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PHYSICO-CHEMICAL PARAMETERS, PRIMARY PRODUCTIVITY AND PHYTOPLANKTON ASSEMBLAGE OF DANDARU LAKE, SOUTHWESTERN NIGERIA

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Abstract: Lakes provide ecosystem services for the society and water quality, primary production and plankton composition are associated with their ability to perform these services. Hence, this study on the Dandaru Lake, on which there is a paucity of information on the primary productivity and phytoplankton assemblage. Monthly samples were collected for six months from five stations. Levels of essential primary productivity nutrients- phosphate (0.44±0.4mg/L) and nitrate (3.99±1.16 mg/L) were low; gross primary productivity was 1.23± 1.68 gC/m2/day, net primary productivity was 0.78 ±1.48 gC/m2/day and community respiration was 0.45 ± 0.72 gC/m2/day. The order of relative abundance of phytoplankton taxa was *Euglenophyceae* > *Bacillariophyceae* > *Cyanophyceace* >*Xanthophyceae*. Pollution tolerant phytoplankton species made up 75.83% of the total phytoplankton encountered in the lake. The mean H' value was 1.66 ± 0.26. The obtained values suggested that the reservoir was moderately polluted.

Keywords: water quality, phytoplankton, primary productivity, shannon-wiener

INTRODUCTION

Lakes serve as critical resources for society by providing water for drinking, bathing, irrigation and power generation. Inland fisheries are other ecosystem services of this water body. Lakes are also hot spots of biodiversity and are often sensitive indicators of environmental changes, both regional and global. The interconnectedness of lakes to their surrounding environments—the habitats they provide and biodiversity they hold, along with society's heavy reliance on their resources makes managing any resultant effects of environmental change important (Beirne et al., 2017).

Primary production, plankton composition and diversity are closely linked to the ability of lakes to perform ecosystem services. Primary productivity is a measure of the rate of carbon assimilation which serves as the base of the food chain in heterotrophic surface water systems. The organic molecules produced, and their potential energy are moved up the food chain through trophic relationships (Spaak and Bauchrowitz, 2010), thus, energizing the entire biosphere. Phytoplankton are the primary producers of organic matter; thus they condition the proper function of the food chain and all the changes in phytoplankton assemblage influence the entire aquatic ecosystem. Phytoplankton can be an early warning indicator and, theoretically, can be used to control subsequent changes in aquatic environment (Pasztaleniec, 2016).

Dandaru Lake was constructed by damming Ogunpa River in Ibadan, Oyo State, Nigeria. The lake is use for various purposes including fisheries and water supply, however different land-based activities occur along the parent river and reservoir that may impact negatively on the water quality. The aim of this research is to determine the primary productivity and phytoplankton community composition of the lake on which there is dearth of information. This will enhance effective management and sustainable fish production in the lake.

MATERIALS AND METHODS

Study Area

Dandaru Reservoir is located in Ibadan, Oyo State between latitudes 7º24'16'N and 7º24' 27'N and longitudes 3º53'32'E and 3º54' 30'E (Fig.1). Five sampling stations were selected on the reservoir. Basic features of the reservoir and the five sampling stations are described in Ayoade et al., 2017.

Physico-chemical Parameters

Physico-chemical parameters of the reservoir were determined by collecting water samples from the five stations with 1L bottle from October, 2015 to March, 2016.

Water temperature, Dissolved Oxygen (DO), pH, Total Dissolved Solids (TDS) and conductivity, were determined in-situ by using the electrochemistry meter (SPER 850081). Other parameters (Biological Oxygen Demand (BOD), nitrate and phosphate) were analysed using methods as described by APHA (1998).

Determination of Primary Productivity

The primary productivity was determined by using standard "light and dark bottle" method of Gardner and Gran (1972), modified by Vollenweider (1974) and Wetzel and Linkens (2000). The dissolved oxygen is estimated from the initial, light and dark bottles with the electrochemistry meter (SPER 850081). The Gross Primary Productivity (GPP), Net Primary Productivity (NPP) and Community Respiration (CR) were determined by using the formulae of Simmons et al., 2004. The observed Gross Primary Productivity (GPP), Net Primary Productivity (NPP) and Community Respiration (CR) in mg/L/day were converted into gC/m2/day by multiplying these values

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with a factor of 0.375 as suggested by Benton and Werner (1972) and cited by Gajanan and Satish (2014).

Phytoplankton Collection and Analysis

Plankton net (55µm mesh size) was used in collecting water samples for phytoplankton analysis. The water samples collected were transferred into labelled 250ml collecting bottles and preserved with 4% formalin. Analysis of plankton was carried out using a binocular microscope 40x magnification and were identified using various taxonomic keys (Whitford and Schumacher, 1973; Cole, 1978; Maosen, 1978 , Needham and Needham, 1978 and Egborge, 1994). Quantitative determination of the phytoplankton community was obtained though sedimentation and counting 1 mL of sedimented samples through a Sedgwick-Rafter counting chamber. Isolated cells, whole colonies and filaments were considered as individuals/organisms during the counting.

Statistical Analysis

Plankton species diversity was determined with the Margalef's (D) Shannon-Wiener index (H'), Simpson and Evenness (E) indices. Values for Shannon-Wiener index, Margalef, Simpson and Evenness indices were computed using PAST Statistical software. The relationship between the physico-chemical factors and primary productivity was established with the Pearson Product Moment Correlation (r). One way ANOVA was used for analyzing differences in the means of primary productivity spatially and between months.

RESULTS AND DISCUSSION

Physico-chemical Parameters

The pH range (7.34-7.88) observed in Dandaru Lake during the study period was within acceptable levels of 6.0-8.5 for fish culture in tropical waters as suggested by Huett (1977). This observed pH range also comply with NESREA (6.5-8.5) standard for aquatic life and USEPA (6.5-9.0) standard for drinking water. It also suggests that the lake's water is good for fish production. The pH of the water may influence the species composition of an aquatic environment, the availability of nutrients and the relative toxicity of many trace elements. The water temperature range (20.60-31.10oC) was within the NESREA acceptable limits for aquatic life in tropical environment Table 1. The electrical conductivity measures the ability of water to conduct an electrical current, and usually related to the concentration of ionized substances in water (Ogbeibu and Anagboso, 2003). Increasing levels of conductivity are the products of decomposition and mineralization of organic materials (Abida & Harikrishna 2008). Values of conductivity ranged from 273-583µs/cm during the study period. This value was within NESREA (≤1000) and USEPA (≤1000) standards for aquatic life and drinking water, respectively. Conductivity gives the indirect measure of total dissolved solids in water bodies. Total dissolved solids range (182.00-389.00mg/L) in the lake during the study period was within NESREA (≤500) and USEPA (≤200) standards. The mean value of total suspended solids (0.82±0.33mg/L) was above NESREA standard (0.25) for drinking water. Solids in water are divided into total, dissolved, suspended, fixed and volatile solids (Rodajevic and Bashkin, 1999). Solids in water are undesirable for they degrade the quality of drinking water, inhibit photosynthetic processes, and reduce the utility of water for different purposes. The mean DO value (5.13±1.50mg/L) of the Lake was within NESREA (≥ 3) and USEPA (≥5) acceptable limit for aquatic life and drinking water, respectively. However, low DO values below NESREA standard, were recorded in some instances. This condition can only be lethal when fish exposure is prolonged (Boyd and Lichtkoppler, 1985). The biological oxygen demand values of the lake did not exceed NESREA(≤ 6) and USEPA limits(≤ 10). Biological oxygen demand is of vital importance in pollution monitoring. Waters with BOD levels less than 4 mg/L are considered clean but those with levels greater than 10 mg/L are regarded as polluted as they contain large amounts of degradable organic material (McNeely et al., 1979). Levels of the essential primary productivity nutrients – nitrate (mean 3.99±1.157mg/L) and phosphate (mean 0.44±0.4mg/L) in the Dandaru Lake during the study period were low. Phosphate is considered a limiting nutrient for algae and macrophytes and since it is actively taken up by plants, is usually found at low concentrations (Horne and Goldman, 1994). High concentration of phosphate could affect diversity and abundance of invertebrates. This could happen in three ways: Reduction of food availability, alteration of the macrophytes community, resulting in a diminution or elimination of the open water and/or reduction of the oxygen content due to shading from plants (Radar, 1999). Most surface waters contain some nitrate (<5 mg/L) but when the concentration is up to 5 mg/L is a reflection of organic pollution as one major source of nitrates is human and animal wastes. Excess nitrate as a result of run-off from fertilizer from nearby farmland, livestock and animal wastes, leaking septic tanks, sewer overflows can lead to eutrophication in water bodies and this may lead to hypoxia which in turn will affect the organism present as those that cannot tolerate low level oxygen will be redistributed.

Primary Productivity

The gross primary productivity of the Dandaru Reservoir ranged between 0.41 – 2.74gC/m2/day (1.23± 1.68 gC/m2/day); net primary productivity was between 0.11 to 1.91gC/m2/day (0.78 ±1.48 gC/m2/day) and community respiration was 0.075 – 1.31 gC/m2/day (0.45 ± 0.72 gC/m2/day) Table1 . Primary productivity (gC/m2/day) was highest in station 3 (GPP, 1.44; NPP, 0.96; CR, 0.48) and least in station 4 (GPP, 0.88; NPP, 0.53; CR, 0.35) Figure 1. The mean GPP of the reservoir was below the >3 gO2 m-2day-1 classified by Karlman (1973) as being high productivity. The gross primary productivity of the reservoir is also low compared to some other water bodies such as Kainji (2.19gO2m-2d-1), Jebba (5.53gO2m-2d-1), Victoria (3.98gO2m-2d-1), Volta (2.55 gO2m-2d-1), Oguta (6.75gO2m-2d-1), Abadaba

(2.67gO2m-2d-1) and Omi Dam (19.58gO2m-2d-1) by (Tailling & Rzóska 1969, Adeniji 1973, Karlman 1973, Ovie et al., 2004) cited in Ovie et al., 2011. This low primary productivity of the reservoir could be due to the total suspended solids (being beyond permissible level) intercepting light penetration, thus reducing photosynthetic activities. The low nutrient level of the water (as suggested by the low phosphate and nitrate concentrations) further led to the low productivity of the reservoir. Higher productivity recorded in station 3 may have resulted from it being the midpoint/centre of the reservoir, thus free from vegetation cover that may affect penetration of light required for photosynthesis. Table 2 shows the correlation between physico-chemical parameters and primary productivity of the reservoir. Significant negative relationship occurred between TDS and GPP/NPP; also between conductivity and GPP/NPP. However, nitrate concentration correlated positively with NPP.

Table 1.

Physico-chemical parameters of Dandaru Lake

Parameters	Minimum	Maximum	Mean	SE
PH	7.34	7.88	7.68	0.13
Air Temperature (oC)	23.70	35.50	30.1	2.45
Water Temperature (oC)	20.60	31.10	27.02	3.18
Depth (cm)	11.80	129.00	54.31	37.06
Conductivity (µS/cm)	273.00	583.00	405.83	62.92
Total Dissolved Solid (mg/L)	182.00	389.00	271.77	42.20
Total Suspended Solid (mg/L)	0.30	1.33	0.82	0.33
Dissolved Oxygen (mg/L)	2.10	7.80	5.13	1.50
Biological Oxygen Dissolved (mg/L)	0.80	5.70	3.29	1.27
Alkalinity (mg/L)	15.00	83.00	36.97	15.89
Nitrate (mg/L)	2.26	11.09	3.99	1.57
Phosphate (mg/L)	0.05	1.83	0.44	0.40
Gross Primary Productivity (g C/m2/day)	0.41	2.74	1.23	1.68
Net Primary Productivity (g C/m2/day)	0.11	1.91	0.78	1.48
Community Respiration (g C/m2/day)	0.075	1.31	0.45	0.72

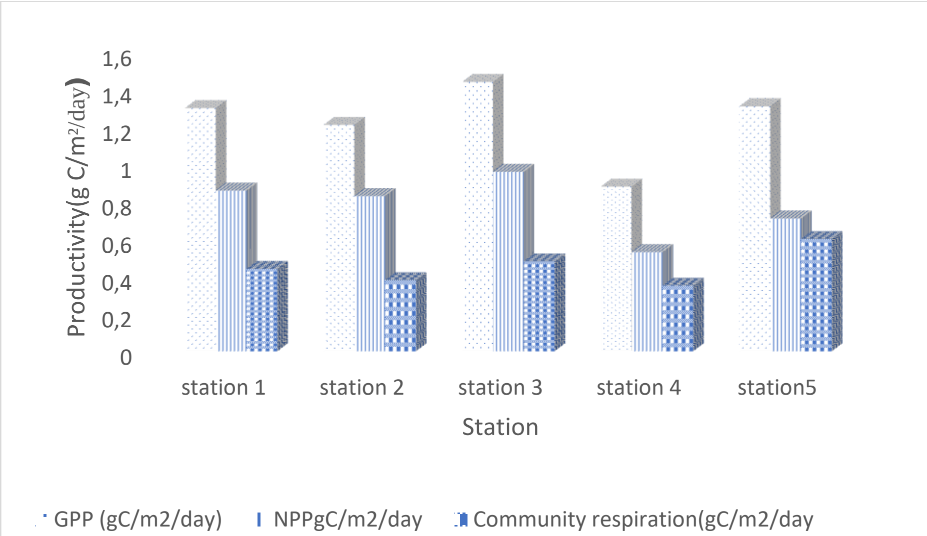

Fig. 1. Spatial variation in productivity (g C/ m2/day) of Dandaru Lake during the study period

Table 2.

Correlation between physico-chemical parameters and primary productivity

	pH	Air Temp . (oC)	Water Temp . (oC)	Dept h (cm)	Conductivit y (µS/cm)	TDS (mg/L)	DO (mg/L)	TSS (mg/L)	BOD (mg/L)	Nitrat e (mg/L)	Phosphat e (mg/L)
Gross Primary Production (g C/m2/day)	.01 4	.129	.210	.052	-.416a	- .4101	.161	-.263	.103	.242	-.294
Net Primary Production	- .02 9	.178	.181	.086	-.4591	- .4421	.063	-.228	.002	.367*	-.226

(g C/m2/day)											
Community Respiration (g C/m2/day)	.092	-.065	.119	-.054	-.028	-.050	.247	-.144	.234	-.188	-.220

*. Correlation is significant at the 0.05 level (2-tailed).
KEY:
Air Temp: Air Temperature DO: Dissolved Oxygen
Water Temp: Water Temperature BOD: Biological Oxygen Demand
TDS: Total Dissolved Solids TSS: Total Suspended Solids

Phytoplankton Composition and diversity

The checklist of phytoplankton encountered is given on Table 3. A total of thirty genera of phytoplankton belonging to five major taxa were encountered. The order of relative abundance of the taxa were *Euglenophyceae* > *Bacillariophyceae* > *Chlorophyceae Cyanophyceace* > *Xanthophyceae* Figure 2. Pollution tolerant phytoplankton species made up 75.83% of the total phytoplankton encountered in the lake. The relative numerical abundance of the phytoplankton groups encountered in the five sampling stations of the Dandaru Lake during the study period is shown on Figure 3. *Xanthophyceae* had the least numerical abundance in all the sampling stations and was completely absent in station 3. Station 1 was dominated by *Chlorophyceae* (132 units/ml, 37.7%). *Euglenophyceae* had the highest numerical abundance in stations 2, 3 and 4 (804 units/ml, 55.3%; 550 units/ml, 43.4% and 281 units/ml, 36.9%, respectively). Station 5 was dominated by *Bacillariophyceae* (254 units/ml; 33.7%). The dominance of members of *Euglenophyceae* in the reservoir suggests that the water body is polluted with organic matters. Nwankwo (1995) stated that some species of *Euglenophyceae* such as species of Euglena and Phacus, are indicators of organic pollution as they can tolerate various levels of organically polluted aquatic systems.

This observation is not in line with most reports of plankton groups observed in freshwater bodies. The *Bacillariophyta* (diatoms), *Chlorophyta* (green algae), and *Cyanophyta* (blue green) have been reported as the three major groups of algae in freshwater ecosystems (Sorayya et al., 2011). Arimoro et al. (2008) reported phytoplankton order of *Bacillariophyceae* > *Chlorophyceae* > Cyanophyceae > *Euglenophyceae* in Orogodo River in Nigeria. Fonge et al. (2012) reported decreasing phytoplankton abundance in the order of: *Chlorophyceae* > *Bacillariophyceae* > *Dinophyta* in Ndop wetland plain, Cameroon. In Awba Reservoir, Anago et al. (2013) observed order of: Cyanophyceae > *Chlorophyceae* > *Euglenophyceae* > *Bacillariophyceae* > *Dinophyceae*.

The least mean density of phytoplankton was recorded in October (115 organism/ml) and highest in February (301 organism/ml) Figure 4. This range is lower than 333 – 555 No./ml of phytoplankton recorded in Omi Dam by Ovie et al., 2011. The low phytoplankton density could have resulted from the nutrient and primary productivity levels of the reservoir that were low.

Chlorophyceae had the highest values for Shannon-Wiener, Margalef, Evenness and Simpson indices (2.42, 2.12, 0.70 and 0.89, respectively) Table 4. Apart from *Xanthophyceae* which was not calculated, Cyanophyceae recorded the least values for Shannon-Wiener (0.99), Margalef (1.05), Evenness (0.34) and Simpson indices (0.45). Shannon-Weiner diversity index values above 3.0 indicate that the structure of the habitat is stable, while values less than 1.0 indicate severe pollution and intermediate values indicate moderate pollution (Shannon & Weaver, 1949; Lenat et al., 1980 and Mandaville, 2002). The mean diversity index value (1.66 ± 0.26) obtained show that the reservoir was moderately polluted.

Table 3.

Checklist of Phytoplankton of Dandaru Lake

Group/Species	Stations				
Bacillariophyceae	1	2	3	4	5
1Navicula sp.	+	+	+	+	+
1Nitzchia sp.	+	+	+	+	+
1Melosira sp.	+	+	+	+	+
Cyclotella sp.	+	+	+	+	+
Frustulia sp.	+	+	+	+	+
Amphora sp.	+	+	-	-	-
1Fragilaria sp.	-	+	+	-	+
1Synedra sp.	+	+	+	-	+
Chorophyceae					
1Scenedesmus quadricauda	+	+	+	+	+
1Scenedesmus acuminatus	+	+	+	+	+
1Scenedesmus obliqus	+	+	+	-	+
1Scenedesmus bijuga	+	+	+	+	+

1Scenedesmus opoliensis	+	+	+	+	+
1Scenedesmus sp.	+	+	+	+	+
Microspora sp.	+	+	+	-	+
1Closterium sp.	+	+	+	+	+
1Pediastrum duplex	+	+	+	-	+
1Pediastrum tetras	+	+	+	-	+
Schroederia sp.	+	+	+	+	+
Selenastrum sp.	+	+	+	+	+
Crucigenia sp.	+	+	+	+	+
1Ankistrodesmus falcatus	-	+	+	+	+
1Ulothrix sp.	-	+	+	+	+
1Chlorella sp.	-	+	+	+	-
Cyanophyceae					
1Anabaena sp.	+	+	+	-	-
Gleocapsa minima	+	+	+	+	+
Lyngbya sp.	-	-	+	-	-
1Merismopedia sp.	+	+	+	+	+
1Microcystis sp.	-	-	-	+	+
1Oscillatoria limosa	+	+	-	+	+
1Oscillatoria sp.	+	+	+	+	+
1Phormidium sp.	-	-	-	-	+
Euglenophyceae					
1Euglena chlamydophora	-	+	+	+	+
1Euglena oxyuris	+	+	+	+	+
1Euglena sp.	+	+	+	+	+
1Phacus brevicauda	+	+	-	+	+
1Phacus longicauda	-	+	+	-	-
1Phacus platalea	-	+	+	+	+
1Phacus undulates	+	+	+	+	-
1Phacus sp.	+	+	+	+	+
Trachelomonas volvocina	-	+	+	+	+
Trachelomonas sp.	+	+	+	+	+
Lepocinclis sp.	+	+	+	+	+
Xanthophyceae					
Tribonema vulgare	+	+	+	+	+

Pollution indicator species, + = Present; - = Absent

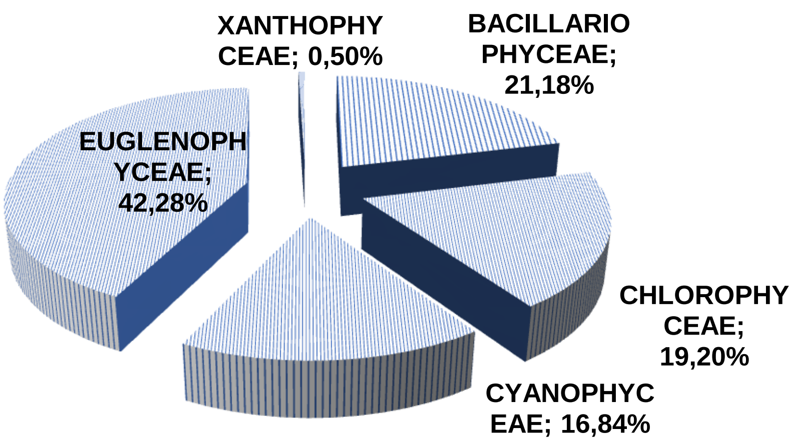

Fig. 2. Percentage composition by number of Phytoplankton in Dandaru Lake

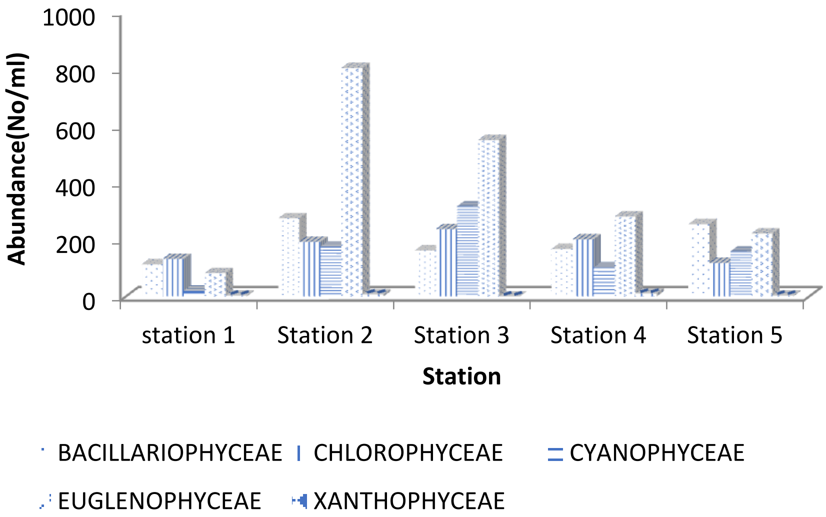

Fig. 3. Spatial distribution of Phytoplankton in Dandaru Lake during the study period

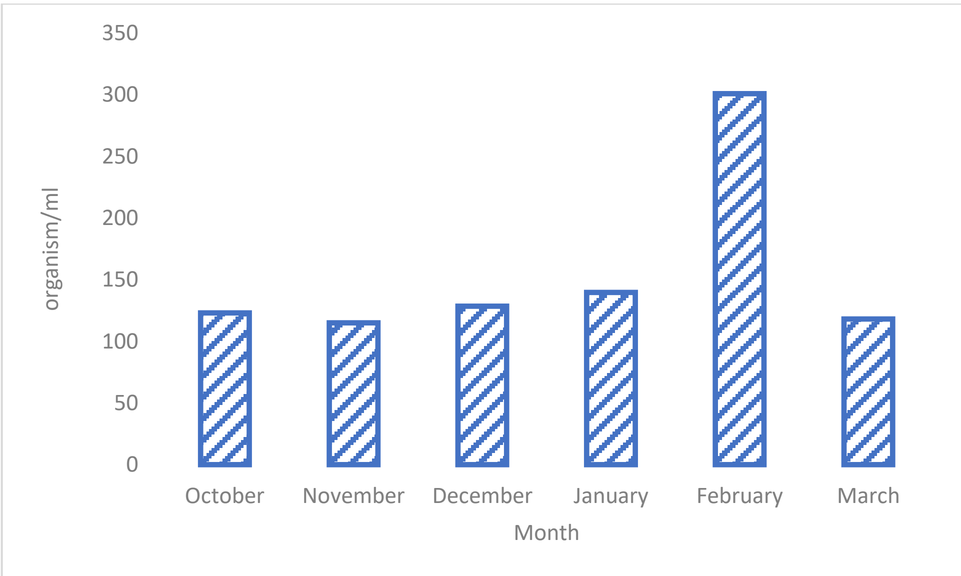

Fig. 4. Monthly Variation in Mean Density of Phytoplankton in Dandaru Lake

Table 4.

Diversity index values of Phytoplankton in Dandaru Lake during the study period

Taxa	Shannon H'	Margalef D	Evenness E	Simpson
Bacillariophyceae	1.60	1.02	0.62	0.76
Chlorophyceae	2.42	2.21	0.70	0.89
Cyanophyceae	0.99	1.05	0.34	0.45
Euglenophyceae	1.62	1.32	0.46	0.75
Xanthophyceae	NC	NC	NC	NC

AUTHORS CONTRIBUTIONS

Conceptualization: Ayoade, A. A; Methodology: Ayoade, A. A. and Izah, B. C.; Data collection: Izah, B. C; Data validation: Ayoade, A. A. and Izah, B. C; Data processing: Izah, B. C.; Writing—original draft preparation: Ayoade, A. A.; Writing—review and editing: Ayoade, A. A.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

Abida B, Harikrishna, M, Study on the quality of water in some streams of Cauvery River. European Journal of Chemistry 5(2), 377-384, 2008.

Adeniji HA, Preliminary investigation into composition and seasonal variation of the plankton in Kainji Lake, in Nigeria. In: W.C.

Ackamuru, Apha G.F and E.B. Worthington(edn) Geophysical monograph series. Man-made Lakes: their problems and environmental effects 17, 617-619, 1973.

Anago IJ, Esenowo IK, Ugwumba AAA, The physico-chemistry and plankton diversity of Awba Reservoir, University of Ibadan, Ibadan, Nigeria. Research Journal of Environmental and Earth Sciences 5(11), 638-644, 2013.

APHA (American Public Health Association),

Standard methods for the examination of water andwastewater. 20th ed. APHA/AWWA/WEF: Washington DC, 1998.

Arimoro FO, Chukwuji MAI, Ogheneghalome O, Effects of industrial wastewater on the physical and chemical characteristics of a tropical coastal river. Research Journal of

Environmental Science 2(3), 209-220, 2008.

Ayoade AA, Onuekwusi UC, Nathaniel OG,

Composition and diversity of macroinvertebrates of a tropical reservoir, southwestern Nigeria. Ethiopian Journal of Environmental Studies and Management 10(10), 1339 – 1349, 2017.

Boyd CE, Lichtkoppler FR, Water quality management in pond fish culture. Blackwell Scientific Publications, Oxford, 1974, 225, 1979.

Cole A, A textbook of limnology. London: Longman. 426, 1978

Egborge ABM, Water pollution in Nigeria vol. 1: biodiversity and chemistry of Warri River. Ben Miller Books Nig. Ltd. 313, 1994.

Fonge BA, Tening AS, Egbe EA, Yinda GS, Fongod AN, Achu RM, Phytoplankton diversity and abundance in Ndop wetland plain, Cameroon. African Journal of Environmental. Science and Technology 6(6), 247-257, 2012.

Gajanan KS, Satish SM, Seasonal variation in

primary productivity of two freshwater lakes of Aurangabad district, Maharashtra, India. International Journal of Fauna and Biological Studies 1 (6), 7-10, 2014.

Gaarder T, Gran HH, Investigation of the production of plankton in the Oslo Fiord. Rapports et Procés-Verbaux des Réunions, Conseil Permanent International pour l'Exploration de la 42 1-48, 1972.

Horne AJ, Goldman CR, Limnology. Mcgraw-Hill, New York. 534pp, 1994.

Huet M, Textbook of fish culture, breeding and cultivation of fish. 2nd edition, News Book Publ. University Press, Cambridge. 438, 1977.

Karlman SG, Pelagic primary production in Kainji Lake.

FAO Technical Report No. 3. FESF/NR, pp. 24- 59, 1973.

Lenat DR, Smock LA, Penrose, DL, Use of benthic

Macroinvertebrates as indicators of environmental quality. Pp. 97-112 in: D.L. Worf (ed.). Biological monitoring for environmental effects. D. C. Heath and Company, Lexington, Mass, 1980.

Mandaville SM, Benthic macroinvertebrates in freshwaters – taxa tolerance values, metrics and protocols. (Project H-1) Soil; water conservation society of Metro Halifax, 2002.

Maosen H, Illustration of Freshwater Plankton. Agricultural Press. 171, 1978.

McNeely RN, Neimanis VP, Dwyer L, Water quality sourcebook. A guide to water quality parameters. Ottawa: Inland waters directorate, water quality branch, 1979.

National Environmental Standards and Regulations Enforcement Agency (NESREA), National environmental (surface and groundwater quality) regulations. S.I. 22, 2011.

Needham JG, Needham, PR, A guide to the study of freshwater Biology. San Francisco, Holde-Day Publishers, 1974.

Nwankwo DI, Euglenoids of some polluted storm-water channels in Lagos, Nigeria, Tropical Freshwater Biology 4, 29-39, 1995.

O'Beirne MD, Werne JP, Hecky RE, Johnson TC,

Katsev S, Reavie ED, Anthropogenic climate change has altered primary productivity in LakeSuperior.Naturecommunications8:15713DOI:10.1038/ncomms15713|www.nature.com/naturecommunication, 2017.

Ogbeibu AE, Anagboso MU, Baseline limnological

investigation of the Utor River in Esan southeast, Edo state, southern Nigeria: Physical and chemical hydrology. Tropical Freshwater Biology, 12/13, 45-62, 2003.

Ovie SI, Olokor JO, Adepoju F, Pelagic primary

production and some related physico-chemical factors of Dadin kowa reservoir, Dadin kowa, Gombe State, Nigeria. Journal of Arid Zone Fisheries 2(2), 42-50, 2004.

Ovie SI, Bwala RL, Ajayi O, A preliminary study on

limnological stock assessment, productivity and potential fish yield of Omi Dam, Nigeria. African Journal of Environmental Science and Technology 5(11), 956-963, 2011.

Pasztaleniec A, An advanced phytoplankton trophic

index: test and validation with a nationwide lake survey in Poland. International Review of Hydrobiology 101(1–2), 20–35, 2016.

Radar RB, The Florida Everglades: Natural variability, Invertebrates diversity and food web (eds.) Invertebrates in freshwater wetlands of North America. John Wiley and Sons, Inc. pp. 331, 1999.

Radojevic M, Bashkin VN, Practical environmental analysis. Royal school of chemistry, Thomas Graham house, science park Cambridge, UK. pp. 645, 1999.

Shannon CE, Weaver W, The mathematical theory of communication. University of Illinois Press, Urbana, Illinois. 144pp, 1949.

Simmons JA, Long JM, Ray JW, What limits the productivity of acid mine drainage treatment ponds? Mine Water and the Environment 23, 44-53, 2004.

Sorayya M, Mohd,S, Sapiyan, PS, Mumtazah SA, A self-organizing map (SOM)guided rule based system for freshwater tropical algal analysis and prediction. Scientific Research Essays 6(25), 5279-5284, 2011.

Spaak P, Bauchrowitz M, Environmental influences and plankton dynamics. Eawag: Swiss Federal Institute of Aquatic Science Technology 69e, 25-27, 2010.

Tailing JF, Rzóska, J, The development of plankton in relation to hydrological regime in the Blue Nile, Journal of Ecology 55, 637–662, 1967.

United States Environmental Protection Agency (USEPA), Drinking Water Health Advisory for Boron, EPA 822-R-08-013, 2008.

Vollenweider RA, A manual of methods of measuring primary productivity in aquatic environments. Edn 2, Research and Development Series 22, 30, 1974.

Wetzel RD, Linkens GE, Limnological analysis. Edn 3, Springer, New York Xv, 2000, 429, 2000.

Whitford LA, Schumacher GJ, A manual of fresh-water algae. Sparks Press, Raleigh, 324, 1973.