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Effects of non-point source pollutants on seasonal variability of phytoplankton in river Nggada, Maiduguri – Borno State, Nigeria

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ABSTRACT

Borno State is the epicenter of Boko Haram crisis which displaced millions of individuals. Maiduguri metropolis became the principal refuge centre, has witnessed a rapid demographic change, land use and economic activities resulting into intense irrigational practice along the bank of river Nggada may result into changes in the physical and chemical parameters of the aquatic ecosystem and this dynamism may disrupt phytoplantonic community. The study was aimed at assessing the effect of non-point source pollutants on the seasonal variability of phytoplanktons in river Nggada, Maiduguri, Borno State, Nigeria. Water samples for physico -chemical analysis were collected bi-weekly for a period of 11 months at three sampling stations. Dissolve Oxygen (DO), Dissolved Nitrate concentration, Dissolved Phosphorus Concentration, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Surface Water Temperature (SWT) and potential Hydrogen (pH)) were determined using standard procedures. Results indicated that all physical and chemical parameters except temperature, DO and pH of the river, during both regimes, were slightly above the National Environmental Standards and Regulations Enforcement Agency's (NESREA) permissible limits. A total of 7 classes (Cyanophyceae Chlorophyceae, Cryptophyceace, Euglenophyceae, Bacillariophyceae, Crysophyceace and Rhodophyceae) and 16 species of phytoplanktons were identified. The results further revealed that the irrigation activities (dry season) have impacted on the physico – chemical parameters (pH, DO, TDS, nitrate and phosphate concentrations) of the study area. Remarkably, the changes in the physico – chemical parameters during the irrigational regime (dry season) have not impacted on the abundance and distribution of phytoplanktons at study period. Hence different classes of phytoplanktons and physico-chemical parameters were both positively and negatively correlated. In conclusion, the non-point pollutants influenced the physico-chemical parameters of the river. However, on the other hand, algal abundance and distribution were not influenced by the changes in the physic-chemical parameters of the river. The study recommends the continuous monitoring and systematic effort to conserve the bio-resources and water quality of the river.

Keywords: Abundance, Algae, Physico-chemical parameters, Water quality**,** Water pollution

INTRODUCTION

Seasonal variation in the aquatic ecosystem relates to a variety of environmental factors, (Spencer 2001; Luke *et al.*, 2010). The aquatic environment is constantly undergoing dynamic ecological changes as a result of either anthropogenically or naturally induced factors. The anthropogenic factors include the release of pollutants and contaminants into surface water bodies via human activities like farming, mining, industrial effluent discharges and many other activities capable of releasing toxic chemicals and contaminants into our oceans, lakes, rivers, streams, and ponds which has led to the destruction of many ecosystem balances over the years (Verma and Agarwal 2008; Chonoi *et al.* 2009).

The seasonal environmental factors such as rain, light intensity and atmospheric temperature have significant effects on the physico-chemical and biological seasonality of aquatic systems (Annalakshmi and Amsath, 2012). Some of these physico-chemical factors include pH, water temperature, dissolved oxygen concentration, and nutrient concentration (Agouru and Audu, 2012). The seasonal variation of this environmental factors results changes in biological component of the aquatic system. Phytoplankton are microscopic and photosynthetic organisms found in the base of the food chain of aquatic system, therefore, they rapidly respond to the variability of physico-chemical factors such as light, temperature, nutrient, pH, and salinity (Annalakshmi and Amsath, 2012), causing migration, increasing or decreasing growth and development, inhibiting or favouring abundance and distributions in some species in the aquatic ecosystem, (Agouru and Audu, 2012).

The abundance and distribution of phytoplankton are dependent on the ambient nutrient concentration (such as nitrogen and phosphorus), light intensity and pH, (Verma and Agarwal 2008; George, *et al.* 2012; Dede and Deshmukh 2015). Most of the physico – chemical parameters of most aquatic environments change seasonally and as such affects their abundance and distribution.

Irrigational runoff into streams, rivers, lakes and oceans are known as non-point source pollutants accumulating chemicals into the surface water-bodies and impacting on the aquatic biodiversity (Chonoi *et al.* 2009). This study was aimed at assessing the effects of non-point source pollutants from irrigational sites on seasonal variability of phytoplankton in river Nggada, Maiduguri – Borno State, Nigeria.

The high rate of immigration into the city of Maiduguri as a result of the terrorist activities in the Northeast, Nigeria and particularly in the Borno State witnessed a rapid demographic change, land use and economic activities resulting into intense irrigational practice along the bank of the river Nggada may result into changes in the physico – chemical parameters of the aquatic ecosystem and this dynamism may disrupt the aquatic bio resource, leading to migration, reduction in productivity and subsequently death (Syed 2011; Akan *et al.* 2013) and hence the need to study the effect of the non-point source pollutants on seasonal variability of phytoplankton in River Nggada, Maiduguri Borno State.

MATERIALS AND METHODS

Study Area

Maiduguri is located on latitude 11° 51’ 42’’N and longitude 013° 09’’ 35E and lies within the northern Sudan Savannah with distinct dry and wet (rainy) seasons. Maiduguri has an average drainage height of about 300m above sea level and the terrain is relatively flat, located on the mega Chad plain (Haruna and Anthony 2011). The city has an annual mean temperature of 37°C with 2 main river systems (Nggadabul and Nggada Rivers) which converge, taking the name River Nggada; both rivers are known for their circular flow (Bukar *et al.* 2016; Bwala 2019, 2020; 2021).

Water from the river is used for irrigation, domestic uses (such as washing, cooking and drinking), animal watering and various industrial activities. The river receives runoff from the irrigated farmlands along its bank (Adeniyi and Yusuf 2007; Haruna and Anthony 2011; Bwala, 2019, 2021).

Sampling Design and Stations

The study area (river) was divided into 3 sections with a sampling station each, based on the 3 different irrigated zones along the river bank as shown in Table 1. The water from the river recedes during the irrigational periods (dry seasons) and forms ponds at 3 identified locations (Custom, Fori and behind Maiduguri Water Treatment Plant) which are used as source of water for dry season farming (irrigational activities) at the sites. The stations were located 3km upstream from each other.

During the period of irrigational activities (November, 2018 – April, 2019), water was abstracted using a water pump for the irrigation of the nearby farmlands. Some of the water was returned to the river as surface irrigation runoff with some observable minor rill erosion at the river bank. At the Sampling Stations, an irrigational runoff monitoring station was established at the edge of the rill erosion at the entering point to the river (Causapé *et al.*2004). A monitoring station was established at each observed rill eroded area close to the riverbank and a composite auto – sampler (Global water WS750 model) was installed at each of the stations to collect samples at intervals (biweekly) during dry seasons (irrigational periods) (November, 2018 – April, 2019) and water samples were also collected at the sampling stations during the rainy seasons.

Table 1: The Sampling Stations in River Nggada, Maiduguri, Nigeria as used in this study from the Months of September, 2018 – July, 2019

S/N	STATION	LOCATION	GPS COORDINATE	ACTIVITIES/REMARK
1	A	Custom Area	N11° 51’ 29.8’’ E013° 11’ 01.0’’	✓ Irrigation sites ✓ Topography: flat
2	B	Fori ward	N11° 48’ 10.2’’ E013° 10’ 18.9’’	✓ Irrigation sites ✓ Topography: Sloppy
3	C	Beside Water Treatment Plant	N11° 47’ 28.1’’ E013° 11’ 33.8’’	✓ less irrigation sites ✓ Topography: Sloppy

Vegetation

The areas of Fori and Water Treatment (sampling stations B and C) are covered with mango (*Mangifera indica*) and cashew (*Anacardium occidentale*) plantations. Custom and Fori areas are sites for dry season farming (irrigational activities). Custom area (sampling station A) has no tree cover. At the sites along the river bank in custom area (station A) records the presence of newly emerging aquatic weeds were observed during the irrigational periods (dry seasons) which disappears during non – irrigational periods.

Human Interference

Custom area (sampling station A) is a commercial area with a populous vegetable market and abattoir located at the bank of the river, again the site also has some local foundries and dyeing industries located along the bank of the river. The river receives effluent from the markets, the abattoir, foundries and dyeing industries. Though, been a commercial area, the station is witnessed high presence of fishermen during fishing periods with differing fishing gears and boats.

Sampling station B (Fori ward) is a residential area, the residents use the water from the river for cooking, washing and other domestic activities. The river bank along this station is heavily irrigated and the river receives runoffs from the irrigation sites. The residents use local fishing gears (lines and hooks) to fish during fishing periods.

The Maiduguri Water Treatment Plant (MWTP) situated along the bank of the river in sampling station C (Behind Water Treatment Plant). The site is also heavily irrigated. The river receives runoffs from the irrigated sites and effluent from the Water Treatment Plant.

The station also witnessed high number of fishermen during fishing periods with boats and local fishing gears.

Topography

The topography of the densely irrigated zone (station A and B) and has a natural levee as part of the floodplain except for areas around custom area (station C) which is relatively a flat land area. The intensity of the irrigational activities varies along the riverbank. Custom and Fori ward areas are heavily irrigated while areas behind the Maiduguri Water treatment is less irrigated during the study period.

Climatology

The climatic condition of the sampling stations was reported to be similar with little temperature difference. The mean annual rainfall of the stations was reported be to about 500 –700mm per annum (NMA 2008); with a temperature range of 38 – 40°C in Custom and Fori area (station A and B) and 36 - 38°C in areas behind Maiduguri Water Treatment Plant (station C), (NMA 2008).

Sample Collection

Water Sample for Physico – chemical analysis

To analyze the physico-chemical parameters of the river, water samples were collected from three stations of the river once every two weeks for 11 months (September, 2018 – July, 2019). During the dry season, irrigational activities were observed at the sampling station and water samples were collected from the point where the pumping machine was used to drain water from the river and a representative sample from the monitoring station. A composite auto – sampler (Global water WS750 model) was installed at each sampling station to collect samples at intervals (biweekly) during dry seasons (irrigational periods) (November, 2018 – April, 2019) and water samples were also collected at the sampling stations during the rainy seasons. Water samples collected were kept in well labelled sampling amber bottles and transported on ice box to the laboratory for further analysis using standard methods.

Surface water Temperature (°C) was determined using mercury thermometer (Syed 2011) at the sampling stations while dissolved Phosphate concentration (mg/L), dissolved Nitrate concentration (mg/L), Total Dissolved Solids (NTU) and Dissolved Oxygen (mg/L) were analyzed using Agilent Tech. (4210 MPAES). while potentia Hydrogenii (pH) was analyzed using pH Mettle Toledo using standard method of Water analysis by APHA, (2005) at National Agency for Food and Drug Administration Control (NAFDAC), Maiduguri laboratory, (Usman *et al.* 2016; Gwana *et al.* 2017) with slight modification.

Water Sample for phytoplankton determination

Samples for the phytoplankton were collected at each of the sampling stations using kick and grab sampling techniques (Bwala 2019).

A 40µm mesh size standard plankton net was used to filter 20L (4L x 5) of the grab sample. The filtered Water sample was then filled into 120ml well labeled air tight sampling bottles at each of the stations. The samples were preserved with 4% formalin within 2minutes of sample collection as recommended by George, *et al.* (2012); Ansa *et al.* 2015 and then transported to the laboratory for analyses using the drop-count method with a light microscope (Şeyda and Meryem, 2014) and plankton identification manual and keys, (Han 1983; NIO 2004; Edward and David 2010).

Determination of Phytoplankton Relative Abundance

The Phytoplanktonic Relative abundance (%Ra) was determined using the formula

$$\%\mathbf{Ra} = \frac{n(100)}{N}$$, cited in (George *et al.* 2012).

Where **n** = total number of plankton under consideration

N = total number of all the species of the plankton group

Statistical Analysis

Data obtained was tabulated using Microsoft Excel 2010. Simple descriptive statistical analysis (mean and percentage) was employed to analysis the data using SPSS statistical software version 21. The field and laboratory data were gotten biweekly but a monthly mean was presented for ease of understanding.

RESULTS

Physico – chemical parameters

Temperature

The mean monthly surface water temperature of the sampling stations as shown in figure I ranged from 19 – 24°C during the months of April – July recorded the highest temperature values across the sampling stations. The months of December – February being Harmattan periods recorded a relatively low temperature range 19 – 21 °C.

Dissolved Phosphate Concentration

The mean monthly dissolved Phosphate concentration of the sampling stations as indicated in figure II ranges from 0.32 – 0.82 mg/L with the months of March and April recording the highest levels of concentration in all the three (3) sampling Stations. Phosphate was high during the irrigational regime (November, 2018 – April, 2019) with highest values recorded in April (0.76 – 0.82 mg/L).

Dissolved Nitrate Concentration

The monthly mean dissolved nitrate concentration of the sampling stations as revealed in figure III ranges from 0.61 – 1.12 mg/L with high values in most of the months of the year, except month of October where all the sampling stations recorded the lowest values (0.62, 0.61 and 0.64 mg/L in sampling station A, B and C respectively). This can be attributed to the fact that the month of October is a bridge month between the rainy farming season and the irrigational farming season as such there was no or little farm run offs into the river which may have caused the low level of concentration of nitrate.

Total Dissolved Solids

The monthly mean TDS of the sampling stations were high in most times of the year as shown in figure IV, ranging from 189 – 285 NTU across the sampling stations. The month of July recorded the lowest TDS in sample B and C (189 and 198 NTU respectively) while sampling station A recorded its lowest value in the month of November (198 NTU).

Dissolved Oxygen

The monthly mean DO of the sampling stations as revealed in figure V, indicates that sampling A recorded its highest value in the month of February (21.0mg/L) and lowest in the month of October (14.1mg/L), sampling station B recorded its highest value in the March (22.2mg/L) and lowest in the month of September (14.1mg/L) while sampling station C recorded its highest value in the month of January (20.1mg/L) and the lowest, also in the month of September (13.8mg/L).

potentia Hydrogenii

The monthly mean pH value of the sampling station as shown in figure VI, revealed that the value ranges between 7.318 in station C to 8.134 in station B, which was within the limit that was said to be favourable to most aquatic organisms (pH ranges from 6.5 – 8.5).

Table 2: Mean of the Physico – chemical parameters of River Nggada, Maiduguri, Nigeria during the two different regimes and NESREA permissible limits

S/N	Physico-chemical parameters/Stations	A		B		C		NESREA Limits
		I	II	I	II	I	II	
1	Temperature (°C)	21±1	22.4±0.9	21.2±1	23±0.8	21.2±0.4	22.2±1	≤ 40
2	Phosphate (mg/L)	0.64±0.3	0.45±0.2	0.58±0.2	0.42±0.3	0.54±0.3	0.40±0.1	3.5
3	Nitrate (mg/L)	0.90±0.2	0.81±0.1	0.87±0.2	0.75±0.3	0.87±0.4	0.73±0.2	0.08
4	Total Dissolved Solids (NTU)	239.3±20	244.2±23	243.3±5	227±10	238.5±8	224.6±9	150
5	Dissolved Oxygen (mg/L)	19.4±4	15.2±3	18.8±0.9	15.8±1.2	18.6±1.6	16.5±0.8	Min. 4.0
6	potentia Hydrogenii	7.8±0.8	7.6±0.3	7.7±0.2	7.6±0.5	7.8±0.4	7.4±0.4	6.5 – 8.5

Values are mean ± SD of the analyzed surface water parameters
I is the irrigational regime Nov., 2018 – Apr., 2019 (Dry season)
II is the non-irrigational periods Sept. – Oct., 2018 and May – July, 2019 (Wet season)

The Abundance and Distribution of Phytoplankton

The composition and distribution of phytoplankton across the sampling stations as shown in table V and VI, reveals a total of 7 classes and 16 species of phytoplankton in all the 3 different sampling stations. The distribution varies slightly during the study period.

The monthly mean abundance of phytoplankton across the sampling stations reveals that the months of March – July recorded a progressive increase in the total abundance of phytoplankton across the sampling stations. However, the result of the both regimes combined as shown in table III, sampling Station A recorded the highest relative abundance of phytoplanton in the class *Cyanophyceae* (69.4%), Sampling Station B has the highest relative abundance of the following classes of phytoplanton: *Chlorophyceae* (42.3%), *Cryptophyceace* (45.0%), *Euglenophyceae* (44.2%), and *Bacillariophyceae* (49.9%) while in Sampling Station C, *Crysophyceace* (44.7%) and *Rhodophyceae* (46.4%) were the highest classes of relative abundance of phytoplanton across the samping stations recorded.

The total mean phytoplanktonic abundance reveals high (292 mm^3L^{-1}) abundance of phytoplankton during the non – irrigational regime as against the irrigational regime (258 mm^3L^{-1}) as shown in table IV.

Table 3: %Ra of class of phytoplankton of River Nggada, Maiduguri, Nigeria from the Months of September, 2018 – July, 2019

S/N	CLASS	A	B	C	TOTAL (%Ra)
A	Chlorophyceae	26.4	42.3	31.3	100.0
B	Cryptophyceae	40.0	45.0	15.0	100.0
C	Chrysophyceae	23.5	31.8	44.7	100.0
D	Cyanophyceae	69.4	30.6	0	100.0
E	Euglenophyceae	27.1	44.2	28.7	100.0
F	Rhodophyceae	32	21.6	46.4	100.0
G	Bacillariophyceae	34.8	49.9	15.3	100.0

Table 4: Mean abundance of Phytoplankton (mm^3L^{-1}) of the two regimes across the Sampling Stations of River Nggada, Maiduguri, Nigeria from the Months of September, 2018 – July, 2019

Stations	A		B		C		Mean of the sum of both regimes	
	I	II	I	II	I	II	I	II
Phytoplankton	84	92	89	102	86	99	258	292

I is the irrigational regime Nov., 2018 – Apr., 2019 (Dry Season)
II is the non-irrigational periods Sept. – Oct., 2018 and May – July, 2019 (Wet Season)

Table 5: The Presence and absence of algal species in River Nggada, Maiduguri – Borno State, Nigeria from the Months of September, 2018 – July, 2019

Phytoplanktonic Abundance in the Sampling Stations				
S/N	**CLASS**	**A**	**B**	**C**
A	**CHLOROPHYCEAE**			
1	*Pteromonas*	+	+	+
2	*Ankistrodemus*	-	-	+
3	*Batryococcus*	+	+	+
4	*Spirogyra*	+	+	+
5	*Ulothrix*	-	+	+
6	*Microspora*	-	+	-
B	**CRYPTOPHYCEAE**			
7	*Crytomonas*	+	+	+
C	**CHRYSOPHYCEAE**			
8	*Synura*	-	+	+
9	*Uroglena*	+	-	+
D	**CYANOPHYCEAE**			
10	*Chroococcus*	+	+	-
E	**EUGLENOPHYCEAE**			
11	*Euglena*	+	+	+
12	*Phacus*	+	+	-
F	**RHODOPHYCEAE**			
13	*Asterocytis*	+	+	+
G	**BACILLARIOPHYCEAE**			
14	*Melosira*	+	+	-
15	*Pinnularia*	-	-	+
16	*Pinnularia*	-	-	+

Table 6: Mean abundance of Phytoplankton (mm^3L^{-1}) across the Sampling Stations of River Nggada, Maiduguri, Nigeria from the Months of September, 2018 – July, 2019

STATION/MONTHS	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**July**
A	76	81	75	68	62	95	101	103	103	98	102
B	85	89	86	67	59	97	99	123	131	104	99
C	96	76	86	71	62	85	98	111	116	102	104
TOTAL	**257**	**246**	**247**	**206**	**183**	**277**	**298**	**337**	**350**	**304**	**305**

DISCUSSION

The concentration of nitrate and phosphate were high during the irrigational regimes at sampling stations. The high concentration of nitrate and phosphate at all the sampling stations during the irrigational regime can be attributed to runoffs of non – point source pollutants from nearby farmlands which might have been fertilized with nitrate and/or phosphate containing fertilizers. Irrigational runoff may have impacted on these physico-chemical parameters (nitrate and phosphate) of the aquatic environment (Chonoi *et al.* 2009).

The mean abundance of Phytoplankton of the different regimes revealed that phytoplankton was higher in non – irrigational regime even though phosphate and nitrate concentrations were lower in in the regime. Both phosphate and nitrate concentratuions where higher during the irrigational regime (0.60mg/L, 0.58mg/L and 0.54mg/L and 0.90mg/L, 0.87mg/L and 0.87mg/L respectively) than the non – irrigational regime (0.45mg/L, 0.42mg/L, 0.40mg/L and 0.81mg/L, 0.75mg/L and 0.73mg/L for both phosphate and nitrate concentrations in all the three sampling stations respectively) as expected. The most interesting findings in this study was that increase in the concentration of phosphate and nitrate in the sampling stations did not translate into algal abundance as expected since nitrate and phosphate are key nutients and act as limiting factor in aqautic environment. The abundance of phytoplankton is less in the irrigational periods (84, 89 and 86 respectively) than the non – irrigational periods (92, 102 and 99 respectively) at all the sampling stations. One of the issue that emerged from these findings is the contradictory relationship between phytoplankton and the chemical parameters (phosphate and nitrate concentration). Although phosphate and nitrate concentrations are higher during the irrigational, phytoplantonic abundance tends to be low during the irrigational regime than the non – irrigational regime. This contradictory result may be due to the fact that several factors act together to influence the abundance and distribution of aquatic organisms such as temperature and phytoplankton are influenced by temperature. Monika *et al.* (2018) reported the optimal temperature requirement for algal growth to be 20 – 30 °C but further revealed that maximum algal growth occurs at 23 ^{0}C. During the non – irrigational regime the temperature ranges from 22.2 – 23 °C which may have translated into the algal abundance in the period. These findings further suggest that the ambient temperature in the non – irrigational period may have acted together with other physico – chemical parameters like availability of sunlight (light intensity and duration) and wind action mixing the little available nutrients to had attributed to the high abundance of phytoplankton (Akintola *et al.* 2011).

The monthly mean of the phytoplankton shows a progressive increase in the abundance of phytoplanktons from the months of March – July (298, 337, 350, 304 and 305). The highest phytoplanktonic abundance was recorded in the months of April and May (337 and 350 respectively) which was marked with high mean surface water temperature (23 and 24 °C in the months of April and May, repectively). Phosphate and Nitrate concentration were also at their peak in the months, with the highest level of phosphate and Nitrate concentration (0.82mg/L and 1.12mg/L repectively) were recorded in the April in Sampling Station A. This suggests that the irrigation runoff which was actively in practiced in April coupled with high temprature ranges in the Month which may had caused high level of evapouration, decreasing the volume of the water thereby increasing the concentration of nutrients might have favoured the abundance and distribution of phytoplankton in the month (George *et al.* 2012; Harris 2012; Bwala 2019). This agrees with Verma and Agarwal (2008); Harris (2012); Dede and Deshmukh (2015) that high temperature rates increase evaporation and together with wind action causes nutrient mixing in surface water bodies, and also when there's good light availability together with the mentioned factors aid the growth, development and subsequent abundance of phytoplankton in the aquatic ecosystem.

The months of December, 2018 and January, 2019 had the lowest phytoplanktonic abundance (206 and 183 respectively) which also recorded the lowest mean monthly surface water temperature ranges (19 – 20 ^{0}C), with a moderate mean monthly phosphate concentration (0.38 – 0.68mg/L), and nitrate concentration (0.68 – 0.96mg/L), pH was also favourable ranging from 7.429 – 7.921 and relatively high range of TDS (212 – 243 NTU). The little presence and abundance of phytoplankton in these months (December and January) can be attributed to the influence of the dust-laden northeastern wind from the Sahara which comes along with large quantity of dust in the months affecting the solar visibility and intensity (Mukhtar *et al.* 2015) which may not have favours phytoplanktonic growth, abundance and distribution in these months. Light intensity is a strong factor that favours phytoplanktonic growth, abundance and distribution (Akintola *et al.*, 2011; George et al, 2012; Harris, 2012; Abba *et al.* 2016; Bwala 2019) and hence its reduction may affect the algal population.

Pearson's Correlation Coefficients

The result for the Pearson's correlation coefficients for the class of phytoplankton in River Nggada, Maiduguri, Nigeria presented Table 7 reveals a positive correlation between *Chlorophyceae* and *Chryptophyceae*, *Chlorophyceae* and *Chrysophyceae*, *Chlorophyceae* and *Euglenophyceae*, *Chlorophyceae* and *Bacillariophyceae*, *Chryptophyceae* and *Cyanophyceae*, *Chryptophyceae* and *Euglenophyceae*, *Chryptophyceae* and *Bacillariophyceae*, *Chrysophyceae* and *Rhodophyceae*, *Cyanophyceae* and *Bacillariophyceae*, *Euglenophyceae* and *Bacillariophyceae.* The result also indicates negative correlation between *Chlorophyceae* and *Cyanophyceae*, *Chlorophyceae* and *Rhodophyceae*, *Cryptophyceae* and *Chrysophyceae*, *Cryptophyceae* and *Rhodophyceae*, *Chrysophyceae* and *Cyanophyceae*, *Chrysophyceae* and *Euglenophyceae*, *Chrysophyceae* and *Bacillariophyceae*, *Cyanophyceae* and *Euglenophyceae*, *Cyanophyceae* and *Rhodophyceae*, *Euglenophyceae* and *Rhodophyceae*, *Rhodophyceae* and *Bacillariophyceae.*

The result for the Pearson's correlation coefficients for the physico-chemical parameters during the irrigational regime in river Nggada, Maiduguri, Nigeria presented Table 8 reveals a positive correlation between Temperature and pH, Phosphate and Nitrate, Phosphate and TDS, phosphate and DO, phosphate and pH, Nitrate and DO, Nitrate and pH, DO and pH. The result further shows negative correlations between Temperature and Phosphate, Temperature and TDS, Temperature and DO, Nitrate and TDS, TDS and DO, TDS and pH.

Similarly, the result for the Pearson's correlation coefficients for the physico-chemical parameters during the non - irrigational regime in river Nggada, Maiduguri, Nigeria presented Table 9 reveals a positive correlation between Temperature and Phosphate, Temperature and pH, Phosphate and Nitrate, Phosphate and TDS, Phosphate and pH, Nitrate and TDS, Nitrate and pH, TDS and pH. The results further show that DO have a negative correlation with all the analyzed parameters (Temperature, Phosphate, Nitrate, TDS and pH respectively) during the non – irrigational regime. Furthermore, the result also indicates that Temperature also has a negative correlation with Nitrate and TDS respectively.
Hence the different classes of phytoplankton and physico-chemical parameters were correlated within themselves both positively and negatively.

CONCLUSION

In conclusion, irrigation activities have impacted on the physico-chemical parameters (pH, DO, TDS, nitrate and phosphate concentrations) of the study area. Amazingly, the changes in the physico-chemical parameters during the irrigational regime have not impacted on the abundance and distribution of phytoplankton in the study period.

Algal abundance and distribution during the irrigational periods were low at the same periods when phosphate and nitrate concentrations were high at all the sample stations. This can be attributed to the favourable temperature during the non – irrigational regime which may not have aided the growth and distribution of phytoplankton in this period.

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