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Preliminary assessment of the deteriorating state of a dam in north-western Nigeria using phytoplankton structural assemblage and environmental factors

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ABSTRACT

Phytoplankton community structure in relation to some physico-chemical parameters in Kalgwai Dam, north-western Nigeria was undertaken monthly in three stations for a period of six months spanning from January to June 2018. Physico-chemical parameters and phytoplankton were collected once in a month on each sampling occasion. Physico-chemical parameters such as Dissolved Oxygen (DO) concentration was lowest in Station 1 (3.79 ± 0.53 mgl^{-1}), and phosphate, pH and turbidity were highest in Station 3. Tukey's Honestly Significant Difference (HSD) test showed that the mean values of DO, TDS, EC, and turbidity were significantly different ($p < .05$) among the three sampled stations. A total of 379 phytoplakton individuals belonging to 6 divisions and 41 taxa were identified in the study area, and Baccillariophyta was the most predominant division of phytoplankton in the dam. Slightly higher abundance of phytoplankton was recorded in the dry season than in wet season. Analysis of variance (ANOVA) calculated for biological indices showed no significant difference among the the months sampled ($p > .05$). Canonical Correspondence Analysis (CCA) model revealed a weak relationship between phytoplankton community structure and measured physico-chemical parameters. Species such as *Microcystis* sp., *Melosira* sp., *Closterium* sp., and *Ulothrix* sp. indicated a strong positive correlation with increasing physico-chemical parameters such as nutrients and BOD$_5$ at Station 1. These species were considered indicators of prevailing environmental conditions in the study area. Cluster analysis (Jaccard similarity) showed species of phytoplankton to be clustered by season rather than by stations. The study revealed anthropogenic pressures to contribute to the current deteriorating state of the dam.

Introduction

Aquatic ecosystems in sub-Sahara Africa are under severe habitat alteration and deteriorating water quality due to population growth, urbanization, industrialization, and technological progress (Edegbene, Arimoro, & Odume, 2019; Parienté, 2017). In urban areas, water pollution negatively impacts the biological structure and function of freshwater ecosystems, including freshwater reservoirs, e.g. dams (Znachor et al., 2020). In Nigeria, freshwater ecosystems draining urban catchments are often poorly managed resulting to severe pollution influx into the ecosystems (Emenike, Neris, Tenebe, Nnaji, & Jarvis, 2020a; Emenike et al., 2020b; Ighalo & Adeniyi, 2020). Freshwater ecosystems in the north-western part of Nigeria is no exception to pollution as they receive pollution inputs from farming (agricultural) actvities which include crop production and cattle grazing. Farming activities in the region primarily rely on the use of fertilizer and pesticides, which contribute high amounts of nutrients and heavy metals into the

freshwater ecosystems (Edegbene, 2020). Additionally farming practices within freshwater ecosystems in the region are poorly regulated and the existing laws and regulations guiding inland waters in the northern part of Nigeria, north-western region inclusive are poorly enforced or unenforced by the appropriate authorities (Edegbene, Arimoro, Odoh, & Ogidiaka, 2015), thus exacerbating the inputs of pollutants into inland waters in the region, and the Kalgwai Dam is no exception. The exacerbating inputs of pollutants into the inland waters have a deleterious effects on the structural assemblages of resident aquatic biota.

Resident aquatic biota, including microorganisms, phytoplankton, zooplankton, macroinvertebrates, and fish are widely used to monitor the levels of freshwater pollution worldwide (Arimoro, Ikomi, Nwadukwe, Eruotor, & Edegbene, 2014; Edegbene & Arimoro, 2014; Patang, Soegianto, & Hariyanto, 2018). Among aquatic biota used in monitoring freshwater ecosystems, phytoplankton are primary producers, and therefore they constitute the base of aquatic food webs

underpinning reservoir ecosystem stability and function (Geider et al., 2001). Anthropogenic nutrient enrichment significantly accelerates phytoplankton productivity and biomass in freshwater ecosystems (Hatt, Fletcher, Walsh, & Taylor, 2004; Heino, 2013; Krynak & Yates, 2018). Therefore understanding the effects of environmental parameters on phytoplankton communities is important to assess the effects of anthropogenic impacts on reservoir ecosystems (Znachor et al., 2020) and to develop strategies for water quality monitoring.

Additionally, phytoplankton is seen as important biological indicators of water quality changes due to their short life spans, quick response to pollutants and ease in determining their numbers (Han, Krause, Mccormick, Carrichk, & Schelscke, 2012), unlike other biodindicators. Despite the increasing use of phytoplankton for water pollution monitoring (Jasim, Sheimmaa, & Ahmad, 2013; Nweze, 2012; Shakila & Natarajan, 2012), only few studies have used phytoplankton as indicator of water quality in Nigeria, especially freshwater reservoirs (Guy et al. 2004; Davies & Ugwumba, 2013; Dimowo, 2013; Effiong & Inyang, 2016). Thus, this study is an addition to the already existing studies using phytoplankton assemblage structure for biological monitoring of freshwater ecosystems globally and Nigeria in particular. Therefore, in the present study, phytoplankton assemblage structure and their relationship with selected physico-chemical parameters were assessed to determine the current deteriorating state of Kalgwai Dam in north-western Nigeria.

Kalgwai Dam was built by the Federal Government of Nigeria in collaboration with a non-governmental organization to supply water for irrigation purposes to farmers around the dam (Edegbene, 2020). However, the aim of the project has been abused by the riparian communities, as the dam now serves as a refuse dump site, place of convenience (toilet) where they defecate, bath and conduct other domestic activities. These activities have a debilitating effect on the inherent biota structural and functional assemblages of the Kagwai Dam. Therefore, this study was conducted to ascertain the impact of these activities on the dam by using phytoplankton community structural assemblage and selected physico-chemical parameters.

Materials and methods

Study area

Kalgwai Dam, an irrigation dam is located few meters away from Kalgwai village in Auyo Local Government Area of Jigawa State, Nigeria (Figure 1). It is a perennial dam, located on the interception of latitude 12°35′N – 10°7′E and longitude 12.230°N – 10.022°E of the equator (Edegbene, 2020). Kalgwai Dam is a storage pond constructed across the Hadejia River for storage. Details of the study area description are contained in Edegbene (2020). The study was carried out seasonally (dry and wet seasons) in three marked out stations over a period of six months between January and June 2018.

The three stations (Station 1: Gajegumi; Station 2: Galadimawa; and Station 3: Yanruwa) were selected based on community and anthropogenic activities (see Edegbene, 2020 for details of selected stations description).
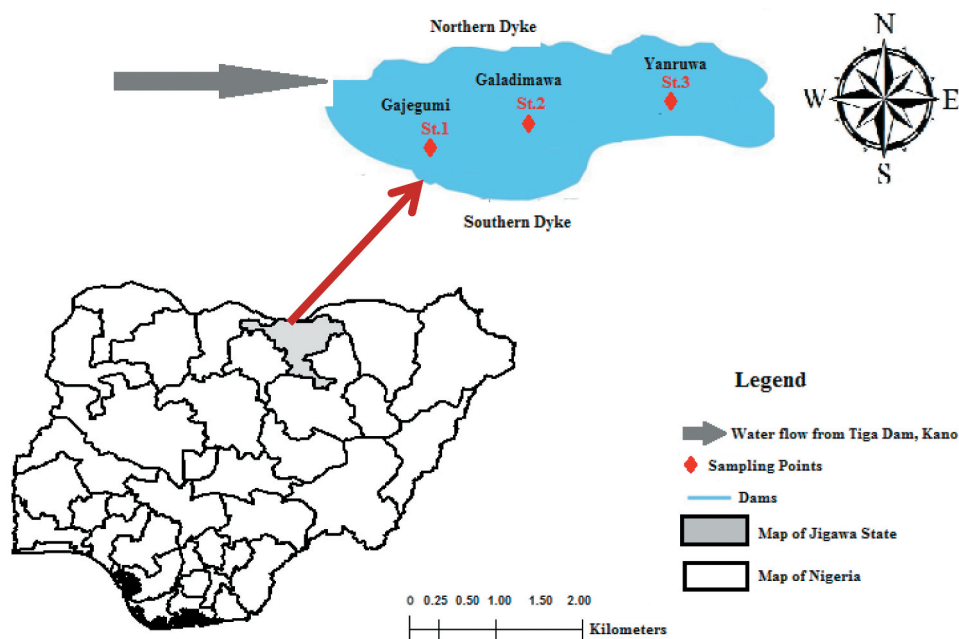

Figure 1. Study area map showing the sampling points.

Physico-chemical parameters sampling and analysis

The following physico-chemical parameters were sampled and analyzed in the present study: water temperature, water depth, electrical conductivity (EC), salinity, total dissolved solids (TDS), pH, dissolved oxygen (DO), five days biochemical oxygen demand (BOD_5), phosphate, and nitrate. At each of the sampling stations on every sampling occasion, subsurface water temperature was determined using a mercury-in-glass thermometer. Water depth was measured using a calibrated rod measured in meters, according to Gordon, McMahon, and Finlayson (1994) method, and EC, salinity and TDS were measured using a conductivity meter (model DDSJ-308A). Portable turbidity meter and pH meter (HANNA HI 9828 multi-probe meter manufactured by HANNA instruments) were used in measuring turbidity and pH of water at each sampling station. DO was measured using hand-held dissolved oxygen meter (model YSI 55). Separate water samples were collected in 50 ml sterile bottles for the measurement of BOD_5, phosphate and nitrate and they were analyzed according to (American Public Health Association, APHA, 2005) methods.

Phytoplankton sampling and processing

Phytoplankton were collected using a plankton net with a small plastic bottle container of 20 ml attached to a narrow end. The net was tied to a metal rod, towed horizontally for a fixed distance of 1 m, and then it was hauled out of water. Five replicates of the samples were collected in different flow regime in each of the stations. Water (containing plankton) was poured into a plastic bottle of 20 ml and immediately fixed with 2 ml of 4% formalin in order to preserve the phytoplankton (Gaswani, 2004). The samples were taken to the laboratory for identification and counting. Before identification, the samples were allowed to settle for 10 minutes and thereafter, 2/3 of each sample was decanted. Two drops of the concentrated sample were taken using a pipette and dropped into a glass slide and viewed under a compound microscope using ×10 magnification and then confirmed with ×40 magnification for identification confirmation. Phytoplankton species were directly counted under a microscope and identified to the lowest possible taxonomic level using identification guide (Han, 1978).

Statistical analyzes

Descriptive statistics (mean ± standard deviation) were computed for the three sampling stations for the six months sampling period using univariate analysis on Paleontological Statistical Package (PAST-Hammer, Harper, & Ryan, 2001). Two-way analysis of variance (ANOVA) was carried out to determine the level of significance of physico-chemical parameters among the three stations. When significant difference occurred (at $p < .05$), Tukey Honestly Significant Difference (HSD) was used to determined which stations differs. ANOVA and HSD were computed using PAST (Hammer et al., 2001). The absolute and relative abundance of major divisions of phytoplankton collected in both dry (January to April) and wet (May to June) seasons were represented in bar charts. Student t-test was computed to show if there is a significant difference in the structural assemblage of phytoplankton between dry and wet seasons, and student t-test was computed using PAST (Hammer et al., 2001). Diversity indices which include; Simpson dominance, (1-D), Shannon Weiner Index (H), evenness, and Margalef index were determined using PAST (Hammer et al., 2001). One-way ANOVA was used to show the significant differences in the diversity indices among the three sampling stations, and was computed using PAST (Hammer et al., 2001). Canonical correspondence analysis (CCA) was used to evaluate associations between phytoplankton community and physico-chemical parameters. Prior to CCA, rare taxa occurring less than 1 % of the overall sample collected per sampling station were removed from the computation of the CCA model. Physico-chemical parameters used for the CCA analysis were logarithmically transformed to prevent the undue influences of extreme values on the final model. A Monte-Carlo permutation test at 999 permutations argument (Jckel, 1986) was used to assess the significance of the first three CCA axes. Cluster analysis based on the Jaccard similarity index was used to ascertain whether the phytoplankton community assemblage structure was influenced either by differences in sampling stations or months. The CCA model, Monte-Carlo test, and cluster analysis were computed using PAST statistical package (Hammer et al., 2001).

Results

Physico-chemical parameters

Summary of physico-chemical parameters are shown in Table 1. Significant differences were noted among the months and sampling stations for BOD_5 and EC ($p < .05$) while water temperature, pH, transparency, water depth, DO and nitrate showed no significant differences among the months and sampling stations ($p > .05$). The DO concentration was lower in Station 1 (3.79 ± 0.53 mgl^{-1}) than other stations, while BOD_5 was higher in Station 1 (2.33 ± 0.93mgl^{-1}), compared to the other two stations. Station 3 had the highest mean value of pH, phosphate and turbidity. Tukey HSD test computed showed stations means of DO, TDS, EC, and turbidity to be significantly different ($p > .05$).

Table 1. Mean values of physico-chemical parameters of the study stations of Kalgwai Dam during the study period (January–June 2018).

Parameters	Station 1	Station 2	Station 3	Months		Stations	
				F value	p value	F-value	P-value
Water Temperature (°C)	24.33 ± 4.60[a] (18.5–31.0)	25.37 ± 4.60[a] (18.2–30.0)	25.83 ± 5.82[a] (17.0–32.0)	20.77	$p > .05$	0.49	$P > .05$
pH	9.73[a] (7.6–10.7)	10.25[a] (8.3–11.4)	10.83[a] (8.2–11.2)	36.98	$p > .05$	3.46	$P > .05$
Transparency (cm)	18.67 ± 4.63[a] (12.5–25.0)	17.83 ± 2.53[a] (15.5–22.0)	19.95 ± 5.72[a] (11.7–28.5)	0.26	$p > .05$	0.04	$P > .05$
Water Depth (m)	0.37 ± 0.47[a] (0.24–0.5)	0.43 ± 0.01[a] (0.17–0.75)	0.57 ± 0.15[a] (0.16–0.81)	4.07	$p < .05$	1.78	$P > .05$
Dissolved Oxygen (DO) (mgl^{-1})	3.79 ± 0.53[a] (3.05–4.49)	4.33 ± 0.29[a] (4.05–4.76)	4.84 ± 0.66[b] (3.95–5.80)	1.28	$p > .05$	7.05	$P < .05$
Biochemical Oxygen Demand BOD$_5$ (mgl^{-1})	2.33 ± 0.93[a] (0.88–3.59)	1.69 ± 0.65[b] (0.95–2.50)	1.73 ± 0.36[a] (0.47–1.60)	8.31	$p < .05$	17.77	$P < .05$
Total Dissolved Solids (TDS) (mgl^{-1})	92.47 ± 11.27[a] (76.3–108.3)	74.58 ± 9.10[b] (64.3–76.9)	71.40 ± 5.34[b] (66.5–80.3)	3.08	$p > .05$	15.95	$P < .05$
Nitrate (mgl^{-1})	0.40 ± 0.15[a] (0.15–0.50)	0.27 ± 0.15[a] (0.17–0.36)	0.27 ± 0.15[a] (0.18–0.31)	2.63	$p > .05$	2.21	$P > .05$
Phosphate (mgl^{-1})	1.10 ± 0.17[a] (1.21–1.63)	1.46 ± 0.29[a] (1.11–1.81)	1.56 ± 0.35[a] (1.00–1.95)	11.44	$p < .05$	0.12	$P > .05$
Electrical Conductivity (EC) (µScm^{-1})	149.0 ± 16.99[a] (125.9–178.8)	118.4 ± 13.2[b] (106.5–141.8)	115.9 ± 10.3[b] (106.1–131.7)	5.06	$p < .05$	26.37	$P < .05$
Turbidity (NTU)	72.67 ± 67.96[a] (18.5–191.5)	150.57 ± 15.4[b] (128.5–171.7)	153.67 ± 14.4[b] (134.4–176.5)	3.09	$p > .05$	15.95	$P < .05$

Note: Values are means± standard deviation. Maximum and minimum values in parenthesis. Mean values having different superscripts along columns are significantly different at ($p < 0.05$).

The phytoplankton assemblage structure

A total of 379 individuals of phytoplankton belonging to six divisions, 41 taxa were identified during the study (Table 2). The division Baccillariophyta was the most dominant phytoplankton in the dam with 17 taxa, followed by Chlorophyta, whereas Xanthophyta was the least abundant division. Absolute abundance of taxonomic groups at the divisions level revealed that Cyanophyta was the most occurring at Station 1 with 60 individuals (Figure 2). Euglenophyta and Pyrophyta were sparingly represented in the three sampling stations. The highest relative abundance was recorded in Station 1 in January (Figure 3). Station 3 did not show much spatio-temporal variation in phytoplankton except in April (dry season) and June (wet season). Overall, slightly higher abundance was recorded in the dry season (January–April) than in the wet season (May–June). Student t-test showed a significant difference in the structural assemblage of phytoplankton between the two seasons ($p < .05$).

Phytoplankton diversity

Summaries of biological diversity metrics are shown in Table 3. The abundance, Simpson dominance, Shannon Weiner diversity, evenness and taxa richness were slightly higher in Station 1 compared to Stations 2 and 3 (Table 3). Generally, the mean value of biological diversity metrics calculated showed no significant difference among the sampling stations ($p > .05$). The biological indices were not significantly different for the months sampled ($p > .05$) but significantly different for the stations ($p < .05$) except for abundance, dominance, Simpson dominance, and evenness.

Relationship between phytoplankton and selected physico-chemical parameters

A CCA ordination revealed a weak relationship between phytoplankton species communities and measured physico-chemical parameters. The Eigenvalues for Axes 1 and 2 are 0.30 and 0.45 respectively (Table 4). The first CCA axis accounted for over 87% of the variation in the data set. A Monte-Carlo permutation showed that the first two canonical axes were not significantly different ($p > .05$). Axis 1 was slightly associated with *Microcystis* sp., *Dactylococcopis* sp., and *Melosira* sp. and they were mostly found in Station 1 and explained by increasing concentrations of BOD$_5$, nitrate and TDS. These species of phytoplankton can be suggested as pollution tolerant species due to their association with increasing concentrations of BOD$_5$ and nitrate. *Ulothrix* sp. and *Closterium* sp. were positioned on the center of the CCA model and they were explained by increasing water transparency. Station 2 had no definite cluster of phytoplankton species around it, and this show that weak relationship existed between Station 2 and the phytoplankton collected during this study. *Anabaenopsis* sp., *Fragilaria* sp. and *Tribonema* sp. were shared between Stations 2 and 3. These organisms distribution on the CCA were mainly associated with pH, DO, turbidity, and EC. *Anabaenopsis* sp. was noticed to be strongly positively correlated with increasing DO concentration. Axis 2 of the CCA triplot was associated mainly with physico-chemical parameters

Table 2. Structural assemblage of phytoplankton in Kalgwai Dam during the study period (January–June 2018).

Divisions/Taxa Name	Station 1	Station 2	Station 3	Total
Cyanophyta				
Dactylococcopsis sp.	8	10	12	30
Microcystis sp.	6	2	2	10
Oscillatoria sp.	4	1	0	5
Anabaenopsis sp.	3	4	3	10
Phormidium sp.	1	2	0	3
Spirulina sp.	4	3	2	9
Rapidiopsis sp.	3	2	0	5
Xanthophyta				
Tribonema sp.	6	5	2	13
Chlorophyta				
Closterium sp.	2	1	0	3
Closteriopsis sp.	5	4	3	12
Gloeocystis sp.	4	2	0	6
Coelosterum sp.	4	1	2	7
Ankistrodesmus sp.	1	1	0	2
Ulothrix sp.	3	2	2	7
Onychonema sp.	5	3	2	10
Mougeotia sp.	3	2	0	5
Tetraedron sp.	4	1	3	8
Oocystis sp.	3	3	1	7
Cosmarium sp.	1	2	2	5
Baccillariophyta				
Melosira sp.	7	3	2	12
Cymatopleura sp.	7	8	9	23
Cymbella sp.	6	5	3	14
Nitzschia sp.	2	4	7	13
Cocconeis sp.	9	10	6	25
Cyclotella sp.	3	0	1	4
Navicula sp.	2	1	0	3
Stephanodiscus sp.	6	7	8	21
Epithemia sp.	5	3	3	8
Rhizosolenia sp.	6	0	2	8
Surirella sp.	5	3	1	9
Gyrosigma sp.	4	0	0	4
Synedra sp.	1	3	0	4
Amphipleura sp.	3	2	1	6
Eunotia sp.	3	3	0	6
Fragilaria sp.	9	10	11	30
Tabellaria sp.	3	4	5	12
Pyrophyta				
Glymnodinium sp.	0	0	6	6
Peridinium sp.	0	3	0	3
Euglenophyta				
Lepocinclis sp.	3	0	0	3
Euglena sp.	1	0	0	1
Phacus sp.	2	3	2	7
Absolute abundance	157	123	103	379

that were seasonally influenced including; water depth, phosphate and EC. Nitrate, BOD_5, and TDS were strongly associated with Axis 1 (Table 4).

Cluster analysis (Jaccard similarity) produced based on phytoplankton $\log(x + 1)$ transformed data showed that species were clustered by season rather than by stations. Samples collected from the same season were closely associated (Figure 5). The highest similarity was noticed in the cluster between January and March while the least similarity was found in the cluster between March and April in Stations 1 and 3, followed by February and April cluster in Station 3.

Discussion

Physico-chemical parameters

Physico-chemical parameters of freshwater ecosystems can be influenced by varied factors such as catchment size, vegetation, soil types, land use patterns, and other anthropogenic activities. These factors can alter the community structure of aquatic biota inhabiting the ecosystem (Arimoro, Odume, Uhunoma, & Edegbene, 2015). For Effective planning of the structural design of a dam or any other man-made aquatic system, it is better to put into consideration these factors that have the potential to either positively or negatively influence the aquatic organisms in the system. The Kalgwai Dam is a very significant water source for irrigation and other domestics activities in Jigawa State in north-western Nigeria. Therfore, the high values of TDS, EC, and turbidity, especially in Station 1 are indicators of the results of human influences on the dam. Local dwellers residing along the banks of the dam use the dam for washing, bathing, and fertilizer runoff from farms around the dam catchments are also evident. These activities may likely be the cause of the deteriorating state of the water quality of the dam. Station 1 had the highest BOD_5 mean value, and this may be attributed to the incessant anthropogenic activities carried out within and around the dam such as crop farming, cattle grazing and domestics activities. Station 3 with the lowest BOD_5 mean value, is as expected as the station is relatively not disturbed due to the absence of farms lands. It could also favorably be argued that the presence of concrete dyke might have prevented much human influences in Station 3, which would have increased the deteriorating state of the station. Nitrate values were relatively low (0.15–0.50 mgl^{-1}) and could be an indication of insufficient inorganic nutrients accumulation. Although farmers around the dam bank use fertilizer for crops farming, but probably the concentration of the fertilizer used in the crop farming may be minimal, hence the relatively low concentration of nutrients in the dam. Further, nutrients uptake by phytoplankton and aquatic macrophytes as well as microbial activities might have contributed to the low nutrients concentration in the dam (Arimoro et al., 2015). The pH values recorded in the present study indicate an alkaline type of water. This result is contrary to the concentration of pH recorded in similar studies in southern parts of Nigeria, where pH is slightly acidic to neutral (Edegbene & Arimoro, 2012; Edegbene et al., 2012). Most freshwater ecosystems catchments in southern parts of Nigeria are forested, hence the acidic state of the waters unlike the Sahel/Sudan savannah catchments of freshwater ecosystems in the north-western part of Nigeria.

Most freshwater ecosystems in Nigeria are subjected to discharges of organic and inorganic materials from activities within the ecosystems catchments (Andem, Okorafor, Eyo, & Ekpo, 2014). In this study, variation in most pollution indicating physico-chemical parameters between Station 3 and the remaining two stations may have contributed to differences in phytoplankton assemblage structure between the sampling stations. The concentrations of phosphate recorded in this dam were slightly high compared with relatively unperturbed freshwater ecosystems elsewhere (Chapman, 1996; Radojevic & Bashkin, 1999)
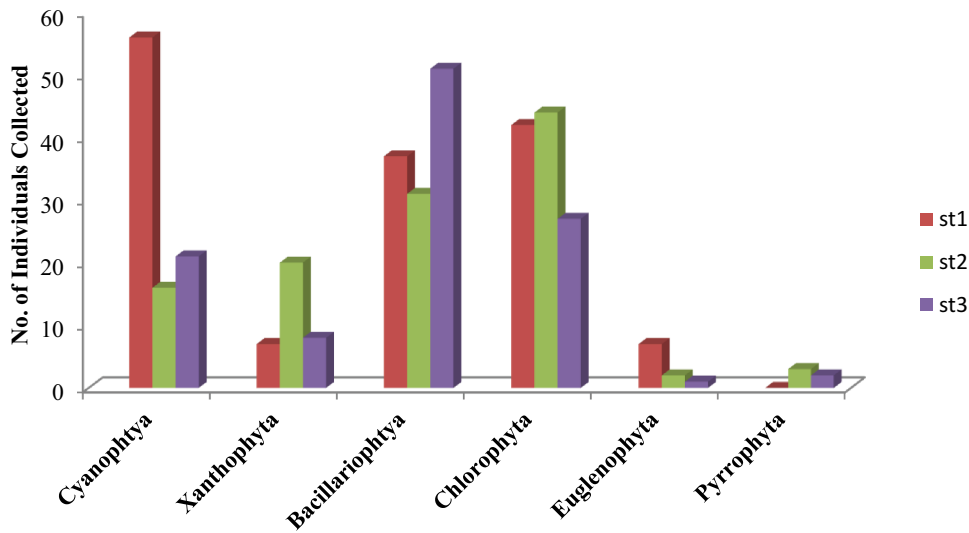
Figure 2. Absolute abundance of major divisions of phytoplankton in the sampling stations of Kalgwai Dam, during the study period (January–June 2018).
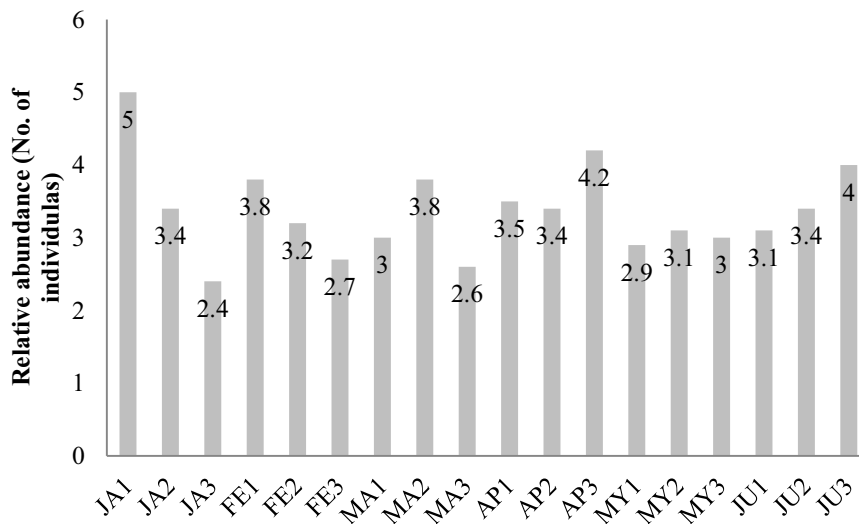

Figure 3. Relative abundance of phytoplankton in Kalgwai Dam during dry season (January–April) and wet season (May–June) in 2018. (JA, January; FE, February; MA, March; AP, April; MY, May; JU, June; and numbers 1, 2, and 3 represent the sampled stations).

Table 3. Mean number of species (taxa), Abundance, Dominance, Simpson Dominance, Shannon Weiner Diversity, Evenness, Margalef's Indices of Phytoplankton in Kalgwai Dam during the study period (January - June 2018). Mean ± standard deviation.

Indices	Station 1	Station 2	Station 3	ANOVA(Stations)	ANOVA (Months)
Taxa (Species No.)	7.17 + 0.75[a]	6.17 + 0.40[a]	6.33 + 0.61[a]	$p < .05$	$p > .05$
Abundance (No. of individuals)	24.17 + 1.33[a]	21.33 + 1.48[a]	19.5 + 2.35[a]	$p > .05$	$p > .05$
Dominance (D)	0.17 + 0.016[a]	0.20 + 0.014[a]	0.22 + 0.03[a]	$p > .05$	$p > .05$
Simpson dominance (D)	0.83 + 0.016[a]	0.80 + 0.014[a]	0.78 + 0.03[a]	$p > .05$	$p > .05$
Shannon Weiner index (H)	1.86 + 0.10[a]	1.71 + 0.069[a]	1.67 + 0.12[a]	$p < .05$	$p > .05$
Evenness (E)	0.92 + 0.018[a]	0.91 + 0.016[a]	0.86 + 0.03[a]	$p > .05$	$p > .05$
Margalef index (taxa richness) (d)	1.93 + 0.21[a]	1.69 + 0.099[a]	1.81 + 0.16[a]	$p < .05$	$p > .05$

Note: Different superscript letters in a row show significant differences ($p < 0.05$) indicated by HSD test.
$p < 0.05$ = ANOVA calculated showed significant difference among sampling stations and months
$p > 0.05$ = ANOVA calculated showed no significant difference among sampling stations and months

and similar to phosphate recorded in perturbed freshwater ecosystems in the sub-Sahara Africa (Adeyemo, Adedokun, Yusuf, & Adeleye, 2008; Ighalo & Adeniyi, 2020).

Phytoplankton assemblage structure and diversity

A total of 379 phytoplankton individuals belonging to six divisions were recorded during the study period in

Kalgwai Dam. This number is low compared to the number of individuals recorded for other water bodies in Nigeria (Davies & Ugwumba, 2013; Effiong & Inyang, 2016; George, Samuel, & Andem, 2012), but higher than species number recorded elsewhere (Jasim et al., 2013; Lasakar & Gupta, 2013).

Of the phytoplankton division recorded in this study area, Baccillariophyta was found to be the dominant division. Earlier, a study has also reported the dominance of Baccillariophyta (Effiong & Inyang, 2016) and their dominance were hinged on accumulated organic pollution in the riverine system. Eleven (11) taxa of Chlorophyta were recorded, and this may not be unconnected to the low nitrate concentration in the dam (Ewebiyi, Appah, & Ajibade, 2015), which would have hampered the productivity of

Chlorophyta if in high concentration. Cyanophyta was represented by pollution tolerant taxa (*Microcystis* sp. and *Anabaenopsis* sp.), and they have been reported to strive well in eutrophic waters (Davies & Ugwumba, 2013) (Figure 4).

The relative abundance of phytoplankton in the dry season was higher than that of the wet season. Similar studies in Nigeria reservoirs and streams have reported the same trend in phytoplankton abundance (Balogun & Ajani, 2015; Ewa, Iwara, Alade, & Adeyemi, 2013), and they attributed this to increased photic depth and reduction in the input of turbid materials during the dry season months (Ewa et al., 2013). In the Kalgwai Dam, similar conditions were noticed during the sampling period in the dry season months (March and April).
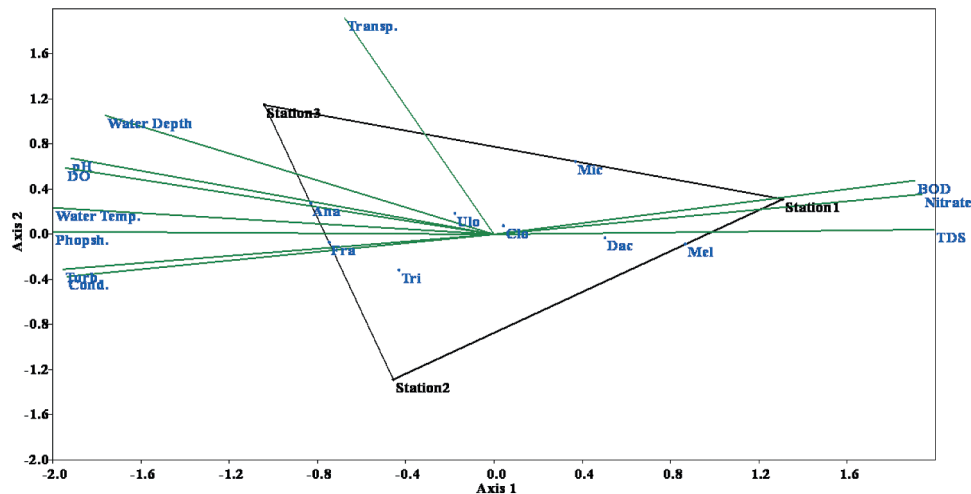

Figure 4. Triplot of the first and second CCA axes of phytoplankton taxa, physico-chemical parameters and the sampling stations of Kalgwai Dam. Phytoplankton abbreviation: Dac (*Dactylococcopis* sp.), Mic (*Microcystis* sp.), Ana (*Anabaenopsis* sp.), Tri (*Tribonema* sp.), Clo (*Closterium* sp.), Ulo (*Ulothrix* sp.), Mel (*Melosira* sp.), and Fra (*Fragilaria* sp.).
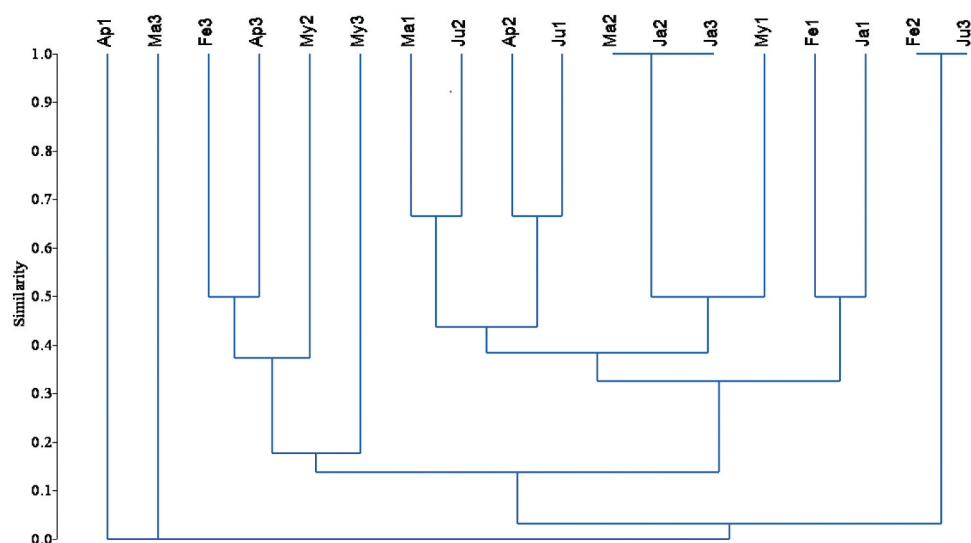

Figure 5. Dendrogram derived from the cluster analysis (Jaccard similarity index) of log (x + 1) transformed phytoplankton abundance data in the Kalgwai Dam during the study periods (January to June, 2018). Ja, January; Fe, February; Ma, March; Ap, April; My, May; Ju, June. Numbers 1, 2, and 3 attached to the months represent the sampling stations.

Table 4. Weighted intraset correlations of environmental variables with the first two axes of canonical correspondence analysis (CCA) in Kalgwai Dam.

Variables	Axis 1	Axis 2
Eigenvalue	0.30	0.45
% variation of species data explained	87.09	12.91
Monte Carlo permutation (*p*-value)	0.66	0.15
Water temperature (°C)	-0.998	0.118
pH	-0.96	0.338
Water depth (m)	-0.881	0.527
DO (mgl^{-1})	-0.972	0.295
BOD$_5$	0.954	0.239
Total dissolved solid (mgl^{-1})	0.997	0.0215
Nitrate (mgl^{-1})	0.971	0.178
Phosphate (mgl^{-1})	-0.999	0.012
Conductivity (Scm^{-1})	-0.969	-0.187
Turbidity (NTU)	-0.977	-0.155

All canonical axes were not significantly different (p > 0.05) for the two axes.

Relating phytoplankton with environmental variables

A CCA ordination showed a weak association between the selected physico-chemical parameters and phytoplankton in the present study. *Microcystis* sp. and *Melosira* sp. are suggested as pollution indicating taxa due to their association with pollution indicating physico-chemical parameters such as BOD$_5$ and nutrients (Dimowo, 2013; Ewebiyi et al., 2015; Shakila & Natarajan, 2012). Similarly, study elsewhere reported correlations of some phytoplankton group with pollution indicating physico-chemical parameters such as increasing concentration of nitrate and ammonia, and decreasing water transparency (Lasakar & Gupta, 2013). *Ulothrix* sp. and *Closterium* sp. in this study were found to be strongly positively associated with increasing water transparency, suggesting that they may be sensitive to pollution (Lasakar & Gupta, 2013).

Conclusion

This present study revealed a deteriorating water quality of Kalgwai Dam and the level of deterioration experienced were occasioned by anthropogenic activities such as crop farming, cattle grazing, bathing, washing, and open defecation. Phytoplankton species such as *Microcytis* sp., *Melosira* sp. and *Ulothrix* sp. were considered as potential indicators of water quality. This research serves as a baseline study for further studies in the use of phytoplankton structural assemblage and environmental factors in assessing the deteriorating state of freshwater ecosystems such as dams, lake, rivers and streams in north-western Nigeria and Nigeria in general.

Declaration of interest

We declare that no conflicting interest in this work.

Authors' contribution

Dr. Edegbene conceptualizes the work. Mr. Ghali and Dr. Edegbene collected the samples, analyzed the samples, performed the statistical analyses, and wrote the first version of the manuscript. Mr. Ghali, Mr. Akamagwuna, Drs. Edegbene, Osimen, Ogidiaka, and Keke proofread and edited the final version of the manuscript and Dr. Edegbene supervised the entire work.

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