

Original Research Article

Spatio-temporal Assessment of Phytoplankton and Physicochemical Parameters of Dangana Lake, Lapai, Niger State Nigeria.

ABSTRACT

Dangana Lake was constructed primarily to provide water for drinking, domestic activities and control flood. Phytoplankton assemblage and physicochemical parameters of Dangana Lake, Lapai, Niger State Nigeria were investigated monthly between March and October 2019 using standard methods and procedures. Water samples were collected from 3 different stations in the Lake. The result of the lake shows water temperature (23.2-29.5°C), Biochemical oxygen Demand (2.30-3.91mg/l), Dissolved oxygen (3.40-4.70mg/l), water pH (6.10-7.5), Electrical conductivity (60.00-121µS/cm), Nitrates (0.30-1.05mg/l) and Phosphate (0.53-1.75mg/l). Temperature, DO, BOD₅, and pH shows no significant difference ($p>0.05$) among sampling sites, however, Electrical conductivity, Nitrate and Phosphate differs significantly among sampling sites ($p<0.05$). Seasonally there was a significant difference ($p<0.05$) among sampling months in all the physicochemical parameter measures. A total of Seventeen (17) species of phytoplankton in six (6) families were encountered. The percentage abundant of phytoplankton revealed Bacillariophyta (36.84%), Dinophyta (33.38%), Chlorophyta (17.05%), Heterokontophyta (6.93%) Cyanophyta, (4.76%), and Euglenophyta (1.02%). Phytoplankton population was significantly higher during the dry season than in the raining season. The Canonical Correspondence analysis (CCA) correlated positively between the measured physicochemical parameters and the observed organisms. The nutrient status of the lake shows a medium range as indicated by the measured environmental parameters.

Keyword. Planktons, Phytoplankton, Physicochemical parameters, Dangana lake

INTRODUCTION

In Nigeria, and many parts of the world, man-made lakes or reservoir is of great value to man. [1]. They are very beneficial to man in which they serve as a means of flood control, biodiversity life support, domestic water supply, irrigation and industrial water sources [1,2]. Lakes are widely utilized by Mankind over the centuries because they constitute a very important part of our heritage [2]. Interaction occurs between living and non-living components of an aquatic basis environment [3,4].

Biodiversity is heterogeneously distributed to biological communities varying in location, space, and time [5,6]. The assessment of the population of various organisms at any particular location and time form a basis of understanding the trophic state of that biological environment [7]. Species abundance and richness are important indicators in understanding changes in the aquatic environment [8]. Health status of aquatic ecosystem is dependent on the physico-chemical properties and biological diversity of the water body [9]. The physical and chemical characteristics of a lake determine the occurrence, diversity and density of both flora and fauna of any aquatic habitat [10,11]. Changes in the physicochemical characteristics of provide valuable information on water quality of an aquatic environment [10,12] In Nigeria, most aquatic ecosystem is threatened by different anthropogenic activities [4,6,10,13]. Planktons are sensitive to the environment in which they live and any change in the environment leads to change in their communities in view of tolerance abundance, diversity and dominance in a particular habitat [1]. Planktons are widely considered as an indicator of environmental health and productivity [14], they are also large consumed by fishes and other higher animals in food chains [3].

The productivity of any water body is determined by the amount of plankton it contains as they are the major primary and secondary producers [15]. Phytoplankton are among the most important biotic component influencing all the functional aspect of an aquatic ecosystem such as food web, food chains, energy flow and cycling matter [16]. The used of phytoplankton to evaluate the trophic state status of the aquatic environment is becoming a novel practice in water maintenance for both aquaculture and portable water [17,18]. This study evaluates the spatial and temporal variation in abundance of Phytoplankton in relation to environmental variables of man-made lake in Northcentral Nigeria.

MATERIALS AND METHODS

Description of Study Area.

The study was carried out at Dangana lake, Lapai, Niger state, Nigeria. This lake is located within longitude 6°36'29.6'E and latitude 9°02'12.02N with elevation of 159m above the sea level. The vegetation of the area reflects that of Savannah zone, the vegetation is mixed, prominent ones include Malaina (*Gmeliana arborea*) Locust beans (*Parkia biglobosa*) Neem (*Azadirachta indica*) and other sparsely native trees and grasses. The climate presents two distinct seasons, a rainy season between April and October, and a dry season (November-March) completely devoid of rain.

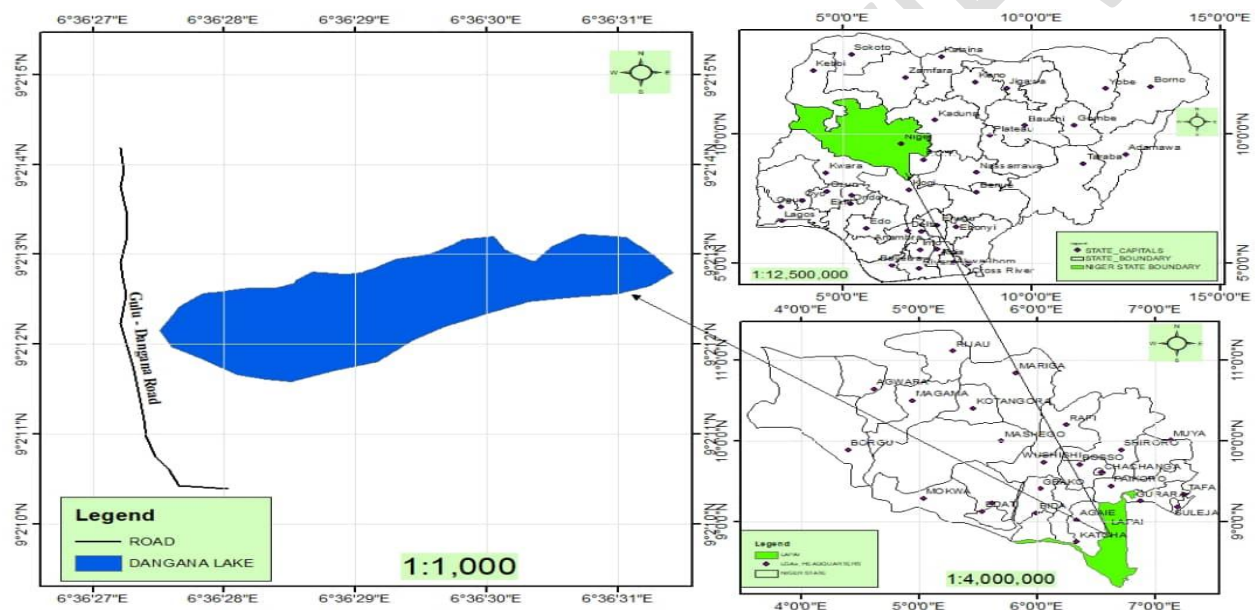


Figure. 1: Map of the study area showing Dangana Lake Lapai, Niger State Nigeria.

Sampling station

Station 1: This is the entry point of water into the lake, it is the place where the lake received its water sources from nearby wetlands and it has few human activities taking place such as fetching of water for drinking and other domestic use.

Station 2: This is a place with high anthropogenic activities. Human activities in this station vary which include laundry, car wash and other domestic activities.

Station 3: This station is free of human activities; it is the quiet region of the lake. It has an opening which allows water to move out of the lake when there is excess water in the lake due to flood or excessive rainfall

Sampling technique

Determination of physicochemical parameters

Water samples for physicochemical parameters were collected monthly between March and October, 2019 from three selected sampling sites in the lake. Sampling period covers both dry and wet season. On the sampling site physicochemical parameters including Water Temperature, Dissolved oxygen (DO), Conductivity and pH were measured using the multipurpose Meter (HANNA model 1910). BOD₅, Nitrate and Phosphate were determined by the methods described by APHA[19]

Phytoplankton Sample Collection

Phytoplankton samples were collected by horizontal towing using a standard plankton net with a mesh size of 20.0µm with a small bottle container attached of 50ml attached to its narrow end. The samples collected were immediately preserved in 4% formalin and transported to the laboratory for further analysis. In the laboratory, phytoplanktons were identified by pipetting 1ml of water sample from field samples and place on a slide which was mounted under light microscope and view under magnification (×40, ×100), counting of planktons was done by counting each cell as individual [20]. Identification was done by comparing the specimen with plankton identification charts [21-24]

Data Analyses

The physicochemical parameter data were subjected by descriptive statistical test, using Microsoft Excel 2010. The mean, range and standard error of each physicochemical characteristic were calculated per station. Physicochemical variables among all stations and months were compared using one way analysis of variance (ANOVA). Biological indices such as taxa richness, evenness indices, diversity index and dominance were also analyzed. Canonical correspondence analysis (CCA) was used to determine the relationship between phytoplankton communities and environmental variables using the paleontological statistical software (PAST).

RESULTS

Physicochemical parameters

The physicochemical parameters of sampling sites of Dangana lake Lapai Niger state for a period of Eight months (March-October 2019) is presented in Table 1. From the entire sampling

site, temperature ranged from 23.5 ± 29.0 in site C to 26.65 ± 0.74 in site B. Dissolved oxygen ranged from 3.98 ± 0.5 in site B to 4.13 ± 0.20 in site C. The Biochemical oxygen demand ranged from 3.00 ± 0.14 in site A to 3.12 ± 0.19 in site C. The pH ranges from 6.88 ± 0.14 in site A to $7.05 \pm$ in site B. The electrical conductivity ranges from 86.43 ± 8.57 in site A to 94.8 ± 8.54 in site C. Nitrate ranged 0.67 ± 0.09 in site C to 0.76 ± 0.08 in site B and Mean phosphate value of 0.85 ± 0.11 in site C to 1.04 ± 0.12 in site B. Temperature, DO, BOD₅, and pH shows no significant difference ($p > 0.05$) among the sampling sites. However, electrical conductivity nitrate and phosphate differs significantly among sampling sites ($p < 0.05$). Seasonally there was a significant difference ($p < 0.05$) among sampling months in all the physicochemical parameter measures.

Table1. Mean value of physicochemical parameters of Dangana Lake, Lapai (March-October 2019)

Parameters	Stations			Probabilities	
	Site A	Site B	Site C	Stations	Months
Water temperature (°C)	26.41 ± 0.38 (23.20-29.50)	26.65 ± 0.74 (23.50-29.00)	23.5 ± 29.0 (24.60-28.90)	0.716	5.81E-06
DO (Mg/l)	4.02 ± 0.10 (3.60-4.40)	3.98 ± 0.15 (3.40-4.50)	4.13 ± 0.20 (3.40-4.70)	0.538	0.001
BOD ₅ (Mg/l)	3.00 ± 0.14 (2.3-3.5)	3.08 ± 0.18 (2.3-3.8)	3.12 ± 0.19 (2.2-3.8)	0.37	3.40E-07
pH	6.88 ± 0.17 (6.1-7.4)	7.05 ± 0.12 (6.3-7.5)	6.98 ± 0.11 (6.5-7.4)	0.13	1.29E-06
Conductivity (μ/Sm)	$86.43 \pm 8.57^*$ (60-120)	91.42 ± 9.04 (65-125)	94.80 ± 8.54 (65-121)	0.02	1.97E-08
Nitrate (Mg/l)	0.68 ± 0.08 (0.3-1.05)	$0.76 \pm 0.08^*$ (0.4-1.15)	0.67 ± 0.09 (0.3-1.05)	0.002	8.25E-12
Phosphate (Mg/l)	0.90 ± 0.10 (0.55-1.5)	$1.04 \pm 0.12^*$ (0.67-1.75)	0.85 ± 0.11 (0.53-1.55)	7.38E-05	3.51E-11

Note; values are Mean±S.E; range in parenthesis; values with asterisk (*) differs significantly

Phytoplankton assemblage and distribution in Dangana lake

A total of Seventeen (17) species of phytoplankton in six (6) divisions was identified in Dangana Lake, Lapai Niger state. Four (4) species of Dinophyta, three (3) species of Chlorophyta, two (2) species of Heterokontophyta, five (5) species of Bacillariophyta, one (1) species of Euglenophyta and two (2) species of Cyanophyta were identified as presented in Table 2. The percentage abundant revealed that Bacillariophyta (36.84%)>Dinophyta(33.38%)> Chlorophyta (17.05%)>Heterokontophyta (6.93%)>Cyanophyta (4.76%)> Euglenophyta (1.02%).

Table2. Phytoplankton composition, distribution and percentage abundance in Dangana Lake, Lapai during the sampling periods

Division	Species	Site A	Site B	Site C	%
Dinophyta	<i>Linguilodinium sp.</i>	21	8	36	
	<i>Akashiwo sp</i>	15	12	7	
	<i>Amylax sp</i>	13	33	18	
	<i>Nuctiluca sp</i>	30	28	10	
	Total	79	81	71	33.38
Chlorophyta	<i>Chlorellasp</i>	7	36	10	
	<i>Volvox sp</i>	10	6	10	
	<i>Spirogyra sp</i>	9	15	15	
	Total	26	57	35	17.05
Hoterokontophyta	<i>Pseudo-nitzchia sp</i>	18	7	9	
	<i>Chaetoceros sp</i>	5	4	5	
	Total	23	11	14	6.93
Bacilliariophyta	<i>Skeletonema sp</i>	28	10	20	
	<i>Nitzchia sp</i>	15	28	12	
	<i>Diatoma sp</i>	25	13	14	
	<i>Fragillaria sp</i>	26	8	7	
	<i>Navicula sp</i>	31	8	10	
	Total	125	67	63	36.84
Euglenophyta	<i>Euglena sp</i>	2	2	3	
	Total	2	2	3	1.01
Cyanophyta	<i>Oscillatoria sp</i>	5	7	0	
	<i>Chrococcus sp</i>	9	5	7	
	Total	14	12	7	4.76

Spatio-temporal distribution of plankton

Spatial distribution of phytoplankton in all sampling sites shows high abundance in the month of March, April and May. There was a decrease in population in the months of June, July, August, September and October. Phytoplankton population was significantly higher during the dry season than in raining season as shown figure 2.

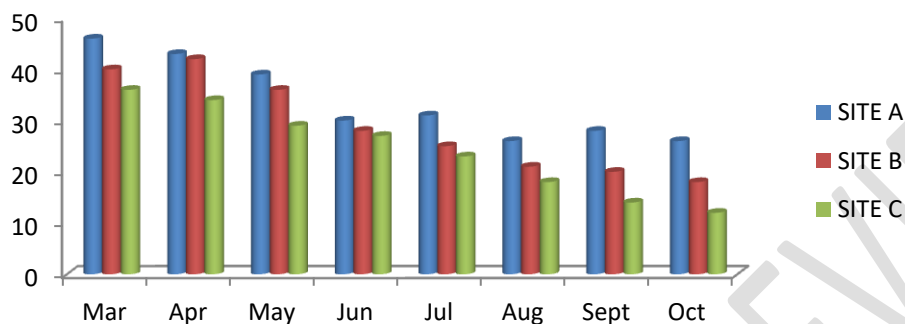


Figure2: Monthly distribution of phytoplankton in Dangana lake

Diversity indices of recovered planktons from Dangana Lake Lapai Niger state

The results of the diversity indices indicate that the lake varied within study station in term of diversity and species distribution. A total of 17 phytoplankton species were recorded in site A and site B of the lake with 269 and 230 individuals respectively while site C recorded 16 species with 193 individuals. Site A recorded dominance index of 0.078, site B recorded indices of 0.0938 followed by site C with 0.087. Shannon and Everest indices operate in a similar pattern by recording highest values in site A, then site C and the lowest values are recorded in site B. Site B recorded highest Margalef's index value of 2.94 and site A and C recorded value of 2.86 and 2.85 respectively (Table 3).

Table 3. Phytoplankton diversity indices value of Dangana lake Lapai Niger State, Nigeria

	Site A	Site B	Site C
Taxa_S	17	17	16
Individuals	269	230	193
Dominance_D	0.0787	0.0938	0.08717
Shannon_H	2.653	2.566	2.608
Evenness_e^H/S	0.8355	0.7652	0.828
Margalef	2.86	2.942	2.85

Phytoplankton and environmental parameters of Dangana lake Lapai Nigers state.

The Canonical Correspondence analysis (CCA) shows a strong positive correlation with the physicochemical parameters and the observed organism. CCA Axis1 account for 68.16% of the specie while Axis2 account for 31.84% of the total species as shown in table 4. From the CCA ordination plot organism in Axis 1 where positively influence by nitrate, phosphate, temperature and biochemical oxygen demand. Organism in Axis 2 correlated positively with pH, electrical conductivity and dissolved oxygen. Organism associated with CCA axis1 are *Oscillatoris* sp, *Nitchia* sp, *Chroccocus* *Flagillania* sp, *Skeletonema* sp, *Navicula* sp, *Pseudo-Nitchia* sp, *Chaetus* sp, *Akashiwo* sp, *Nuctiluca* sp Organisms associated with CCA Axis 2 are *Lingollidium* sp, *Ceriodaphnia* sp, *Amylax* sp, *Euglena* sp, *Volvox* sp, p and *Spyrogyara* sp as shown in figure 3.

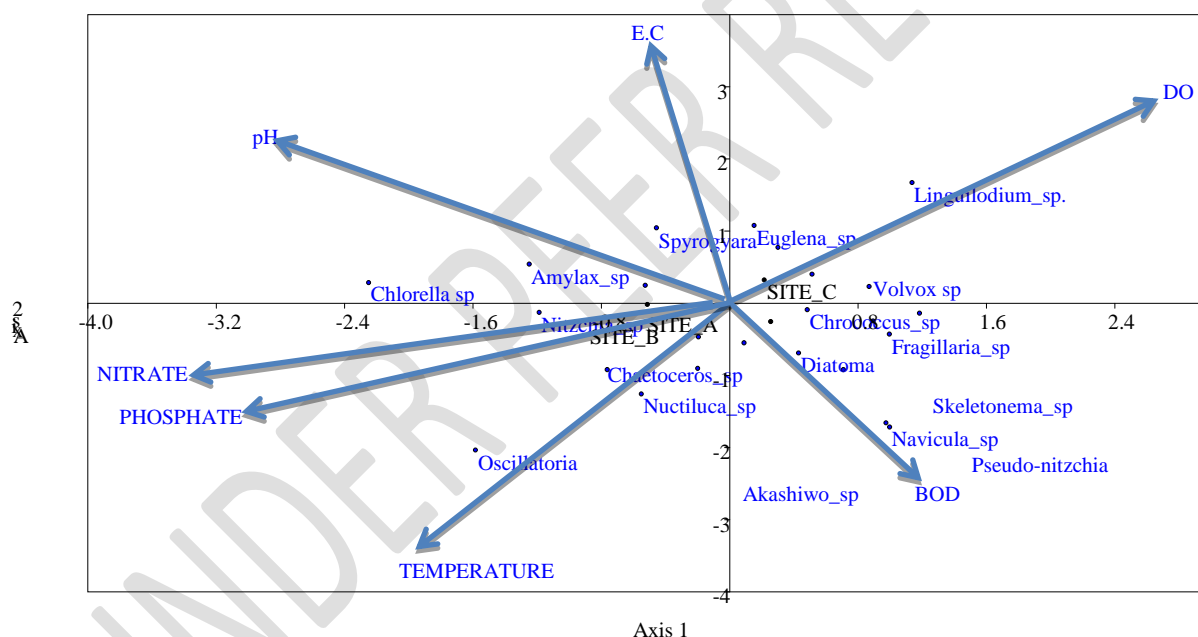


Figure 3. CCA ordination plot for phytoplankton species among sampling sites of Dangana lake Lapai Niger state

Table 4. Weighted intraset correlation of engine value parameters with axis of CCA

	Axis1	Axis 2
Eigenvalue	0.1218	0.056896

%	68.16	31.84
Temperature	0.518952	-0.882061
DO	-0.67248	0.775994
pH	-0.25542	0.87453
BOD	0.234387	0.957775
E.C	-0.15642	0.977589
Nitrate	0.989068	-0.201652
Phosphate	0.954414	-0.350546

DISCUSSION

Physicochemical parameters

The conservation and management of water ecosystem is critical to the interest of the entire mankind, as long as biodiversity constitutes valuable natural resources in socio-economic, cultural, aesthetic, scientific and educational terms [25]. The physical and chemical characteristic of the lake shows general and similar trends that have been reported for other lakes in Nigeria [26]. The seasonal trend in the concentrations of Dissolved oxygen, Biochemical Oxygen demand, pH, Nitrate and Phosphate in the lake is in conformity with the usual pattern for most inland waters in Nigeria [12,27]. The result of the physicochemical parameters obtained in these studies shows no significant difference among sampling station ($p > 0.05$) except Conductivity, Nitrate and Phosphate. All the physicochemical parameters show spatial and temporal variation between sampling months; this could be as a result of some natural factors and different anthropogenic activities taking place around the lake [10,28].

Water temperature of Dangana Lake Lapai Niger state was within the normal temperature range of 20 to 30°C required by aquatic organisms for metabolic activities [28]. The water temperature was moderate throughout the sampling period due to high rainfall and minimum amount of sunlight. The Dissolved oxygen (DO) concentration observed in this study ranged from 3.40 to 4.70mg/l. Higher DO value were recorded during raining season than in the dry season, this could be due to increase in volume of water in raining season and high temperature coupled with high sunlight intensity in the dry season [28,29]. Biochemical oxygen Demand (BOD) concentration ranged from 2.30 to 3.91mg/l. The higher BOD concentration recorded in raining

season was as a result of influx of organic matters into the lake through surface **run-off** [15]. The water pH (Hydrogen ion concentration) range from 6.10 to 7.5 obtained from all the sampling sites was close to neutral in both seasons. The pH value obtained from Dangana Lake slightly falls within the recommended pH of 6.5-8.5 for productivity in natural waters [12]. Electrical conductivity (E.C) value ranged from 60.00 to 121 μ S/cm obtained from the sampling sites of Dangana lake Lapai Niger state. The **high** electrical conductivity value observed in rainy season could be attributed to high amount of suspended and dissolved solid material and increases the concentration of dissolved cation such as calcium, magnesium and sulphate in the sampling sites [13].

Nitrates and Phosphate are among the limiting factors in aquatic environment [30]. This study revealed **a** high value of Nitrate and phosphate in the raining season which could be high anthropogenic activities around the lake and surface **run-off** from the surrounding [6,13].

Spatial and temporal variation in Phytoplankton assemblage of Dangana lake

Plankton abundance and distribution are affected by seasonal changes of both physical and chemical parameters as well as microplant life in aquatic environments [31]. Changes in plankton population in the lake could be distributed to various species having different nourishment in temperature, pH, Do, BODs and nutrients [32]. High nutrient **levels** such as nitrate and phosphate enhance the growth of Bacillariophyta which forms the major diet of **zooplankton** [32]. In this study a significant abundance of some phytoplankton species were observed this could be attributed to increase in the intensity of solar radiation that can be captured by phytoplankton, hence increased photosynthesis and other metabolic activities which lead to **a** subsequent increase in population density of planktons [12,33]. Dinophyta, Chlorophyta, Heterokontophyta, Bacillariophyta, Euglenophyta and Cyanophyta were the phytoplankton groups encountered in the lake. Their presence has also been reported in other freshwater bodies of Nigeria [26,34,35]. The dominance of diatoms in this study could be due to the fact that they can withstand broadly changing hydrographical conditions [26]. Similarly, high intensity of the light in the tropics favors the development of Chlorophyta [26]. Increase in domestic, agricultural and industrial pollution in lakes accelerate the growth of Chlorophyceae and Cyanophyceae [36]. Wetzel [37] stated that the predominance of **diatom** population in a lake is an indication of eutrophic conditions. Several among the diatoms observed in Dangana lake

are *Nitzschia* sp. and *Navicula* sp. which are good indicators of pollution as described by Palmer [38]. *Spirogyra* sp and *Oscillatoria* sp. are also pollution indicator species belonging to chlorophyceae [12]. The presence of *Euglena* sp. is a direct indication of pollution load because this specie is generally, considered to be dominant and tolerant genera of polluted ponds [38].

There is a great seasonal influence on abundance of the green algae in Dangana Lake as plankton population increases during the dry season and decreases during wet season. The low abundance of planktons observed during the wet season could best be attributed to further dilution of essential growth nutrients in the area [26]

Conclusion

Dangana Lake shows seasonal variation in physicochemical parameters and phytoplankton assemblage within the study period. There were different anthropogenic activities at the lakeshore and within the lake. The nutrient status of the lake shows a medium range as indicated by the measured environmental parameters.

Competing interests disclaimer

Authors have declared that no competing interests exist. The products used for this research are common and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

REFERENCES

1. Akachukwu EN, Arimoro FO, Keke UN, Ayanwale AV. Zooplankton community structure and seasonal variation in a Tropical Lake in Nigeria. 2nd Annual conference of Freshwater Biological Association of Nigeria, Books of proceeding 2019;47-57.
2. Magami IM, Ibrahim S. Limnological variables and algal diversity of Shagami Reservoir Sokoto. *The zoologist*, 2016;14: 1-6
3. Tanko D, Chia MA, Nuhu G. Zooplankton community structure and dynamics during the transition from dry to rainy season: A case study of Kufena Inselberg(Rock) pool Zaria Nigeria. *The Zoologist* 2016;14: 7-13
4. Mohammed YM, Arimoro FO, Ayanwale AV, Adama BS, Keke UN, Auta YI, Umar BL. Seasonal changes in the abundance of benthic macroinvertebrates & physico-chemical condition of Moussa stream Bida, Nigeria. *Tropical Freshwater Biology*. 2020;29(1): 57-70.
5. Soininen J, Heino J, Wang J. A meta-analysis of nestedness and turnover components of beta diversity across organism and ecosystems. *Global ecology and Biogeography*, 2018;27(1): 96-109
6. Mohammed YM, Arimoro FO, Ayanwale AV, Adamu KM, Keke UN, Abubakar, MD, Achebe AC. The current state of water quality and benthic invertebrate fauna in Chikke Stream (North-Central Nigeria). *Ukrainian Journal of Ecology*. 2021;26-34, https://doi.org/10.15421/2021_136.
7. Hamed AE, Hala SA, Farhad AA, Rizwan I, Saleh AA, Esam S. Aquatic ecosystem health and trophic status classification of the bitter lakes along the main connecting link between the Red Sea and the Mediterranean. *Saudi journal of biological sciences* 2018;25(2): 204-212.
8. Moura LCS, Santos SM, Souza CA, Santos CRA, Bortolini JC. Phytoplankton richness and abundance in response to seasonality and spatiality in a tropical reservoir. *Acta Limnological brasiliensa*. 2021;33(3).
9. Mohammed AZ, Agbaja JE, Arimoro FO. Zooplankton community response to deteriorating water quality in Tungan Kawo (Wushishi Dam), Northcentral Nigeria. *International Journal of innovative research and advance studies*. 2016;3(4): 51-56.
10. Mohammed YM, Arimoro FO, Ayanwale AV, Adamu KM, Ismail A, Umar M, Kanki H. Assessment of some physicochemical parameters of Moussa stream, Bida, Niger State Nigeria. *Journal of Public Health and Environmental Pollution*. 2020;4(2):020-024.
11. Ayodele HA, Adeniyi IF. The zooplankton fauna of Sia impoundment on the River Osun, Southern Nigeria. *The zoologist* 2006; 4:49-67.
12. Mustapha MK. Seasonal influence of Limnological variables on plankton Dynamics of a small shallow Tropical Reservoir. *Asian Journal of Experimental Biological Sciences*. 2010;1(1): 60-79.

13. Arimoro FO, Keke UN. The intensity of human-induced impact on the distribution and diversity of Macroinvertebrates and water quality of Gbako River, North Central Nigeria. *Energy Ecology and Environment* 2016.
14. Aniel KT, Girish C, Seema K. Zooplankton Diversity in shallow lake of Su-Itampour National park Gurgaon (Haryana). *International journal of Applied Biology and Pharmaceutical Technology*, 2014;5(1): 35-40.
15. Davies OA, Abowei JFN, Tawari CC. Phytoplankton community of Elechi Creek, Niger Delta, Nigeria- A nutrient polluted tropical creek. *American Journal of Applied Sciences*, 2009;6(6): 1143-1152.
16. Park KS, Shin HW. Studies in phytoplankton and zooplanktons composition and its relation to fish productivity in a west coast fish pond ecosystem. *Journal environmental Biology*. 2007; 28:415-422.
17. Offem BO, Ezikiei OA, Gabriel UI, Ada FB, Steven NO. Plankton based assessment of the Trophic state of three tropical lakes. *Journal of environmental protection*. 2011;2: 304-315.
18. Mohammed AZ, Arimoro FO. Olayemi IK, Ajai AI, Auta YI, Ayanwale AV. Zooplankton community structure and seasonal variation in a Tropical Lake in Nigeria. 2nd Annual conference of Freshwater Biological Association of Nigeria, Books of proceeding. 2019;160-169.
19. APHA (American Public Health Association) Standard methods for examination of water and wastewater. New York. 2012.
20. Tash JC. The zooplankton of fresh and brackish water of the cape Thompson area Northern Alaska. *Hydrobiologia*, 1971;38(1): 93-121
21. Shiel RJ. A guide to identification of rotifers, cladocerans and copepods from Australian inland waters. Water cooperative research center for freshwater Ecology and identification guide 1995;3 1-150
22. Botes L. Phytoplankton identification catalogue, Saldanha Bay South Africa, Globallast monograph Series no7. IMO London. 2003; 10-86
23. Perry R. A guide to the marine plankton of southern California. <http://www.msc.ucla.edu/oceanglobe> retrieved 28th July 2014
24. Witty LM. Practical guide to identifying freshwater crustaceans zooplankton. Cooperative freshwater ecology unit. 2004;2nd edition
25. Miaomiao Y, Shengnan C, Tinglin H, Baoqin L, Nan L, Kaiwen L, Rongrong Z, Yutian M, Xin H.. Community Compositions of Phytoplankton and Eukaryotes during the Mixing Periods of a Drinking Water Reservoir: Dynamics and Interactions. *International Journal of Environmental Research and Public Health*. 2020;17: 1128-1137.

26. Yusuf ZH. Phytoplankton as bioindicators of water quality in Nasarawa reservoir, Katsina State Nigeria. *Acta Limnologica Brasiliensia*. 2020;32(4): 17-29.
27. Akindele EO, Adeniyi IF, Indabawa I. Spatio-temporal assessment and water quality characteristics of Lake Tiga, Kano, Nigeria. *Research Journal of Environmental and Earth Sciences*. 2013;5(2): 67–77.
28. Mustapha MK. Assessment of the Water Quality of Oyun Reservoir, Offa, Nigeria, Using Selected Physico-Chemical Parameters. *Turkish Journal of Fisheries and Aquatic Sciences*, 2008; 8: 309-319.
29. Raji MIO, Ibrahim YKE, Tytler BA, Ehinmidu JO. Physicochemical Characteristics of Water Samples Collected from River Sokoto, Northwestern Nigeria. *Atmospheric and Climate Sciences*. 2015;5: 194-199.
30. Arimoro FO, Odume NO, Uhunoma SI, Edegbene AO. Anthropogenic impact on water chemistry and benthic macroinvertebrate associated changes in a southern Nigeria stream. *Environment Monitoring Assessments*. 2015; 187: 1-14.
31. Norris B, Laws EA. Nutrients and phytoplankton in a shallow Hypereutic Urban lake, prospects for restoration. *Water*, 2017;9 (431): 2-11.
32. Chia AM, Adelanwa MA, Ladan, Z, Lortsuun DN, Adanyi SE, Stephen BJ. Interaction of ipomoea aquatica and ultricularia reflex a with phytoplankton densities in a small water bodies in Northern Nigeria. *Oceanology and Hydrobiology studies*. 2012; 41(2): 39-47.
33. Tanimu Y, Bako SP, Adakole JA, Tanimu J. Phytoplankton as bioindicators of water quality in Saminaka reservoir, Northern-Nigeria. *International Symposium on Environmental Science and Technology*. Dongguan, Guangdong Province, China; Environmental Science and Technology. 2011; 12: 83-87.
34. Magami IM, Adamu T, Aliero AA. Physicochemical Flux and Phytoplankton diversity in Shagari Reservoir, Sokoto, Nigeria. *Nigerian Journal of Basic and Applied Science*. 2014;22 (3&4): 67-72.
35. Essien-Ibok MA, Ekpo I. Assessing Environmental Impact on Phytoplankton Composition and Distribution in a Tropical River in Southern Nigeria. *International Journal of Engineering Science*. 2015;5(7): 40–48.
36. Anago IJ, Esenowo IK, Ugwumba AA. The Physico-chemical and Plankton Diversity of Awba Reservoir University of Ibadan, Ibadan. *Nigeria Research. Journal of Environment and Earth Science*. 2013; 5(1): 638-644.
37. Wetzel RG. *Limnology: Lake and river ecosystems*. 3rd ed. Academic Press, San Diego, CA. 2001: p1-100
38. Palmer CM *Algae & Water Pollution*. Castle House Publishers Ltd, England: 1980; p1-150