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Variation of water quality parameters and correlation among them and fish catch per unit effort of the Tono Reservoir in Northern Ghana

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ABSTRACT

Water quality is essential for fish survival and growth in reservoirs. However, little information is known about the water quality status and its relation with fish production in the Tono Reservoir. This study sought to assess water quality parameters and examine association among them as well as determine the correlation between the water quality parameters and fish catch per unit effort of the Tono Reservoir. A three-level stratified sampling was adopted and samples were collected on a monthly basis. Water quality parameters such as water level, temperature, pH, electrical conductivity, transparency, turbidity, dissolved oxygen, chloride, sulphate, phosphate-phosphorus, silica, nitrate-nitrogen, nitrite-nitrogen, chlorophyll-a, and fish catches were measured simultaneously from each of the three strata of the reservoir. The water quality parameters of the reservoir fell within the recommended range for fish production. Concentrations of water quality parameters for the riverine, transitional and lacustrine zones showed no significant difference ($p > 0.05$). Catch per unit effort correlated significantly positive with only chloride ($r = 0.61$, $p < 0.05$) attributable to fertilisers used on surrounding farm lands and carried by runoff or floods to the reservoir. The reservoir could be classified as mesotrophic based on chlorophyll-a concentration. It was recommended that the reservoir water quality should be monitored quarterly by the Ministry of Fisheries and Aquaculture Development to ensure safe fish production.

Introduction

Reservoirs store water from dammed rivers and this stored water can undergo several physical and chemical transformations that can alter the quality of fish habitat within the reservoir and the river downstream. The retention time of water in reservoirs, which is a function of the capacity of the reservoir is a major determinant of the degree of

transformation of the water quality. The longer the time of retention of water in the reservoir, the higher the chance of water quality degradation and vice versa (Khatri and Tyagi 2015).

Water quality includes all physical, chemical and biological factors of water that influence the beneficial use of the water (Alley 2007; Spellman 2013). Water quality is important in drinking water supply, irrigation, fish production, recreation and other purposes for which the water must have been impounded. Some of the most important physical and chemical characteristics of reservoir water include temperature, turbidity, conductivity, dissolved oxygen, pH, nitrogen and phosphorus.

Physiologically, dissolved oxygen and temperature are essential for sustaining aquatic life. In a related manner, both temperature and dissolved gases regulate other physical and chemical properties of the water which can affect aquatic life especially fish assemblage in the reservoir. Additionally, nutrient enrichment mostly with phosphorus and nitrogen stimulates unnecessary primary production, which can reduce oxygen. Turbidity is also a key water-quality characteristic because its effects on light transmission and water clarity define habitat characteristics. Furthermore, water pH regulates aquatic chemistry, which can affect water use and habitat.

The health of an aquatic ecosystem is highly depended on the physico-chemical and biological characteristics of the water (Venkatesharaju et al. 2010; Rameshkumar et al. 2019). Changes in fish populations can be indicators of aquatic ecosystem health (Moyle 1994). The existence and richness of fish species can be associated to the physical and chemical properties of water (Deacon and Mize 1997). Reduced water quality is reported to affect fish communities by impacting habitat, food availability, and dissolved oxygen levels, which in turn influence their growth potential and reproductive abilities (Reynolds 2014; Shetty et al. 2015).

The deterioration of water quality in reservoirs usually comes from excessive nutrient inputs, eutrophication, acidification, heavy metal contamination, organic pollution and obnoxious fishing and aquaculture practices (Wetzel and Likens 2006; Khatri and Tyagi 2015). The effects of these "imports" into the reservoir do not only affect the socio-economic functions of the reservoir negatively, but also bring loss of fish populations in the reservoir and consequently reduces fish catches.

Some anthropogenic activities have been identified to promote water quality deterioration of water bodies. These activities include farming, application of fertilizers, manures and pesticides, animal rearing activities, aquaculture, improper irrigation practices, deforestation, indiscriminate discharge of industrial effluents and domestic sewage, mining, and recreational activities (Khatri and Tyagi 2015). These activities could eventually lead to increase in concentrations of nutrient load, heavy metals, mercury and coliforms. The rise of agricultural and industrial activities and increase in population over the past century have led to significant eutrophication of surface waters around the world (Schindler et al. 2006; Chislock et al. 2013).

It has been widely reported that the major vectors of pollutants to water bodies are runoff and flood. In recent times, flood has become a perennial phenomenon in many areas as a result of human activities including urban expansion and agricultural activities on floodplains among others (Woodward et al. 2016). In Ghana, the most frequently reported impacts of floods are physical cost, destruction of economic infrastructure and health concerns (Mensah and Ahadzie 2020). Unfortunately, little attention is given to the impacts of these floods on the aquatic ecosystems, fish populations and catches.

Studies have also shown that floods can cause an upsurge of pollution load of reservoirs within a short period and can also generate substantial sediment pollution along
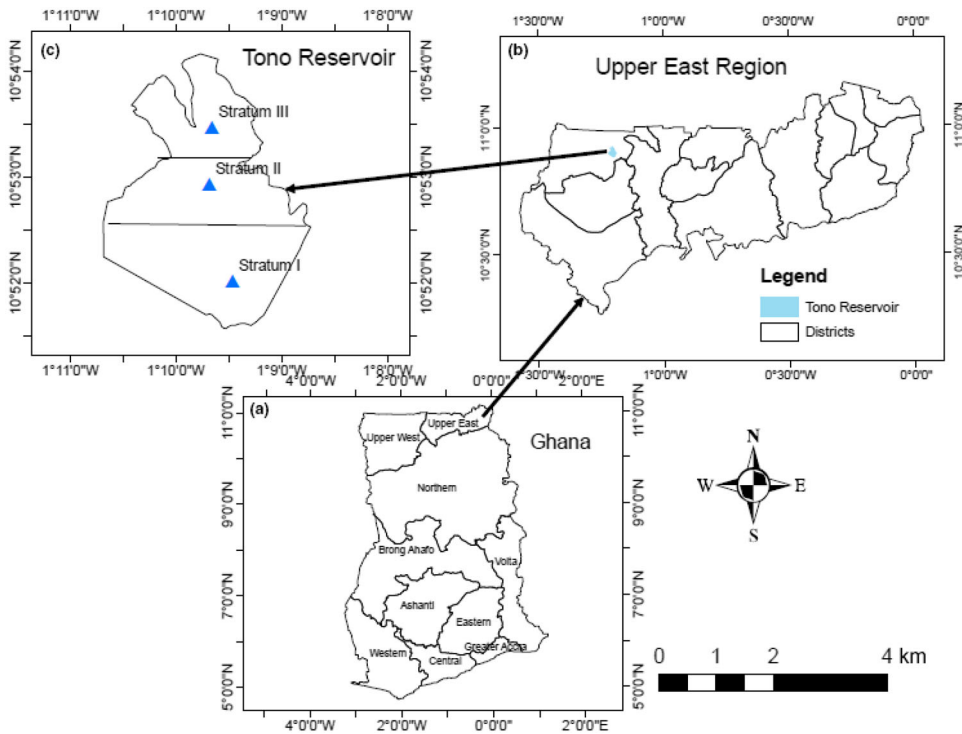
Figure 1. Map of Ghana (a) showing Upper East Region (b) and the Tono Reservoir (C) apportioned into 3 strata (Akongyuure, Amisah, Edziyie 2017).

with the continual deposition of pollutants into the reservoir (Ciszewski 2001). Previous research has noted that runoff and pollution load peaks occur earlier during higher intensity rainfall occasions (Nazari–Sharabian et al. 2019). Wang et al. (2006) observed that the sediments carried into a reservoir in a single flood incident can represent more than 0.5 percent of the storage capacity. Consistently, the change in reservoir capacity has received more attention when the water level of the reservoir continues to decline, whilst the impact on water quality and fish catches is often unnoticed.

Globally, it has been reported that the water quality of many reservoirs have been affected negatively by endogenous and exogenous factors (Shi et al. 2016; Obisesan and Christopher 2018; Sojka et al. 2018). Mustapha (2008) reported high nitrate and phosphate concentrations in the rainy season caused by run off of nitro-phosphate fertilizers from nearby farmlands at Oyun reservoir, Nigeria. The reservoir high ionic content, high nutrient and dissolved oxygen levels, good pH, low level of pollution and shallow depth were responsible for the high estimate of the fish yield. Karikari and Ansa-Asare (2006) noted a high nutrient load in the Densu basin in Ghana owing to agricultural, domestic and industrial activities. The high level of chloride was identified and attributed to fertilizer use, household effluents and other anthropogenic point sources.

Several studies of reservoir fisheries exist, mostly on aspects of fish catch, growth, reproduction or diet in a single reservoir but very few relate them to water quality data (Granado-Lorencio et al. 1985). Though physico-chemical characteristics of other reservoirs and lakes in Ghana have been studied by Alhassan et al. (2015), Alhassan (2011), Kwarfo-Apegyah (2008), Quarcoopome et al. (2008), Ofori-Danson and Ntow (2005) among others, little information is known about the Tono reservoir which contributes to

the livelihood of the people in the region by employing over 900 fishers (Akongyuure, Amisah, Agyemang, et al. 2017; Akongyuure, Amisah, Edziyie 2017).

The use of the physical, chemical and biological properties of water to assess water quality gives a good impression of the status, productivity and sustainability of such water body. The changes in physical characteristics like temperature, conductivity, transparency and chemical elements of water such as dissolved oxygen, nitrite, nitrate, silica and phosphate provide valuable information on the quality of the water, the source(s) of the variations and their impacts on the functions and fisheries of the reservoir.

Effective management of reservoirs through bio-manipulation, phosphorus inactivation and sediment oxidation, artificial circulation, hypolimnetic aeration and removal of sediment for increased fish populations and consequently increased fish catches can only be achieved if there is reliable limnological data. The objectives of the study were to (i) assess annual, seasonal and spatial variation of selected water quality parameters, (ii) examine the association among water quality parameters and (iii) determine the correlation between water quality parameters and catch per unit effort (CPUE) of the Tono Reservoir.

Materials and methods

Study area

The Tono reservoir is found in the Kassena-Nankana West District of northern Ghana (10° 52′ N, 1°08′ W) (Figure 1). The annual rainfall in the area is $800 - 1100$ mm. The wet season begins in May and ends in October, whilst the dry season starts in November and lasts until April. The reservoir stretches for about 5 km long and a water storage capacity of 93 000 000 m³. The mean depth is approximately 8.0 m and the total surface area is 12.5 km². About 950 active fishers operate at the reservoir using mainly gillnet, cast net, trap and hook-and-line to harvest major fish species dominated by Cichlids (Akongyuure, Amisah, Agyemang, et al. 2017; Akongyuure, Amisah, Edziyie 2017). Recent studies reported 18 fish species, 15 genera belonging to 8 families. The same study indicated low fish catch and fish diversity in the Tono reservoir (Akongyuure, Amisah, Edziyie 2017).

Study design

In order to achieve effective sampling, a three-level stratified random sampling approach was adopted. The reservoir was apportioned into Stratum I, Stratum II and Stratum III (Figure 1). The first stratum is characterised by broad, deep and lake-like basin (Lacustrine zone); the second stratum is characterised by broader and deeper basin (Transitional zone); and the third stratum is characterised by a narrow and channelised basin (Riverine zone) (Thornton et al. 1996). A two designated hydrological seasons: dry season (November – April) and wet season (May – October) was also adopted.

Measurement of water quality parameters

Sampling was done once every month for 24 months from January, 2015 to December, 2016. Water level of the reservoir was recorded from the gauge mounted on the reservoir. Readings of temperature, pH, dissolved oxygen, and electrical conductivity were measured *in situ* using Hanna Meters. The probes were immersed in the water at each of the three sampling strata and the figure registered on the screen recorded. Three readings each at 3

different points per stratum were taken at about 30.0 cm below the water surface for each of the above mentioned parameters and the average calculated and recorded. The strata I, II, and III represented the lower, middle and upper portions of the reservoir respectively. Transparency was measured using Secchi disc to the nearest 0.1 cm. Three water samples were also taken from the same depth at each stratum with a 1.0-litre white polyethylene bottles for turbidity, dissolved oxygen, chloride, sulphate, phosphate, silica, nitrite, nitrate and chlorophyll-*a*. Chlorophyll-*a* sample bottles were immediately placed in black polythene bags at the time of collection to avoid chlorophyll-*a* degradation. All samples were preserved in an iced chest at 4 °C and transported to the Council for Scientific and Industrial Research (CSIR)-Water Research Institute laboratory, Tamale station for analysis. The water samples were analysed in the laboratory using the procedure outlined in the Standard Methods for the Examination of Water and Wastewater (APHA (American Public Health Association)) 1998). Phosphate, nitrate, nitrite, sulphate and silica were analysed within 24 hours upon arrival at the laboratory using 6305 UV/Visible Spectrophotometer.

Laboratory analysis

For phosphates analysis, 10 ml of the water taken into a 25 ml test tube. A drop of phenolphthalein was added. A few drops of HCl is added if pink colour is developed to dispense the colour (indicating that the pH of the sample higher than 8.3). The acid creates an acidic condition favourable for the reaction (colour formation). 0.4 ml of ammonium molybdate was added and mixed well followed by a drop of stannous chloride to form blue molybdenum complex indicating the presence of phosphates in the water sample. The sample was then allowed to stand for 2 minutes. The colour intensity measured at 690 nm. The concentration of phosphate was recorded in mgL^{-1} and reported to three decimal places.

Nitrates analysis was done using hydrazine reduction followed by diazotization and colour intensity measured at 520 nm. A 10 ml of water sample was taken into a 25 ml test tube. 1 ml of 0.3 M NaOH was added then 1 ml of reducing reagent (comprising of copper sulphate, hydrazine sulphate and sodium hydroxide each in their right proportion). The samples were then heated in a water bath at 60 °C for 10 minutes and cooled. 1 ml of colour reagent was added and allowed to stand for 5 minutes. Brown colour indicated the presence of nitrate in the sample. A blank was prepared using distilled water and treated with same reagents but without heating and used to zero the machine before reading of the samples. The concentration of nitrate was calculated knowing the absorbance directly from the calibration curve and the results expressed in mgL^{-1} to three decimal places.

Sulphate analysis was carried out by measuring 10 ml of water sample into a 25 ml Erlenmeyer flask. Exactly 0.5 ml conditioning reagent was added and mixed by stirring. A spoonful of barium chloride crystals was then added while still stirring and timing immediately for 60 seconds at a constant speed. After stirring, the absorbance rate was measured at 420 nm on the spectrophotometer within 5 minutes. The concentration of sulphate was calculated knowing the absorbance directly from the calibration curve and the results expressed in mgL^{-1} to three decimal places.

Chloride determination was done using Argentometric method (silver nitrate titration method). A 50 ml of water sample directly titrated in the pH range 7 to 10 (using a pH meter). 0.5 ml K_2CrO_4 indicator solution was added and titrated with standard $AgNO_3$ titrant to a pinkish yellow end point. The results were expressed in mgL^{-1} to 2 decimal places.

Table 1. Detailed description of gears used to catch fish during the study period (2015 -2016) at the Tono Reservoir, Ghana.

Gear	Mesh size (cm)/Size	Length (m)	Breadth/Radius (m)
Plank canoe	–	$5.0 - 8.1$	$0.90 - 1.0$
Monofilament gillnet	$< 1.0 - 10.0$	100 m per bundle	$1.5 - 4.0$
Cast net	2.5	$2.0 - 4.0$	$2.0 - 2.5$
Trap	–	$0.4 - 1.0$	$0.5 - 1.0$
Hook-and-line	$1/0 - 6/0$	$10 - 50$ m/line	–
Experimental gillnets	5.0 cm and 7.0 cm	200 m each	2.0

For silica determination, 0.2 ml $1 + 1$ HCl and 0.4 ml ammonium molybdate reagent was added in rapid succession to 10 ml sample. The solution was then mixed by inverting at least six times and allowed to stand for 5 to 10 minutes in test tube. About 0.4 ml oxalic acid solution was added and mixed thoroughly. The colour (yellow) was read after 2 minutes but before 15 minutes at 410 nm using the UV/Visible Spectrophotometer, measuring time from addition of oxalic acid. To correct for colour and turbidity, a blank was prepared by adding HCl and oxalic acid. The photometer was adjusted to zero absorbance with the blank containing no molybdate before the reading absorbance of molybdate-treated samples. The results were expressed in mgL^{-1} to two decimal places.

For chlorophyll-a, the sample (1.0 L) was filtered under vacuum through a glass fibre paper. The filtrate was discarded and the filter paper placed in a stoppered bottle immersed in acetone (90%) to allow extraction to proceed overnight in the refrigerator. The content in the bottle was centrifuged for 15 minutes at 2000 rpm to separate suspended fragments of filter. The supernatant obtained was carefully decanted into a cell and optical density measured at 630, 645, 663 and 750 m using the 90% acetone as a blank in the compensating cell. Small turbidity blank was corrected by subtracting the 750 nm absorption from 663, 645 and 630 absorptions. Chlorophyll-a values were calculated in mg pigment/m^3 following the methods described in APHA (American Public Health Association)) (1998).

Measurement of CPUE

Fish samples were recorded monthly from both experiment gillnets and commercial fishermen who use gillnet, cast net, traps and hook-and-line for a period of 24 months. Fish catches comprised *Auchenoglanis occidentalis*, *Chrysichthys auratus*, *Clarias gariepinus*, *Hemichromis bimaculatus*, *Hemichromis fasciatus*, *Oreochromis niloticus*, *Coptodon/Tilapia zillii*, *Sarotherodon galilaeus*, *Labeo coubie*, *Marcusenius senegalensis*, *Marcusenius ussheri*, *Pollimyrus isidori*, *Odaxothrissa mento*, *Pellonula leonensis*, *Sierrathrissa leonensis* *Paradistichodus dimidiatus*, *Schilbe intermedius* and *Schilbe macropogon*. .When available, fish catches from 20 plank canoes were usually sampled per sampling day. This sample size represents between $90 - 95\%$ of sampling accuracy in small population (Stamatopoulos 2004).

Fish samples were collected by systematic random sampling from the most active landing sites namely Bay 1, Bay 2, and Bay 5 representing lower/lacustrine zone, middle/transitional zone and upper/riverine zone of the reservoir respectively. Samples were obtained from experimental gillnets and commercial fishermen operating gears such as gillnet, cast net, trap and hook-and-line. Table 1 shows the detailed characteristics of the gears where fish samples were obtained at the Tono Reservoir. Fish catches were recorded using a 20-kg capacity top pan balance scale from every second canoe until sample size was reached on each sampling time.

Table 2. Annual variation of physico-chemical parameters of Tono Reservoir, Ghana for the study period 2015 – 2016 using Mann Whitney U test for test of difference between the 2 years.

Parameter	Range		Mean ± Standard Deviation			P-value
	2015	2016	2015	2016	2015 – 2016	2015 & 2016
Water level (m)	$2.00 - 10.50$	$6.60 - 10.50$	6.02 ± 3.35	8.71 ± 1.30	7.30 ± 2.11	0.083
Temperature (°C)	$22.66 - 29.80$	$22.31 - 32.23$	28.15 ± 2.14	28.60 ± 3.34	28.16 ± 2.86	0.187
pH (unit)	$7.47 - 8.87$	$6.56 - 9.05$	8.15 ± 0.50	7.90 ± 1.28	8.05 ± 0.65	0.716
Electrical conductivity (μ Scm^{-1})	$46.63 - 72.56$	$58.11 - 99.97$	65.73 ± 7.17	73.50 ± 11.32	68.74 ± 6.72	0.098
Transparency (cm)	$8.78 - 50.11$	$18.00 - 66.11$	22.98 ± 13.94	39.43 ± 16.51	30.94 ± 12.02	0.032*
Turbidity (NTU)	$42.50 - 242.66$	$7.57 - 57.89$	142.56 ± 75.16	22.67 ± 17.15	72.31 ± 42.19	0.000*
Dissolved Oxygen (mgL^{-1})	$5.31 - 18.65$	$4.48 - 20.08$	11.30 ± 4.58	9.92 ± 5.39	10.20 ± 3.49	0.339
Chloride (mgL^{-1})	$1.16 - 5.41$	$2.87 - 6.79$	3.20 ± 1.19	4.51 ± 1.26	3.93 ± 1.01	0.023*
Sulphate (mgL^{-1})	$4.73 - 33.01$	$0.05 - 33.79$	16.96 ± 11.11	11.19 ± 10.82	13.19 ± 5.09	0.156
Phosphate-Phosphorus (mgL^{-1})	$0.03 - 4.10$	$0.01 - 8.12$	0.58 ± 1.42	0.71 ± 2.33	0.55 ± 1.26	0.028*
Silica (mgL^{-1})	$3.47 - 24.04$	$0.02 - 22.67$	14.53 ± 7.37	9.56 ± 5.80	11.64 ± 4.21	0.093
Nitrate-Nitrogen (mgL^{-1})	$0.03 - 10.86$	$0.01 - 1.81$	3.51 ± 3.10	0.51 ± 0.58	1.76 ± 1.63	0.004*
Nitrite-Nitrogen (mgL^{-1})	$0.01 - 0.50$	$0.01 - 0.09$	0.16 ± 0.20	0.04 ± 0.03	0.09 ± 0.09	0.119
Chlorophyll-a (mgm^{-3})	$3.53 - 8.30$	$4.00 - 8.10$	6.52 ± 1.74	6.00 ± 1.82	5.62 ± 1.71	0.763

*Means p-values that are statistically significant at 5% confidence level

Data analysis

Data were subjected to Anderson-Darling normality test before applying appropriate test after organising them into means. Since most concentrations were not normally distributed, non-parametric analysis was performed using Spearman's correlation to show relationship between water quality parameters by Palaeontological Statistics (PAST) version 3. Additionally, Kruskal-Wallis test was used to detect differences in means of the strata. Multiple comparison analysis was done using Mann Whitney U pairwise test to see the variations due to seasons and space (strata). The probability value of ≤ 0.05 was considered statistically significant for all tests. CPUE was estimated as *catch/canoe x fishing day*. Monthly pattern of water level and CPUE parameters was presented by line graph using Microsoft Excel 2013.

Results

Annual levels of water quality parameters for the study period

The range and mean values of water quality parameters for the study period are presented in Table 2. The mean water level reduced to as low as 2.0 m in 2015 compared to 6.6 m in 2016 and attained a maximum level of 10.5 m in both years. The mean surface water temperature varied marginally in the range of $22.66 - 29.80\,°C$ in 2015 and $22.31 - 32.23\,°C$ in 2016. Mean pH fell to a minimum of 6.56 in 2016 slightly lower than a minimum of 7.87 in 2015 and rose to a maximum of approximately 9.00 in both years. The range in mean conductivity was much higher in 2016 ($58.11 - 99.97$ μ Scm^{-1}) than in 2015 ($46.63 - 72.56$ μ Scm^{-1}). Transparency values were significantly higher ($p = 0.032$) in 2016 than in 2015. On the other hand, turbidity was significantly high ($p = 0.000$) in 2015 than in 2016. Averagely, there was no significant difference ($p = 0.339$) in levels of dissolved oxygen for both years. The mean level of chloride was much higher in 2016 than in 2015 ($p = 0.023$). There was no significant difference

Table 3. Seasonal variation of physico-chemical parameters of Tono Reservoir, Ghana for the study period 2015 – 2016 using Mann Whitney U test for test of difference between the 2 seasons.

Parameter	Dry season	Wet season	Dry Mean ± S.D.	Wet Mean ± S.D.	P-value
Water level (m)	4.63 − 9.05	4.55 − 10.33	6.97 ± 1.87	7.63 ± 2.46	0.575
Temperature (°C)	22.30 − 30.00	28.95 − 30.71	26.54 ± 3.37	29.78 ± 0.59	0.076
pH (unit)	7.51 − 9.05	6.59 − 8.60	8.20 ± 0.57	7.91 ± 0.74	0.575
Electrical conductivity (μ Scm^{-1})	62.21 − 82.71	56.06 − 71.63	70.52 ± 7.63	66.95 ± 5.79	0.378
Transparency (cm)	18.00 − 50.00	14.06 − 33.09	38.50 ± 11.34	23.39 ± 7.23	0.045*
Turbidity (NTU)	82.33 − 324.10	27.00 − 146.17	54.02 ± 29.27	90.60 ± 47.49	0.298
Dissolved Oxygen (mgL^{-1})	4.48 − 13.37	5.88 − 15.72	10.60 ± 3.23	9.79 ± 4.00	0.810
Chloride (mgL^{-1})	2.70 − 4.52	3.2 − 5.85	3.51 ± 0.28	4.35 ± 1.15	0.126
Sulphate (mgL^{-1})	4.96 − 15.19	13.53 − 20.44	9.34 ± 3.76	17.04 ± 2.71	0.013*
Phosphate-Phosphorus (mgL^{-1})	0.01 − 4.10	0.03 − 2.06	0.72 ± 1.65	0.38 ± 0.82	0.689
Silica (mgL^{-1})	6.48 − 19.38	7.30 − 15.44	10.62 ± 4.89	12.66 ± 3.55	0.298
Nitrate-Nitrogen (mgL^{-1})	0.07 − 2.48	0.63 − 5.84	0.93 ± 0.93	2.59 ± 1.84	0.066
Nitrite-Nitrogen (mgL^{-1})	0.02 − 0.07	0.05 − 0.28	0.03 ± 0.02	0.14 ± 0.10	0.014*
Chlorophyll-a (mgm^{-3})	3.23 − 8.30	3.53 − 7.22	5.62 ± 2.07	5.62 ± 1.47	0.936

*Means p-values that are statistically significant at 5% confidence level

($p > 0.05$) in levels of sulphate, silica, nitrite and chlorophyll-*a* for both years. Phosphate and nitrate levels were both significantly high ($p < 0.05$) in 2015 than in 2016.

Seasonal variation of water quality parameters

The seasonal variations of water quality parameters for the entire period of study are shown in Table 3. The seasonal variation of water level, temperature, pH, electrical conductivity, turbidity, dissolved oxygen, chloride, phosphate, silica, nitrate and chlorophyll-*a* was not significant ($p > 0.05$). Mean transparency varied significantly ($p = 0.045$) seasonally in the Tono Reservoir for the study period with dry season (38.50 ± 11.34 cm) recording higher transparency mean value than wet season (23.39 ± 7.23 cm). Sulphate and nitrite were significantly (p < 0.05) higher in the wet season than in the dry season.

Spatial variation of water quality parameters

Table 4 shows spatial variation of water quality parameters of the Tono Reservoir for the study period. The results showed no significant difference (p > 0.05) in levels of water quality parameters in the lower, middle and upper portions of the reservoir for all the parameters investigated during the study period.

Association among water quality parameters and CPUE

Table 5 shows the associations among water quality parameters and catch per unit effort (CPUE) in Tono Reservoir. The results showed a significant difference ($p < 0.05$) between water level (WL) verses turbidity (Turb), chloride, phosphate and chlorophyll-*a* (Chl-a) suggesting a strong negative relationship of water level with turbidity ($r = -0.76$), phosphate ($r = -0.68$) and chlorophyll-a ($r = -0.70$) and positive relationship with chloride (r = 0.76). Temperature correlated significantly positive with sulphate ($r = 0.76$, $p < 0.05$), silica ($r = 0.71$, $p < 0.05$), nitrate-nitrogen ($r = 0.70$, $p < 0.05$), nitrite ($r = 0.62$, $p < 0.05$) and chlorophyll-*a* ($r = 0.59$, $p < 0.05$). The reservoir water pH related significantly negative ($r = -0.71$, $p < 0.05$) with phosphate. Transparency associated significantly

Table 4. Spatial variation of water quality parameters of the Tono Reservoir, Ghana for the study period 2015 – 2016 using Kruskal-Wallis test.

Parameter	Mean ± S.D.			P-value
	Stratum I	Stratum II	Stratum III	
Temperature (°C)	28.46 ± 3.14	27.24 ± 4.87	28.17 ± 2.87	0.996
pH (unit)	7.90 ± 1.14	10.66 ± 12.91	8.03 ± 0.99	
Electrical conductivity (μ Scm^{-1})	70.22 ± 10.33	68.72 ± 13.86	69.74 ± 9.24	
Transparency (cm)	35.79 ± 19.39	37.21 ± 21.29	35.55 ± 20.76	
Turbidity (NTU)	84.38 ± 79.93	83.34± 79.88	88.55 ± 79.27	
Dissolved Oxygen (mgL^{-1})	10.65 ± 5.28	11.21 ± 5.71	11.64 ± 5.93	
Chloride (mgL^{-1})	3.96 ± 1.58	4.73 ± 4.71	4.06 ± 1.63	
Sulphate (mgL^{-1})	14.78 ± 10.85	13.26 ± 10.84	14.08 ± 11.12	
Phosphate-Phosphorus (mgL^{-1})	0.09 ± 0.09	1.03 ± 5.12	0.09 ± 0.03	
Silica (mgL^{-1})	12.52 ± 6.82	11.43 ± 5.93	12.50 ± 7.33	
Nitrate-Nitrogen (mgL^{-1})	2.04 ± 2.58	2.09 ± 3.97	2.21 ± 2.64	
Nitrite-Nitrogen (mgL^{-1})	0.11 ± 0.17	0.15 ± 2.47	0.13 ± 0.16	
Chlorophyll-a (mgm^{-3})	5.85 ± 3.20	5.36 ± 1.42	5.28 ± 3.06	

negative ($r = -0.60$, $p < 0.05$) with nitrate-nitrogen. Turbidity correlated significantly positive with sulphate ($r = 0.72$, $p < 0.05$), nitrate-nitrogen ($r = 0.73$, $p < 0.05$), and chlorophyll-a ($r = 0.62$, $p < 0.05$). Chloride related in a significantly positive manner with nitrite-nitrogen ($r = 0.60$, $p < 0.05$) and CPUE ($r = 0.61$, $p < 0.05$). There was a strong significant positive relationship ($r = 0.80$, $p < 0.05$) between sulphate and nitrate-nitrogen.

Monthly trends in water level and CPUE for 2015 and 2016

Figure 2 shows the pattern of water level and CPUE for the 2015 study period. The lowest level of water was noted in May and the highest was recorded in August for 2015. On the other hand, February had the lowest CPUE and the greatest CPUE was noted in October for 2015. In 2016, the reservoir attained the lowest water level in April and the highest in September whereas the lowest CPUE was recorded in April and December obtained the greatest CPUE (Figure 3).

Discussion

The lowest water level (2.0 m) was observed in 2015 largely owing to high discharge of water for irrigation activities especially during the dry season (November – April). Nonetheless, the maximum level of 10.5 m was attained during the rainy season for both years largely owing to almost the same amount of rainfall for 2015 (859.8 mm) and 2016 (922.7) as reported by Akongyuure, Amisah, Edziyie (2017). The obvious lack of pre-impoundment data on the reservoir poses a serious challenge for comparison and conclusive comments on the formative stages of the reservoir. The strong negative correlation ($r \geq -0.70$) of water level and turbidity, phosphate and chlorophyll-*a* suggests that when water level of the reservoir increases, concentrations of turbidity, phosphate and chlorophyll-*a* will decrease and vice versa. This is typical because fluctuation of water level causes re-distribution of the levels of these parameters (Likens 2009).

Surface water temperature did not vary for the study period. However, the slight variation in the two seasons could have been influenced by the harmattan winds and high rainfalls in the dry and wet seasons respectively rendering the reservoir less stratified. Past studies noted that low temperatures in northern part of Ghana are essentially caused by cold harmattan winds during the dry season in late December to January and the heavy

Table 5. Association among water quality parameters and, the relation between these parameters and CPUE of Tono Reservoir, Ghana for the study period 2015 – 2016 using spearman's correlation.

	WL	Temp	pH	EC	Tran	Turb	DO	Cl^-	SO_4^{2-}	$PO_4^{3-}\text{-P}$	SiO_2	$NO_3^-\text{-N}$	$NO_2^-\text{-N}$	Chl-a	CPUE
WL		0.282	0.430	0.846	0.457	0.005*	0.443	0.004*	0.308	0.015*	0.457	0.297	0.312	0.011*	0.308
Temp	−0.339		0.768	0.662	0.393	0.130	0.350	0.784	0.005*	0.845	0.010*	0.011*	0.042*	0.044*	0.854
pH	0.252	0.095		0.499	0.354	0.527	0.880	0.727	0.557	0.009*	0.983	0.342	0.770	0.880	0.863
EC	−0.063	0.141	0.217		0.983	0.379	0.618	0.214	0.354	0.286	0.101	0.729	0.326	0.812	0.880
Tran	−0.238	−0.272	−0.294	0.007		0.542	0.366	0.845	0.183	0.235	0.746	0.039*	0.133	0.471	0.863
Turb	−0.755*	0.462	−0.203	−0.280	0.112		0.729	0.128	0.008*	0.075	0.366	0.007*	0.709	0.033*	0.342
DO	−0.245	0.296	0.049	−0.161	0.287	0.112		0.896	0.795	0.948	0.527	0.846	0.467	0.125	0.983
Cl^-	0.761*	−0.089	−0.113	−0.387	−0.063	−0.465	−0.042		1.000	0.196	0.467	0.524	0.052*	0.064	0.034*
SO_4^{2-}	−0.322	0.755*	−0.189	−0.294	−0.415	0.720*	−0.084	0.000		0.417	0.152	0.002*	0.096	0.112	0.729
$PO_4^{3-}\text{-P}$	−0.678*	−0.063	−0.713*	−0.336	0.371	0.531	−0.021	−0.401	0.259		0.779	0.880	0.340	0.175	0.183
SiO_2	−0.238	0.709*	0.007	0.497	−0.105	0.287	0.203	−0.232	0.441	−0.091		0.245	0.201	0.118	0.713
$NO_3^-\text{-N}$	−0.329	0.702*	0.300	−0.112	−0.601*	0.734*	−0.063	−0.204	0.804*	−0.049	0.364		0.133	0.199	0.557
$NO_2^-\text{-N}$	0.336	0.621*	0.100	−0.327	−0.482	0.127	0.245	0.596*	0.527	−0.318	0.418	0.482		0.915	0.519
Chl-a	−0.699*	0.589*	−0.049	−0.077	0.231	0.616*	0.468	−0.549	0.483	0.420	0.476	0.399	−0.036		0.075
CPUE	0.322	−0.060	−0.056	0.049	0.056	−0.301	0.007	0.613*	−0.112	−0.413	−0.119	−0.189	0.218	−0.531	

p-values

Spearman's r values
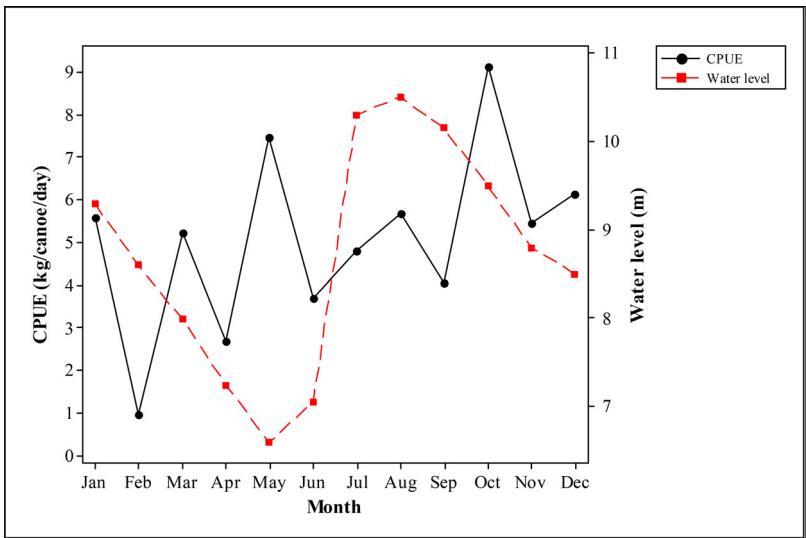
*Indicates correlation is significant at $p < 0.05$

Figure 2. Monthly pattern of water level and fish catch per unit effort (CPUE) for the 2015 sampling year at the Tono Reservoir, Ghana.
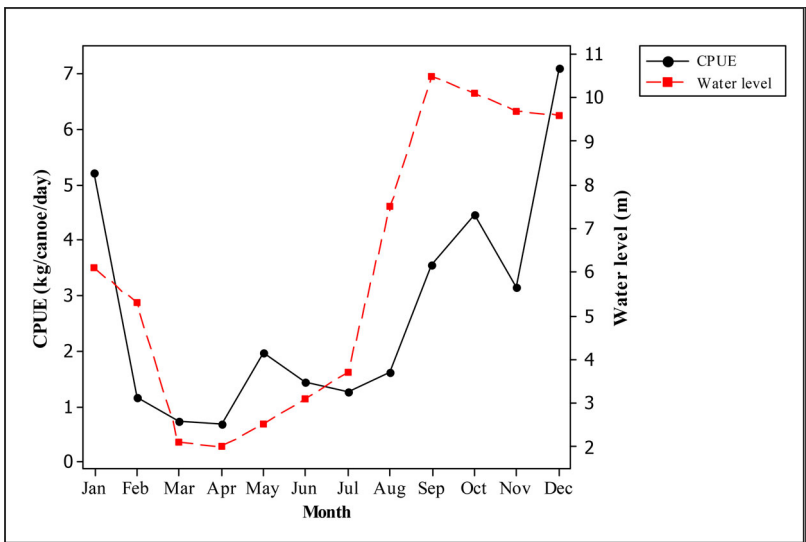

Figure 3. Monthly pattern of water level and fish catch per unit effort (CPUE) for the 2016 sampling year at the Tono Reservoir, Ghana.

rains together with the south-westerly monsoon from June to September (Biswas 1969; Viner 1969). The surface water temperature $(22.3 - 32.2\,°C)$ observed in this study was conducive and could support fisheries and aquatic life. Similar result of $23.1 - 29.6\,°C$ was reported on Oyun Reservoir, Offa, Nigeria (Mustapha 2008). The surface water temperature of freshwaters in the tropics mostly varies between 25 and $35\,°C$ (Alabaster and Lloyd 1980). Surface temperature also positively associated with sulphate, nitrate, nitrite and silicate indicating that higher temperatures increase the mineralization rate of fresh easily degradable organic material and release of minerals from rocky bottoms as reported by Hou et al. (2013).

Water pH recorded in this current study was found to be within the optimal range $(6.5 - 8.5)$ as noted by previous studies (Svobodova 1993; Tepe et al. 2005). Related findings were observed in the Bontanga and Libga reservoirs (Quarcoopome et al. 2008). Fish generally adapts to low or high pH by producing high quantity of mucus on the skin and on the inner side of the gill covers. It is well noting that exceedingly high or low pH values cause damage to fish tissues around the gills, sometimes resulting in reduced reproduction and death (Svobodova 1993). Water pH related negatively with phosphate in this study because pH regulate the release rate of dissolved phosphorus from sediments (Kim et al. 2003).

Electrical conductivity refers to the degree in which water conducts electric current as a function of dissolved minerals and salts in water. Sources of such compounds may include dissolution of natural minerals within the reservoir and unnatural ones from agricultural fertilizers, animal waste, septic system and runoff water. Conductivity values of the Tono Reservoir were within tolerable range of $30 - 5\,000$ μScm^{-1} (Boyd 2015). However, electrical conductivity values in this study were considered low compared to the range $112.8 - 164.3$ μScm^{-1} in Dawhenya (Alhassan 2011) and $214.0 - 369.0$ μScm^{-1} in Weija (Anim et al. 2011) reservoirs in Ghana. The difference in results could be linked to variation in natural minerals within the reservoirs. Dry season registered the higher electrical conductivity. Leaching of minerals from agricultural fertilizers used principally in the dry season farming close to the shore of the reservoir might have caused the higher conductivity values recorded in this study.

Transparency values were high in 2016 than in 2015 because of relatively high water level. Transparency was low in the rainy season and this could be due to runoff impacts resulting in heavy inputs of sediments, silts, debris, organic and inorganic suspended particles into the reservoir. Higher transparency in the dry season could also be attributed to settling of the particles at the bottom of the reservoir. Similar results were obtained from the Oyun Reservoir, Offa, Nigeria (Mustapha 2008). Turbidity values were within the recommended limit of 240.0 NTU or 80.0 mgL^{-1} (Karmakar et al. 2011) for fish growth since highly turbid water restricts light penetration resulting in low primary productivity. Turbidity correlated positively with sulphate, nitrate and chlorophyll-a in this study indicating that high turbidity levels caused by nutrient runoff, sediment and silt will result in correspondent increase in concentrations of sulphate, nitrate and chlorophyll-a and vice versa.

Dissolved oxygen was relatively high throughout the study period and this suggests that the reservoir was well oxygenated; ideal for the growth and survival of fishes. Harmattan winds causing turbulence of water could be the reason for the slightly higher amount of dissolved oxygen in the dry season than the wet season. Boyd (1979) reported that dissolved oxygen concentration of $3.0 - 12$ mgL^{-1} will support the growth and survival of fish in reservoirs. Dissolved oxygen threshold required to sustain fish life in freshwaters was also reported to be 5.0 mgL^{-1} (Chapman and Kimstach 1996).

The mean concentration of chloride for the study period was low indicative of less eutrophication (Kausik et al. 1992). Chloride is non-reactive in nature and are mostly leached through the soil and into the groundwater from animal/human effluents and potash fertilizers (Yousuf et al. 2012). The possible source of chloride to the Tono Reservoir could be from fertilizers used on farms at the periphery and carried by runoff/leached into the reservoir. This is also explained in the strong positive correlation ($r \geq 0.70$) between chloride concentration and water level in the sense that high water level increases the concentration of chloride and vice versa.

The concentration of sulphate in this study was comparatively lower than the recommended range. Recommended limits for sulphate concentration for aquaculture ranged from 5.0 to 100.0 mgL^{-1} (Boyd 1998).Wet season recorded a significantly higher concentration of sulphate than dry season primarily due to sulphate fertilizers from farmlands, dissolution of minerals and rocks aided by rains. It has been reported that fish can tolerate high sulphate concentrations beyond 500.0 mgL^{-1} (Tucker 1991).

A phosphate range of $0.01 - 3.00$ mgL^{-1} is prescribed for fish survival and growth (Boyd 1998). This means that phosphate concentration in this current study was high in certain periods, exceeding the recommended upper limit. High concentrations of phosphate might have originated from anthropogenic sources such as animal dung, washing of cloth and bathing with phosphate based detergents/soaps into the reservoir as well nitrophosphate from nearby farmlands (Mustapha 2008). On the other hand, seasonal mean concentrations were found to be within acceptable range.

The mean concentration of silicate (11.6 ± 4.2 mgL^{-1}) in this study supports the results of Talling and Talling (1965) that concentration over 10.0 mgL^{-1} of silicate is common in African water bodies. The presence of alumnio-silicate minerals in the rocky bottom complex assisted by dilution from the rains could have accounted for the level of silicate in the reservoir. High levels of silicate is good for fish because it stimulates high growth of diatoms, an important food source for fish, hence increasing primary productivity and supporting sustainable fish production of the reservoir (Mustapha 2008).

The mean concentration of 1.8 mgL^{-1} of nitrate was found to be within recommended limit for fish survival and growth. Nitrate concentration in reservoirs range from less than 1.0 mgL^{-1} to 5.0 mgL^{-1} (Chapman and Kimstach 1996). High concentration of nitrate above 5.0 mgL^{-1} recorded in 2015 ($0.03 - 10.86$ mgL^{-1}) could be caused by human or animal wastes and fertilizer run-off and this can promote excessive algal growth known as eutrophication. Nitrite is an intermediate in the oxidation of ammonium to nitrate. Nitrite and chloride concentrations significantly correlated positively in this study. Whenever nitrite is present in the ambient water, a part of the chloride uptake will be shifted to nitrite-uptake (Jensen 2003). Thus, in systems with existing or chronic high nitrite levels, chloride will often be added to prevent the fish from succumbing to nitrite toxicity which can kill fish.

Chlorophyll-a concentrations, an indicator of algal biomass/primary productivity (Chapra 2008) in this current study registered no observable change from 2015 to 2016. The reason could be that nutrient inputs into the reservoir had been relatively constant yearly and seasonally confirming the report of Shaw et al. (2000) that chlorophyll-a concentration only varies throughout the growing season and from year to year depending on nutrient input and weather. Based on the mean concentration ($5.6 \pm 1.71 \, mgm^{-3}$) of chlorophyll-a, the trophic state of the Tono Reservoir could be classified as mesotrophic. Trophic state classification scheme proposed by Forsberg and Ryding (1980) indicated that mesotrophic reservoirs have their chlorophyll-a concentration in the range $3.0 - 7.0 \, mgm^{-3}$. The findings were similar to that of Khan and Agugo (1990) who classified the Kongingiri Dam, in Jos Plateau, Nigeria as oligo-mesotrophic. The positive correlation of chlorophyll-a concentration and temperature noted in this study is that high temperatures (above 30 °C) is 'toxic' for most algae, except for some cyanobacteria that tolerate temperatures as high 55 °C in hot seasons (Likens 2009). Therefore, both high and low temperatures may reduce or increase algal biomass.

The correlation results indicated that CPUE was not influenced greatly by all the water quality parameters except chloride. However, the relationship is not well understood by this study because chloride levels can affect fish health in two ways: as the major

constituent of salinity or as a treatment to prevent nitrite toxicity (Jensen 2003). Sodium chloride was observed to reduce the negative impacts of total ammonia and nitrogen in an experiment conducted to determine the influence of sodium chloride on water quality and growth of *Oreochromis niloticus* in earthen ponds (Liti et al. 2005). In this present study, the interactive effect of chloride with other fertilisers washed from the fringe farmlands probably favoured the growth of fish species in the Tono Reservoir resulting in an increase in fish populations which could influence the catch per unit effort. Freshwater fishes, being hyper-osmotic to the immediate environment, encounter the physiological problem of solute loss and in order to pay off this, they resort to active uptake of salt ions from the surrounding medium (Towers 2016).

Concentrations of water quality parameters did not differ spatially or longitudinally, that is from the lacustrine zone to the riverine zone of the reservoir. The results of the current study disagreed with Green et al. (2015) who observed that the nutrient and turbidity levels of reservoirs reduce from the riverine zone towards lacustrine zone. Additionally, Kennedy et al. (1985) have highlighted the noticeable "longitudinal gradients in reservoirs, ranging from the light-limited, turbidity dominated, upper riverine zone to the lacustrine zone at the dam, which may behave like a natural lake". The dissimilarity of results could be attributed to the less pronounced gradient nature of the Tono Reservoir.

It was noted from the results that the monthly trends in water level and CPUE increased marginally from the dry season and attained peaks in the wet season for both years. The highest CPUEs for both years were obtained during the wet/rainy season when water level was high thus the pattern indicates that CPUE is influenced by water level of the reservoir. During high water levels as a result of rains, flood waters and runoff, nutrient inputs are likely to be high thus stimulating primary productivity which fish feed to survive, growth to big size and possibly reproduce successfully. The findings of this study differed from Quarcoopome et al. (2008) who observed that CPUE was associated with decreasing water levels in the Libga reservoir in the Northern region of Ghana. The variation of results could be due to differences in fishing efforts and gear selectivity.

Conclusions

The water quality parameters assessed in this study showed that all were within tolerable levels for fish survival and growth. Change in seasons significantly affected the transparency level, sulphate and nitrite concentrations but did not significantly influence water level, temperature, pH, electrical conductivity, turbidity, dissolved oxygen, chloride, phosphate, silicate, nitrate, chlorophyll-*a,* and CPUE. Concentrations and levels of the water quality parameters did not vary significantly along the reservoir indicating uniform distribution spatially. The variation of CPUE was significantly and positively impacted by only chloride. In order to maintain good water quality in the reservoir for fish survival and growth, it was recommended that regulation of farming activities closed to the reservoir should be enforced by Ministry of Fisheries and Aquaculture Development, Irrigation Company of Upper Regions (ICOUR), District Assembly and Traditional Authority to forestall future pollution of the reservoir water. Regular monitoring of the water quality of the Tono Reservoir will be a great step in contributing towards conservation and sustainable use of aquatic resources as stipulated in the Sustainable Development Goal 14 ("Life below water"). The maintenance of water quality in reservoirs will also support the efforts of the government of Ghana to increase domestic fish production through its "Aquaculture for food and jobs" programme.

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Disclosure statment

No potential conflict of interest was reported by the author(s).

Data availability statement

The data of this study are available and can be accessed upon request.

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