

EFFECTS OF FISH CAGE CULTURE ON WATER AND SEDIMENT QUALITY IN THE GORGE AREA OF LAKE VOLTA IN GHANA: A CASE STUDY OF LEE FISH CAGE FARM

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Abstract

The study determined the impacts of fish cage farming on the gorge area of Lake Volta. Water and sediment samples were collected from six sites in the Lee Cage Farm; four from sections with cages and two from about 1300 m upstream of the farm which served as the control. Water quality variables monitored were pH, temperature, dissolved oxygen, nitrate-nitrogen, ammonia-nitrogen, orthophosphate, faecal coliforms and total coliforms. Variables monitored in the sediment were organic matter, total carbon, total nitrogen and total phosphorus. There were variations in water quality between the farmed and control sites but the differences were not significant ($p > 0.05$). The mean counts of total coliform in the water ranged from 940 - 3318 cfu/100 ml while faecal coliforms ranged from 113 - 552 cfu/100 ml at the farmed site. The mean total coliform count at the control site ranged from 837 - 6960 cfu/100 ml while the faecal coliforms ranged from 48 - 120 cfu/100 ml. Therefore, there was significant variation between the faecal coliforms count at the two sites ($p = 0.046$). The results suggest that the general microbiological quality of the water at the study area was unacceptable.

Keywords: Cage culture, coliforms, gorge area, water quality, sediment quality

Introduction

Major challenge faced by developing countries of which Ghana is no exception is the impact of aquaculture practices on the environment (FAO, 2006). High amount of discharges which include waste food and faeces, nutrients, medications and pesticides are released from cage farms. The impact of these effluents on the receiving environment depend largely on the quantity of waste discharged, the time period at which the discharge takes place, the ability of the environment to absorb the

discharges and the rate at which the receiving water body is able to flush the effluent (Masser, 2008). The sediments beneath the cages may be organically enriched, as a result the activity of the benthic organisms such as the microbes and macrofauna may be affected (Findlay *et al.*, 1995).

Environmental impacts associated with cage culture are primarily because production involves large input of high-quality artificial feeds to fish cages of which only a portion is consumed and assimilated by the cultured

species. This leads to large discharges of organic and inorganic wastes to the surrounding environment. The discharged organic wastes which has high levels of nitrogen (N) and phosphorus (P) have the ability to contaminate the waters and sediments beneath the cage farms causing local eutrophication, increased turbidity, loss of biodiversity and other impacts.

The Lake Volta with its water quality and a consistent year round warm temperatures has a number of cage farms located on it in the Eastern and Volta regions of Ghana. The number of new commercial farms on the Volta Lake that are into intensive tilapia cage culture continue to increase at a fast rate whilst existing ones like Crystal Lake, Tropo Farms, West African Fish. Limited have expanded their operations. The Lake Volta has substantial number of fish farms without much management concerning water quality, waste and excess food therefore pose a risk of polluting the environment (Rao *et al.*, 2012).

There are currently five large farms and several small to medium sizes farms on the lake. The large ones are West African Fish Limited, Tropo Farms, Sunwoo Farms, Triton and Lee's Farm, each producing between 165 to 5,000 tonnes of fish annually (Karikari *et al.*, 2016). The gorge area of the Volta Lake had two of the large farms at the time of the study. These cage farms produce wastes (nitrogen and phosphorus) which are released in dissolved form into the water column and bottom sediments. High nutrient inputs (feed) is perceived to cause eutrophic conditions characterised by high phytoplankton blooms, high ammonia built up, high nitrite, low dissolved oxygen and high turbidity. Uneaten

feed and waste are discharged directly into the surrounding water. Islam (2005) reported that about 132 kg of nitrogen and 25 kg of phosphorus are discharged when a ton of fish is produced at the end of each culture period. Also, Gondwe *et al.* (2011) reported that about (81 - 90) % of carbon is released from cages into the recipient environment in tilapia cage culture; this could threaten the cultured fish (Effendie *et al.*, 2005). Waste food and metabolic waste from the cage culture can also be an important source of organic matter and nutrient enrichment of the sediment. This enrichment often promotes the growth of microorganisms in the water and sediment.

Since the studies conducted during the formation years of the Lake (Biswas, 1966, 1969; Entz, 1969), there has not been any consistent monitoring of the physico-chemical and bacteriological quality of this section of the Lake. Research by Ofori-Danson & Ntow (2005) and Karikari *et al.* (2013) on water quality of the lake were limited to the areas of Yeji and Kpong. Also work done by Ameworwor (2014) and Clotey (2014) was also restricted to stratum III of the Lake (Fig 1). It therefore becomes a challenge to establish trends in water quality since the proliferation of cage farms in the gorge area. This study looks at the possible effects of cage culture practices on the quality of water and sediment of the Volta Lake.

The study was undertaken to determine the physical and chemical parameters of water and sediment samples at the farmed and control sites and also to determine the nutrient and bacteriological contents of water and sediment from the farmed and control sites.

Experimental

Study site and sampling station

The Volta Lake (Fig. 1) lies on latitude 6° 15' N, 9° 10' N and longitude 1° 30' W, 0° 20' E (Asmah *et al.*, 2014). It is the largest man-made lake in the world by surface area (8,480 km²) and the world's third largest by volume approximately 150 billion m³ (Béné, 2007). The Lake has a shoreline of 5,200 km and an

average depth of 18.8m. The deepest portions of the lake are about 90 m. The seasonal rise and fall is about 2.0 – 6.0 m and the areas covered by seasonal fluctuations are about 100,000 ha (Rurangwa *et al.*, 2015).

The study was carried out at Lee Farms located in the gorge area of the Volta Lake (Fig. 1). The main species cultured is the Nile tilapia (*Oreochromis niloticus*). The farm has been in operation since 2008. The farm has 66 cages

for grow out, 22 cages for fingerlings and 108 cages for broodstock. The size of a cage is (5x5x5) m³. The average stocking density (fingerling per cage) is 80 fish/m³. Total production per year is 200 - 300 tonnes. The fish are fed with extruded floating feed. The quantity of feed used per day is 1,750 kg. The average depth of the water at Lee Farms is 8 m. The area of the farm is 95,040 m².

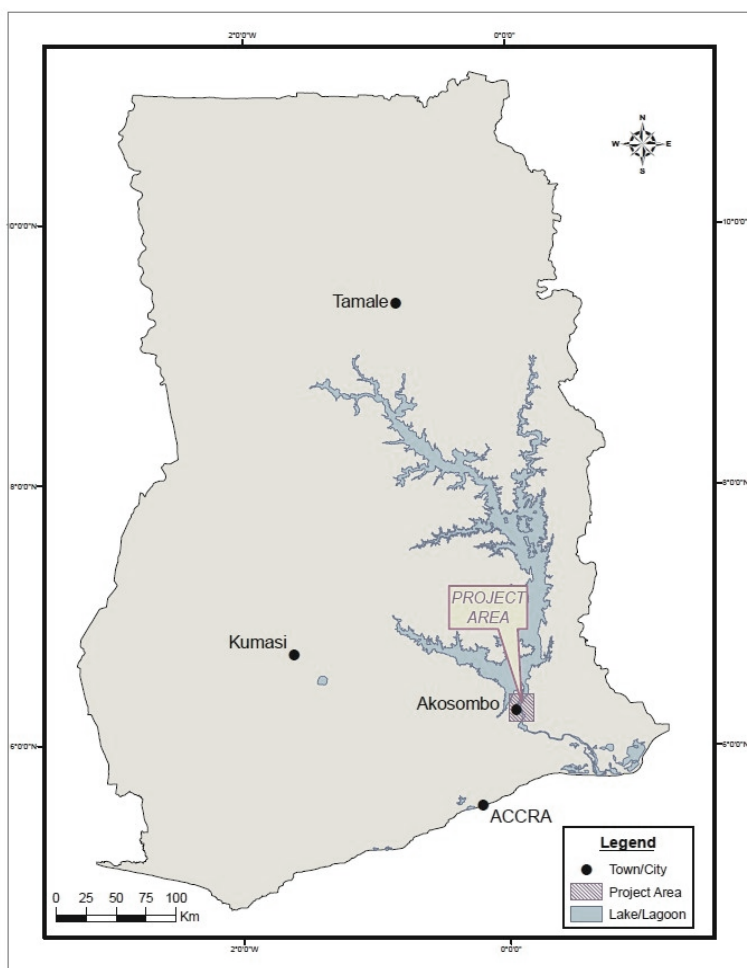


Fig. 1: Map of Ghana showing the study area.

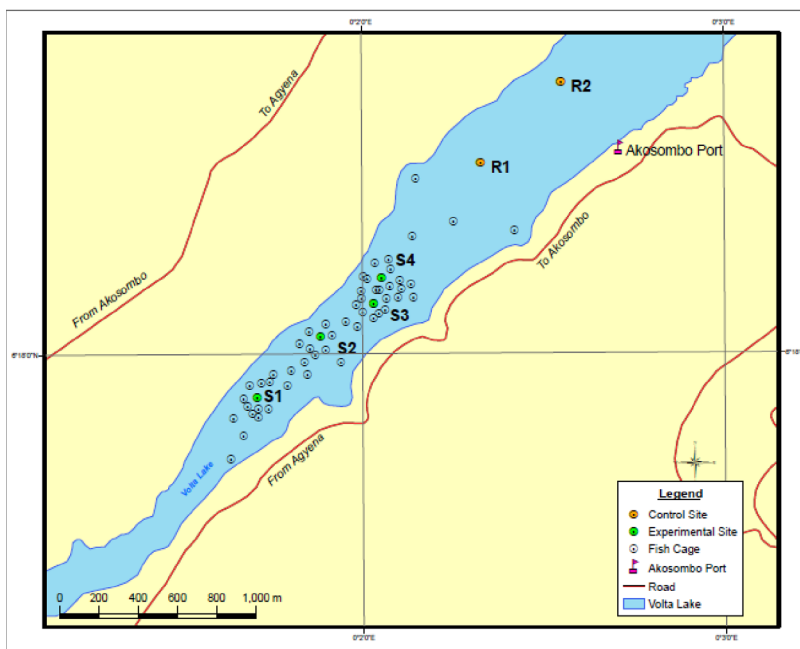


Fig. 2: Map of the study area showing the sampling points.

Sample collection

Water and sediment samples were collected monthly from November 2014 to April, 2015 from six sampling points. The sampling stations were divided into two; four sampling points in the area where the fish cages were located and this served as the impacted site while the other two sampling points were located upstream in areas with no cages and this served as the control site. A total number of 108 samples were collected in the six-month period from the sampling sites.

Water quality determination

Water samples were collected from a metre below the surface at each sampling site using a Van Dorn water sampler into pre-cleaned 1 L Nalgene sample bottles for the physico-chemical parameters. Samples for

bacteriological assessment were collected directly into 500 ml sterilized glass bottles for the bacteriological quality assessment. Each bottle was corked and labelled with full details of the site, time and date of collection and brought to the Council for Scientific and Industrial Research Water Research Institute (CSIR-WRI) laboratory in a cool box for analysis.

Laboratory analysis

The following physico-chemical and bacteriological parameters were analysed; Dissolved oxygen, ammonia-nitrogen, nitrate-nitrogen, nitrite-nitrogen, electrical conductivity, total hardness, turbidity, alkalinity, chlorophyll-a, sulphate, phosphorus, total and faecal coliform bacteria of the water were determined monthly. All water quality measurements and sam-

ple collection were made between 09:00 and 14:00 hours GMT and analyzed using standard methods for the examination of water and wastewater (APHA, 2012)

Temperature, pH and dissolved oxygen were measured in situ using a multiparametric water quality analyser (Hach Hydrolab). Turbidity was measured using HACH 2100P turbidimeter.

Total hardness was measured using EDTA Titrimetric method. Nitrate was determined using the Hydrazine Reduction Method. Phosphate was determined by Stannous Chloride Method.

Ammonium-Nitrogen was determined using the Direct Nesslerization Method. Diazotization Method was used in the determination of nitrite-nitrogen. Total and faecal coliforms were determined by membrane filtration method using M-Endo-Agar Les (Difco) at 37°C and on MFC Agar at 44°C, respectively.

Sediment sampling and analysis

Sediment samples were collected with an Ekman grab sampler from beneath the cages and at the control sites and put in plastic bags, sealed, preserved on ice and transported to the laboratory for analyses. Parameters determined were total phosphorus, total organic carbon, total nitrogen and total organic matter. The Walkley-Black procedure was used for organic carbon determination. Total phosphorus was determined by spectrophotometry (Cary 1E, 880 nm). The Kjeldahl procedure was used to

determine total nitrogen. Total organic matter was determined by loss on ignition.

Statistical analysis

The data collected were analysed using Statistical Package for Social Scientist (SPSS) version 20. Descriptive statistics was used to determine the mean, range and standard deviation for the various parameters. Student t-test was used to test for the level of significance. A probability value of 5% was assumed.

Results and Discussion

Fish cage culture impact on water quality

The water quality at the farmed and control sites were within ranges observed by previous studies on the Volta Lake. The mean water temperature at the farmed site was 29.03°C and that at the control site was 29.29°C (Table 1) showing very minimal variation. The values obtained were similar to those obtained by TICOMFE (2011) and Asase (2013). They reported mean temperatures of 27.7°C and 28.42°C respectively. Also comparable to this study are findings of Ameworwor (2014) and Clotley (2014) who observed temperatures of 25.66°C to 29.06°C at the farmed sites and 26.20°C to 29.30°C at control sites respectively. All biological and chemical processes in an aquaculture operation are influenced by temperature (Devi *et al.*, 2017).

TABLE 1
Physico-chemical characteristics of the gorge area of the Volta Lake

Parameters	Farmed Site (Mean \pm SD)	Control Site (Mean \pm SD)	Optimum ranges for Tilapia culture	p-value
Dissolved oxygen (mg/l)	5.73 \pm 0.78	6.43 \pm 1.21	>6.5 and <9.0 (Karikari & Asmah, 2016)	0.220
pH	7.10 \pm 0.28	7.14 \pm 0.21	>6.5 and <9.0 (Karikari & Asmah, 2016)	0.721
Conductivity (μ s/cm)	66.87 \pm 2.19	67.57 \pm 5.63	100-2000 (Stone et al., 2013)	0.304
Turbidity (NTU)	1.46 \pm 2.00	0.67 \pm 0.88	30-80 (Bhatnagar and Devi, 2013)	0.250
Total Hardness (mg/l)	21.53 \pm 1.04	22.25 \pm 1.76	>20 and <350 (Karikari & Asmah, 2016)	0.420
Alkalinity (mg/l)	35.68 \pm 1.96	35.66 \pm 2.38	<5.0 (Karikari & Asmah, 2016)	0.687
Chlorophyll-a (mg/m ³)	1.95 \pm 0.23	1.20 \pm 0.21	1-15 (Bhatnagar & Devi, 2013)	0.555
Temperature ($^{\circ}$ C)	29.03 \pm 0.82	29.29 \pm 0.84	>22 and < 38 (Karikari & Asmah, 2016)	0.361

*p<0.05- Significant difference

*p>0.05- No significant difference

Dissolved oxygen (DO) is a necessary requirement in aquaculture. Fish require it for respiration and other metabolic processes. The DO values indicate the extent of pollution in a water body (Amankwaah *et al.*, 2014). The mean DO concentration recorded for the farmed site was 5.65 \pm 1.30 mg/l and that recorded at the control site was 6.42 \pm 1.37 mg/l (Table 1). There was no significant difference between the two sites at a 95 % confidence level. The concentration of DO at the farmed site ranged from 3.78 - 8.38 mg/l and that at the control site ranged from 4.21 - 8.55 mg/l. DO mean concentration at the

control site was higher (6.43 \pm 1.21) mg/l than the farmed site (5.73 \pm 0.78) mg/l indicating that there could be some impact, but the difference was statistically insignificant (p > 0.05). The slight difference may be due to high concentration of fish per unit area (80 fish/m³) as compared to the control site. This might result in higher metabolic activities of the fish such as respiration and excretion compared to the control site. Microbial metabolism of the excreted material and other fish waste increase biological oxygen demand in the vicinity of the cages (Mente *et al.*, 2006). Obstruction of water current flows by the cage structures could

also lead to minimised water exchange hence the lower DO concentrations at the farmed site. The values recorded for the farmed and control sites in this study were similar to findings by Antwi & Ofori Danson (1993) who recorded 7.78 mg/l at the Kpong area of the Lake and TICOMFE (2011) which recorded 5.08 mg/l-8.64 mg/l in the gorge area of the Volta Lake. Similar to this study, Clottey (2014) recorded DO levels ranging from 5.21 to 9.0 mg/l at farmed sites and 4.51 to 8.84 mg/l at control sites on the Lake Volta.

The pH values recorded for both monitoring sites were about neutral. The values for the farmed and control sites were 7.09 and 7.14 respectively (Table 1). The pH values were within levels typical of most natural waters i.e. 6.0 to 8.5; and that set by the European Union (EU) for fisheries and aquaculture environment of 6 to 9 (Chapman, 1992). Statistically, there was no significant variations in pH values between the two sites ($p > 0.05$). The slight drop in pH at the farmed site may be due to waste decomposition from the fish farm (Pitta *et al.*, 1999) and extraction of DO in respiration by higher number of fish in the cage area. pH levels observed in this study at both sites were similar to findings by Asase (2013) who recorded a pH value of 7.70 in the Volta lake in Akosombo. It is also comparable to findings of Karikari *et al.* (2013) who recorded 6.80 and 7.50 at Kpong and Yeji sections of the Volta Lake.

Electrical conductivity (EC) is the numerical expression of an aqueous solution to carry electrical current and is a useful indicator of the mineralization in a water sample (Jain *et al.*, 2005), and it also gives an account of all the dissolved ions in solution. The conductivity values recorded for farmed site was 66.87 $\mu\text{s/cm}$ and that of the control site was 67.57 $\mu\text{s/cm}$. Variations between the two stations were

not significant at a 95% confidence level ($p > 0.05$). These values were comparable with observations by Clottey (2014) who recorded 56.68 $\mu\text{s/cm}$ at the Kpeve section of the Volta lake, and Antwi & Ofori-Danson (1993) 62.0 - 77.5 $\mu\text{s/cm}$ at Kpong., the low conductivity values confirms the low ionic content of the Volta Lake (Karikari *et al.*, 2013). According to Clottey *et al.* (2016), the low ionic content of the Volta Lake which indicates its low conductivity makes it favourable for the growth of aquatic life.

Turbidity reflects the existence of dissolved and suspended organic and inorganic materials and also plankton and other microorganisms. Turbidity values for the farmed and control sites respectively ranged from 0.00 - 5.00 NTU with a mean value of 1.46 ± 2.00 NTU and 0.00 - 2.00 with mean 0.67 ± 0.88 NTU, indicating that turbidity was relatively higher at the farmed site but like other parameters, the difference was not significant ($p > 0.05$). The slightly higher turbidity at the farmed site could be associated with excess feed, fish faeces as well as fouling and debris removed from the cage nets at the farmed site (Nyanti *et al.*, 2012). Increased turbidity can affect the penetration of light thereby impeding photosynthesis by phytoplankton and other vegetation in the water column (Harrison *et al.*, 2005; Cole, 2002). High turbidity reduces the productivity of fish, clog filters and injure fish gills (WRC, 2003). The values observed are consistent with the observations of Asmah *et al.* (2014) who had values ranging from 1.55 to 6.91 NTU in stratum II of the Volta Lake. Clottey (2014) and Ameworwor (2014) also observed slightly high levels of turbidity at farmed sites with mean values of 3.38 ± 0.60 NTU and 2.46 ± 0.52 NTU compared to control sites values of 3.00 ± 0.60 NTU and 2.11 ± 0.64 NTU mg/l.

Calcium and magnesium ions result in hardness. Total hardness plays key role in aquaculture. The total hardness values observed for both sites were similar. The minimum value for total hardness at the farm site was 20.45 mg/l and the maximum value was 23.10 mg/l. The minimum value for the control site was 19.50 mg/l and the maximum was 24.90 mg/l. These values were consistent with findings of Asmah *et al.* (2014) who obtained minimum and maximum values of 22 mg/l and 24 mg/l respectively confirming the soft nature of the Volta Lake (19 - 38 mg/l CaCO₃) (Ofori-Danson & Antwi, 1994). The values observed in this study were within the range of 20 to 100 mg/l considered suitable for aquaculture (CSIR-WRI, 2003).

Alkalinity for both farmed and control sites during the period of study were similar

ranging from 33.00 - 38.80 mg/l with mean values 35.68 ± 1.96 mg/l and 33.40 - 39.60 mg/l with mean 35.66 ± 2.38 mg/l respectively. However, the alkalinity of the control site was slightly higher than the farmed site but variation between them was not significant ($p > 0.05$). The values recorded were slightly higher but comparable to findings by Asase (2013) who had mean value of 28.50 ± 0.04 mg/l on the Volta Lake in Akosombo. When compared with the values of 34 - 52 mg/l showed by Abdul-Razak *et al.* (2009) in the Oti arm of the Volta Lake, alkalinity values during this study was lower. Samah (2012) also recorded alkalinity values of 12.68 - 16.05 mg/l in the Asukawkaw River. Alkalinity values more than 20 mg/l in water is recommended for good tilapia culture (Lucas & Southgate, 2012)

TABLE 2
Nutrient concentration of the Volta Lake from November, 2014 to April, 2015.

Parameter	Farmed Site (Mean \pm SD)	Control Site (Mean \pm SD)	Optimum ranges for Tilapia culture	p-value
Nitrate (mg/l)	0.04 \pm 0.03	0.05 \pm 0.04	<10.0 /l (Karikari & Asmah, 2016)	0.983
Nitrite (mg/l)	0.01 \pm 0.01	0.01 \pm 0.01	< 0.10 (Karikari & Asmah, 2016)	0.659
Ammonia (mg/l)	0.22 \pm 0.16	0.32 \pm 0.13	< 5.0 (Karikari & Asmah, 2016)	0.600
Phosphate (mg/l)	0.09 \pm 0.05	0.13 \pm 0.06	< 1.5 (Karikari & Asmah, 2016)	0.628
Sulphate (mg/l)	2.90 \pm 0.77	2.98 \pm 0.85	< 500 (Karikari & Asmah, 2016)	0.749

*p < 0.05- Significant difference

*p > 0.05- No significant difference

Nitrate-nitrogen is an important nutrient for the growth of plants in the water. In an aerobic situation, the protein will be broken down by microorganisms into ammonia which later in the nitrification process will be oxidized into nitrate. The concentrations of nitrate-nitrogen for both the control and farmed site ranged from 0.02 - 0.12 mg/l and 0.00 - 0.09 mg/l. The difference between the two sites when tested statistically was not significant ($p > 0.05$). The concentrations of nitrate-nitrogen recorded for both farmed and control sites were very low (0.04 and 0.05 mg/l respectively) compared to observations from earlier studies by Samah (2012) who recorded nitrate levels ranging from 0.96 - 0.12 mg/l in the Asukawkaw river. Higher results have, however been reported for other sections of the Lake; Karikari *et al.* (2013) recorded nitrate concentrations of 0.29 - 1.70 mg/l at Yeji upstream in the riverine section of the Volta Lake. Similar means of nitrite-nitrogen concentrations were recorded for both sites. The nitrite nitrogen levels in this study ranged from 0.00 - 0.02 mg/l with mean value 0.01 ± 0.01 mg/l at the farmed site and 0.00 - 0.01 mg/l with mean value 0.01 ± 0.01 mg/l at the control site. These results agree with Stirling & Dey (1990) who observed no difference in nitrite levels between farmed and control stations. Asmah *et al.* (2014) reported nitrite-nitrogen levels of 0.005 to 0.115 mg/l with a mean value of 0.035 mg/l in stratum II of the Volta Lake. Nyanti *et al.* (2012) reported that the nitrite concentration at cage stations was higher than control due to the contribution from fish waste and excess feed. It is found that increasing pH, low dissolved oxygen and high ammonia can increase its toxicity (Devi *et al.*, 2017).

The concentrations of phosphate-phosphorus ranged between 0.00 - 0.15 mg/l with mean values 0.09 ± 0.05 mg/l at the farmed

site and 0.06 - 0.23 mg/l with mean value 0.13 ± 0.06 mg/l at control site. Phosphate-phosphorus concentrations at the farmed site were lower (0.09 mg/l) than the control site (0.13 mg/l). Comparatively, the difference between both sites was not significant ($p > 0.05$). Phosphate-phosphorus is not harmful at low concentrations but becomes harmful at higher levels thus higher doses of phosphate tend to interrupt digestion in both humans and animals (Samah, 2012). The phosphate concentrations in this study was within the range obtained by Clotey *et al.* (2016) which ranged from 0.057 - 0.291 mg/l in stratum II of the Volta Lake. The phosphate levels observed in this study was also similar to Ameworwor (2014) who recorded 0.057 - 0.29 mg/l and 0.029-0.43 mg/l at both farmed and control sites respectively. Santos *et al.* (2012) reported that the acceptable value of phosphorus was 0.025 mg/l for Nile Tilapia.

Ammonia-nitrogen concentrations for the farmed and control sites varied from 0.00 - 0.39 mg/l with mean value 0.22 mg/l and 0.12 - 0.47 mg/l with mean value 0.32 mg/l. Concentrations of ammonia-nitrogen at the farmed site was quite higher than the control site. At 95% confidence level, the difference between both sites was not significant ($p > 0.05$). The mean ammonia-nitrogen levels in this study (Table 2) was low which is consistent with findings of Antwi & Ofori-Danson (1994) in the Kpong Reservoir with mean of 0.02 mg/l and varying between < 0.001 and 0.12 mg/l. At Akuse, CSIR-WRI (1999) reported a mean of 0.21 mg/l ammonia with range of 0.193–0.227 mg/l. Also TICOMFE (2011) observed values of 0.01 - 0.05mg/l in the gorge area. According to Chapman (1992), waters that are not contaminated have little levels of ammonia normally smaller than 0.1 mg/l. Clotey *et al.* (2016) also observed

low ammonianitrogen levels at both farmed ($<0.001 - 0.444$) and control ($<0.001 - 0.242$) sites. The concentrations of ammonia-nitrogen in the study site during the study period was not alarming which may be due to low anthropogenic activities reaching the area.

Sulphate is widely distributed in nature and may be present in natural waters in concentrations ranging from a few to several thousand milligrams per liter (APHA, 2012). Mean monthly concentration of sulphate for the farmed site was 2.00 - 4.00 mg/l and that of the control site was 1.79 - 4.35 mg/l for the study period. Samah (2012) observed sulphur-sulphate levels ranging from 6.33 - 51.30 mg/l in the Asukawkaw River. Also, Ameworwor (2014) observed Sulphate levels of 0.43-5.14 mg/l at farmed sites in stratum II of the Volta Lake. The level of Sulphate in our study was slightly higher at the control site than the farmed site and this could be due to the discharge of industrial wastes and domestic sewage which tend to increase its concentration.

However, the difference between both sites was not significant ($p > 0.05$). Sulphates, when added to water, tend to accumulate to progressively increasing concentration (WRC, 2003).

Chlorophyll-a recorded at the farmed and control sites were 1.95 mg/m³ and 1.20 mg/m³ respectively. Chlorophyll-a levels at the farmed site was higher than the control sites. Although the p-value for the test between the two sites was not significant ($p > 0.05$), chlorophyll-a concentration at the farmed site was higher 1.95 mg/m³ giving indication of some impact

by the fish farm. This is similar to findings of Ameworwor (2014) who also observed slightly higher concentration of chlorophyll-a at cage sites. The increase in concentration of chlorophyll-a at the cage station may be due to fish excretion and excess fish feed as the nutrients from the excess feed and fish waste provided the necessary nutrients of nitrogen and phosphorus for algal bloom (Nyanti *et al.*, 2012). Similar to this study, Demirak *et al.* (2006) observed no difference in chlorophyll-a level at 7 cage farms in Turkey when compared to control sites.

Microbiological quality of the study area

The mean monthly counts of total coliform for the farmed site ranged between 940 - 3318 cfu/100 ml and that of the control site was 837 - 6960 cfu/100 ml (Fig. 3). Variations between the two sites was not significant ($P > 0.05$). The TC recorded in this study was similar to values observed by Abdul-Razak *et al.* (2009) who recorded TC levels ranging from 770 - 8820 cfu/100 ml. The high TC counts observed at the control site in this study may be due to anthropogenic activities such as tourism and sewage from the villages around the area. The people living along the lake depend on it for domestic purposes and a means of recreation such as swimming. The counts were above the Water Resources Commission recommended limit of <1000 cfu/100 ml of total coliforms for aquaculture. Clotley *et al.* (2016) also observed TC levels of 132 - 1708 cfu/100 ml in stratum II of the Volta Lake.

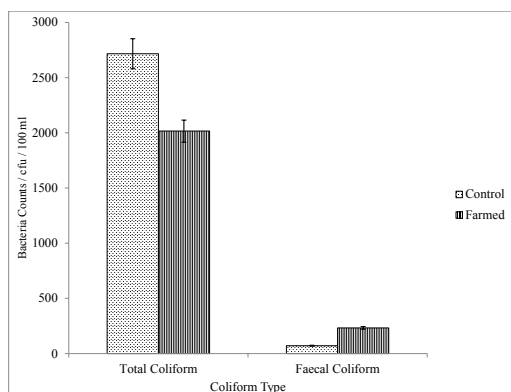


Fig. 3: Mean counts of bacteria concentration of the water at the control and farmed sites

The counts of faecal coliform bacteria at the farmed site was significantly higher than the control site ($P = 0.046$). The faecal coliforms varied between 113 - 552 cfu/100 ml at the farmed site and 48 - 120 cfu/100 ml at the control site.

This indicates that the microbiological quality of the water at the study area, as shown by counts of faecal coliform, were unusually high. The counts were above the Water Resources Commission (WRC) recommended limit of <math><10</math> cfu/100 ml for faecal coliforms for aquaculture.

The increase in coliform numbers recorded in the gorge area of the Volta Lake depicts the cultivation of fish in net cages which requires the use of large quantity of alimentary inputs resulting in a discharge of large amounts of

alimentary residues to the environment which can influence the microbiological quality of water (Gorlach-Lira *et al.*, 2013)

Also the high temperature of the water observed in the gorge area and the neutral and alkaline pH are favourable for the growth of bacteria (Gorlach-Lira *et al.*, 2013). Such conditions were observed in this study where the water temperature ranged from 27.3 - 30.55°C and the majority of samples showed a pH of over 7.00 during the period of study.

Sediment quality of the gorge area of the Volta Lake

An important feature of impact of cage farm is increased levels of organic carbon in the sediment. Mean monthly concentrations of Total Organic Carbon (TOC) recorded at the farmed and control sites ranged from (0.22 - 4.27) % and (0.35 - 4.56) % (Fig. 4) with overall mean values of (1.27 ± 0.39) % and (2.13 ± 1.18) % respectively. Similar range of values were observed by Temporetti *et al.* (2001) in the sediment of a salmon cage culture facility. The authors reported values of 0.2% to 5.3%. The TOC values for both sites were generally low and the difference in mean values was not significant ($p > 0.05$). The concentration at the control site was, however, higher than that at the farmed site which is quite contrary to findings by Hargrave *et al.* (1997) who found TOC levels at a cage station in Canada to be 40% higher.

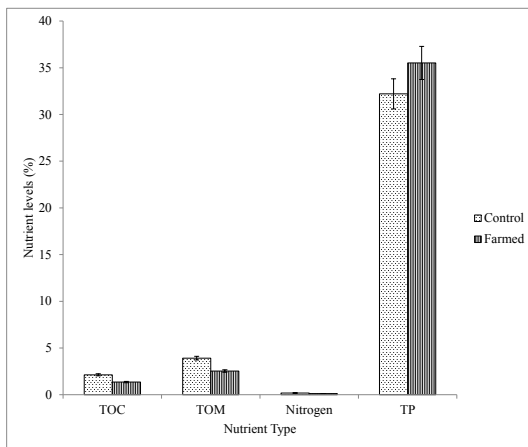


Fig. 4: Mean levels of nutrients in the sediment at the farmed and control sites.

TOC: Total Organic Carbon

TOM: Total Organic Matter

TP: Total Phosphorus

The Total Organic Matter (TOM) content at the control site was marginally higher than the farmed site. Mean values for the farmed and control sites were (2.54 ± 0.98) % and (3.92 ± 2.07) % respectively. TOM is an estimation of the content of organic matter contents in the bottom sediments and for aquaculture its levels is determined by the cultured organisms, method of culturing, the type of feed used, and management practices (Wu, 1995). It is likely that the water current velocity was enough to distribute the solid waste thereby minimizing the accumulation of TOM in the sediment at the farmed site and its environs.

Total Nitrogen concentrations at the farmed and control sites were $(0.02 - 0.37)$ % and $(0.03 - 0.39)$ (%) respectively. The variation between the two sites was not significant ($p > 0.05$). The concentrations of nitrogen increase in sediments under fish farms due to organic materials that settle at

the bottom. The cultured organisms release nitrate and nitrite which are as a result of the breakdown of waste and excess or uneaten feed. The mean total nitrogen levels observed in this study for both farmed and control sites were similar (0.12 ± 0.05) % and (0.19 ± 0.01) % respectively.

The level of Total Phosphorus concentration in the sediment during the entire period ranged from $(22.50 - 54.34)$ % and $(25.62 - 38.50)$ % at the farmed and control sites respectively. The mean concentration at the farmed site was quite higher (35.51 ± 4.05) % than at the control site (32.20 ± 3.58) % which indicates a possible contribution from the cage farm. However, the difference was not significant ($p > 0.05$). Total Phosphorus (TP) in the form of fish faeces and uneaten food is released beneath aquaculture sites and it is an indicator of fish farm impact (Apostolaki *et al.*, 2007). The fish cages mainly contributed to the increase in phosphorus levels at the farmed site, which were largely provided by the release of nitrogen and phosphorus obtained from uneaten feed, faeces and urine (Kibria *et al.*, 1998). Similar to this study, Phillips *et al.* (1994) observed that more than 85% of phosphorus used is lost into the cage and the recipient waters.

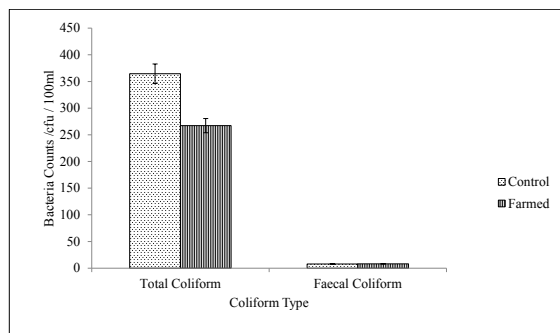


Fig. 5: Mean counts of bacteria in the sediment at the farmed and control sites.

Faecal coliforms (FC) counts at the farmed and control sites ranged from 0 - 186 cfu/100 ml and 0 – 90 cfu /100 ml (Fig. 5) respectively. The difference between the counts of FC at both the farmed and control sites was not significant ($p > 0.05$). The mean count of total and faecal coliforms in the sediment was quite high but did not exceed the limits recommended by WRC for aquaculture. The total coliforms counts at the control site was higher (364 cfu/100 ml) than the farmed site (267 cfu/100 ml). However, difference between both sites was not significant ($p > 0.05$). The high counts of bacteria may be due to open defaecation by the people and livestock in the area and also the discharge of sewage from the human settlement along it. Also the load of faecal coliform at the farmed site was slightly higher (8 cfu/100 ml) than the control site (7 cfu/100 ml).

The fact that no significant difference was found for the parameters measured in the sediment between the farmed and control site may imply that during the study period, no obvious accumulation of waste from the farm had occurred.

Conclusion

Generally, the physicochemical parameters observed at the farmed and control sites were within the range that has been observed by previous studies on the Volta Lake except the bacteriological parameters that were above the Water Resources Commission (WRC) recommended limits for aquaculture. The average maximum and minimum temperature, pH, total alkalinity, total hardness, ammonium, nitrite, nitrate and phosphates during the study remained within the limits for good tilapia culture (Boyd, 1990) and were suitable for cage cultured *Oreochromis niloticus*.

From the sediment analyses, impact of the fish farming on total organic carbon, total organic matter, total nitrogen and total phosphorus was not significant as the content of organic matter in the sediment was less than 15 %. Phosphorus concentration in the farmed site was high and this was attributed to the excess feed.

The mean count of total and faecal coliforms in the sediment was quite high but not statistically significant and did not exceed the limits recommended by WRC for aquaculture. Therefore, there should be regular monitoring of not only the physico-chemical parameters, but also the microbiological parameters which are often not included in the monitoring of fish farm water quality.

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