KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

COLLEGE OF SCIENCE

EFFECTS OF FISH CAGE CULTURE ON SEDIMENT AND WATER QUALITY IN THE GORGE AREA OF THE VOLTA LAKE

A THESIS SUBMITTED TO THE DEPARTMENT OF THEORETICAL AND APPLIED BIOLOGY, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF

MASTER OF SCIENCE

IN

ENVIRONMENTAL SCIENCE

BY

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DECEMBER, 2015

DECLARATION

I hereby declare that this thesis, ―Effects of fish cage culture on the sediment and water quality in the gorge area of the Volta Lake consists entirely of my own work produced from research undertaken under the supervision of Dr. Samuel Aikins of the Department of Theoretical and Applied Biology and Dr. Ruby Asmah of the Council for Scientific and Industrial Research-Water Research Institute; and that no part of it has been published or presented for another degree elsewhere, except for the permissible references from other sources, which have been duly acknowledged.

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DEDICATION

I dedicate this work to God Almighty for helping me throughout this studies.

ACKNOWLEDGEMENT

My greatest gratitude goes to God almighty for his protection and guidance during my entire studies. I want to express my sincere gratitude to my supervisors, Dr. Samuel Aikins of the Department of Theoretical and Applied Biology, Kwame Nkrumah University of Science and Technology and Dr. Ruby Asmah of the Council for Scientific and Industrial Research-Water Research Institute. Their leadership, support, attention to detail and hard work have set an example I hope to match someday.

My deepest gratitude goes to the Leverhulme Royal Society Africa Award Project, United Kingdom, for providing funds to fully sponsor this project.

I also want to thank Messrs. Serapis, Daniel, Richard, Victor, Selorm and all the staff at the Microbiology and Environmental Chemistry Laboratories of the Water Research Institute for their contribution and guidance during the course of this study. I am indeed very grateful. I will also like to appreciate Mr. Charles Ofori Gyamfi, Mr. Amos Asase and Mr. Emmanuel Sarpong for their immense contribution towards the completion of this work. I also thank Mr. Anthony Karikari for providing the necessary equipment for this project. I am also grateful to Dr. Felix Attipoe for his support throughout this research and all the staff of ARDEC. My profound gratitude also goes to my husband Mr. Mark Ofori Boateng for believing in me and supporting me throughout this study to make my dream a reality. Finally, I want to thank all my colleagues for providing a challenging and wonderful experience throughout the entire study period.

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CHAPTER ONE

INTRODUCTION

1.1 Background

Aquaculture involves the cultivation of organisms which include molluscs, crustaceans, fish aquatic plants, reptiles and amphibians in an aquatic environment (FAO, 2014). Globally it is seen to develop at a high rate and is the quickest sector of food production (Troell *et al*., 2009; Abreu *et al.,* 2011), with closely half of the supply of the world's seafood currently obtained from aquaculture (FAO, 2010).

In Ghana, marine and inland capture fisheries production has declined since the mid 90's. The production from marine fisheries between 2000 and 2013 has declined by 17% according to Ministry of Fisheries and Aquaculture Development (MOFAD) data. From 2012 to 2013, the production from inland fisheries has decreased by 8.7% from 95,000 metric tons to 86,741 metric tons. Due to this reduction, aquaculture is therefore being encouraged in Ghana as an assured way of meeting fish requirement. The aquaculture industry consist of small scale farmers who usually produce on subsistence basis, and medium scale to large scale producers. The systems of production have moved from predominantly extensive and semi-intensive culture in earthen ponds to intensive water based culture in cages. Currently, aquaculture production with respect to culture systems in practice are about 8% from pond sources, 4% being derived from dugouts, dams and reservoirs and 88% from cages (Kassam, 2014).

Cage aquaculture, the system of cultivating organisms in nets and cages in fresh and marine water bodies is prevalent around the world.

The first commercial cage system in Ghana was established in 2001 (Kassam, 2014). Cage farming as a commercial venture has expanded in the last years with annual rate of growth of

73% between 2009 and 2014(Rurangwa *et al.*, 2015). From 2011-2014, fish cage culture has contributed about 88% to aquaculture.

Rurangwa *et al.*, (2015) reported that production from fish cage culture in 2014 was about 33,500 metric tons whilst that of tanks and ponds was estimated to be 3,000 metric tons. The major species cultured is the Nile Tilapia which is cultured commercially in cages either as mixed sex or all males and makes up about 90% of production from aquaculture whiles catfishes (*Clarias spp.* and *Heterobranchus spp.)* and *Heterotis niloticus* account for the 10% remaining. (Attipoe, 2006). The most significant method for producing Nile tilapia in Ghana is the cage culture system, which is usually done on small-scale and large-scale basis on the Volta Lake (Asmah *et al.*, 2014). The tilapia fingerlings are stocked at 60-150 fingerlings per m^3 and fed on complete formulated diets of 30 to 35 percent crude protein levels (Attipoe, 2006).

In 2014, the production of the Nile Tilapia from cage farms on the Volta Lake alone was 33,000 tons. These tilapia farms are usually sited in the South Dayi and Asuogyaman districts of the Volta and Eastern regions respectively with most of them on the Volta Lake. There are about 60 cage farms which are situated in Asuogyaman District, majority of which are engaged in small-scale production which are sited between the Akosombo and Kpong Dams.

Fish cage farming overcomes significant limitations of pond aquaculture such as water and land availability necessary for earthen pond construction. The demand for Nile tilapia in the urban and rural areas of the country is high. This means that cage aquaculture has an enormous potential for fish production in the country. Cage aquaculture in Ghana is affected by a number of constraints such as high cost of fingerlings, lack of expertise to manage the farms and the high cost of feed.

1.2 Problem statement

Although, cage aquaculture in the Lake Volta provides income, livelihood and employment to the people, there are negative effects associated with the development of this industry in Ghana. Cage farms encounter diverse setbacks but one of such is minimizing its impact on the environment in spite of the sustained continued increase in fish production (Navarrete-Mier *et al.,* 2010).

The main difficulty that is faced by developing countries of which Ghana is no exception is the effects of aquaculture practices on the environment. It is therefore necessary to ensure adequate planning to enable effective monitoring and evaluation in the premises of aquaculture facilities. High amount of discharges which include waste food and faeces, nutrients, medications and pesticides are released from cage farms. The impact of these effluents released into 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 ((Axler *et al.,* 1996; Kelly *et al.,* 1996). 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 (Gowen and Bradbury, 1987; 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 (Folke & Kautsky, 1989). 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 Volta River with its water quality and a consistent year round warm temperatures has a number of cage farms located on it in the Eastern region 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, 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 which pose a greater risk of pollution to the environment (Rao *et al.*, 2012).

1.3 Justification

There are currently five large farms on the Volta Lake. These are West African Fish Limited, Tropo Farms, Sunwoo, Triton and Lee's Farm. The gorge area of the Volta Lake has quite a number of these large farms. 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 build 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 132kg of nitrogen and 25kg of phosphorus are discharged when a ton of fish is produced at the end of each culture period. Also, Gondwe (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, 2005). Waste food and metabolic waste from the cage culture can 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 portion of the Lake. Research by Ofori-Danson and Ntow (2005) and Karikari et al., (2013) on water quality of the lake are limited to the areas of Yeji and Kpong. Also work done by Ameworwor (2014) and Clottey (2014) was also restricted to stratum II of the Lake. It therefore becomes a challenge to establish trends in water quality since the proliferation of cage farms in the gorge area; thus, this study would look at the possible effects of cage culture practices on the quality of water and sediment of the Lake.

1.4 Objectives

The main objective of this work was to determine the effects of fish cage culture on the water and sediment quality of the gorge area of the Volta Lake.

1.4.1 Specific objectives

The specific objectives of this work were;

- To determine the physicochemical parameters of water and sediment samples at the study area
- To determine the nutrient contents of water in the cage area and the control site
- To determine the bacteriological contents of both the water and sediment from the experimental and control sites

CHAPTER TWO

LITERATURE REVIEW

2.1 World aquaculture overview

Aquaculture is the cultivation of organisms such as crustaceans, fish, aquatic plants, reptiles and amphibians in an aquatic environment (FAO, 2014). Due to the decrease of wild capture fisheries in both marine and freshwater, aquaculture is seen as an avenue of providing the demand for fish and fishery products worldwide. The cultivation of tilapias which include Nile tilapia and other cichlids species is the most popular form of aquaculture in the world (FAO, 2014). Aquaculture and fisheries sector serve as a means of income and livelihood to a great number of people worldwide. There are a number of environments that are used for aquaculture practices. These are brackish, marine and fresh water environments for culturing various organisms (FAO, 2014). The cultivation of aquatic organisms in fresh water environments is usually done in cages or pens and fish ponds. The systems for culture consist of extensive, semi intensive and intensive and typically depends on the density at which the organisms are stocked, the feed input and the management system employed.

2.2 Aquaculture in Ghana

Aquaculture started in 1953 in the northern part of Ghana. It is being practiced in all the regions, especially in the central and southern parts, where there are small scale and semi-intensive pond fish farming constituting about 98% of fish farms (Odei, 2015). The fish farming industry consists of small scale culture systems and quite a number of commercial medium to large scale producers.

2.3 Types of production systems

The production systems used in Ghana are land based or water based. Extensive aquaculture is practiced around the northern regions, semi-intensive fish farming in ponds around the southern and central areas and intensive small and medium scale enterprise (SME) and large

scale production of fish cage culture system on commercial basis on the Volta Lake (Odei, 2015).The extensive system is mostly associated with ponds, dams and small reservoirs. The semi-intensive system of production is utilized by farmers who produce in small quantities on subsistence level in ponds.

2.4 Facilities for production

Until recently aquaculture in the country depended largely on earthen ponds where rainfall, ground water and stream were the main sources of water (Asmah, 2008). Pens and cages are recent developments in the aquaculture industry. Asmah (2014) reported that fish production from cages on the Lake Volta accounts for more than 90 % of total fish production from aquaculture. Currently aquaculture production with respect to culture systems in practice are about 80-85% in cages, 7.6% from pond sources and 7.2% being derived from other holding forms such as pens and reservoirs (Rurangwa *et al.,* 2015).

2.5 Types of fish cultured

Nile Tilapia (*Oreochromis niloticus)* and Catfish (*Clarias gariepinus)* are typically the species that are cultured *(*Kaunda *et al.,* 2010). Production from aquaculture is made up of about 90% Nile Tilapia which is cultured in cages for commercial purpose either as mixed sex or all males whiles catfishes (*Clarias spp.* and *Heterobranchus spp.)* and *Heterotis niloticus* constitute about 10% (Attipoe 2006). Other species which have been introduced and grown on an experimental scale are the silver carp (*Hypophthalmichthys moltrix)*, tiger prawn (*Penaeus monodom*) and Longfin tilapia (*Oreochromis macrochir)* are species that have been tried and are cultured on experimental basis.

2.6 Cage culture

Due to the increasing demand for aquatic organisms in the world, cage farming has increased over the years (Blow and Leonard, 2007). Cage farming is the system of production where the aquatic organisms are held in enclosed units in a water body whilst ensuring that water

exchange and removal of waste is released into the immediate environment (Masser, 2008). According to Beveridge and Little (2002) cages were first used by fishermen as a convenient holding facility for fish until ready for sale. Cages come in various shapes and are usually made up of wooden slats or bamboo, nylon and synthetic material. Cage units typically are a m^3 to several hundred m^3. Cages can have a variety of shapes but typically they are rectangular, cylindrical or square (Schmittou, 2006).

2.7 Systems of cage culture

Cage culture systems can be grouped into four types; fixed, floating, submersible and submerged. Fish culture in cages can be classified based on the feed use as extensive, semi-intensive and intensive systems. The intensive system of cage culture, such as floating cages is common all over the world, and is a good way of producing fish intensively in tropical regions (Outtara *et al.*, 2003; Liao *et al.*, 2004).

2.8 Benefits of cage aquaculture

Cages are simple to construct and also easy to manage. They are appropriate for both commercial large scale and subsistence small scale production (Blow and Leonard, 2007). Cage aquaculture enhances food security and serves as a major source of income and community development. A very significant aspect of cages is their use of already existing water resources, which makes it convenient for communities that lack lands to have access to fish farming (Blow and Leonard, 2007). Cage culture systems have their own disadvantages such as; Cages take up space and also interferes with access thereby making it difficult to navigate. Also, they devalue the land scape and the flow of current is changed thereby increasing the rate of sedimentation locally. Cage culture makes use of resources and as a result waste is produced. In spite of the system used in culturing, pathogens introduction or the interference of the cycles of parasite and diseases can be attributed to cage culture, changing aquatic plants and animals, and disrupting the distribution and character of the

community of wild fish. Also cage culture of organisms in intensive system accounts for the discharge of uneaten food and faeces into the surrounding water body, which enhances primary production and affect the quality of water and sediment negatively.

2.9 Cage culture in Ghana

Cage culture has been developing consistently over the last decade (Anane-Taabeah *et al.*, 2012) especially in the Volta Lake. It overcomes significant limitations of pond aquaculture such as water and land availability necessary for pond construction. The first commercial cage in Ghana was established in 2001 (Ofori *et al.*, 2010). Cage farming as a commercial activity has increased aquaculture production by 88% from 2011 to 2014 and its annual growth rate is averagely 73% from 2009 to 2014 (MOFAD, 2014).

Fish farming in cages is an important means of producing tilapia in Ghana. MOFAD (2014) reported that 33,500 metric tons of fish was produced from cages whilst 3000 metric tons was produced from tanks and ponds in 2014. The production of tilapia in cages on the Lake Volta has accelerated by 500% since 2009. The Asuogyaman district has a great number of cage farms (about 60) on the Lake Volta of which most are producing on small scale with the farms located mostly between the Kpong and Akosombo dams.

A number of medium and small scale enterprise farms are fast developing in Kpeve, Sedom and Akrusu areas of the Lake Volta (Kassam, 2014). There are about six commercial big farms on the Volta Lake of which most are sited in the gorge area which covers about 35km from the Akosombo dam. Some of these farms are West African Fish LTD, Tropo, Sunwoo, Triton and Lee farms. It is expected that fish farming in cages on the Volta Lake will highly increase due to efforts being made by the government to promote it. According to (Ofori *et al.*, 2010), as part of the measures undertaken by government to promote cage farming in Ghana, 8700km^2 of the Lake's surface area has been designated for cage culture.

2.10 Species cultured

As already stated, tilapia is the major species cultured in cages in Ghana and accounts for about 90%production from aquaculture (Cobbina, 2010). The rest consist of catfishes (*Clarias spp.* and *Heterobranchus spp.)* and *Heterotis niloticus* (Ofori *et al.*, 2010).

2.11 Cage types

Most cages are made with simple local materials which are submerged in the Volta Lake with growing tilapia secured in them. A typical cage used in the Volta Lake is cubic shape and made of 13 to 15 mm multifilament stretched mesh net attached to a pipe frame buoyed by plastic barrels, or oil drums (Asase, 2013).

2.12 Fish feed used in Ghana

Cage cultured fish are entirely dependent on formulated ration. However, in Ghana the most serious constraint to commercial cage farming is obtaining high quality locally manufactured feed. In fish farming, feed accounts for the high cost of production (about 60%), more especially in cage aquaculture where farmers depend largely on floating feeds (Mensah and Attipoe, 2013).There are two main feed types which are used by the farmers; extruded (floating) and non-extruded (sinking) feeds. Some of the floating feeds are manufacture in Ghana whilst others are imported. Raw materials for the feed production include wheat bran, corn fish meal and soya bean cake. Extruded feed is produced in Ghana by Raanan in large quantities commercially. Companies such as West Africa LTD, Agro Food Company LTD (GAFCO) and Beacon Hill produce feed in small quantities. Skretting, Cargill and Coppens are also imported feeds available on the market.

2.13 Problems to cage farming in Ghana

The main bottlenecks to cage culture in Ghana are; lack of expertise to manage the farms, high cost of feed and lack of quality fingerlings. Moreover the main problem that happens in some portions of the Volta Lake especially the southern part and where the water is shallow

is the inadequate oxygen levels in February and July, August and September, most of the cage farms face the challenge of having access to areas with conducive oxygen levels.

2.14 Cage culture and physico-chemical properties of the lake Volta

In aquaculture, water quality refers to when the organisms cultured are successfully raised in the system without any difficulty. The organisms under culture depend largely on the quality of water. Therefore, there is the need to ensure that the water quality is good in order to have a high rate of growth and survival. The quality of the water is shown by the availability of optimum levels of oxygen and low amount of metabolites. The important water quality parameters related to tilapia culture in cages are temperature, dissolved oxygen (DO) and hydrogen-ion concentration (pH). Other parameters that are equally significant are ammonia, nitrates, phosphates, alkalinity and hardness.

2.14.1Temperature

Organisms in aquatic environments are able to regulate the temperature of their bodies to suit the environment in which they are under normal conditions. Biological and chemical reactions are affected by temperature. When temperature increases by 10^{o}C, the rate of metabolism of fish increases twice the normal rate. Hence the necessary factors like food conversion ratio, oxygen requirement, and demand for food and growth rate are directly affected. The ideal temperature surrounding tilapia in production should be about 26°C to 28°C and within optimum range of about 23°C to 30°C (Boyd, 1990).

With respect to the Volta Lake, Karikari *et al.*, (2013) reported that the average water temperatures measured at the surface at Kpong were 28.5^{o}C and 27.9°C at 100 and 500 m respectively offshore. TICOMFE (2011) also reported similar values in the gorge area of the lake. According to Obeng (1984), the surface temperature measured along the axis of the Volta Lake over an eight year period did not exceed 33 ^{o}C and the bottom temperature did not fall below 23^{o}C in any season.

2.14.2 Dissolved oxygen (DO)

DO is a very important factor in the aquaculture environment. Diffusion of oxygen in the water occurs when phytoplankton and other aquatic plants undergo photosynthesis. The level at which oxygen diffuses is largely dependent on the inadequate oxygen levels in the water, the rate of water movement and the surface area of the water in contact with air. Low levels of oxygen is one of the major limiting factors affecting water quality in an aquatic environment. Low concentrations of oxygen limit the rate of growth and feed intake of the culture organisms. Inadequate levels of oxygen increases ammonia levels making the environment toxic to the organisms. DO is an environmental factor that influences the rate of production and growth through its direct impact on metabolic rate and feed consumption.

In a study carried out by Karikari *et al.,* (2013) on the Volta Lake, the mean DO levels measured at the water surface at Kpong was between 7.3 and 8.1 mg/l. Antwi and Ofori-Danson (1993) also reported mean level of DO 7.78 mg/l at the Kpong area. TICOMFE (2011) measured DO levels of 5.08 to 8.6mg/l at the gorge area of the Volta Lake. Asmah *et al.* (2014) observed DO levels of 4.7 to 7.3 mg/l in their study area.

2.14.3 pH (Hydrogen ion concentration)

pH determines how acidic or alkaline a system is. Cage tilapia performs well in water bodies that are alkaline or neutral in nature. Therefore, there is the need to take pH into consideration in aquaculture since it directly influences the physiological and metabolic rate of the organisms being cultured. Nevertheless, drastic fluctuation in pH causes stress to culture organisms. Normally, the daily fluctuation should be maintained within 0.4. It is important to regulate pH in order to reduce ammonia and hydrogen sulphate becoming toxic to the organisms cultured. The surface mean pH of the Volta Lake as reported by Asase (2013) at Akosombo was 6.52 to 6.89. In a study carried out by Mensah and Attipoe (2013), on the Volta Lake, they recorded pH of 7.2.

2.14.4 Nutrients

Organisms in aquatic ecosystems like fish has ammonia as a major byproduct of nitrogen and protein synthesis. Increasing concentrations of ammonia occur as a result of intake of feed rich in protein, excess feed and over feeding which release gas which is toxic in addition with the ammonia being excreted by the fish, building up to concentrations that are high. In natural water bodies, phosphorus occurs in organic and inorganic forms. Algae and plants in aquatic environment require phosphorus for growth. Nevertheless, high levels of this element in water bodies can lead to algal blooms. Effluents from septic tanks, run-off from farms, discharge from industries and waste water are the main sources of phosphorus. Fish farms situated close to such areas can have high phosphate loads in the water. Studies by Karikari *et al.,* (2013) observed low levels of nutrients in the lake. Also a study by TICOMFE (2011) at the gorge area of the Volta lake recorded low levels of nutrients ranging from 0.01to 0.05mg/l. Braimah (2000) also reported that the concentration of nutrient in the lake was quite low with low levels of phosphates, nitrates, nitrites, ammonia and sulphate observed at 0-40m surface of the lake. Nevertheless, measurable levels of these nutrients were observed in the waters at the bottom (Biswas 1966; Antwi 1990). Asmah *et al.,* 2014 in their study observed phosphate, ammonium, and nitrite levels of <0.001-0.42, <0.001-0.400 and 0.005-0.115mg/l respectively. They observed that despite fish cage culture activities on the lake, its nutrients level was still very low.

2.14.5 Turbidity

Turbidity of water is the measure of materials that are in solution or suspended in the water which prevent the penetration of light .The rate of photosynthesis is reduced as turbidity affects the penetration of light at the bottom of the water. Studies by Karikari *et al.,* (2013) indicated that the mean turbidity of the Volta Lake was varied between 2.14 to 7.38 NTU at the water surface of Kpong, Dzemeni and Kpando-Tokor. CSIR-Water Research Institute

(1999) also observed variations of 1.70 to 6.50 NTU at these areas. Furthermore, Asmah *et al.* (2014) reported turbidity levels of 1.55-6.91 NTU on the Volta Lake where fish cage farming was being practiced.

2.14.6 Conductivity and Alkalinity

Conductivity determines the saltiness of water. Organisms in aquatic environments require levels of salt that is low naturally for growth. However, increase in conductivity levels in rivers and lakes can lead to problems in the aquatic environment and cause complications to humans. Antwi and Ofori-Danson (1993) measured conductivity levels of 68.7 at Kpong and Yeji whilst Ofori Danson and Ntow (2005) observed 84.0 μScm-1 at the same area of the Volta Lake. Biswas (1966b) reported increased levels of the alkalinity of the lake during the post-impoundment phase and 41 mg calcium carbonate (CaCO3)/l was recorded in 1989. Karikari *et al.,* (2013) recorded conductivity level of 64.0 μScm/1 at the Kpong portion of the Volta Lake.

2.15 Microbiology of the Volta Lake

Work carried out on the microbiology of the Volta lake is minimal. For the purpose of this study, emphasis will be made on Total Coliforms (TC) and Faecal Coliforms (FC).

Biswas (1969) studied the microbiology of the Lake at Ajena, a kilometer from the dam and reported that the bacteria load at the surface of the water was high in 1964 and 1965. However, Amoah (1999) observed high loads of bacteria population around Akosombo and the Afram tributary after the formation of the Lake. Biswas (1972) and Amoah (1979) also observed a reduction in the counts of bacteria in the Lake at 10m at the surface. However, they observed high counts of bacteria at 20m below.

2.16 Coliform bacteria in water

Bacteria coliforms comprise of various genera that belongs to the *Enterobacteriaceae* Family. Total coliform bacteria (TC) and faecal coliform bacteria (FC) are usually used to

indicate water quality (Kasetsart, 2009). Faecal Coliform are the commonest bacteria that resides in the intestines of humans and animals (Addy *et al.,* 2003).

According to Amoah (1989), coliform bacteria at the banks of Lake Volta varied between log cfu/ml 1.9-2.5.

2.17 Faecal Coliforms (FC)

Faecal Coliform bacteria is usually seen in the intestines and faecal matter of humans and warm blooded animals. They do not cause disease but indicates the presence of disease causing bacteria. Diseases such as typhoid fever, hepatitis and dysentery are caused by high loads of FC. Discharges from industries and septic tanks, animal and human waste, run-off from farms and high temperatures are the main sources of FC. Gordon *et al.* (1999) reported that the Institute of Aquatic Biology (IAB) observed counts of total coliform bacteria 0 - 3,000MPN/100ml in the Volta Lake as an evidence of faecal pollution. Bannerman (1983) also reported counts of FC values ranging from 0 and 20/1 between Atimpoku and Ada.

2.18 Total Coliform

Studies by Bannerman (1983) showed that the total coliform counts between Atimpoku and Ada range from 0-100 l-1; He found out high total coliform loads at Sokakope and Asutuare due to anthropogenic activities.

Clottey (2014) in a study at stratum II of the Volta Lake observed that the experimental site which had the presence of fish cage farms, had quite higher total coliform concentration (ranging 132-1708 cfu/100ml) than the reference site with no cage farms (ranging 145-1209 cfu/100ml). That indicated that there was possible contribution from the cage farms to the bacterial concentrations that naturally existed in the water. She found out that the counts were higher than maximum limit of 400 cfu/100ml required by EPA, Ghana for waste discharge but averagely, less than that recommended for irrigation (<1000 cfu/100ml).

2.19 Effects of fish cage culture on lakes

The environmental impact of waste from cage fish farms is an increasing issue of concern around the world. Organic matter and nutrient build-up is the main impact of cage culture on water and sediment of the culture environment (Demir *et al.*, 2001).

The waste from cage farms mainly comprises of excess feed, faeces, fish scales, and soluble wastes such as phosphorus and nitrogenous compound (Cornel and Whoriskey, 1993). Cage farming cause nutrient build up which result in eutrophication. Nevertheless, cage farm impacts depends largely on the quantity of waste that is discharged, the period over which the waste is discharged and the ability of the receiving water to take up or flush the waste.

2.20 Effects of fish cage farming on the quality of water in the Volta Lake

Cage farming by its nature maintains high densities of organisms that generate considerable amounts of dissolved and particle-like waste (Islam, 2005). Generally, the waste is discharged into the surrounding environment which acts as a diluting and dispersing agent. However, each type of waste can have an impact on the environment. Cage farming increases nutrient levels, impact negatively on sediment organic matter and turbidity, and decreases secchi depth, dissolved oxygen levels and pH (Phillips *et al.*, 1985; and Pitta *et al.*, 1999).

Environmental concerns have been raised regarding chemicals that are used in cage farms and also the use of new genetic strains and chemicals such as vitamins and antibiotics. Cage aquaculture has impacted the water and sediment quality of a lot of lakes around the world.

With the proliferation of fish cage farms in the gorge area of the Volta Lake, the same impact on the water quality can undoubtedly be expected if the operations of these farms are not monitored.

Works done by Clottey (2014) and Ameworwor (2014) in stratum II of the Volta Lake found out that the mean DO levels recorded during their study ranged between 5.21 to 9 mg/l at cage sites and 4.51 to 8.84 mg/l at reference sites respectively, which indicated insignificant

impact of the fish farms. Conductivity values obtained for their experimental and control sites were 49.92 to 56.68(µs/cm) and 49.92 to 63.68 (µs/cm) respectively which showed no significant impact of the the cage activity. They found turbidity of the Volta Lake to be quite low in spite of fish cage farm activity. Turbidity of their experimental sites had a range between 2.46 and 3.79 NTU and 2.46 to 4.4 NTU respectively and control sites 2.11 to 3.95 NTU. They both observed phosphate-phosphorus concentrations to be generally low varying between 0.057 and 0.291 mg/l. A study by Mensah and Attipoe (2013) observed alkalinity and hardness in the Lake in Akosombo to be 28.1 mg/l and 26.7mg/l respectively. Clottey (2014) observed Ammonium-nitrogen levels to be higher in the cage area (<0.001 to 0.444) mg/l than the reference sites (<0.001 to 0.242) mg/l. Ameworwor, 2014 recorded temperatures 25.66^{o}C to 30.08^{o}C and 26.2^{o}C and 30.05^{o}C at cage and reference sites respectively. Asmah *et al.* (2014) did not observe any significant impact of fish cage culture on the Volta Lake.

Ameworwor (2014) found out that mean chlorophyll-a concentration recorded were higher at fish cage culture sites than reference sites, however there was no significant difference between concentrations at cage and reference sites ($p>0.05$).

2.21 Sources of solid from cage culture

Aquatic organisms cultured in cages utilize pelletised feed which are given to them two to three times daily. The waste and uneaten food are discharged into the recipient environment directly. Islam (2005) reported that for a ton of fish to be produced, 132.5 kg of nitrogen and 25.0 kg of phosphorus are discharged into the surrounding environment.

Also, for tilapia cage farming, a huge percentage of carbon is lost from the cages to the environment (Gondwe, 2011).

2.22 Effects of fish cage culture on sediment quality in the gorge area of the Volta Lake

Fish cage farms have impacted the sediment quality of water bodies around the world; hence its effect on the sediment quality in this area cannot be under-estimated. The sediment that is close to the fish cage culture sites receives a great deposit of faeces and non-consumed food (Méndez, 2002). The faeces and the food leftovers have greater contents of carbon, nitrogen and phosphorus than the natural sediments (Morrisey *et al*., 2000). This causes the sediment underneath these farming systems to have a high content of organic matter and nutrients.

One impact of cage farming on the sediment is increase in the level of organic carbon in the cage area. Hargrave *et al.* (1993) reported high levels of organic carbon (about 40%) in a salmon cage farm in Canada. According to Brooks *et al.* (2003a), when organic matter build up in the sediment at cage site, it leads to high biological and chemical oxygen demand. Also (ASI, 1999) reported that the total amount of nitrogen that is lost from cages to the environment is usually 72% to 79% of the feed that is used. Furthemore, Alpaslan and Pulatsu (2008) observed elevated levels of total nitrogen, total carbon, total phosphorus and total organic matter at cage sites in Turkey. A study by Hallare *et al.*(2009) on the Taal lake in Philippines clearly demonstrated that fish cage culture has a harmful impact on lake quality particularly the sediment phase.

Although cage aquaculture in the gorge area of the lake Volta has lot of benefits such as employment creation for the people in the community and cheap source of protein, if the water and sediment quality of the lake in this area is polluted by the activities of the fish farm, it will disrupt the life of many aquatic lives especially the endemic species. Therefore, continual monitoring of the water and sediment quality should be ensured.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study site and sampling station

The Volta Lake lies on latitude 6º 15' N, 9º 10'N and longitude1º 30' W, 0º 20'E (Vanderpuye, 1982). It has a surface area of about 8,480 km^2 which makes it the largest artificial lake in the world (Bene, 2007). The shoreline of the lake is 5,200 km and a depth of approximately 18.8 m. The lake has deepest portion of about 90 m. The seasonal fluctuation of the lake is about 2.0 – 6.0 m and the areas that show the rise and fall of the seasons are about 100,000 ha (Rurangwa *et al.,* 2015).

This study was carried out at Lee Farms (GPS number N 13^o48'54.905"E) which is located in the area of the gorge, from November, 2014 to April 2015. The main fish species cultured is the Nile tilapia. The farm has been in operation since 2008. The farm has 66 cages for grow out, 22 cages for fingerlings and 108 cages for brood stock. The size of the cages is (5x5x5) m^3.Total production per year is 200-300 tons. The fish are fed with Raanan which is a floating feed. The amount of feed used in a day is 70 bags each of 20 kg. The depth of the water at Lee is 20 m. The area of the farm is 95,040 m^2.

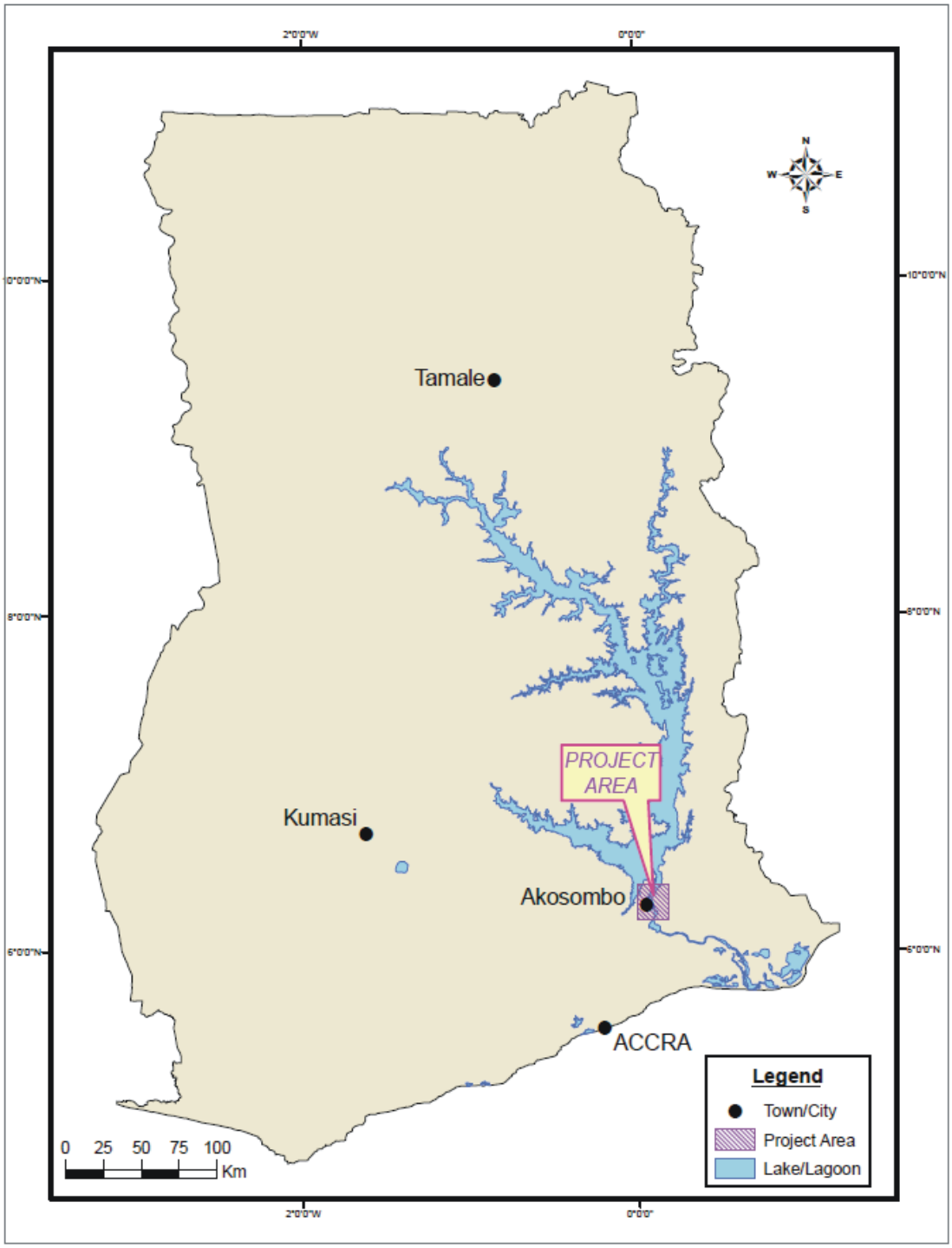

Figure 3.1. Map of Ghana showing the study area

3.2 Sample collection

Water and sediment samples were collected 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 cages were located (around the grow-out cages) served as the experimental site whereas two sampling points where there were no cages served as the control site. A total number of 108 samples were collected in triplicates for period of six months at all the sampling sites.

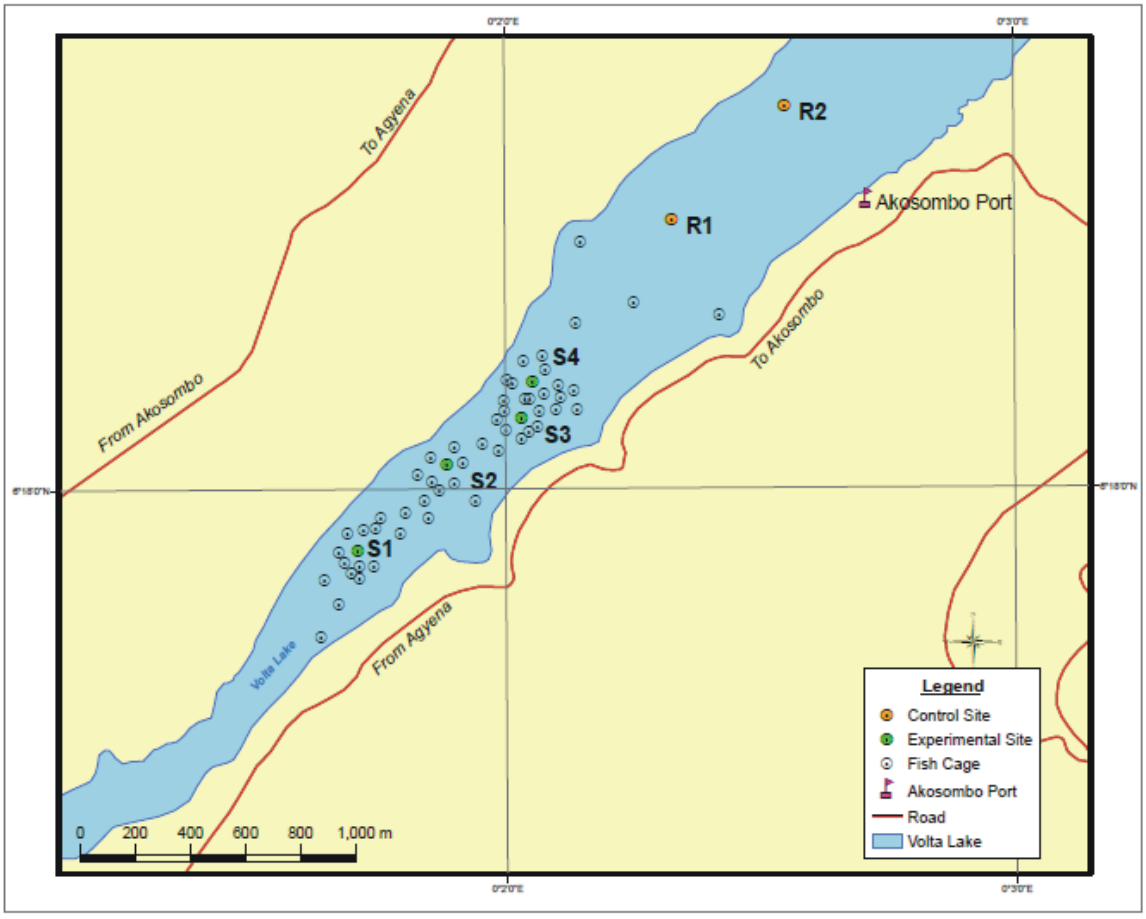

Fig. 3.2. Map of the study area showing the sampling points

3.3 Water Quality Determination

Physico-chemical and bacteriological parameters of water in the vicinity of the cages and the control site were taken monthly for six months. Water samples were taken a metre below the surface at each site into pre-cleaned 1 L plastic bottles for the physico-chemical parameters

and 500 ml sterilized glass bottles for the bacteriological quality assessment. The bottles for the physico-chemical parameters at the collection site were rinsed with portions of the lake water prior to sampling. Each of the bottles was corked and labelled with full details of the site, time and date of collection and brought to the laboratory of Water Research Institute (WRI) in a cool box to analyse.

Plate A. Taking water quality data with the multiparametric water analyser (Hach Hydrolab) metre.

Plate B. Typical cage structure with a walk-way at the study site

For the purpose of this studies, the following physico-chemical and bacteriological parameters were determined; Dissolved oxygen, ammonium-nitrogen, nitrate-nitrogen, nitrite-nitrogen, electrical conductivity, total hardness, turbidity, alkalinity, chlorophyll a, sulphate, phosphorus, chemical oxygen demand, total and faecal coliform bacteria of the water were determined monthly. The collection of samples and the measurement of water quality parameters were done from 9:00 am to 2:00 pm and the analysis was done by standard methods (APHA/AWWA, 2005) as below:

3.3.1Temperature, Dissolved Oxygen and pH.

Temperature, pH and dissolved oxygen were recorded in the field by using a multiparametric water analyser (Hach Hydrolab) metre. The probe of the metre was immersed into the Lake water at a depth of 1m. The temperature and dissolved oxygen were read directly from the metre in degrees celsius (°C) to one decimal place for temperature and dissolved oxygen in mg/l to two decimal places when equilibrium was achieved.

3.3.2 Turbidity

Turbidity was measured using the Turbidity metre. About 5 ml of water samples from each site was poured into a cuvette and inserted into the cell holder of the metre and the value read from the already calibrated metre in Nephelometric Turbidity Units (NTU).

3.3.3 Total Hardness

Using EDTA Titrimetric method, 25 ml of water sample was pipetted into a conical flask and 2 ml of buffer solution was added to produce pH of 10.0. A quantity of crystals of Eriochrome Black T indicator was added and constantly mixed. The solution was titrated against a 0.01M standard EDTA until the colour changed from purple to bright blue.

Calculation, Total Hardness= (AXBX100)/V where A=ml EDTA that is titrated, B= mg of $CaCO_3$ which is equal to 1.00ml EDTA ad V= sample volume

3.3.4 Alkalinity

A 50 ml of water sample was measured into a conical flask and appreciable quantity of methyl orange was then added to it and the solution that resulted was then titrated against standard of 0.01 M HCl until the colour changed to pale pink. The equation below was used in the calculation;

3 A×M 50/ 100. Alkanity mg/CaCO Volume sample ml where A = titre value M = molarity of HCl used 50 = equivalent of $CaCO_3$

3.3.5 Nitrate- Nitrogen (NO_3 –N)

Nitrate was determined using the Hydrazine Reduction Method. Twenty (20) ml of sample was measured into a test tube and 1ml of 0.3 M NaOH solution was added and mixed gently. One (1) ml reducing mixture was then added. The mixture was then heated for 10 minutes at 60 ^{o}C and cooled to room temperature. One (1) ml of colouring reagent was added, mixed gently and 15 minutes reaction period was allowed for pink colour development. A 20 ml deionised water zero blank and a standard of 0.25 mg NO_3 –N/l were treated the same way and used to calibrate the HACH DR/2000 Direct Reading Spectrophotometer at a wavelength of 507 nm using a 2.5 cm light path cell. The nitrate concentration in the sample was measured and the result expressed in mg NO_3-N/l to two decimal places.

3.3.6 Phosphate-Phosphorus (PO_4 –P)

Phosphate was determined by Stannous Chloride Method. Twenty five (25) ml of a sample of water was measured and 1 drop of phenolphthalein indicator was added and mixed. One (1) ml molybdate reagent was added and mixed followed by three drops of stannous chloride reagent. The solution was mixed thoroughly and after 10 minutes a blue colour developed indicating the presence of phosphate-phosphorus. A 25 ml deionised water zero blank and standard of 0.50 mg/l PO_4–P were treated the same way and used to calibrate the HACH DR/2000 Direct Reading Spectrophotometer at a wavelength of 890 nm using a 2.5 cm light

path cell. Phosphate concentration in the sample was measured and the result expressed in mgPO_4–P/l to two decimal places.

3.3.7Ammonium-Nitrogen (NH4 –N)

Ammonium-Nitrogen was determined using the Direct Nesslerization Method. Twenty five (25) ml of the water sample was discharged into a conical flask and a drop (0.05 ml) of ethylenediaminetetra acetic acid (EDTA) reagent was added mixed well. One (1 ml) of Nessler's reagent was then added, mixed well and the solution was made to stand for 10 about minutes for the development of a yellow colour. 25 ml deionized water zero blank and a standard solution of 1.00 mgNH_4 –N/l were also treated the same way. The zero blank and standard solutions were used to calibrate a HACH DR/2000 Direct Reading Spectrophotometer at wavelength of 425 nm using a 2.5 cm light-path glass cell. The ammonium concentration in the sample was then measured and the result expressed in mg NH_4-N/l to two decimal places.

3.3.8 Nitrite-Nitrogen (NO_2 –N)

Diazotization Method was used in the determination of nitrite-nitrogen. Twenty (20) ml each of water sample was measured into a conical flask and 1ml of 0.3 M sodium hydroxide (NaOH) solution was added and mixed gently. One ml colouring reagent was added to the sample and mixed gently. The resulting solution was then made to stand for 15 minutes for the development of a pink colour. A 20 ml deionised water zero blank and standard of 0.250 mg/l NO_2 –N were treated the same way and used to calibrate the HACH DR/2000 Direct Reading Spectrophotometer at a wavelength of 507 nm using a 2.5 cm light path cell. The nitrite concentration in the sample was read and the result expressed in mgNO_2 –N/l to three decimal places.

3.3.9 Chlorophyll a

Samples of water were collected into 1 L clean plastic containers and stored in the dark. A 1000 ml of water was filtered by means of Whatman GF/C filter paper. Ninety percent acetone was used to extract Chlorophyll-a from the filter paper into solution and centrifuged at 3200 rpm for 10 minutes and the resulting solution was poured and absorbance recorded by using the spectrophotometer at 750, 663, 645 and 630 nm respectively. The turbidity correction was determined by subtracting the 750 nm absorption from 663 nm, 645 nm and 630 nm absorptions. The chlorophyll-a content (Chl a) was calculated from the equation:

Chl a (mg / m^3) = ((11.64 (E663) – 2.16 (E645) + 0.1 (E630)) x Ve) / (Vs x L) (Lorenzen, 1967)

Where: Ve = volume of acetone extract in ml

Vs = volume of sample in litres

L = light path of cell in centimeters

3.3.10 Enumeration of Total Coliform in water sample

Using the membrane filtration technique, 100 ml of sample was passed through a 0.45µm filtration membrane using a single chambered manifold. With the aid of a sterile forceps, the membrane filter was transferred onto the plated media (selective media, Harlequin). It was inverted and placed into an incubator at a temperature of 37±1^{o}C for a period of 18-22 hours. Red and blue colonies that grew were counted as total coliforms.

3.3.11 Enumeration of Faecal Coliform in water sample

Using the membrane filtration technique, a known volume of the water sample (100 ml) was filtered through a 0.45µm membrane filter using a single chambered manifold. With the aid of a sterile forceps, the membrane filter was transferred onto the plated media (selective media, mFC media). It was inverted and placed into an incubator at a temperature of 44±1^{o}C

for a period of 18-22 hours. Blue colonies that grew were counted as faecal coliform counts using the colony counter.

3.4 Sediment quality determination

Sediment samples were collected with a sediment grab (602-001 Ekman bottom grab sampler) from the cages stations and the control sites and put in sterilized plastic bags and sealed.

3.4.1Organic Carbon (OC) Determination

The Walkley-Black procedure was used. 5g of dried sediment sample was ground to pass through a 0.5 mm sieve.1g of the ground sediment sample was weighed into 500 ml Erlenmeyer flask and 10 ml dichromate solution was added. With a measuring cylinder, 20ml of concentrated sulphuric acid was carefully added to it. The solution in the flask was mixed gently by swirling and made to stand for 30 minutes in a fume chamber. With a measuring cylinder, 250 ml of water and 10 ml of phosphoric acid were then added and made to cool. 1ml indicator solution was added and titrated with ferrous sulphate solution while stirring the solution. The titration was done till the colour changed from purple to green.

CALCULATION

$$\%C = M \times \frac{V_1 - V_2}{s} \times 0.39 \times mcf$$

Where

M = molarity of the ferrous sulphate solution from blank titration)

V1= ml ferrous sulphate solution that is needed in blank titration

V2= ml ferrous sulphate solution that the sample needs

S= weight of air-dry sample in gram

$0.39 = 3 \times 10^3 \times 100\% \times 1.3$ (3= equivalent weight of carbon)

Mcf= moisture correction factor

3.4.2 Total phosphorus and nitrogen

Preparation of sample for analysis

The wet weight of samples (200 and 400 g) was measured and digested in 6 ml sulphuric acid for 5 minutes. It was then allowed to oxidize by adding 15 ml hydrogen peroxide (30%) by using HACH Digestdal instrument. The resulting solution was diluted to 100 ml and left to stand overnight for suspended materials to precipitate.

3.4.3 Total phosphorus (TP) Determination

An approximate volume of 0.5 ml of the sample solution was measured into a 50 ml conical flask and further diluted with water to 25 ml. Total phosphorus was measured by spectrophotometery (Cary 1E, 880 nm) after formation of the complex and further reduced by ascorbic acid.

3.4.4 Total Nitrogen (TN) Determination

The Kjeldahl procedure was used. 5 g of dried sediment samples were ground and sieved through a 0.5 mm sieve. 1 g of the ground sample was then measured into a digestion tube. 2.5 ml of the mixture from the digestion tube was measured and 3 aliquots of 1 ml hydrogen peroxide was added. The tubes were then heated for about an hour at 200^0 C. The temperature was then increased to 330^0 C with continuous heating until mixture was transparent. The heater was put off and the tubes were made to cool. 10 ml of water was then added while swirling. 20 ml of NaOH 38% was then measured into the digestion tube and distilled for about 7 minutes. The distillate was titrated with 0.01 M HCl until the development of a pink colour.

CALCULATION

$$\%N = \frac{a-b}{s} \times M \times 1.4 \times mcf$$

Where

a= ml HCl for sample

b= ml HCl for sample

s = air - dry sample weight in gram

M = molarity HCl

$1.4 = 14 \times 10^{3} \times 100$ % (14 = atomic weight of nitrogen)

Mcf = moisture correction factor

3.4.5 Determination of Total Organic Matter (TOM)

Loss on ignition was used to determine TOM. 500 mg of the sample was taken and dried in the oven at 105 °C for two hours. After drying, it was weighed and kept at 550 °C for 2 hours in a furnace. It was then weighed again. The dry weight was measured as the difference between weight of wet sample and oven dried one. The difference between the oven dried weight and weight after being in the furnace was used to calculate TOM. TOM is expressed as the percentage of the oven dried weight.

3.4.6 Enumeration of Total Coliform in sediment sample

The whirl pak bag which contained the sediment sample was rotated five times to ensure even mixing. Using a balance and a sterile spatula, 10 grams of the sample was measured into one sterile, labelled 50 ml tube and 20 ml of sterile PBS was added. It was then vortexed for 30 seconds and the pH was adjusted to 9.0 with a 0.1 N NaOH. It was then shaken vigorously on a rotator or shaker for 30 minutes. The sample was allowed to settle for 15 minutes and then with a pipette 10 ml of the supernatant was carefully transferred into a new sterile 50 ml tube labelled in pen with the sample id and date. Using the membrane filtration technique, 100 ml of the supernatant was passed through a 0.45µm filtration membrane using a single chambered manifold. With the aid of a sterile forceps, the membrane filter was transferred onto the plated media (selective media, Harlequin). It was inverted and placed into an incubator at a temperature of 37 ± 1^{o}C for a period of 18-22 hours. Red and blue colonies that grew were counted as total coliforms.

3.4.7 Enumeration of Faecal Coliform in sediment sample

The whirl pak bag which contained the sediment sample was rotated five times for even mixing. Using a balance and a sterile spatula, 10 grams of sample was measured into one sterile, labelled 50 ml tube and 20 ml of sterile PBS was added. It was then vortexed for 30 seconds and the pH was adjusted to 9.0 with a 0.1 N NaOH. It was then shaken vigorously on a rotator or shaker for 30 minutes. The sample was allowed to settle for 15 minutes and then with a pipette 10 ml of the supernatant was carefully transferred into a new sterile 50 ml tube labelled in pen with the sample ID and date. Using the membrane filtration technique, 100 ml of the supernatant was filtered through a 0.45µm membrane filter using a single chambered manifold. With the aid of a sterile forceps, the membrane filter was transferred onto the plated media (selective media, MFC media). It was inverted and placed into an incubator at a temperature of $44\pm1^{o}C$ for a period of 18-22 hours. Blue colonies that grew were counted as faecal coliform counts using the colony counter.

3.5 Data analysis

The data collected was entered into a computer on excel sheet. The data was transferred to SPSS version 20 and analysed. Microsoft Excel was used to compute the descriptive statistics such as the means, standard deviations and errors. Student t-test was used to test for the level of significance between water samples from both sites and the sediment samples as well. A correlation analysis was also done for the sediment and water quality of the two sites. Correlation between water quality parameters and bacteriological was also done.

CHAPTER FOUR

RESULTS

4.1 Fish cage culture impact on water quality

The results of physico-chemical analyses are presented in Table 4.1 and 4.2. The mean temperature value recorded for the experimental site was 29.03^{o}C and that of the control site was 29.29^{o}C (Table 4.1). The highest temperature for the experimental site was recorded in November with a mean of 30.12^{o}C and the lowest was in February with a mean value of 27.6^{o}C. The highest temperature for the control site was observed in December with a mean value of 30.25^{o}C and the lowest in February and March with a mean value of 28^{o}C.Variations in temperature at both sites was not significant ($p>0.05$)

Table 4.1. Physical p*ar*ameters of the gorge area of the Volta Lake from November, 2014 to April, 2015, mean values (units) ± standard deviation of physicochemical parameters, n=18

Parameters	**Experimental Site** (Mean ± SD)	**Control Site** (Mean ± SD)
DO (mg/l)	5.73±0.78	6.43±1.21
pH	7.10±0.28	7.14±0.21
Conductivity(µs/cm)	66.87±2.19	67.57±5.63
Turbidity (NTU)	1.46±2.00	0.67±0.88
TH (mg/l)	21.53±1.04	22.25±1.76
Alkalinity(mg/l)	35.68±1.96	35.66±2.38
Chlorophyll(mg/m^3)	1.95±0.23	1.20±0.21
Temperature(^{o}C)	29.03±0.82	29.29±0.84

The mean DO concentration recorded for the experimental site was 5.646±1.303mg/l and that recorded for the control site was 6.428±1.370mg/l which was a little higher than that of the experimental site (Table 4.1). DO was highest at both control and experimental sites in the

month of December with mean values 8.48 and 5.77mg/l respectively. The lowest DO level recorded for both sites during the study period was in the month of February with mean values of 5.17 and 4.26 mg/l respectively. There was no significant difference between the two sites at a 95 % confidence level ($p>0.05$). The concentration of DO in the river varied between 6.60–7.16 mgl-1, therefore, the river water will enhance the aquatic environment.

The mean pH recorded for both sites were about neutral for the study period. The values for the experimental and control sites were 7.088 ± 2.75 and 7.140 ± 2.11 respectively. The pH was within the levels prevalent with most natural waters which varies from 6.0 to 8.5 (Chapman, 1992). The highest pH value recorded for both experimental and control site was in the month of December with mean values of 7.54 and 7.44 respectively. Both sites recorded the lowest pH value in the month of February with mean value of 6.70. Statistically, there was no significant variations in pH values between the two sites ($p>0.05$).

The conductivity values recorded for the experimental site was 66.87 ± 2.19 µs/cm and that of the control site was 67.57 ± 5.63 µs/cm. Conductivity was lowest at the experimental site in November with a mean value of 63.39 µs/cm and highest in April with a mean value of 69.12 µs/cm. The control site recorded a high conductivity value in April with a mean value of 77.7µs/cm and the lowest value of 62.6 µs/cm was in November and February. Variations between the two stations were not significant at a 95% confidence level ($p>0.05$).

Turbidity values for both sites during the study period ranged between 1.46±2.00NTU and 0.67±0.88NTU, indicating that turbidity was relatively higher at the experimental site. Turbidity was generally lower at the control site but than at the experimental site. The highest value for the experimental site was recorded in February with an average value of 5 NTU. Variation between the two sites was not significant ($p>0.05$).

The values recorded for total hardness for the control site was 22.25±1.76 mg/l and that of the experimental was 21.53±1.04 mg/l. The lowest total hardness recorded for the experimental

site was in February and April with an average of 20.75 mg/l and that of the control site was in April with an average of 19 mg/l. The highest value for total hardness recorded at the experimental site was in the month of December with an average of 23.1 mg/l and that of the control site was in November with an average of 24.9 mg/l.

Alkalinity for both experimental and control sites during the period of study were similar with mean values of 35.68±1.96 mg/l and 35.66±2.38 mg/l respectively. November recorded the lowest value of alkalinity for the control site with mean 33.4 mg/l and the lowest for the experimental site was recorded in January with a mean of 34.7 mg/l. The highest alkalinity that was recorded for the experimental site was in December with a mean of 38.8mg/l and the control site was recorded with a mean of 39.6 mg/l in January. At a 95% confidence level, difference between the two sites was not significant.

Table 4.2. Mean ± SD of the nutrient concentrations of the water samples in the study area from November, 2014 to April, 2015, n=18

Parameter	Experimental (Mean±SD)	Control (Mean±SD)
Nitrate(mg/l)	0.04±0.03	0.05±0.04
Nitrite(mg/l)	0.01±0.01	0.01±0.01
Ammonia(mg/l)	0.22±0.16	0.32±0.13
Phosphate(mg/l)	0.09±0.05	0.13±0.06
Sulphate(mg/l)	2.90±0.77	2.98±0.85

From table 4.2 the concentrations of nitrate for both the control and experimental site ranged between 0.04±0.03 mg/l and 0.05±0.04mg/l. High levels of nitrate was recorded at the control site in November with 0.121 mg/l as mean and for the experimental site, December recorded

high levels of nitrate with mean of 0.08 mg/l. The lowest for both sites was observed in April. The difference between the two sites when tested statistically was not significant ($p>0.05$).

Similar means of nitrite was recorded for both sites. February recorded the highest value of nitrite for the experimental site with a mean value of 0.02 mg/l whilst April observed same for the control site with a mean of 0.03 mg/l. Both sites recorded no concentrations of nitrite in January. Statistically, there was no significant difference between the two sites.

The concentrations of phosphorus varied between 0.09±0.05mg/l and 0.13±0.06 mg/l. High levels of phosphorus was recorded for both sites in November with mean of 0.23mg/l for control site and 0.16mg/l for experimental site whilst the lowest was in April with mean values 0.053mg/l and 0.05mg/l for control and experimental sites respectively. Throughout the study, there was no significant difference in the amount of phosphorus at both sites ($p>0.05$).

Ammonia concentrations for the control and experimental sites ranged between 0.32±0.13mg/l and 0.22±0.16mg/l. Concentrations of ammonia at the experimental site was quite higher than the control site. The two sites recorded the lowest concentration in April with mean values 0.011 and 0.05 for control and experimental sites respectively. The control site recorded the highest ammonia concentration in December with an average of 0.46 mg/l and experimental site was in January with a mean of 0.387mg/l. At 95% confidence level, the difference between both sites was not significant ($p>0.05$).

Mean monthly concentration of sulphate for the experimental site was 2.90±0.77 mg/l and that of the control site was 2.98±0.85mg/l for the study period. The highest sulphate concentration for the experimental site was recorded in December with 3.61 mg/l as the mean and that of the control site was in November with 4.35 mg/l as the mean. The lowest value of sulphate recorded for the control site was in January with a mean of 1.79 mg/l and that of the experimental site was in February with 2 mg/l as the mean value. The level of sulphate was a

little bit higher at the control site than the experimental site. However, the difference between both sites was not significant ($p>0.05$).

Chlorophyll-a recorded at the experimental and control sites were 1.95±0.23mg/m^3 and 1.20±0.21mg/m^3 respectively. Chlorophyll-a levels at the experimental site was higher than the control sites. Both sites recorded their highest value in February with means of 1.505 mg/m^3 and 2.25 mg/m^3 for control and experimental sites respectively. The lowest value for both sites was recorded in April with mean values of 0.87 mg/m^3 and 1.565mg/m^3 for the control and experimental sites respectively. The p-value for the test between the two sites was not significant ($p>0.05$).

4.2 Microbiological quality of the study area (gorge area of the Volta Lake)

The mean monthly counts of total coliform for the experimental site ranged between 2015±1041cfu/100ml and that of the control site was 2715±2196cfu/100ml (Fig. 4.1). The experimental site had the highest counts of TC in December with mean of 3318.75cfu/100ml and the lowest in January with mean of 940cfu/100ml. The control site had the highest counts of TC in January with a mean of 6960cfu/100ml and the lowest in April with a mean of 837cfu/100ml. Variations between the two sites was not significant ($P>0.05$).

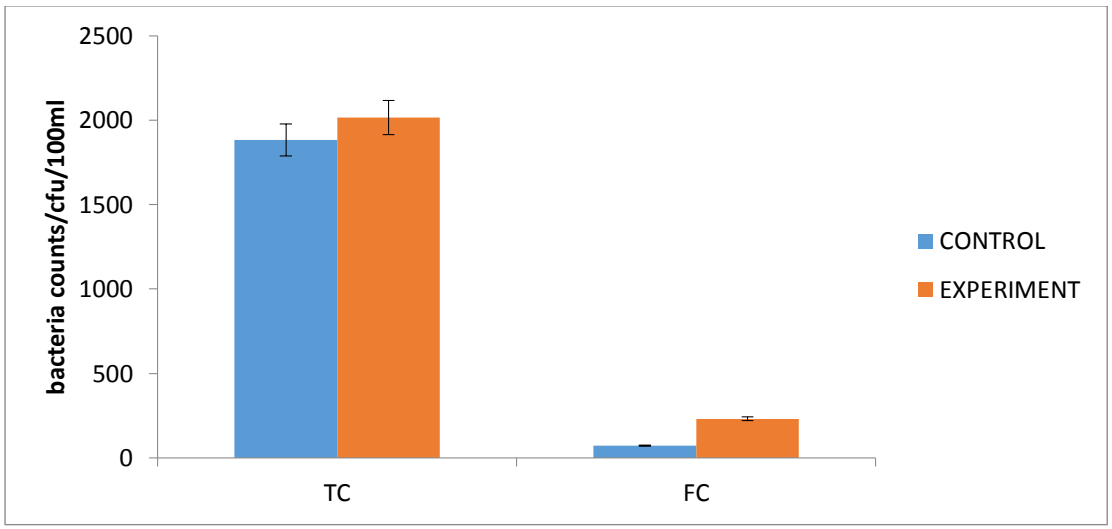

Fig.4.1 Mean counts of bacteria concentration of the water at the control and experimental sites

Plate C. Total and faecal coliforms in Harlequin and MFC media respectively on petri-dishes

The mean monthly counts of faecal coliform bacteria recorded for the experimental and control sites were 232±170.74cfu/100ml and 71±25cfu/100ml respectively (Fig. 4.1). Both sites recorded the highest faecal coliform levels in February with means 120cfu/100ml for the control site and 552cfu/100ml for the experimental site. The lowest faecal coliform count recorded for both sites was observed in April with mean values of 48cfu/100ml for the control site and 113cfu/100ml for the experimental site. The counts of faecal coliform bacteria recorded at the experimental site was more at the experimental site compared to the control. The difference between both sites was significant ($p<0.05$).

4.3 Sediment quality data of the gorge area of the Volta Lake

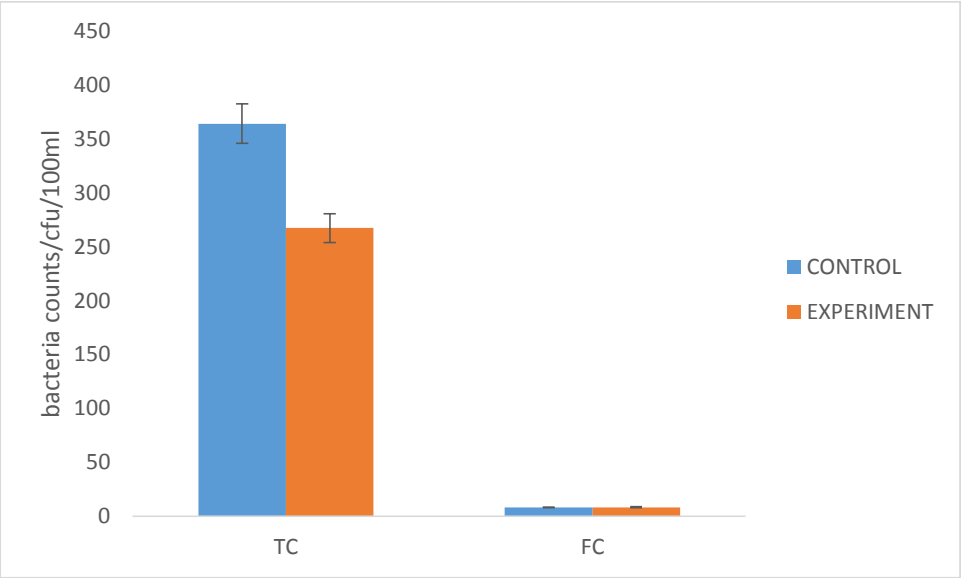

Fig. 4.2 Mean counts of bacteria in the sediment at the experimental and control sites

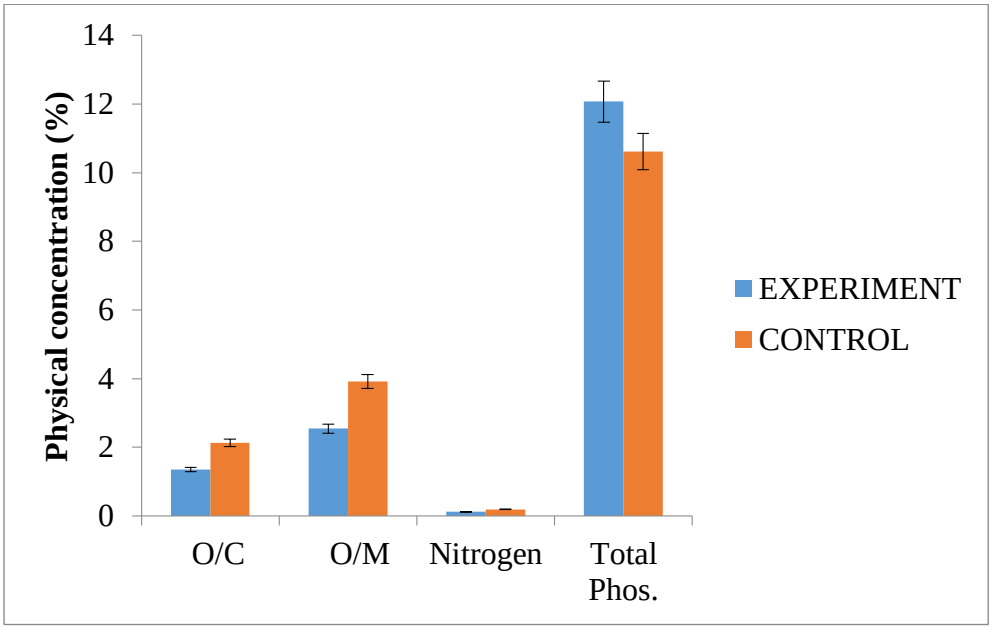

Fig. 4.3. Means of the nutrient parameters in the sediment at the experimental and control sites (%)

The graphs above shows the monthly means and standard deviations of the physicochemical and microbiological parameters of the sediment measured for the entire period of study from November 2014 to April, 2015.

The mean monthly concentrations of organic Carbon recorded at the experimental and control sites ranged between 1.27±0.39 % and 2.13±1.18 % respectively (Fig 4.3). April recorded the highest organic carbon content at the experimental site with a mean value of 1.825% whilst December had the highest for the control site with a mean of 4.15%. The lowest concentration of organic carbon was recorded in January for the experimental site with a mean value of 0.61% and April for the experimental site with a mean of 0.92%. The p-value for the test of the two sites was not significant ($p>0.05$).

The organic matter content recorded for the control site during the study period was 3.92±2.07 % and that of the experimental site was 2.54±0.98%. Organic matter content at the control site was marginally higher than the experimental site. The highest value recorded for the control site was in December with a mean of 7.13% and the lowest was in April with a mean of 1.59%. The experimental site had the highest in February with a mean of 3.98% and the lowest in January with a mean of 1.05%.

Total Nitrogen concentrations at the experimental and control sites were 0.12± 0.05(%) and 0.19±0.10 (%) respectively. In April the highest and lowest level of total nitrogen (TN) was recorded for the experimental and control sites with means of 0.2% and 0.08% respectively. Nitrogen concentration was low at the experimental site in January with a mean value of 0.05% but high at the control site in December with a mean of 0.36%. The variation between the two sites was not significant ($p> 0.05$).

The level of total phosphorus concentration in the sediment during the entire period ranged between 35.5±4.05 and 32.20±3.58 (%) at both the experimental and control sites respectively. The concentration at the cage site was quite higher than at the control site. However, the difference between both sites was not significant ($p>0.05$). The highest value of 42.15% was recorded in January for the experimental site and 37.85% in December for the

control sites. The lowest was recorded in February for control with a mean value of 26.98% and in November for the experimental with a mean of 33.76%.

Counts of TC in the sediment at the experimental site was 267±63 (cfu/100ml) and that of the control was 364±197 (cfu/100ml) (Fig. 4.2). December recorded the highest for the experimental site with a mean value of 355 cfu/100ml and November had the lowest for the control site with mean value of 11cfu/100ml. The lowest record for the experimental site was in February with a mean value of 162 cfu/100ml and the highest for the control was in April with a mean value of 604 cfu/100ml. Concentrations of TC in the sediment at the experimental site was lower than at the control site. The difference between the two sites was not significant (p=0.28)

Faecal coliforms counts at the control and experimental sites ranged between 7±18 cfu/100ml and 8±19 cfu/100ml respectively. Both sites had the lowest counts of FC in January and the highest in December. The difference between the counts of FC at both the experimental and control sites was not significant (p=0.98).

Table 4.3 Correlation matrix of r-values of mean data for sediment parameters at sampling sites

	O/C	O/M	Nitrogen	Total Phos.	TC	FC
O/C	1					
O/M	.955**	1				
Nitrogen	.980**	.925**	1			
Total Phos.	-.028	-.106	-.005	1		
TC	.348	.287	.307	.076	1	
FC	.496	.392	.451	.262	.256	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

4.4 Correlation between the physico-chemical, bacteriological and sediment quality parameters of all the sampling site

The relationship between the various parameters measured in the water and sediment were determined by Spearman's correlation coefficient, r, $p<0.05$ and 0.01 significant levels (Table 4.3 and Appendix H). The mean concentrations of the various parameters in the water and sediment from the sampling sites were used. The Spearman's correlation for the sediment and water are presented in Table 4.3 and appendix H. From Table 4.3, organic matter strongly correlated with organic carbon ($r=0.955$) at the $p\leq=0.01$ significant level. Total Nitrogen also strongly correlated with organic carbon ($r=0.980$) at the $p\leq=0.01$ level of significance and Organic Matter ($r=0.925$) at the $p\leq=0.01$ significance level (Table 4.3). There was a weak negative correlation between total phosphorus and organic carbon ($r=-0.28$) and organic matter ($r=-0.106$).

Appendix H indicates that Dissolved oxygen correlated positively with pH ($r=0.447$) at the $p\leq=0.01$ significance level. Turbidity and pH negatively correlated ($r=-0.445$) at the $p\leq=0.01$ level of significance (Appendix H). Furthermore, faecal coliform and turbidity correlated positively ($r=0.444$) at the $p\leq=0.01$ significance level. Sulphate and nitrate also correlated positively ($r=0.407$) at the $p\leq=0.05$ level of significance (Appendix H). There was a weak correlation between conductivity and DO, total hardness and pH. There was a moderate positive correlation between chlorophyll-a and turbidity ($r=0.33$) at the $p\leq=0.05$ level of significance.

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CHAPTER FIVE

DISCUSSION

5.1 Fish cage aquaculture and water quality in the Volta Lake

Good water quality is vital in ensuring the growth of the organisms cultured in the aquatic environment. Poor quality of water can affect the cultured organisms, lead to diseases in humans, low quality of products and less profit. Aquaculture organisms rely on the water to perform their physiological activities. When there is contamination of the water in an aquatic environment, the rate of production drops and as a result growth is reduced and mortality of the organisms being cultured occurs. Because of its nature, fish cage farming maintains high densities of organisms that generate considerable amounts of dissolved and particle-like waste (Islam, 2005). Generally, the waste is discharged into the surrounding environment which acts as a diluting and dispersing agent. Nonetheless, each type of waste can have an impact on the environment.

5.1.1 Impact of fish cage culture on physico-chemical parameters of water quality in the Volta Lake

Generally, the physicochemical parameters observed at the experimental 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. Also the impact on water quality as a result of the cage farms was minimal. Average maximum and minimum temperature, pH, total alkalinity, total hardness, ammonium, nitrite, nitrate and phosphates during the study (Table 4.1 and 4.2) remained within the limits for good tilapia culture (Boyd, 1990) and were suitable for cage cultured *Oreochromis niloticus* (Schmittou, 2006).

Dissolved oxygen is a necessary requirement in aquaculture. The fish require it for respiration and other activities such as metabolism. Fish kills are usually as a result of decreased DO

levels. In this study, values of DO recorded at the experimental and control sites did not differ significantly. However, the DO concentration at the control site was higher (6.43±1.21)mg/l than the experimental site (5.73±0.78)mg/l indicating a slight impact of the farm. This can be linked to the operations of the cage farm such as fish respiration and also microbial metabolism which can increase biological oxygen demand in the vicinity of the cages as well as obstruction of water current flows by the cage structures. Increased oxygen demand caused by enrichment of the water with cage wastes may reduce DO in the water column, (Mente *et al.,* 2006). The values recorded for the experimental and control sites in this study were similar to findings by Antwi and Ofori Danson (1993) who recorded 7.78mg/l at the Kpong area of the Lake and TICOMFE (2011) which recorded 5.08mg/l-8.64mg/l in the gorge area of the Volta Lake. Similar to this studies, Clottey (2014) recorded DO levels ranging 5.21 to 9.0 mg/l at cage sites and 4.51to 8.84 mg/l at control sites on the Lake Volta.

Chlorophyll-a in the experimental and control sites did not differ significantly ($p>0.05$). However Chlorophyll-a concentration at the experimental site which was where the cages were located was higher (1.95±0.23) mg/m^3 than the control site (1.20±0.21) mg/m^3 indicating a minimal impact of the fish farm. This is similar to the findings of Ameworwor (2014) who also observed slightly high level of chlorophyll-a at cage sites 12.02 mg/m^3 compared to control sites which was low 11.83mg/m^3. 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 chl- *a* level at 7 cage farms in Turkey when compared to control sites.

pH values for experimental and control sites during the period of study were similar (7.10 and 7.14 respectively) indicating no impact of the farm. The slight drop in pH at the experimental site may be due to waste deposits from the fish farm (Pitta *et al.,* 1999). The standard pH value that has been set by the European Union (EU) for fisheries and aquaculture environment varies between 6 to 9 (Chapman, 1996). The neutral pH obtained in the study area was within these ranges. Based on this, the pH recorded in the study area would not adversely affect the aquatic life. pH levels observed during the 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 6.8 and 7.5 at Kpong and Yeji portions of the Volta Lake.

The nitrite values recorded for the two sites were similar (Table 4.1); therefore there was no significant variation among them. These results agree with Stirling and Dey (1990) who observed no difference in nitrite levels between experimental and reference stations. The values observed in this study were in agreement with findings by TICOMFE (2011) which recorded 0.001-0.008mg/l in the gorge area of the Lake Volta.

All biological and chemical processes in an aquaculture operation are influenced by temperature. Temperature observed for both the experimental and control site did not showed no significant difference ($p>0.05$).The recorded values for this study (Table 4.1) were similar to findings of TICOMFE (2011) and Asase (2013) on the Volta Lake which had mean temperatures of 27.7^{o}C to 29.7^{o}C and 26.5^{o}C to 28.8^{o}C respectively. Therefore, cage farming did not impact on temperature. Also comparable to this studies is the findings of Ameworwor (2014) and Clottey (2014) who observed temperature ranges of (25.66-30.08) ^{o}C at cage sites and (26.20-30.50)^{o}C at control sites.

The mean ammonia levels recorded in this study (Table 4.2) was low which is consistent with findings of Antwi & Ofori-Danson (1993) in the Kpong Reservoir with mean of 0.02 mg/1

and varying between < 0.001–0.12 mgl-1. At Akuse, CSIR-Water Research Institute (1999) reported a mean of 0.21 mg/l ammonia with range of 0.193–0.227 mg/l. Also TICOMFE PROJECT (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 of 0.1 mg/l. Clottey (2014) also observed low ammonia levels at both cage (<0.001-0.444) and control (<0.001-0.242) sites The concentrations of ammonia in the study site during the study period was not alarming which may be due to low anthropogenic activities reaching the area.

Phosphate concentrations at the experimental site were lower (0.09mg/l) than the control site (0.13mg/l) (Table 4.2). But comparatively the difference between both sites was not significant ($p>0.05$). The higher levels of phosphate at the control site may be due to anthropogenic activities such as tourism, run offs of pesticides and livestock grazing. The phosphate concentrations recorded in this study is comparable to values recorded by Karikari *et al.* (2013) and Ofori Danson and Ntow (2005) who recorded 0.23mg/l and 0.34-0.50 mg/l in the Volta Lake.

The concentrations of the nutrients showed significant positive correlation except phosphate which showed weak relationship. This may be due to the transportation of phosphorus in particulate form from farm lands to aquaculture environments by erosion (Ansah-Asare and Karikari, 2003). Phosphate 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 levels observed in this studies was also similar to that found by Ameworwor (2014) who recorded (0.057-0.29) mg/l and (0.029-0.43) mg/l at both experimental and cage site respectively.

Alkalinity for both control and experimental site were similar (35.68 mg/l and 35.66 mg/l respectively). However, the alkalinity of the control site was slightly higher than the

experimental site but variation between them was not significant ($p>0.05$). The values recorded were comparable to findings by Asase (2013) who had mean value of 28.5mg/l on the Volta Lake in Akosombo.

Turbidity reflects the existence of dissolved and suspended organic and inorganic materials and also planktons and other microorganisms. Turbidity values observed at both experimental and control site did not vary significantly ($p>0.05$). However, the value recorded at the experimental site was higher (1.46NTU) than the control site (0.67NTU).This indicates fish farm impact on the water quality. The slightly high turbidity values recorded at the experimental site can be associated with excess feed and fish faeces (Nyanti *et al.,* 2012). Also it can be attributed to the washing of the cage nets in the experimental site. When turbidity increases, it may affect the penetration of light thereby making it difficult for phytoplankton and the vegetation at the bottom sediment to undergo photosynthesis (Harrison *et al.,* 2005; Cole, 2002). When turbidity is high it reduces the productivity of fish, clog filters and injure fish gills. According to WRC (2003), turbidity levels ranges from 0-5 NTU. In spite of fish cage aquaculture in the study area, the values recorded are still within this range. The values are consistent with the observations of Karikari *et al.* (2013) who recorded 2.14-7.38 mg/l in the Kpong area of the Volta Lake. Clottey (2014) and Ameworwor (2014) also observed slightly high levels of turbidity at cage sites (3.38 and 2.46) mg/l compared to control sites (3.00 and 2.11) mg/l respectively.

Conductivity values at the control and experimental site were similar. The mean conductivity value for the experimental site was 66.87 mg/l and that of the control was 67.57mg/l. The difference between both sites was not significant ($p>0.05$). These values were consistent with observations of Antwi & Ofori-Danson (1993) who recorded a range of 62.0-77.5µs/cm at Kpong on the Volta Lake. The cage farm had no impact on the conductivity of the water in the study area.

Nitrate 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 recorded for both experimental and control sites were very low (0.04 and 0.05) mg/l respectively compared to observations from earlier studies. Karikari *et al* (2013) found nitrate concentrations of 0.51-0.97 mg/l. Ofori Danson and Ntow (2005) reported that an important aspect of the chemistry of the Lake Volta was its low level of nutrient. The same conclusion has been reached by earlier researchers like Ewer (1966); Entz, (1969) and Ofori-Danson & Antwi, (1994).

Calcium and magnesium ions comprise hardness. The total hardness values observed for both sites were similar. The mean total hardness recorded for the experimental site was 21.53 mg/l and that of the control site was 22.25 mg/l. These values were consistent with findings of Asase (2013) and TICOMFE (2011) in the Volta Lake indicating that despite the activities of the cage farm, the total hardness of the water quality has not changed over time.

The concentration of sulphate at both experimental and control sites were similar (2.9 mg/l and 2.98 mg/l respectively) indicating no significant variations between them ($p>0.05$).

5.1.2 Impact of fish cage culture on the microbial loads of the Lake Volta

The mean total coliforms count at the experimental site varied between 940 and 3318 cfu/100 ml and faecal coliforms varied between 113 and 552 cfu/100 ml. Mean total coliform count at the control site was between 837 and 6960 cfu/100ml while the faecal coliforms ranged between 48 and 120 cfu/100ml. This was similar to findings of Clottey (2014) who found high TC levels of (132-1708) cfu/100ml at cage sites and low levels (145-1209) cfu/100ml at the control sites.

There was significant variation between the faecal coliforms count at the experimental and the control site ($p=0.046$).This indicates that the microbiological quality of the water at the

study area, as shown by counts of total coliform, were unusually high. The counts were above the Water Resources Commission (WRC) recommended limit of <1000 cfu/100ml for total coliforms and <10cfu/100ml for faecal coliforms for aquaculture. According to Hodgkiss (1988), the rate of contacting disease increases as contamination from faecal sources become high. Hence aquatic organisms cultured in water contaminated by sewage may adversely affect the health of the cultured species and humans as well. The poor microbiological quality recorded at the study area may result from activities by humans and livestock that contaminate the water. The high TC counts observed at the control site 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. Livestock also defaecate into the water as they drink from it thereby contaminating it. The sources of FC at the experimental site can be attributed to the sewage from people living along the river and sewage originating from the care taker's hut at the cage farms.

5.2 Impact of fish cage culture on sediment quality of the Volta Lake

Studies from across the world show that fish cages could be important point-sources of nutrients to hosting water bodies due to their ability to generate large amounts of wastes that have high carbon (C), nitrogen (N) and phosphorus (P) concentrations which are discharged into the surrounding environment (Gondwe *et al.*, 2011). Uneaten food and fecal material pass through the cages and are dispersed into the receiving water, potentially leading to change in water and sediment quality as well as nearby phytoplankton and benthic communities (Iwama, 1991). Some of this organic material will be lost by leaching or will be broken up and dissolved into the water column, and some will be consumed by wild fish. The remaining organic fraction usually settles in the sediments.

Gondwe *et al.* (2011) observed that 81-91% of carbon, 59-80% of nitrogen and 85-92% of phosphorus are lost from cage farms into the surrounding environment which shows that cage farming contributes to nutrient loads in the recipient water bodies. Cage farms affect the bottom sediments through organic matter build-up which leads to oxygen deficit at the bottom. Hence analysis of the sediment is a necessary tool to determine the level of pollution in a cage farm.

5.2.1 Physico-chemical quality of sediment

The total organic carbon level recorded in the study for both experimental and control site was low (1.27% and 2.13% respectively) indicating no impact of the fish farm. The level recorded for the control site was higher than the experimental site. This may be due to anthropogenic activities in the area such as livestock grazing and run-offs from farms (Troell and Berg, 1997).

Similar to this study, Temporetti *et al*. (2001) observed organic carbon levels of 0.2% and 5.3% in the sediment of a salmon cage culture facility. An important feature of impact of cage farm is increase levels of organic carbon in the sediment. Contrary to this study, Hargrave *et al.* (1993) reported that total organic carbon levels at a cage station in Canada was higher by 40% compared to a control site.

Total organic matter (TOM) is an estimation of the content of organic matter in the bottom sediments of an aquaculture facility. Organic matter input is determined by the cultured organisms, method of culturing, the type of feed used, and management practices (Wu, 1995). The mean total organic matter values recorded in this study for the experimental site was lower (2.54%) than the control site (3.92%). However, there was no significant variation between them. The high levels of total organic matter at the control site may result from sewage from the rural settlements along the lake, dumping of refuse and agriculture.

The concentrations of nitrogen increase under fish farms due to changes in the organic material that settles at the bottom. The cultured organisms do not release nitrate and nitrite, but these nutrients are eutrophication indicators in a particular area. The mean total nitrogen levels observed in this study for both experimental and control site were similar (0.12% and 0.19% respectively). However, it was slightly higher in the control site than the experimental site. This high content of total nitrogen could be that the control site was closer to a human settlement, so it was the site with the highest impact from anthropogenic activities, such as tourism, agriculture and livestock grazing. These activities discharge organic wastes into the aquatic environment, which are transformed into nitrogen compounds that alter the natural cycles of the environmental elements (Beveridge and Phillips, 1993).

Total Phoshorus (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 total phosphorus concentrations at the experimental site was higher (35.51%) than the control site (32.20%) which indicates a possible contribution from the cage farm. However the difference between them was not significant ($p>0.05$). The fish cages mainly contributed to the increase in phosphorus levels at the experimental site, which were largely provided by the release of nitrogen and phosphorus obtained from uneaten feed, feces and and urine (Beveridge and Phillips 1993; Kibria *et al.,* 1998). Similar to this studies, Phillips *et al.* (1994) observed that more than 85% of phosphorus used is lost into the cage and the recipient waters.

5.2.2 Microbiological quality of the sediment

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 count at the control site was higher (364 cfu/100ml) than the experimental site (267 cfu/100ml). However, difference between both sites was not significant ($p>0.05$).This 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 experimental site was higher (19.5 cfu/100ml) than the control site (18.9 cfu/100ml). This can be a possible impact of the cage farm as a result of faeces waste from the cage activity.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The impact of cage aquaculture on sediment and water quality in the gorge area of the Volta Lake was studied. The experimental site which was the area where the cages were located was compared with the control site which had no cages. Although there was no significant difference between the physico-chemical parameters of the water quality in the experimental and control sites, however, the levels of total and faecal coliform measured in the study site were above the recommended levels for aquaculture. When considering the different sources of contamination that are present in the area of study, it could be observed that it is negatively impacted by the anthropogenic activities developed outside the cage culture system.

With the analyses of the sediment, impact of the fish farm on total organic carbon, total organic matter, total nitrogen and total phosphorus was not significant. It is estimated that for an area to be considered as non-contaminated, the content of organic matter in the sediment must range from 0.5 to 5 %, whereas the sediments with more than 15 % of organic matter are typical in contaminated zones (Méndez, 2002). The samples analyzed had a minimum and maximum content of organic matter of 1.05% and 3.97%, respectively, values less than the 15 % that indicates that there is no contamination of the sediments in this area. Phosphorus concentration in the experimental site was also high which can also be attributed to the excess feed.

Total and faecal coliforms count in the sediment of the study area was quite high but not statistically significant. The fact that no significant difference was found for the parameters measured in the sediment between the experimental and control sites may imply that during the study period, no obvious accumulation of waste from the farm had occurred. Also it is likely that the water current velocity was enough to distribute solid wastes, thereby

preventing the effects of accumulation of organic sediment at the cage facility and the environment.

At the end of the study period, it can be concluded that the existence of fish cage culture in the gorge area of the Volta lake has not shown a significant decline in the physicochemical quality of the water and sediment ($p>0.05$), however, the microbial load has increased in the water as a result of fish farm impact which can pose a health risk to people.

6.2 RECOMMENDATIONS

- There is the need to manage the sewage system of the people living along the Lake and that of the care taker's hut.
- It is important for cage operators to improve the management of the fish feed supplied to the reared fish in order to reduce waste generation and discharge into the surrounding environment. Feeding management will reduce feed losses from the cages which will eventually reduce environmental impacts of cage operations
- It is also important that the MOFAD, cage operators and other stakeholders put together a simple monitoring program for water and sediment quality in the vicinity of the fish cages as production expands.
- The organisms that are being cultured in the cages should be monitored and also the cages should be rotated more often to reduce the impact of the operations of the farms.
- There should be regular monitoring of not only the physico-chemical parameters, but also the analysis of microbiological parameters which are often not included in the assessment of fish farm water quality.
- There is the need to have more fish farmers with education and training in aquaculture and also have adequate aquaculture extension officials with access to logistics to operate.

- There is the need to strengthen environmental laws that check feed administration to fishes and aquaculture activities around the lake in order to protect the water body and the ecosystem.

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APPENDICES

Appendix A: Lee's farm with cage structures

Appendix B: Mean monthly water quality parameters of the control site

Parameter	Nov'14	Dec	Jan'15	Feb	Mar	Apr
DO	6.82	8.48	5.78	5.17	6.81	5.49
Con	62.6	62.6	65.7	69.25	67.59	77.7
PH	7.12	7.44	7.17	6.79	7.14	7.17
Turb.	2.0	0.5	1.5	0	0	0
Temp (^{o}C)	29.6	30.55	29.2	27.3	28	28.7

Parameter	Nov'14	Dec	Jan'15	Feb	Mar	Apr
TH/mg/l	24.9	22.7	22.7	21.55	22.15	19.5
NO_3-N/mg/l	0.12	0.04	0.03	0.015	0.047	0.023
PO_4/mg/l	0.23	0.108	0.165	0.092	0.129	0.053
S04/mg/l	4.35	3.145	1.79	3.14	2.99	2.43
NO_2-N/mg/l	0.32	0.468	0.455	0.248	0.323	0.119

Parameter	Nov'14	Dec	Jan'15	Feb	Mar	Apr
Alkalinty/	33.4	37.2	39.6	34.2	35.6	33.9

Chl- a	1.18	1.18	1.32	1.50	1.11	0.87
TC	1302	1990	6960	2490	2715	837
FC	55.5	75	60	120	71.5	48

Appendix C: Mean monthly water quality parameters of the experimental site

Parameter	Nov'14	Dec	Jan'15	Feb'15	Mar'15	Apr'15
Temp (^{o}C)	29.5	30.1	29.2	27.1	27.6	28.5
Turb.(NTU)	0.25	0	1.25	5	2.5	0
pH	6.94	7.54	7.22	6.70	7.09	7.01
Cond. (µS/cm)	63.9	64.72	65.82	65.7	66.84	69.12
TH	21.9	23.1	22.1	2.75	20.76	20.75
DO	5.50	6.55	5.77	4.26	5.66	6.17
NO_3-N	0.04	0.08	0.06	0.02	0.04	0.02
PO4	0.16	0.102	0.146	0.107	0.111	0.05
NH4-N	0.21	0.37	0.38	0.27	0.25	0.05
Chl- a	1.9	1.88	2.06	2.25	1.95	1.56

Parameter	Nov'14	Dec	Jan'15	Feb	Mar	Apr
SO4	3.6	3.61	2.28	2.00	2.80	2.67
NO_2-N	0.21	0.37	0.38	0.27	0.25	0.05
Alk	36.7	38.8	34.7	35.7	35.7	35.15
TC	1021.5	3318.7	940	3195	2036	1581
FC	130.7	298.75	135	552.5	161.75	113.5

Appendix D: Mean monthly concentrations of sediment quality parameters for experimental site

Parameter	Nov'14	Dec	Jan'15	Feb	Mar	Apr
TOC	1.28	1.82	0.61	1.41	1.16	1.82
TOM	2.19	2.27	1.05	3.98	2.58	3.13
TN	0.12	0.12	0.05	0.12	0.09	0.20
TP	33.76	34.52	42.15	29.85	36.55	36.25
TC	264.5	355	249.7	162.5	267.2	304
FC	0.25	48	0	0.25	0.5	0

Appendix E: Mean monthly concentrations of sediment quality parameters for control site

Parameter	Nov'14	Dec	Jan'15	Feb	Mar	Apr
TOM	0.97	4.15	2.13	2.46	2.14	0.925
TOC	1.66	7.13	4.52	4.22	4.38	1.59
TN	0.1	0.36	0.17	0.21	0.21	0.08
TP	30.71	37.85	32.48	26.98	33.68	31.53
TC	11.5	445	434.5	325.5	363.5	604.5
FC	0.5	46.5	0	0.5	0	

Appendix F: Correlation matrix of r-values of mean data for sediment parameters at experimental si**te**

	O/C	O/M	Nitrogen	Total Phos.	TC	FC
O/C	1					
O/M	.771	1				
Nitrogen	.961**	.638	1			
Total Phos.	-.617	-.837*	-.399	1		
TC	.169	-.401	.230	.327	1	
FC	.060	-.132	-.035	-.124	.673	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix G: Correlation matrix of r-values of mean data for sediment quality parameters at control site

	O/C	O/M	Nitrogen	Total Phos.	TC	FC
O/C	1					
O/M	.981**	1				
Nitrogen	.991**	.973**	1			
Total Phos.	.579	.602	.599	1		
TC	.232	.257	.185	.295	1	
FC	.837*	.758	.829*	.766	.191	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix H : Cages at study site with care takers hut

Appendix I : Correlation matrix of r-values of mean data of water quality parameters at all sampling sites

	DO	pH	Conductivity	Turbidity	TH	Alkanility	Nitrate	Nitrite	Ammonia	Phosphate	Sulphate	Chlorophyll	TC	FC
DO	1													
pH	.447**	1												
Conductivity	0.177	0.059	1											
Turbidity	-0.283	-.445**	-0.19	1										
TH	0.038	0.305	-.440**	-0.11	1									
Alkanility	0.164	0.189	0.134	-0.091	0.065	1								
Nitrate	.331*	.464**	0.05	-0.097	.407*	-0.071	1							
Nitrite	-0.064	0.023	0.187	0.102	-0.146	-0.055	0.264	1						
Ammonia	.342*	0.111	0.188	0.117	0.161	0.211	.351*	.352*	1					
Phosphate	-0.018	0.056	-0.238	0.019	0.002	-.526**	.362*	0.087	0.033	1				
Sulphate	0.314	0.278	-0.002	-0.241	0.267	-0.181	.540**	0.036	0.055	.477**	1			
Chlorophyll	-0.267	-0.221	-0.152	.391*	-0.011	-0.042	-0.108	0.027	-0.226	-0.077	0.087	1		
TC	-	0.088	-0.111	0.238	0.1	0.272	-	-0.068	.402*	-0.12	-0.282	-0.174	1	

	0.163				99		0.101						
FC	-0.19	-0.179	0.168	.444**	-.351*	0.055	-0.089	0.036	-0.042	0.075	-0.144	0.037	0.231	1
temperature	-0.297	-0.181	0.116	-0.075	-0.158	-0.119	0.051	0.091	-0.189	0.015	-0.007	0.143	-0.186	-0.014

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix J : Correlation matrix of r-values of mean data of water quality parameters at Experimental site

	DO	pH	Conductivity	Turbidity	TH	Alkalinity	Nitrate	Nitrite	Ammonia	Phosphate	Sulphate	Chlorophyll	TC	FC
DO	1													
pH	.823*	1												
Conductivity	.481	.559	1											
Turbidity	-.949**	-.652	-.330	1										
TH	.549	.777	.091	-.489	1									
Alkalinity	.195	.566	.340	-.044	.335	1								
Nitrate	.402	.835*	.604	-.161	.611	.795	1							
Nitrite	-.303	-.135	.372	.524	-.473	-.079	.160	1						
Ammonia	-.105	.463	.268	.320	.413	.824*	.852*	.206	1					
Phosphate	-.259	.245	.225	.460	.074	.851*	.699	.316	.926**	1				
Sulphate	.696	.471	.008	-.711	.576	-.417	-.008	-.283	-.400	-.668	1			
Chlorophyll	-.705	-.342	-.670	.717	.139	.026	-.033	-.002	.414	.353	-.282	1		
TC	-.281	.075	.468	.442	.092	-.028	.405	.626	.448	.302	-.119	.227		
FC	-.730	-.379	-.031	.763	-.074	-.132	.046	.375	.368	.290	-.395	.628		

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix K: Correlation matrix of r-values of mean data of water quality parameters at Control site

	DO	pH	Conductivity	Turbidity	TH	Alkalinity	Nitrate	Nitrite	Ammonia	Phosphate	Sulphate	Chlorophyll	TC
DO	1												
pH	.798	1											
Conductivity	-.659	-.298	1										
Turbidity	.161	.172	-.619	1									
TH	.476	.140	-.914*	.805	1								
Alkanility	.222	.441	-.360	.208	.112	1							
Nitrate	.449	.218	-.592	.725	.822*	-.312	1						
Nitrite	.277	.051	.171	-.840*	-.460	-.135	-.498	1					
Ammonia	.627	.499	-.863*	.485	.651	.773	.221	-.120	1				
Phosphate	.243	.052	-.737	.900*	.934**	.075	.844*	-.728	.490	1			
Sulphate	.379	-.097	-.445	.283	.608	-.670	.790	.014	-.049	.497	1		
Chlorophyll	-.175	-.532	-.488	.172	.381	.253	-.124	.030	.423	.244	.063	1	
TC	-.206	-.018	-.270	.330	.164	.860*	-.293	-.415	.591	.241	-.651	.478	1
FC	-.198	-.621	-.101	-.428	-.068	-.109	-.401	.576	.004	-.277	.119	.781	.016

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).