UMYU Scientifica, Vol. 1 NO. 1, September 2022, Pp 315 – 326
https://doi.org/10.56919/usci.1122.040
ISSN: 2955 – 1145 (print); 2955 – 1153 (online)
A periodical of the Faculty of Natural and Applied Sciences, UMYU, Katsina

ORIGINAL RESEARCH ARTICLE

Seasonal Variability of Phytoplanktons in the Non-Point Source Polluted River Nggada, Maiduguri – Borno State, Nigeria

Mathias Nzitiri Bwala
National Environmental Standards and Regulations Enforcement Agency, (NESREA), Borno State Field Office, Maiduguri, Nigeria

ABSTRACT
Borno State is the epicenter of Boko Haram crisis which displaced millions of individuals. Maiduguri metropolis which 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. This may result into changes in the physico – chemical parameters of the aquatic ecosystem and the dynamism may disrupt phytoplantonic community. The study was aimed at assessing the seasonal variability of phytoplanktons in non-point source polluted river Nggada of Maiduguri. Water samples for physico -chemical analysis were collected bi-weekly for a period of 11 months at three sampling stations. Physico-chemical parameters, including 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 physico – chemical parameters except temperature, DO and pH of the river during both irrigational and non-irrigational 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 genera 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. Hence, the non-point pollutants influenced the physico – chemical parameters of the river butalgal abundance and distribution were not influenced by the changes in the physico – chemical parameters of the river. The study thus, recommends the continuous monitoring and systematic effort to conserve the bio-resources and water quality of the river.

ARTICLE HISTORY
Received: August 8, 2022
Accepted: September 2, 2022
Published: September 30, 2022

KEYWORDS
Irrigational period, Physico – chemical parameters, Algal Abundance

INTRODUCTION
Seasonal variation in the aquatic ecosystem relates to a variety of environmental factors (Spencer 2001; Luke and Nigel, 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 climatic factors which determine seasonal variation such as rain, light intensity and atmospheric temperature have significant effects on the physical and chemical characteristics of biological 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 these environmental factors result in changes of biological component of the aquatic system. Phytoplanktons are microscopic and photosynthetic organisms found at the

Correspondence: Mathias N. Bwala National Environmental Standards and Regulations Enforcement Agency, (NESREA), Borno State Field Office, Maiduguri, Nigeria: *mathias.bwala@nesrea.gov.ng*
How to cite: Mathias N. B. (2022). **Seasonal Variability of Phytoplanktons in the Non-Point Source Polluted River Nggada, Maiduguri – Borno State, Nigeria** *UMYU Scientifica*, 1(2), https://doi.org/10.56919/usci.1122.040

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, increased or decreased growth and development as well as inhibition or favouring abundance and distributions in some species in the aquatic ecosystem (Verma and Agarwal, 2008; Agouru and Audu, 2012; George, *et al.*, 2012; Dede and Deshmukh, 2015).
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). The high rate of immigration into the city of Maiduguri as a result of the terrorists 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. This has resulted in the changes of 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. This study was therefore, 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.

MATERIALS AND METHODS

Study Area

The study was conducted at Maiduguri which is located between latitude 10°48N and 14°51N and longitude 11°31E and 14°41E and lies within the northern Sudan Savannah with distinct dry and wet (rainy) seasons. Maiduguri has an average drainages 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) which converge, taking the name River Nggada. Both rivers are known for their circular flow (Bukar *et al.*, 2016; Bwala, 2019, Bwala and Tarfa, 2020; Bwala, 2021a,c).

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 *et al.*, 2008; Haruna and Anthony 2011; Bwala, 2019, 2021b,c).

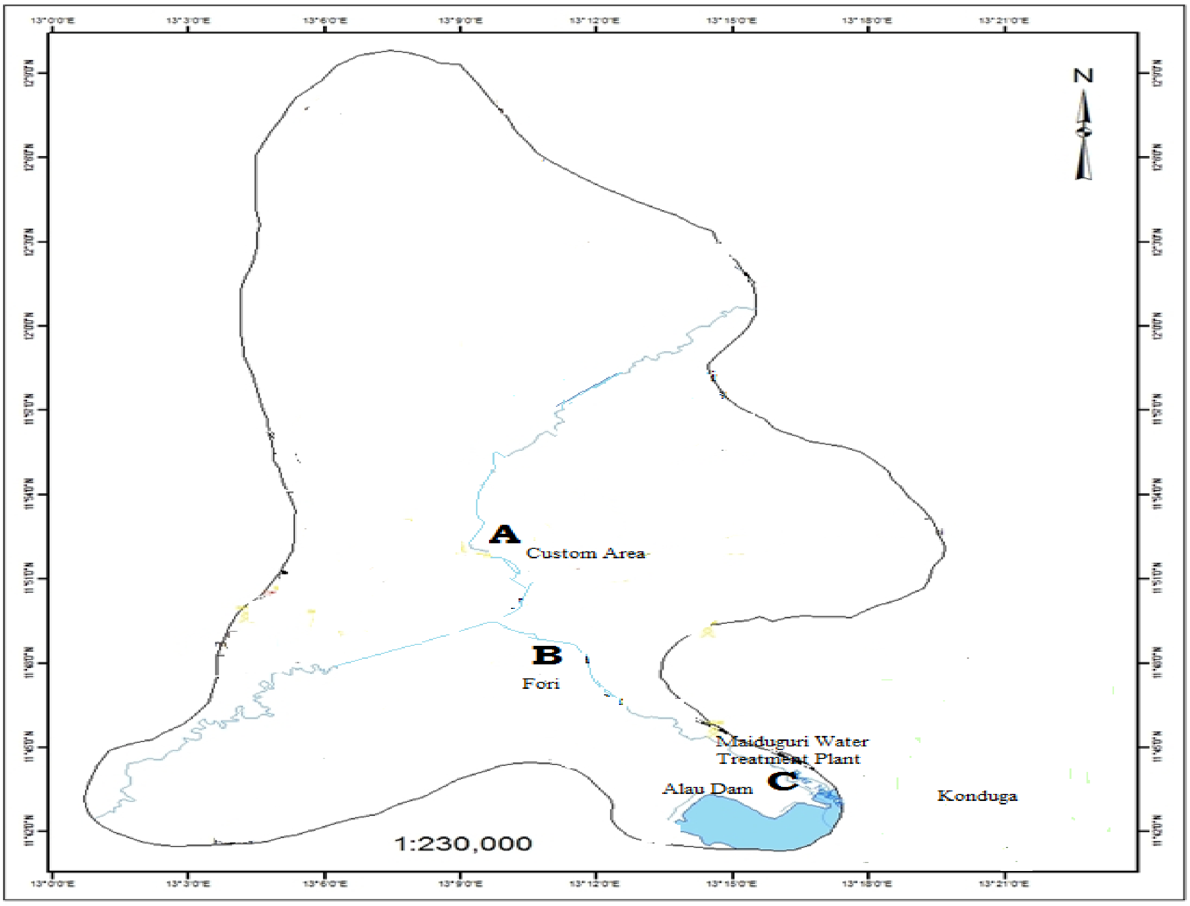


Plate 1: The Map of the Study Area
Source: Sharah, 2020

Sampling 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.

Table 1: The Sampling Stations selected in River Nggada, Maiduguri, Nigeria

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

In terms of vegetation cover, areas of Fori and Water Treatment plant (sampling stations B and C) are covered with mango (*Mangifera indica*) and cashew (*Anacardium occidentale*) plantations. However, Custom area (sampling station A) has no tree cover newly emerging aquatic weeds were observed along the river bank during the irrigational periods (dry seasons) which disappears during non – irrigational periods.

Custom area (sampling station A) has a lot of human interference because it is a commercial area with a populous vegetable market and abattoir located at the bank of the river. The site has also 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. Although, been a commercial area, the station has being witnessing high presence of fishermen during fishing periods with differing fishing gears and boats.

Sampling station B (Fori ward) on one hand is a residential area and 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) is situated along the bank of the river in sampling station C (Behind Water Treatment Plant). The site is also heavily irrigated and the river receives runoffs from the irrigated sites and effluent from the Treatment Plant. The station also witnessed high number of fishermen during fishing periods with boats and local fishing gears.

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

The following parameters were then determined accordingly. For surface water Temperature (°C) mercury thermometer was used (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 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) and 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).

The preserved samples were centrifuged and a drop was placed on a slide. The slide was further covered with a cover slip. The slide was then placed on a compound light microscope and focused both with light on and off at a varying magnification (125, 250 and 1000X) for four (4) minutes(Şeyda and Meryem, 2014).

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

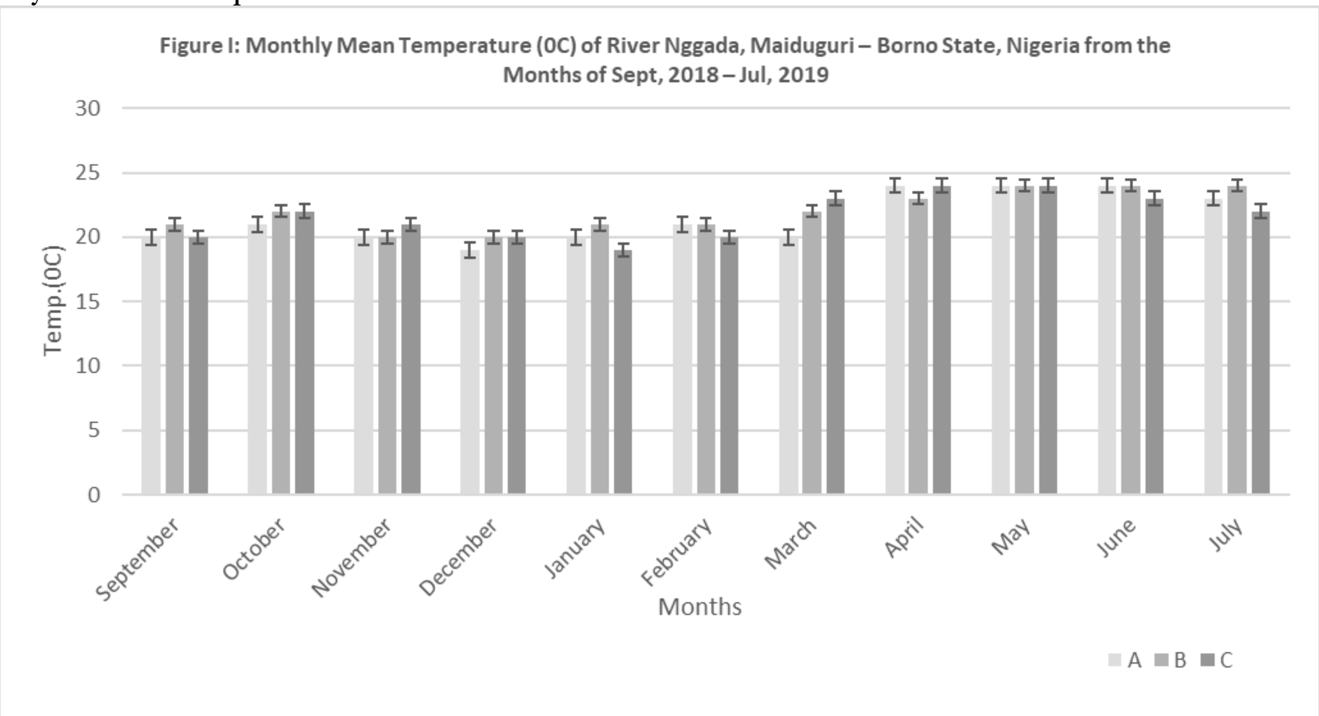
N = total number of all the species of the plankton group

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. Pearson's correlation was employed on the different classes of phytoplankton and also on the physicochemical parameters.

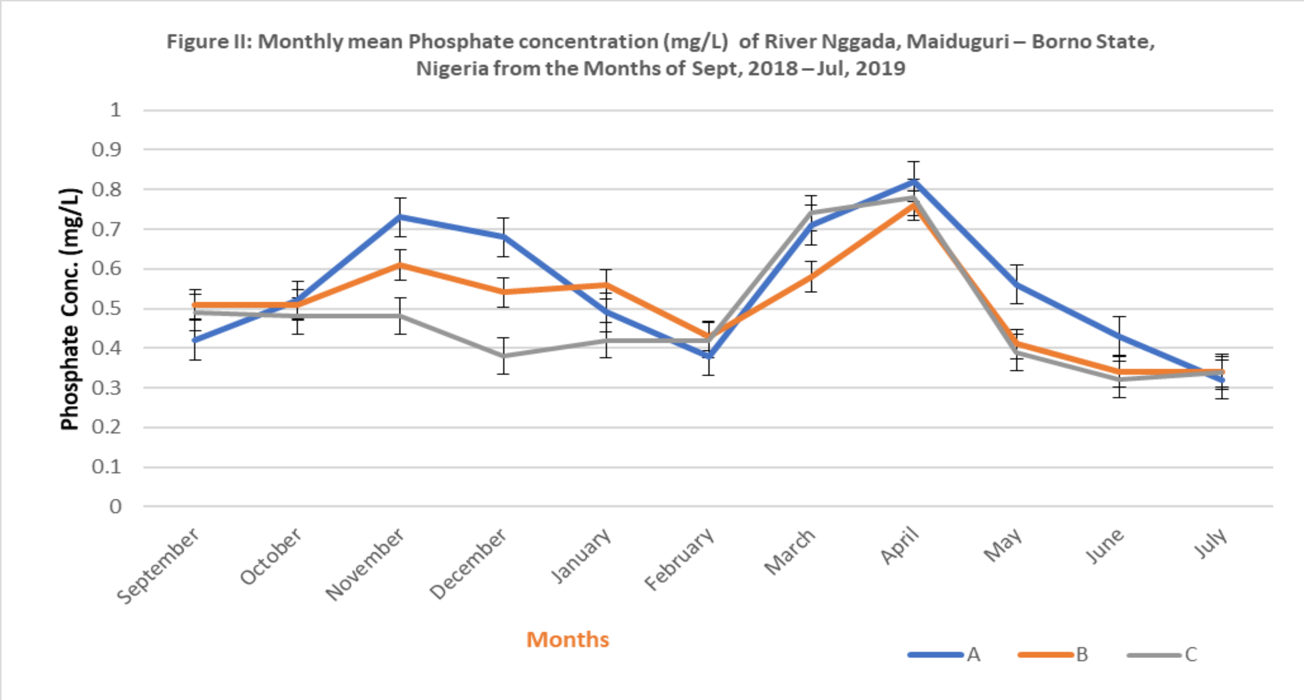
RESULTS

Physico – chemical parameters



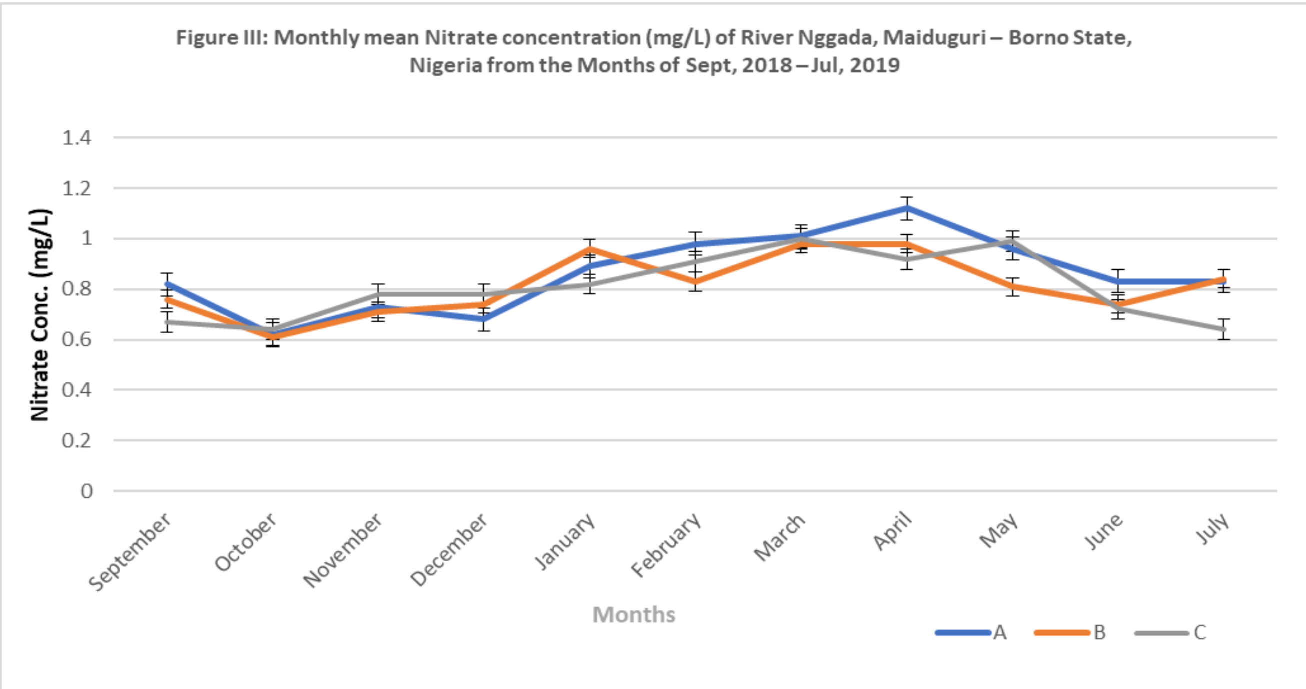
Temperature

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.



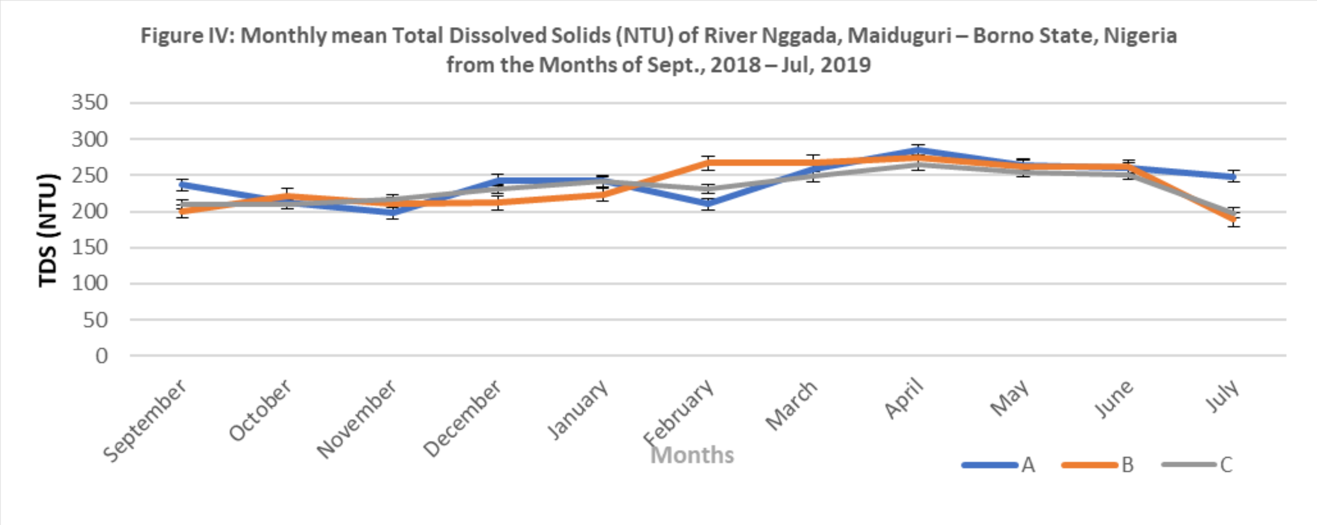
Dissolved Phosphate Concentration

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).



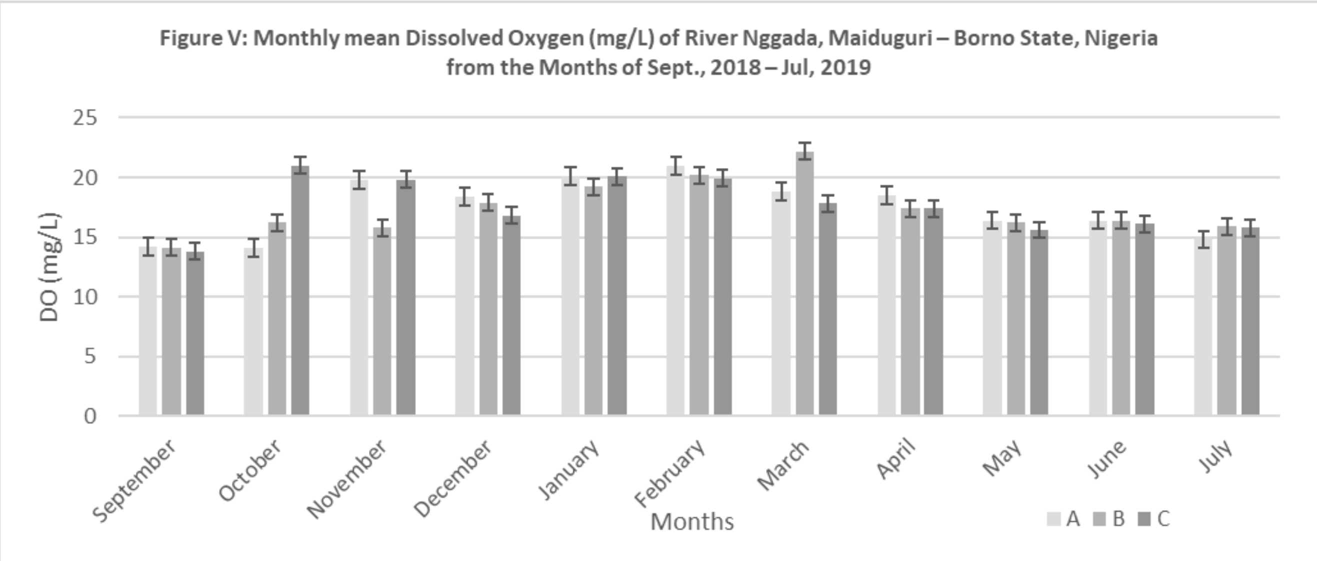
Dissolved Nitrate Concentration

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.



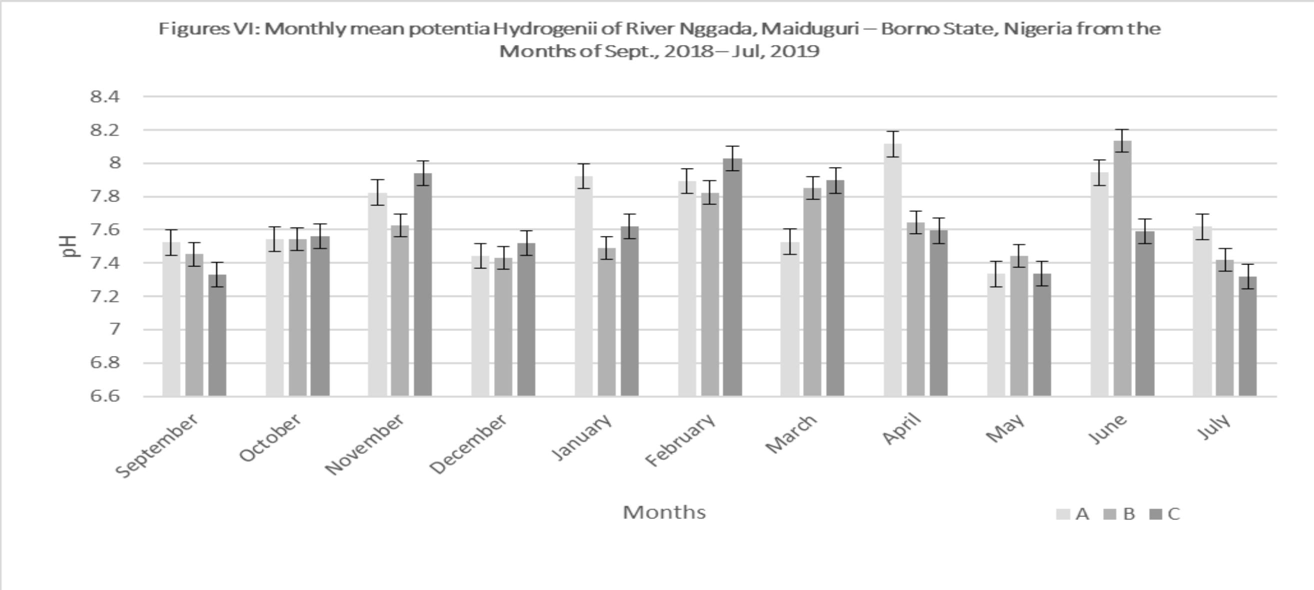
Total Dissolved Solids

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 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 3, 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 during the non – irrigational regime as against the irrigational regime (258 mm^3L^{-1}) as shown in Table 4.

The composition and distribution of phytoplankton across the sampling stations as shown in Table 5 and 6, 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.

Table 3: 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**

Table 4: % Relative abundance of phytoplankton classes in River Nggada, Maiduguri, Nigeria from the Months of September, 2018 – July, 2019

S/N	*CLASS*	*A*	*B*	*C*
A	***Chlorophyceae***	26.4	42.3	31.3
B	***Cryptophyceae***	40.0	45.0	15.0
C	***Chrysophyceae***	23.5	31.8	44.7
D	***Cyanophyceae***	69.4	30.6	0.0
E	***Euglenophyceae***	27.1	44.2	28.7
F	***Rhodophyceae***	32.0	21.6	46.4
G	***Bacillariophyceae***	34.8	49.9	15.3

Table 5: 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 6: The composition of algal genera 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*	-	-	+

DISCUSSION

The concentration of nitrate and phosphate measured 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 the runoffs of non – point source pollutants from nearby farmlands which might have been fertilized with nitrate and/or phosphate containing fertilizers. Chonoi *et al.* (2009) have reported that irrigational runoff may have impacted on nitrate and phosphate of the aquatic environment.

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. 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 issues 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 could be due to the fact that several factors act together to influence the abundance and distribution of aquatic organisms. 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 abundance shows a progressive increase from the months of March – July and the highest phytoplanktonic abundance was recorded in the months of April and May which was marked with high mean surface water temperature. Phosphate and Nitrate concentration were also at their peak, with the highest level of phosphate and Nitrate concentration recorded in the April in Sampling Station A. This suggests that the irrigation runoff which was actively practiced in April coupled with high temprature may had caused high level of evapouration, decreasing the volume of the water thereby increasing the concentration of nutrients which may in turn favoured the abundance and distribution of phytoplankton in that month (George *et al.* 2012; Harris 2012; Bwala 2019). This agrees with Verma and Agarwal (2008), Harris (2012) as well as 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 is good light availability growth, development and subsequent abundance of phytoplankton in the aquatic ecosystem are enhanced.

The lowest phytoplanktonic abundance recorded in the months of December, 2018 and January, 2019 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.

Table 7: Correlation coefficient of the class of phytoplankton of River Nggada, Maiduguri, Nigeria from the Months of September, 2018 – July, 2019

	Chlorophyceae	*Cryptophyceae*	*Chrysophyceae*	*Cyanophyceae*	*Euglenophyceae*	*Rhodophyceae*	*Bacillariophyceae*
Chlorophyceae	1						
Cryptophyceae	0.37	1					
Chrysophyceae	0.18	-0.85	1				
Cyanophyceae	-0.37	0.73	-0.98	1			
Euglenophyceae	0.98	0.56	-0.04	-0.15	1		
Rhodophyceae	-0.60	-0.962	0.68	-0.52	-0.76	1	
Bacillariophyceae	0.62	0.96	-0.66	0.50	0.78	-1.0	1

Table 8: Correlation coefficient of the physico-chemical parameters (Irrigational Regime) of River Nggada, Maiduguri, Nigeria

	Temp. (°C)	Phosphate *(mg/L)*	*Nitrate (mg/L)*	*TDS (NTU)*	*DO (mg/L)*	*pH*
Temperature (°C)	1					
Phosphate (mg/L)	-0.80	1				
Nitrate (mg/L)	-0.5	0.92	1			
Total Dissolved Solids (NTU)	-0.63	0.04	-0.36	1		
Dissolved Oxygen (mg/L)	-0.69	0.99	0.97	-0.13	1	
potentia Hydrogenii	0.5	0.12	0.5	-0.99	0.28	1

Table 9: Correlation coefficient of the physico-chemical parameters (Non - irrigational Regime) of River Nggada, Maiduguri, Nigeria

	Temp. (°C)	Phosphate *(mg/L)*	*Nitrate (mg/L)*	*TDS (NTU)*	*DO (mg/L)*	*pH*
Temperature (°C)	1					
Phosphate (mg/L)	0.13	1				
Nitrate (mg/L)	-0.04	0.99	1			
Total Dissolved Solids (NTU)	-0.17	0.96	0.99	1		
Dissolved Oxygen (mg/L)	-0.28	-0.99	-0.95	-0.90	1	
potentia Hydrogenii	0.69	0.80	0.69	0.59	-0.89	1

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, the physico – chemical parameters (pH, DO, TDS, nitrate and phosphate concentrations) of the study area during irrigation activities were affected and these effects have not impacted on the abundance and distribution of phytoplanktons in the study period. Therefore, algal abundance and distribution during the irrigational periods were low at the same periods when phosphate and nitrate concentrations were high in all the sample stations.

ACKNOWLEDGEMENT

I acknowledged the staff and management of NESREA Borno for granting me permission to use their facilities and acknowledge. My acknowledgement also goes to Mr. Charles Joshua Sharah (Borno State Coordinator NESREA) for the support.

REFERENCE

Abba, A., Musawa, B.B. and Ugya, A. (2016). Study on Physico-Chemical Parameters and Zooplankton Diversity in Kpata Lake, Lokoja Nigeria. Katsina Journal of Natural and Applied Science, 5(2):10-22.[Crossref]

Adeniyi, A.A., Yusuf, K.A. and Okedeyi O. O (2008). Assessment of the exposure of two fish species to metals pollution in the Ogun River catchments, Ketu, Lagos, Nigeia. Environmental Monitoring and Assessment. 137: 451 - 458. [Crossref]

Agouru, C.U. and Audu, G. (2012). Studies on the Range of Plankton in River Benue, North Central, Nigeria Western Africa. Greener Journal of Biological Sciences, 2(2): 028 - 034. [Crossref]

Akan, J.C., Mohammed, Z., Jafiya, L. and Ogugbuaja, V.O. (2013). Organochlorine Pesticide Residues in Fish Samples from Alau Dam, Borno State, North Eastern Nigeria. Journal of Environmental & Analytical Toxicology, 3(3): 1 -9.[Crossref]

Akintola, S.L., Anetekhai, M.A. and Lawson, E.O. (2011). Some Physicochemical Charateristics of Badagry Creek, Nigeria. West African Journal of Applied Ecology, 18: 12 - 21. [Crossref]

Ansa, E.J., Kingdom, T. and Seikorowei, L.B. (2015): Checklist of Plankton of Forcados River, Niger Delta, Nigeria. Nigerian Journal of Fisheries, 12 (2): 21 - 35.

Annalakshmi, G. and Amsath, A. (2012). Studies on the Hydrobiology of River Cauvery and its Tributaries Arasalar from Kumbakonam Region (Tamilnadu, India) with Reference to Zooplankton. International Journal of Applied Biology and Pharmaceutical Technology, 2: 37 - 46.

APHA (American Public Health Association) (2005). Standard methods for the examination of water and wastewater, 21st edition. American Public Health Association.

Bukar, P.H., Zakari, I.Y., Oladipo, M.O.A. and Ibeanu, I.G.E. (2016). Assessment and Distribution of Metal Pollutants in the Sediments of River Ngadda and Alau Dam in Maiduguri, Borno State, Nigeria. American Journal of Research Communication, 4(4): 12 - 21.

Bwala, M.N. (2019). The Abundance of Phytoplankton in River Nggada and River Ngadda-Bul, Maiduguri Metropolis, Borno State, Nigeria. Global Educational Research Journal, 7(7): 820-829.

Bwala, M.N and Tarfa K.B (2020). Impact of Nonpoint Source Pollutant Loadings from Irrigation Sites on River Ngadda, Maiduguri - Borno State. Global Research Journal of Fishery Science and Aquaculture, 8(6): 005-012.

Bwala, M.N. (2021a): Effect of Irrigational Activities on Water Quality of River Ngadda, Maiduguri - Nigeria. Sule Lamido University Journal of Science and Technology, 2(3) 8-18.

Bwala, M.N. (2021b): The Impact of Irrigational Activities on the Abundance and Distribution of Cat Fish (Clarias gariepinus) in River Ngadda, Maiduguri, Borno State. Nigerian Journal of Science and Research, 2(1), 7-12.

Bwala, M.N. (2021c): Impact of Nonpoint Source Pollutant on Fish Biodiversity in River Ngadda, Maiduguri - Borno State. Nigerian Journal of Pure and Applied Sciences, 34(1): 3631 - 3640.

Causapé, J., Quílez, D., and Aragüés, R. (2004). Assessment of irrigation and environmental quality at the hydrological basin level II. Salt and nitrate loads in irrigation return flows. Agricultural Water Management, 70: 211 - 228. [Crossref]

Chonoi, S., Maeda, S, Kawachi, T, Unami, K. and Takeuchi, J. (2009). Dynamics of Nonpoint Source Pollutant Loadings from Agricultural Watershed: A Case Study in Paddy-farming Area with 122 Drainage Water Outfalls Exactly Identifiable. Journal of Rainwater Catchment Systems, 14 (2): 21-28. [Crossref]

Dede, A.N. and Deshmukh, A.L. (2015). Study on Zooplankton Composition and Seasonal Variation in Bhima River near Ramwadi Village, Solapur District (Maharashtra), India. International Journal of Current Microbiology and Applied Sciences, 4(3): 297 - 306.

Edward G.B and David C.S. (2010): Freshwater Algae: Identification and Use as Bioindicator. Wiley-Blackwell Publishers. ISBN: 9780470058145, New Jersey, USA.

George, E.E, Samuel, I.U. and Andem, A.B. (2012). Composition and abundance of Phytoplankton of Adiabo River in Calabar River System, Southeast Nigeria. European Journal of Zoological Research, 1(4): 93 - 98.

Gwana, A.M., Umaru, B.W., Halima, M.B., and Wanas, L.N. (2017). Physico - Chemical Water Quality Analyses of Lake Alau, North - Eastern Nigeria, Journal of Water Resources and Ocean Science, 6(1), 14-22. **[Crossref]**

Harris, F. (2012). Global Environmental Issues. Wiley - Blackwell, A John Wiley & Sons Ltd Publications, UK

Haruna, K.A. and Anthony, D. (2011). Environmental Sciences: An Introductory Text. Apani Publications, Nigeria

Han, M. (1983). Illustration of fresh water plankton. Agricultural Press, Auburn, Alabama, USA.

Luke, M.M. and Nigel, F. (2010). Pollutant Loads Returned to the Lower Murray River from Flood-Irrigated Agriculture. Water Air Soil Pollution, 211: 475-487. **[Crossref**

Monika, P., Małgorzata, W. and Małgorzata, P. (2018). The influence of temperature on algal biomass growth for biogas production. MATEC Web of Conferences, 24: 04-08.

Mukhtar, B., Khiruddin, A. and Mohd, N. (2015). Long-Term Trend and Seasonal Variability of Horizontal Visibility in Nigerian Troposphere. Atmosphere, 6: 1462-1486; **[Crossref]**

NIO (National Institute of Oceanography) (2004). Phytoplankton Identification Manual. Ministry of Environment & Forests, New Delhi, India

NESREA (2011). (National Environmental Standards and Regulations Enforcement Agency) (2011). National Environmental (Surface and Groundwater Quality Control) Regulation, 2011.

NMA (Nigerian Metrological Agency) (2008). Annual Report, Office Memo File North-eastern Nigeria.

Şeyda, E. and Meryem, B.Y. (2014). Phytoplankton Counting and Identification Methods. A Technical Assistance for Capacity Building on Water Quality Monitoring Training Manual. 2 - 34.

Sharah J.C. (2020). Assessment of Base Transceiver Stations Compliance to Environmental Standards in Maiduguri Metropolis, Borno State Nigeria. Unpublished MSc Thesis submitted to the Department of Geography, University of Maiduguri, Borno State - Nigeria.

Spencer, H.G (2001). Optimization in Evolution Limitation. International Encyclopedia of the Social and Behavioral Sciences, Pergamon, Vol(issue):10882-10887, **[Crossref]**

Syed, A.I. (2011). - Pollution: The Ugly Face of Environment. Discovery Publishing House PVT Ltd, New Delhi, India - 110 002. ISBN 978-81-8356-810-4

Usman, Y.M., Mohammed, A., Ibrahim, B. and Saleh, B.A. (2016): - Assessment of Groundwater Quality Status along River Nggada in Maiduguri, Nigeria. International Journal of Engineering and Sciences, 5(1): 08 - 14.

Verma, P.S. and Agarwal, V.K. (2008). Environmental Biology (Principles of Ecology). S. Chand & Company Limited Publishers, India. ISBN: 81-219-0859-0.