International Research Journal of Environment Sciences ISSN 2319–1414
Vol. **6(2),** 19-29, February **(2017)** *Int. Res. J. Environment Sci.*

Seasonal variation in phytoplankton community and relationship with environmental factors of Lake Nokoué in Benin

Firmin M. Adandedji[1*], Luc O. Sintondji[2], Ousmane Touré Boukari[1] and Daouda Mama[1]
[1]Laboratory of Applied Hydrology, National Institute of Water, University of Abomey-Calavi, 01 BP: 526 Cotonou Benin
[2]Laboratory of Hydraulics and Water Control, National Institute of Water, University of Abomey-Calavi
m.firminadandedji@yahoo.fr

Available online at: www.isca.in, www.isca.me
Received 16th December 2016, revised 23rd January 2017, accepted 19th February 2017

Abstract

Phytoplankton abundance, composition and environmental parameters are monitored in a tropical lake for one year period. Samples of water and phytoplankton in a freshwater of Lake Nokoué located in South of Benin (Lat: 6 °25' N and Long: 2°36' E) were collected every season between November 2015 and October 2016. Data were submitted to Principal Component Analysis (PCA) and to the correlation to determine the grouping pattern of phytoplankton and their relationship to environmental factors. A total of 40 species of phytoplankton belonging to six classes (diatoms, Chlorophyta, Zygophyta, Euglenophyta, Cyanophyta and Xanthophyta) were identified. The diatoms with the specie Cyclotella Meneghiniana and melosiravarians having the highest dominance throughout the period of the study and the Cyanophyta, Euglenophyta with respectively 83.69% and 1.79% and 13.76% in dry season (November and February) against 80.77% for diatoms, 6.17% (Cyanophyta) and 12.75% (Euglenophyta) in rainy season (June and October). The Euglenophyta were significantly presents in dry season (November and February) and made up 13.76% with the species Euglena oxyuris and Euglena acus. The Cyanophyta were represented by the toxic species Microcystis Elachista and Anabaena affinis. The others groups (Chlorophyta and Xanthophyta) were also present but in low numbers. These results show that the seasons influence the distribution of the phytoplankton in the lake. The average chlorophyll a concentration for the seven sites area was 0.103µg/L. The maximum (0.309 µg/L) and the minimum (0.002 µg/L) values were both obtained in rainy season (October 2016). The results of the Principal Component Analysis (PCA) indicated that TP, NH_4^+, NO_3^-, NO_2^-, DO and NTK were mainly the environmental factors that had the greatest influence on the distribution of the phytoplankton community throughout the entire year. It is strongly important that a water quality model is developed for sustainable management of Lake Nokoué.

Keywords: Phytoplankton, Nutrient, Lake Nokoué, Pollution, Water.

Introduction

Water is one of the most important factors for every living organism on this planet. Water is mainly used for drinking bathing, fisheries and other domestic purposes. During recent years there has been increasingly greater concern for inland fresh water resources. Which are affected in different ways by all kinds of human activities[1]. Phytoplankton is composed of freely floating single called photosynthetic organisms[2]. It is also known that human activities have impacts on river phytoplankton[3]. Consideration of the alterations caused by human activities on rivers is now a major concern. This requires a multidisciplinary approach to anthropogenic effects combining biological and physico-chemical components. The algal community is an essential component of aquatic environments. It is a nutrient source for many aquatic organisms such as zooplankton insects and certain poisons such as filterers and grazers by its concentration on submerged or suspended substrates in the water column[4]. In Africa, very little scientific work has been done on freshwater ecosystems especially on algae despite their importance in hydrosystems. The most outstanding works are those of Compère in 1970. In Benin a few scientific research is focused in phytoplankton studies. Therefore scientific study needs to review strategies for conservation and better utilization of ecology and factors influencing the habitat of phytoplankton to assess water quality for sustainable management of the lakes. The relationships between nutrient and phytoplankton may be used to indicate which parameters are important in determining phytoplankton biomass and community structure[5]. Phytoplankton plays an important role in lake ecosystems as they produce oxygen and food which sustains all other forms of life[6]. Actually, environmental instability, temporal and spatial changes determine the community of phytoplankton present in a lakes[7]. The objectives of this paper are the following: i. to determine the composition and distribution of the phytoplankton in the lake Nokoué; ii. to assess the effects of the environmental factors that can influence the phytoplankton dynamics.

Materials and methods

Study area: The Nokoué Lake is located in southern Benin in West Africa between (6 °25 'N and 2°36 E) and is the biggest lake in Benin. Located in the sub-equatorial area. It's underwent two rainy seasons and two dry seasons with unequal durations. The Annual rainfall is 1309 mm, the average temperature of 27.7°C with the maxima up to 33°C and minimum at 23°C. It covers an area of $150km^2$ in dry season and 200 km^2 in wet season. This lake is connected to Porto-Novo lagoon at the East by the Totchè Canal at south by the Atlantic Ocean through the channel of Cotonou and at north by the river Sô and Ouémé stream of which it depends[8]. This communication together with the impact of natural flood of Sô and Ouémé stream causes very significant seasonal variations of salinity which is parameter of that the variations during the year are the most important[9]. The lake could be considered ranging from shallow (0.4 to 3.4m).

Sampling: In total, seven sampling sites were monitored for phytoplankton and physico-chemical parameters study during the two major seasons: dry (November 2015 and Feburay2016) and rainy (June 2016 and October 2016) (Figure-2). Two major reasons justify the choice of these sites: the entrances, exits and areas where various human activities on the lake occur.

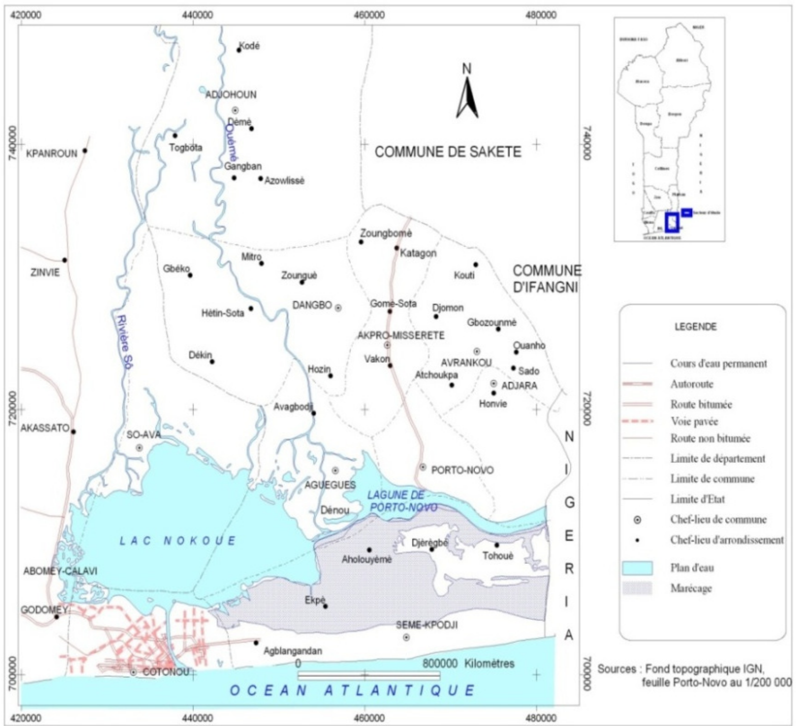


Figure-1: Location of the study area.

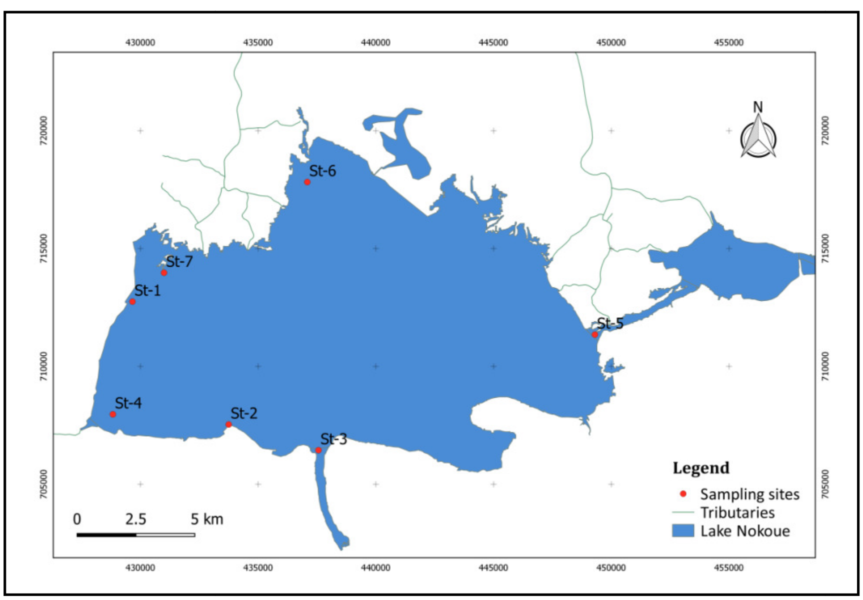


Figure-2: Location of the sampling sites.

Methods: Water and phytoplankton sampling and analysis: Water samples were collected from seven sites (Figure-2). Each season from November 2015 to October 2016. The phytoplankton net (20µm) was used to collect and concentrate phytoplankton from the top 5 cm of the water column. The volume of 250 mL of the sampled water is fixed with 4% formaldehyde and 4% of lugol's solution for quantitative analysis. In the laboratory, each sample was then allowed to settle for at least 36h and the supernatant was carefully removed and the remaining volume was adjusted to 50 mL, a 1mL of the sample was observed using photonic microscope (WRW) at 10X and 40X magnification. The taxonomic groups and different species identification references consulted included[10-18] and also scientific papers related to phytoplankton are used to recognize each specie of phytoplankton.

Physico-chemical parameters: For physico-chemical parameters analysis the methods used in this study were to make in situ measurements and laboratory analyzes of some indicative pollution parameters.

The water samples were taken and cover the following periods: i. November 2015 corresponding to the long dry season and low water period. ii. February 2016 corresponding to the start of the dry season, iii. June 2016 and corresponding to the rainy season, iv. October 2016 corresponding to the rainy season.

These water samples were taken in calm water at 5cm from water surface with 1.5 liter plastic bottles previously rinsed and dried and then are kept cool in a cooler at 4°C. Some parameters were measured in situ. Others are determined in the laboratory.

The measures carried out in-situ mainly concern: i. the location of sampling stations with a Garmin GPS 72; ii. the water depth with Secchi disk, iii. the salinity, the electrical conductivity, the Total Dissolved Solid and the temperature of the water with a conductivity meter (HACH), iv. the pH with a pH meter (HACH). v. the dissolved oxygen with an oximeter WTW340i.

Different laboratory analysis methods were referenced to standard methods AFNOR (Table-1).

Statistical Analysis: Principal Component Analysis (PCA) was used to understand the relationship between phytoplankton and environmental variables during the study period. This method extracts synthetic gradients from biotic and environmental matrices and the explanatory variables are quantitatively represented by arrows in graphical biplots[19]. The arrow direction indicates positive or negative correlations and their length is relative to the importance of the explanatory variable in the ordination[20]. For statistical analysis, the data was processed with Minitab and R software version 3.0.3 for PCA. The abundance of phytoplankton was calculated using the formula indicated by APHA[21]: $A = (n / V_1) * (V_2 / V_3)$ where A is abundance in number of species per milliliter; n is the number of each specie counted with photonic microscope; V_1 is the observed volume of the sample; V_2 is the volume of the concentrated organisms; V_3 is the total volume sampled.

Table-1: Laboratory analysis methods.

Monitored parameters	Materials and used methods
pH. Temperature. Dissolved oxygen	Direct measurement by multi-parameter pH / Oximeter WTW 340i
Conductivity. Salinity	Direct measurement by multi-parameter pH / Oximeter WTW 340i
Suspended Solids (SS). Turbidity	Colorimeter HACH DR/890. Method 8025
Nitrite. Nitrate. Nitrogen	Spectrophotometric method HACH LANGE DR 2800 NitraVer®5 Nitrate Reagent for 10mL sample. cat 21061-69Pk/100 NitriVer®2 Nitrite Reagent for 10mL sample. cat 21075-69Pk/100 Colorimetric method (cadmium reduction method for Nitrates; diazotization method nitrites. The Nessler Method for ammonium and nitrogen Kjeldahl)
Biochemical Oxygen Demand (BOD_5)	Oxytop Respirometric method in a thermostatic chamber
Chemical Oxygen Demand (COD)	AFNOR NF T90-101. Colorimeter. potassium dichromate method
Chlorophyll a (Chla)	Scor UNESCO method NF T 90-117
Total phosphorus and Ortho-Phosphates	Acid ascorbic Method
Transparency (SD)	Secchi Disk

Results and discussion

Results: The Table-2 shows the mean values of the physico-chemical parameters as well as the standard error of the monitored sites of the Lake Nokoué from November 2015 to October 2016. The temperature is between 25°C and 35°C. The pH was around the value 7 during the period of the study and fluctuated from 5.45 (June 2016) to 8.6 (October 2016). The higher salinity and conductivity was obtained in February. The mean dissolved oxygen (DO) value increased from November to February with respectively 4.01 mg/L to 7.48 mg/L in February the highest value (14.47 mg/L) was also obtained in this month. The total dissolved solids (TDS) and the turbidity were positively correlated (Table-2). The lowest (0.005µg/L) and the highest (0.39 µg/L) values of chlorophyll a were obtained in the same month (October 2016). The total phosphorus and the ortho-P have the highest concentrations in November and February characterized by the dry season. The maximum of nitrate and the nitrite concentrations was recorded in October with respectively 5.9 mg/L and 0.021 mg/L. It is also the case of ammonia which rises up from 0.12 mg/L in February to 1.26 mg/L in June and October 2016. The highest value (540.6 mg/L) of Chemical Oxygen Demand was obtained in February (Dry season). In contrary those of Biological Oxygen Demand (BOD) was recorded in October (Rainy season). This is clearly shown by the negative correlation between the two parameters (Table-2).

Table-2: Mean and range of physico-chemical parameters.

Variable	November 2015		February 2016		June 2016		October 2016	
	Mean Range		Mean	Range	Mean	Range	Mean	Range
Temp (°)	29.85± 0.283*	29.20 ~31.10	29.85 ± 0.283	29.20~31.10	26.586 ± 0.14	26.10~27.20	29.771± 0.68	26.700 ~ 32.10
pH	7.421 ± 0.118	6.12 ~ 8.37	7.421 ± 0.118	6.99 ~ 7.900	6.504 ± 0.291	5.450 ~ 8.01	7.504± 0.21	6.810 ~ 8.60
Sal (psu)	10.96 ± 2.03	0.0 ~ 4.70	10.96 ± 2.03	2.60 ~ 19.70	6.21 ± 1.54	0.800 ~11.30	0.1286± 0.096	0.0 ~ 0.70
Cond (mS/m)	20.08 ± 3.43	5.34 ~ 34.30	20.08 ± 3.43	5.34 ~ 34.30	10.87 ± 2.77	0.180~19.67	14.27 ± 3.44	0.800 ~ 28.30
DO (mg/L)	4.01 ± 1.06	0.70 ~ 9.15	7.48 ± 1.64	2.80 ~ 14.47	7.799 ± 0.828	5.140 ~11.26	1.95± 1.71	0.100 ~ 12.20
TDS (mg/L)	10.52 ± 1.94	2.56 ~ 18.92	10.52 ± 1.94	2.56 ~ 18.92	127± 120	0.940 ~ 845	372± 191	106 ~ 1505
Turb (NTU)	21.48 ± 6.02	5.11 ~ 49.60	21.48 ± 6.02	6.08 ~ 51.80	1643 ± 7.06	1.00 ~ 52.00	20.71 ± 5.46	3.00 ~ 45.00
SS (mg/L)	67.71 ± 7.95	50.00 ~ 112	67.71 ± 7.95	50.00 ~ 112	9.00 ± 4.34	1.00 ~ 33.00	10.43± 2.57	5.00 ~ 24.00
Chla (µg/L)	0.021± 0.0085	0.010 ~ 0.07	0.021 ± 0.0085	0.010 ~ 0.07	0.031 ± 0.11	0.005 ~ 0.092	0.1750± 0.0638	0.002 ~ 0.3900
T P (mg/L)	2.73 ± 0.45	1.58 ~ 4.81	1.964± 0.24	1.190 ~ 2.95	0.115 ±0.005	0.093 ~ 0.142	1.019± 0.467	0.210 ~ 3.710
Ortho-P (mg/L)	0.13± 0.02	0.04 ~ 0.22	0.421 ± 0.105	0.05 ~ 0.85	0.147 ± 0.01	0.093 ~ 0.142	0.1470± 0.01	0.0930 ~ 0.223
NO_2^-	0.0114± 0.005	0.00 ~ 0.04	0.01157± 0.005	0.00 ~ 0.04	0.013± 0.002	0.0040~ 0.02	0.0137± 0.002	0.004 ~ 0.021
NO_3^- (mg/L)	1.057 ± 0.141	0.400 ~ 1.60	.057 ± 0.141	0.400 ~ 1.60	3.057± 0.55	1.000 ~ 5.90	3.057± 0.553	1.000 ~ 5.900
NH_4^+ (mg/L)	0.46 ± 0.06	0.27 ~ 0.70	0.453 ± 0.114	0.12 ~ 0.89	0.61± 0.16	0.180 ~ 1.26	0.613± 0.169	0.180 ~ 1.260
NTK	1.77± 0.15	1.0 ~ 2.0	0.889± 0.337	1.536 ~ 0.31	1.536± 0.31	0.750 ~ 3.00	1.536± 0.315	1.536±0.315
COD (mg/L)	68.1± 36.6	3.67 ~ 282	218.8 ± 70.3	46.5 ~ 540.6	115.6± 11.1	67.1 ~ 164.6	115.6± 11.1	67.1 ~ 164.6
BOD (mg/L)	9.86± 2.09	1.00 ~ 15	10.86 ± 1.55	6.00 ~ 16.00	13.29± 1.49	9.00 ~ 20.00	13.29± 1.49	9.00 ~ 20.00
SD (m)	0.749 ± 0.199	0.13 ~ 1.81	0.749 ± 0.199	0.13 ~ 1.81	0.564± 0.15	0.300 ~ 1.50	0.100 ~ 12.20	0.37 ~ 0.81

*Mean± Standard Error(S).

Table-3: Correlation matrix of physico-chemical parameters

Parameters	Temp (°C)	pH	Sal (psu)	Cond (°C)	DO (mg/L)	TDS (mg/L)	Turb (NTU)	SS (mg/)	Chla (µg/L)	TP (mg/)	Ortho-P (mg/L)	NO_2^- (mg/L)	NO_3^- (mg/L)	NH_4^+ (mg/L)	NTK (mg/L)	COD (mg/L)	BOD (mg/L)	SD (m)
Temp	1																	
Ph	0.44	1																
Sal	0.20	-0.02	1															
Cond	-0.10	0.24	0.69	1														
DO	0.17	0.06	0.54	0.42	1													
TDS	0.058	-0.10	-0.48	-0.43	-0.29	1												
Turb	0.16	0.24	-0.36	-0.39	-0.25	-0.25	1											
SS	0.25	0.27	0.42	0.24	0.18	-0.16	0.45	1										
Chla	0.06	-0.11	-0.35	0.08	-0.34	-0.005	-0.11	0.45	1									
TP	0.70	0.27	-0.019	-0.17	-0.15	-0.15	-0.13	0.09	0.24	1								
Ortho-P	0.28	0.007	0.45	0.39	0.44	-0.16	0.18	0.67	-0.13	0.15	1							
NO_2^-	0.03	-0.05	-0.22	-0.19	0.19	0.04	0.44	0.05	0.11	0.24	0.027	1						
NO_3^-	-0.57	-0.06	0.08	0.32	0.19	-0.09	-0.18	-0.18	-0.33	-0.60	-0.14	0.10	1					
NH_4+	-0.23	0.19	-0.15	-0.17	-0.06	0.13	0.43	0.10	-0.17	-0.19	0.033	0.27	0.27	1				
NTK	-0.01	-0.03	-0.43	-0.37	-0.24	0.27	0.20	-0.25	-0.07	0.03	-0.28	0.42	-0.08	0.37	1			
COD	-0.78	0.27	0.56	0.54	0.11	-0.27	-0.34	0.20	-0.08	0.05	-0.05	-0.19	0.028	-0.26	-0.25	1		
BOD	0.40	0.08	0.19	0.29	0.08	-0.22	-0.40	-0.31	0.28	-0.01	-0.13	0.03	0.17	-0.31	-0.16	0.48	1	
SD	-0.03	0.27	0.69	0.73	0.34	-0.29	-0.38	0.14	-0.02	-0.11	0.15	-0.33	0.12	-0.26	-0.28	0.37	0.28	1

Phytoplankton composition, abundance and biomass: Fourty (40) species belonging to six classes were identified. Diatoms (82.12%), Chlorophyta (0.28%), Zygophyta (0.19%), Cyanophyta (4.15%), Euglenophyta (13.22%) and Xanthophyta (0.05%) are present. Diatoms, Euglenophyta and Cyanophyta were the most representative groups. *Cyclotella meneghiniana, Microcystis elachista, Euglena acus, Euglena oxyuris, Pediastrum duplex and Naviculasp* were the most common species observed during the study period. They were an important seasonal difference in the quantitative and qualitative composition of phytoplankton communities in the Lake Nokoué (Table-4). During the sampling period. June 2016 was the month in which phytoplankton reached the maximum values in term of abundance and diversity with 2661.60. 10^3 $Ind.L^{-1}$ in abundance and 0.049 $\mu g.L^{-1}$ in biomass). *Cyclotella-meneghiniana and melosira varians* were the most abundant species during the study period. The two species contribute to the high abundance recorded in June 2016. Mean phytoplankton density (340.28 10^3 $Ind.L^{-1}$) reached the maximal values in the two seasons: dry for November 2015 and February 2016, rainy for June and October 2016. Phytoplankton abundance was the highest at site 3 where the nutrient concentrations were obviously higher than the others sites due to the anthropogenic activities, input sewage coming from Missèbo and Dantokpa, and also from human waste pour in the water. The bibliography has shown that the nutrient enrichment resulted in high algal densites[22].

Principal component analysis (PCA): The analysis of PCA is shown in Table-5. The phytoplankton abundance was positively correlated with Chla, NH_4^+ and NTK but negatively correlated with pH, DO, Chla, TP, NH_4^+ in rainy season, but in dry season it was positively correlated NO_3^-, COD, BOD, NO_2^-, NH_4^+ and NTK (Table-5). The list of phytoplankton species identified was showed in Table-6.

Table-4: Phytoplankton abundance and biomass in Lake Nokoué from November 2015 to October 2016 (Abundance: $\times 10^3$ Ind.L^{-1} ; Biomass: $\times \mu g.L^{-1}$).

Date/Sites	St-1	St-2	St-3	St-4	St-5	St-6	St-7	Mean
Nov. 2015	2360.20	417.40	320.20	504.00	20.80	64.60	114.60	543.11
	(0.01)*	(0.029)	(0.012)	(0.014)	(0.072)	(0.007)	(0.009)	(0.024)
Feb. 2016	42.40	271.40	14.20	50.60	161.40	42.80	11.20	84.86
	(0.138)	(0.02)	(0.202)	(0.859)	(0.43)	(0.215)	(0.229)	(0.88)
Jun. 2016	57.80	3.00	2661.60	3.40	113.80	40.60	27.20	415.34
	(0.036)	(0.005)	(0.049)	(0.019)	(0.007)	(0.091)	(0.01)	(0.035)
Oct. 2016	167.60	11.80	514.00	162.40	237.20	1004.6	127.00	317.80
	(0.008)	(0.389)	(0.021)	(0.161)	(0.002)	(0.343)	(0.30)	(0.154)
Mean	657.00	175.90	877.50	180.10	133.30	288.15	70.00	340.28
	(0.048)	(0.964)	(0.071)	(0.263)	(0.127)	(0.164)	(0.136)	(0.273)

* For phytoplankton biomass.

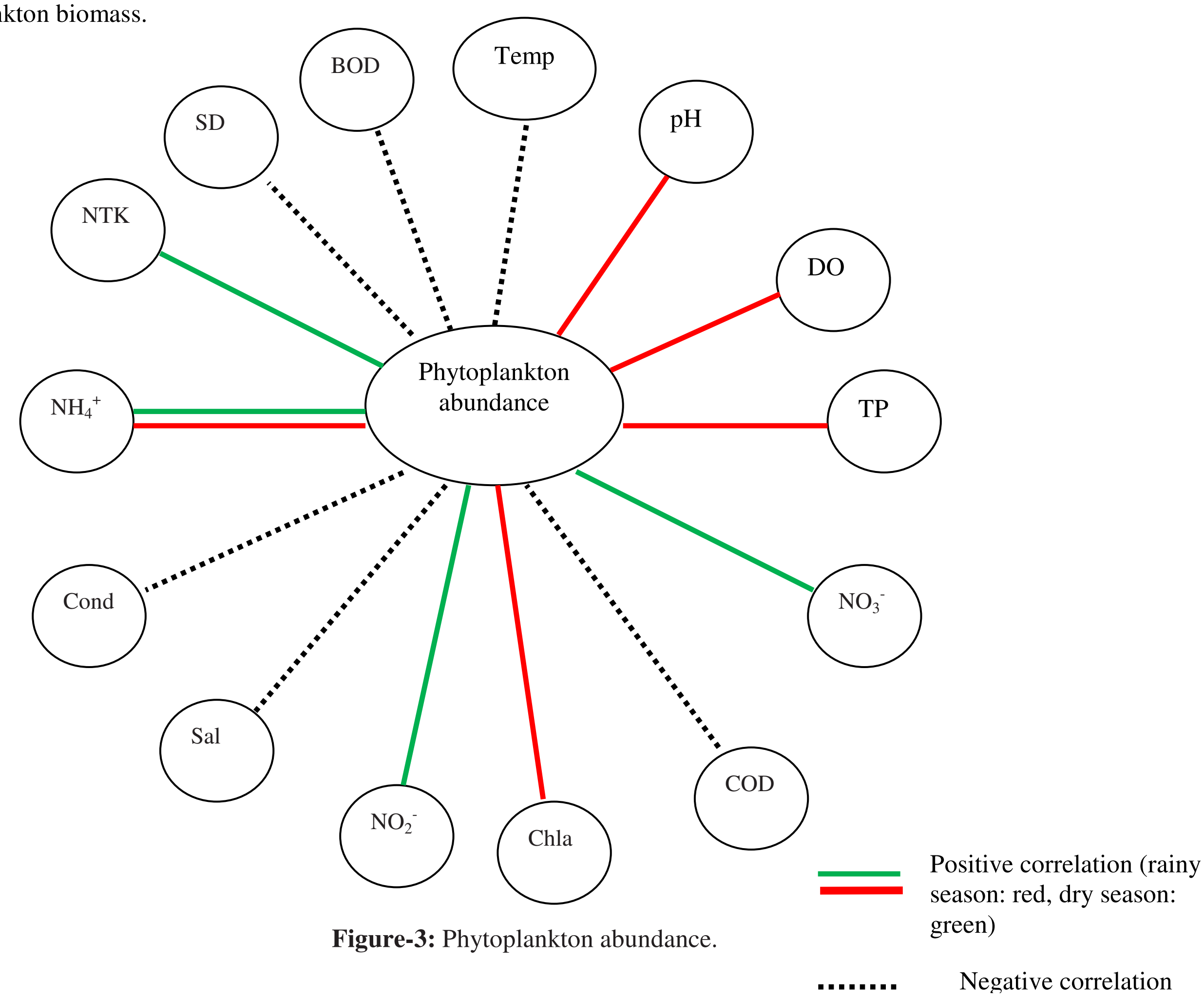


Figure-3: Phytoplankton abundance.

Table-5: Correlation coefficients between phytoplankton abundance and environmental variables.

Rainy season

Variables	Temp	pH	DO	Chla	TP	NO_3^-	COD	BOD	NO_2^-	Sal	Cond	NH_4^+	NTK	SD
Abundance	-0.64	0.15	0.018	0.29	0.067	-0.01	-0.09	-0.12	-0.21	-0.10	-0.004	0.27	-0.31	-0.19
p-Value	0.73	0.73	0.96	0.52	0.88	0.73	0.83	0.78	0.01*	0.82	0.99	0.55	0.48	0.67

Dry season

Variables	Temp	pH	DO	Chla	TP	NO_3^-	COD	BOD	NO_2^-	Sal	Cond	NH_4^+	NTK	SD
Abundance	-0.36	-0.90	-0.29	-0.25	-0.33	0.024	0.11	-0.18	0.58	-0.155	-0.25	0.73	0.87	-0.33
p-Value	0.42	0.84	0.51	0.58	0.45	0.16	0.81	0.68	0.16	0.97	0.95	0.05*	0.011*	0.46

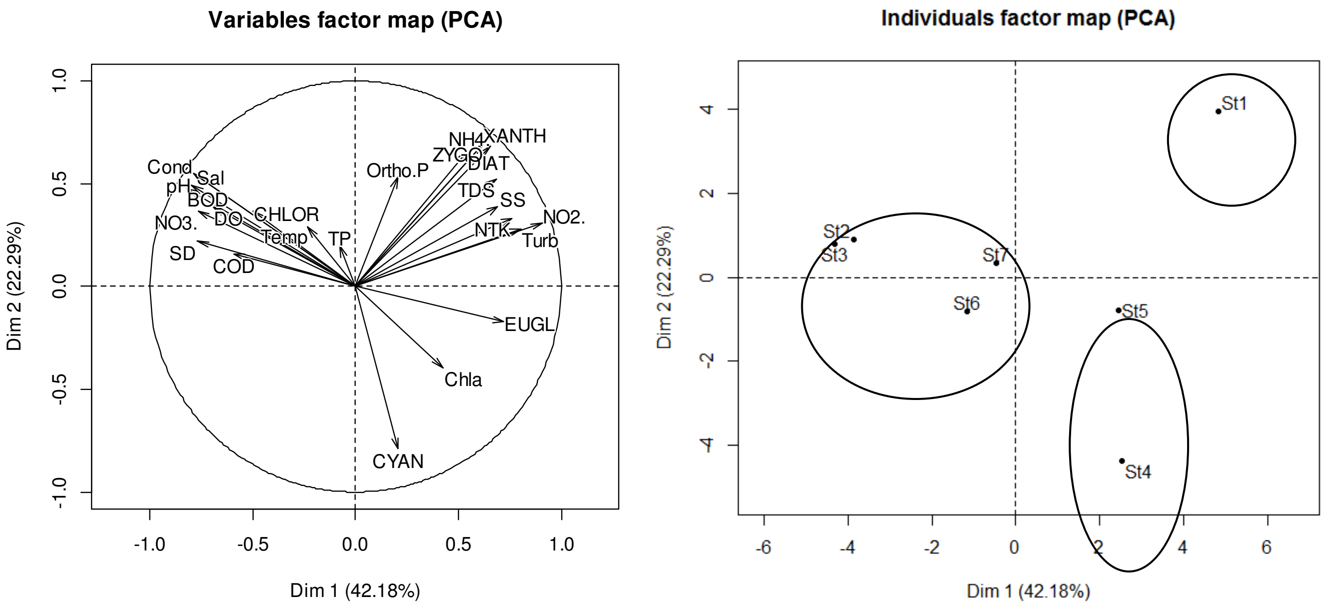
*For p< 0.05 **for p<0.01

Table 6: Phytoplankton species identified

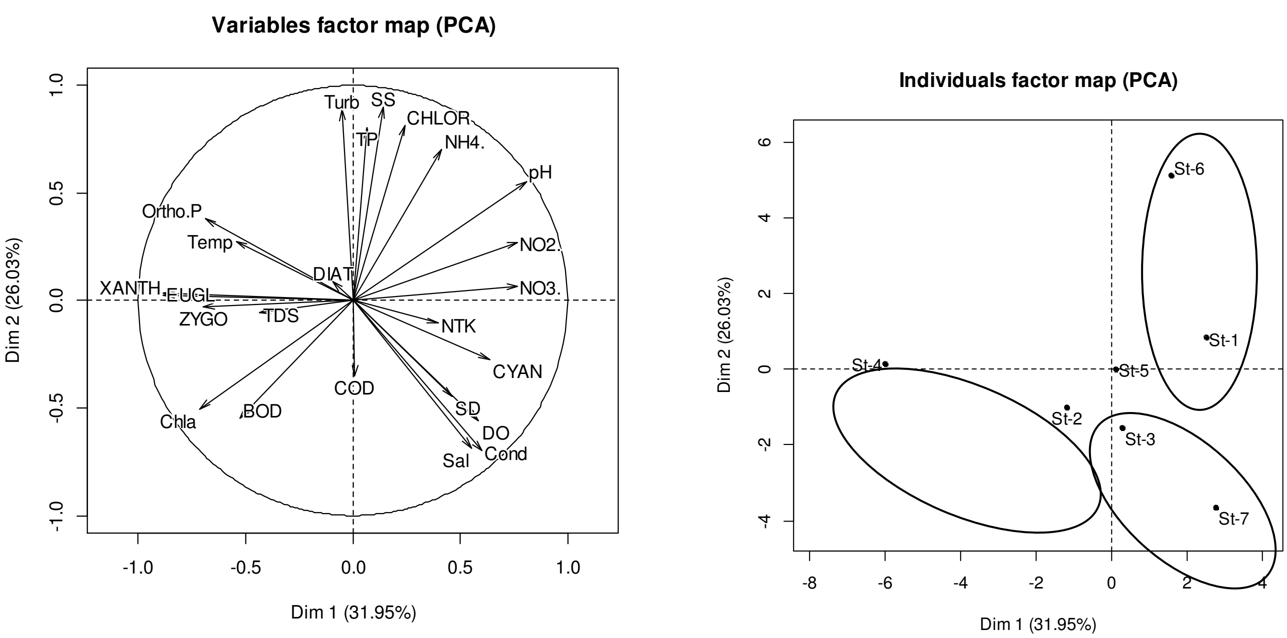
Codes	Species name	Nov. 2015	Feb. 2016	June 2016	Oct. 2016
	DIATOMS (DIAT)				
s1	*Gyrosigma sp*	+	-	+	-
s2	*Cyclotella meneghiniana.*	+	+	+	+
s3	*Fragillaria ulna*	+	-	-	+
s4	*Navicula sp*	+	-	-	+
s5	*Melosira varians*	+	+	+	-
s6	*Coscinodiscus granii*	-	+	+	-
s7	*Amphiphora ovalis*	+	-	-	-
s8	*Asterionnella glacialis*	-	-	+	+
s9	*Surivella linearis*	+	-	-	-
s10	*Fragillariasp*	+	-	-	-
s11	*Thallassionema nitchzschoides*	-	-	+	-
S12	*Navicula Bory*	-	-	+	-
s13	*Synedrasp*	-	+	-	-
s14	*Dictyumsp*	-	-	+	-
s15	*Pleurosigma normanii*	-	-	+	-
S16	*Diploneis ovalis*	+	-	-	-
s17	*Navicula cryptocephala*	-	-	+	-
s18	*Amphiprora ornata*	-	-	+	-
s19	*Coscinodiscus wallesii*	-	+	+	-
s20	*Closterium sp*	+	-	-	-
s21	*Chaetoceros affinis*	-	-	+	-
s22	*Spirogyra sp*	+	-		+
s23	*Diploneis bombus*	-	-	+	-
s24	*Navicula acuminatum*	-	-	-	+
s25	*Denticula lauta*	-	-	+	-
s26	*Achantesexiguioides*	-	-	+	-
S27	*Gomphonema olivaceum*	-	+	-	-
s28	*Nitzchia closterium*	+	-	+	+
	Euglenophyta (EUGL)				
s29	*Euglena oxyuris*	+	+	-	+
s30	*Phacuslongicauda var rotondus*	+	-	-	+
S31	*Euglena acus*	+	-	-	+
s32	*Strombomonas fluviatilis defl*	+	-	+	+
	Cyanophyta (CYAN)				
s33	*Microcystis elachista*	+	-	-	+
s34	*Oxillatoria platensis*	-	-	+	-
s35	*Anabaena affinis*	-	-	-	+
s36	*Oxillatoria sp*	-	-	-	+
	Chorophyta (CHLOR)				
s37	*Scenedesmus opoliensis*	-	-	+	-
s38	*Pediastrum duplex*	+	-	+	+
	Zygophyta (ZYGO)				
s39	*Closterium parvalum*	-	-	+	-
	Xanthophyta (XANTH)				
s40	*Goniochlorisfallax*	+	-	-	-

+: presence, - : absence.

The statistical results of PCA analysis was shown in Figure-4. These results represented the relationships between environmental factors and the different classes of phytoplankton. Classes-environmental factors correlation for axis 1 and 2 was high, indicating a strong correlation between phytoplankton classses distribution and environment variables.



PCA for dry season



PCA for rainy season

Figure-4: Spatial ordination resulting from PCA of phytoplankton classes and physico-chemical parameters.

The Figure-3 showed the PCA results for both dry and rainy season. The results that in dry season, Ortho-P, NH_4^+, TDS, NO_2^-, NTK, Chla and Turbidity had positive correlations. Nevertheless, COD, SD, NO_3^-, pH, Sal, DO, BOD, Temp and TP has a negative correlation. In rainy season, SS, TP, NH_4^+, pH, NO_2^-, NO_3^- , NTK, SD, DO, Cond and Sal had the positive correlations but Ortho-P, Temp, Chla, BOD, TDS and Turb had negative correlations. We noticed that from dry season to rainy the different classes of phytoplankton are influenced by different nutrient parameters. Thus, the changing in phytoplankton abundance had resulted in major shifts in nutrient concentration.

Discussion: The investigation of the structure and function of the phytoplankton communities are important for the lacustrine ecosystems' dynamics studies[23]. Previous studies of the Lake Nokoué concerning the phytoplankton composition[24] identified 15 genuses with diatoms in the highest abundance. The present study indicated that the spatial and temporal variation of phytoplankton in the lake Nokoué is present and the main environmental factors were responsible for the phytoplankton community variation. During the study period, we identified a total of '40 taxa of phytoplankton. The phytoplankton was dominated by diatoms both in dry season and rainy season. The dry season showed diatoms and Euglenophyta in respectively 83.69% and 13.76%. In the rainy season, the diatoms are in 80.77% and Euglenophyta in 12.75%. The high proportion of diatoms is caused by the high level of the nutrient concentration. Diatoms are the major phytoplankton group in coastal ecosystem, controlled by a complex suite of regulating factors[25]. The similar result had been reported by Adjahouinou in 2010 from Cotonou lagoon study[26]. The presence of Euglenophyta in lakes is a sign of organic pollution coming from untreated wastewater[27]. All these results justify the classification of the Lake Nokoué as eutrophic characterized by high nutrient and proliferation of macrophytes[8,28]. The high level nutrient concentration in ecosystem are the causes of macrophytes proliferation and the growth of phytoplankton[29,30]. This phenomenon has undesirable changes in species composition of an aquatic ecosystem[31], and has been identified as the major threat to the survival of aquatic ecosystems and biodiversity[32,33]. The consequences of coastal, eutrophication caused by excessive anthropogenic inputs of nutrients are: Increase in biomass of phytoplankton, zooplanktons and macrophytes, domination of algal bloom forming species which is toxic to consumers of eutrophic ecosystem, increase in biomass of consumer species due to increase of biomass of benthic and epiphytic algae, anoxic conditions in the aquatic ecosystem results in frequent fish kills, decline in species diversity of aquatic ecosystem, decrease in harvestable fish biomass, decrease in water transparency[34]. This is showed by the decreasing of the species proportion from dry season when the nutrient concentration is higher than rainy season because of organic matter coming from anthropogenic activities and dilution during rainy season.

The physico-chemical factors of Lake Nokoué varied seasonally during the study period. The PCA results reflected the corresponding correlations between phytoplankton communities and major environmental variables. In dry season we had 83.69% of diatoms, 13.76% of Euglenophyta and 1.79% of Cyanophyta against 80.77% of diatoms, 12.77% of Euglenophyta and 6.17% of Cyanophyta in rainy season. The PCA analysis showed the phytoplankton are closed of nutrients in the two seasons. In rainy season, the reduction of light energy resulted in phytoplankton abundances decreased, which is associated to cool temperatures. The PCA performed on the data revealed that the phytoplankton abundances in the Lake Nokoué had obvious dynamics throughout the two seasons and were mainly regulated by TP, NH_4^+, NO_3^-, NO_2^-, DO and NTK. But different lakes had diverse influencing factors. Habib et *al*[35]showed that silicate was more important than nitrate and phosphate as an environmental determination influencing phytoplankton assemble in Lake Loch Lomond. The nutrient supply and its ratios have a decisive effect on the species composition of the phytoplankton since different algal species have different nutrient requirements[36]. Arhonditsis et *al*[37] found in 2004 that the solar radiation, the total phosphorous and gazing pressure are the environmental factors that control the dynamics of phytoplankton in Lake Washington. For the good environmental monitoring and management, it is important to investigate the phytoplankton community structure and dynamics, It's also help to understand eutrophication effects, remains a research challenge[38].

Conclusion

This scientific research shows clearly that there is a seasonal changes in the phytoplankton community and abundance. The changes are caused by the environmental factors such as nutrient which are the main cause of phytoplankton variability in Lake Nokoué. Also, it showed that phytoplankton community could generally be explained by physico-chemical parameters, despite the complexity of the environmental factors involved. The lake Nokoué needs therefore a very big attention to enhance its protection against all kind of pollution for sustainable management.

Acknowledgements

The present study was carried out in the National Water Institute in Benin. The authors are grateful to the research team of National Institute of Water in Benin.

References

1. Vinod Jena, Satish Dixit, Ravi Shrivastava and Sapana Gupta (2013). Study of pond water quality by the assessment of physico-chemical parameters and water quality index. *International Journal of applied biology and pharmaceutical technology,* 4(1), 47-52 .

2. Yun Ma, Guibai Li, Jing Li, Hao Zhou and Bing Jiang (2014). Seasonal succession of phytoplankton community and its relationship with environmental factors of North Temperate Zone water of the Zhalong Wetland. in China. Ecotoxicology, 23(4), 618-625. *doi:10.1007/s10646-014-1231-9*.

3. Wager D.B. and Schumacher G.J. (1970). Phytoplankton of the Susquehanna River near Binghamton. New York, Seasonal variations: effect of sewage effluents. *J .Phycol.,* 6(2), 110-117.

4. Large A.R.G., Wade P.M., Pautou G. and Amoros C. (1993). Producteurs et productions primaires. In Amoros C and Petts GE (Eds) : *Hydrosystèmes fluviaux. Masson*. 107-124.

5. Royle R.N. and King R.J. (1992). The phytoplankton of Lake Liddell. New South Wales: chlorophyll a concentrations. Species seasonal succession and covariation with nutrients. *Hydrobiologia,* 245(1), 41-52.

6. Khan T.A. (2003). Limnology of four saline lakes in western Victoria. Australia. *Limnologica,* 33(4), 327-339.

7. Figueredo C.C. and Giani A. (2001). Seasonal variation in the diversity and species richness of phytoplankton in a tropical eutrophic reservoir. *Hydrobiologia,* 445(1), 165-174.

8. Mama D. (2010). Méthodologie et résultats du diagnostic de l'eutrophisation du lac Nokoué (Bénin). Thesis dissertation from the University of Lausanne, 157.

9. Dehotin U.A., Laleye P.A., Dauta A. and Moreau J. (2007). Ecological factors and fish diversity of a West African lagoon: Lake Nokoué in Benin. *Journal of Afrotropical Zoology*. Special Issue. 49-55

10. Bourrelly P. (1966). Les algues d'eau douces, Algues Vertes. Édition Boubéeet Cie. Paris. 511.

11. Bourrelly P. (1968). The freshwater algae. Yellow and brown algae. Edition Boubée and Cie. Paris. 438.

12. Bourrelly P. (1985). The Blue algae or Cyanophyceae, 5th part. Edition Boubée Paris. 297, 303, 457-458, 606.

13. Compère P. (1974). Algae from the Lake Chad region. II Cyanophyceae. *Cah. O.R.S.T.O.M., ser. Hydrobiol*., 8(3-4), 165-198.

14. Compère P. (1975). Algaefrom the Lake Chadregion III-Rhodophyceae, Euglenophyceae, Cryptophyceae, Dinophyceae, Chrysophyceae, Xanthophyceae. *Cah. O.R.S.T.O.M., ser. Hydrobiol*., 9(3), 167-192.

15. Compère P. (1975). Algae from the Lake Chad region. IV-Diatomophyceae. *Cah. O.R.S.T.O.M., ser. Hydrobiol*., 9(4): 203-290.

16. Compère P. (1976). Algae from the Lake Chad region. V-Chorophycophyta 1ere partie. *Cah. O.R.S.T.O.M., ser. Hydrobiol.*, 10(2), 77-118.

17. Compère P. (1976). Algae from the Lake Chad region. VI-Chorophycophyta 2nd part: Ulotrichophyceae, Zygnemataceae. *Cah. O.R.S.T.O.M., ser. Hydrobiol.,* 10(3), 135-164.

18. Guiry M.D. and Guiry G.M. (2012). AlgaeBase. http://www.algaebase.org/search/genus/detail/?genus. Accessed on 06 June 2016.

19. Muylaert K., Sabbe K. and Vyverman W. (2000). Spatial and Temporal Dynamics of Phytoplankton Communities in a Freshwater Tidal Estuary (Schelde. Belgium). *Estuar. Coast and Shelf Science,* 50(5), 673-687.

20. Abrantes N., Antunes S.C. Pereira M.J. and Goncalves F. (2006). Seasonal succession of cladocerans and phytoplankton and their interactions in a shallow eutrophic lake (Lake Vela. Portugal). *Acta Oecol*, 29(1), 54-64.

21. APHA (1965). Standard Methods for the examination of water and wastewater. 20TH EDN, American Public Health Association, New-York, NY.

22. Smith V.H., Tilman G.D. and Nekola J.C. (1999). Eutrophication: impacts of excess nutrient inputs of freshwater, marine and terrestrial ecosystems. *Environ Pollut*, 100(1), 179-196.

23. Lopes M.R.M., Bicudo C.E.M. and Ferragut M.C. (2005).Short term spatial and temporal variation of phytoplankton in a shallow tropical oligotrophic reservoir, southeast Brazil. *Hydrobiologia,* 542(1), 235-247.

24. Goussanou A. (2012). Diversité du phytoplankton du lac Nokoué. Mémoire de Master. Université d'Abomey-calavi. Benin, 56.

25. Pitchaikani Selvin J. and Lipton A.P. (2016). Nutrients and phytoplankton dynamics in the fishing grounds off Tiruchendur coastal waters, Gulf of Mannar, India. *SpringerPlus*, 5(1), 1405. DOI 10.1186/s40064-016-3058-8 .17p.

26. Adjahouinou D. Clément (2010). Diversity of the Phytoplankton and degree of pollution of the waters of the Dantokpa collector (Cotonou-Benin).

27. Thomas C.S. (2003). Protist phylogeny and the high-level classification of Protozoa. *Europ. J. Protistol.* 39(4), 338-348.

28. Zandagba Josué, Adandedji Firmin M., Mama Daouda, Chabi Amédée and Afouda Abel (2016). Assessment of the Physico-Chemical Pollution of a Water Body in a Perspective of Integrated Water Resource Management: CaseStudy of Nokoué Lake. *Journal of Environmental Protection,* 7(5), 656-669.

29. Rovira J.L. and Pardo P. (2006). Nutrient pollution of waters: eutrophication trends in European marine and coastal environments. *Contrib Sci,* 3(2), 181-186.

30. Ansari A.A. and Khan F.A. (2013). Response of Eichhornia crassipes to eutrophic waters receiving nutrients from various sources. *Int J Environ Sci,* 4(1), 39-45.

31. Romermann C., Tackenberg O., Jackel Kathrin Anne and Poschlod P. (2008). Eutrophication and fragmentation are related to species' rate of decline but not to species rarity: results from a functional approach. Biodivers Conserv, 17(3), 591-604.

32. Murphy K.J., Dickinson G., Bini L.M., Dick K., Greaves K., Kennedy M.P., Livingstone S., McFerran H., Milne J.M., Oldroyd J., Wingfield R.A. and Thomaz S.M. (2003). Aquatic plant communities and predictors of diversity in a subtrophical river flood plain: the upper Rio Parana Brazil. *Aquat Bot,* 77(4), 257-276.

33. Murphy K.J. (2002). Plant communities and plant diversity in softwater lakes of northern Europe. *Aquat Bot,* 73(4), 287-324.

34. Ansari Abid Ali, Rehman Hasibur, Ghanim Sulaiman Al, Abbas Zahid Khorshid, Subrata Trivedi and Saggu Shalini (2015). Seasonal dynamics in the trophic status of water, floral and faunal density along some selected coastal areas of the Red Sea, Tabuk, Saudi Arabia. *IntAquat Res*, 7(4), 337-348. *doi10.1007/s40071-015-0118-6* .12p.

35. Habib O.A., Tippett R. and Murphy K.J. (1997). Seasonal changes in phytoplankton community structure in relation to physico-chemical factors in Loch Lomond. Scotland. *Hydrobiologia,* 350(1-3), 63-79.

36. Hodgkiss I.J. and Lu S.H. (2004). The effects of nutrients and their ratios on phytoplankton abundance in Junk Bay, Hong Kong. *Hydrobiologia,* 512, 215-229.

37. Arhonditsis G.B., Winder M., Brett M.T. and Schindler D.E. (2004). Patterns and mechanisms of phytoplankton variability in Lake Washington (USA). *Water Res.,* 38(18), 4013-4027.

38. Crossetti L.O. and Bicudo CEM (2005). Structural and functional phytoplankton responses to nutrient impoverishment in mesocosms placed in a shallow eutrophic reservoir (Garças Pond), São Paulo, Brazil. *Hydrobiologia,* 541(1), 71-85.