correlated to nutrient inputs from the rivers. The occurrence such species as, filamentous cyanobacteria (*Anabaena planctonica* Brunnthaler, *Oscillatoria limosa* C.Agardh ex Gomont, *Pseudanabaena sp.*, *Oscillatoria princeps* Vaucher ex Gomont and *Planktothrix agardhii* (Gomont) Anagnostidis & Komárek) and colonial cyanobacteria (*Microcystis aeruginosa* (Kützing) Kützing) may be an indication of the level of pollution of the lagoon. Onyema (2013), Fonge *et al.* (2012), Khalifa and Add El-Hady (2010), Asmah (2010) and Panigrahi *et al.* (2009) recorded these blue greens among the phytoplankton algae in Onijedi Lagoon (Nigeria), in Ndop wetland plain (Cameroon), in Wadi El-Raiyan (Egypt), in Sakumo Lagoon (Ghana) and in Chilika Lagoon (India). Also, Asmah (2010) indicated that there taxa blooming arise when the Lake in being highly eutrphic. It is possible that wastes from surrounding areas may be a major pollution problem particularly in turning the site into nutrient trap excessive algal growths. Chlorophyll a concentration showed a peak during the SDS and SRS while the lower values were observed during the LRS. The values of Chlorophyll a concentration have the same seasonal pattern as the abundance. Comparison with the spatial distributions of dissolved nutrients and salinity indicated that the phytoplankton proliferate in the lagoon when the NO_3^- values were high and salinity relatively low. The characteristics of Shannon-Wiener's (Hs), Margalef (D) and Equitability (j) show that the distribution and occurrence of species changed from one season to another within the lagoon. For instance, values for these indices were generally lower in LRS than in other subsequent season.

Finally, with regard to the physical, chemical, and biological variables studied, it can be concluded that the water of the Grand-Lahou Lagoon is under pollution stress.

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