Available online at www.elixirpublishers.com (Elixir International Journal)

Agriculture

Elixir Agriculture 121 (2018) 51535-51541

ISSN: 2229-712X

Dynamics of Phytoplankton Assemblages in Lake Chad Nigeria

Idowu Rachel Toyosi[1], Ali Faisal Abdulhakim[2,*], Mathew Onyemaobi[3] and Ahmed Abbator[4]

[1,3]Department of Biological Sciences,Unıversity of Abuja, Nigeria.

[2,4]Department of Biological Sciences,University of Maiduguri, Nigeria.

ARTICLE INFO

Article history:

Received: 12 June 2018;

Received in revised form: 2 August 2018;

Accepted: 15 August 2018;

Keywords

Abundance,

Lake Chad,

Diversity.

ABSTRACT

The effect of environmental variables on the species composition and abundance of Phytoplankton was studied in Lake Chad for a period of 12 months in 2013. Five stations with varying anthropogenic activiteis across the Lake were sampled. A total of 33 phytoplankton species belonging to six taxonomic families were identified. Chlorophyceae family was the most abundant (32%) and Chrysophyceae being the least (9%). Numbers of species and individuals were both significantly reduced during the dry season of March to May and it corresponds to reduced water level. Phytoplankton numbers varied from $1.1x10^2$org/ l to $5.3x10^2$org/l with the highest density noted in the raininy season. Statistically significant difference ($P<0.05$) between seasons were discovered in the case of number of taxa and density. In terms of abundance by station, station 3 had the highest number of species (30) which was significantly different at $P<0.05$ from all other stations. The mean temperature value ranged from 26.8± 0.23 ?(Station 1) to 30.3±1.8 (Station 4). The highest mean depth of 8.5±0.74m was recorded by Station 3 with station 5 recording the least (4.5±0.1m). Station 4 was the most turbid (56±3.5NTU) and station 1 the least 43.3±1.2 NTU). The pH value was acidic for all stations whıle Total Dissolved Solids (TDS) was very significantly higher $P<0.05$ in station 2 (80±0.56) while lowest value of 23±0.78mg/l was recorded in station 5. The Shannon Weiner and Margalef diversity index revealed that station 3 had the biggest diversity (1.681)(6.675) while station 1 recorded the least (0.695)(3.001) in both richness and eveness respectively. Considering the importance of phytoplanktons in the trophic function and health of water bodies, regular assessment of their status should be done regularly especially in areas with threats of anthropogenic perturbations.

Introduction

Phytoplankton are very important group of freshwater organism, they occupy the primary trophic level as primary producers and food source for invertebrates and vertebrate groups in the aquatic environments. They form the base of food webs and foundation of life for all aquatic organisms.Without phytoplankton no other part of food chain could exist, as producers of their own food through photosynthesis, they provide food to consumers larger than themselves who in turn provide food for the next creature up the food chain.

Distribution and composition of phytoplankton in freshwater environment depends on many factors as water temperature, type of substrate, water current and depth, these make them to vary widely in pyhsical and chemical requirements for population growth. Some species of phytoplankton can have harmful effect on organisms at different trophic level. Blooms of some otherwise harmless species can result in massive fish kills by depleting dissolved oxygen or by clogging gills of fish (Frank, 1992). Phytoplankton undergo photosynthetic processes accounting for half of all photosynthetic production in the world. They fix carbon and produce oxygen through primary productivity . Natural processes and human impacts on the environment also influence primary production through high turbidity which eventually reduces light availability (Whitford and Schumacher, 1973).

Several studies have been done on the seasonal characteristics, physical, chemical characteristic and population of planktons in Nigerian lakes. Egborge (1970, 1973) in Asejire Lake , Abdullahi (1989), Tiga Lake , Ovie (1989) in Jebba lake and Ona River (Elemi, 1993) etc. However, the phytoplankton composition of Lake Chad have not been reviewed in the recent past especially in relation to the primary productivity of the Lake which is facing severe pressures from both climatic and anthropogenic sources which is causing it to shrink at an alarming rate.

Consequently, the aim of the study was to evaluate changes in the phytopankton structure durıng the period of 12 months comprising of the three major distinct seasons (Harmattan, dry/ hot periods and the raining seasons) commonly found in the area. Specifically, the study aims to gather information on the seasonal differences in phytoplankton occurences, determine their species compositions and abundance and above all the effect of environmental factors on their seasonal changes.

Materials and Methods

The Study Area

Lake Chad is Africa's fourth largest lake by surface area, situated in the North East Arid Zone of Nigeria specifically at the tail end of Borno State and shared by three (3) other countries of Cameroon, Niger and Chad. It is a fresh water ecosystem heavily affected by human activities.

Tele:

E-mail address: hakabdali@gmail.com

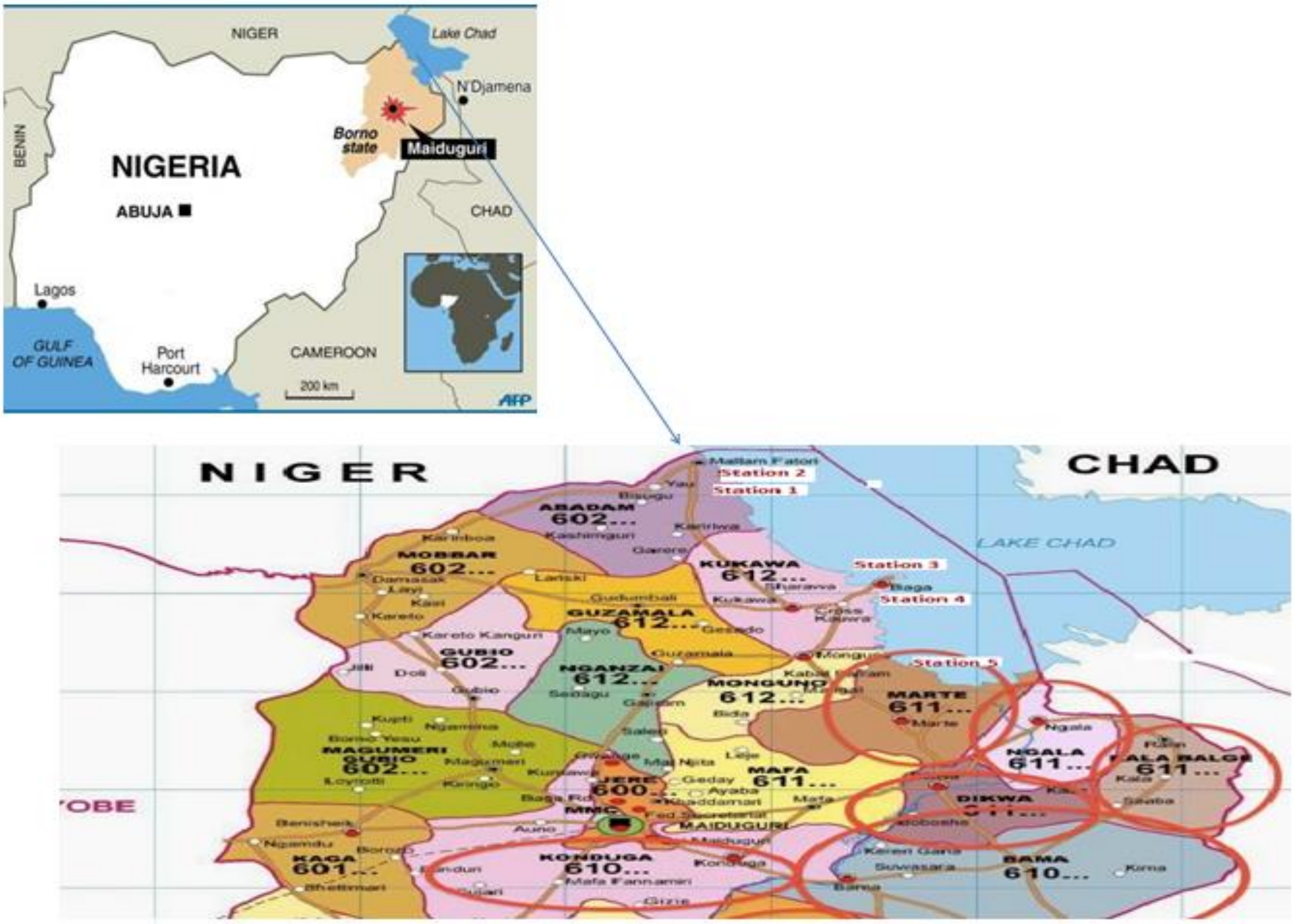

Fıg 1. Map of Nıgerıa Showıng Locatıon of Borno State and sampling stations.

For years, Lake Chad has been a centre of trade and cultural exchange between people living in the north of the Sahara and people in the Southern part of Nigeria. It is located between Latitude 13⁰ 0'0 and Longitude 14⁰ 10'0 . (See Fig. 1) with an elevation of 938 ft above sea level. The mean Depth is 1.5m while the maximum depth is 8.0m. The rainfall pattern in the Lake Chad basins have changed significantly in the past 30 years, resulting in a significant drop in water level, a decline in vegetation and increase in vulnerability to erosion (Birkett and Mason, 1995).

Lake Chad Basin houses some of the poorest people of the world and provides food for about 20 million people living in the basin (Lablanc *et al.*, 2007). Agriculture has always been the backbone of the regional economy and continues to engage about 60% of the basins population (Odada *et al.*, 2006). Traditionally, animal husbandry, irrigation farming as well as fishing were the main occpation of the population but large numbers of people and their livestocks have migrated due to the changes in rainfall and desertifications. The combined effect of climate change and unsustainable water project have made significant reduction to the flow of rivers into the Lake Chad. The annual average rainfall over the entire basin is rather low at 320mm (Fortnem and Oguntola, 2004).

Generally, there is insufficient knowledge about water resources, ecological aspect and aquatic ecosystem functions of Lake Chad. No systematic and continous research for monitoring quantity and quality of fresh water resources due to lack of experts in the areas of limnology , and the distance from the main state capital as well as the security situation in the area. Research work in this area is highly risky due to occasional filteration of terrorist around the area.

Methods

Sampling Collection and Laboratory Analysis

The data for this study were collected monthly between January 2013 to December 2013 from 5 sampling stations selected randomly around the Lake. The stations, which are roughly 20kms apart are: Yau (station 1), Malamfatori (station 2), Baga North (station 3), Baga South (station 4) and New Marte (station 5) (Fig.1). Samples were collected at 1m depth interval from the surface with water temperature (^{0}C) and dissolved oxygen mg/l measured with YSI- 52 DO meter. Transparency (m) was recorded with a Secchi disk; electrical conductivity was determined with a YSI model 31 conductance meter; alkalinity was measured with a Fisher model 520 digital pH meter while $S04^{2-}$, Cl^- and Na^+ were analyzed by emmission spectrometer by the CACs Analtical laboratory at University of Maiduguri following the procedures in APHA (1989).

Phytoplankton was sampled with triplcate tow by using a 30 cm diameter conical plankton net of (96µm mesh) from 1m to the surface. The samples were fixed with Lugol's solution and then preserved with sugar formalin at a final concentration of 4% (Haney and Hall, 1973 , Uraba, 1990). The cell count were made at 300 × magnifications for two 0.05ml subsamples without concentration. Mean cell volumes were estimated for all general from the measurements of 20-80 cells applied to common geometric shapes (Willen, 1976). The identification of phytoplankton species was based on several publications Whitford *et al*. (1973), Willen (1976) and Horner (2002). Counting was done with sedimentation chambers with volumes of 5-100ml. Cell counts were converted to biovolume. Average density, species composition and abundance were calculated as suggested by Reynolds, (1980, 1984).

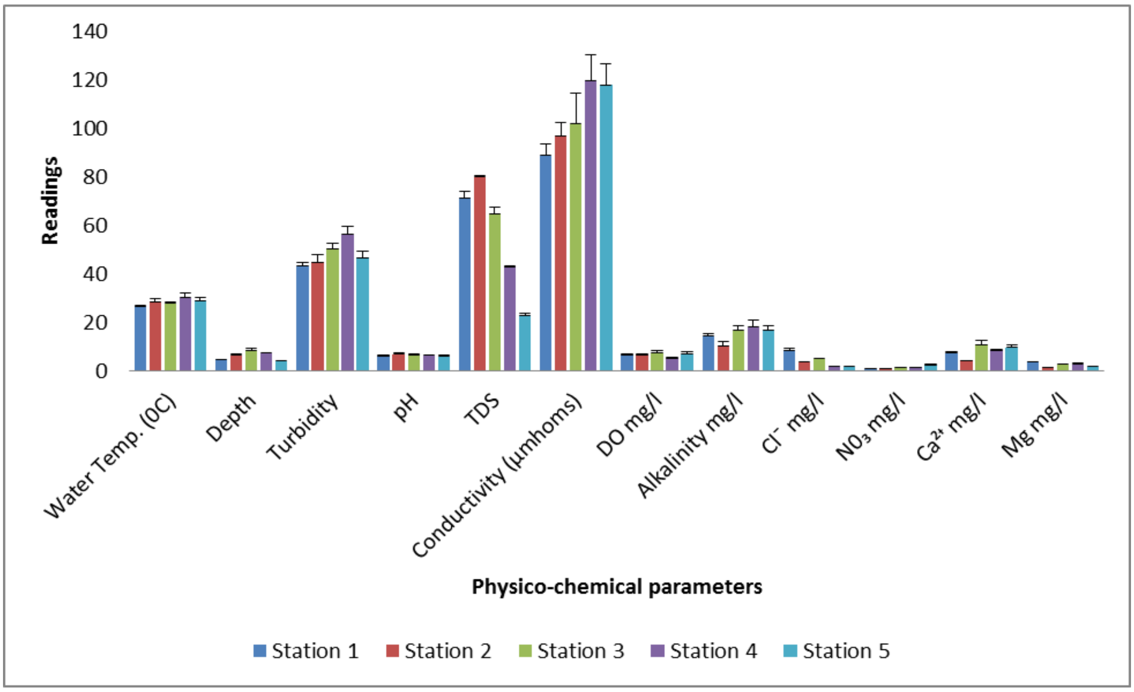

Figure 2. Physico-chemical parameters across stations in Lake Chad.

The richness and eveness (spresd) of species were calculated using the Shannon-Wiener diversity Index (H) and Margalef Species richness index. Differences between group samples in period and place were computed using Analysis of Variance (ANOVA) at P<0.05 with the aid of the Statistical Package for Social Sciences (SPSS). Significant differences between seasons was tested with respect to each of the studied environmental variables, and the relationship between the species composition of the phytoplankton and Correlations between phytoplankton variables and environmental variables were tested. Pearsons correlation coefficient was used for the latter purpose.

Results

Figure 2 shows the results of the environmental variables sampled for the 5 stations studied. The mean temperature value ranged from 26.8± 0.23 in station 1 to 30.3±1.8 in station 3. Station 3 has the highest mean depth of 8.5±0.74m, followed by Station 4 (7.3±0.34m) and the least depth of 4.5±0.1m in station 5. Mean turbidity value was very high in station 4 with 56±3.5 and 50.4±2.1 NTU in station 5. The pH value was acidic for all stations with the lowest value of 5.9±0.6 in station 5 other stations have mean value higher than this. TDS was significantly higher in station 2 (80±0.56) while lowest value of 23±0.78mg/l was recorded in station 5.The mean value for conductivity was significantly different at P<0.05 in station 3, 4 and 5 compared to 1 and 2. The Dissolved oxygen varied between 5.2±0.54mg/l in station 4 and 7.5±0.78mg/l in station 5 while alkalinity was very high in station 4 (18.2±2.7 mg/l) but lowest in station 2 (10±1.9mg/l)) . NO_3 was 2.6±0.06mg/g in station 5 and lowest value of 0.91±0.01 was observed in station 1. Ca^{2+} value was significantly higher 10.9±1.51mg/l in station 3 and lowest (4.3±0.04mg/l) in station2 (Figure 2). There were significant differences between recorded values for environmental variables across the various stations.

Table 1 shows the results of the monthly water temperature range and air temperature in lake Chad. From all the stations. There was a significant and gradual in creasein both temperature values from March till July. From 32 - 37^{0}C for water temperature and 34- 40^{0}C for air temperature. The lowest temperature for all stations was recorded in January and it varied from 19 - 21^{0}C.

A total of 6 families and 33 species of phytoplankton were observed in this study. The average density of organisms varied from 1.1x10²org/ l to 5.3x10²org/l. The highest density was noted in the raining season. And statistically significant difference P<0.05 between the seasons were discovered with regards to number of taxa and density.

Table 1. Monthly Temperature Values For The Fıve Statıons In Lake Chad.

Month	S1	S2	S3	S4	S5	T^{0}C Range	Mean T^{0}C
Jan	19	21	19	20	19	19-21	19.6
Feb	24	23	23	22	23	22-23	23
Mar	37	35	32	34	35	32-37	34.6
Apr	33	32	30	32	31	30-33	32.2
May	34	32	34	32	30	30-34	32.4
Jun	30	31	30	32	31	30-32	30.8
Jul	29	28	29	28	27	27-29	28.2
Aug	26	24	25	25	24	24-26	24.8
Sept	25	26	24	23	24	23-26	24.4
Oct	23	24	23	21	23	21-23	22.8
Nov	21	20	21	21	22	20-21	21
Dec	20	21	20	21	20	20-21	20.4

There was a gradual decrease in the number of phytoplanktons from January to July. The highest number was observed in station 4 (5.3x10²org/l)in January and in station 2 (2 4.3x10² in February) which were significantly higher (P<0.05) than stations 1, 3 and 5. The lowest number recorded was between May and July which varied between 1.1x1² org/l in station 5 in June to 1.8x10²org/l in station 1 in July. A gradual increase was recorded from August to December. The peak was observed in October for all the stations.

The total number of family and species collected are shown in figure 3a–3f. Phytoplankton families recorded were grouped into 6 families with 33 species.The family comprised of Chlorophyceae, Cyanophyceae, Bacillariophyceae, Chrysophyceae, Cryptophyceae, and Euglenophyceae. In terms of percentage compositin, *Closterium aculum* had the highest percentage composition of 10% in Station 1, followed by *Xanthidium antilopacum* with 8.5%, *Anaebana sp* was the lowest. *Cosmerium notable* had the highest percentage abundance (5.8%) in station 2, followed by *Chloela vulgaris* with the least being *Oscillatoria* *minnesotensis* and *Chrooccus varius*. *Rhodomonas lacustris* and *Dinobryon indriana* had 9.1% each, *Navicula incarta* 8.8% and *Chlorella* vulgaris had the least 1.2% in station 3. In station 4, *Phacus longicuda* and *Dynobryon cylindrica* had the same percentage composition of 10.5% each while station 5 had 10% for *Euglena sanguinei* and 8% for *Dinobryon locustris*. *Anacyst rupastris*, *Choocus varina*, *Frangilaria capucirus*, *Melosira varian* occured in few stations while family Chrysophyceae was not encountered in station 1.

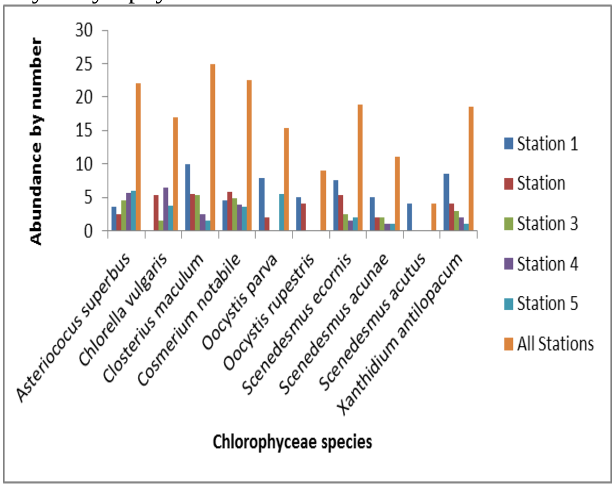

Fig.3a. Chlorophyceae species by abundance across stations.

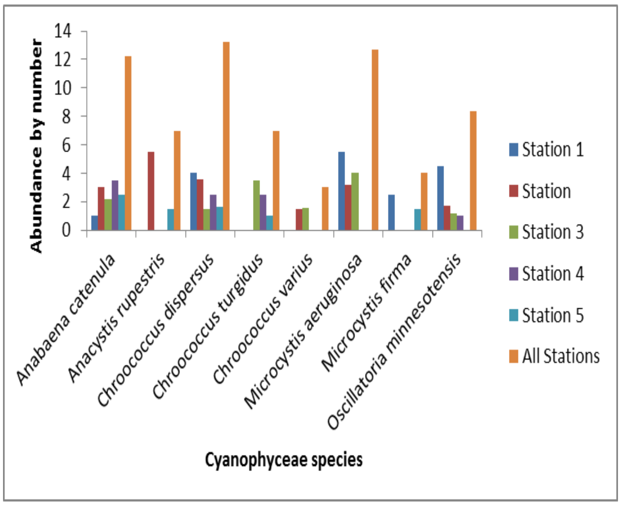

Fig.3b. Cyanophyceae species by abundance across stations.

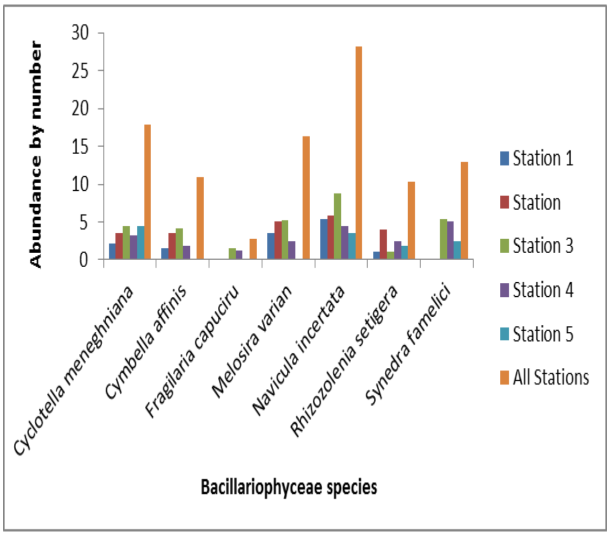

Fig. 3c. Bacillariophyceae species by abundance across stations.

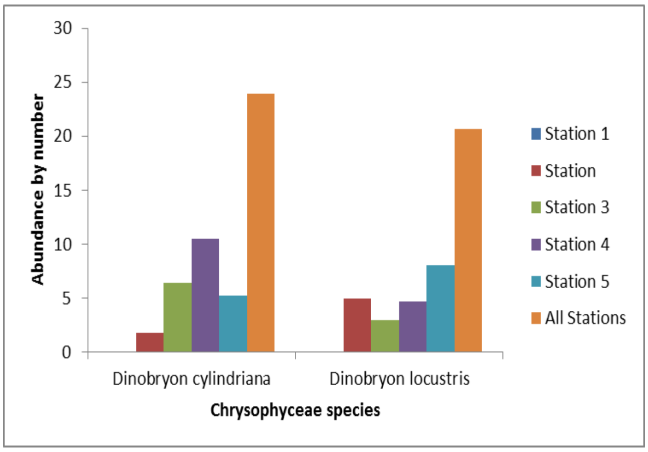

Fig. 3d. Chrysophyceae species by abundance across stations.

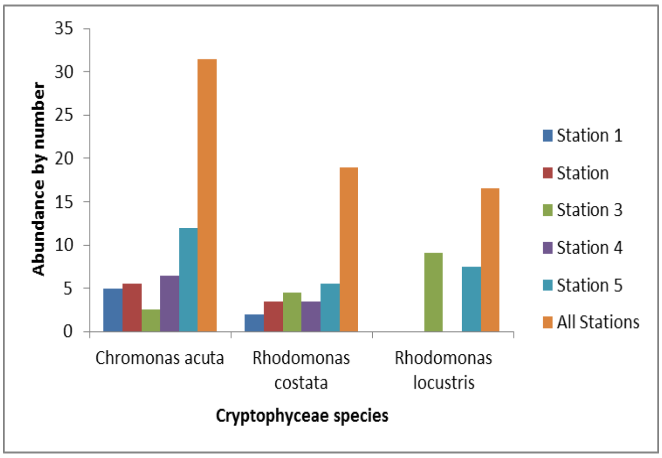

Fig. 3e. Cryptophyceae species by abundance across stations.

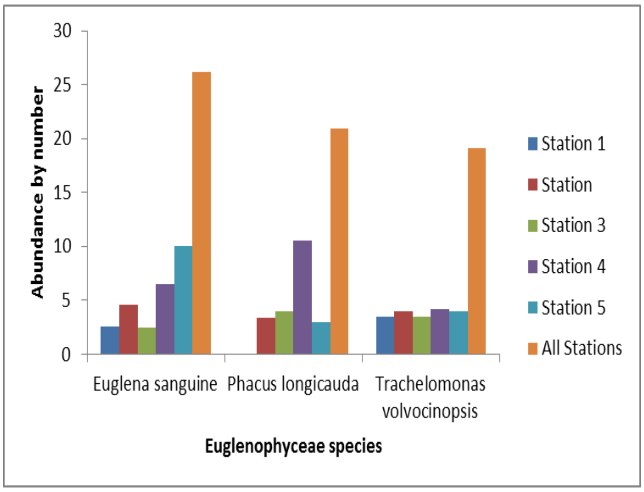

Fig. 3f. Euglenophyceae species by abundance across stations.

Figure 4 shows the percentage composition of the phytoplankton families in relation to stations. Chlorophyceae has the highest percentage composition of 55.9% in station 1 followed by Cyanophyceae and the least was Euglenophyceae while Cyanophyceae was not encountered. In station 2, Chlorophyceae recorded 35.4%, followed by Bacillariophyceae 21.97%, Cyanophyceae with 18.45% and the least was Chrysophyceae 6.78%. Bacillariophyceae had the highest composition of 30.6% in station 3 while Euglenophyceae had the least of 6.4%. In station 4, Chlorophyceae had the highest composition of 22.9% while Cyanophyceae had the least of 9.3%. Cryptophyceae recorded 25% in Station 5 and the least was Cyanophyceae with 8.15%.

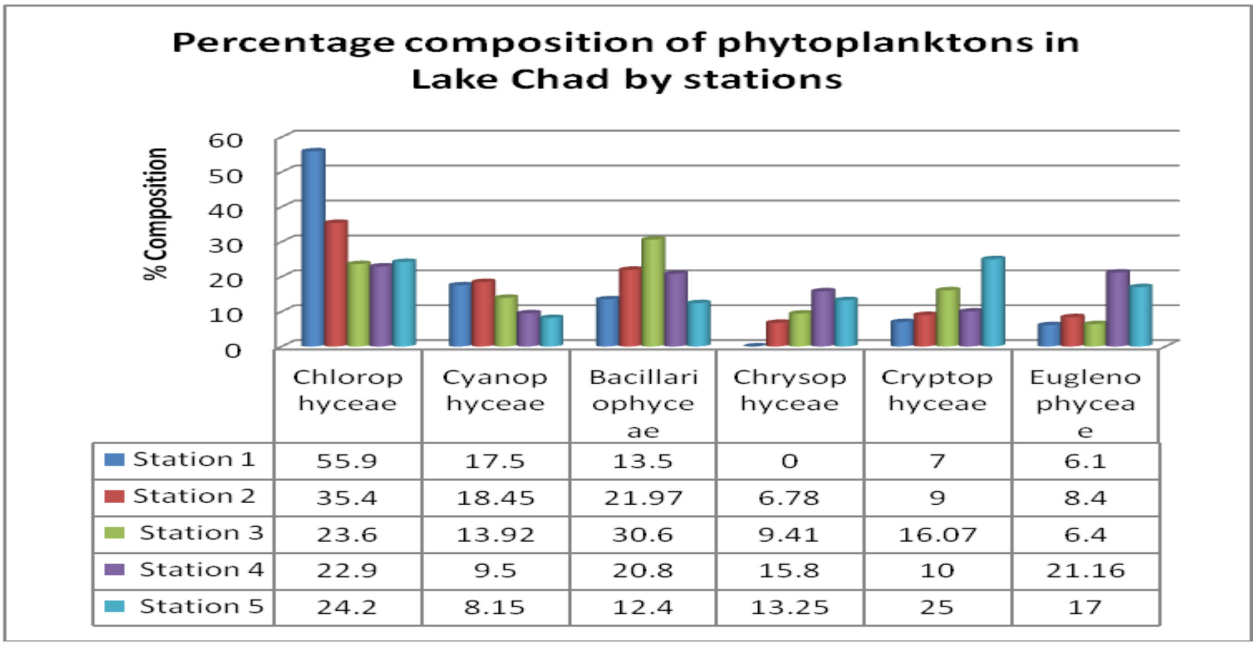

Figure 4. Percentage composition of phytoplanktons by stations.

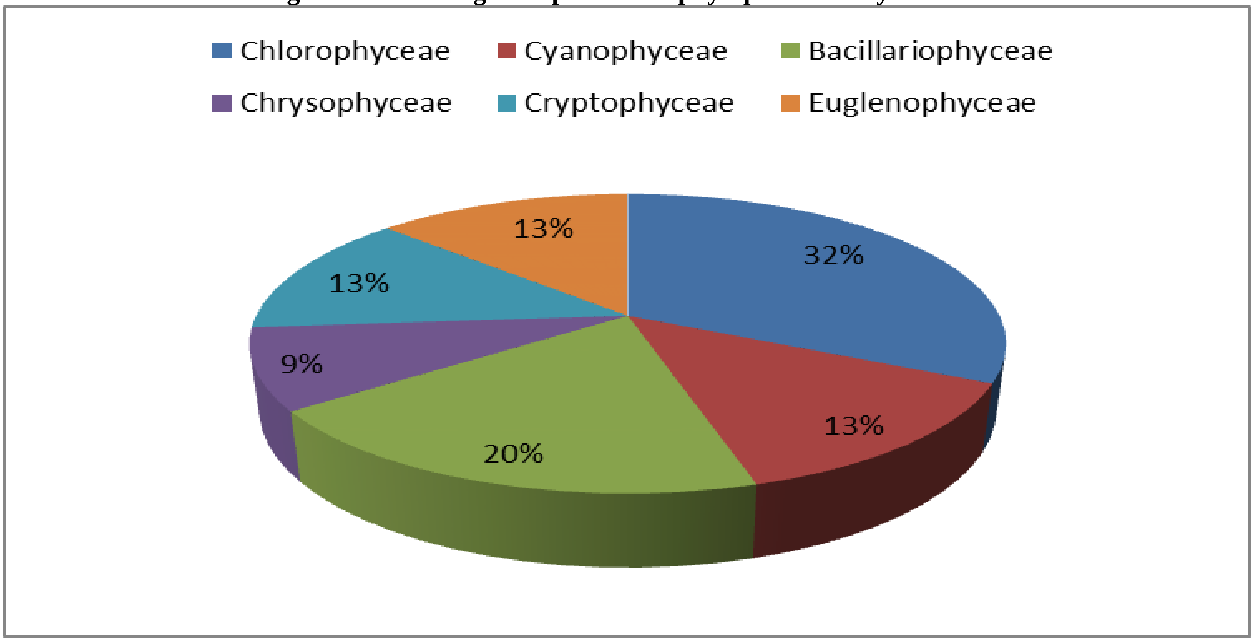

Figure 5. Percentage composıtıon of phytoplankton famıly (combıned statıons) ın Lake Chad.

Figure 5 shows the total number of Phytoplankton family and the percentage compositions of their species when the total station samples were combined. Chlorophyceae recorded 10 species with percentage composition of 30% which is significantly higher than all other families. Cyanophyceae and Bacillariophyceae had 24.24% (8 species) and 21.22% (7species) respectively. Cryptophyceae and Euglenophyceae recorded the same number of species and the same percentage composition of 9.09% while Chrysophyceae recorded the least number of species of 2 representing 6% of total composition.

Table 2 shows the Pearson Correlation coefficient calculated for some selected environmental variables and the Phytoplankton families.There was high positive correlationbetween all the Phytoplankton families and many of the environmental variables. Negative correlations were however observed between depth and all the phytoplankton families except Chlorophyceae. Alkalinity also had negative correllations with Chlorophyceae, Cyanophyceae, bacillariophyceae and Chrytopyceae. Significant differences in correlation were observed with pH, Alkalinity, Dissolved oxygen, Total Dissolved Solid and Euglenophyceae. The same trend was observed between pH and Cryptophyceae.

Table 2. Pearson Correlatıon Coeffıcıents (R) Between Plankton Taxa And Some Selected Envıronmental Varıables İn Lake Chad.

Phytoplankton family	pH	Alkalinity	DO	T^0C	Conductivity	Depth	TDS	Turbidity
CHLOROPHYCEA	0.88	-0.64	0.48	0.73	0.87	0.89	0.93	0.78
CYANOPHYCEA	0.78	-0.54	0.67	0.69	0.62	-0.76	0.62	0.64
BACILLARIOPHYCEA	0.65	-0.46	0.44	0.64	0.76	-0.65	0.59	0.83
CHRYSOPHYCEA	0.43	-0.67	0.53	0.63	0.59	-0.75	0.88	0.53
CRYPTOPHYCEA	0.35	0.55	0.54	-0.54	0.62	-0.48	0.35	0.51
EUGLENOPHYCEA	0.23	0.45	0.34	0.57	0.63	-0.49	0.27	0.55

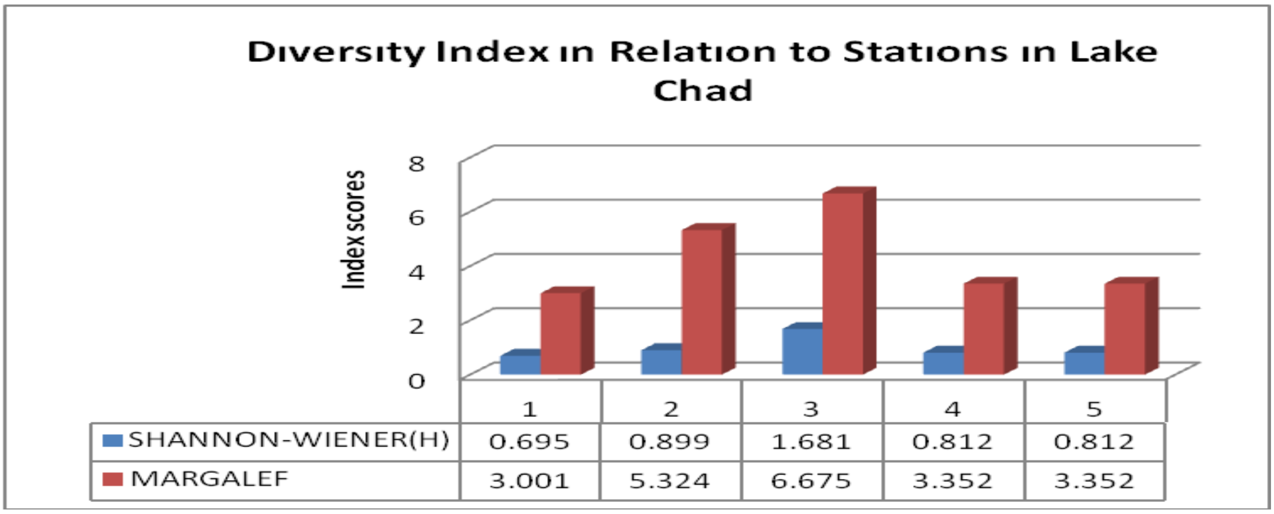

Figure 6. Specıes number and dıversıty ındex ın relatıon to statıons ın Lake Chad.

The results of the species numbers observed and their diversity index is shown on figure 6. The calculated diversity index values for both Shannon- Wienner (H) and Margalef (M) shows station 3 had the highest value M6.675, H1.68 which is significant at $P < 0.05$. The total number of species for all station was 33 while the total Shannon Weiner (H) was 1.978 while Margalef (M) was 7.843.

Discussion

Phytoplankton are the most important plants in all natural bodies of water because they serve as the foundation of food chain that support the higher forms of the aquatic life. One of the primary reasons that the effect of environmental variables on aquatic ecoystems are difficult to assess is the fact that historical Lake water data are often lacking (Brennner *et al*., 1993). A total of 6 phytoplankton families comprising of 33 species were identified in the five stations in this study. A large fraction of the variation in the annual average of phytoplankton can be explained by some of the environmental variables observed in the course of the study. Melach (1979), suggested other factors such as water column, stability and length of growing season. The study results showed marked difference in physical and chemical characteristics of the 5 studied station through out the year. Water depth variation was similar at all station. pH and DO concentrations showed little fluctuation from among stations in response to seasonal pattern. Temperature seems to be one of the most important ecological factors influencing the phytoplankton community in the Lake Chad as it was significantly positively correlated with all the phytoplankton taxon, which shows that temperature was the most powerful predictor of phytoplankton assemblage in Lake Chad. Other environmental variables also have influence on the composition and abundance, such as Dissolved Oxygen (DO) profile, water depth, conductivity, alkalinity which all varied among stations with the same trend through out the year.

Predominant species of the phytoplankton families in each station coincide with low or high temperature. İt was observed that periods of relatively high conductivity and alkalinity coincides with correwsponding high phytoplankton density with maximal density recorded during the rainy season (July to September) and harmattan season (October to January) when the water volume was high. Conversely, at all stations, phytoplankton abundance were low in the dry seasons between February and June. Environmental changes stimulate seasonal reaction of organism and their effects being influential in shaping and controlling phytoplankton abundance which aligned with the position taken by Pinel *et.al*., (1990).

Distribution and abundance of phytoplankton was highly dynamic during the rainy season, until the onset of harmattan when the water started reducing and followed an abrupt decline. This agrees with the findings of Cloern *et.al*. (1985) who noted that phytoplankton biomass is graetest during the spring in Francisco Bay. At all stations, the density of phytoplankton reached maximum density in September and maintained it till October there after declined gradually with some oscillations. Average densities from July to October were higher in all stations compare with other months respectively. Chlorophyceae was found to dominate and was more abundant in all stations through out the study period except station 3 where Bacillariophycea was much more dominant. Equally, during the study period, *Asteriococus superbulus, Closterium aculum, Cosmerium notabile,Scenedesmus ecornis, Xanthidium antilopacum, Anabaena catenula, Cyclotela meneghniana, navicula incertata, Rhizozolena setigera,Chromonas acuta, rhodomonas costata, Euglena sanguinea, Trachelomonas vovocinopsis* were common in all the stations for the entire period of sampling.

Phytoplankton concentrations varied considerably in time and in space from minimum of 1.1×10^2org /l to a maximum of 5.3×10^2org/ l cells. The differences between the densities and the percentage composition and abundance of each phytoplankton group indicates significant spatial variation for all groups ($P<0.05$). in terms of total abundance across all the stations, station 3 had the highest number of species (30) which was significantly different $P<0.05$ from all other stations with the least being 25 from stations 4 and 5. Additionally, most of the stations show low to moderate ions and cations concentrations, which could indicates low level of pollution.

The Shannon Weiner and Margalef diversity index revealed the significant differences among the 5 studied areas. Station 3 was observed to have the highest species richness and eveness as can be seen from the very high index recorded, this was followed closely by the nearby station 2 with the least being station 1. The high species richness of station 3 could be attributed to its high conductivity, rich dissolved oxygen and mild temperature. Overall, the results obtained from the study shows that most of the environmental variables were within the observed range recorded by Idowu, 2004 and Idowu *et. al.,* 2004 in Lake Alau, Maiduguri, Borno State and were found to be within tolerable limits for biodiversity, specie, primary production as well as human consumption. The study observed that most of the chemical parameters in Lake Chad are within ranges comparable with other West African Sahel reservoirs. The slight variation in the concentration of phosphate and nitrates in some of the stations may be attributed mostly to the discharge of waste water from domestic and agricultural activities as well as direct deposition of dry and wet particles by harmattan winds and rainy seasons flood.

Conclusion

Thirty six phytoplankton species belonging to six taxonomic families were encountered in this study. The chlorophyceae family was the most dominant while the chrysophyceae were the least dominant. Station 3 recorded the most diversity with highest number of species and highlighted in it recording the highest species richness and diversity indices owing to its recording comparatively low ionic concentration levels indicative of lesser pollution. Station 1 recorded the least diversity characterised by a higher ionic concentration and the highest dominance of chlorophyceae family as a result of excess nutrient enrichment resulting form waste deposits from the nearby hide and skin shops. It also recorded the highest mean temperature which is not favourable to planktonic survival.

References

Anderson, M.J. (2001) A new method for non-parametric multivariate analysis of variance. *Aust.Ecol*(26).32-46

Allen,T.P.H., Bartek, S.M. & Koonce, J.F. (1977) Multiple stable configuration in ordination of phytoplankton community change rate*: Ecology* 58: 1076-1084.

APHA (1992) *Standard method for the examination of water and waste water* . American Public Health Association.

Bırkett, C & Mason, I. (1995) A new global lakes database for remote sensing programmestudying climatically sensitive large lakes. *Journal of Great lakes Research,* 21 (*3*) 307-318.

Brıkett, C.M. (2000) Synergistic remote sensing of Lake Chad, variability of basin inundation. *Remote sensing envt* vol 72: (*2*) pp 218-236.

Coe, M.T. & Foley, J.A. (2001) Human and natural impacts on the water resources of the lake Chad basin. *Journal of Geophysical Research.* 1006:3349-3356

Eark, J.C., Duthıe, H.C. & Koonce, J.F. (1986) Analysis of the phytoplankton composition of 95 labrador lakes , with special refrence to national anthropogenic acidification . *Can. Journ. Fish .Aquat. Sci* 43:1804 -1811

Fortnam, M & Oguntola, J.A. (2004) Lake Chad Basin GIWA Regional Assessment 43, University of Kalmer, Kalmer. Sweden. (ed) UNEP.

Franks,P.J.S. (1992) Phytoplankton blooms at fronts pattern, scales and physical forcing mechanisms. Review of Aquatic Science. Vol 6 No 2 pp 121-137

Horner, R.A. (2002) *A Taxonomic guide to some common phytoplankton.* Biopress Limited Dorset Press, Dorchester. U.K.

Idowu, R.T. (2OO4) Limnological assessment of Lake Alau . PhD.Thesis University of Nigeria Nsukka. 193pp

Idowu, R.T., Inyang, N.M.& Ezenwajı, H.M. (2004) Heavy metal concentration in a West African Sahel Reservoir. *Animal Research International* Vol 1 No 11 , 12-15

Idowu, R.T., Inyang, N.M.& EYO, J. (2004) The physico – chemical parameter of an African Arid Zone man mada Lake. *Animal Research International* Vol1,No 2 , 113-119

Melak, J.M. (1979) Temporal variability of phytoplankton in tropical lakes, *Oecologia* 44:1-7

Notter, B. Macmıllen, Vıvırolı, L., Weıngartner, R. & Lınıger, H. (2007) Impacts ofenvironmental change on water resources in the Mt. Kenya region. *Journal of Hydrology* 343.pp 266-278.

Odada, E., Oyebade, L. & Oguntola, J.A. (2006) Lake Chad experience and lessons learned. www.ıelearnn.net/publications/11/lake chad .pdf

Reynolds, C.S. (1980) Phytoplankton assemblage and their periodicity in stratifying lake system. *Holarctic Ecol.* 3: 141-159.

Reynolds, C.S. (1984) Phytoplankton periodicity, the interaction of form , function and environmental variability. *Freshwater .Biol.* 14: 111-142

Pınel- Allow, B.G., Methot, G., Verrault & Vıgneault, Y. (1990) Phytoplankton in Quebec lake. Variation into lake morphometry, and with national and anthropogenic acidification. *Can. Journ. Fish.Aquat. Sci*. 47:1047-1057

Sarch, M.T. (2001) Fishing and farming at Lake Chad: Institution for access to rural resources. *Journal of Environmental Management* 62: 185-199

Urabe, J & Murano, M. (1986) Seasonal and horizontal variation in the zooplankton community of Ogochi Reservoir Tokyo. Bull.Plankton Soc. Jpn 33:101-112

Whıtford, L.A. & Schumacher, G.J. (1973) *A manual of freshwater Algae*. Sparks Press. Raleigh, North Carolina.

Wıllen, E. (1976) A simplified method of phytoplankton. *County .Br. Phycol. Journ* 11: 265-278

Wılkınson, L. (1987) SYSTAT, the system for statistics. SYSTAT Inch.

Whıttaker, R.H. (1972) Evolution and measurement of species diversity. *Taxon* 21, 213- 251.

Acknowledgement

Thanks to TUBITAK for giving the lead authour the short Sabbatical fellowship and for the financial assistance and to Prof. Dr. Okan Kukoyluoglu for the mentorship, provision of laboratory facilities and other resources that were invaluable to the sucess of this study. Our profound appriciation to all the academic and non academic staff, post graduate and undergraduate students of Abant Izzet Baysal University, Bolu, Turkey for their hospitality.