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Seasonal Assessment of Physico- Chemical Parameters, Phytoplanktons Composition and Abundance in Ajiwa Reservoir, Katsina State, Nigeria

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Abstract

Anthropogenic activities, climatic changes, and dam geology have been reported to influence the productivity of reservoirs. This study aimed to determine the seasonal variability of physico-chemical parameters, phytoplankton composition, and abundance in Ajiwa Reservoir, Katsina State, Nigeria. Water samples were collected from December 2022 to September 2023 and analyzed for phytoplankton composition and physico-chemical conditions using standard methods. The results revealed that the mean water temperature (25.12±3.76°C), pH (7.03±0.55), dissolved oxygen (6.84±0.75mg/L), biochemical oxygen demand (3.00±0.79mg/L), electrical conductivity (119.67±14.40µS/cm), total dissolved solids (16.55±4.80mg/L), turbidity (100.47±14.56NTU), water hardness (86.46±4.93mg/L), nitrate-nitrogen (7.91±2.69mg/L), and phosphate-phosphorus (5.43±2.40mg/L) were significantly different across seasons (P < 0.05). The percentage compositions of phytoplankton were Chlorophyceae (33.50%), Bacillariophyceae (22.36%), Cyanophyceae (12.57%), Cryptophyceae (12.48%), Euglenophyceae (6.58%), and Dinophyceae (4.55%) from four sampling sites during the study period. Phytoplankton were found to be more abundant in the wet season (858) than the dry season (327). The correlation matrix showed significant correlations between phytoplankton and physicochemical parameters. The compositions of phytoplankton in the reservoir were affected by seasonal variations and fluctuations in physicochemical parameters.

Key words: Ajiwa, Reservoir, Physicochemical, Phytoplankton, Composition.

INTRODUCTION

Water is one of the most important substances available on earth, upon which the survival and quality of human life depend. The lives of aquatic animals are directly or indirectly influenced by the quality of water (Mustapha, 2011). Reservoirs are commonly used for water impoundment, ensuring year-round availability of water and reducing obstructions from rivers. They serve as valuable sites for studying the factors that influence the abundance and distribution of aquatic organisms (Atobatele and Ugwumba, 2008). It is widely recognized that a reservoir's productivity is closely tied to its ecological state, and through continuous monitoring of water quality, productivity can be enhanced to achieve a maximum sustainable fish yield (Mustapha, 2011).

Maintenance of a healthy aquatic environment and the production of sufficient food in reservoirs are primarily linked to successful reservoir culture operations. To keep the aquatic habitat favorable for the existence of living organisms, physical and chemical factors such as temperature, turbidity, pH, odor, dissolved gases (oxygen and CO2), salts, and nutrients must be regularly monitored, either individually or synergistically (Ahmed, 2012). The activity of living organisms is influenced by the seasonal and diurnal changes in these parameters (Akinyeye et al., 2011). Various studies have been conducted on the changes brought about by biotic and abiotic factors in rivers as a result of damming. However, the responses of rivers and their ecosystems to damming are complex and varied as they depend on local sediment supplies, geomorphic constraints, climate, dam structure, and operation (Offem and Ikpi, 2011).

This study aimed to assess the physico-chemical conditions of Ajiwa Reservoir, its phytoplankton diversity, and abundance during both the wet and dry seasons to evaluate the reservoir's water quality for domestic and agricultural purposes, and its suitability as a habitat for aquatic life.

MATERIALS AND METHODS

Study Area

Ajiwa Reservoir was constructed in 1975 and is situated in a sub-desert area at latitude 12°98'N and longitude 7°75'E in Batagarawa Local Government Area (LGA), Katsina State, Nigeria (Figure 1). Primarily intended for irrigation and water supply to the residents of Katsina, Batagarawa, Mashi, and Mani LGAs of the State, the reservoir had an original height of 12m, which was increased to 14.7m following rehabilitation in 1998. Initially, the reservoir crest length was 880m, but post-rehabilitation, it stands at 1491.8m. Spanning a surface area of 607 hectares with a water volume of approximately 22,730,000m3, the reservoir plays a crucial role in sustaining the livelihoods of the nearby communities (Tanimu, 2011).

Sampling Station

The reservoir water was divided into four sampling stations; A, B, C, and D, for the purpose of this study (Figure 1). Station A was located at the shore of the Reservoir (12°58' 51"N, 7°41'16"E), where human activities like bathing and washing take place. Station B was situated in the middle of the reservoir (12°58'51"N, 7°50'16"E), with fewer human activities occurring. Station C was positioned at 12°52'44"N, 7°41'16"E, where irrigation activities take place, while Station D was located downstream of the reservoir (N12°52' 55"N 7°50'16"E), experiencing fewer human and agricultural activities (Tanimu, 2011).

Sample Collection and Procedure

Water samples for physico-chemical analyses and phytoplankton assessment were collected from the stations in one-liter transparent plastic bottles by sliding the container over the water's surface with its mouth open, allowing undisturbed passage of the water into the bottle (Tanimu, 2011). Sampling was conducted in the morning between 7:00 am and 10:00 am, from December 2022 to September 2023 (APHA, 2010). The samples were then transported to the Biology Laboratory at the Department of Biology, Umaru Musa Yaradua University, Katsina (UMYUK), for analysis of physico-chemical parameters, phytoplankton composition, and abundance (Tanimu, 2011). Water temperature (°C) was measured by immersing a glass mercury thermometer into the water at each station for 1-2 minutes, and the readings were recorded (APHA, 2010). The water pH was determined using a Hanna 420 pH meter, with the electrode submerged in the water sample for 2-3 minutes, and readings were recorded (APHA, 2010). Dissolved oxygen was assessed using a calibrated Hanna dissolved oxygen microprocessor HI 98186 model, where a water sample was collected in a 100ml beaker, and the electrode of the dissolved oxygen microprocessor was immersed in the sample for 2-3 minutes. The readings were recorded in mgL^{-1}. Biochemical oxygen demand was calculated by incubating a 10ml portion of the sample for five days at room temperature, and the difference in dissolved oxygen before and after incubation was used to determine the biochemical oxygen demand of the water sample (Mahar, 2003; APHA, 2010).

The turbidity of water was measured using a turbidity tube calibrated at the bottom with an "X" mark in black color. A 200ml water sample was gradually poured into the turbidity tube while observing the calibration mark at the bottom until it disappeared. The depth at which it disappeared was recorded in Nephelometric Turbidity units (NTU) from the graduated readings of the turbidity tube (Nathanson, 2003). Water hardness was determined by collecting a 10ml water sample into a conical flask using a 10ml pipette. Buffer Tablet (Eriochrome black-T) 0.5 mg and 1ml of concentrated ammonium hydroxide (NH_4OH) were added as indicators and titrated against 0.1N (EDTA) solution. These parameters were measured using a WTW 320 conductivity meter. Water samples were placed into a clean 100ml beaker, and the conductance cell of the meter was immersed into the sample solution. The resistance was measured in µS/cm, and the readings of conductivity and total dissolved solids were noted with the WTW 320 conductivity meter by changing the mode of measurement to TDS. The cell was rinsed in a 100ml beaker with distilled water after each reading. Phosphate-phosphorus was determined using the Deniges method (APHA, 2010). One milliliter of Deniges reagent and 5 drops of stannous chloride were added to a 100ml water sample. Absorbance at 690nm was measured using a spectrometer model S101 with distilled water as the blank. The phosphate-phosphorus concentration of the water samples was read from the calibration curve in mgL^{-1}. Nitrate-nitrogen was determined by pouring 100ml of water sample into a crucible, evaporating it to dryness, and cooling it. Two milliliters of phenoldisulphonic acid were added and smeared around the crucible. After 10 minutes, 10ml of distilled water was added followed by 5ml of strong ammonia solution. The spectrophotometer model S101 was set at a wavelength of 430nm, and the absorbance of the treated sample was obtained using distilled water as a blank. The concentration of nitrate-nitrogen was obtained from the calibration curve in $mgL^{-1.}$

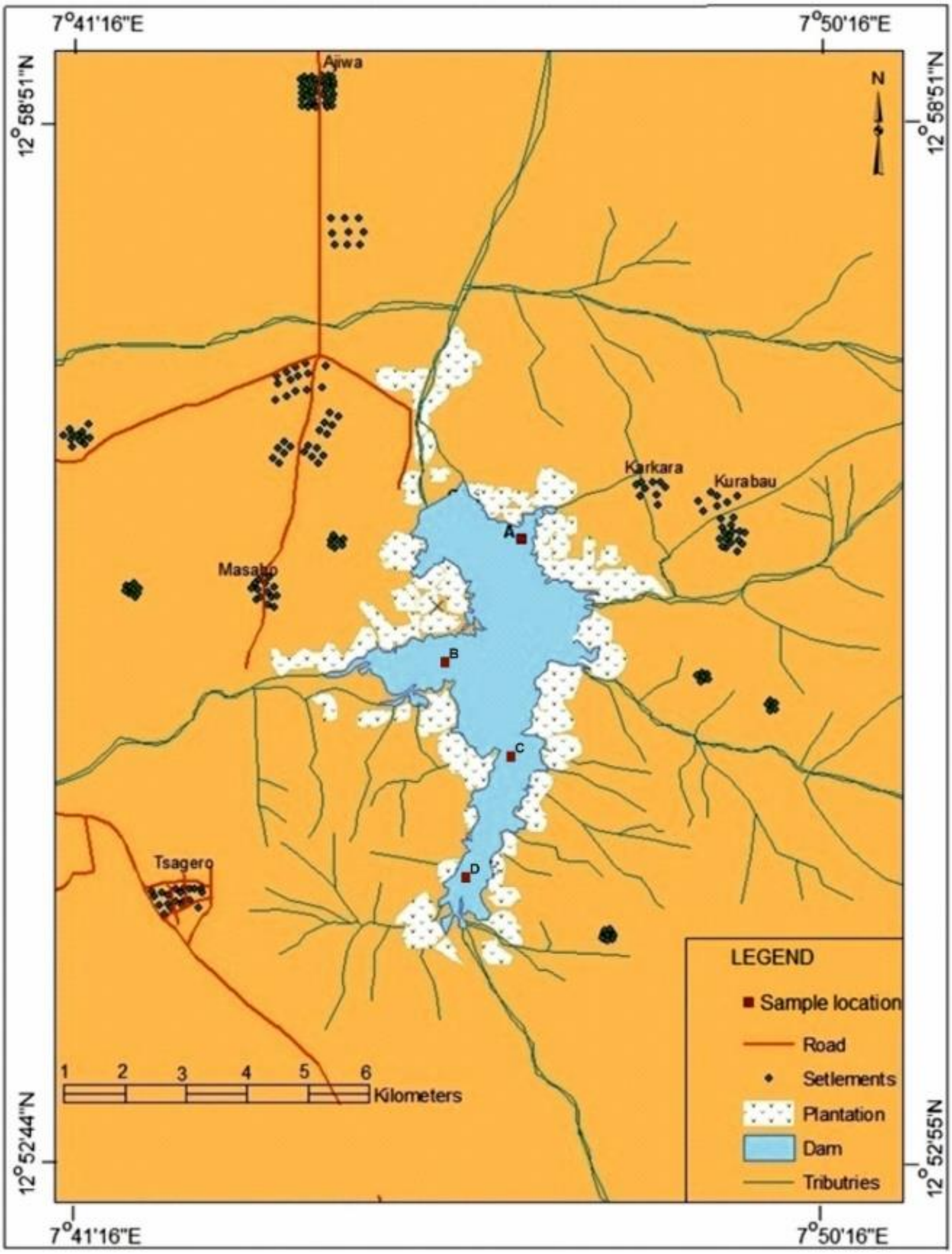

Figure 1: Map of Ajiwa Reservoir, Katsina State Showing Sampling Sites
Source: National Administration and Space Administration Spot Image (NASASI, 2020)

Phytoplankton samples were collected with a one-liter transparent plastic bottle at each station by dipping the bottle and sliding it over the upper surface of the water with its mouth open to permit the undisturbed passage of the water into the bottle (Tanimu, 2011).

Samples were labeled according to each station, preserved with Lugol's iodine solution, and brought to UMYUK for analysis (APHA, 2010).

Taxonomic identification of phytoplankton was carried out with the help of taxonomic keys such as Verlencar (2004) and Edward and David (2010). The phytoplankton were counted and recorded.

Statistical Analyses

One-way analysis of variance (ANOVA) was used to compare the means of various parameters between months; t-test was employed to compare the means between seasons, while Pearson's Correlation was utilized to test the relationship between various parameters. The significance level was set at $P < 0.05$. All analyses were conducted using SPSS software version 20.0.

RESULTS

All the physico-chemical parameters analyzed during the study period showed no significant difference between stations (Table 1), while a significant difference exists between seasons (Table 2).

Phytoplankton identified from the four stations belong to six groups, which include *Bacillariophyceae*, *Chlorophyceae*, *Cyanophyceae*, *Chryptophyceae*, Dinophyceae, and *Euglenophyceae*. Overall, green algae (Chlorophyceae) exhibited higher abundance compared to other types of algae, with species such as *Spirogyra sp.*, *Scenedesmus sp.*, *Volvox* sp., and *Chlamydomonas* sp. identified, followed by *Bacillariophyceae*, *Cryptophyceae*, *Cyanophyceae*, *Dinophyceae*, and Euglenophyceae, respectively. The lowest number of phytoplankton taxa recorded during the study period was Euglenophyceae, with a total of 83 individuals representing 12.86% of the population. The percentage composition of phytoplankton indicated that *Chlorophyceae* had 161 individuals, accounting for 24.96% of the total identified species population, as shown in Table 3 below.

Table 1: Mean Physico-Chemical Parameters of Ajiwa Reservoir in Relation to Stations and Seasons During the Month of December, 2022 to September, 2023.

	MEAN±SD				
Phyico-Chemical Parameters	STATION A	STATION B	STATION C	STATION D	AVERAGE
TEMP(˚C)	25.3 ± 3.50^a	23.5 ± 3.84^a	25.5 ± 4.18^a	24.93 ± 4.02^a	24.080 ± 0.292^a
pH	6.94 ± 0.26^a	6.35 ± 0.27^a	6.756 ± 0.38^a	6.97 ± 0.47^a	6.754 ± 0.091^a
DO(mg/L)	7.06 ± 089^a	7.37 ± 0.61^a	7.078±0.43^a	6.95 ± 0.85^a	7.115 ± 0.216^a
BOD(mg/L)	3.95 ± 0.89^a	3.67 ± 0.78^a	3.812 ± 0.90^a	3.62 ± 0.90^a	3.763 ± 0.059^a
EC(µS/cm)	127.08 ± 8.59^a	124.84±9.61^a	124.8±8.92^a	125.98±10.17^a	125.675±0.707^a
TDS(mg/L)	16.26 ± 4.64^a	15.81±4.86^a	14.84 ±5.41^a	15.21 ± 5.17^a	15.53 ± 0.339^a
TURB(mg/L)	94.68 ± 7.78^a	93.4 ± 6.42^a	93.22± 6.46^a	93.6 ± 6.55^a	93.725±0.6530^a
HARD.(mg/L)	88.29 ± 2.56^a	87.05 ± 2.7^a	87.03±3.75^a	84.49 ± 9.18^a	86.715 ± 3.134^a
NO_3^{-N}(mg/L)	9.63 ± 2.82^a	9.93 ± 3.04^a	9.63 ± 3.07^a	9.86 ± 3.06^a	9.763 ± 0.119^a
PO_4^{-P}(mg/L)	6.97 ± 2.86^a	5.92 ± 2.51^a	6.66 ± 2.94^a	6.35 ± 2.52^a	6.475 ± 0.225^a

Rows with the same superscript are not significantly different Values represent Mean ± SD
Key: Temp = Temperature, DO = Dissolved oxygen, BOD = Biochemical oxygen demand, EC = Electrical conductivity, TDS = Total dissolved solids, Turb = Turbidity, Nitrate-Nitrogen = NO_3^{-N}, P_{04}^{-P} = Phosphate-phosphorus Hard = Water hardness.

Table 2: Physico-Chemical Parameters of Ajiwa Reservoir During dry and wet Seasons (December, 2022 t0 September, 2023.

Phyico-Chemical Parameters	SEASON	
	DRY SEASON	WET SEASON
TEMP (˚C)	27.354±0.727[a]	25.24 ± 4.190[b]
pH	6.924 ±0.478[a]	6.88 ± 0.216 [b]
DO (mg/L)	6.858±0.846[a]	7.214±0.423[b]
BOD (mg/L)	3.14 ± 0.742 [a]	10.39±13.506[b]
TURB. (NTU)	89.644 ±5.004[a]	97.916 ±5.105[b]
EC (µS/cm)	120.814±6.228[a]	130.406±9.475[b]
HARD. (mg/L)	85.402±2.829[a]	91.27 ± 2.980[b]
T D S (mg/L)	13.258 ±2.248[a]	17.92± 6.045 [b]
NO_3^{-N} (mg/L)	10.304 ±2.049[a]	9.296 ± 3.518 [b]
PO_4^{-P} (mg/L)	6.808±2.140[a]	6.174±3.242[b]

Rows with the same superscript are not significantly different Values represent Mean ± SD
Key: Temp = Temperature, DO = Dissolved oxygen, BOD = Biochemical oxygen demand, EC = Electrical conductivity, TDS = Total dissolved solids, Turb = Turbidity, Nitrate-Nitrogen = NO_3^{-N}, P_{O4}^{-P} = Phosphate-phosphorus, Hard = Water hardness.

Table 3: Phytoplankton Individuals Percentage Composition in Ajiwa Reservoir

	Individuals					
	Bacill.	*Chloro.*	*Crypto.*	*Cyano.*	*Dino.*	*Eugleno.*
Total number	110	161	107	98	86	83
Percentage Composition (%)	17.05	42.96	16.58	15.19	13.33	2.86

KEY: *Bacci* = bacillariophyceae, *Chloro* = *Chlorophyceae*, *Cyno* = cyanophyceae, *Crypto* = *Cryptophyceae*, *Dino* = *Dinophyceae*, *Eugleno* = *Euglenophyceae*.

Table 4: Phytoplankton individuals in Ajiwa Reservior During Dry and Wet Season December, 2022 to September 2023

Season	Month	Taxon Mean ± SD					
		Bacill.	*Chloro.*	*Cyano.*	*Crypto.*	*Dino.*	Eugleno.
Dry Season	December January February March April	26.00±3.5[a]	66.00±2.1[a]	39.00±3.83[a]	40.00±2.12[a]	36.00±3.11[a]	34.00±4.15[a]
Wet Season	May June July August September	84.00±4.8[b]	75.00±3.6[b]	59.00±4.44[b]	67.00±6.70[b]	52.00±3.38[b]	49.00±5.72[b]

Key: columns with different superscripts are significantly different. *Bacci* = bacillariophyceae, *Chloro* = *Chlorophyceae*, *Cyno* = cyanophyceae, *Crypto* = *Cryptophyceae*, *Dino* = *Dinophyceae*, *Eugleno* = *Euglenophyceae*.

Table 5: Correlation between Water Parameters and Phytoplankton in Dry Season December, 2022 to April 2023

Physico-chemical Parameters	*Bacill.*	*. Chloro*	*Cyno.*	*Crypto.*	*Dino.*	*Eugleno.*
Temp.	-0.332	-0.233	-0.060	0.538*	-0.191	-0.744
pH	0.614*	0.265*	0.032*	0.103*	-0.390	-0.614
DO	0.903*	0.791*	0.784*	0.115*	0.192*	-0.169
BOD	0.858*	0.937*	0.970*	-0.233	-0.611	-0.114
EC	-0.186	-0.166	-0.345	-0.801	-0.174	0.968*
TDS	0.358*	0.311*	0.127*	-0.731	-0.058	0.866*
Turb.	0.332*	0.449*	0.312*	-0.989	-0.753	0.856*
Hardness	0.638*	0.683*	0.539*	-0.872	-0.534	0.775*
NO_3^{-N}	-0.135	-0.130	0.060*	0.836*	0.178*	-0.970
PO_4^{-P}	0.032*	0.072*	0.259*	0.697*	-0.035	-0.920

Key: * indicates strong correlation. Temp. = Temperature, DO = Dissolved Oxygen, BOD = Biochemical Oxygen Demand, EC = Electrical Conductivity, TDS = Total Dissolved Solids, NO_3^{-N} = Nitrate-nitrogen, PO_4^{-P} = Phosphate-phosphorus, Turb. = Turbidity, Hard = Hardness, *Bacill.* = *Bacillariophyceae*, *Chloro* = *Chlorophyceae*, *Cyno* = cyanophyceae, *Crypto* = *Cryptophyceae*, *Dino* = *Dinophyceae*, *Eugleno* = *Euglenophyceae*.

Table 6: Correlation between Water Parameters and Phytoplankton in Wet Season May to September 2023

	Bacill.	*Chloro.*	*Cyno.*	*Crypto.*	*Dino.*	*Eugleno.*
Temp.	-0.382	-0.572	-0.170	-0.130	-0.052	0.239*
pH	0.010*	0.246*	-0.191	0.011*	0.455*	0.167*
DO	0.578*	0.360*	0.685*	0.179*	-0.914	-0.740
BOD	0.887*	-0.873	0.781*	0.286*	-0.773	-0.896
EC	-0.816	-0.836	-0.852	-0.977	0.259*	0.202*
TDS	0.550*	0.557*	0.654*	0.978*	-0.017	0.124*
Turb.	0.554*	0.332*	0.668*	0.171*	-0.901	-0.719
Hard.	-0.008	0.236*	-0.148	0.293*	0.641*	0.431*
NO_3^{-N}	0.103*	0.291*	0.074*	0.671*	0.625*	0.566*
PO_4^{-P}	-0.477	-0.572	-0.270	0.120*	0.364*	0.636*

Key: * indicates a strong correlation, Temp. = Temperature, DO = Dissolved Oxygen, BOD = Biochemical Oxygen Demand, EC = Electrical Conductivity, TDS = Total Dissolved Solids, NO_3^{-N} = Nitrate-nitrogen, PO_4^{-P} = Phosphate-phosphorus, Turb. = Turbidity, Hard = Hardness, *Bacill.* = *Bacillariophyceae*, *Chloro* = *Chlorophyceae*, *Cyno* = cyanophyceae, *Crypto* = *Cryptophyceae*, *Dino* = *Dinophyceae*, *Eugleno* = *Euglenophyceae*.

DISSCUSSION

The phytoplankton identified in the four sampling stations belong to six groups, which include *Bacillariophyceae*, *Chlorophyceae*, *Cyanophyceae*, *Chryptophyceae*, Dinophyceae, and *Euglenophyceae*. In general, the green algae (Chlorophyceae) had the highest abundance compared to other algae, and the species identified were Sp*irogyra* species, *Scenedesmus* species, *Volvox* species, and *Chlamydomonas* species. The results agree with the findings of Abdullahi and Indabawa (2015) on the assessment of phytoplankton content of Nguru Lake, Yobe State, Nigeria. Euglenophyceae was the least taxa in the study area. This could be due to the fact that members of this group find the environment not favorable for their normal growth and reproduction, which checks their abundance in the reservoir. Chlorophyceae revealed a positive correlation with dissolved oxygen and biochemical oxygen demand, which indicated the productivity of the Reservoir, especially during the wet season. Mahar (2013) also observed that a phytoplankton community was affected by strong seasonal influence. The monthly and seasonal variation of composition and abundance of phytoplankton may be due to the fluctuations of water and physico-chemical parameters in the reservoir. Abubakar (2019) made a similar observation that there was a distinct fluctuation in the abundance of phytoplankton in tropical regions during the dry and rainy seasons. Anago *et al*. (2013) reported that in lakes where domestic, agricultural, and industrial pollution is accelerated, the growth of *Chlorophyta* and *Cyanophyta* results. The higher abundance during the wet season could be due to the presence of more nutrients and water level in the reservoir. This corresponds with the observation of Tisser *et al*. (2018) who reported that phytoplankton form the vital source of energy in the freshwater environment. Phytoplankton abundance showed a positive correlation with Dissolved Oxygen, pH, Biochemical Oxygen Demand, Total Dissolved Solids, Turbidity, and Water hardness in both seasons. Abubakar (2019) made a similar observation in Sabke Lake, Katsina State. The high concentration of nutrients like Nitrate-nitrogen and Phosphate-phosphorus results in the blooming of algae, which is a sign of eutrophication, though the concentration of both Nitrate-Nitrogen and Phosphate-Phosphorus in the reservoir was within the acceptable range (APHA, 2010). Nutrient limitation is also an important factor for phytoplankton abundance in shallow freshwater (Araoye and Owolabi, 2015).

CONCLUSION

All the physico-chemical parameters analyzed during the study period are within the acceptable range stated by WHO (2017) except for phosphate-phosphorus. The highest value of phosphate-phosphorus was recorded in August during the wet season, while the lowest value was recorded in January during the dry season. Similarly, the study revealed that the reservoir had six (6) dominant phytoplankton families in the order of abundance: Chlorophyceae > Bacillariophyceae > Cryptophyceae > Cyanophyceae > Dinophyceae > Euglenophyceae. A total of 161 species of Chlorophyceae were identified in the study, with more species recorded in the wet season compared to the dry season. The water quality was deemed acceptable for agricultural, domestic, and drinking purposes.

RECOMMENDATIONS

Based on the findings of this study, the following recommendations are provided:

i. Adequate monitoring of the water quality and regulation of anthropogenic activities in and around the reservoir are recommended to slow down its deterioration and conserve it for a longer period.

ii. More studies should be carried out to identify the phytoplankton composition using polymerase Chain Reaction (PCR) and other taxonomic identification methods that were not utilized in this study.

iii. Farmers around the reservoir should be educated on the impact of their activities on the water body, particularly regarding the use of inorganic fertilizers and pesticides during rainy season farming and irrigation when water levels are low.

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