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Research Article

Physicochemical Parameters and Fish Catches of Zobe Reservoir in Katsina State, Nigeria

***[1]Nababa, A. S., [2]Yusuf, Z. A., and [1]Umaru, J.**

[1]Department of Fisheries and Aquaculture, Federal University Dutsin-ma, Katsina State Nigeria
[2]Department of Fisheries and Aquaculture, Federal University of Lafia, Nasarawa State, Nigeria

***Corresponding Author:** naababa77@gmail.com, +234(0) 7066210660

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ABSTRACT

This study aimed to examine the physicochemical characteristics and fish catches of the Zobe reservoir. The study was carried out for a period of 12 months at five fishing stations (Tabobi, Makera, Garhi, Gada, and Raddawa). Standard techniques were employed to determine the physicochemical parameters of the reservoir. The ranges of values obtained were: temperature (22.00±2.2.54 – 32.00±.2.2.54°C); pH (5.90±0.50 – 9.00±0.50); Turbidity (4.5±0.84 - 8.00±0.84); Dissolved Oxygen (6.00±0.50 mgL^{-1} – 8.50±0.50 mgL^{-1}); Biological Oxygen Demand (0.50 ± 0.54 mgL^{-1} – 3.80±0.07 mgL^{-1}; Electrical Conductivity (EC): 65.00±13.23µS/cm – 199.00±13.227µS/cm; Alkalinity: 20.10 ±3.507 – 33.00 ±2.28ppm); Ammonia (0.10ppm ±0.20 – 0.50ppm±0.08ppm). Catches of fishers comprised thirteen (13) fish species from seven (7) families. *O. niloticus* of the Cichlidae family had the highest Catch per Unit Effort (CPUE) (22.28 and 9.93) for the dry season, whereas *C. gariepinus* had the highest CPUE in the wet season (22.22 and 9.80). Furthermore, *C. anguilaris* has the lowest CPUE, which is (0.08) in Makera in the dry season and (0.04) in Raddawa at the rainy season. Turbidity and fish catches had a negative correlation (-0.98), while EC and fish catch had a strong positive correlation (0.60). Physicochemical properties fall within permissible ranges for fish production. In conclusion, Zobe reservoir has enormous potential for fish production which could said to be not optimally utilized. Sustainable research is recommended to maximize the utilization of the fishery resources of the reservoir.

Keywords: Fish Catches, Physicochemical Parameters, Katsina, Zobe Reservoir

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INTRODUCTION

The ability of fisheries, whether they are marine or inland, to supply a significant amount of animal protein, jobs, and other economic advantages to society is what makes them inevitable resources to humanity (Food And Agricultural Organization, 2022). According to statistical surveys, the demand for fish in Nigeria exceeds its supply; additionally, domestic production is still very low compared to the rate of growing human population (Dadi-Mahmud *et al.,* 2014). Aquaculture production is rising in comparison to artisanal sources, and between 2007 and 2017, it accounted for 22% of all domestic fish production (FAO, 2018). Aquatic productivity seemed particularly unlimited, however, with increased in the knowledge and the dynamic development of fisheries and aquaculture, it was realized that living aquatic resources, although renewable, are not infinite and need to be properly managed; if their contributions to the nutritional, economic and social well-being of the growing world's population are to be sustained

(Ekpo *et al.,* 2016). Due to a sharp rise in pollution, the use of abusive fishing methods globally, illegal, unreported, and unregulated fishing have been decreasing landings and fish populations have been diminishing for almost thirty years, frequently at frightening rates (United Nations Educational, Scientific and Cultural Organization, 2010).

Overexploitation and inadequate water body management practices are to be blamed for the deterioration in Nigeria's fishing resources (Lawson and Olusanya, 2010). Understanding the species composition, diversity, and richness of the water bodies is essential for the sustainability of these resources (Nababa *et al*., 2022a & Sogbesan and Kwaji, 2018). One of Nigeria's most significant sources of dependable animal protein is the capture fisheries (Federal Department of Fisheries, 2008). Investigating the state of the fisheries, composition, and stock assessment is necessary for the proper management of aquatic resources to establish a correlation between the quantity of fish, the selectivity of fishing techniques, and the long-term sustainable catch. That is, to optimize the amount that can be timely harvested without jeopardizing the fishing resources' biological or economic sustainability (Nababa *et al*., 2022b & Yusuf and Abdulkarim, 2015). Nigeria is endowed with an abundance of freshwater, marine, and estuarine natural resources; the marine resources are found in the country's 200 nautical mile Exclusive Economic Zone (EEZ) and coastal seas. Information on the influence of physicochemical parameters on fish catches of Zobe reservoir is lacking. The goal of this research is to study the physicochemical parameters of the Zobe reservoir; identify the different fish species composition and correlate the physicochemical parameters with the catches.

MATERIALS AND METHODS

Study Area

Zobe reservoir is an earth-filled structure with a height of 19 m and a total length of 2,750m. The reservoir coordinated between latitude 12 ° 20' 34.62 N to 12 ° 23 ' 27.48 N and longitude 7° 27 ' 57.12 E to 7 ° 34 ' 47.68 E, in part of Dutsin-ma and Matazu Local Government areas of Katsina State (Figure 1). The southern part of the reservoir is bounded by many villages that include; Marke, Makera, and Tsakko, by the south-east, are Tuga, and Kuka-Damisa, whilst by the north are Garfi, Badole, Daguda, Katsalle, and Tabobi remotes. The reservoir covers 4500 hectares of land and during the rainy season stores 177 million cubic meters of water which is released downstream for irrigation and town water supplies (Nababa et al., 2019 & SRBDA, 1981). The reservoir was created for local irrigation of 8,000 hectares, power generation, and water supply. Zobe Reservoir has only two tributaries; River Karaduwa and River Gada in which River Gada drains to River Karaduwa (SRBDA, 1981). The Reservoir was constructed to Dam River Karaduwa and covers about 2.7 Kilometres long flowing North Westward to the Sokoto Basin. The sources of this reservoir bring Agricultural waste and other organic matter in the catchment area of the rivers, especially during the rainy season (Nababa *et al.,* 2022b & Apollos *et al.,* 2016).

Fish Species Identification

Fish species collected from fishers/canoeists were identified using Key/Identification guides recommended by Olaosebikan and Raji (2004) and (Reed *et al.,* 1967). Nevertheless, personal communications in identification and local naming with experienced fishers was also used as in Dan-kishiya *et al.,* (2018).

Fish Catch and Water Sampling

Samples of fish were collected from 5 canoeists/fishers per sampling unit at one-week intervals. Water samples were also collected in the morning hours, between 7:00 am to 11:00 am using sampling tools (glass jar, and 2-liter plastic containers). All samples were collected at one-week interval from March 2020 to February 2021. The study was conducted in five (5) major fishing spots/stations of Zobe Reservoir which are Tabobi (A); Makera (B); Garhi (C); Gada (D); and Raddawa (E).

Physicochemical Parameters and Water Analysis

Physical Properties of Water

The physical characteristics of water determined were as follows:

Temperature (°C)

Temperature reading was taken using a graduated Mercury in glass thermometer by first exposing it to the surface to allow it to collide with an ambient surface temperature. It was then sunk into the water body and allowed for about two (2) minutes and then lift up to record the reading in Degree Celsius ^{O}C (Nababa *et al*., 2022b).

Turbidity (cm)

Graduated Secchi disc was used in the determination of the water transparency for this study. It was held using long graduated rope of one meter long and inserted gently into the sampling point until the alternate colours on the plate start disappearing then the transparency reading was recorded as the immediate point of the colour disappearance (Apollos *et al.,* 2016). It was recorded in centimetre (cm).

Chemical Properties of the Water

Chemical properties of water such as Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Ammonia (NH_3), and Alkalinity were determined using volumetric method , whilst, Conductivity, and pH were measured individually by mechanical method (using mobile Hanna combo meter, Model HI96301, with automatic temperature compensation) as described by Lind and Barcena (2003).

RESULTS

Water Quality Parameters of Zobe Reservoir

The physicochemical parameters of Zobe reservoir showed (Figures 2 and 3) elucidated the annual mean values, and standard deviation, with maxima, and minima values of all the parameters studied from the reservoir. Eight (8) water physical and chemical parameters from Zobe reservoir were studied: three (3) physical and five (5) chemical parameters were monitored for the period of twelve (12) months cutting across both dry and wet seasons. Similarly, monthly values of each parameter measured were graphically presented (Figures 4 to 11). Catches were used to examine the fish species composition, relative abundance and relative distribution from the five (5) major fishing stations across the length and breadth of the reservoir.

The water temperature ranges between 22.00±2.2.54 and 32.00±.2.2.54°C. The pH values ranges between 5.90±0.497 and 9.00±0.497; Turbidity of the reservoir ranges from 4.5±0.844 and 8.00±0.844; The dissolved Oxygen values in the reservoir ranged from 6.00mgL^{-1}±0.495 and 8.5 mgL^{-1}±0.495; The biochemical oxygen demand (BOD) of the reservoir ranged between 0.50 mgL^{-1}±0.538 and 3.80 mgL^{-1}± 0.07;The Electrical conductivity ranged from 65.00±13.227µS/cm and 199.00±13.227µS/cm; Total alkalinity of the reservoir ranged between 20.10 ±3.507 and 33.00 ±2.275ppm; ammonia (NH_3) ranges between 0.10ppm ±0.1168 and 0.50ppm±0.078ppm.

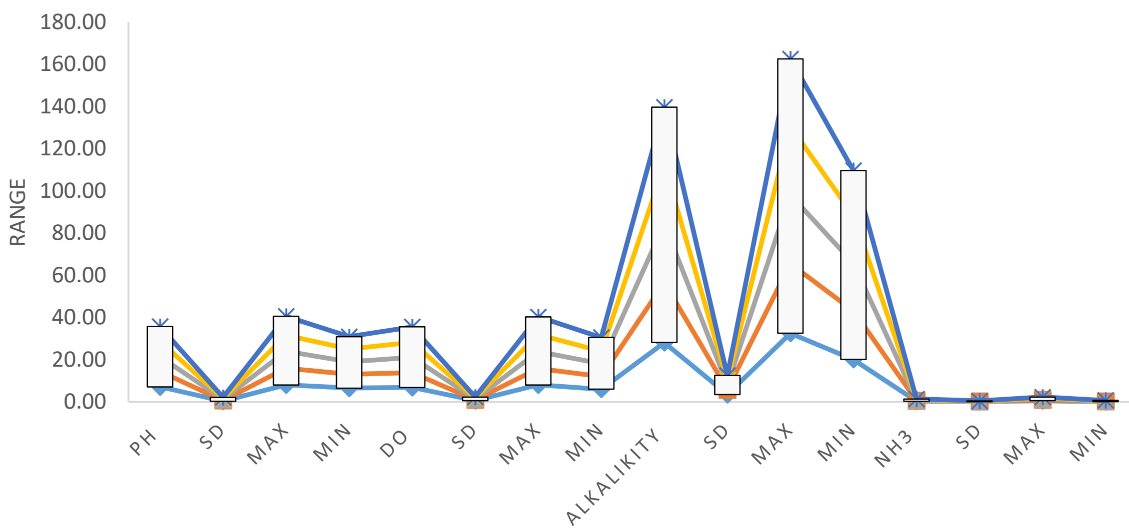

Figure 2: Annual Mean Values of pH, Dissolved Oxygen (DO), Alkalinity, Ammonia (NH_3) of Zobe Reservoir (Garhi Tabobi Makera Gada)

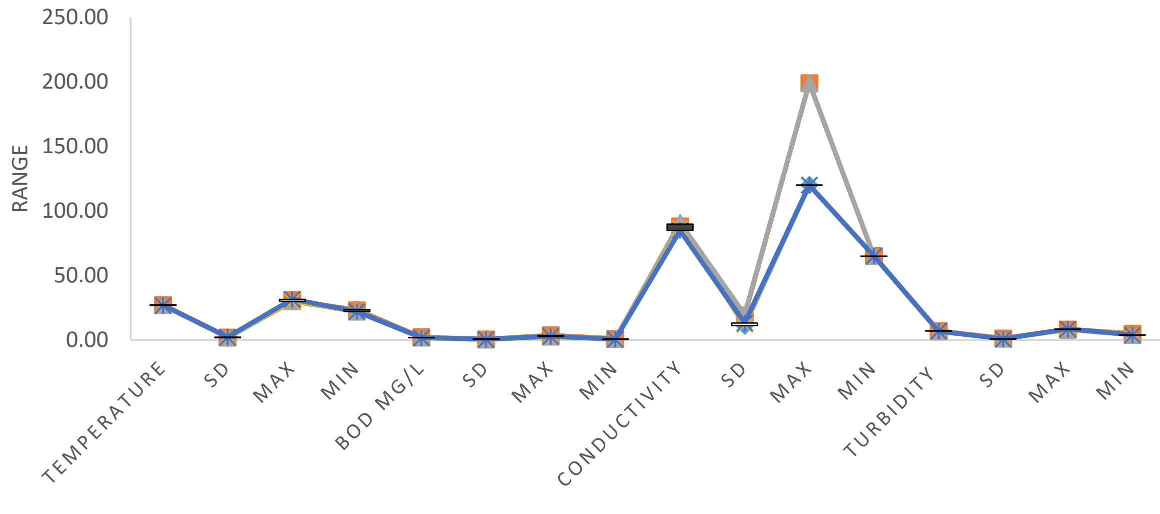

Figure 3: Annual Mean Values of Temperature, Biological Oxygen Demand (BOD), Conductivity and Turbidity of Zobe Reservoir (Garhi Tabobi Makera Gada)

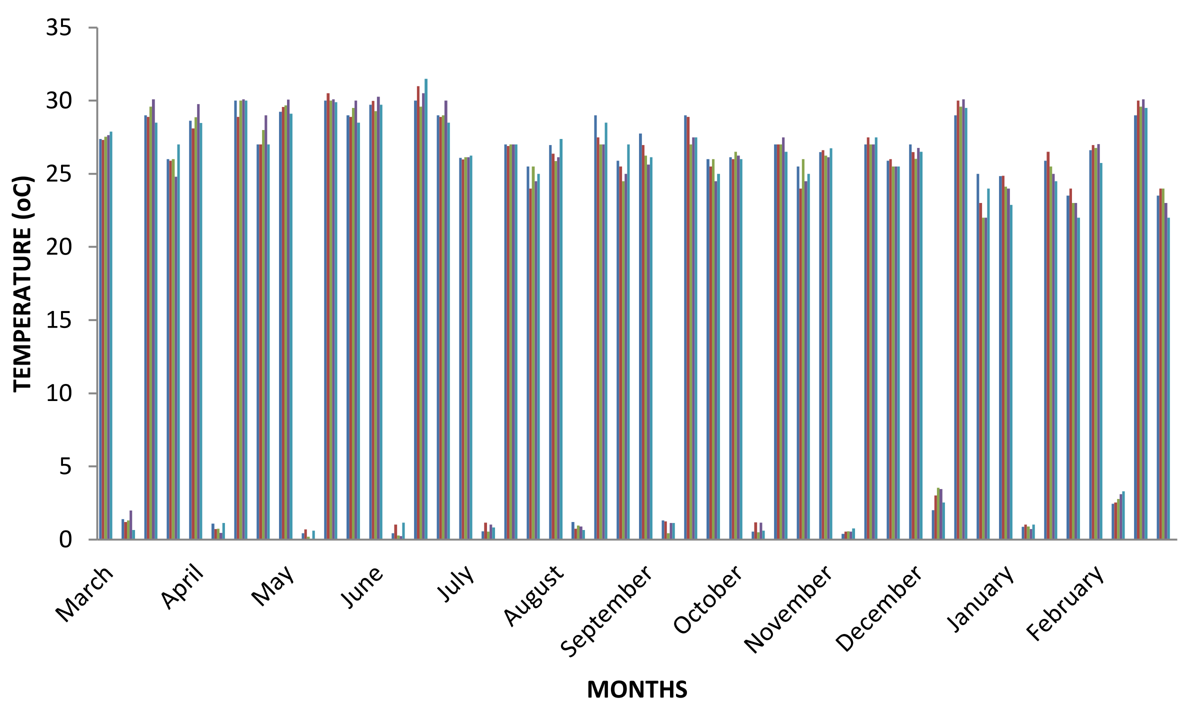

Figure 4: Monthly Mean Values of Temperature of Zobe Reservoir (Garhi Tabobi Makera Gada)

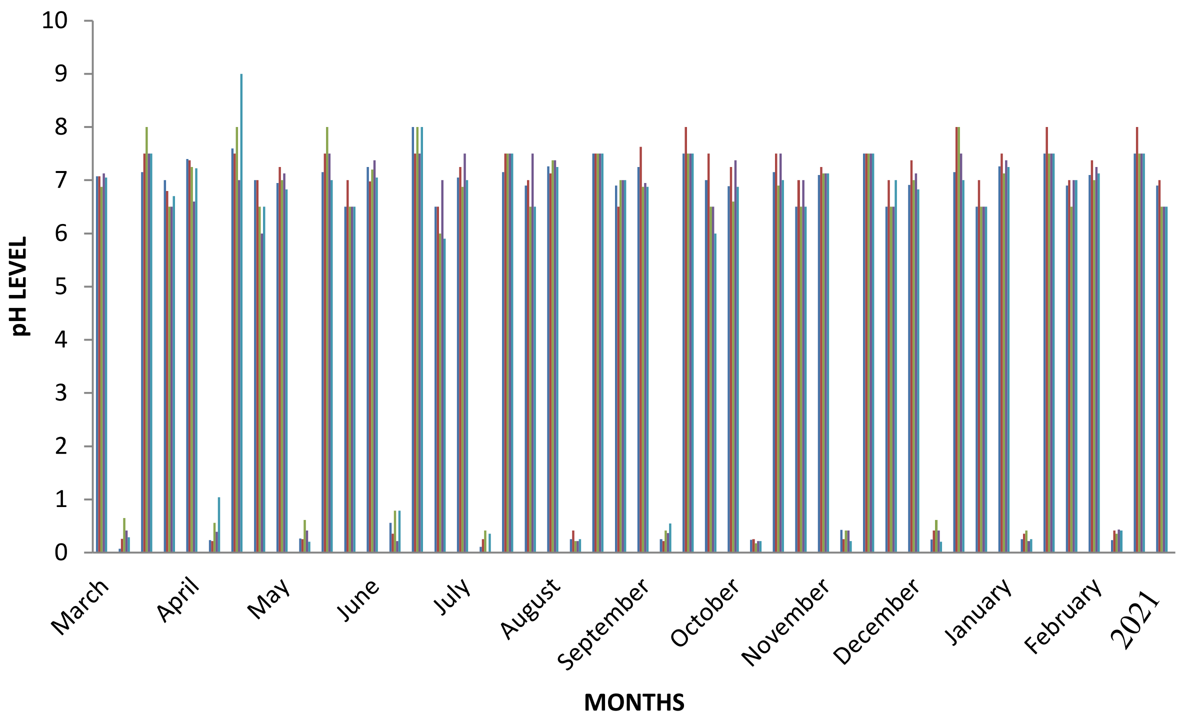

Figure 5: Monthly Mean Values of pH of Zobe Reservoir (Garhi Tabobi Makera Gada)

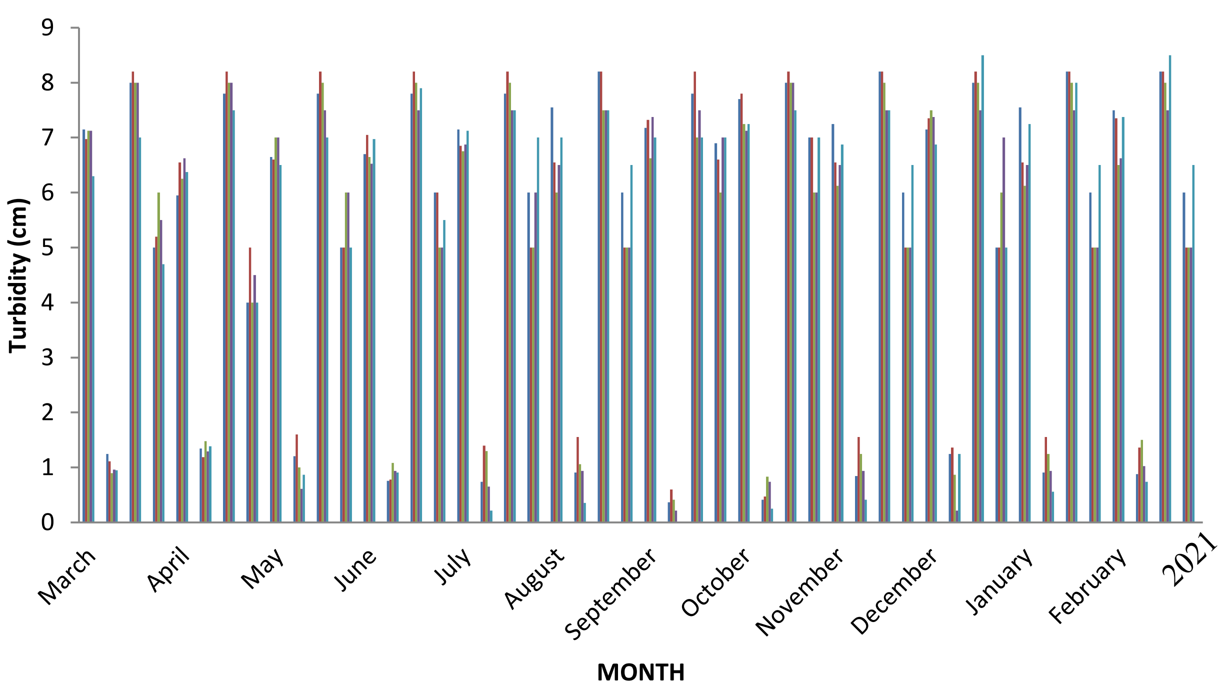

Figure 6: Monthly Mean Values of Turbidity of Zobe Reservoir (Garhi Tabobi Makera Gada)

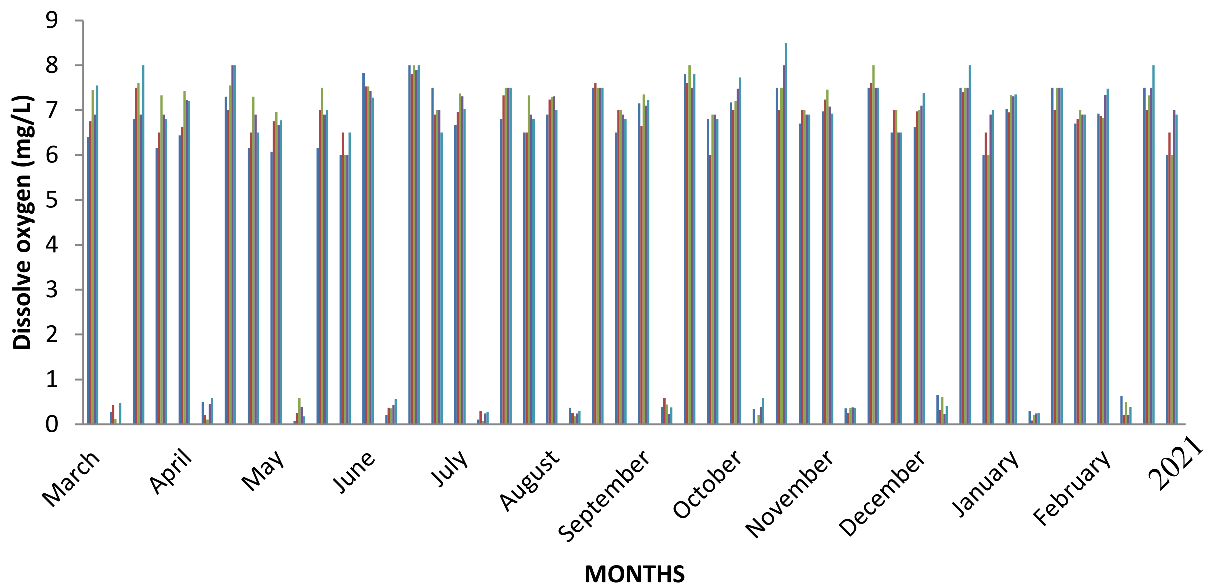

Figure 7: Monthly Mean Values of Dissolved Oxygen (DO) of Zobe reservoir (Garhi Tabobi Makera Gada)

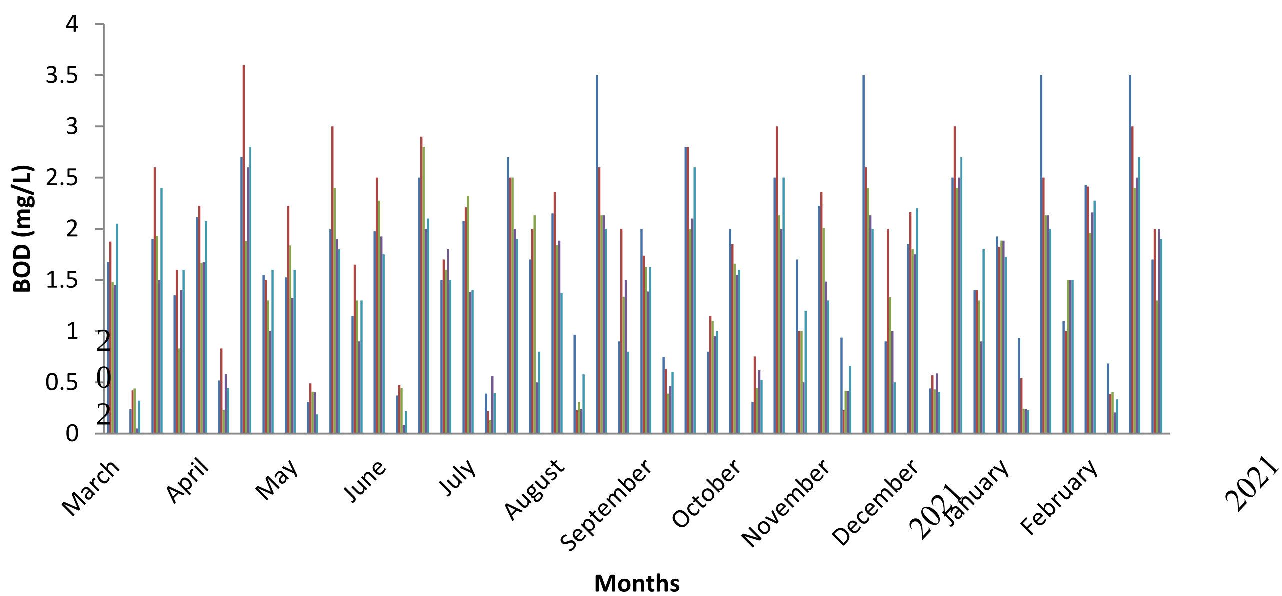

Figure 8: Monthly Mean Values of Biological Oxygen Demand (BOD) of Zobe Reservoir (Garhi Tabobi Makera Gada)

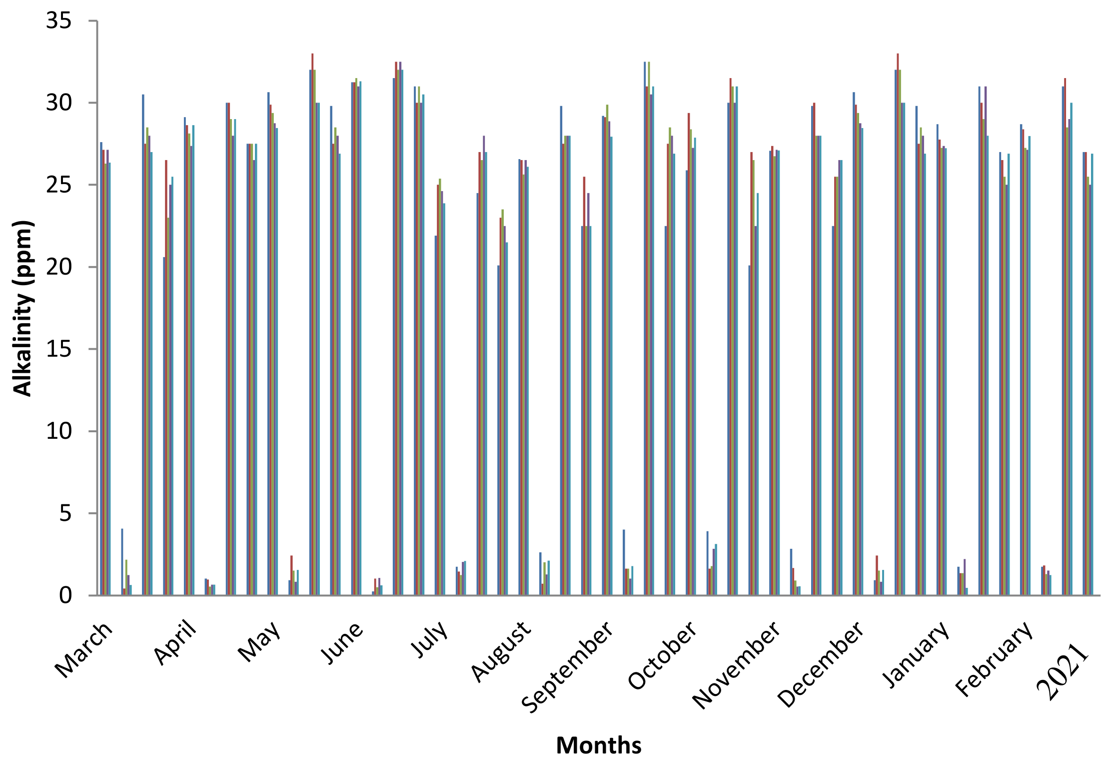

Figure 9: Monthly Mean Values of Alkalinity (ppm) of Zobe Reservoir (Garhi Tabobi Makera Gada)

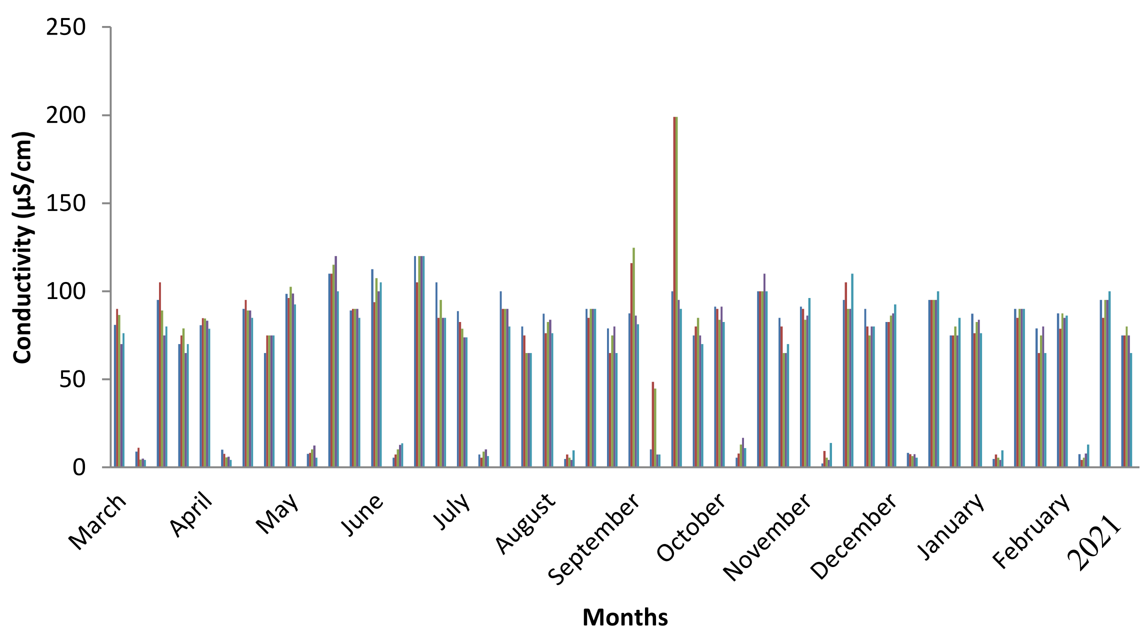

Figure 10: Monthly Mean Values of Conductivity (µS/cm) of Zobe Reservoir (Garhi Tabobi Makera Gada)

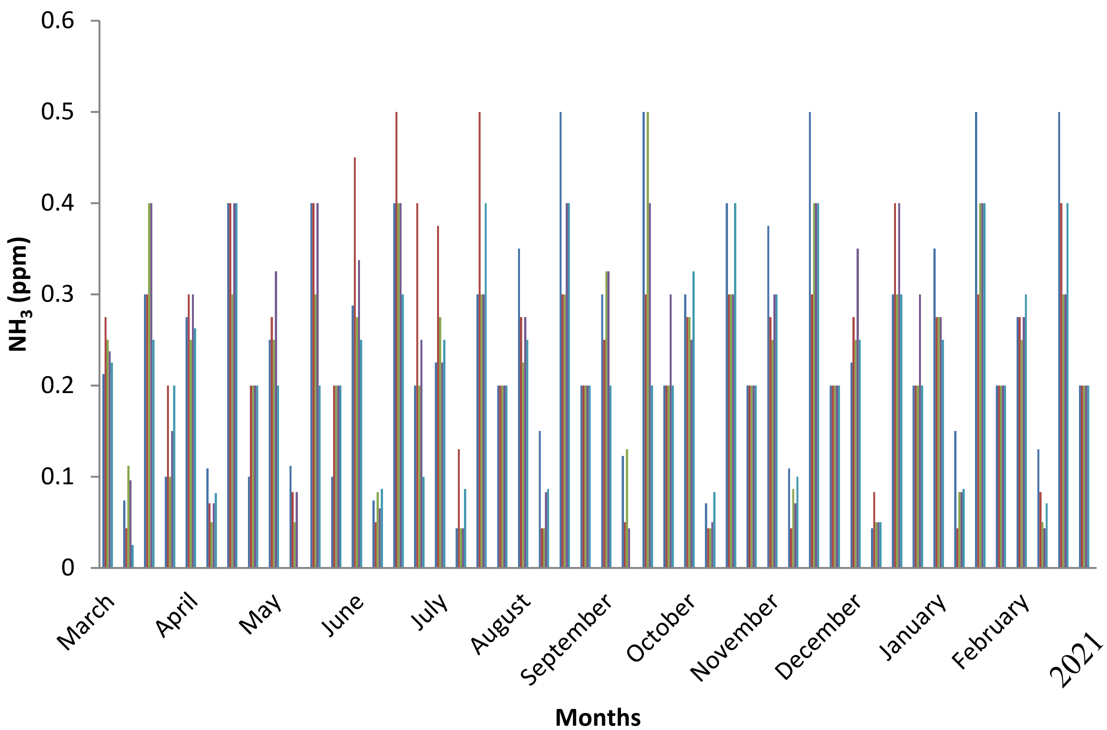

Figure 11: Monthly Mean Values of Ammonia, NH₃ (ppm) of Zobe Reservoir (Garhi Tabobi Makera Gada)

Fish Species Composition, Relative Abundance and Relative Distribution

Monthly catches of fishers were presented in Figure 12 while a total of thirteen (13) fish species belonging to seven (7) families were recorded during the study period (Tables 1 and 2). The family Bagridae was represented by *Bagrus bayad* and *Bagrus docmac*; the family Claridae was represented by two (2) species: *Clarias gariepinus* and *Clarias anguillaris*; Cichlidae was represented by four (4) species: *Oreochromis niloticus*, *Tilapia mosambicus*, *Tilapia zillii*, and *Sarotherodon galileus*; Mormyridae was represented by *Mormyrus rume*; while the Schilbeidae was represented by only *Schilbe mystus*; Mochokidae was represented by *Synodontis membranaceus*; and lastly Alestiidae was represented by two (2) species: *Brycinus nurse* and *Alestes dentex.* Relative abundance of fish species in Zobe reservoir showed that all the species were present in all the sampling stations except for *Clarias anguilaris* which is absent in Tabobi, Gada, and Makera (Table 2).

Catch Per Unit Effort (CPUE)

Catch per Unit Effort for both dry and wet seasons were estimated in the fishing stations using unit of man days. The results (Table 3) elucidated that the CPUE vary across all the stations. Nevertheless, *O. niloticus* happened to have highest CPUE (22.279 man days and 9.9286 man days in dry and wet seasons respectively) followed by *C. gariepinus* (22.216 mandays and 9.80 man days in dry and wet seasons respectively) in Garhi fishing stations. On the other hand *C. anguilaris* had zero CPUE in both seasons for all stations except Makera in dry season (0.08 man days) Raddawa in wet season (0.043 man days).

Correlation Analysis of Fish Catches and Physicochemical Parameters

Table 4 elucidated the values of strong negative correlations between turbidity and catch (-0.9779) and also, a strong positive correlation between conductivity and catch (0.60407). While catch has weak negative correlations with other physicochemical parameters except for dissolved oxygen which is positive weak correlation. There are also strong positive correlations between temperature and pH; Temperature and NH_3; pH and turbidity; pH and Alkalinity; pH and NH_3; BOD and Alkalinity; BOD and Conductivity; Alkalinity and Conductivity as well as Alkalinity and NH_3. However, there are strong negative correlation between Temperature and DO; pH and DO; Turbidity and DO; DO and BOD; DO and Alkalinity.

Table 1: Fish Species Composition and Relative Distribution in Fishing Stations of Zobe Reservoir

Fishing Station	C.g	O.n	Sy.m	S. me	B.d	B.b	A. d	T.m	C.a	M.r	S.g	B.n	T.z	TT
RD	16.256	17.635	18.375	12.857	15.709	17.437	9.283	13.316	42.857	6.301	21.519	10.345	7.595	14.574
TB	9.7826	12.51	10.777	4.2857	13.027	9.814	5.1849	3.395	0	9.786	2.532	15.060	4.430	10.043
GD	19.034	18.705	27.209	48.571	31.801	26.521	24.039	25.326	0	17.694	24.684	19.564	31.013	21.544
GR	26.594	22.276	20.141	15.715	17.433	21.736	24.039	31.071	0	30.295	22.152	20.690	16.772	23.579
MK	28.333	28.874	23.498	18.571	22.031	24.493	37.455	26.893	57.143	35.925	29.114	34.342	40.190	30.261
TT	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Keys: RD: Raddawa, TB: Tabobi, GD: Gada, GR: Garhi, MK: Makera, and TT: Total. *Clarias gariepinus* (C.g), *Oreochromis niloticus* (O.n), *Schilbe mystus* (Sy.m), *Synodontis menbra*naceous (S.me), *Bagrus docmac* (B.d), *Bagrus bayad* (B.b), *Alestes dentex* (A.d), *Tilapia mosambicus* (T.m), *Clarias anguilaris* (C.a), *Momyrus rume* (M.r), *Sarotherodon galileus* (S.g), *Brycinus nurse* (B.n), and *Tilapia zilli* (T.z).

Table 2: Fish Species Composition and Relative Abundance of Fish Species in fishing Stations in Zobe Reservoir (%)

		C.g	O.n	Sy.m	S.me	B.d	B.b	A. d	T.m	C.a	M.r	S.g	A.n	T.z	TT
Fishing Stations	**RD**	26.622	34.680	4.114	0.713	3.244	8.505	10.138	2.017	0.119	1.859	1.345	5.815	0.949	100
	TB	23.249	35.591	3.502	0.344	3.904	6.946	8.2090	0.746	0	4.191	0.230	12.29	0.804	100
	GD	21.086	24.806	4.121	1.820	4.442	8.750	17.742	2.596	0	3.532	1.044	7.439	2.62	100
	GR	26.919	26.993	2.787	0.538	2.225	6.553	16.210	2.910	0	5.526	0.856	7.189	1.296	100
	MK	22.347	27.262	2.534	0.495	2.191	5.754	19.680	1.962	0.0762	5.106	0.876	9.297	2.42	100
	TT	23.867	28.571	3.263	0.807	3.010	7.108	15.900	2.208	0.0404	4.3041	0.911	8.193	1.822	100

Key: RD: Raddawa, TB: Tabobi, GD: Gada, GR: Garhi, MK: Makera, and TT: Total. Where C.n, O.n, Sy.m, S.me, B.d, B.b, A. d, T.m, C.a, M.r, S.g, A.n, and T.z, stands for; *Clarias gariepinus, Oreochromis niloticus, Schilbe mystus, Synodontis menbranaceous, Bagrus docmac, Bagrus bayad, Alestes dentex, Tilapia mosambicus, Clarias anguilaris, Momyrus rume, Sarotherodon galileus, Alestes nurse and Tilapia zilli* respectively.

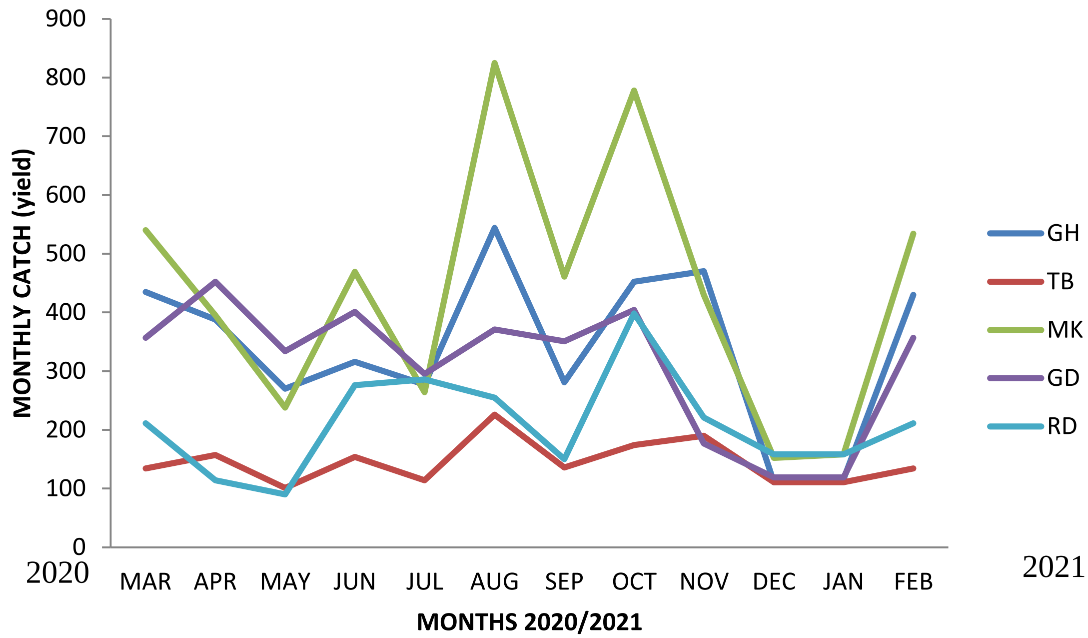

Figure 12 Monthly Fish catch of Zobe Reservoir from Five Fishing Stations GH, TB, MK, GD, and RD stands for Garhi, Tabobi, Makera, Gada and Raddawa respectively.

Table 3: Catch Per Unit Effort (CPUE) Per Species per Fishing Spot for Dry and Wet Seasons

Fish Spots	GARHI CPUE (Man days)		TABOBI CPUE (Man days)		MAKERA CPUE (Man days)		GADA CPUE (Man days)		RADDAWA CPUE (Man days)	
Species	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**
C.g	22.216	9.8	2.800	2.986	7.18	11.629	3.6864	7.571	4.98	5.942
O.n	22.279	9.9286	5.571	3.286	10.62	12.857	3.857	9.386	7.54	6.971
Sy. M	2.301	1.071	0.371	0.500	1.02	1.171	0.714	1.486	1.04	0.743
S.me	0.443	0.171	0.086	-	0.04	0.343	0.514	0.457	0.04	0.229
B. d.	1.844	1.214	0.743	0.229	0.32	1.414	0.957	1.414	0.28	0.971
B.b	5.424	3.200	1.429	0.399	1.2	3.457	0.786	3.886	1.2	2.214
A. d	13.341	4.029	0.286	1.757	8.18	8.914	3.271	6.2	2.24	1.957
T.m	2.400	1.014	0.129	0.057	0.52	1.1	0.429	0.957	-	0.729
C.a	-	-	-	-	0.08	-	-	-	-	0.043
M.r	4.552	1.6	0.643	0.4	2.12	2.314	0.343	1.543	0.16	0.557
S.g	0.710	0.5	0.057	-	0.12	0.571	-	0.557	0.28	0.285
A.n	5.946	3.286	2.943	0.114	2.92	4.886	0.514	3.457	0.74	1.571
T.z	1.066	0.300	0.114	0.043	1.96	0.414	1.057	0.343	0.2	0.2
Total	82.522	36.114	15.17	9.671	36.28	49.07	16.129	37.257	18.7	22.414

Keys: C.n, O.n, Sy.m, S.me, B.d, B.b, A. d, T.m, C.a, M.r, S.g, A.n, and T.z, stands for; *Clarias gariepinus, Oreochromis niloticus, Schilbide mystus, Synodontis menbranaceous, Bagrus docmac, Bagrus bayad, Alestes dentex, Tilapia mozambique, Clarias anguelaris, Momyrus rume, Saratherodon galileus, Alestes nurse and Tilapia zilli* respectively.

Table 4: Correlation Analysis of Catch and Physicochemical Parameters of Zobe Reservoir

	Catch	Temperature	pH	Turbidity	DO	BOD	Alkalinity	Conductivity
Temperature	-0.004							
pH	-0.600	0.620						
Turbidity	-0.978	0.353	0.641					
DO	0.265	-0.810	-0.563	-0.858				
BOD	-0.331	0.310	0.477	0.428	-0.740			
Alkalinity	-0.225	0.431	0.569	0.197	-0.747	0.972		
Conductivity	0.604	0.183	-0.129	-0.134	-0.021	0.544	0.619	
NH_3	-0.327	0.834	0.717	0.463	-0.694	0.436	0.609	0.089

Keys: DO: Dissolved Oxygen, BOD: Biological Oxygen Demand, NH_3: Ammonia

DISCUSSION

Physicochemical Parameters

The parameters were discussed separately under physical and chemical components as follows:

Physical Parameters

The physical parameters are as follows:

Temperature

Fish growth, reproduction, and maturity are all influenced by water temperature (Bala and Bolorunduro, 2011). The primary elements of the fish food chain, aquatic micro- and macroorganisms, are also impacted (Yerima *et al.,* 2017; Dadi-Mahmud et al., 2014 and Anago, 2013). There is an ideal temperature for each species of fish at which each individual exhibits optimal physiological function. Additionally, temperature affects dissolved oxygen content and, in turn, fish respiration rate (Yerima *et al.,* 2017 and Adakole and Annue, 2003).

During the study period, the water temperature of Zobe reservoir varied between 22 0C and 31 ^oC (Figures 3 and 4). Raddawa station recorded the highest temperature (31.50 ^oC), while both Gada and Raddawa stations recorded the lowest temperature (22.00 ^oC). Raddawa's short depth and the fact that it is the uppermost section of the reservoir and the first to receive water from the Karaduwa water sheds may be the cause of its temperature fluctuations. The water temperature recorded in Zobe reservoir falls within the OATA (2008) permissible limit for freshwater fish farming in tropical regions. Boyd (1990) and Apollos *et al*. (2016) noted that the ideal temperature range for warm-water fish growth is 25 to 32 ^0C.

The annual temperature range of Zobe reservoir based on this research is within sustainable range for fish production. The results are similar to the work of Sogbesan and Kwaji (2018); Yerima *et al.,* 2017; Abdulakrim and Lamai, (2012); Bala and Bolorunduro (2011) and Adakole and Annue (2003). However, some authors reported lower minimum ranges: the report by Scheffer (1998) that the normal temperature in tropics that fish is adapted to be between 8°C and 30°C. Abdullahi and Abolude (2006) also reported a temperature range of 20 to 27°C from two reservoirs in Northern Nigeria. Hitherto, Haruna (2005) observed that the temperature range for optimal growth of fish in the tropics was 16°C and 32°C.

Turbidity/Transparency

From the Dam's head to its tail water, the turbidity diminishes. Monthly variations are displayed in the turbidity value. Figures 3 and 6 show the minimum, maximum, and average turbidity values that were recorded during the study period: 4 cm, 8.5 cm, and 6.66 cm. The rainy season's observed high turbidity (low water transparency) in the reservoir could be related to silt, sediments, debris, and suspended organic and inorganic particles being washed into it by surface runoff and flooding. However, during the dry season, comparatively low water turbidity (high water transparency) was noted. This could be because there was no floodwater present and the particles settled to the reservoir's bottom. Additionally, as stated in the American Public Health Association (1995) report, lower transparency during the rainy season, when there was turbulence and high turbidity, corresponds to lower primary productivity because turbidity reduces light penetration, which in turn reduces photosynthesis and, consequently, primary productivity. The monthly data's fluctuating reduction in water transparency during the dry season could be linked to an increase in anthropogenic activities around the reservoir, such as irrigation during the dry season, bathing, and laundry during the study period.

Electrical Conductivity (µS/cm)

Total dissolved solids (TDS) concentration is correlated with specific conductance or electrical conductivity (EC µS/cm). The EC outcome was shown in (Figure 3). According to Anago *et al.* (2013) and Abdullahi and Abolude (2006), conductivity values below 50µmhos/cm are considered low, those between 50-600µmhos/cm are considered medium, and those above 600µmhos/cm are considered high. Throughout the study period, a monthly change in conductivity was noted in the Zobe reservoir (Figure 10). Based on the classification, the conductivity range (84.7 to 90.8µS/cm) for the reservoir under study can be classified as medium to moderate. This study corroborated the findings of Apollos *et al*. (2016), who similarly found a moderate range of EC values (84.40 – 175.55 µS/cm). According to Oniye *et al*. (2002) and Atobatele and Ugwumba (2008), diluting from heavy rains may be the cause of the decreased conductivity in the wet season compared to the dry season. Similar to this, the Zobe Reservoir's EC value peaked during the dry season and decreased during the wet season. The higher EC values in dry season may be due to the reduction in the water level and increases in nutrients due to run off of inorganic fertilizer from nearby irrigated farmlands around the reservoir coupled with higher rate of evaporation that reduces the level of the water during the dry season; thus conductivity of water depends upon the concentration of ions and its nutrients status.

Chemical Parameters

The chemical parameters are as follows:

Power of Hydrogen Ions (pH)

The mean pH values from Zobe reservoir were within the range of 5.90 ± 0.497 to 9.00 ± 0.497 (Figure 2) in all the five (5) sampling stations. Scheffer (2006) recommended pH range of 6.0 – 9.0 for aquatic life. The results also corroborate that of Apollos *et al*. (2016) who also reported similar results from Zobe reservoir. Similarly, the result was similar to the findings of Abdulkarim and Lamai (2012) who reported 5.8 to 9.0 from Gubi Dam, Bauchi State. Nevertheless, Ibrahim *et al*. (2009) reported pH of 6.5 - 8.5 from Kontagora reservoir, Niger state, Nigeria which is nearly neutral throughout both seasons. These pH values are good indication for optimal biological activity in the water. Aquatic organisms exhibit optimal growth and survival at certain ranges of pH. Although each organism has an ideal pH requirements (Dadi-Mahmud *et al.,* 2014), most aquatic organisms prefer pH of 6.5 to 8.0 (Kelly *et al.,* 2004). Below or beyond this acclaimed pH levels, organisms become physiologically stressed and it is said to be at lethal range. This range may be conducive for fish since they usually live at pH levels between 6.0 and 9.0, although Adefemi *et al*. (2007) reported that they may not tolerate a sudden change within this range.

The pH in Zobe reservoir was slightly acidic to alkaline may be attributed to the influence of fertilizer run-off from all year round Agricultural activities into the reservoir which might influence the water chemical parameters. This suggests that the reservoir water is good for fish production since it is within the acceptable range (Boyd, 1990) and productive waters (Tarzwel, 1959).

Dissolved Oxygen (DO)

Dissolved oxygen (DO) is the most important chemical parameter in water for living organisms. Low dissolved oxygen level is responsible for most fish and other animal mortality, either directly or indirectly, than all other problems combined. Dissolved oxygen concentration of Zobe reservoir showed some seasonal variations, and monthly variations as well (Figures 2 &7) throughout the study period. The annual DO values ranged from 6.00mg/L to 8mg/L (Figure 2) across all the sampling stations and between seasons. DO as an important parameter that determines the spatial as well as temporal distribution of organisms particularly the fish fauna (Araoye, 2009) is within acceptable range for aquatic living in the reservoir. Dissolved oxygen supply in water mainly comes from atmospheric diffusion and photosynthetic activity of plants (Akomeah *et al.,* 2010).

A concentration level of at least 5 mg/L is desirable while values lower than this can put undue stress on the fish, while value less than 2 mg/L is considered as lethal range (Utang and Akpan, 2012). Sensitivity to low levels of DO is species specific; however, most species of fish are distressed when DO falls below 2-4 mg/L. Mortality usually occurs at concentrations less than 2 mg/l and usually larger fishes are affected by low DO than smaller fishes. The mean concentration of dissolved oxygen in Zobe reservoir range between 6.8m/L to 7.2 m/L. Dwivedi *et al.* (2002) reported that the amount of oxygen in a water body depends on the extent of contact with the atmosphere. The dissolved oxygen falls above the recommended value of 5mg/l as reported by Viveen *et al.,* (1985).

Oniye *et al.,* (2002) reported mean oxygen concentration of 0.17mg/l in Zaria dam, while the DO value of 4.8 – 8.2mg/L has also been reported by various scientists from various reservoirs in Nigeria (Mustapha, 2008; Sogbesan and Baka, 2017; Sogbesan and Kwaji, 2018; Dan-kishiya *et al.*, 2018, and Nababa *et al.*, 2022)

Biological oxygen Demand (BOD)

Biological oxygen Demand in the Zobe reservoir fluctuated during the study period in all the five (5) sampling stations (Figures 3 and 8). The BOD value recorded ranges from 0.50 mgL^{-1} ± 0.54 to 3.80 mgL^{-1} ± 0.07, which is a good indication that the reservoir is not polluted. According to Clerk (1986) BOD value of 4mg/L and below does not indicate water pollution. The reservoir revealed higher values of BOD during the rainy season which may be due to increase in photosynthetic activities (production of more DO) as a results of wash-off of more fertilizer from extensive agricultural activities, which increases the deposition of both organic and inorganic substances in the reservoir. This assumption contradicts the findings of Ibrahim (2014) who reported the higher values of biochemical oxygen demand in Kontagora Reservoir, Niger state, Nigeria during the dry season, this could be due to reduction of phytoplankton and decomposition of other living organisms in the reservoir. Mahar (2003) made similar observation and proffered that it might be due the depletion of oxygen in the water during decomposition in dry season. Due to high biological activities, such as decomposition of dead and decaying organic matter, photosynthesis and so forth resulting to massive microbial population and their activities, hence oxygen will be consumed in the water and increases BOD (Abida and Harikrishna, 2008).

Alkalinity

Alkalinity is a measure of the acid-neutralizing capacity of water. According to Murphy (2008) total alkalinity level of 20ppm to 200ppm are typical of freshwater stream. Alkalinity value of 100ppm to 200ppm can stabilize the pH level in a stream that is, buffering capacity. In most natural waters, it is due to the presence of carbonate (CO_3^-), bicarbonate (HCO_3^-), and hydroxyl (OH^-) anions according to Stone and Thomforde (2006). However, borates, phosphates, silicates, and other bases also contribute to alkalinity if present (Wilson, 2010).

In the present study the mean annual value for Alkalinity ranges between 27.604 ppm to 28.11 ppm (Figures 2 and 9). Alkalinity is the measure of the capacity of water to neutralize or buffer acids using carbonate, bicarbonate ions, and in rare cases by hydroxide, thus protecting the organisms from major fluctuations in pH. This also agreed with the work of Apollos *et al.,* (2016). The alkalinity values recorded in this study were within the recommended values between 5- 500mg/l (Lawson, 1995). Other works that observed similar results within acceptable range include Mustapha (2008) who recorded 20ppm to 80ppm from Oyun Reservoir, while Andem *et al*. (2012) reported a range 59.38 – 68.8mg/L in Ona River.

Ammonia (NH_3)

The total ammonia nitrogen values ranged from 0.10ppm ± 0.081 and 0.298ppm ± 0.088 in Zobe reservoir (Figures 2 and 11). NH_3 is the principal form of toxic ammonia. It has been reported that it is toxic to fresh water organisms at the concentration ranging from 0.53 and 22.8mg/l; however, the toxic levels are both pH and temperature dependent. Toxicity increases as pH decreases and as temperature decreases (Kigbu and Muhammad, 2014). Bala and Bolorunduro (2011) reported a ranged of 0.3 – 1.17mg/l ammonia-nitrogen concentration in Sabke reservoir, while Andem *et al*. (2012) reported an ammonia level between 0.11ppm – 0.15ppm concentration from Ona River. According to OATA (2008) Ammonia level between 0.00ppm to 0.3ppm were considered safe for fish production. The highest ammonia value from this study obtained in Tabobi fishing stations, and this may be due to intense of agricultural activities in the area year-in and year-out.

Fish Species Composition, Relative Distribution and Abundance in Zobe Reservoir

With thirteen (13) fish species from eight (8) genera and seven (7) families (Tables 1 and 2), the Ichthyofauna of the Zobe reservoir appears to be richer than the twelve (12) fish species from the same reservoir reported by Ahmad *et al*. (2014) and the twelve (12) fish species found in the Dogon Ruwa water body by Oguntade *et al*. (2014) and Allison and Okadi (2013). According to this study, the most prevalent species in each of the five stations of the Zobe reservoir are Bagrids, Clariids, and Cichilids. The findings of Dan-Kishiya *et al*. (2012), who said that the Cichlidae family was the most prevalent species in the lower Usuma reservoir, were comparable to this one. Sarotherodon and O. niloticus were found to be the most prevalent species in Lake Geronyo by Abiodun and Miller (2005). Similarly, *O. niloticus* was found to be the most prevalent in Gbedikere Lake, Bassa, Kogi State, according to Adeyemi *et al.* (2009). *O. niloticus* of the family Cichlidae was the most widely distributed and relatively numerous species in Lake Geronyo, according to the relative abundance of the 13 species that were identified.

The species richness is, however, lower than that of the 81 fish species found in the River Ovia, Edo State, by Odiko *et al*. (2010); the 45 fish species found in Urie Creek by Meye and Ikomi (2008); and the 26 fish species found in Dadin Kowa dam, Gombe State, Nigeria, by Ja'afaru and Abubakar (2015). The capacity of cichlids to breed roughly three or four times a year may be the reason for their supremacy (Bankole *et al*., 1994; Reed *et al.,* 1967).

Catch per unit Effort (CPUE) and Correlation of Catches with Physicochemical Parameters

In all five (5) fishing sites, catch per unit effort (Man days) was examined for both the wet and dry seasons (Figure 12 and Table 3). CPUE is the total amount of fish that each man catches in a given day and is thought to be directly correlated with fish availability (Yusuf and Abdulkarim, 2015). By averaging and adding the estimates of abundance in each local region, one can determine the overall abundance of the target species (as an extrapolation) (Ita and Pandogari, 1987). According to Abiodun and John (2005), this provides a preliminary estimate of the stock size for the entire fishery in the research region. Table 4's robust positive association between conductivity and catch indicates that the likelihood of fish presence might be anticipated using conductivity of the water, however there is an inverse association indicated by the substantial negative correlation between catch and turbidity. Furthermore, Kibira and Webber (2000) found that during the dry season, EC values were higher (162.13 ± 11.0 mg/L); yet, EC from the Zobe reservoir correlates positively with temperature, BOD, alkalinity, and fish catch. Conversely, there is a negative relationship between DO, turbidity, and pH. Strongly correlated physicochemical parameters can be used to predict one another either directly or inversely, depending on whether the correlation is positive or negative.

The study's findings of higher wet season than dry season catches and species have similarly been reported by Ja'afaru and Abubakar (2015) in Dadin Kowa dam, Gombe State; Sogbesan and Barka (2017) in Njoboliyo Lake; and Kwaji *et al*. (2015) at Lake Ribadu. This outcome, however, is at odds with that of Meye and Ikomi (2008), who observed that species and captures in Urie Creek at Igbide, Delta State, were higher during the dry season than during the wet season.

The increased availability of fish food, which in turn leads to increased reproduction, particularly by members of the family Claridae (Reed *et al*., 1967), such as *Clarias gariepinus*, which is the second most abundant species in this study (Table 1), the cause of the higher wet season catches could be associated with the ability of the fishermen to access areas of the fishing grounds that are otherwise unreachable during the dry season in their canoes during the wet season due to increased water depth and available space. Furthermore, during the rainy season, water quality indices improve.

CONCLUSION

Despite a clear evidence of run-off of fertilizer and residues/leftovers from year-round farming activities surrounding the reservoir, it was concluded that the physicochemical characteristics of the Zobe reservoir falls within permissible norms for fish production. Zobe reservoir, like the majority of Nigeria's inland water bodies, offers enormous potential for fisheries exploitation provided the necessary management measures are implemented. The study's findings demonstrated that the reservoir is home to thirteen 13 commercially significant fish species, the most common and widely spread species is *O. niloticus*. The species might be best utilized. Fish catches is negatively correlated with turbidity, therefore activities such as farming (year in, year out), flooding, washing household goods, and potential garbage disposal into reservoirs can all have an adverse effect on the water quality and subsequently on the fishes.

The following strategic recommendations are suggested to Sokoto Rima Basing Development Authority (SRRBDA), Katsina State government and all other stakeholders for better fisheries management to enable the optimum fish production and exploration in Zobe reservoir.

i. Implementation and enforcement of the existing national inland fisheries decree and states edict in Zobe reservoir;

ii. Implementation of a general principles and guidelines for a sound management of the inland water particularly in checkmating pollution from anthropogenic activities

iii. Promotion of community participation and increase local awareness through extension programmes using multiple media such radio programmes, brochures, TV, and for the abundance of fishery resources.

Conflict of Interests

We the authors agree to the totality of the findings and conclusions of this work. We, therefore, declared that there is no conflict of interest of all kind.

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