Anchor University Journal of Science and Technology (AUJST)
A publication of the Faculty of Science and Science Education, Anchor University Lagos

URL: journal.aul.edu.ng

In AJOL: https://www.ajol.info/index.php/aujst

Vol. 3 No 1, December 2022, Pp. 194 - 202

ISSN: 2736-0059 (Print); 2736-0067 (Online)

PHYTOPLANKTON AS BIO-INDICATOR TO ASSESS POLLUTION STATUS OF YARDANTSI RESERVOIR, GUSAU, NIGERIA

Jabbi A.M.[1*]; Isah B.[2]

[1]Department of Biological Sciences, Faculty of Science, Federal University, Gusau
[2]Department of Biological Sciences, Faculty of Science, Nigeria Police Academy, Wudil

***Corresponding author:**
E-mail: jabbiam@fugusau.edu.ng

Competing Interests: The authors declare no competing interests.

ABSTRACT

Background: Phytoplankton are hydrophytes with photosynthetic ability, they play a vital role in the aquatic food chain; the herbivorous zooplankton feed on them and in turn serve as an energy source to animals in higher trophic levels, fishes inclusive.. Yardantsi Reservoir is the main source of water for Gusau populace; it receives both organic and inorganic waste through runoffs from the catchment area.
Objectives: The study aimed to determine the status / water quality and productivity of Yardantsi Reservoir, Gusau using phytoplankton as a bio-indicator.
Methods: The samples were collected between May, 2015 and April, 2017 using standard methods. Four (4) groups of phytoplankton (viz; Bacillariophyta, Chlorophyta, Cyanophyta and Dinophyta) comprising eleven (11) various species were observed.
Results: Bacillariophyta, Chlorophyta, Cynophyta and Dinophyta account for 27.25%, 39.29%, 11.50% and 21.96% respectively. Similarly; Bacillariophyta, Chlorophyta, Cynophyta and Dinophyta recorded 25.51%, 35.17%, 12.84% and 26.48% for the dry season and 28.36%, 41.90%, 10.65% and 19.10% for the rainy season respectively. The first two PCA components accounted for 89.6% and 9.3% respectively, making a total of 98.9% of the total percentage variance observed. Phytoplankton exhibited a positive correlation with temperature, NO_3-N, pH and dissolved oxygen; highly positive correlation with sulphur and PO_4-P; negative correlation existed with hardness, alkalinity, total dissolved solids, transparency, chloride and electrical conductivity.
Conclusions: The study revealed that the reservoir is slightly polluted. Effective management strategies such as restricting cultivation on steep slopes should be employed to improve water quality.

Keywords: Bio-indicator, Phytoplankton, Pollution, Reservoir

INTRODUCTION

Phytoplankton encompasses organisms whose size, mobility, or both are at the mercy of water movements; they are hydrophytes with the photosynthetic ability and play a vital role in the aquatic food chain; the herbivorous zooplankton feed on them and in turn serve as an energy source to animals in higher trophic level, fishes inclusive. (Jabbi, 2018). The pelagic fishes such as sardines, mackerels and silver bellies consume mostly the plankton. The fish mostly breed in areas where planktonic organisms are readily available so that their young ones could get sufficient food for survival and growth (Goswami, 2004). A key to the use of aquatic biota as reliable indicators of changes in an aquatic ecosystem is unveiling the integrated environmental information in species-rich assemblages (Sutela *et al.,* 2013). Biological monitoring has now become an important branch of applied ecology where the economic and scientific interests of society meet in the management of aquatic ecosystems (Salmaso *et al.,* 2014). The algae are important components of aquatic ecosystems and their diversities are determined by the anthropogenic influences on the system (Kshirsagar, 2013). They play an important role by purifying water bodies through the absorption of many impurities such as nutrients and heavy metals i.e. global cycling of nitrogen, phosphorus, silica and carbon and also served as sites for the breakdown of bacterial and other organic contaminants (Chia *et al.,* 2013; Salmaso *et al.,* 2014). Water quality assessment encompasses the use of physico-chemical parameters of the aquatic system to provide an insight in to the water quality (Thagaradjou *et al.,* 2012) and the use of the biological variables, which is to provide a direct measure of ecological integrity by the use of response of biota to changes in environmental conditions (Joshi *et al.,* 2013). The quality of any given water body is governed by factors such as, biological, chemical and physical, which interact with one another and greatly influence its productivity (Ajana *et al.,* 2006). Bhuyan *et al*. (2003) stated that in recent years, activities to preserve the water quality of man-made reservoirs have been encouraged. For example, research on the classification of the water quality of reservoirs/lakes based on land use has been carried out. Biological monitoring has now become a very important branch of applied ecology where the scientific and economic interests of society meet in the management of aquatic systems (Salmaso *et al.,* 2014). The biotas inhabiting the aquatic systems are a function of the nature of physico-chemical parameters of the aquatic systems, thus providing a direct measure of the status of the systems (Lindstead *et al.,* 2012). Therefore, the ultimate monitor of the aquatic systems is the aquatic life itself (Brabets and Ourso, 2013). The eutrophication of many reservoirs has accelerated as a result of human activities, thereby changing the status and quality of water and its resources (Siemieniuk *et al.,* 2016). The study aimed to determine the status / water quality and productivity of Yardantsi Reservoir, Gusau using phytoplankton as a bio-indicator.

MATERIALS AND METHODS

Study Area

The Reservoir is dammed across the tributary of Sokoto River, with flanking earth dams and a mass concrete weir surmounted by five steel gates which are operated by electric motors and bar-link chains with provision for emergency manual operation. It is located in Gusau Local Government Area of Zamfara State, Nigeria, located between latitude 12° 10'12.86"-12°17'02.40"N and longitude 6° 39'50.83"-6°66'41.20"E (Jabbi *et al.,* 2018) and occupies an area of 3,364km^2 (1,298.8sqmi). Gusau Local Government had a population of 383,162 people (NPC, 2006). The mean annual rainfall in the area is 990mm. The type of vegetation in this area is the Sudan savannah, mostly dominated by grasses, and small trees (Ibrahim and Magami, 2016). The Reservoir was constructed purposely to provide water for domestic uses to Gusau populace as well as to improve, irrigation and fishing activities in the area (ECAN, 1990 and Jabbi *et al.,* 2018).

Surface Water Collection

Surface water samples were collected in duplicate one-litre capacity plastic bottles, and are preserved in a water cooler before analyses. The samples were taken to the Hydrobiology laboratory of the Biology Department Ahmadu Bello University, for the determination of physico-chemical parameters. Temperature, pH, electrical conductivity, total dissolved solids, transparency and mean depth were determined *in situ* using a portable HANNA Combo pH/ EC/Temp metre model/HI 98129 (Tanimu, 2015).

Plankton Collection and Preservation

Plankton samples were collected monthly between 6am and 7am, from five sampling stations from May 2015 to April 2017 using a standard cone-shaped plankton net (10µm mesh size) with an opening diameter of 20cm and was hauled over a distance of 5m. The net had a collection vial of 50ml at the base; where filtered plankton were collected. The collections were transferred to labelled sterile plastic bottles of 100ml capacity. Samples were preserved immediately (i.e. within the first five minutes after collection); two drops of Lugol's iodine solution were used to prevent tissues damage by bacterial action and autolysis (Jabbi, 2018).

The collections were taken to the Hydrobiology Laboratory of the Biology Department Ahmadu Bello University, Zaria for further analysis. Samples were allowed to stay for ten days as minimum fixation periods; later, the samples were transferred and stored in an airtight sterile container with preservative; while transferring, due care was taken to avoid sample disruption (Goswami, 2004; UNEP, 2004; Udo *et al.,* 2009).

Plankton Identification and Counting

The samples were concentrated by allowing them to settle and later decanted, 1ml of the concentrated sample was transferred on to Sedgwick rafter counting chamber and left for half an hour to sediment; placed on the mechanical stage of the Mr Jefferson microscope (optic-YG-100) and viewed at x100 magnification. The Sedgwick rafter was moved horizontally along the first row of squares and the observed phytoplankton in each square of the row were thus identified using the plankton guide by Jeje and Fernando (1986) and counted. The same procedure was repeated for the rest of the rafter rows. The total number of cells was then computed by multiplying the number of individuals counted in transects with the ratio of the whole chamber area to the area of the counted transects. Three (3) replicate counts of 1ml sample were done for statistical treatments. The average values were taken into account for calculation. The total number of plankton present per litre of water sample was measured using the formula (Goswami, 2004):

$$\text{Number of plankton (N)(ind/L)} = \frac{n \times v \times 1000}{V} \ldots\ldots\ldots\ldots (i)$$

Where; n = Average number of phytoplankton individuals in 1 mL of plankton sample

v = Volume of phytoplankton concentrate (mL)

V = Volume of water filtered (L)

$$V = \pi r^2 d \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . (ii)$$

Where; r = Radius of the mouth of the net

d = Length of the water column traversed by the net.

Data Analysis

Species richness was estimated in line with Margalef's indices (1974) and the diversity index was also computed according to Shannon and Wiener (1949). Principal Component Analysis (PCA) ordination program was also applied using Palaeontological statistics (PAST) software, version 4.03 (Hammer *et al* 2020). Relative abundance (%) of macro-benthic invertebrates was calculated using equation *i* (Lucy, 2016).

RESULTS

Relative Abundance

The relative abundance of the phytoplankton composition of Yardantsi reservoir during the study period is presented in table 1. Eleven (11) species were identified, belonging to four groups of phytoplankton; Bacillariophyta, Chlorophyta, Cynophyta and Dinophyta accounting for 27.25%, 39.29%, 11.50% and 21.96% respectively. Similarly; Bacillariophyta, Chlorophyta, Cynophyta and Dinophyta recorded 25.51%, 35.17%, 12.84% and 26.48% for the dry season and 28.36%, 41.90%, 10.65% and 19.10% for the rainy season respectively. Chlorophyta recorded the highest abundance in both seasons, while Dinophyta recorded the lowest percentage in both seasons (Table 1).

Surface Water Physico-Chemical Parameters

Some surface water physico-chemical parameters of Yardantsi Reservoir, Gusau were studied to establish their concentrations. Alkalinity (40.57±0.69), chloride (74.08±1.67), electrical conductivity (186.32±3.84), hardness (59.20±1.01), total dissolved solids (96.00±1.95) and transparency (48.82±1.08) were significantly higher during the dry season ($p<0.001$). Whereas nitrate-nitrogen (4.44±0.07), phosphate-phosphorus (173.48±2.78) and sulphate (71.80±1.82) were significantly higher during the rainy season ($p<0.001$) as presented in Table 2.

Table 1: Mean Population Density of Phytoplankton Species of Yardantsi Reservoir, Gusau

Phytoplankton	Dry Season		Rainy Season		Total	Relative
	Ind/L	RA (%)	Ind/L	RA (%)		Abundance (%
Bacillariophyta	**731**	**25.51**	**1286**	**28.36**	**2017**	**27.25**
Asterionella formosa H.	356	12.42	652	14.38	1008	13.62
Cymbella timida B.	277	9.67	429	9.46	706	9.54
Synedra ulna N.	98	3.45	205	4.52	303	4.10
Chlorophyta	**1008**	**35.17**	**1900**	**41.90**	**2908**	**39.29**
Oosystis sp.	103	3.59	104	2.29	207	2.80
Palmella sp.	257	8.97	619	13.65	876	11.84
Spirogyra sp.	648	22.61	1177	25.95	1825	24.66
Cynophyta	**368**	**12.84**	**483**	**10.65**	**851**	**11.50**
Chroococcus sp.	0	0.00	43	0.95	43	0.58
Microcystis sp.	94	3.28	106	2.34	200	2.70
Oscillatoria limosa C.	274	9.56	334	7.36	608	8.22
Dinophyta	**759**	**26.48**	**866**	**19.10**	**1625**	**21.96**
Ceratium hirundinella M.	376	13.12	676	14.91	1052	14.21
Ceratium teridenella L.	383	13.36	190	4.19	573	7.74
Total	**2,866**		**4535**		**7401**	

Note; RA = Relative Abundance (%)

Principal Component Analysis (PCA) for Phytoplankton Species

PCA shows the relationship that existed between the phytoplankton species and environmental variables (Fig. 1). The first two PCA components accounted for 89.646% and 9.252% respectively, making a total of 98.898% of the total percentage variance observed. *Palmella* sp, *Spirogyra* sp., *Chroococcus* sp. and *Ceratium hirundinella* M. exhibited a positive correlation among themselves and with temperature, NO_3-N, pH and dissolved oxygen. They also exhibited a highly positive correlation with sulphur and PO_4-P and a negative correlation existed with hardness, alkalinity, total dissolved solids, transparency, chloride and electrical conductivity. While *Ceratium teridenella* L., *Asterionella formosa* H., *Cymbella timida* B., *Synedra ulna* N., *Oosystis* sp., *Microcystis* sp. and *Oscillatoria limosa* C. exhibited a highly negative correlation among selves and a negative correlation existed with hardness, alkalinity, total dissolved solids, transparency, chloride and electrical conductivity; a highly positive correlation with sulphur and PO_4 -P.The result revealed that Shannon and Weaver diversity index ranged between 2.441 in July and 2.524 in November, while Margalef diversity index ranged between 3.175 in May and 3.572 in August (Figure 2).

Table 2: Mean (±SE) Annual and Seasonal Variation of different Surface Water Physico-Chemical Parameters of Yardantsi Reservoir, Gusau

	Seasons		
Parameters	**Dry Season**	**Rainy Season**	**P-value**
Alkalinity (mg/L)	40.57±0.69	27.87±0.51	0.000
BOD (mg/L)	2.71±0.09	2.48±0.05	0.017
Chloride	74.08±1.67	37.64±0.96	0.000
DO (mg/L)	7.80±0.11	6.91±0.10	0.000
EC (µs/cm)	186.32±3.84	108.05±5.43	0.000
Hardness (mg/L)	59.20±1.01	32.18±0.94	0.000
Mean Depth (m)	2.12±0.05	2.65±0.04	0.000
NO_3-N	2.28±0.08	4.44±0.07	0.000
pH	7.61±0.15	7.96±0.13	0.091
PO_4-P	123.72±1.44	173.48±2.78	0.000
Sulphate	31.62±1.45	71.80±1.82	0.000
Temperature (^{0})	26.62±0.34	30.12±0.17	0.000
TDS (ppm)	96.00±1.95	63.70±3.68	0.000
Transparency (cm)	48.82±1.08	22.07±0.87	0.000

Note; BOD= biological oxygen demand; DO= dissolved oxygen; EC=electrical conductivity; NO_3-N= nitrate-nitrogen; PO_4-P= phosphate-phosphorus; and TDS=total dissolved solids

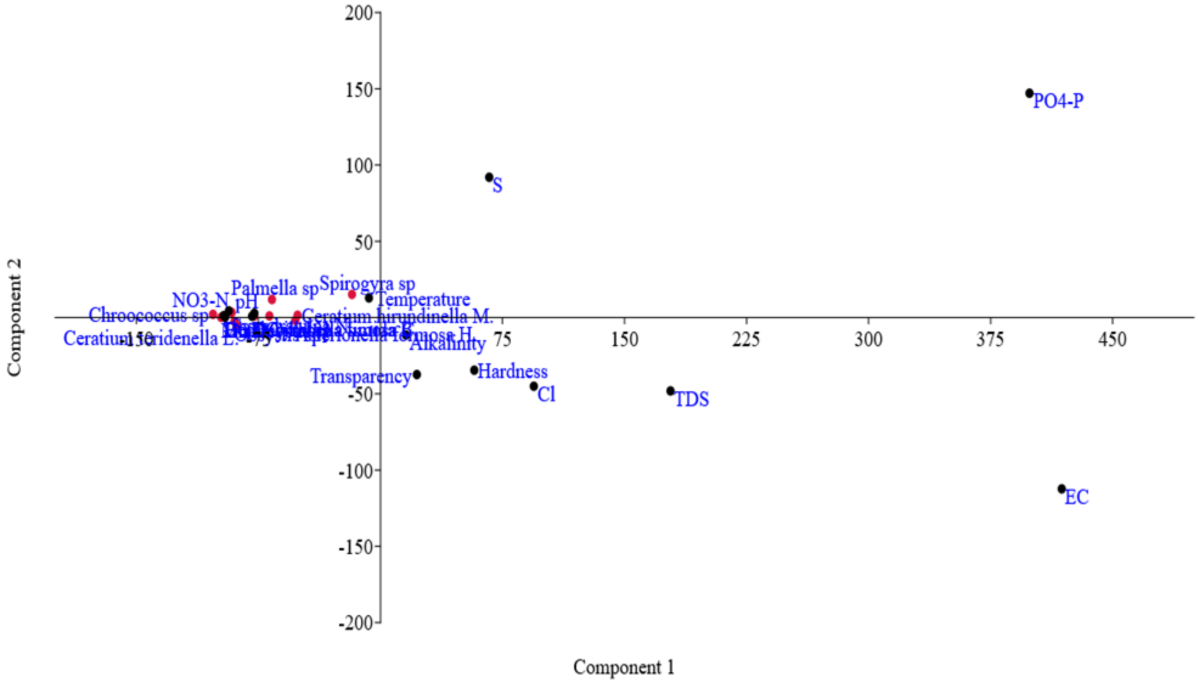

Figure 1: Principal Component Analysis (PCA) Biplot for Phytoplankton and Physico-Chemical Parameters of Yardantsi Reservoir, Gusau

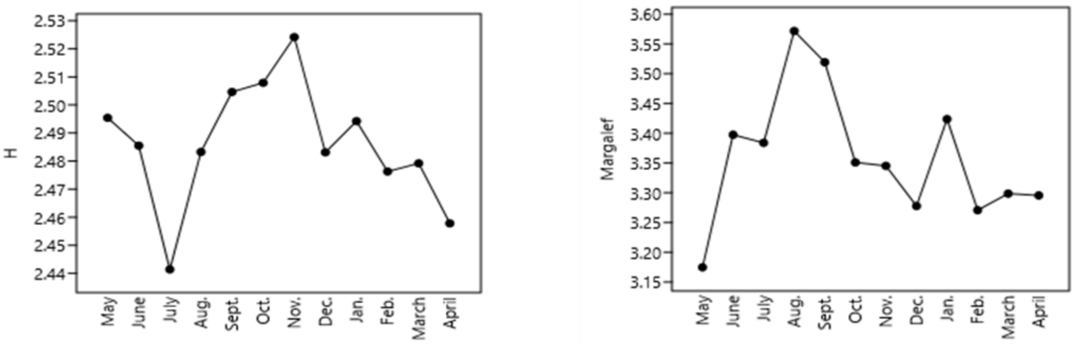

Figure 2: Changes in the Margalef's Index and Shannon-Weiner Index in Yardantsi Reservoir during the Study Period

DISCUSSION

Phytoplankton showed the following percentage order of abundance: Chlorophyta > Bacillariophyta > Dinophyta > Cyanophyta in both seasons. The variations could be attributed to species resistivity to anthropogenic inputs of the reservoir. This disagrees with the findings of Ali *et al.* (2013) in their studies on the Lower Niger River, Kogi State, Nigeria.

Cymbella timida (Bréb.) Van Hanerck (*C. timida*), *Palmella* sp., *Spirogyra* sp., *Asterionella formosa* Hass (*A. formosa*), *Oscillatoria limosa* C.Agardh ex Gomont (*O. limosa*) and *Ceratium hirundinella* (Müller) Dujardin (*C. hirundinella*) were observed to be present throughout the seasons, even though they were more prominent during the rainy season. However; some species (*Synedra ulna* (Nitzsch) Ehrenberg (*S. ulna*), *Oosystis* sp., *Microcystis* sp. and *Ceratium teridenella* (Lemm) Skr. (*C. teridenella*) disappear and reappear in some months of the year while *Cosmarium* sp. disappears during the dry season and reappear in the rainy season. These could be attributed to the differential response to variation in biological and physiological factors.

Based on percentage composition, Chlorophyta constituted the highest abundance for both dry and rainy seasons (35.17% and 41.90% respectively) to the total phytoplankton population which coincided with the abundance of the Cladocera, this shows that Chlorophytes provide the food supplements for the Cladocerans. These findings are in agreement with the findings of Ariyadej *et al.* (2004) and Mohammad *et al.* (2014).

The composition and abundance of reservoir plankton species may be attributed to periodic changes in the ecosystem caused by seasonal variations in the environmental conditions. These may be directly or indirectly alter the time and rate of reproduction depending upon the availability of food, competition, predation and mortality as evidenced by the seasonal fluctuation of plankton density and composition as reported by Balarabe (1989).

Maiti (2004) reported that Margalef and Shannon diversity indices values above three (3) indicates clean water, whereas values fewer than three (3) would indicate pollution, also the higher the value, the greater the diversity. This study revealed that Shannon diversity index ranges from 2.441 and 2.524 in July and November respectively, while Margalef diversity index ranges from 3.175 and 3.572 in May and August respectively (Figure 2). Going by the Shannon diversity index which is less than three (3) shows that the reservoir is polluted. While Margalef diversity index which is greater than three (3) indicated that the reservoir is polluted. While Margalef diversity index which is greater than three (3) indicated that the reservoir is clean. Margalef and Shannon diversity indices together determined the status of an aquatic ecosystem as reported by Maiti (2004), based on these therefore the reservoir is said to be slightly polluted. The higher index values in the rainy season could be attributed to sampling methods and the increase in the volume of the water and to the effect of dredging going on at the time of this study and the dilution. These findings are in line with the studies of Nkwoji and Edokpayi (2013) and Alhassan (2015).

CONCLUSION

Four (4) groups of phytoplankton (viz; Bacillariophyta, Chlorophyta, Cyanophyta and Dinophyta) comprise eleven (11) various species, with Chlorophyta having the highest abundance for both dry and rainy seasons (35.17% and 41.90% respectively). Phytoplankton were used to determine the pollution level of the reservoir using diversity indices (Shannon and Wiener diversity index and Margalef diversity index); this indicated that the reservoir surveyed could be considered to be slightly polluted. Based on the results obtained we therefore recommended that Government shall ensure that sustainable and responsible agriculture practices are to be carried out within the catchment area, by restricting cultivation on steep slopes and the reservoir input shall be monitored and the sediment sources be mitigated.

ACKNOWLEDGEMENTS

This is to acknowledge Mr. Sylvanus O., Mrs. Nafisa B., Mal. Magaji A. of Hydrobiology Laboratory, for their technical support, Prof. M.L. Balarabe, Prof. A.K. Adamu, Dr. Tanimu Y., Dr. I.M.K. Gadzama and Mal. A.A. Bala of the Biology Department, ABU Zaria, for their resourceful contribution and TETFund for the financial support.

REFERENCES

Ajana, A.M., Adekoya, B.B., Alunuya, O.A. and Ayansanwo, T.O. (2006). *Practical Fish Farming Alliance for Community*. Transformation Publishers, 22-23.

Alhassan, A.B. (2015). *Macrobenthic Invertebrates Composition in Relation to Some Physico-Chemical Characteristics of Makwaye and Kubanni Reservoirs in Zaria, Nigeria.* (Master's Dissertation, Ahmadu Bello University, Zaria, Nigeria). Retrieved from http:// hdl.handle.net/123456789/7978.

Ali, M.Z., Adelanwa, M.A. and Tanimu, Y. (2013). Physico-Chemical Characteristics and Phytoplankton Abundance of the Lower Niger River, Kogi State, Nigeria. *IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT) 2*(4): 31-37.

Ariyadej, C., Tansakul, R., Tansakul, P. and Angsupanich, S. (2004). Phytoplankton Diversity and its Relationships to the Physico-chemical Environment in the Banglang Reservoir, Yala Province Songklanakarin. *Journal of Science Technology*, *26* (5):595-607.

Balarabe M.L. (1989). *Limnology and Zooplankton of Makwaye (Ahmadu Bello University Farm) Lake, Samaru, Zaria - Nigeria* (Master's Dissertation, Ahmadu Bello University, Zaria Nigeria).Retrieved from http:// hdl.handle.net/123456789/972.

Bhuyan, S.J., Koelliker, J.K., Marzen, L.J. and Harrington, J.A. Jr. (2003). An Integrated Approach for Water Quality Assessment of a Kansas Watershed. *Environment and Model Software. 18*(1):473-484.

Brabets, T.P. and Ourso, R.T. (2013). *Water Quality of Streams Draining Abandoned and Reclaimed Mined Lands in the Kantishna Hills Area, Denali National Park and Preserve, Alaska, 2008–11.* Published by the U.S. Geological Survey, Reston, Virginia, USA. 84p.

Chia, A.M., Lombardi, A.T., Melão, M.G. and Parris, C.C. (2013). Lipid Composition of *Chlorella vulgaris* (Trebouxiophyceae) as a Function of Different Cadmium and Phosphate Concentrations. *Aquatic Toxicology,* 128–129:171–182. *Conservation 29* (1):21-38.

Engineering and Consulting Associates Nigeria Limited (ECAN) (1990). Gusau Water Supply 10-MGD Water Treatment Plant Project, Progress Report. 1p.

Goswami, S.C. (2004). *Zooplankton Methodology, Collection & Identification – A Field Manual* 1ed. Bioinformatics Centre, National Institute of Oceanography, Dona Paula, Goa 1-15.

Hammer Ø., Harper, D.A.T. and Ryan P.D. (2020). *PAST - Palaeontological Statistics Software Package for Education and Data Analysis*. Palaeontologia Electronica *4*(1):9p.

Ibrahim, S. and Magami, I.M. (2016). Trophic Status of Kware and Shagari Lakes, Northwestern Nigeria. *Biological and Environmental Sciences Journal for the Tropics, 13*(3):38-41.

Jabbi, A.M. (2018). *Some Aspect of Limnology of Yardantsi Reservoir, Gusau- Nigeria* (PhD Thesis, Ahmadu Bello University, Zaria Nigeria). Retrieved from http://hdl.handle.net/123456789/11358

Jabbi A.M., Zurmi, R.S., Balarabe, M.L. and Adamu, A.K. (2018). Assessment of Surface Water Physico-Chemical Parameters of Yardantsi Reservoir, Gusau Nigeria. *Bayero Journal of Pure and Applied Sciences. 11*(1): 183-188.

Jeje, C.Y. and Fernando, C.H. (1986).*A practical Guide to identification of Nigerian Zooplankton*. Published by Kainji Lake Research Institute, Niger State, Nigeria.87-140.

Joshi, M., Bakre, P.P. and Bhatnagar, P. (2013). Avian Guano: A Non-destructive Biomonitoring Tool for Organic Pollutants in Environment. *Ecological Indicators*, *24*: 284–286.

Kshirsagar, A.D. (2013). Use of Algae as a Bio-indicator to Determine Water Quality of River Mula from Pune City, Maharashtra, India. *Universal Journal of Environmental Research and Technology, 3*(1):79-85.

Linstead, C., Maltby, E. and Moss, B. (2012). Ecosystem-Based Indicators for Monitoring the Status of Rivers in Ghana. *West African Journal of Applied Ecology, 21*(3):1-10.

Lucy K. (2016). Assessment of the Ecological Integrity of Lower Sabaki River using Macro-benthic Invertebrates as Biological Indicators. (M.Sc. Thesis, Pwani University, Kilifi Kenya). Retrieved from https://elibrary.pu.ac.ke/20170518

Maiti, S.K. (2004). *Handbook of Methods in Environmental Studies*: *Water and Wastewater Analysis*. Second Edition ABD Publishers B-46, Natraj Nagar, Imliwala Phatak Jaipur, India. 1: 255-258.

Margalef, R. (1974). *Perfectives in Ecological Theory*. University of Chicago Press. 3rd edition. 111p.

Mohammad, M.A., Rabiu M.K. and Balarabe, M.L. (2014). Effects of Environmental Variables on Phytoplankton Distribution in Kusalla Reservoir, Nigeria. *International Journal of Biosciences*. *4*(9):266-271, http://dx.doi.org/10.12692/ijb/4.9.266-271.

National Population Commission (NPC) (2006). NPC Census, Gusau Local Government Gusau. Wikipedia, the free encyclopedia.Retrieved on 10 August, 2017, from http://en.wikipedia.org/wiki/Gusau.

Nkwoji, J.A. and Edokpayi C.A. (2013). Hydrochemistry and Community Structure of Macrobenthic Invertebrates of Lagos Lagoon, Nigeria. *Research Journal of Pharmaceutical, Biological and Chemical Sciences,* 5: 119-1130.

Salmaso, N., Naselli-Flores, L. and Padisak, J. (2014). Functional Classifications and their Applications in Phytoplankton Ecology. *Freshwater Biology,* doi:10.1111/fwb.12520.

Shannon, C. E and Weaver, W. (1949) *The Mathematical Theory of Communication*. University of Llinoio Press, Urbana 117 pp.

Siemieniuk, A., Szczykowska, J. and Wiater, J. (2016). Eutrophication as a Priority Issue of Water Quality in Small Retention Reservoirs. *Journal of Ecological Engineering*, *17*(3):143–147.

Sutela, T., Aroviitab, J. and Keto, A. (2013). Assessing Ecological Status of Regulated Lakes with Littoral Macrophyte, Macroinvertebrate and Fish Assemblages. *Ecological Indicators*, 24: 185–192.

Tanimu Y. (2015). *Algae-Based Indices in Relation to Anthropogenic Impact on Water Quality of Tudun Wada-Makera Drainages and a Segment of River Kaduna* (Doctoral Dissertation, Ahmadu Bello University, Zaria Nigeria). Retrieved from http://hdl.handle.net/123456789/8124.

Thangaradjou, T., Vijayabaskara, G., Sethubathi, Raja, S., Poornima, D., Shanthi, R., Balasubramanian, T., Babu, K.N. and Shukla, A.K. (2012). Influence of Environmental Variables on Phytoplankton Floristic Pattern Along the Shallow Coasts of Southwest Bay of Bengal. *Algal Research,* 1: 143 –154.

Udo, E.J., Ibia, T.O., Ogunwale, J.A., Ano, A.O. and Esu, I.E. (2009). *Manual of Soil, Plant and Water Analyses.* Sibon Books Limited.

UNEP, (2004). *Analytical Methods for Environmental Water Quality*. National Water Research Institute, Burlington, Ontario, CANADA.