

**ENVIRONMENTAL AND SOCIOECONOMIC IMPACTS OF CAGE  
AQUACULTURE AT KPEVE TORNU SECTION OF THE VOLTA LAKE**

**BY**

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**THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN  
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**INTEGRI PROCEDAMUS**

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## DECLARATION

I hereby declare that this piece of work has been done entirely by myself under the supervision of Dr. Ted Yemoh Annang and Dr. Benjamin D. Ofori, and has never been previously submitted for any other university degree or qualification. All sources of information presented in this thesis have duly been acknowledged.

..... Dated .....

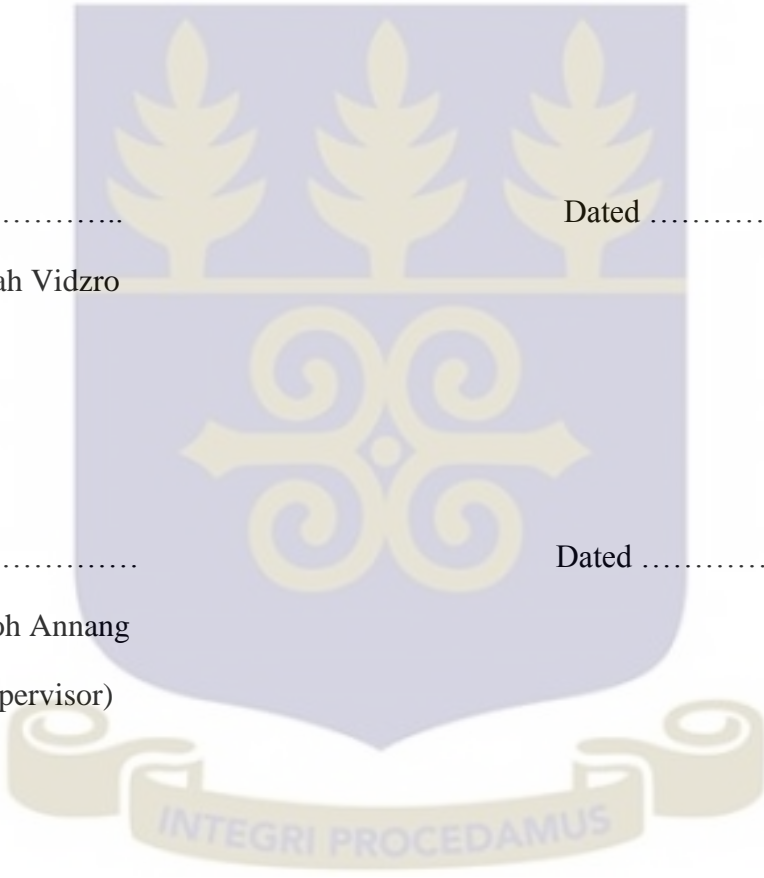
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## DEDICATION

To all who contributed positively to making this work a success.



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## ABSTRACT

Cage aquaculture involves fish farming in floating cages in an existing water body that permits exchange of water, nutrients and waste materials between the cage and the water environment. While some experts claim that cage aquaculture negatively impacts on water quality, others found no significant impacts of fish farming in floating cages on water environment. While information on cage aquaculture abounds in some countries to enhance the industry, little information exist on the impact of cage aquaculture on the Volta Lake. Adequate data on the financial viability of cage aquaculture in Ghana is limited, and little is also known of the effects of fish farming on the Volta Lake on fishing communities. Information on compliance levels of fish farm owners on aquaculture regulations is also not much known.

The study therefore sought to examine these relevant issues at Kpeve Tornu, a fishing community in Afadjato South District in the Volta Region. Laboratory analysis of physicochemical parameters indicated that there were no significant differences between water quality parameters from four fish farms and two control sites. A cost-benefit analysis on five cages of volume 360 cubic meters each was 1.34 in the first production cycle and a gross margin of 104.41 percent in the second production cycle indicating that cage aquaculture business in Ghana was financially viable. The cage aquaculture business also impacted positively on the livelihoods of the people of Kpeve Tornu in areas of employment, poverty alleviation, trade and food security. Cage fish farm owners did not comply fully with aquaculture regulations. Aquaculture regulations were effective on fingerlings and aquaculture related chemicals producers, but the regulations on fish farmers needed a review since there were no definitions for intensive and semi-intensive fish farming in the aquaculture regulations of Ghana.

The study recommends that a research be conducted into the impact of stocking density in cage aquaculture environments to prevent deterioration of water quality in the near future. A research into sediment chemistry, zooplankton assemblage, impact of escaped fish on local species, management of hormones by fingerlings producers and the concentration of canola oil were also recommended.



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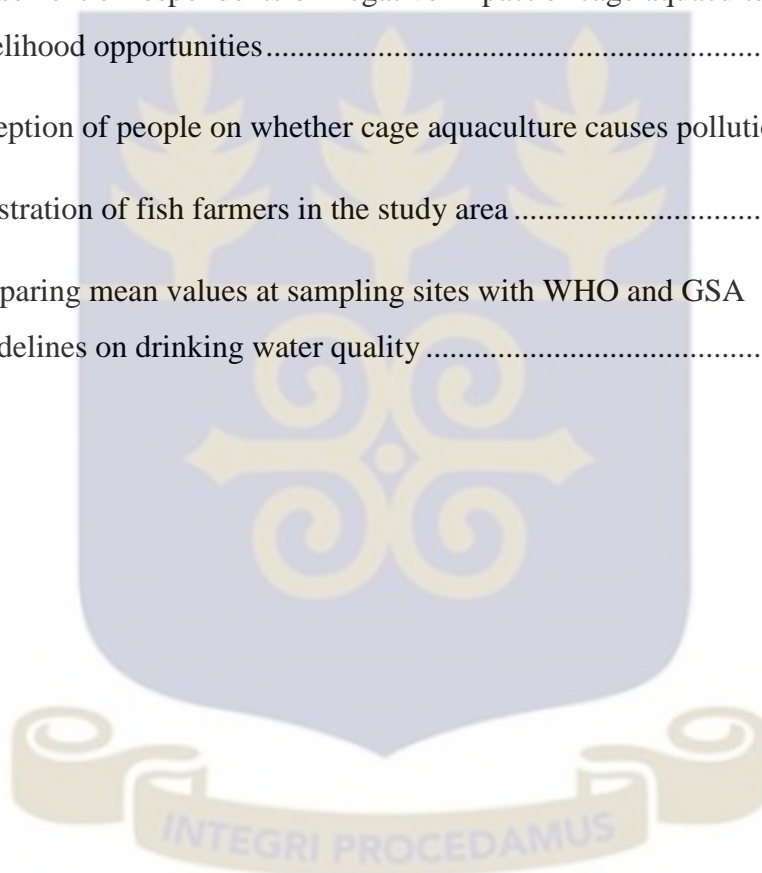
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## CHAPTER ONE

### INTRODUCTION

#### 1.1 Background to the study

Cage culture is defined by Bocek (n.d.) as the method of raising fish in an enclosed container that holds the fish in an existing water body while permitting water exchange and waste removal into the surrounding water body. According to the United States Department of Agriculture (2009), cage culture is a form of aquaculture by which fish are raised commercially in cages. The definition implies that cage culture takes place in an existing water body, such as lakes, rivers, lagoons and seas. Cage culture also shares an existing water body with other users like fishermen, riverine communities and water transport operators.

Cage culture is highly advantageous for various reasons. Fish can be confined in cages for easy feeding, monitoring, harvesting and for other management purposes (US Department of Agriculture, 2009).

According to Beveridge (1987), cage aquaculture (fish farming in floating cages) is commonly practiced worldwide in both freshwater and marine environments, including open ocean, estuaries, lakes, reservoirs, ponds and rivers. However, Beveridge (1987) maintains that the environmental impacts of cage culture are often ignored and rarely subjected to research or investigation.

In Ghana, cage culture (though at a developmental stage) plays an increasingly important role for fish production, which involves many small-scale farmers, private individuals, investors, private companies and some local institutions. Historically, culture-based fisheries

in Ghana started during the water conservation program which the colonial government of Ghana started in the 1940's in the northern regions of Ghana (Macpherson and Agyenim-Boateng, 1991). This was to supplement national fish demand and increase livelihood opportunities (FAO, 2013).

Fish farming (aquaculture) has greatly contributed to the economy of Ghana. It is estimated that 10 percent of the population is involved in the fishing industry from both urban and rural areas and women dominate the post-harvest activities, according to FAO (2005). Even though the majority of cage farmers operate on small scale, farmers consider fish farming as a source of income and therefore fish produced are mainly sold as opposed to being consumed by the fish farmer's family. In addition, aquaculture also provides employment for family members and neighbours (FAO, 2005). Other opportunities for value-addition that have been identified include fish processing such as frying, salting and smoking, which are done in the villages (FAO, 2013).

In spite of the economic benefits of cage aquaculture, it has serious environmental concerns (Guo and Li, 2003). Water pollution, for example, has become an environmental concern, and this threatens the survival of humans and other life forms though access to water in adequate quantity and quality is a basic human requirement.

Water pollution, according to Hart (2009), is the contamination of water by foreign matter such as microorganisms, chemicals, industrial waste, heavy metals, hazardous waste, sediment or sewage which deteriorates the quality of the water and renders it harmful to living things. Water pollution arises from the discharge of industrial, agricultural and human wastes into freshwater, estuaries and seas. This may result in poisoning of aquatic

organisms or the depletion of oxygen owing to the excessive growth of micro-organisms which makes the water less habitable for fish (Bell, 2006). Applin (1994) contends that water pollution leads to eutrophication, diseases and death of living organisms.

Fish farming in floating cages has implications for water quality. Phuong (1998) observes that cage cultured fish are entirely dependent on formulated diet and the waste produced from this consumption is released directly into the water body. Consequently, Pillay (1992) writes that cage culture contributes nutrients, organic matter (Biochemical Oxygen Demand), and turbidity which result in the deterioration of water quality and biota downstream. In their contribution to cage culture and waste produced in surrounding waters, Cowey and Cho (1991) stated that the quantity of wastes discharged from a fish cage depends on the quantity and quality of feed inputs. Since formulated feed are relatively of considerable amounts of protein and carbohydrate, nutrient loading from the culture of Nile tilapia waste is likely to be high in cages. Waste in the form of organic matter, particulate matter and suspended solids may result in major heavy sediment accumulation and Biochemical Oxygen Demand near the site of cage culture systems (Ali *et al.*, 2006).

According to Pallerud and White (2005), only 40% of inputs are utilized by cage fish as the rest enter the environment as organic sediment and dissolved nutrients. While research has been done on seed propagation and diet formulation for cage aquaculture, little effort has been expended on mitigating environmental impacts and improvement of water quality (Beveridge, 1987) to ensure sustainability of cage culture in countries like Ghana.

As a result of rapid expansion in cage culture project in Kpeve Tornu section of the Volta Lake, water quality was feared to have deteriorated to affect other users of the lake in the

area. It is also interesting to note that the establishment of fish cages at Kpeve Tornu section of the Volta Lake had raised concerns of water pollution since majority of the people of the host community depended on the same water source for purposes like drinking, washing, cooking, transportation, fishing and entertainment. Another worthy point to note is that the Kpeve Headwork, a facility of the Ghana Urban Water Company, draws water from the vicinity of the cage culture area for treatment for consumers in four different administrative districts in the Volta Region.

It was therefore prudent to study into the environmental and socioeconomic impacts of the cage culture system to establish the level of pollution (if any) in the surrounding waters to inform decision making. It was also necessary to investigate the socioeconomic impacts of the project on cage farmers (investors) and the local people. It would also be beneficial to investigate environmental regulations adopted by cage farmers and authorities to ensure environmental safety.

## **1.2 Problem statement**

### **1.2.1 Socio-economic importance of cage aquaculture**

The development of cage aquaculture has the potential of contributing more to meeting the fish demand in Ghana in addition to providing employment, earning foreign exchange as well as improving the financial status of cage fish farmers. Fish farming in floating cages in Ghana will also improve the nutritional status of many Ghanaians.

Heck *et al.* (2007) observed that the current capture methods from freshwaters have depleted natural supplies, and suggest that aquaculture could serve as a way to fill the existing global gap between supply and demand. The FAO 2007 on the state of the world

fisheries and aquaculture report indicates that worldwide aquaculture output has more than quadrupled since the year 1985 and more than doubled in the last decade, and reaching 62.9 million tons in the year 2005. This statistics indicate that aquaculture has the potentials in supplying the world with its protein needs in adequacy in the not too distant years if the growing trend is maintained.

In 2004, average consumption of fish per capita in Ghana was estimated at 27.2 kilograms (FAO, 2005). Brummet, *et. al.* (2009) observed that aquaculture provides food security for many Ghanaian small farmers since it constantly supplies protein for the people. According to Aggrey-Fynn (2001), Ghanaians regard fish as the most important source of animal protein in their daily nutritional requirements. This is because fish is relatively cheaper in terms of price and requires relatively cheaper preservation technologies such as drying, salting and smoking, compared with other sources of animal protein including milk, egg and meat. Fish is therefore regarded in Ghana as a very important part of the daily nutritional requirements for many people due to its unique advantages over other sources of protein available in Ghana.

Aquaculture provides significant income for fish farmers in Ghana. Ofori *et. al.*, (2009) report that fish farmers in Ghana who averagely produce 20 tons per month all year round earn significant amount of income indicating that large scale aquaculture is financially viable in Ghana. In Ghana, fish farming provides food security, income and employment for family members and neighbours (FAO, 2005).

### **1.2.2 Potential environmental and socio-economic effects of cage aquaculture at Kpeve Tornu**

In spite of the socioeconomic gains of aquaculture, the development of the cage culture system at Kpeve Tornu is likely to be associated with a few problems including user conflicts. Environmental and socioeconomic impacts are likely to arise from the activities of cage farmers.

Increase in the level of pollutants from fish cages may lead to an increase in water treatment cost as the Ghana Water Company continues to source water from the vicinity of the cage culture area for commercial purposes. There are undocumented evidences that the Ghana Water Company complains of poor water quality due to the activities of the fish farmers close to the intake points. This problem will likely affect consumers of treated water since water quality in aquaculture systems is affected with physical as well as chemical factors which include low or high dissolved oxygen, high concentration of ammonia, nitrate and hydrogen sulphide (Krom, *et al.*, 1985).

Nutrients load from fish cages lead to increased algal bloom resulting in a depletion of dissolved oxygen and fish kills. Chen, *et al.*( 2000) proved that cage culture negatively impacts on water quality since it leads to significant increases in suspended solids as well as nutrients (such as phosphorus and nitrogen) and a substantial decrease in dissolved oxygen within the vicinity of the cage culture areas (Chen, *et al.*, 2000). This implies that cage culture has serious environmental effects on existing water quality. Cage culture according to Beveridge, (1995) leads to a reduction in dissolved oxygen and increases biological oxygen demand and nutrients such as phosphorus, organic and inorganic nitrogen as well as carbon in the water column in the cage culture area. In their contribution, Guo and Li (2003)

write that an increase in the quantity of nutrients in surrounding waters is associated with the establishment of intensive cage culture system. They maintained that the increase in the quantity of nutrients also results in an increase in phytoplankton biomass also resulting in a high population of herbivores invertebrates. Krom, *et. al.* (1995) observed that mass aquatic mortality is likely to result from an excess or shortage of dissolved oxygen in cage culture areas, thus, leading to a deteriorating of water quality.

The livelihoods of the people at Kpeve Tornu are under threat as their main source of water is likely to be polluted. This is because many of the inhabitants largely depend on the lake for their livelihoods. The lake water is used for various purposes such as drinking, fishing, transportation, among others. Krom, *et al.*(1995) were with the view that problems with water quality in aquaculture systems are associated with both physical and chemical factors such as low or high dissolved oxygen, high concentration of ammonia and nitrate as well as an increase in the levels of hydrogen sulphide. This situation leads to the deterioration of water quality.

There is the fear that pollutants from floating fish cages may increase the population of schistosomiasis as the area is highly endemic with urinary schistosomiasis (*Bilharzia*) being the upstream of the Volta Lake (Béné and Russell, 2007). Pollutants from fish cages will lead to eutrophication which affects water quality. Tundisi (2003) reported that environmental impacts of cage aquaculture result in eutrophication and zooplankton assemblage. Yucel-Gier *et. al.* (2007) confirmed that cage culture results in eutrophication which is a major environmental problem that causes alteration in benthic assemblage in adjacent water column and sediments. There is therefore the need to study the environmental and socioeconomic impacts of cage culture to establish carrying capacity in

cage culture areas to prevent the deterioration of water quality in the study area. Guo and Li (2003) write that an increase in the quantity of nutrients in surrounding waters is associated with the establishment of intensive cage culture system. Islam (2005) also reports that excess feed and waste are directly released into the immediate water body, and also estimates that out of every ton of fish produced in cage culture, 132.5kg of nitrogen and 25.0kg of phosphorus is released into the water environment. Tilapia cage on the other hand has been reported to lose 81-90% carbon from the cage into surrounding water environment (Gondwe, *et al.*, 2011). The establishment of carrying capacity is possible based on pollution estimates of experts.

In conclusion, cage culture contributes largely to the socioeconomic growth of a country in terms of food security, employment and income. In spite of these, it has serious implications on our environment and livelihoods of people in caged farming areas. There was therefore the need to establish carrying capacity in the fish farming areas to minimize or prevent its negative impacts.

### **1.3 Objectives**

To achieve the purpose of this study, environmental and socioeconomic impacts of cage culture business have been considered. Brugère *et al.* (2010) suggest that in planning aquaculture projects to achieve long-term sustainability, environmental, economic and social dimensions must be involved to ensure that it contributes to poverty alleviation and economic growth. In their report, Fezzardi, *et al.* (2013) maintain that indicators of sustainable aquaculture projects should take into consideration the following dimensions: economic, social, environment and governance.

The general objective of this study is to assess the environmental and socio-economic impacts of cage aquaculture at the Kpeve Tornu section of the Volta Lake.

#### **1.4 Specific objectives**

The study aims at achieving four main specific objectives.

- 1) Assess the concentration of pollutants from fish cages into the lake.
- 2) Estimate the cost and returns (cost-benefit ratio and gross margin) associated with the cage culture business in the first and second production cycles respectively.
- 3) Determine the socioeconomic impacts of the cage culture project on the livelihoods of people in Kpeve Tornu Community.
- 4) Assess the compliance levels of fish farmers with aquaculture regulations.

#### **1.5 Research questions**

The study aims at finding answers to four main questions.

- 1) To what extent does cage aquaculture impact on lake water quality?
- 2) Does cage culture business provide significant source of income for farmers (investors)?
- 3) How does the cage culture project impact on the livelihoods of the people in the communities close to cage culture areas?
- 4) Will aquaculture regulations adopted by authorities adequately minimize environmental, economic and social impacts of cage culture in the study area?

## 1.6 Hypotheses

1. There is significant impact of cage culture on lake water quality.
2. There are financial gains in cage culture business.
3. Cage culture project at Kpeve Tornu has positive impacts on the livelihoods of the people in the community.
4. Aquaculture regulations adopted in cage culture area adequately minimize impacts on water quality and people's livelihood.

## 1.7 Significance of research

The US Department of Agriculture (2009) explained that limited research on cage aquaculture was conducted owing to the fact that the open culture system of fish farming was more economical thus making researchers focused their efforts on the open culture system.

There is little information on the impacts of cage culture on the Volta Lake (the largest man-made lake in the world). Little is also known of the financial viability of cage culture in Ghana (Asmah, 2008), and its impacts on the livelihoods of people in communities close to cage culture areas. This piece of work focuses on providing information on these areas to researchers, the government, investors and small scale startups.

The cage culture of tilapia originated in recent years (mainly 2000 onwards) in Ghana and has spread widely along the Volta Lake. One of the best known areas for intensive tilapia production from cage aquaculture is Kpeve Tornu in the Volta Region where production started approximately in the year 2009 with 5 cages, and increased to 682 cages as at January, 2014. The total fish production is on the increase as more investors arrived at the

bank of Kpeve Tornu section of the Volta Lake where tilapia cages were concentrated. The study therefore seeks to assess the environmental and socio-economic impacts of fish farming activities in the study area.

Since the proliferation of 5 cages in 2009 to 682 cages in January, 2014, there is no known scientific study conducted on the environmental aspects of the cage culture operation in Kpeve Tornu section of Lake Volta. Hence, this study is intended to contribute knowledge with regard to the establishment of the cage fish farm and its financial viability, impacts on water quality and livelihoods of the people, and adoption of environmental regulations to minimize water pollution and socioeconomic impacts.

Specifically, the results of this research would provide useful information on the financial viability of cage culture for investors and farmers, and for better management of their cages with regard to water quality and hydrological parameters. It would also enable authorities and managers to estimate carrying capacity of the cage culture area, which is essential to allow governmental agencies (Volta River Authority, Environmental Protection Agency, Fisheries Commission and local assemblies) to establish sustainable policy and plans for cage culture development in Ghana. The research findings would provide some evidence on the degree of water quality deterioration in the cage culture area. This is highly important because majority of inhabitants of Kpeve Tornu still depend on the lake for domestic uses, among others. The Ghana Urban Water Company which sources water from the vicinity of the cage culture area for treatment and distribution to consumers in four administrative districts in the Volta Region will be well informed on the impact of. The findings would be used to educate people in the community on the need to consume good drinking water. Findings and recommendations would also encourage further research into lake water

sediment chemistry and drinking water quality in the area as well as the incidence of bilharzia in the study area.

### **1.8 Justification**

Water resources improperly managed can die. A case in point is the Thames River which died due to the continuous release of pollutants into the water body. It is however important to continuously monitor a similar resource like the Volta Lake so as to identify gradual changes in quality especially where there have been records of increase in cage aquaculture business. To ensure the sustainable utilization of the lake this study will identify key shortfalls in enforcement and compliance of aquaculture regulations so as to make timely interventions in saving the environment.

The calls by government to invite individual and investors into the aquaculture industry to meet national demand for fish may be a recipe for disaster if continuous monitoring is not done on farm owners who are driven more by profits than compliance to regulations especially in a poorly regulated environment. This may imply that farm owners will take undue advantage of the situation to do whatever they want. This study will provide important information for decision makers on investment ventures in cage culture business and the current farm management practices.

## CHAPTER TWO

### LITERATURE REVIEW

#### 2.1 Aquaculture and food security

FAO (2002) in a report indicated that the introduction of new techniques and new species has largely contributed to an increase in aquaculture production from less than 10 million tons in 1989 to more than 24 million tons in 2001. Cage culture, the farming of aquatics in nets and cages, is widely spread around the world. This obviously is in response to high demand for fish coupled with the performance of captured fisheries being below expectation. Estimated records show that tilapia, milkfish, carps, marine mollusks and catfish contribute 80 percent of the global aquaculture output totaling 29 million tons in 1997, according to Naylor *et al.* (2000).

Enell (1995) also reports that there has been a steady development of fish farming over the last few decades with regards to the feeding and farming technology as well as the increase in production quantities. Enell (1995) again estimates that between 1974 and 1994, aquaculture production increased from 15,800 to about 250,000 tons annually in the Nordic countries adding that commercially, over 50 fish species are now in use for cage aquaculture worldwide. His claim suggests a rapid increase in the number of species being introduced into the aquaculture industry.

According to Naylor, *et al.* (2000), aquaculture is a fast-expanding mode of production in the world. It has also been estimated by Naylor *et al.* (2000) that fish farming accounts for a quarter of the total fish directly consumed by humans, using shellfish and finfish species. Global aquaculture has also doubled in recent years (Naylor *et al.*, 1998). Aquaculture

worldwide therefore seems to be competing favorably with captured fisheries to meet the demand of the growing world population.

Globally, fish provides more than 1.5 billion people with almost 20 percent and 3.0 billion people with at least 15 percent of their average per capita intake of animal protein (FAO, 2012). Fish products can therefore be valued as of high demand worldwide as a significant size of the population depends on it for their daily food intake.

The United Nations Food and Agricultural Organisation reports that aquaculture is a fast growing industry, and more rapidly than all other animal food-production sectors in the world (FAO, 2012). The report states that the contribution of aquaculture to global supplies of several species of fish, mollusks and crustaceans increased from 3.9 percent of total production by weight in 1970 to 33 percent in 2005 (FAO, 2012). It has also been estimated by the Food and Agriculture Organisation (FAO) that fisheries and aquaculture supplied the world with about 110 million metric tons of food fish per year providing per capita supply of 16.7 kilograms. Forty-seven (47 %) of this supply is contributed by aquaculture (FAO, State of the World Fisheries and Aquaculture 2010). This suggests that aquaculture is becoming a more concentrated industry with much more farms.

Heck *et al.*, (2007) observes that current capture methods from freshwater have depleted natural supplies, and suggested that aquaculture could serve as a way to fill the existing global gap between supply and demand. This suggestion is perhaps in response to the observed level of depletion of fish resources and high demand of fish products in the face of growing population.

In 1997, FAO predicted that fish supplies from traditional marine and inland capture fisheries were unlikely to increase substantially in the future and aquaculture production will therefore need to rise significantly to help satisfy growing global demand for fisheries products (FAO, 1997). This prediction was based on the observed level of natural fish stock depletion and global population rise.

Studies on the future global demand for, and supply of, fish and fishery products predict the continued expansion of aquaculture, due to the stagnation of worldwide output from the commercial fisheries (Brugère and Ridler, 2004; Delgado *et al.*, 2003; Ye, 1999). These studies reveal the inability of the captured fisheries industry to meet global demand for fish products, and confirm aquaculture as the surest alternative to address the situation.

Capture fisheries production worldwide, in 2008, was about 90 million tons and landings have not shown any significant increase in the past decade. Aquaculture, on the other hand, is a fast growing industry worldwide and accounted for about 47 percent of total food fish supply globally. Total production from global fish industry increased at an average rate of 8.3 percent per annum and reached 52.5 million tons in 2008 valued at US\$98.4 billion according to FAO report (2012).

Diana (1993) and FAO (2005) agreed that the production in capture fisheries has become relatively stable over recent years, whereas aquaculture is the fastest-growing food production system worldwide, with an increase in the production of animal products of about 9 percent per annum since the year 1985. This agreement confirms the fact that the growth of the fish farming industry is at a fast rate.

In summary, aquaculture has immensely contributed to worldwide supplies of aquatic animals such as fish, mollusks, and crustaceans. The industry has also increased geometrically in recent years. For example, while aquaculture contributed only 3.9 percent of global output by weight in 1970, its contribution in 2000 was 27.1 percent and forming one-third of global production by weight in 2004 which is 32.2 percent. Comparatively, aquaculture has grown rapidly more than any other animal production sector (FAO, 2007). While the average growth rate in aquaculture since 1970 records 8.8 percent per annum, the rates from capture fisheries and terrestrial farmed meat production sectors have been 1.2 percent and 2.8 percent respectively during the same period under investigation. The depletion of fisheries resources in natural waters renders the fisheries industry unable to meet global demand for fish products. Aquaculture can therefore be rated as a major option to ensure food security in the world.

## **2.2 Overview of Aquaculture in Ghana**

Brummet, *et al.*(2009) observe that aquaculture which is a means of producing fish for consumption provides food security for many Ghanaian small farmers since it constantly supplies protein for the people. According to Aggrey-Fynn (2001), many people, example Ghanaians, regard fish as the most important source of animal protein in their daily nutritional requirements. This is because fish is relatively cheap, and requires relatively cheaper preservation technologies such as drying, salting and smoking, compared with other sources of animal protein including milk, egg and meat. In 2004, average consumption per capita in Ghana was estimated at 27.2 kilograms (FAO, 2005). Fish is therefore regarded in Ghana as a very important part of the daily nutritional requirements for many people due to its unique advantages over other sources of protein available in Ghana.

Aquaculture provides significant source of income for fish farmers in Ghana. Ofori, *et al.*,(2009) report that farmers in Ghana who averagely produce 20 tons of fish per month all year round earn significant amount of income through aquaculture business. This is an indication that large scale aquaculture is financially viable in Ghana.

In Ghana, fish farming provides food security, income and employment for family members and neighbours (FAO, 2005). Fish processing such as smoking, salting and drying mainly provided by women in rural areas add value to captured fish. In 2004, national production from aquaculture yielded 950 tons, according to estimates, and worth US\$ 1.5 million. Aquaculture is also said to contribute largely to employment, food security and poverty alleviation. However, there is lack of accurate and reliable data on the various benefit components of aquaculture in Ghana (FAO, 2005).

Historically, aquaculture (fish farming) started in Ghana when the former Department of Fisheries began to build fishponds (precisely in 1953) in the northern sector of Ghana presently comprising the three northern regions (Northern, Upper East and Upper West). The fishponds were to produce fingerlings to boost the then aquaculture-based reservoir fisheries development programme initiated by the British colonial administration aimed at supplementing national fish demand of Ghanaians and to increase livelihood opportunities (FAO, 2005). In the 70s, General Kutu Acheampong launched Operation Feed Yourself (OFY) and Operation Feed the Nation (OFN) programme to increase agriculture productivity and to ensure food security in the country. The decision was to help overcome our chronic protein deficiency in Ghana. Fish farming was encouraged to increase fish productivity in Ghana (Sakyi, 2012,) (unpublished data).

Aquaculture is still at a developmental stage in Ghana. The recent development is to ensure that the country meets its shortfall of domestic consumption needs, and for export (Aggrey-Fynn, 2001). Commercial production is a recent development to increase production in an attempt to meet national demand (FAO, 2005). Another policy objective is to ensure that the Ghanaian fish farmers produce to meet at least 60 percent of the country's protein intake (Aggrey-Fynn, 2001). However, there has not been any appreciable increase in production to achieve the purpose of aquaculture development in Ghana. For example, Ghana produced only 51.7 percent of national fish demand through domestic production in 2004 while achieving 68.1 percent in the following year (2005) jointly through domestic production and imports (FAO, 2005).

Nile tilapia (*Oreochromis niloticus*) is the major fish species cultured in Ghana constituting a little over 80 percent (760 tons) of total farmed fish production with other species mainly the catfishes (*Clarias gariepinus*, *Heterobranchus bidorsalis*) and (*Heterotis niloticus*) forming the remaining 20 percent (190 tons) based on Department of Fisheries and FAO (2005) estimates.

After Ghana's independence in 1957, the state government initiated a policy to convert 5 percent of all state-owned irrigation facilities into a fish farming project. The adopted policy was to develop fishponds within all irrigation schemes in independent Ghana (FAO, 2005).

In recent years, the technology of aquaculture has improved tremendously. This can be seen in areas such as fingerlings production, improved pellet feed and water quality management (FAO, 2005). Relevant researches are also underway to develop aquaculture in Ghana.

In conclusion, aquaculture is very significant in the socioeconomic aspects of Ghana. It provides employment, food, income and foreign exchange for Ghanaians. Due to its tremendous role in Ghana's economy, attempts were made since pre-independence era to develop aquaculture in Ghana. However, aquaculture development in Ghana has not yielded the expected results in meeting the total fish needs of Ghanaians. Efforts are underway to improve cage culture on commercial basis to increase production of fish species such as Nile tilapia and catfishes which are mainly cultured in Ghana.

### **2.3 Cage culture: definition, history and importance**

Cage culture is defined by Bocek (n.d.) as the method of raising fish in an enclosed container that holds the fish in an existing water body while permitting water exchange and waste removal into the surrounding water body. The definition implies that cage culture must essentially take place in an existing water body, examples, lakes, rivers, lagoons and seas.

Beveridge (1996) reports that cage aquaculture is an old farming practice dating back to the 10<sup>th</sup> century when Chinese fishermen began to fatten fish fries in small cages made of simple local materials such as bamboo sticks and baskets. Cage culture according to Beveridge (1996), started developing with considerable expansion a few decades ago particularly during the late 1980s. This implies that China a Southeast Asian country is recognized as the region where cage culture began. It also shows that even though cage culture is an ancient practice, it did not develop until in recent years.

According to the United States Department of Agriculture (2009), the origin of cage culture is not well known, but believes that the first true cages were raised by Southeastern Asian fishermen around the end of 19<sup>th</sup> century. These cages were made of bamboos or wood as

the fish were fed with food scraps. The Department maintains that modern cage culture began with the introduction of synthetic materials suitable for the construction of durable cages (USDA, 2009). The view of the USDA is an indication that different records on the origin of cage culture provide different origins of cage aquaculture, or record no specific origin of the fish farming method. It is interesting, however, to note that the same Department mentions Southeastern Asia as the location where well identified cages were employed to culture fish (USDA, 2009).

Hu, (1994) writes that fish cage culture originated in the Chinese Yangtze Delta approximately 760 years ago. Hu's attempt to list the specific location where cage culture began is to highlight China as the origin of cage culture.

Bocek (n.d.) records that Southeast Asian fish farmers started cage aquaculture purposely to hold their fish catches alive for short periods of time, and also increase their sizes – a technology that dates back as early as 1900s. Bocek's claim supports the age-old practice as originating from Southeast Asia.

According to Beveridge (1984, 1996), cage culture has numerous advantages over the conventional land based aquaculture systems such as fish ponds. He maintains that cage aquaculture is fast becoming very popular among fish farmers since it requires comparatively low investment and usage of simple technology. Cage culture systems do not use organic and inorganic fertilizers containing nitrogen and phosphorus as it is with other land based aquaculture systems, but it employs the use of feed containing higher nutrient contents of nitrogen and phosphorus (Ackefors and Enell, 1990).

Cage culture is also very advantageous due to high market value for cultured fish, availability of improved feed and fingerlings and water quality conditions. The growth and expansion of cage aquaculture in recent decades is largely due some factors. Aquaculture has high market value and demand for cultured fishes worldwide. There is an improvement in technology for cage culture in various oceanographic conditions and offshore areas. Availability of suitable coastal areas for cage culture around the world is a strong factor that favours aquaculture development. Availability of technical support and good quality inputs such as feed and fry also contributes to the fast rate of aquaculture development (Eng and Tech, 2002).

The benefits of cage culture include increases in farm productivity and profitability without any net increase in water consumption (Ali *et al.*, 2006). This assertion implies that cage aquaculture facilitates water management while enhancing economic viability.

Selock and Swann (1994) also enumerated some advantages of cage culture. Cage culture is an inexpensive method of aquaculture development. It is also easier to monitor the health and growth of fish. Harvesting is simple. Selock and Swann (1994) also listed that pond construction costs are eliminated when existing ponds are used.

To prove that cage aquaculture has some special benefits, the USDA (2009) also listed some advantages of cage aquaculture. Many different types of water resources can be used for cage aquaculture, including lakes, reservoirs, ponds, strip pits, streams, and rivers that could otherwise not be harvested. It requires a relatively low initial investment in an existing water body. The USDA (2009) stated that harvesting is very simple with cage aquaculture

making observation and sampling of fish easy. Sport fishing or the culture of other species is possible with the pond USDA (2009).

#### **2.4 Environmental impacts of cage culture**

Cage aquaculture impacts on water quality. Available studies conducted on the impact of cage culture on water quality indicate that there are significant increases in suspended solids as well as nutrients such as phosphorus, nitrate and nitrite and a substantial decrease in dissolved oxygen within the vicinity of the cage culture areas (Chen, *et al.*, 2000). The implication is that cage culture has environmental effects on existing water quality.

According to Gooley *et al.* (2000), cage aquaculture negatively impacts on freshwater bodies since it increases nutrients in the sediments as well as adds to water pollutants. Cage culture is therefore a fish farming practice that impacts negatively on water quality.

It has been reported by Vista *et al.* (2006) that the lakes of Philippines are constantly under serious threats of deterioration with a serious impact on the lakes ecosystem health. They mentioned factors threatening the lakes as heavy metal pollution, agricultural and domestic pollution, unregulated open fishing and more recently cage aquaculture. The reports also indicated that unconsumed feed from cages interact with other pollutants to endanger the whole ecosystem of the lakes. Between 1998 and 2001, there have been 38 reported cases of fish kills in Pilipino lakes (Dela Vega, 2001; Vista *et al.*, 2006).

Environmental impact of aquaculture largely depends on stocking density, fish species involved, feed type, culture method and hydrographic conditions of the cage culture site (Wu, 1995). Faeces production, feed wastage from unconsumed feed as well as fish

excretion largely contribute to most phosphorus, nitrogen and carbon inputs found in the fish culture system. Marte *et al.* (2000) also reported that when units of cage aquaculture are released into existing water column coupled with overfeeding of cultured fish, it leads to the deterioration of existing water quality. Cage culture in this sense can be managed to minimize environmental impacts. This can be done through the adoption of environmentally friendly technology and establishment of carrying capacity in the cage culture areas.

In fish cage culture system, the solid wastes in the form of uneaten feed, mucus and faeces as well as soluble wastes in the forms of phosphorus and nitrogen compounds are directly dispersed into the surrounding waters and this according to Demir *et al.* (2001) poses eutrophication risks. Other experts also observed that the main sources of ammonia, nitrites, phosphates and other inorganic substances are excretion of nitrogenous compounds by caged fish and microbial decomposition of leftover food and other forms of organic matter found in the caged environment (Neori *et al.*, 1989; Hall *et al.*, 1992). Méndez (2002) also reported that organic matter dispersion from cages into surrounding waters causes nutrient enrichment, with resultant changes in the number of species, the abundance of organisms, and biomass of the communities in the vicinity of cage farms.

Islam (2005) reported that excess feed and waste from fish cages are directly released into the immediate water body. He also estimates that out of every ton of fish produced in cage culture, 132.5 kg of nitrogen and 25.0 kg of phosphorus are released into the water environment. Tilapia cage on the other hand has been reported to lose 81-90 percent carbon from the cage into surrounding water environment (Gondwe *et al.*, 2011). It can therefore be deduced from this observation that factors contributing to environmental impacts of cage culture are substantial, and must be seriously considered. These factors can also be managed

through the establishment of carrying capacities in cage culture areas to ensure good water quality.

Cage culture leads to a reduction in dissolved oxygen and increases biological oxygen demand (BOD) and nutrients such as phosphorus, organic and inorganic nitrogen as well as carbon in the water column in the cage culture area (Beveridge, 1985). Ali *et al.* (2006) supported these findings by proving that there are significant differences between cage culture areas and non-cage areas on River Nile with respect to chemical water parameters. Their comparison shows that dissolved oxygen level decreases significantly in intensive cage areas compared to non-caged areas of the Nile River. Their findings also demonstrated that a significant increase in ammonia, total nitrogen, biological oxygen demand and total organic carbon in the surrounding floating cage areas.

The impact of intensive cage culture practices on the environment is very significant. Guo and Li (2003) in their report indicate that the quantity of nutrients in surrounding waters is associated with the establishment of intensive cage culture system. They maintained that the increase in the quantity of nutrients also results in an increase in phytoplankton biomass also resulting in a high population of herbivorous invertebrates. Krom *et al.* (1995) also reported that problems with water quality in aquaculture systems are associated with physical as well as chemical factors such as low or high dissolved oxygen, high concentration of ammonia and nitrate as well as an increase in the levels of hydrogen sulphide. They concluded that mass fish mortality results from an excess or shortage of dissolved oxygen since fish depends on dissolved oxygen.

Nitrogenous compounds such as ammonia (NH<sub>3</sub>), carbon dioxide (CO<sub>2</sub>) are normally found in the water column after a bloom of phytoplankton. During phytoplankton bloom and collapses, carbon dioxide and ammonia are released into the water column. Since freshwater has a low buffering capacity, the CO<sub>2</sub> lowers the pH of the water considerably, and eventually reduces the amount of ammonia (Tucker *et al.*, 1984).

Hankanson (2005) observed that the most important environmental impact of cage aquaculture is the increased nutrient availability. The impacts result in eutrophication and zooplankton assemblage (Tundisi, 2003). Tundisi (2008) and Matsumura-Tundisi (2008) enumerate the most affected ecological attributes resulting from nutrient loads from cage system into surrounding waters as species richness, composition diversity and abundance of zooplankton assemblages.

Yucel-Gier *et al.* (2007) in their observation pointed out that cage culture results in eutrophication which is a major environmental problem that causes alteration in benthic assemblage in adjacent water column and sediments. Garren *et al.* (2008) also observed that feed waste and fecal matter from fish cages are deposited into surrounding waters either as organic matter or soluble inorganic matter leading to a significant deterioration of water quality including a reduction in the level of dissolved oxygen and increased levels of turbidity.

In most cases, environmental impact of wastes from aquaculture operations are localized within areas less than 100 meters from the cage culture areas. Depending on the type of feed, water currents, among other factors, the impacts may be detrimental to the fish, and may also affect wild populations a few distance away (Chen *et al.*, 2000). However, Gowen

and Branbury (1987) observed that the effects of pollutants from aquaculture are limited to the immediate vicinity of the fish farms. This may be due to the dispersal of faecal matter and uneaten food from the cages (Frid and Mercer, 1987) since they increase turbidity.

The major sources of suspended solids in fish cage farms are faecal pellets and uneaten feeds which may be released from fish cages through the water column and deposited on water sediment (Nash, 2001; Winsby *et al.*, 1996). The quality and quantity of the suspended solids largely depend on the type or quality of feed which is dictated by factors such as nutritional requirements, the life stage of the cultured fish, technology involved in feed formulation, environmental conditions, the health status of the caged fish and management practices (Nash, 2001; Chen, 2003 and Crawford *et al.* 2002). For example, high energy feeds have been observed to be more environmentally friendly owing to lower nitrogen and carbon contents of faecal matter from fish cages attributable to high digestibility (Chen *et al.*, 2000). Also, higher stocking density poses the risk of environmental degradation as it increases solid wastes in fish farms (Forster, 2003).

A substantial amount of phosphorus is released into water column in fish cage farms. According to Guo and Li (2003), for every kilogram of fish produced in a cage, 35 grams representing 89 percent of phosphorus from feed is lost in cage polyculture of catfish and mandarin fish\_which were fed on fresh and dry feeds. This means a greater proportion of phosphorus in feed is underutilized by cage fish which is an obvious threat to water quality. Green *et al.*, (2002) in their report highlighted that soluble inorganic phosphorus is excreted by fish through urine. The concentration of phosphorus in freshwater contributes to algal bloom. Diaz *et al.* (2001) also claimed that phosphorus from fish cages resulted in changes

in water quality indicating that the release of phosphorus from fish cages affects water quality.

The loss of nitrogen from fish cages is quite substantial. Storebakken *et al.* (2000) reported that nitrogen loss from salmon cages amounted to 54 percent of total nitrogen intake with some 82 percent of the waste excreted in soluble form. They added that ammonia is one of the most common types of nitrogen waste released from salmon cage ranging from 65 - 90 percent. According to De la Vega (2001), unconsumed feed settle and degrade at cage bottoms which are degraded by microbes leading to increased ammonia that is toxic to fish embryo. Sumagaysay and Chavoso (2003) observed under laboratory conditions that milkfish excreted between 333 and 60.8 mg/kg/day of ammonia nitrogen in small and large fish respectively. Nitrogen in the form of ammonia and ammonium increase the growth of phytoplankton in fish cage farms (Winsby *et al.*, 1996; Nash, 2001). This is an indication that intensive cage culture poses environmental risks in fresh water.

Feed wastage, respiration of fish and re-release of pollutants from sediments may contribute to a depletion of dissolved oxygen in water column. There may also be a significant amount of oxygen consumed by fish under intensive cage farms. According to the Environmental Assessment Office of the British Columbia, Canada (1996), one cubic meter of salmon cage would demand 500 grams of oxygen per day since a 4kg salmon consumes 20g of oxygen per day. Winsby *et al.*, (1996) state in their record that dissolved oxygen in overlying waters at a fish cage farm is 30 percent lower than the level in undisturbed areas. It is significant, however, to note that the depletion of dissolved oxygen in fish cage farms is in most cases insignificant since water currents minimize the impacts (Brooks and Mahnken, 2003; Heining, 2000).

The acidity and alkalinity of a water body influences aquatic life. Pollutants from fish cages have the tendency to either increase or lower the pH of the surrounding water. Carbon, for example, reduces the acidity in water bodies. Gondwe *et al.* (2011) estimated that 81-90 percent of carbon is lost from tilapia cages into surrounding environment. This implies that carbon emissions from fish cages have significant influence on the acidity of the existing water body.

## **2.5 Legislative instruments governing fisheries and aquaculture**

There are laws that govern and regulate fisheries and aquaculture development in Ghana.

Notable among them are the Fisheries Act of 2002 (Act 625), Aquaculture Regulations of Ghana, 2010 (LI 1968), Environmental Protection Agency Act, 1994 (Act 490), Environmental Regulations Assessment, 1999, (LI 1652) and Public Health Act, 2012 (Act 851). Also worth mentioning are The Volta River Development Act 1961 Act 46 amended by Volta River Development (Amendment) Act, 2005 (Act 692) and the Abuja Declaration of Sustainable Fisheries and Aquaculture in Africa.

The Fisheries Act of 2002 (Act 625) is the main legislative instrument that governs fisheries activities and the practice of aquaculture in Ghana. The sections of Act 625 that are relevant with respect to environmental safety are as follows:

1. Section 60 of the Act deals with licences for aquaculture and recreational fishing in Ghana. The section makes it mandatory for all interested individuals in aquaculture projects to submit their application to the Fisheries Commission and accompany the application with an environmental impact assessment report.
2. Section 93 of Act 625 requires for Fisheries Impact Assessment. Subsection (1) of the Act makes it mandatory for any individual who wants to undertake any activity

other than fisheries but likely to affect fisheries resources in Ghana to inform the Fisheries Commission for prior approval before the commencement of the planned activity. Subsection (2) empowers the Fisheries Commission to prepare or commission reports and make recommendations that must be taken into account by the person, government department or other agency in the planning of the activity and in the development of means of preventing or minimizing any adverse impacts. Subsection (3) states that the Fisheries Impact Assessment is in addition to any other requirements of the Environmental Protection Agency.

3. Section 139 of Act 625 stipulates that the sector Minister (Minister for Fisheries and Aquaculture Development) may, on the recommendations of Fisheries Commission, establish regulations in relation to aquaculture development in Ghana. This section resulted in the establishment of the Aquaculture Regulations of Ghana, 2010 (LI 1968).

The Fisheries Act of 2002 (Act 625) is not explicit on legal rights, ownership and tenure as well as protection against other resource users such as fishermen, irrigation farmers and communities that largely depend on open water resources. The Act is also silent on relevant issues such as fish health, food or product safety and quality assurance.

Aquaculture Regulations of Ghana, 2010 (LI 1968) seeks to ensure sustainable development in the fish farming industry.

1. Regulation 52 of Aquaculture Regulations of Ghana, 2010 (LI 1968) requires an environmental permit from the Environmental Protection Agency in compliance with the Environmental Assessment Regulations, 1999 (LI. 1652) before an aquaculture or aquaculture related activity is undertaken. A water use permit is also required in accordance with the Water Resource Commission Act, 1996 (Act 522).
2. The Fisheries Commission is mandated by regulation 55 to enter any aquaculture facility to monitor and ensure compliance with the provisions of the Regulations.
3. Regulation 61(1a) issues a warning against environmental degradation resulting from aquaculture related activities.
4. Regulation 74(1) prevents the positioning of cages and the concentrations of aquaculture related structures from hampering navigation, water circulation and water quality.
5. The use of drugs and other chemicals in aquaculture establishments is only permitted under the approval of a veterinary officer. This regulation is specified under Regulation 75(1).
6. To ensure compliance, Regulation 71 provides penalty units against failure to take steps with compliance regulations. A fine of not more than one hundred and fifty penalty units or an imprisonment of not more than twelve months or both have been specified.

The regulations also ensure food safety and hygiene, respect for other users and record keeping. It is however silent over ownership and compensation rights and efforts to minimize socioeconomic impacts of aquaculture on communities close to aquaculture

establishments. The regulations also fail to define what it means by intensive and semi-intensive aquaculture projects making it easy for prospective fish farmers to refuse registration.

Environmental Protection Agency Act, 1994 (Act 490) and Environmental Assessment Regulations 1999 (LI 1652) function to regulate activities that ensure the safety of Ghanaian environment. The relevant sections are as follows:

1. The Minister responsible for the environment is empowered under section 28 of the Environmental Protection Agency Act, 1994 (Act 490), and on the advice of the Environmental Protection Agency Board, to make regulations for the conduct and submission of environmental impact assessment reports or statements. The outcome of this mandate is the Environmental Assessment Regulations 1999, (LI 1652).
2. Schedule 2, regulation 3 of the Environmental Assessment Regulations, 1999, lists land-based aquaculture as one of the undertakings that require a mandatory environmental impact assessment (EIA).
3. Schedule 5, regulation 30(2) contains the provisions to regulate the activities of cage culture. The regulation categorizes water trapped for domestic purposes, water within controlled or/and protected areas as well as water which supports wildlife and fisheries activities as environmentally sensitive areas that require mandatory EIAs before the commencement of any undertaking on them.
4. To ensure compliance with environmental regulations, the LI 1652 makes provisions for the possession of environmental permit (regulation 21), environmental certificate (regulation 22), environmental management plan (regulation 23), and the submission of annual environmental report (regulation 25) by the operator.

The two legislative instruments are effective in safeguarding the environment in response to fish farming activities.

The Public Health Act is purposed to revise and consolidate the laws relating to public health so as to prevent diseases, promote, safeguard, maintain and protect the health of humans and animals and to provide related matters. It empowers the Food and Drugs Authority to prevent the sale of unwholesome, poisonous or adulterated and unnatural substances and lays down penalties for breaching the state law.

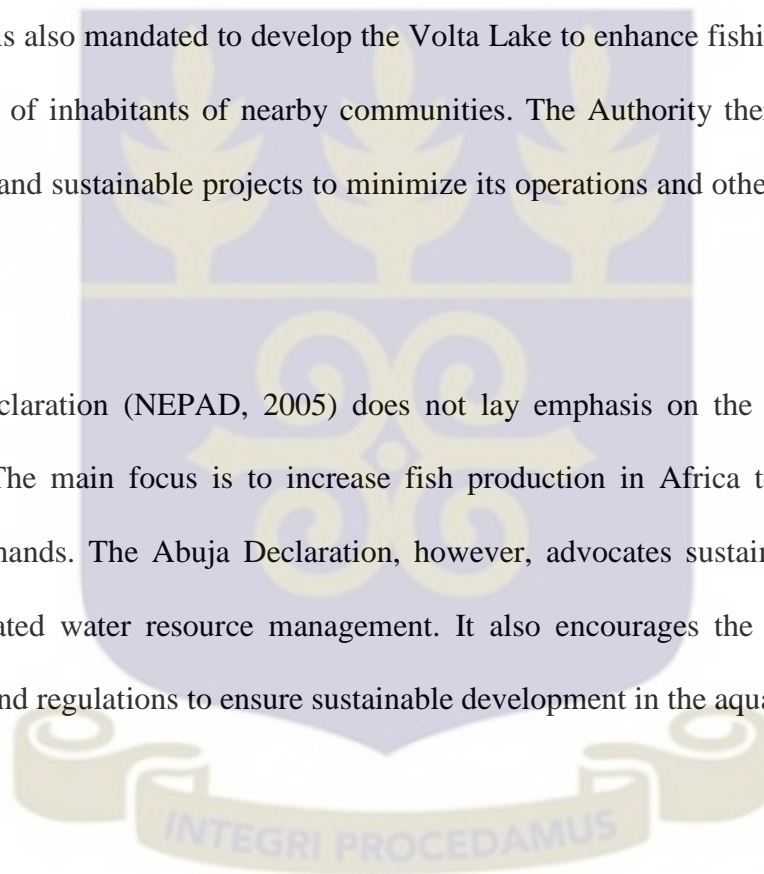
1. Section 51 of the Act prohibits the sale, serving or offering of food that is unwholesome or unfit for human or animal consumption.
2. Section 54 bars the pollution or fouling of a water resource that is used or intended to be used for human consumption. A person does so only under lawful authority.
3. Section 82 (a) mandates the Food and Drugs Authority to ensure adequate and effective standards for food, drugs, cosmetics, household chemicals and medical devices.
4. Section 100 (3) prohibits the sale of food that has in it harmful substances or unfit for human or animal consumption or adulterated or injurious to health.
5. Section 148 mandates the Food and Drugs Authority to issue regulations and codes of practice in connection with food and drugs and any other products or devices regulated by the Authority in food and drugs industry and the persons shall comply with the guidelines and codes of practice. The aim of this provision is to ensure the health of consumers of food and drugs products.

The Authority is however yet to initiate regulations in accordance with the Act. Penalty units specified in the Act are also attractive enough to deter offenders, if the provisions are effectively implemented.

The Volta River Development Act 1961 Act 46 amended by Volta River Development (Amendment) Act, 2005 (Act 692) mandates the Volta River Authority to develop the Volta Lake for fishing and transportation. Additionally, the Authority is to develop the lakeside area to enhance the health and well-being of nearby communities. The Authority therefore runs a well-equipped hospital and also handles relevant matters concerned with sanitation and public health through a Health Services Department.

The Authority is also mandated to develop the Volta Lake to enhance fishing, transportation and well-being of inhabitants of nearby communities. The Authority therefore carries out environmental and sustainable projects to minimize its operations and other activities on the environment.

The Abuja Declaration (NEPAD, 2005) does not lay emphasis on the protection of the environment. The main focus is to increase fish production in Africa to meet increased population demands. The Abuja Declaration, however, advocates sustainable aquaculture through integrated water resource management. It also encourages the use of local and regional laws and regulations to ensure sustainable development in the aquaculture industry.



## CHAPTER THREE

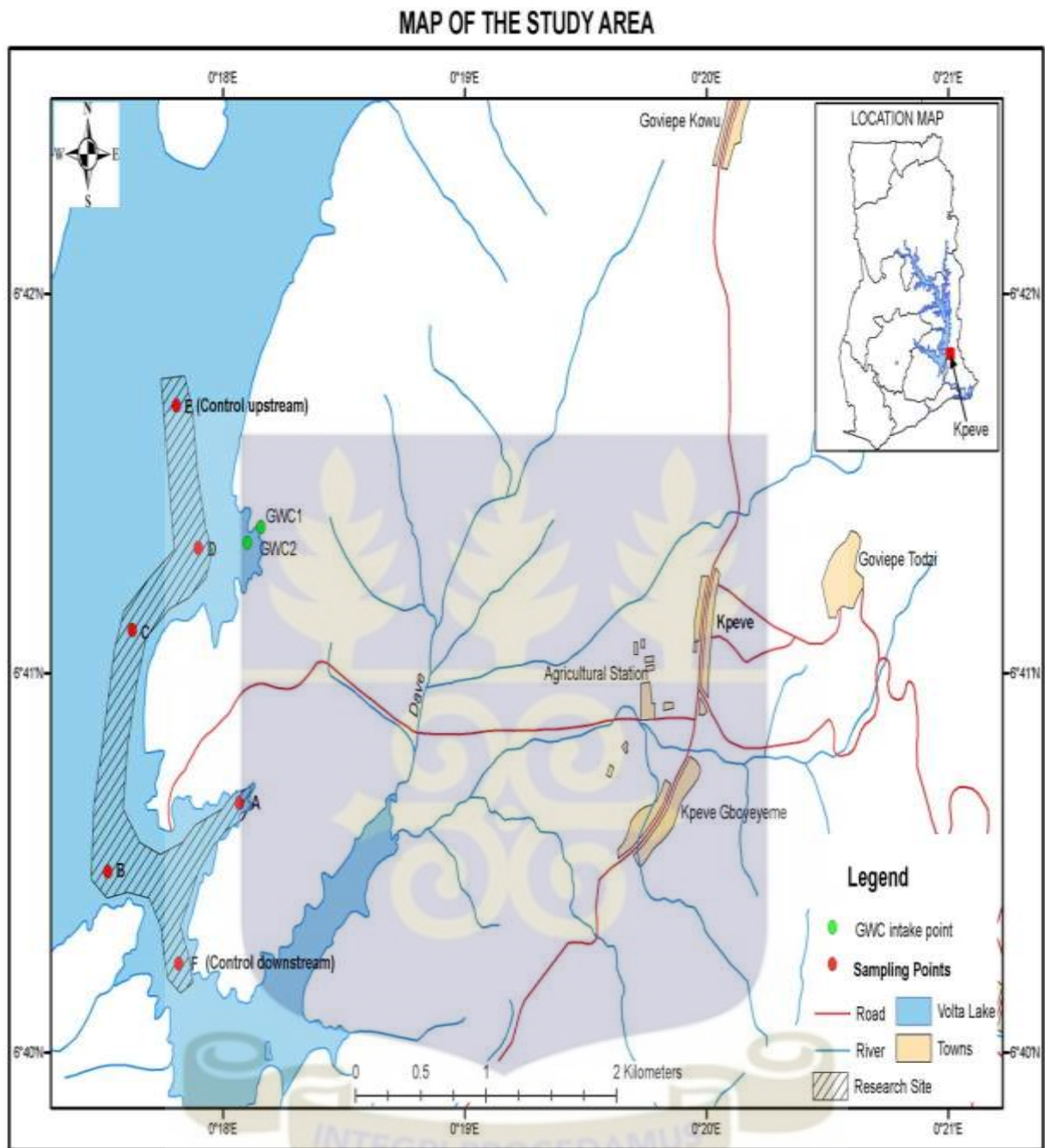
### METHODOLOGY

#### 3.1 The study area

##### 3.1.1 The profile of Kpeve Tornu Community

Kpeve Tornu is a small fishing community located on an inlet of the Volta Lake found at south-eastern part of Afadjato South District in the Volta Region of Ghana. The most conspicuous physical features of the area are the Akwapim-Togo-Atakora ranges which form the eastern boundaries between Afadjato South and Ho West Districts, south of latitude 3.028°N.

The population of the people in the community as at September, 2010 was 721 and estimated at 763 as at September, 2013 based on the District population growth rate. Adult population was estimated at 412 based on the District estimate of 54 percent. The percentage sex distribution was 48.5 percent totaling 200 for males with female population forming 212 representing 51.5 percent. Majority of the people engage in fishing activities for their livelihood. Trading and peasant farming also form parts of their livelihood activities. The livelihoods of the people largely depended on the Volta Lake as it was their main water source for drinking, washing, cooking, fishing, recreation, among others. Kpeve Tornu is a settler community inhabited by people mainly from Southern Volta and eastern part of Greater Accra Region.



**Figure 1: A map showing Kpeve Tornu section of the Volta Lake and water sampling sites**

**Source:** Department of Geography and Resource Development, University of Ghana, Accra (2014).



**Plate 1: Community members using the Volta Lake for different purposes**

The area is also associated with the Ghana Water Company (Kpeve Headworks) which sources water from the same area for commercial purposes.

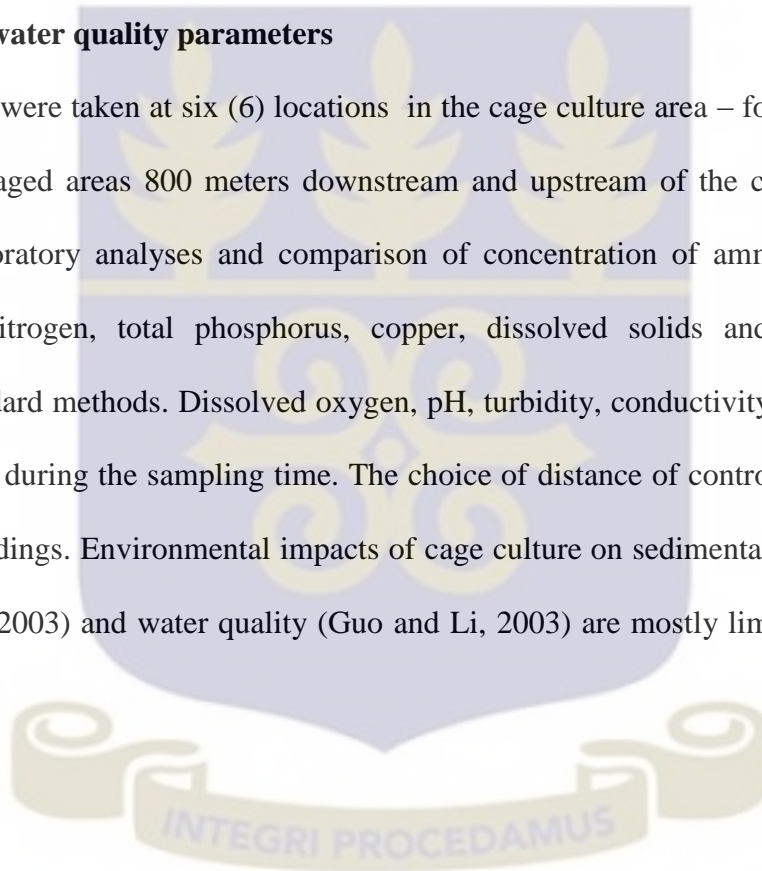


**Plate 2: The two (2) intake points of Ghana Water Company at Kpeve Tormu**

The community has been identified by investors of cage farming business as economically vantage point perhaps due to the presence of a community of a sizeable human population to prevent poaching, and also the availability of labour force to provide services such security services, maintenance of fish cages and harvesting. At the time of this write up, there were about six hundred and eighty two (682) cages at the cage culture area with a few also under construction. (Afadjato South District Statistical Department, 2013).

### **3.2 Assessing water quality parameters**

Water samples were taken at six (6) locations in the cage culture area – four (4) fish farms, and two non-caged areas 800 meters downstream and upstream of the cage area (control sites) for laboratory analyses and comparison of concentration of ammonia, suspended solids, total nitrogen, total phosphorus, copper, dissolved solids and organic matter following standard methods. Dissolved oxygen, pH, turbidity, conductivity and temperature were measured during the sampling time. The choice of distance of control sites was based on research findings. Environmental impacts of cage culture on sedimentation (Nash, 2001; Carrrol *et. al.*, 2003) and water quality (Guo and Li, 2003) are mostly limited to within 50 meters.





**Plate 3: A sample of a fish cage in the study area**

Water samples were taken at two (2) months intervals (from December, 2013 to April, 2014). Four (4) cages were randomly selected as a representative sample of the cage culture area and two (2) control sites. For each site, three (3) water samples were taken, measured and the mean values found for each site. Results from the six (6) sampling sites were statistically compared to determine any significant differences between data obtained.

Clean and treated (sterilized) containers were used to avoid contamination of samples during sampling, handling and storage, and working conditions were carefully selected. At each sampling site, water samples were collected into a plastic bucket for *in-situ* measurements of temperature, pH, conductivity and total dissolved solids were measured *in-situ* using HANNA Temp/pH/EC/TDS meter (Model HI 99301). The dissolved oxygen was determined using a dissolved oxygen meter (Model Milwaukee MW600). Turbidity was

determined using HACH 2100P turbidimeter and the reading recorded in Nephelometric Turbidity Units (NTU). Field work was conducted between 7.00 am and 8.am on each sampling day.

### 3.3 Laboratory analysis

A 1.5-liter pre-treated plastic container was filled with water at each site and kept on ice in an ice chest before transporting them to the laboratory. This was subsequently used in the laboratory for *ex-situ* analysis. Water samples that were not analyzed immediately were stored in a refrigerator below 4 °C. The samples were analysed within 5 days to avoid inaccuracy.

Chemical properties of the water samples were determined at the Ecological Laboratory of the Institute for Environment and Sanitation Studies, University of Ghana. The chemical parameters determined were as follows: nitrate-nitrogen, phosphate, ammonia-nitrogen, total suspended solids, organic matter (BOD) and copper. The analysis was carried out using a HACH DR/2010 UV Spectrophotometer. All the laboratory measurements were done following established standard methods (APHA, 1998; WHO, 1989 and UNESCO/WHO 1978).

About 500 ml of water sample was stirred for exactly 2 minutes. The stirred sample was poured into a one-litre beaker, stirred and 25 ml aliquots immediately poured into a sample cell prepared. The sample was swirled to remove any bubbles and uniformly suspend any residue and the reading recorded with a spectrophotometer set at 810 nm which has previously been calibrated using 25 ml of demineralized water as the blank to zero reading.

Next the sample was placed into the cell holder and reading taken in milligram per liter suspended solids (Hach Company, 2001a).

The turbidity of the samples was determined using a portable turbidimeter (Model 2100P). A sample cell was filled with 15 ml of sample and the cell was capped. The cell was wiped with a soft, line-free cloth to remove water spots and fingerprints. A thin film of silicone oil was applied and wiped with the soft cloth to obtain an even film over the entire surface. This was placed in the cell holder and the reading taken in Nephelometric Turbidity units (Hach Company, 2001b).

The 5-day BOD test was used. This method consists of filling with sample an airtight bottle of the specified size and incubating it at the specified temperature for 5 days. Dissolved oxygen was measured initially after incubation, and the BOD was computed from the difference between the initial and final Dissolved Oxygen (APHA, 1995).

The nitrate level in each sample was measured using nitrate powder pillows in a direct reading Hach Spectrophotometer (Model DR. 2010). Twenty five (25) milliliters of the sample was measured into sample cell. One Nitraver 5 Nitrate Reagent Powder Pillow was added to the sample and vigorously shaken for 1 minute. The solution was allowed to react for 5 minutes after which another cell was filled with 25 ml of only the sample (blank). After the 5 minutes reaction period, the blank sample was placed in the spectrophotometer for calibration (zeroing). The prepared sample was then placed in the cell holder to determine the nitrate concentration at 500 nm.

The sample cell was filled with 25 ml of sample and one Phos Ver 3 Phosphate Powder Pillow reagent was added to the cell content (the prepared sample) and swirled immediately to mix. A two-minute reaction period was allowed. Another sample cell (serving as the blank) was filled with 25 ml of sample and placed into the cell holder to calibrate it. After the reaction period the prepared sample was placed into the cell holder and the level of phosphorus was determined at 890 nm.

A measuring cylinder was used to measure 100 ml of the sample and transferred into a clean 250 ml Erlenmeyer flask. The contents of one chloride 2 Indicator Powder Pillows were added and swirled to mix. The delivery tube tip was placed into the solution and the flask swirled while titrating with silver nitrate from a yellow to red-brown obtained.

The copper level in each sample was measured using Powder Pillows in a direct reading Hach spectrophotometer (Model DR. 2000). Ten (10) milliliters of the sample was measured into sample cell. One Cu Ver I Copper Reagent Powder Pillow was added to the sample cell (as prepared sample) and swirled to mix. The solution was allowed to react for 2 minutes after which another sample cell was filled with 10 ml of the sample (to same as blank). After the 2 minutes reaction period, the sample blank was placed in the spectrophotometer for calibration. Then the prepared sample was placed into the cell holder of the spectrophotometer to determine the copper concentration at 560 nm. (Hach Company, 2001a).

### 3.4 Assessment of financial viability of cage aquaculture

A basic benefit-cost ratio analysis was conducted to determine the economic viability of the cage culture project. The benefit-cost ratio was obtained by dividing the returns (sales) by total cost of production (fixed cost and variable cost).

$$\text{Benefit-Cost Ratio} = \frac{\text{Returns on Investment}}{\text{Total Cost of Production}}$$

The basic benefit-cost ratio analysis was estimated in the first production cycle to include the cost incurred on fixed inputs.

The gross margin was obtained by subtracting the variable cost from returns on investment. This was estimated during the second production cycle. Five cages of 360 cubic meters each were used to collect data on cost and returns for the two production cycles. An approved framework for the data collection and estimation on the financial viability of cage aquaculture in Ghana was modified and used. This framework was designed by the Water Research Institute (Ghana) in 2009 in collaboration with the World Fish Center in Malaysia (Ofori, *et. al.*, 2009).

Five (5) entities involved in the aquaculture business in the area were selected to represent various business interests and to provide relevant information to establish financial inputs and gains using a designed framework. The selection criterion was based on book keeping records. The business interests were Sole Proprietorship (3 'As' Agri Solutions), Partnership (Catchrite Farms), Direct Foreign Investor (Worldings Investment Ghana Limited), Training and Consultancy (Global Agricultural Foundations) and the Best Farmer-Based Organization in Ghana (2013) namely Volta Lake Fish Farmers Association.

### **3.5 Assessment of the impact of cage culture business on the livelihoods of the people of Kpeve Tornu**

Twenty five percent (25%) of the adult population was purposely selected from the fish farming community to assess the perception of the people on the impacts of the cage culture projects. One hundred and three (103) respondents were purposely selected because the population of the people in Kpeve Tornu was estimated to be 763 with adult population of 412 based on the District adult population rate of 54% as at September, 2013. Gender issues were considered in the selection process as 53 (51.5%) of the respondents were women and 50 (48.5%) represented men during the interview process. This made a total of one hundred and three (103) respondents. The quota sampling used was based on the composition of male and female in the District population estimates.

The questionnaire designed to gather relevant information from the people was tested on twenty-one (21) community members for modification. Information gathered included the impact of cage farming activities on (1) fishing activities in the community, (2) water transport, (3) occupation, (4) cultural values and, (5) other relevant social activities. The people's perception on the impact of cage culture on water quality in the area was also verified during the interview. Data was also collected on the socioeconomic background of the people in the community which was later analyzed. These included age, sex, occupation and educational background.

### **3.6 Socioeconomic characteristics and regulatory compliance of fish farmers**

Socioeconomic aspects of eighteen (18) randomly selected cage farmers (investors) out of twenty-nine (29) known farmers were interviewed to obtain relevant information. The questionnaires comprised social and economic characteristics of cage farmers (including

age, sex, occupation and educational background), and sources of investment capital using a set of designed questionnaire. Relevant information obtained included assessment of financial viability of fish farming, where harvested fish is sold (markets) as well as problems and challenges involved in fish farming in floating cages.

Relevant environmental regulations and documents with respect to the fish farming projects were studied. Environmental management plans, environmental permits and other regulatory procedures were examined from cage farmers through questionnaire administration to determine compliance levels in accordance with regulations. Appropriate laws that govern aquaculture business in Ghana in relation to environmental safety were also studied. Notable among them were the Fisheries Act of 2002 (Act 625), Environmental Protection Agency Act, 1994 (Act 490), Environmental Regulations Assessment, 1999, (LI 1652), Aquaculture Regulations of Ghana, 2010 (LI 1968), Public Health Act of 2012 (Act 851) and the Abuja Declaration on Sustainable Fisheries and Aquaculture in Africa.

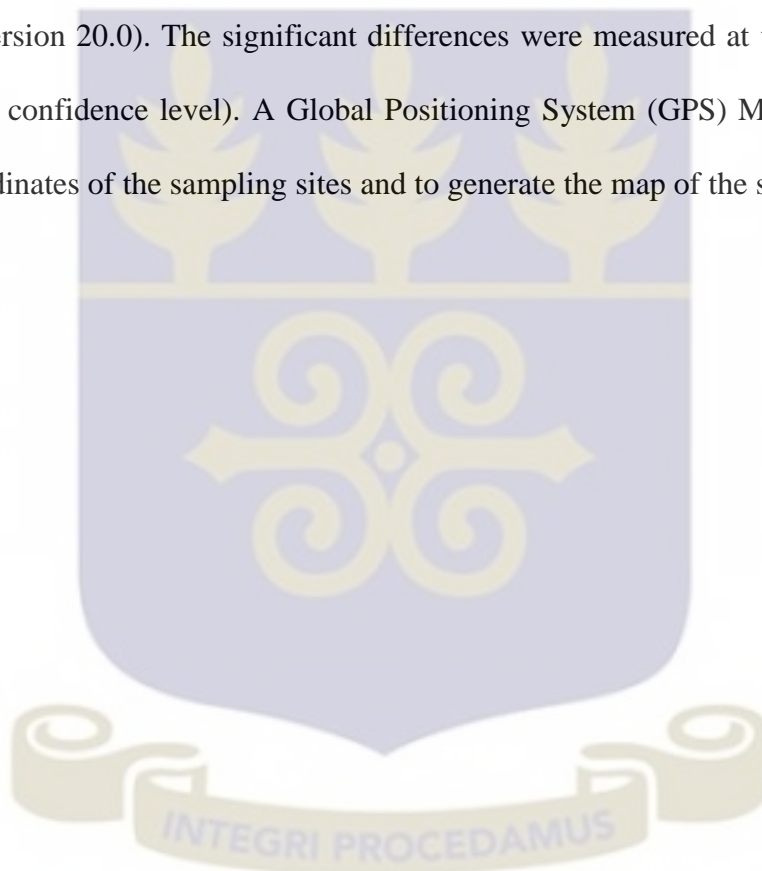
### **3.7 Statistical data gathering and analysis**

Field works were conducted between December, 2013 and April, 2014. This period represented the time when the people in the community depended most on the Volta Lake for livelihood opportunities such as fishing and farming.

Microsoft Excel 2012 was used to store all relevant quantitative data on water quality parameters and also to generate bar graphs to compare water quality parameters from cage culture area with non-cage areas (control sites). These were dissolved oxygen, BOD, turbidity, conductivity, suspended solids, dissolved solids, pH, copper, nitrate, ammonia, phosphate and temperature.

Recorded measurements from the field were statistically analyzed using Statistical Package for Social Scientists (SPSS) software package (version 20.0). The questionnaire was coded and built on SPSS to generate figures, tables and graphs for significant differences in water quality parameters and socioeconomic background of fish farmers as well as the socioeconomic background of people living in Kpeve Tornu.

Data collected on water quality parameters were statistically analyzed using SPSS Software Programme (version 20.0). The significant differences were measured at the probability of 0.05 (at a 95% confidence level). A Global Positioning System (GPS) Model was used to locate the coordinates of the sampling sites and to generate the map of the study area.



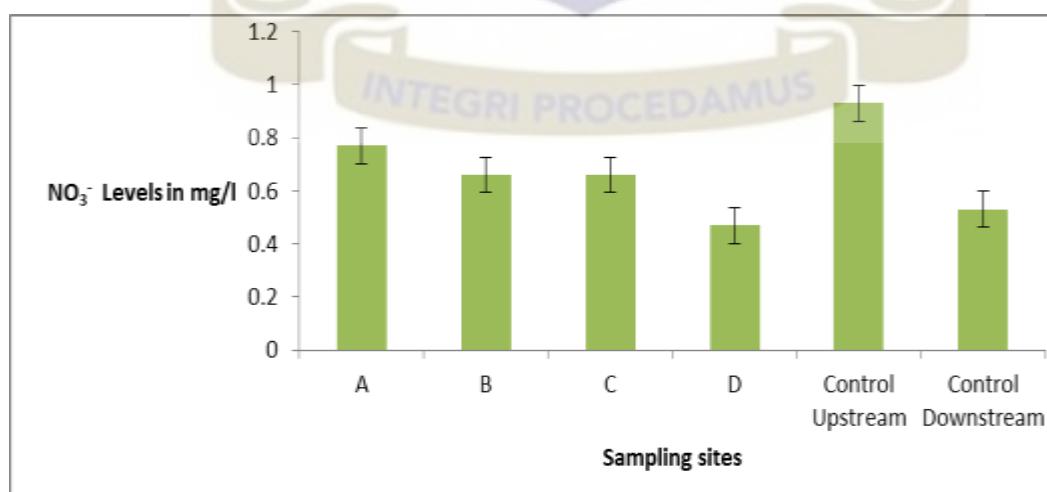
## CHAPTER FOUR

### RESULTS

#### 4.1 Water quality parameters

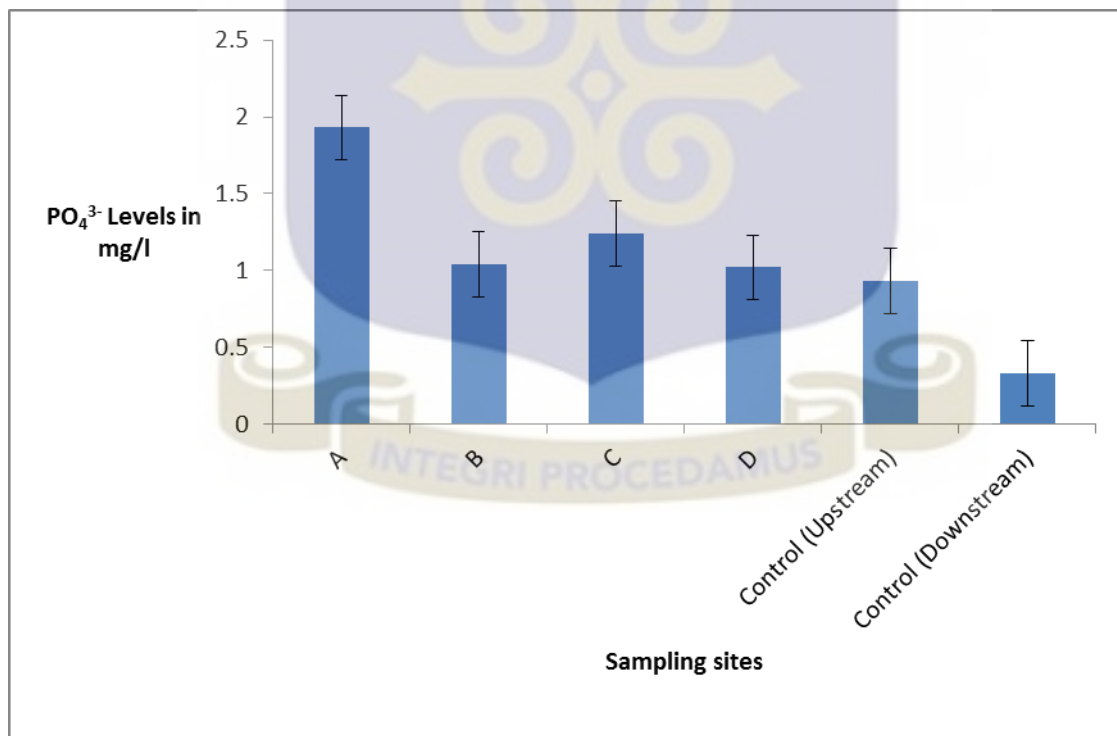
The results of the twelve (12) water quality parameters from the field are presented in this chapter. Bar graphs are used to represent the results graphically.

Nitrate concentration in December, 2013 ranged from 0.2 mg/l to 0.6 mg/l. The control downstream recorded the least value of 0.2mg/L while site A and the control upstream recorded the highest value of 0.6 mg/l. Sites C and D recorded 0.5 mg/L each and B 0.4 mg/l . In February, 2014, the least nitrate level recorded 0.3 mg/l for site D. Sites A, D and the control upstream recorded the highest value of 0.7 mg/l. Sites B and control downstream recorded 0.6 mg/l each. The concentration of nitrate in the study sites in April, 2014 ranged from 0.6 mg/l for site D to 1.5mg/l for control upstream. 0.8 mg/l was recorded for sites B, C and control downstream while site A registered 1.0 mg/l for the same period. The mean values for the sampling sites during the study periods were A 0.77 mg/l, B 0.6 mg/L, C 0.66 mg/l, D 0.47 mg/l, control upstream 0.93 mg/l and control downstream 0.53mg/l (Figure 2).



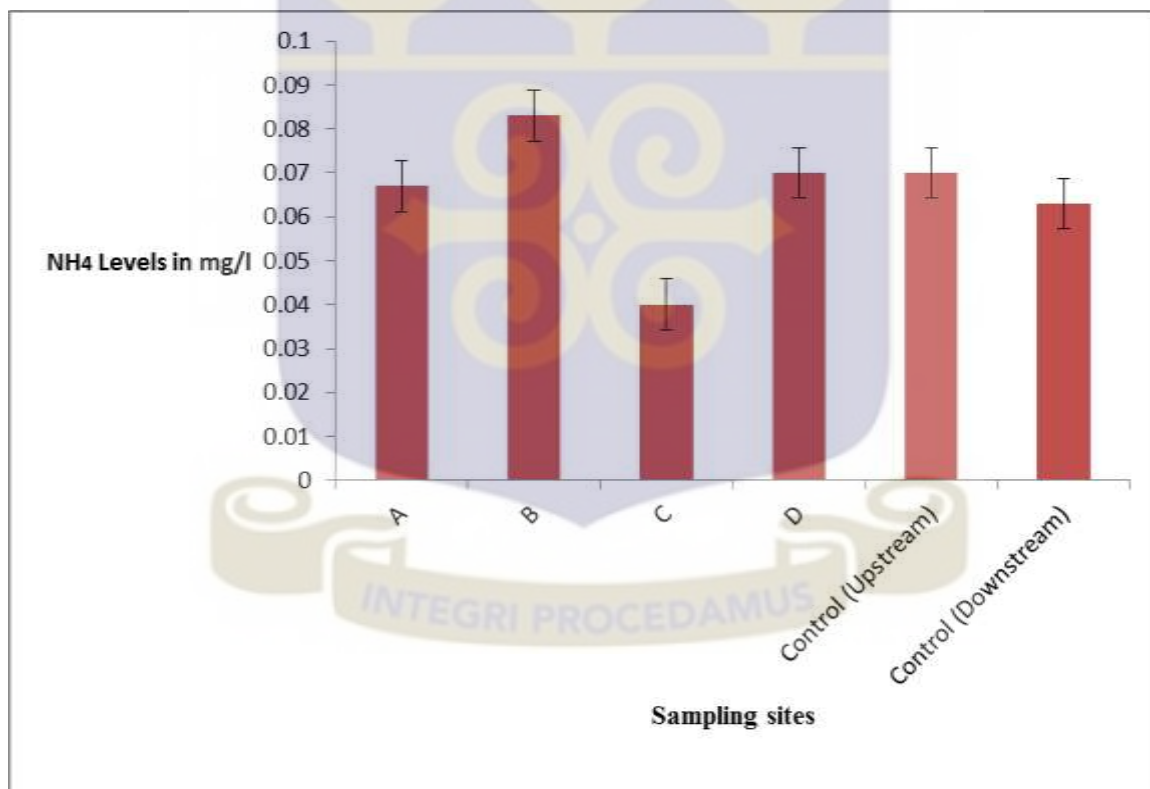
**Figure 2: Graph showing variations in mean nitrate values at the various sampling points**

Phosphate levels in the study area ranged from 0.24 mg/l in the control downstream to 0.44 mg/l at site A. Site B recorded 0.36 mg/l, site C 0.28 mg/l, control upstream 0.25 mg/l and site D recording 0.26 mg/l all in December, 2013. In February, 2014, it ranged between 0.32 mg/l at site B and 0.46 mg/l at site A. Site D recorded 0.36 mg/l while C and control downstream recorded 0.42 mg/l each with control downstream 0.39 mg/l in the same month. The concentration of phosphate in April, 2014 recorded the least value of 0.34 mg/l at control downstream and the highest at site A being 4.9 mg/L. Other values were 2.43 mg/l for site B, 3.02 mg/L for site C, 2.44 mg/l for D and 2.14 mg/l for upstream control. The mean values for phosphate concentration at the sampling sites during the study period were A (1.93 mg/l), B (1.04 mg/l), C (1.24 mg/l), D (1.02 mg/l), control upstream (0.93 mg/l) and control downstream (0.33 mg/l) (Figure 3).



**Figure 3: Graph showing the variations in mean phosphate levels at the various sampling points**

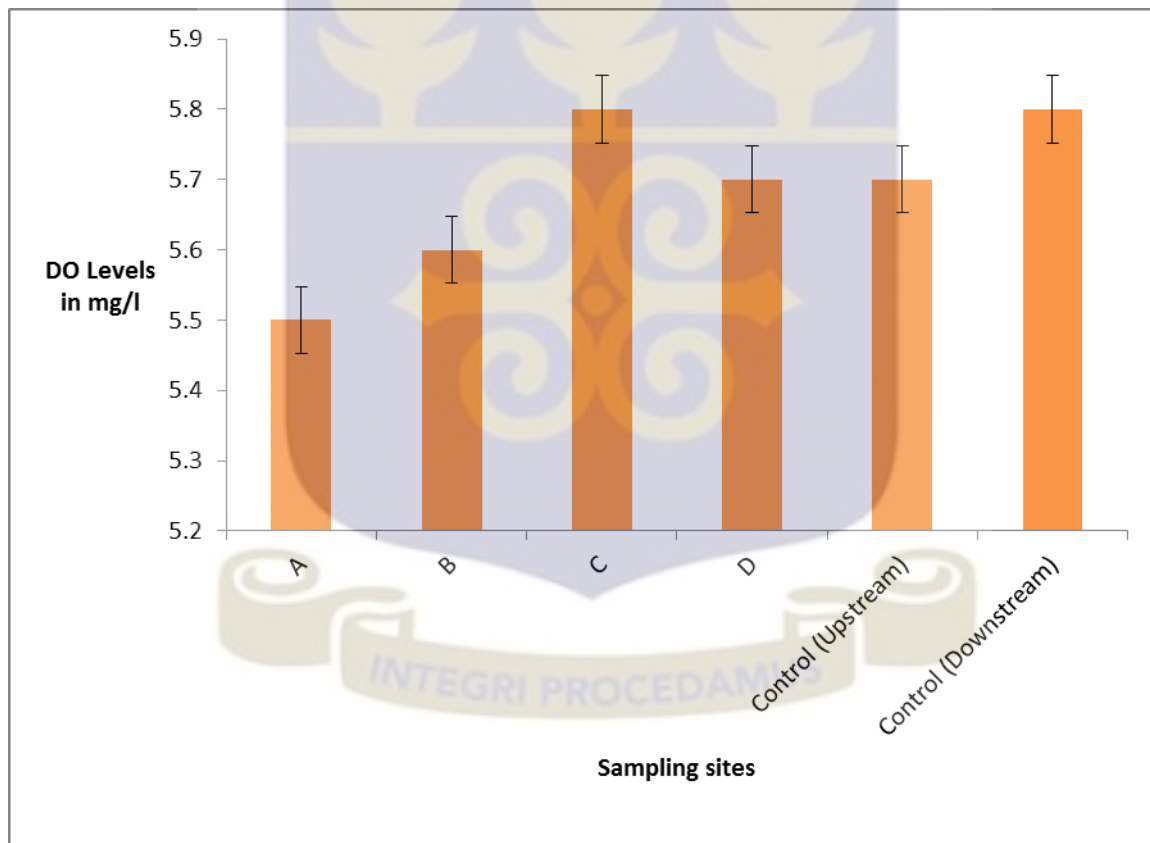
Ammonium concentrations in the study area in December, 2013 fell within the ranges of 0.04 mg/l for site D and control downstream to 0.07 mg/l for sites A and B. Both C and the control upstream sites recorded 0.05 mg/l. In February, 2014, ammonium levels were between 0.01 for sites A, C and D and 0.05 mg/l for control sites while B recorded 0.04mg/L. Ammonium concentration in April, 2014 recorded the least value of 0.06 mg/l for site C and the highest value of 0.17mg/l for D. Other values were control downstream 0.1 mg/l , control upstream 0.11 mg/l , A 0.12 mg/L and B 0.14 mg/l . The mean values for the sampling sites during the study periods were A 0.067mg/L , B 0.083mg/L , C 0.04mg/l, D 0.07mg/l , control upstream 0.07 mg/l and control downstream 0.06 mg/l (Figure 4).



**Figure 4: Graph showing variations in mean ammonium levels at the various sampling points**

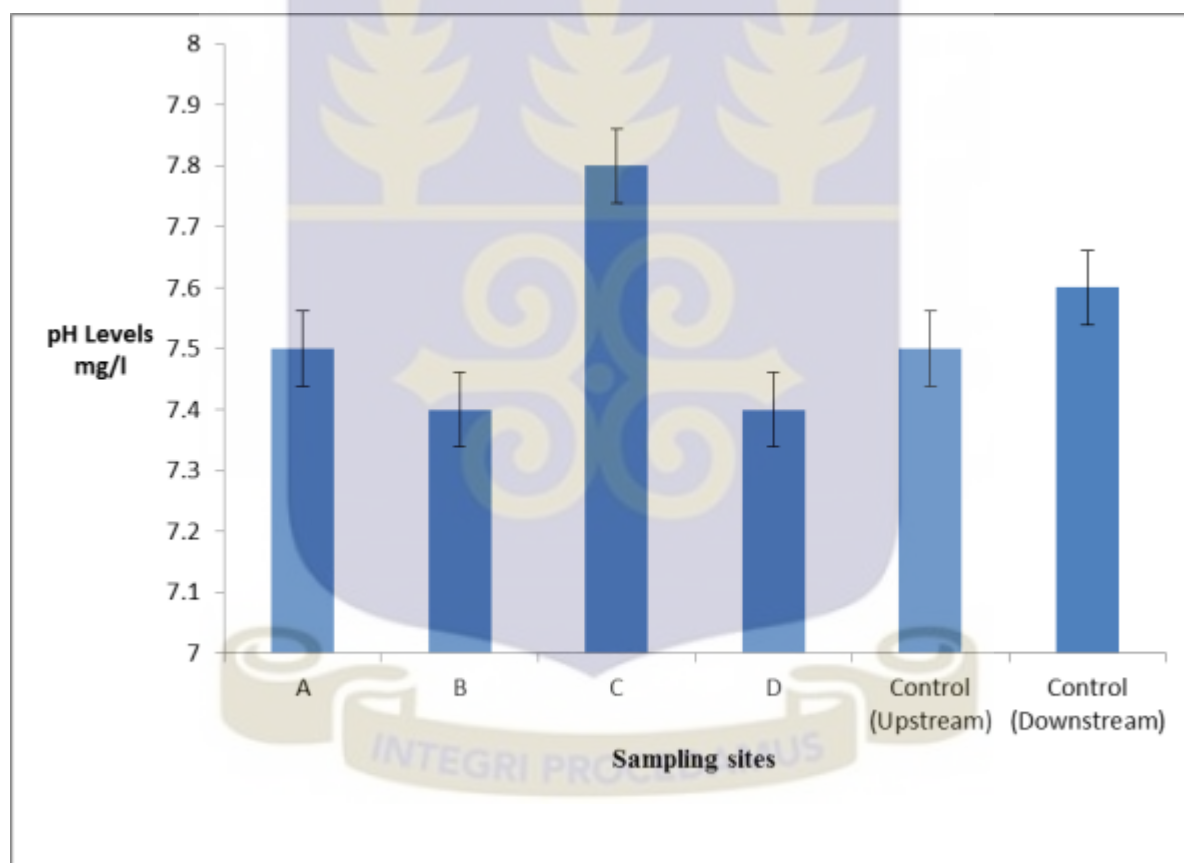
Dissolved oxygen concentrations varied in the study area in December, 2013 with site B recording the lowest value of 3.21 mg/l and site D recording the highest value of 4.1 mg/l.

Others were A 3.5mg/L, B 3.92 mg/l, control upstream 3.97 mg/l and control downstream 4.02 mg/l. In February, 2014, dissolved oxygen values ranged between 5.59 mg/l for site B and 6.2 mg/l for control downstream with sites A, C, D and control upstream recording 6.1 mg/l, 5.89mg/l, 5.85 mg/l and 5.79 mg/l respectively. Dissolved oxygen values in April, 2014 were A 6.9 mg/l, B 7.9 mg/l, C 7.5 mg/l, D 7 mg/l, control upstream 7.2 mg/l, and control downstream 7.1 mg/l. The mean values for the sampling sites during the study periods for dissolved oxygen were A 5.5 mg/l, B 5.6 mg/l, C 5.8mg/L, D 5.7 mg/l, control upstream 5.7 mg/l and control downstream 5.8mg/L (Figure 5).



**Figure 5: Graph showing variation in mean dissolved oxygen levels at the various sampling points**

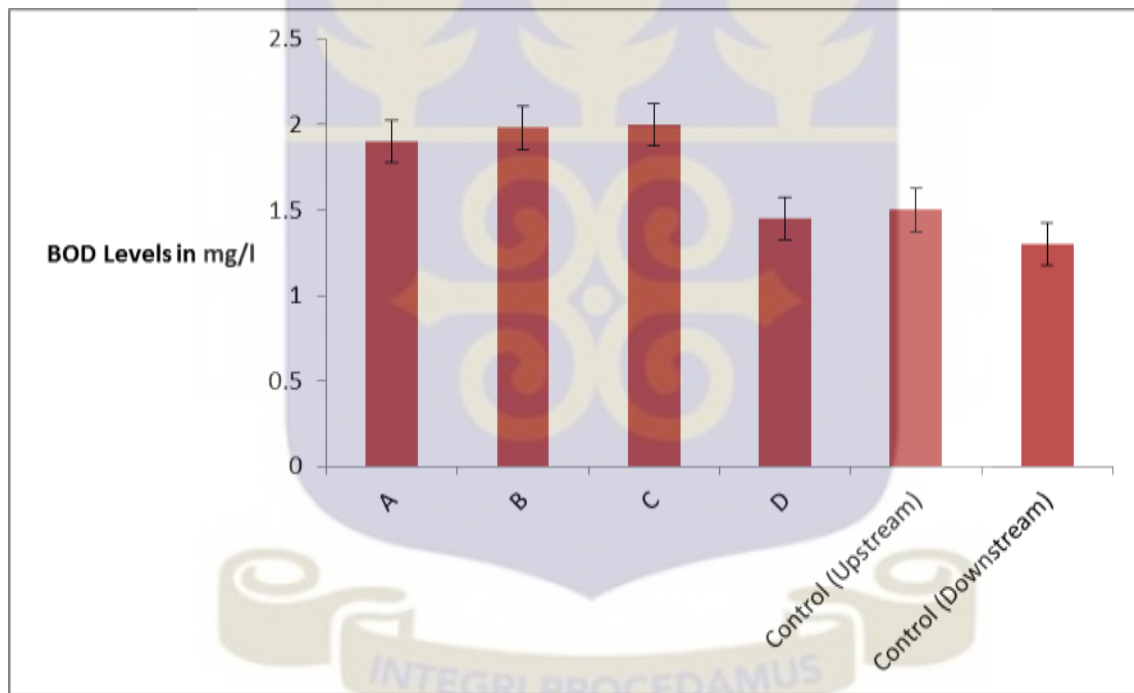
The pH value for site A was 7.1 and 7.6 for control downstream in December, 2014. All other values were 7.3. The values in February, 2014 ranged from 7.5 for sites B and downstream control to 8.1 for sites C and control upstream. The values in April, 2014 were A 7.8, B 6.9, C 7.9, D 7.5, control upstream 7.1, and control downstream 7.6. The mean values for the sampling sites during the study periods were A 7.5, B 7.4, C 7.8, D 7.4, control upstream 7.5 and control downstream 7.6 (Figure 6). Differences in the results were not significant (ANOVA;  $P < 0.05$ ) indicating that the fish farming activities in the study area did not significantly impact on water quality in the area.



**Figure 6: Graph showing variation in mean pH levels at various sampling points**

Biochemical oxygen demand (BOD) in the study area in December, 2013 ranged between 1.75 mg/l for site B to 2.25 mg/l for site A. Site C recorded 1.82 mg/l, site D 2.23 mg/l while the upstream and downstream control sites registered 1.7 mg/l and 1.8 mg/l

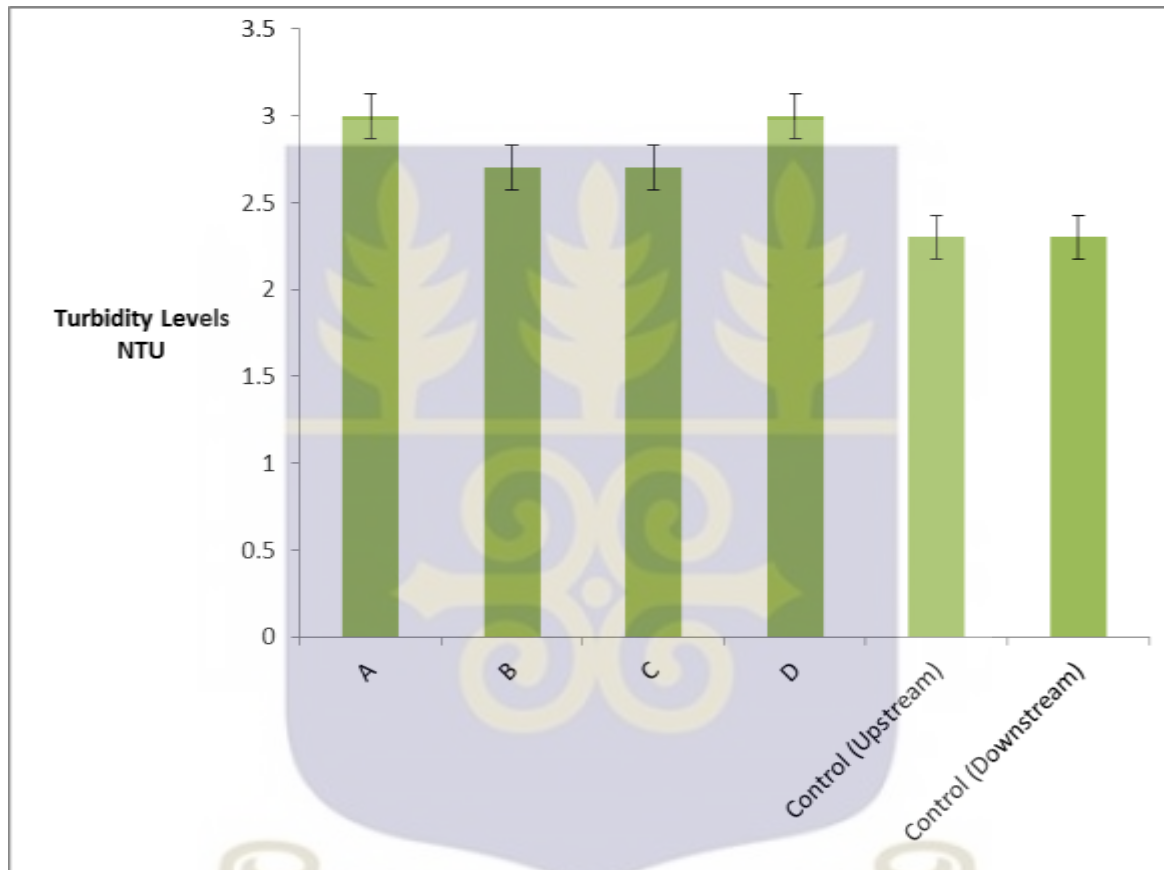
respectively. In February, 2014, the concentration of BOD ranged from as low as 0.05mg/L for the downstream control site to 1.7 mg/l at point A. Other values were control upstream 0.09 mg/l, B 0.67 mg/l, C 1.09 mg/l and D 0.32 mg/l. The concentration of organic matter at the sampling sites in April, 2014 were A 1.9 mg/l, B 3.5 mg/l, C 3.1 mg/l, D 1.8 mg/l, control upstream 2.6 mg/l, and control downstream 2.1 mg/l. The results indicate that there were fluctuating figures in the BOD recorded at the study sites. However, it is significant to note that site A recorded the highest levels of BOD in the three months. The mean values for the sampling sites during the study periods were A 1. mg/l, B 1.98 mg/l, C 2.0 mg/l, D 1.45 mg/l, control upstream 1.5 mg/l and control downstream 1.3 mg/l (Figure 7).



**Figure 7: Graph showing variations in mean BOD levels at the various sampling sites**

Turbidity level at control downstream was 1 NTU, and all other sampling sites were the same in December, 2013, that is, 2 NTU each. However, in February, 2014, the upstream control site maintained the 2 NTU while all other sites increased slightly to 3 NTU. In April, 2014, turbidity value at sites A and D was 4 NTU with other sampling sites recording 3 NTU each. The mean values for the sampling sites during the study periods were A 3.0

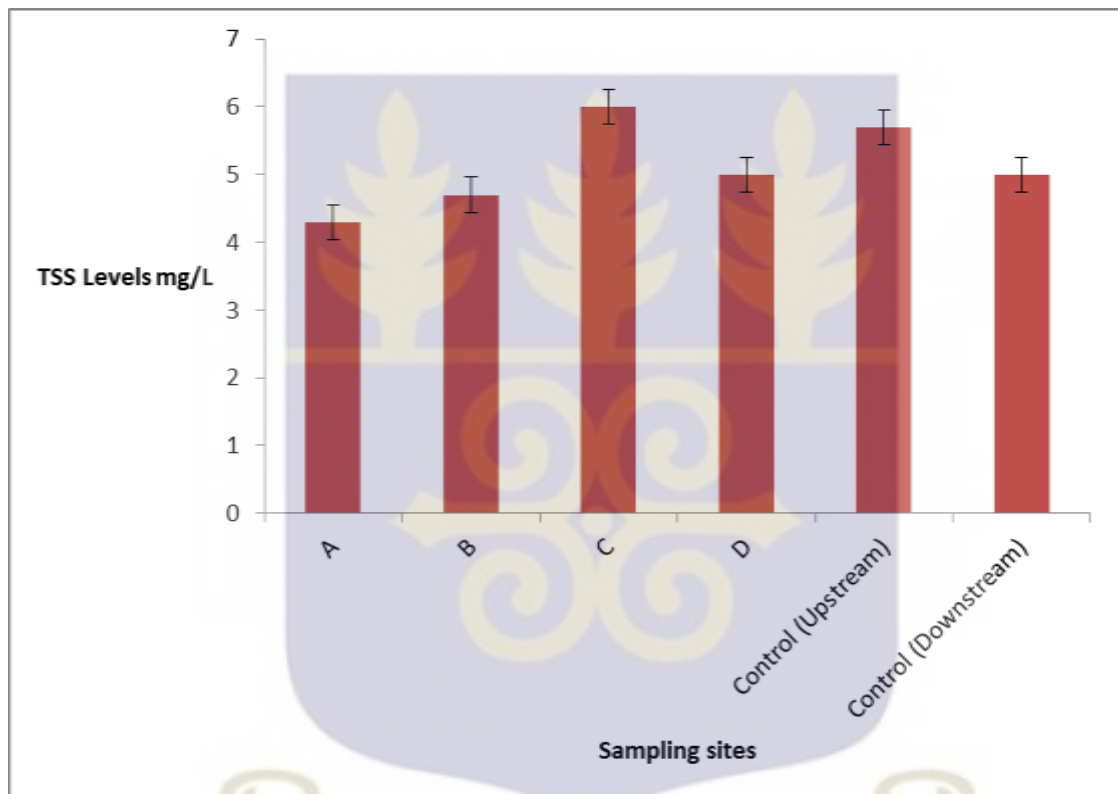
NTU, B 2.7 NTU, C 2.7 NTU, D 3.0 NTU, control upstream 2.3 NTU and control downstream 2.3 NTU (Figure 8). This suggests that cage aquaculture has a slight impact on turbidity in the study area but this is of little significance. There was also no significant differences (ANOVA;  $P < 0.05$ ) between fish cage sites and control sites.



**Figure 8: Graph showing variations in mean turbidity levels at various sampling points**

Suspended solids in the study area in December, 2013 were 4 mg/l at site A and 5 mg/l for downstream control site. Other sites recorded 6 mg/l each. In February, 2014, sites B, C and upstream control recorded 3 mg/l each while A recorded 1 mg/L, D 2 mg/l and downstream control registered 5 mg/L. Recorded figures for total suspended solids in April, 2014 were A 7 mg/l, B 5 mg/l, C 9 mg/L, D 7 mg/l, control upstream 8 mg/L and control downstream 6

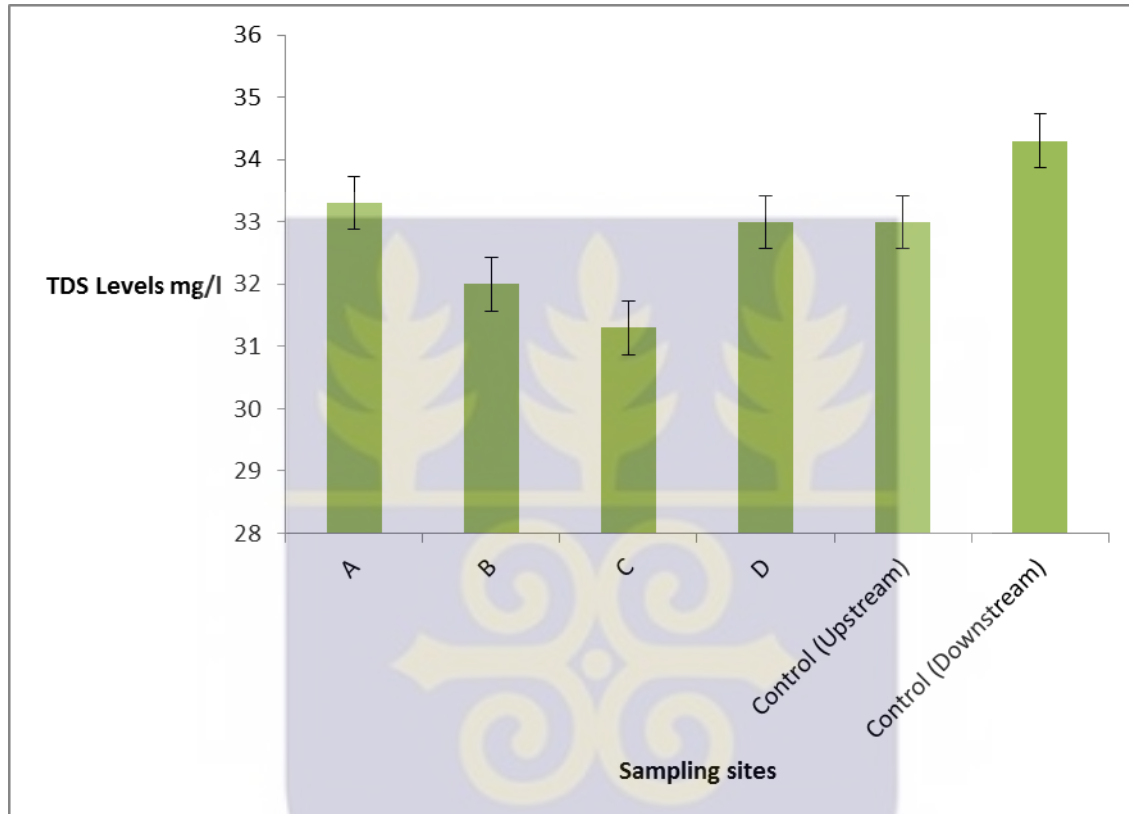
mg/l. The mean values for the sampling sites during the study periods were A 4.3mg/l, B 4.7mg/l, C 6.0mg/L, D 5.0mg/l, control upstream 5.7 mg/l and control downstream 5.0mg/l (Figure 9). The results suggest variations in the levels of suspended solids in the study area with time. However, differences within sampled sites were not significant (ANOVA;  $P < 0.05$ ).



**Figure 9: Graph showing variations in mean suspended solids levels at the various sampling points**

Dissolved solids in the sample sites ranged from 29 mg/l for farm D to 32 mg/l for control downstream and C while farm B and the control upstream recorded 30 mg/l each. Farm A recorded 31 mg/l. February, 2014 recordings were 34 mg/l (farm C), 38 mg/l (farm B), 39 mg/l (farm A), 40 mg/l (the control), 41 mg/l (farm D) and 42 mg/L (control downstream). Total dissolved solids values in April, 2014 were 30 mg/l for site A and 28 mg/L for site B. All other sampling sites recorded 29 mg/l each. The mean values (Figure 10) for the

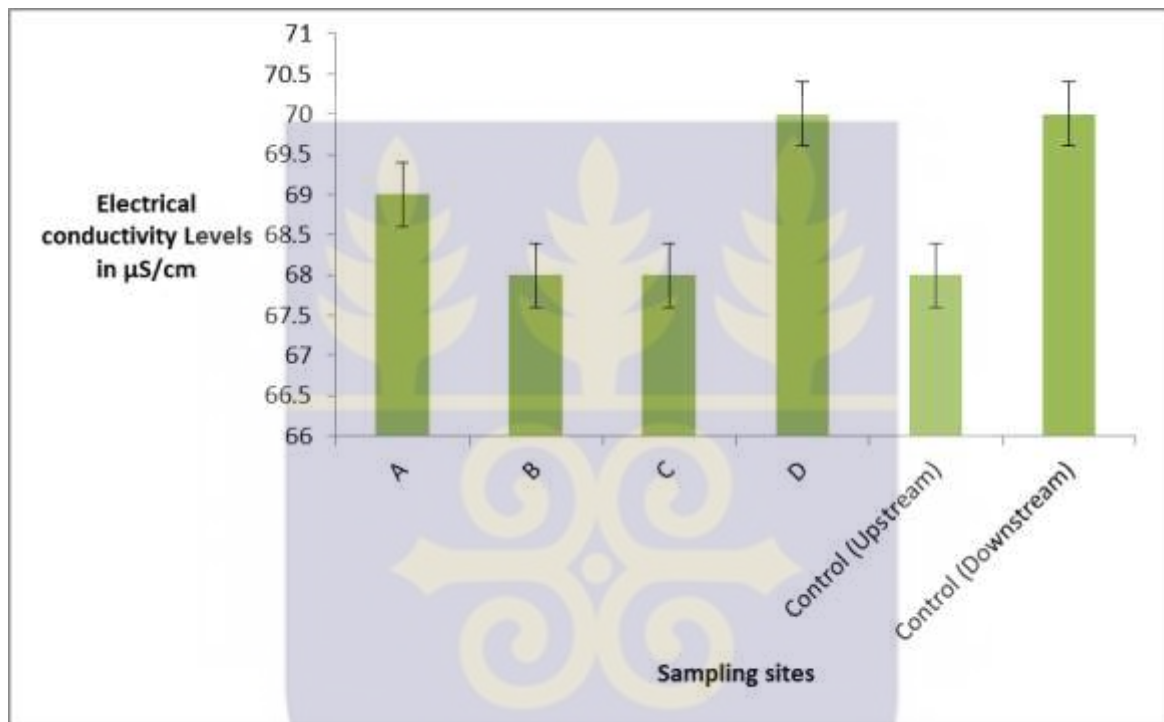
sampling sites during the study periods were A (33.3mg/l), B (32.0mg/l), C (31.3mg/l), D (33.0mg/l), control upstream (33.0 mg/l) and control downstream (34.3mg/l). The results suggest no significant differences (ANOVA;  $P < 0.05$ ) in the concentration of dissolved substances in the six sampled sites.



**Figure 10: Graph showing variations in mean total dissolved solids levels at the various sampling points**

Electrical conductivity values in the study area in December, 2013 were the same for sites A, B, C, and D recording  $63\mu\text{S}/\text{cm}$  while  $62\mu\text{S}/\text{cm}$  and  $64\mu\text{S}/\text{cm}$  were recorded for the control upstream and downstream sites respectively. In February, 2014, electrical conductivity ranged between  $78\mu\text{S}/\text{cm}$  for farms A and C, and  $79\mu\text{S}/\text{cm}$  for farm B. Upstream control recorded  $80\mu\text{S}/\text{cm}$ , and farm D and downstream control recording  $83\mu\text{S}/\text{cm}$  each. In April, 2014, electrical conductivity levels were  $63\mu\text{S}/\text{cm}$  each for B, C and control upstream,  $64\mu\text{S}/\text{cm}$  for D and control downstream and site A recording the highest

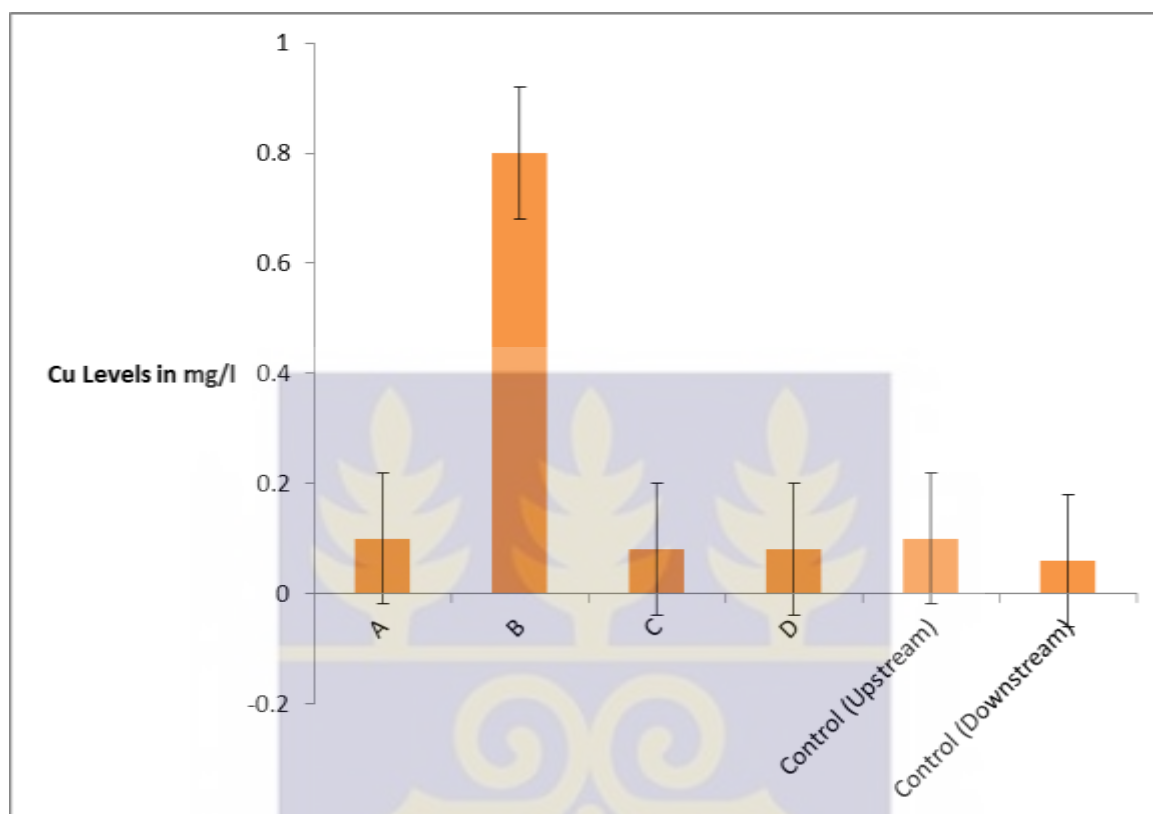
value of 67  $\mu\text{S}/\text{cm}$  at the same period. The mean values for the sampling sites during the study periods were A 69  $\mu\text{S}/\text{cm}$ , B 68  $\mu\text{S}/\text{cm}$ , C 68  $\mu\text{S}/\text{cm}$ , D 70  $\mu\text{S}/\text{cm}$ , control upstream 68  $\mu\text{S}/\text{cm}$  and control downstream 70  $\mu\text{S}/\text{cm}$  (Figure 11). Results indicate that differences in the electrical conductivity in the study area were not significant (ANOVA;  $P < 0.05$ ) between December, 2013 and April, 2014.



**Figure 11: Graph showing variations in mean conductivity levels at the various sampling sites**

Copper concentration varied from 0.02 mg/l for control downstream to 0.07 mg/l for sites A and D in December, 2013. 0.05 mg/l were recorded for sites B, C and upstream control sites. Values in February, 2014 ranged from 0.06 mg/l for sites C and D to 0.13 mg/L for the upstream control site. Site A recorded 0.12 mg/l, B registering 0.08 mg/l and downstream control 0.07mg/l. Copper concentrations in April, 2014 were A 0.13mg/L, B 0.12mg/L, C 0.12mg/L, D 0.11mg/l, control upstream (0.19mg/l and control downstream 0.1mg/L). The mean values for the sampling sites during the study periods were A (0.1mg/L), B (0.8mg/l), C 0.08mg/l, D 0.08mg/l, control upstream 0.1 mg/l and control downstream

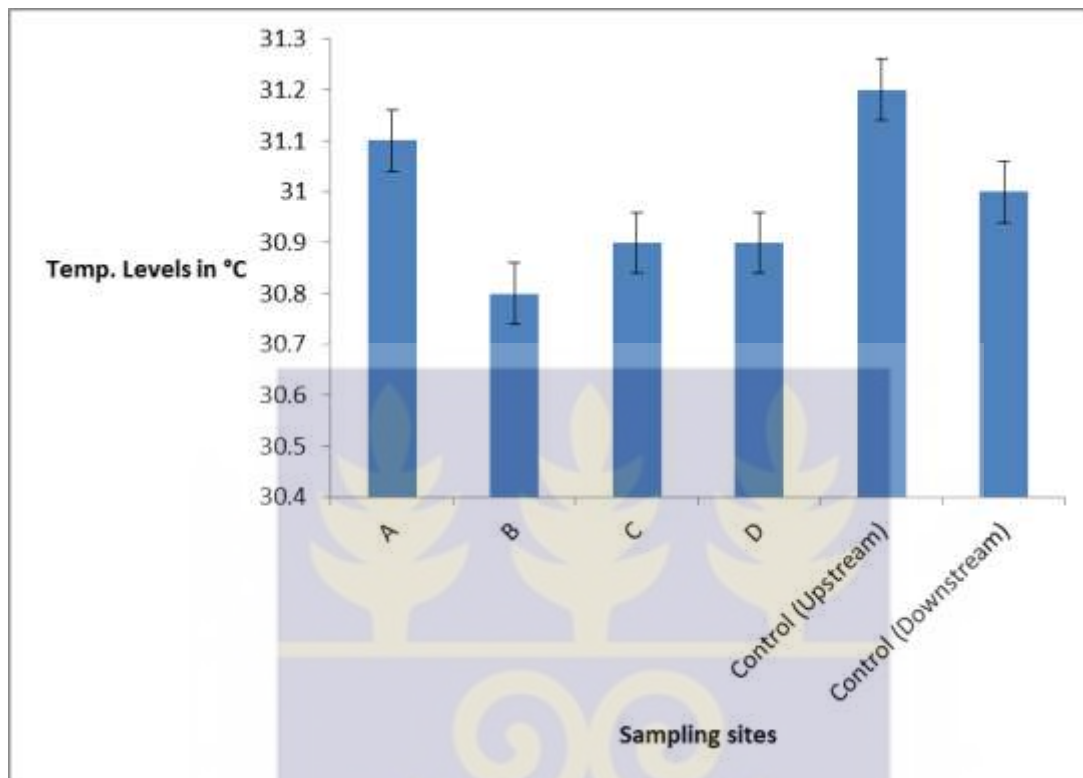
0.06mg/l (Figure 12). The results indicated low levels of copper concentrations with no significant differences (ANOVA;  $P < 0.05$ ) between sampling sites.



**Figure 12: Graph showing variations in mean copper levels at the various sampling sites**

Temperature levels in December, 2013 ranged between 29.6 °C for A and 30.17 °C for C. the rest recorded B (30.17 °C) , D 29.6 °C) , control upstream (29.9 °C) and control downstream (29.8°C). February, 2014 records were A (30.12 °C), B (29.93 °C), C (30.17 °C), D (29.6 °C) , control upstream (29.9 °C) and control downstream (30.9°C). Temperature levels at sampling sites in April, 2014 were A (32.3 °C), B (31.9 °C), C (32.2 °C), D (32.6 °C) , control upstream (32.9 °C) and control downstream (32.3°C). The mean values for the sampling sites during the study periods were A (31.1 °C), B (30.8 °C), C (30.9 °C), D (30.9 °C), control upstream (31.2 °C) and control downstream (31.0 °C) ( Figure 13). These suggest that there were no significant differences (ANOVA;  $P < 0.05$ )

between temperature levels at the six sampling sites indicating that cage aquaculture activities do not significantly impact on water temperature levels in the study area.



**Figure 13: Graph showing variations in mean temperature levels at the various sampling sites**

#### **4.2 Financial viability (cost-benefit ratio and gross margin) of cage aquaculture in the study area**

Financial viability of a business entity determines how economically sustainable the business venture is. Cost-benefit ratio was calculated during the first production cycle while gross margin was computed in the second production cycle.

Expenditure for the five selected business entities in the study area for five single cages of size 360 cubic meters each ranged between GHC 22,941.00 for Volta Lake Fish Farmers Association to GHC 51,625.00 for Global Agricultural Foundation. The average expenditure

was 34,573.00. Revenue levels ranged between GH¢ 28,800.00 and GH¢ 91,980.00 for Volta Lake Fish Farmers Association and Global Agricultural Foundation respectively with average revenue for the five business entities of GH¢ 48,176.00. Average net income for the same period (January, 2014) was GH¢ 13,603.00. The cost-benefit ratio ranged between 1.11 for 3 A'S Agri Solutions and 1.78 for Global Agricultural Foundation and 1.34 on average. Returns on investment was 10.87% for 3 A'S Agri Solutions and 78.17% for Global Agricultural Foundation with an average of 33.818% for the five business entities (Table 1).

**Table 1: Expenditure and returns on investment in the first production cycle (in GH¢)**

<u>Business Entity</u>	1 <sup>ST</sup> PRODUCTION CYCLE (6 MONTHS)				
	<u>Expenditure</u>	<u>Revenue</u>	<u>CBR</u>	<u>Net Income</u>	<u>Returns (%)</u>
1. 3 A'S Agri Solutions	31,118.00	34,500.00	1.11	3,382.00	10.87
2. Catchrite Farms Ltd.	32,743.00	39,600.00	1.21	6,857.00	20.94
3. Global Agricultural Foundations	51,625.00	91,980.00	1.78	40,355.00	78.17
4. Worlding Investment (GH) Ltd.	34,438.00	46,000.00	1.36	11,562.00	33.57
5. Volta Lake Fish Farmers Association	22,941.00	28,800.00	1.26	5,859.00	25.54
Average	34,573.00	48,176.00	1.344	13,603.00	33.818

(1 GH¢ = US\$ 0.41623)

The expected expenditure for the second production cycle (in Ghana Cedis) for the next six months ranged from GHC 11,883.00 for Volta Lake Fish Farmers Association to GHC 40,967.00 for Global Agricultural Foundation, and average expenditure for the five business entities was GHC 23,506.00. The average expected revenue was 48,176.00 with an average net income of GHC 24,670.00. The average gross margin calculated in percentage was 104.41 (Table 2).

**Table 2: Expenditure and returns on investment in the second production cycle (in GHC)**

2ND PRODUCTION CYCLE (6 MONTHS)				
<u>Business Entity</u>	<u>Expenditure</u>	<u>Revenue</u>	<u>Net Income</u>	<u>Gross Margin</u>
3 A'S Agri Solutions	19,860.00	34,500.00	14,640.00	73.72
Catchrite Farms Ltd.	21,485.00	39,600.00	18,115.00	84.31
Global Agricultural Foundations	40,967.00	91,980.00	51,013.00	124.52
Worlding Investment (GH) Lt.	23,335.00	46,000.00	22,665.00	97.13
Volta Lake Fish Farmers Association	11,883.00	28,800.00	16,917.00	142.36
Average	23,506.00	48,176.00	24,670.00	104.41

(1 GHC = US\$ 0.41623)

### **4.3 Impact of cage aquaculture on the livelihood of people in fish farming communities**

This sub-section deals with the socio-economic background of the people, the perception of the people on negative impacts of cage aquaculture. The socio-economic impacts of cage aquaculture on the people in the community also feature in this section.

#### **4.3.1 Socio-economic background of the people**

Fifty-one (51) people representing 49.5% fall within the age of 18-35 years (the youth) were interviewed followed by thirty-five (35) middle aged people (36-59 years) representing 34% and 17 aged people representing 16.5% were interviewed. The figures indicated a substantial youth population in the community. The Kpeve Tornu community is a settler community and a few aged may be leaving the community for their original homes.

Fifty (50) males were interviewed to represent 48. %, and fifty-three (53) females interviewed in the community representing 51.5 % in the community. The ratio reflects the sex composition in the area.

Thirty (30) people randomly interviewed representing 29.1% had no formal education with thirty-five (35) of them representing 33.9 % ending their education at the primary school level. Twenty-nine (29) of them representing 28.2% have either attained or dropped out at the junior high school/middle school level. Nine (9) of them representing 7.8% reached or completed senior high or technical schools, and one (1) person attained a tertiary level of education.

The economic activities of the people in the community were mainly farming (19.4%), farming and trading (2.9%), fishing and fish farming (4.9%), farming and fish farming (3.9%), fishing (4.9%), fish farming (14.6%), trading (28.2%), farming and fishing (5.8%),

farming, fishing and fish farming (1.9%). 10.7% of the people were engaged in other economic activities such as carpentry, masonry and dressmaking. Only 2.9% of the people were unemployed. Most people also engaged in multiple economic activities.

64.1% of the people interviewed have stayed in the community for more than ten years. 12.6% of the interviewees have resided in the community for between six to ten years. 21.4% of them have been in the community for one to five years, and less than 2% of the people interviewed have been in the community for less than one year. The figures suggested that a vast majority of the people (64.1%) have stayed in the community for more than ten (10) years. There was also an influx of people into the community in the last five years indicating an attraction of people towards the fish farming activities in the community since people who have stayed in the community between one to five years are more than those within six to ten years.

#### **4.3.2 Main sources and uses of water in the community**

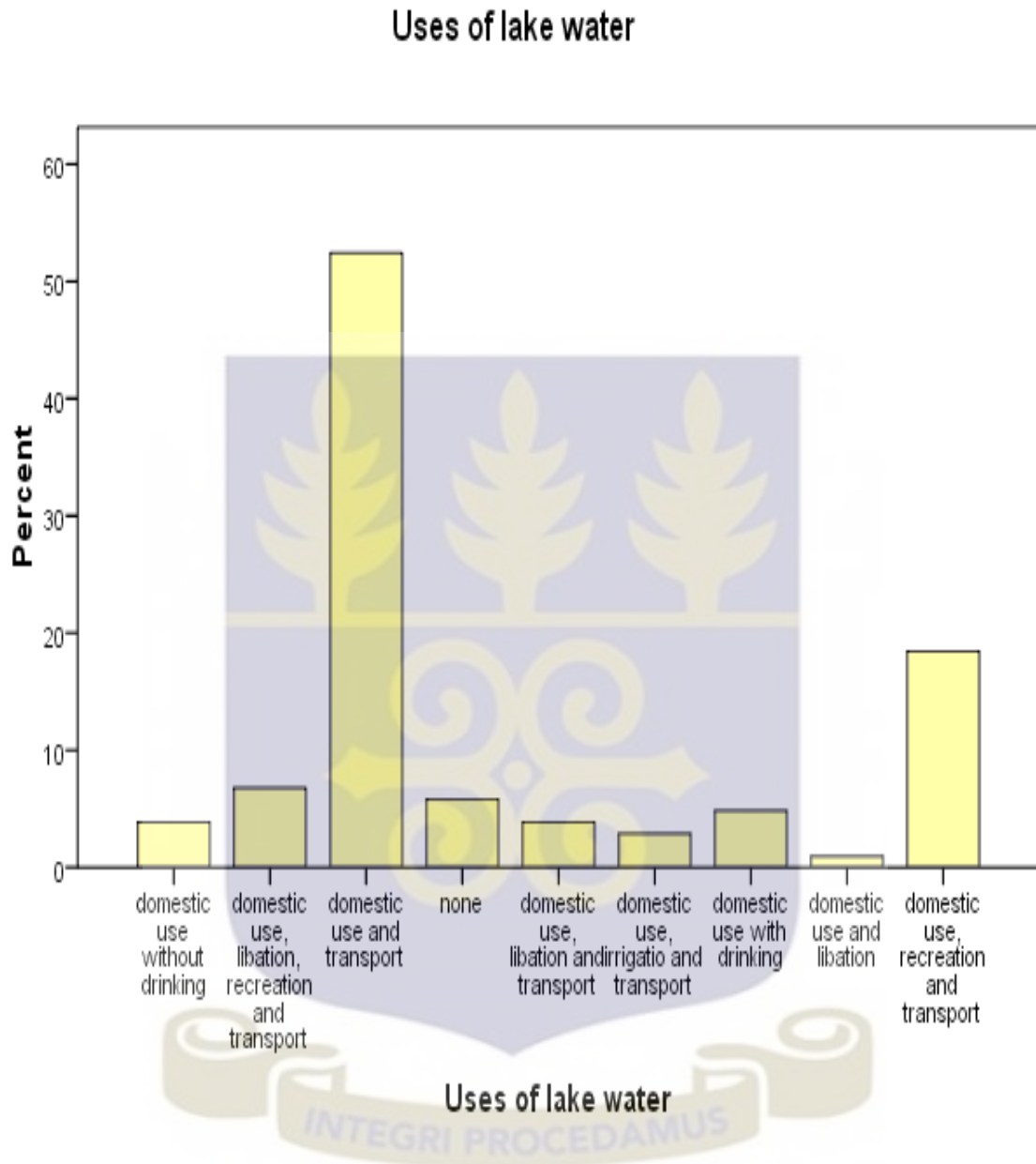
9.7% of the people in the community depend solely on pipe-borne water while 19.4% depend on lake water. 70.3% combine lake water and pipe-borne for various purposes (Table 3).



**Table 3: Main sources of water for the people in the community**

Main sources of water	Frequency (No. of people)	Percent
Pipe - borne water	10	9.7
Lake water	20	19.4
Pipe borne and lake water	73	70.9
Total	103	100.0

Only 5.8% of the people in the community did not use the lake water for livelihood purposes. Water from the lake was mainly used for drinking, cooking and washing (94.2 %). Other uses included water transport (84.4 % of the people), recreation (25.2 %) as well as libation (traditional worship) (11.7 %) and irrigation (2.9 %). The people in the community use lake water for different purposes (Figure 14).



**Figure 14: Main uses of the lake water in the community**

**4.3.3 Perception/Assessment of people on the impacts of cage aquaculture on their livelihood and water quality**

93.2% of the people in the community has the perception that cage aquaculture does not affect their activities in the community. 6.8 %, however, thought they were affected by the cage aquaculture activities in the community (Table 4).

**Table 4: Assessment of respondents on negative impact of cage aquaculture on livelihood opportunities**

Response	Frequency	Percent (%)
Yes	7	6.8
No	96	93.2
Total	103	100.0

1 % of the people thought cage aquaculture affected recreation while another 1% was with the perception that aquaculture negatively affected fishing activities close to the community. They thought the beauty of the lake is masked by the concentration of the cages on the lake.

Fishing activities close to the shoreline was also affected. 4.9 % were with the view that the activities of the fish farmers impacted negatively on water quality in the area.

18.4 % of the people interviewed thought fish farming activities on the lake caused pollution while 66 % thought otherwise. 15.5 % were, however, not certain about whether pollution resulted from cage aquaculture or not (Table 5). This indicates that majority of the people thought the environment was not negatively affected by fish farming in floating cages.

**Table 5: Perception of people on whether cage aquaculture causes pollution**

Response	Frequency	Percent
Yes	19	18.4
No	68	66.0
Not certain	16	15.5
Total	103	100.0

The people's own assessment of the attitude of fish farmers towards the water environment in the area were as follows: good (64.1 %), average (8.7 %) and poor (13.7 %), and 13.7 % of the people were not certain as to whether the fish farmers handled the environment well or not. This suggested that majority of the respondents were satisfied with the way fish farmers handled the lake water during their farming activities.

#### 4.3.4 Benefits of cage aquaculture to the community

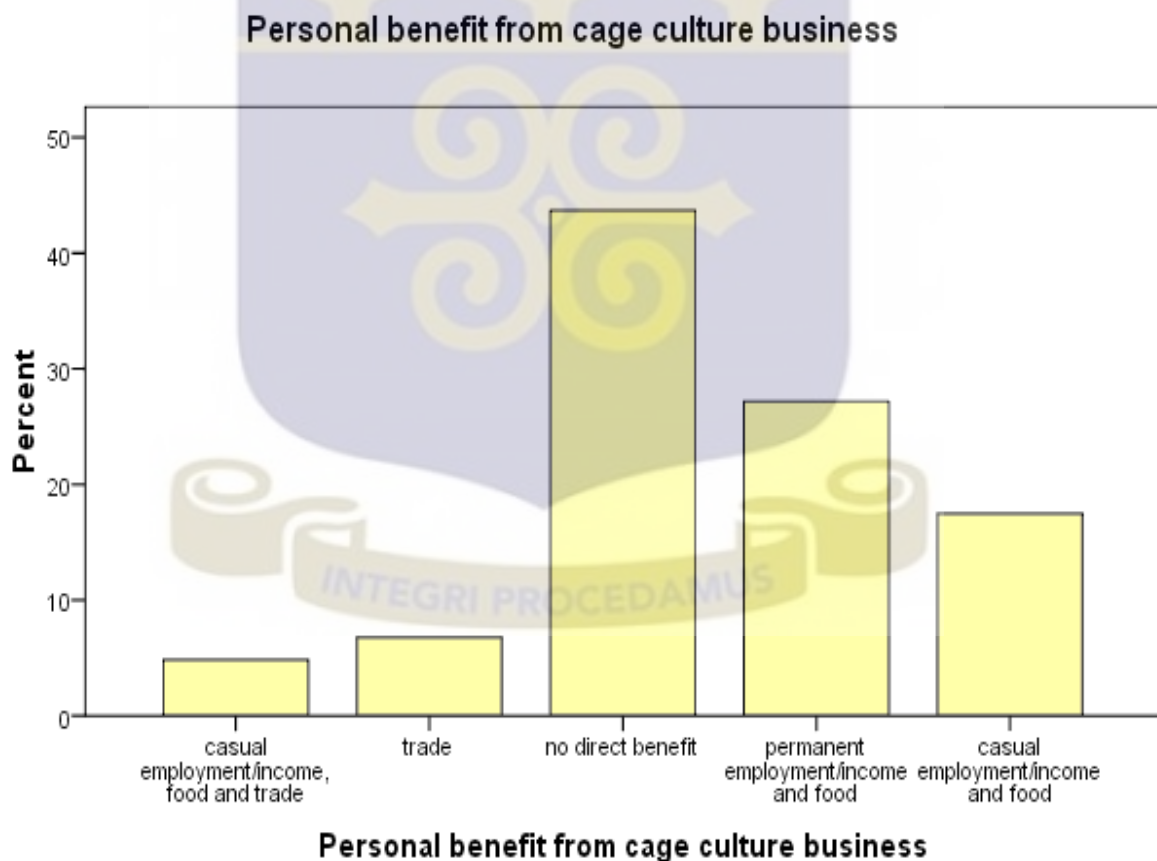
The respondents agreed that the fish farming has greatly improved upon living conditions in the community especially in areas of employment, revenue, food and trade. This implies that the cage aquaculture business has impacted positively on the livelihood of the people.

Women in the community benefitted more than the men from cage farming activities since they are highly employed to assist in harvesting activities than men.



**Plate 4: A section of the people engaged in fish farming activities for income**

From Table 15, 43.7 % of the people interviewed did not benefit directly from the cage aquaculture business in the community. The rest (56.3 %) have direct benefits from fish farming activities. 4.9% gained from casual employment, income, food and fish trade. 6.8% benefited from fish trade. 27.2% benefited from permanent employment, income and food. 17.5% gained from casual employment, income and food. Permanent jobs in the fish farming business included supervision of workers, feed rationing in cages, maintenance of fish nets and provision of security services at night. Casual jobs also included fish harvesting, conveying, sorting and grading, weighing, and gutting of fish before cold storage.



**Figure 15: Personal benefits from fish farming**

The respondents demanded livelihood assistance from fish farm owners to improve their living conditions. These included the establishment of more fish farms in the area (33 %), support for educational projects (16.5 %), road construction (11.7 %) and health facilities (18.4 %). Three female respondents representing 2.9 % also asked for the employment of females in permanent fish farming jobs such as feeding of fish in cages and diving to mend fish nets. A few respondents (6.8 %) called on fish farm owners to be law abiding, and avoid chemical usage. The rest had no idea (10.7 %) as to what fish farmers should do to help their community.

#### **4.4 Aquaculture regulations and compliance levels of fish farm owners**

Not all fish farmers have registered their business entity. Sources of income for fish farming business vary since the business is capital intensive. Compliance with aquaculture regulations by fish farmers has not been encouraging.

##### **4.4.1 Socio-economic background of cage farm owners in the study area**

All the fish farm owners in the study area interviewed were males.

Only one (1) fish farm owner was between the ages of 18-35 years, eleven (11) of them fell between the ages of 35-59 years while six (6) of them were 60 years and above.

All the fish farm owners interviewed have attained higher forms of education. 22.2 % accessed senior high or technical education while 77.8 % of them had educational certificates at tertiary levels. The results indicated that most fish farmers in the area are highly educated businessmen.

All the farm owners in the study area engaged in other economic activities apart from fish farming. Fish farming therefore was their secondary economic activities.

50 % of the fish farm owners were government workers while the rest were self-employed.

#### 4.4.2 Registration of fish farming business in the study area

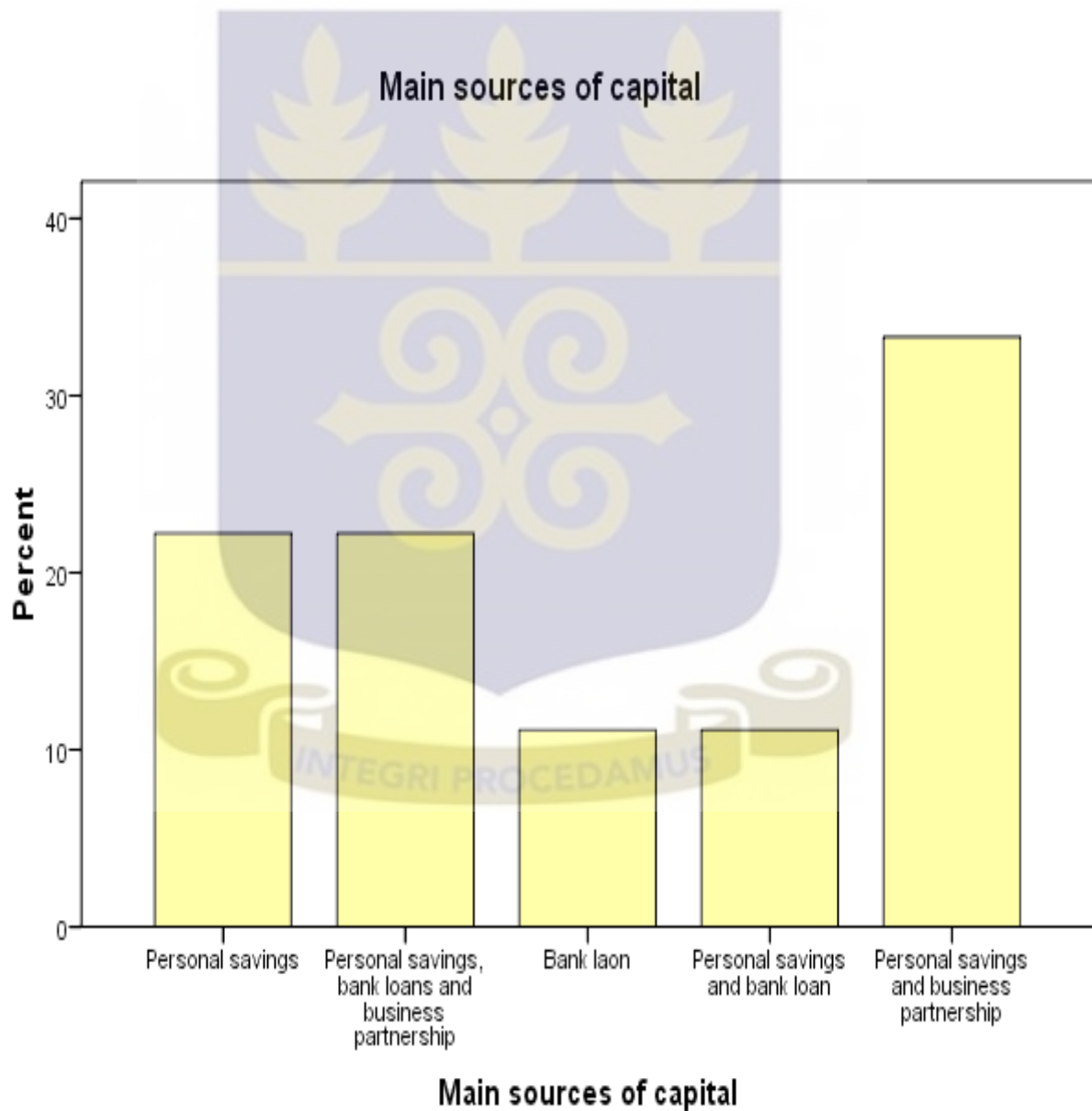
Ten (10) out of the eighteen (18) respondents have registered their business entities with various authorities such as the Local Assemblies, the Fisheries Commission and the Registrar General's Department. Eight (8) of them have not register their businesses (Table 6). This implies that there were some fish farms in the study area that were operating without registration, and that regulations on aquaculture in Ghana were not being followed by some of these fish farmers.

**Table 6: Registration of fish farmers in the study area**

Registration of business	Frequency	Percent (%)
Yes	10	55.6
No	8	44.4
Total	18	100.0

#### 4.4.3 Main sources of capital for fish farming business in the study area

Fish farmers combined three different sources of funding in their business (Table 16). Four of them (22.2%) depend solely on personal savings, two (11.1%) rely solely on bank loans. Two others (11.1%) combine personal savings and bank loans. Six of them (33.3%) enter into business partnership with their personal savings while four of them (22.2% combine personal savings, bank loans and are in business partnership (Figure 16).



**Figure 16: Main sources of capital for aquaculture business**

#### **4.4.4 Financial viability of cage aquaculture business in the study area**

All the fish farm owners agreed that cage aquaculture was financially viable even though it is capital intensive.

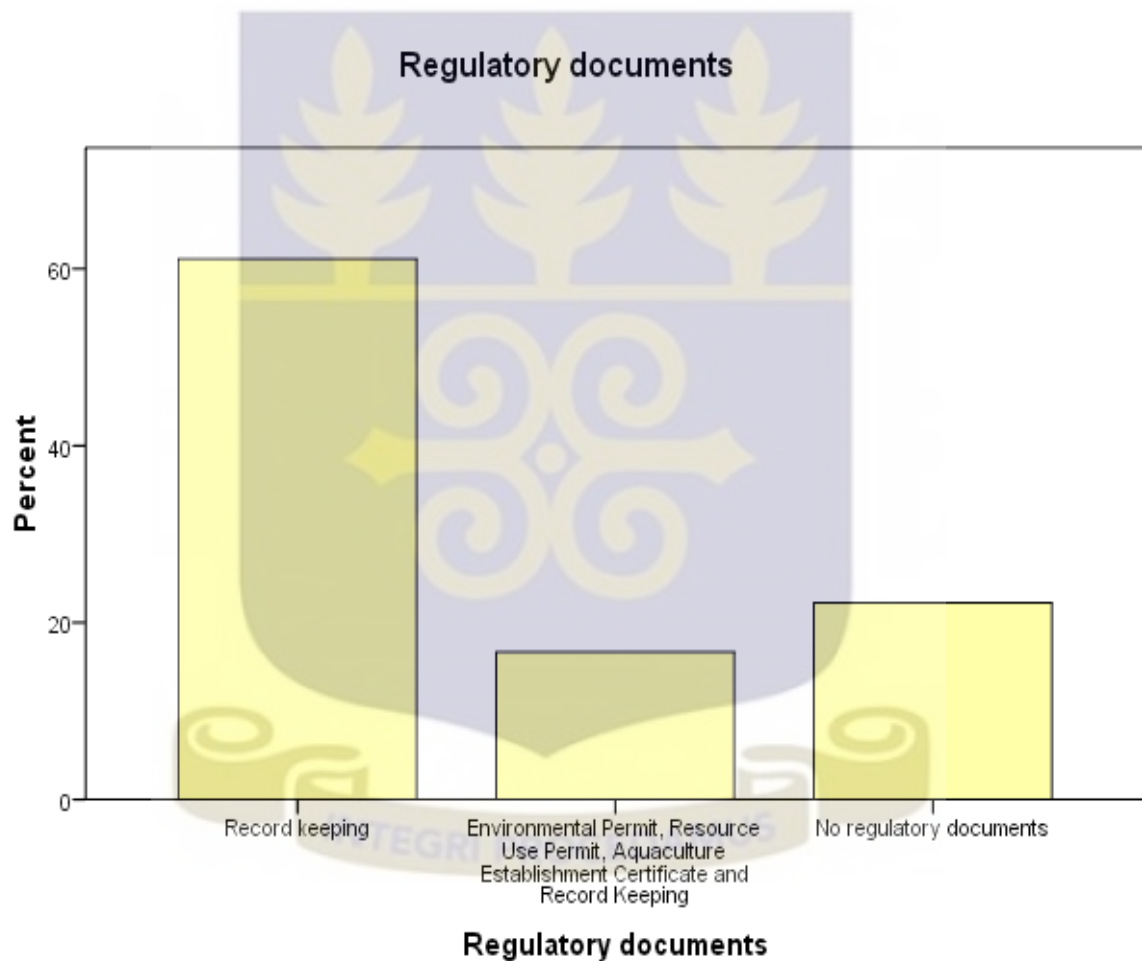
83.3 % of respondents agreed that they reinvested part of their earnings in the fish farming projects while 16 % occasionally reinvested part of their profit in fish farming. This suggests that fish farming in floating cages on the Volta Lake was financially viable, and this explains the purpose of reinvestment of profits back into production for expansion of the business for more profits.

All the fish produced in the study area were sold in Ghanaian markets, and none was exported. Tilapia produced in the area has high demand in Ghanaian markets.

#### **4.4.5 Compliance with aquaculture regulations in the study area**

The results suggested that most fish farmers in the study area do not comply with aquaculture regulations in Ghana. The Aquaculture Regulations of Ghana, 2010 (LI 1968) directs all prospective farmers to obtain three main documents before operating an aquaculture projects in the country. These are acquisition of Environmental Permit from Environmental Protection Agency, Water Use Permit from Water Resources Commission and Aquaculture Establishment Certificate from the Fisheries Commission. The Abuja Declaration on Sustainable Fisheries and Aquaculture in Africa also advocates sustainable aquaculture through integrated water resource management, and the use of locally available legislations to protect the environment.

No fish farming entity complied fully with the regulations governing aquaculture projects in Ghana. In all, fourteen (14) entities representing 77.8 % of respondents kept records in different forms while four (4) of them had no legal documents to back their fish farming projects. Three fish farming groups had environmental permits, water resource use permits and aquaculture establishment certificates, and none of the organizations had environmental management plan (Figure 17).



**Figure 17: Compliance with aquaculture regulations in the study area**

Only one (1) respondent did not provide knowledge and skill training for field workers to safeguard against environmental damage. The rest made provisions for training workshops for their workers.

#### **4.4.6. Challenges facing aquaculture business in the study area**

The farm owners enumerated the challenges facing aquaculture business in the study area. These were inadequate capital for investment, high feed prices, mismanagement, and poaching and fish mortality.



## CHAPTER FIVE

### DISCUSSIONS

#### 5.1 Water quality parameters

The fish feed used in the area is within the recommended feed formulation composition which according to Lovell (1998) are Protein ( $\geq 52\%$ ), Fat ( $\geq 14\%$ ), Moisture ( $\leq 10\%$ ), Minerals ( $\leq 12\%$ ) and other trace elements ( $\leq 10\%$ ). This could have contributed to water quality deterioration (Ali *et al.*, 2006). However, Lovell (1998) reported that fish utilizes protein efficiently as a source of energy since fish has an efficient way of excreting nitrogen. Natural biological processes also ensure the degradation of waste produced in aquaculture ponds (Gross, *et al.*, 2000).

Total nitrate concentration in the sampling sites during the study period did not show significant variations (ANOVA;  $P < 0.05$ ) between the four fish cage farms and the two control sites. The results suggest that nutrient inputs from the tilapia cages in the study area do not significantly impact on the lake water quality. The nitrate figure recorded were below the World Health Organisation WHO (1993, 1998) standards for drinking water quality which is 10 mg/L indicating that the lake water is within drinking water level. Denitrifying bacteria have the natural ability to transform nitrate-nitrogen into gaseous nitrogen that may be lost into surrounding air (Gross, *et al.* 200) A similar research conducted by Effendie *et al.* (2005) on the impacts of fish farming in floating cages on water quality reported undetectable values of nitrates in water under net cages.

Phosphate levels in the study area increased slightly in subsequent months (December, 2013 to April, 2014). The results indicate that while the phosphate values increased in values, site

A maintained the highest values in all the three months. This implies a slight impact of the fish farm at site A on water quality. The highest recorded values of phosphate at site A might be because of higher feed inputs at site A, an area of the lowest depth of the sampling areas. It was found out from the study that the fish farm at site A provided high quantity of feed (13.8 tons per cage) and has also been a site of lowest depth of average 5.2 meters. However, there are no significant differences between cage sites and control sites. Phosphate may be lost either through adsorbing into water sediments or may precipitate directly as insoluble calcium phosphate ( $\text{CaPO}_4$ ) from water (Masuda and Boyd, 1994). The findings are similar to earlier works done by Alston, *et al.* (2005) who suggested that nutrient inputs from cages have no significant effects on the concentration of phosphates in Puerto Rican waters.

The mean values of ammonium concentrations in the study area over the study period for all sampling sites showed no significant differences (ANOVA;  $P < 0.05$ ) between fish farms and control sites. The results imply that ammonium concentration was insignificant in the study area. Water quality in the study area as compared to WHO and Ghana Standards Authority Water Quality Standards (Table 7) is good and this has the natural ability to assimilate waste products from fish cages (Boyd, 2006). The results does not support the works of Ali *et al.* (2006) who demonstrated a significant difference in the concentration of ammonium between caged and non-caged areas in the Nile River. Effendie *et al.* (2005), however, showed no significant differences caged areas and the control sites in a similar study in Lake Cirata in Indonesia.

Average dissolved oxygen concentrations at sampling sites showed recommended levels for aquatic productivity. The results also suggest fluctuation levels of dissolved oxygen

concentration in the four fish farms as well as the control sites. The same results also indicate that dissolved oxygen concentration in the study area was not significantly affected by fish farming activities in the study area. Significant differences (ANOVA;  $P < 0.05$ ) do not therefore exist between the four fish farms and the two control sites. Water currents naturally minimize the depletion of oxygen in natural waters (Brooks and Mahnken, 2003). Alston, *et al.*(2005) detected no significant differences in dissolved oxygen concentration between cage farms and control sites in Puerto Rican waters in a similar research.

The pH value for all the sampling sites during the comparative study were approximately neutral to basic. This reveals that the lake water quality is good for aquaculture productivity which was recorded by Spicer (1997) as between 6.0 and 8.0, and within the WHO Standards of 6.5 – 8.5. Differences in the results were not significant (ANOVA;  $P < 0.05$ ) indicating that the fish farming activities in the study area did not significantly impact on water quality in the area. Helsley (2000) in a report suggested that environmental impacts of open water aquaculture systems are negligible.

The results indicate that there were fluctuating figures in the organic matter recorded at the study sites. However, it is significant to note that site A recorded the highest levels of organic matter in all the three months. This could have been an indication of higher rates of decomposition in site A possibly due to higher levels of waste feeds around the site in question. The mean values, however, show no significant variations (ANOVA;  $P < 0.05$ ) between sampling sites. This result is similar to earlier study by Alston *et al.*(2005) who detected no significant differences in the water quality between cage farms and control sites. Turbidity levels varied slightly between the three months, but not significant (ANOVA;  $P < 0.05$ ) between study sites. Turbidity levels were also below WHO (1993, 1998) Standards of

5.0 indicating that the water quality in the study area was not significantly affected by fish farming activities. This suggest that cage aquaculture has no impact on turbidity in the study area. This result does not support the findings of Garren, *et al.* (2008) who maintained that feed waste and fecal matter from fish cages that are deposited into surrounding waters increase the turbidity of the water environment. However, in another study, Pitta *et al.* (1999) found no significant differences between cages at study sites and the control to suggest that nutrient load from cages poses no serious impacts on water quality.

The results recorded during the study period suggest variations in the levels of suspended solids in the study area with time. However, differences between sampled sites were not significant (ANOVA;  $P < 0.05$ ). The results support earlier works done by Pitta *et al.* (1999) and Alston *et al.* (2005) who found no significant impacts of nutrient inputs from cages on the concentration of suspended solids in adjacent waters.

Results show no significant differences (ANOVA;  $P < 0.05$ ) in the concentration of total dissolved substances at the six sampling sites. Alston, *et al.* (2005) detected no significant differences in the cage farms and the control site.

Results in mean electrical conductivity values indicate that differences in the electrical conductivity in the study area were not significant (ANOVA;  $P < 0.05$ ). Conductivity was also far below WHO Standards of  $700 \mu\text{S}/\text{cm}$  for drinking water. This implies that fish farming in floating cages in the study area has no significant impact on lake water quality.

The mean values in copper concentrations showed no significant (ANOVA;  $P < 0.05$ ) variations. Copper concentration was also below WHO Standards ( $2.0 \text{ mg}/\text{L}$ ) for drinking water quality which shows that the lake water is within drinking water quality and was not

significantly affected by fish farming activities in the study area. Copper in certain concentrations is toxic to some aquatic organisms such as algae and has been used in fish feed formulation to prevent fungal attack on fish nets (Brooks and Mahnken, 2003). However, Buschmann (2002) found no significant difference between the concentration of copper in treated nets and control sites.

Winsby *et al.* (1996) in their report detected no difference in copper concentration in a fish net and a control site of 700 meters away from the fish net. Similarly, Nash (2001) recorded the concentration of copper in fish cages at levels less than approved standard norms.

Average water temperatures suggest that there were no significant differences (ANOVA;  $P < 0.05$ ) between temperature levels at the six sampling sites, and that cage aquaculture activities do not significantly impact on water temperature levels in the study area. In a similar study, Alston, *et al.* (2005) found no significant differences in water temperatures between fish cages and control sites.

## **5.2 Financial viability of cage aquaculture in the study area**

The records from financial inputs and expenditure in the first production cycle suggested that the average cost-benefit ratio of cage aquaculture indicates the business in the area is financially viable. The differences in profit margins could have been mainly due to differences in stocking density and amount of fish feed used per cage since it was found out that though all the fish farmers used imported feed from almost the same sources, feed rationing is different from one fish farm to another. The FAO (2005) in a report indicated that fish farming provides significant source of income for farmers in Ghana.

The expected inputs and outputs indicated that the expected average expenditure for the second production cycle was reduced by 32 percent. This was mainly due to the presence of fixed inputs which attracted relatively no cost in the second production cycle. The results also implied that cage aquaculture business in Ghana is financially viable with high profit margins in the second production cycle. Ofori *et al.* (2009) indicated that farmers in Ghana who averagely produce substantial amount of fish all year round earn significant amount of income through aquaculture business.

### **5.3 Impact of cage aquaculture on the livelihood of people in fish farming communities**

The figures indicated substantial youth population in the community. 48.5 % of the people interviewed were males while 51.5 % were females. The ratio reflected the sex composition in the study area. The 2010 population census of Ghana estimated that females constitute 51.3 % of Ghana's population (Ghana Statistical Service, 2011).

The study indicated a low level of education in the study area. This is in line with a study conducted in Bangladesh on the livelihood status of the indigenous people who produced fingerlings for fish farmers, and putting the illiteracy level of the people at 64 % (Gupta and Haque, 2011). Another study in Croatia on fish farmers record 3.45 % as fish farmers attaining high schools (Mrčelić and Slisković, 2010).

The economic activities of the people in the community involved farming, fishing, fish farming, and trading with a few engaging in artisanship such as carpentry, masonry and dressmaking. This was an indication that the people's livelihood greatly depended on the Volta Lake. Béné and Russell (2007) maintained that a large set of different activities exist even within the same fishing communities along the Volta Lake, and emphasize that

farming combined with fishing constitute the most important sources of economic activities in fishing communities.

Majority of the people have stayed in the community for more than 10 years. There was also an influx of people into the community in the last five years indicating an attraction of people towards fish farming activities in the community.

Majority of the people in the community largely depended on the lake for livelihood purposes which include water transport, recreation, libation (traditional worship) and irrigation. The results suggested that the Volta Lake contributes largely to the livelihood status of the people in fish farming communities.

The study revealed that 93.2 % of the people in the community were with the perception that cage aquaculture does not negatively affect their livelihood opportunities. The assessment of the people implied that aquaculture activities did not negatively impact on the majority of the people in the community.

Only a handful of the people (6.9 %) were with the perception that fish farming in floating cages have negative impacts on water quality, recreation and fishing activities. They (6.9%) perceived that the concentration of cages in the areas affected the beauty of the lake, and also hampered the setting of fish traps in areas close to the shoreline. This was an indication that fish farming activities did not negatively impact on people's livelihoods of majority of community members in the study area.

The majority of the people thought the water environment was not negatively affected by fish farming in floating cages. This confirmed the assertion that cage aquaculture impacts on the water environment are negligible. Pitta *et al.* (1999) also report in their study that environmental impacts of cage aquaculture on natural water resources are not statistically significant.

The people's own assessment of the attitude of fish farmers in the area towards the water environment was encouraging. This suggested that majority of the respondents endorsed the way fish farmers handled the environment in the area.

The results revealed that fish farming in floating cages has greatly improved upon living conditions in the community especially in areas of employment, revenue, food, trade and poverty alleviation. The community charged a fee before the establishment of fish cages close to the community. The revenue is used for community development. This implies that the cage aquaculture business has impacted positively on the livelihood of the people. This is in line with FAO (2005) findings that fish farming in Ghana provides food security, income and employment for family members and neighbors (FAO, 2005).

The results also indicated that fish farming in the area has benefited individuals in areas of casual employment, permanent employment, income, and fish for household consumption, trade and poverty alleviation. Women dominated the fish farming activities since as their services were more needed during harvesting periods. Women in the community are employed for harvesting, conveying, sorting and grading, weighing, fish gutting, recording and packaging. This helps to improve economic conditions of women in the study area. Permanent jobs in the fish farming business included supervision of workers, feed rationing in cages, maintenance of

fish nets and provision of security services at night. Casual jobs also included fish harvesting, conveying, sorting and grading, weighing, and removal of fish scales and intestines before cold storage. These findings agree with earlier researches conducted that revealed that aquaculture is a means of providing food security (Brummet *et al.*, 2009), income generation (Ofori, *et al.*, 2009) and employment (FAO, 2005).

The respondents demanded livelihood assistance from fish farm owners to improve their living conditions. These included the establishment of more fish farms in the area and other livelihood support services such as education, health, road construction and avoidance of chemical usage in cage aquaculture. The appeal from the community may be because the community members were aware of the financial gains in the fish farming industry, and also for the fact that the community was deprived of essential amenities. According to Béné and Russell (2007), fishing communities in developing countries have been socially and economically marginalized, and this situation has affected access to public services such as health, transport, education, market and banking services.

#### **5.4 Aquaculture regulations and compliance levels of fish farm owners**

All the fish farm owners in the study area interviewed were males. The finding supports the earlier work done by Asmah (2008) that fish farming in Ghana is dominated by men. The results also indicated that middle aged people dominated the fish farming business in the study area compared to the youth and the aged. Most fish farmers in the study area are highly educated businessmen. This finding contradicts a study conducted in Croatia on fish farmers which recorded only 3.45 % as fish farmers attaining high schools (Mrclelic and Sliskovic, 2010). The finding is, however, positive information for Ghana since fish farm owners can therefore be educated to comply with aquaculture regulations.

All the farm owners in the study area engaged in other economic activities apart from fish farming. Fish farming therefore was their secondary economic activity. Exactly 50 percent each of the fish farm owners were either government workers or self-employed businessmen. This reveals that fish farming is not regarded by most Ghanaians as permanent jobs which might be the result of the fact that the business venture is capital intensive, and associated with a few challenges. Hiheglo (2008) claimed in another study that even though many Ghanaians are interested in aquaculture business, most people see the business as part-time economic activities.

Many fish farms in the study area were operating without registration. This is an indication that regulations on aquaculture in the area were not being fully complied with by fish farmers. Some farmers may also not be aware of the available regulations due to lack of intensive public awareness and education.

Personal savings, bank loans and individual contributions through business partnership dominated sources of funding for aquaculture business. The results indicated that sources of funding for aquaculture ventures vary due to its capital intensive nature. Lack of financial resources for aquaculture development in Ghana constraints aquaculture productivity, according to Hiheglo (2008).

All the fish farm owners in the study area agreed that cage aquaculture is financially viable even though it is capital intensive. This is an indication that fish farming business in Ghana can contribute largely to the socio-economic development of Ghana. Ofori, *et al.*, (2009) and FAO (2005) agree that fish farming generates substantial income for fish farmers.

Most fish farm owners reinvest part of their profits into cage aquaculture. This suggests that fish farming in floating cages on the Volta Lake is financially viable. It also shows that fish farmers expand their business for more profits.

The tilapia produced in the study area has high demand for consumers in Ghana since all the harvested fish were sold in Ghanaian markets. There is an annual fish deficit of 460,000 tons in Ghana estimated by the Directorate of Fisheries (2009). Expansion in fish farming business will therefore lead to favourable economic gains in Ghana.

The results from the study suggest that no fish farmer complied fully with aquaculture regulations in Ghana. The Aquaculture Regulations of Ghana, 2010 (LI 1968) directs all prospective farmers to obtain three main documents before operating an aquaculture project in the country. These are acquisition of Environmental Permit from Environmental Protection Agency, Water Use Permit from Water Resource Commission and Aquaculture Establishment Certificate from the Fisheries Commission. The Abuja Declaration on Sustainable Fisheries and Aquaculture in Africa also advocates sustainable aquaculture through integrated water resource management, and the use of locally available legislations to protect the environment.

Provisions were made for training workshops in cage aquaculture activities for workers. The skill and knowledge training may be helping to reduce environmental impacts of cage aquaculture on the water environment.

The main challenges identified with aquaculture business in the study area were inadequate capital for investment, high feed prices, mismanagement, and poaching and fish mortality.

This implies that one has to deal with these challenges before the full benefits of aquaculture can be realized. In another study, Hiheglo (2008) listed poaching and lack of credit and other financial resources among the challenges facing aquaculture development in Ghana.



## CHAPTER SIX

### CONCLUSIONS AND RECOMMENDATIONS

#### 6.1 Conclusions

1. Cage aquaculture is fish farming in floating cages whereby fish and/or other aquatics are held in enclosures that permit the exchange of water and waste products between the cage and the surrounding water environment. Cage aquaculture contributes significantly to the socioeconomic development of a nation in areas of employment, foreign exchange, income generation and food security. Cage aquaculture impacts negatively on water environment leading to deterioration in water quality. Other experts, however, found no significant impacts of cage aquaculture on water quality.

2. Little was known of the impacts of cage aquaculture on the Volta Lake. Little was also known of impacts of cage aquaculture on communities close to cage aquaculture environments. Data on the financial viability of fish farming in floating cages was not readily available in Ghanaian business environment. Not much was also known of aquaculture regulatory compliance levels among fish farm owners. The study therefore sought to provide answers to these relevant issues.

3. Kpeve Tornu in the Volta Region of Ghana was chosen as the study area because tilapia cages were highly concentrated in this community. The Ghana Water Company also sourced water from the same area for commercial purposes to serve four administrative districts in the Volta Region.

4. Water samples were taken from four fish farms, analyzed and compared with two control sites between December, 2013 and April 2014. Twenty five (25) percent of adult inhabitants

in the community were interviewed to assess the impacts of the fish farming projects on their livelihood opportunities. Five (5) business entities were selected for data on cost and returns in cage aquaculture business for cost-benefit analysis. Sixty (60) percent of fish farm owners were also interviewed to assess the compliance levels with aquaculture regulations.

5. Results indicated that significant differences did not exist in water quality parameters at fish farms and control sites. There was also a positive impact of fish farming on members in the community in areas of employment, income generation and fish for household consumption. The study revealed that cage aquaculture was financially viable in Ghana even though it was capital intensive. Aquaculture regulations were effective on fingerlings and aquaculture related chemicals producers, but the regulations on fish farmers needed a review since there were no definitions for intensive and semi-intensive fish farming in the aquaculture regulations of Ghana. Compliance levels also needed an improvement.

## **6.2 Recommendations**

1. A research into the impact of stocking density in cage farms is needed to prevent the deterioration of water quality in the near future. A buffer zone must also be created in the vicinity of the intake points of Ghana Water Company (Kpeve Headworks).
2. A research must be conducted to assess the impact of cage aquaculture on sediment chemistry of the fish farms. This is necessary as sediments serve as a reservoir for pollutants from fish cages (Braunbeck et al. 2005).
3. There is also the need for a research into the environmental impacts of fingerlings production activities around the Volta Lake. Fingerlings production involves the use of

hormones mainly for growth and sex reversal, and there is the need to research into how the waste water is being managed by producers.

4. A study will also be needed into the structure of the community of zooplankton in the study area since nutrient loads from cages are likely to attract zooplankton assemblage around cages. The same study will also be needed to assess the impact of cage aquaculture on the population of the fluke that causes bilharzia.

5. Fingerlings that are smaller than fish nets mesh escape into the surrounding waters. Fish of any size also escape from torn nets. There is therefore the need to conduct a study into the impact of escaped fish on local species.

6. Canola oil is used by many fish feed formulators as antibiotics to prevent fish mortality in cages. Canola is a genetically modified plant whose future effects are not yet known. A research into the concentration of this essential oil in fish cage farms is therefore needed.

7. The Volta River Authority, Environmental Protection Agency and the Fisheries Commission must collaborate and intensify regular monitoring of cage aquaculture on the Volta Lake to ensure best practices.

8. The Government of Ghana must ensure the institution of reasonable tax reliefs, subsidies, sustainable aquaculture development fund and a financial support for local fish feed formulation industries to reduce aquaculture input cost.

## REFERENCES

- Ackefors, H., & Enell, M. (1990). Discharge of nutrients from Swedish fish farming to adjacent sea areas. *Ambio* 19 (1), 28–35.
- Afadjato South District Statistical Department (2013). Afadjato South District District Assembly
- Aggrey-Fynn, E. (2001). The contribution of the fisheries sector to Ghana's economy. *A Paper Prepared on Behalf of the FAO as an Input into the Sustainable Fisheries Livelihoods Study*. April 2001.
- Ali, M. Abdel-Meguid M. & Abdin, A. (2006). Assessment of floating fish cages impacts on the water, fauna, flora, sediments, aquatic weeds, fish and hydraulics of Damietta branch. *Scientific Bulletin, Faculty of Engineering, Helwan University*, April, 2006.
- Alston, D.E., Cabarcas, A., Capella, J., Benetti, D.D., Keene-Meltzoff, S., Bonnilla, J., & Cortés, R. (2005). *Environmental and social impact of sustainable offshore cage culture production in Puerto Rican waters*. Mayagüez: Department of Marine Sciences, University of Puerto Rico. Pp 1- 208
- APHA-AWWA-WEF. 1998. Standard methods for the examination of water and wastewater, 20th edition. Washington DC, USA: American Public Health Association.
- Applin, D. (1994). *Key Science: Biology*. Cheltenham: Stanley Thornes Publishers Ltd.
- Asmah R. (2008). Development potential and financial viability of fish farming in Ghana. (PhD thesis ). Institute of Aquaculture, University of Sterling.
- Béné, C. & Russell, A.J.M. ( 2007). Diagnostic study of the Volta basin fisheries part 2 - livelihoods and poverty analysis, current trends and projections. *Report commissioned by the focal basin project - Volta*. Cairo Egypt: WorldFish Center Regional Offices for Africa and West Asia, 66p
- Bell, N. (2006). *Pollution*. Microsoft® Encarta® 2006 (CD). Microsoft Corporation, 2005
- Beveridge, M.C.M., (1984). Cage and pen fish farming. carrying capacity models and environmental impact. FAO Doc. Tech. Peches. No. 255. FAO, Rome, 126 pp.
- Beveridge, M. (1987). *Cage Aquaculture*. Fishing News Books Ltd., England.
- Beveridge, M.C.M.. (1995). Cage and pen fish farming, carrying capacity models and environmental impact. FAO Fish technical paper 255, 131.
- Beveridge, M.C.M., (1996). *Cage Aquaculture* (2<sup>nd</sup> ed.). Oxford: Fishing News Books Ltd., 346 pp.

- Bocek, A. (n.d.). *Introduction to intensive cage culture of warmwater fish*. Alabama: Auburn University Publications. Pp 1 - 14
- Boyd, C. E. (2006). *Farm-Level Issues in Aquaculture Certification: Tilapia, Auburn, Alabama, USA, Dec. 2006*
- Braunbeck, T. Bottcher, M. Hollert, H. Kosmehl, T. Lammer, E. Leist, E. Rudolf, M. Seitz, N. (2005). Towards an alternative for the acute fish LC50 test in chemical assessment: the fish embryo toxicity test goes multi-species- an update. *Altex* 22: 87- 102.
- Brooks, K. M., & Mahnken, C.V.W. (2003). Interaction of Atlantic salmon in the Pacific northwest environment, II. organic wastes. *Fisheries Research* 62: 255-293.
- Brooks, M.K., & Mahnken, C.V.W. (2003b). Interaction of Atlantic pacific salmon in the Pacific Northwest environment, III. Accumulation of zinc and copper. *Fisheries Research* 62: 295- 305.
- Brugère, C. & Ridler, N. (2004). Global aquaculture outlook in the next decades: An analysis of national aquaculture production forecasts to 2030. *FAO Fisheries Circular, No. 1001*. Rome, FAO. 55 pp.
- Brugère, C., Ridler, N., Haylor, G., Macfadyen, G., & Hishamunda, N. (2010). Aquaculture planning: Policy formulation and implementation for sustainable development. *FAO Fisheries and Aquaculture Technical Paper*. No. 542. Rome, FAO. 2010. 70p.
- Brummet, R.E., Lazard, J., & Moehl, J. (2009). African aquaculture: Realizing the potential. *Food Policy*, 181 (1-2): 37-59
- Buschmann, A. 2002. *Environmental impact of Chilean salmon farming: The situation in the Tenth region of the lakes*. Terram. [www.terram.ch/publication](http://www.terram.ch/publication) 22.12.2013
- Carrol, M.L., Cochrane, S., Fieler, R., Velvin, R. & White, P. (2003). Organic enrichment of sediments from salmon farming in Norway: Environmental factors, management practices and monitoring techniques. *Aquaculture* 226: 165 – 180
- Chen, Y.S., Beveridge, M.C.M. & Telfer, T.C. (2000). Settling rate characteristics and nutrient content of the faeces of Atlantic salmon, *Salmo salar* L., and the implications for modeling of solid waste dispersion. *Aquaculture Research* 30: 395-398.
- Chen, Y.S., Beveridge, M.C.M., Telfer, T.C. & Roy, W.J. (2003). Nutrient leaching and settling rate characteristics of the faeces of Atlantic salmon (*Salmo salar* L.) and the implications for modeling of solid waste dispersion. *J. Appl. Ichthyol.* 19: 114-117.

- Cho, C.Y., J.D. Hynes, K.R. Wood, & Yoshida, (H.K. 1991). Quantification of fish culture wastes by biological and chemical (limnological) methods. In: C.B. Cowey and C.Y. Cho (Editors), *Nutritional Strategies and Aquaculture Waste*. University of Guelph, Canada.
- Crawford, C., Macdonald, C. & Mitchell, I. (2002). Evaluation of techniques for environmental monitoring of salmon farms in Tasmania. Tasmanian Aquaculture and Fisheries Institute, University of Tasmania, Australia.
- De la Vega, J.T. (2001). Feeds and feeding management of tilapia in cages. Paper Presented at the 4th Southern Luzon Zonal R and D Review, DAP Tagaytay City, Philippines.
- Delgado C.L., Wada, N., Rosegrant, M.W., Meijer, S. & Mahfuzuddin, A. (2003). Fish to 2020 supply and demand in changing global markets. *Technical Report*, 62.
- Dela Vega J.T. (2001) *Feeds and feeding management of tilapia in cages*. Paper Presented at the 4th Southern Luzon Zonal R and D Review, DAP Tagaytay City, Philippines.
- Demir, N., Kirkagac, M. U., Pulatsu, S. and Bekcan, S. (2001). Influence of trout cage on water quality, plankton and benthos in an Anatolian Dam Lake. *The Israeli Journal of Aquaculture-Bamidgeh* 53:115-127.  
Department of Geography and Resource Development, University of Ghana, Accra (2014).
- Diana JS. (1993). *Conservation and utilization of fish genetic resources in capture and culture fisheries*. Pages 89–103: In JI Cohen, CS Potter, (Eds.), *Case studies of genetic resource conservation in natural habitats*. Washington (DC): American Association for the Advancement of Science.
- Diaz, M.M., Temporetti, P.F. and Pedrozo, F.L. (2001). Response of phytoplankton to enrichment from cage fish farm waste in Alicura Reservoir (Patagonia, Argentina). *Lake and Reservoirs: Research and Management* 6.
- Directorate of Fisheries (2009). *Annual report for fisheries commission of the ministry of food and agriculture*. Accra:Ministry of Food and Agriculture, Ghana.
- EAO (Environmental Assessment Office of the British Columbia, Canada) (1996). The salmon aquaculture review. Final Report. 2003.
- Effendie, I., Nirmala, K., Hasan, S. U., Sudrajat, A. O., & Muhammad, J. H. (2005). Water quality fluctuations under floating net cages for fish culture in Lake Cirata and its impact on fish survival. *Fisheries Science*. 71: 972-977.
- Enell, M., (1995). Environmental impact of nutrients from Nordic fish farming. *Water Science and Technology* 31 (10), 61–71.
- Eng, C.T. and Tech, E. (2002). History of cage culture. In P.T.K. Woo, (editor). *Disease and disorders of finfish in cage culture*. CABI Publishing.

- FAO (Food and Agriculture Organization of the United Nations, Rome). (1997). *Review of the state of the world aquaculture*. FAO Fisheries Circular no. 886 FIRI/C886 (rev. 1).
- FAO (2002). *Fishstat plus*. Software. Rome, Italy.
- FAO (Food and Agriculture Organization of the United Nations). (2005). *Yearbook of Fishery Statistics*. Rome: FAO.
- FAO (Fisheries and Aquaculture Department Food and Agriculture Organization of the United Nations). (2010). *The State of World Fisheries and Aquaculture*. Rome: FAO
- FAO. (2005). *Results of the 2003-2004 baseline survey of Ghanaian fish farmers*. Accra: FAO Regional Office for Africa. pp. 77.
- FAO (2012). *The state of world fisheries and aquaculture 2010*. Rome: Food and Agriculture Organization of the United Kingdom.
- Food and Agriculture Organisation (FAO). 2007. *The State of the World Fisheries and Aquaculture 2006*. FAO Fisheries and Aquaculture Department. Rome, 2007. <ftp://ftp.fao.org/docrep/fao/009/a0699e/a0699e.pdf> (Date Read:15.01.13)
- Fezzardi, D., Massa, F., Àvila-Zaragoza, P., Rad, F., Yücel-Gier, G., Deniz, H., and Ben Salem, S. (2013). *Indicators for sustainable aquaculture in Mediterranean and Black Sea countries. Guide for the use of indicators to monitor sustainable development of aquaculture. Studies and reviews. General fisheries commission for the Mediterranean*. No 93. Rome, FAO. 2013. 60 pp.
- Food and Agriculture Organisation (2013). *National Acquaculture Review Ghana*. Rome: Fish and Aquaculture Department.
- Frid, C.L.J. & Mercer, T.S. (1987). Environmental monitoring of caged fish farming in microtidal environment. *Marine Pollution Bulletin*, 20:379-383.
- Garren, M., Smriga, S. and Azam, F. (2008). Gradients of coastal fish farm effluents and their effect on coral reef microbes. *Environ Microbial* 10:2299–2312.
- Ghana Standard Authority Water Quality Standards, 2012
- Ghana Statistical Service. (2011). *2010 Population and housing census: Summary report of final results*. Accra: Ghana Statistical Service.
- Green, J. A., Hardy, R.W., & Brannon, E.L. (2002). Effect of dietary phosphorus and lipid levels on utilization and excretion of phosphorus and nitrogen by rainbow trout *Oncorhynchus mykiss*. 1. Laboratory Scale Study. *Aquaculture Nutrition* 8: 279-290.

- Gondwe, M.J., Guildford, S.J., & Hecky, R.E. (2011). Carbon, nitrogen and phosphorus loadings from tilapia fish cages in Lake Malawi and factors influencing their magnitude. *J. Great Lakes Res.*, 37(1): 93-101.
- Gross, A., Boyd, C. E., & Wood, C. W. (2000). *Nitrogen transformations and balance in channel catfish ponds. Aquacultural Engineering 24:1-14.*
- Guo, L., & Li, Z. (2003). Effect of nitrogen and phosphorus from fish cage on the communities of shallow lake in Middle Yangtze River Basin of China. *Aquaculture 226: 201-212.*
- Gupta, N., & M. Haque, M. (2011). Assessing livelihood impacts of cage based fish fingerlings production on *Adivasi* households in north-east and north-west Bangladesh. Mymensingh: Department of Aquaculture, Bangladesh Agricultural University.
- Government of Ghana. Aquaculture Regulations of Ghana, 2010 (LI 1968)
- Government of Ghana. Environmental Assessment Regulations.1999. (L.I. 1652).
- Government of Ghana. Environmental Protection Agency Act, 1994. (Act 490).
- Government of Ghana. Fisheries Act, 2002. (Act 625). Government printer, Assembly Press. Accra. P. 23
- Government of Ghana. Public Health Act, 2012. (Act 851). Government printer, Assembly Press. Accra.
- Government of Ghana. Volta River Development Act 1961 Act 46 amended by Volta River Development (Amendment) Act, 2005 (Act 692). Government printer, Assembly Press. Accra.
- Gooley, G.S., De Silva, S.S., Horne, P.W., McKinnon, L.J., & Ingram, B.A. (2000). Cage aquaculture in Australia: A developed country perspective with reference to integrated aquaculture development within inland waters. In: I.C. Liao & C.K. Lin (eds.). *Proceedings of the first symposium on cage aquaculture in Asia*. Asian Fisheries Society. Manila, pp 19-34
- Gowen, R. J. & Bradbury, N. B. (1987). The Ecological impact of salmonids farming in coastal waters: A review. oceanography and marine biology. *An Annual Review 25:563-575.*
- Hankanson, L. (2005). Changes to lake ecosystem structure resulting from fish cage farm emissions. *Lakes & Reservoirs: Research and Management, 10: 71-80.*
- Hall, P.O.J., Holby, O., Kollberg, S., & Samuelsson, M.O. (1992). Chemical flux and mass balances in a mariculture fish cage farm. iv. nitrogen. *Mar. Ecol. Pro. Ser.* 89: 81–91.

- Hart, J. (2009). *Water Pollution*. Microsoft® Student 2009 [DVD]. Redmond, WA: Microsoft Corporation, 2008.
- Heck, S., Béné, C., & Reyes-Gaskin, R. (2007). Investing in African fisheries: Building links to the millennium development goals. *Fish and Fisheries*, 8, 211-226.
- Heinig, C.S. (2000). *The impact of salmon aquaculture: The difficulties of establishing acceptability limits and standards*. Report presented to Aquaculture/Environment Workshop. University of Massachusetts, Boston, USA. Jan. 11-13, 2001.
- Helsley, C.E. (2000). *Hawaii open ocean aquaculture demonstration program*. Nice, France: European Aquaculture Society Special Publication N°. 28.
- Hiheglo, P.K. (2008). *Prospects, challenges, antidotes and future prospects of aquaculture in Ghana*. Tromso: Norwegian College of Fishery Science, University of Norway.  
[www.ub.uit.no/munin/bitstream/10037/1431/thesis.pdf](http://www.ub.uit.no/munin/bitstream/10037/1431/thesis.pdf) Read on 12/02/14.
- Hu, B.T. (1994). Cage development and its role in aquaculture in China. *Aquaculture and Fisheries Management*, 24:305-310.
- Islam, M.S., (2005). Nitrogen and phosphorus budget in coastal and marine cage aquaculture and impacts of effluent loading on ecosystem: review and analysis towards model development. *Marine Pollut. Bull.*, 50: 48-61.
- Krom, M.D., Porter, C. & Gordin, H. (1995). Causes of fish mortalities in the semi-intensively operated seawater ponds in Eilat, Israel. *Aquaculture* 49: 159–177.
- Lovell, T. (1998). Dietary requirements. In T. Lovell (Eds.), *Nutrition and feeding of fish* (pp. 13-69). Boston, MA: Kluwer Academic Publishers.
- MacPherson, N.J. & Agyenim-Boateng C.E. (1991). *A synthesis report on technical assistance and investment*.  
<http://www.fao.org/docrep/field/003/AC112E/AC112E00.htm>
- MacPherson, N.J., & Agyenim-Boateng C.E. (1991). *The development of aquaculture and culture-based fisheries in Ghana: The social and cultural contexts*.  
<http://www.fao.org/docrep/field/003/AC107E/AC107E00.htm>
- Marte, C.L., Cruz, P. and Flores, E.E.C. (2000). Recent development in freshwater and marine cage aquaculture in the Philippines. In: I.C. Liao & C.K. Lin (eds.). *Proceedings of the First Symposium on Cage Aquaculture in Asia*. Manila : Asian Fisheries Society., pp 75-88
- Masuda, K. and Boyd, C. E. (1994). *Phosphorus fractions in soil and water of aquaculture ponds built on clayey, Ultisols at Auburn, Alabama*. *Journal of the World Aquaculture Society* 25:379-395.

- Méndez, N. (2002). Annelid assemblages in soft bottoms subjected to human impact in the Urías Estuary (Sinaloa, Mexico). *Oceanologica Acta* 25:139-147.
- Mrcelic, G. J., & Sliskovic, M. (2010). The impact of fish cages on water quality in one fish farm in Croatia. *World Academy of Science, Engineering and Technology* 44 2010.
- Nash, C.E. (editor). (2001). The net-pen salmon farming industry in the Pacific Northwest. *U.S. Dept. of Commer., NOAA Tech. Memo. NMFS-NWFSC-46*.
- Naylor, R. L., Goldberg, R.G., Mooney, H., Beveridge, M., Clay, J, Folke, C., & Williams, M. (1998). Policy Forum: Ecology. Nature's subsidies to shrimp and salmon farming. *Science* 282.
- Naylor, R. L., Goldberg, R.G., Primavera, J.H., Kautsky, N., Beveridge, M.C.M., Clay, J. .... & Troell, M. (2000). *Effect of aquaculture in the world food supplies. In Nature. The down side of fish farming*. London: Macmillans Magazines Ltd. pp. 1017–1024
- Neori A., Krom M.D., Cohen, I., & Gordin, H. (1989). Water quality conditions and particulate chlorophyll *a* of new intensive seawater fishponds in Eilat, Israel: Daily and diel variations. *Aquaculture* 80: 63–78.
- Ofori, J.K., Dankwa, H.R. Brummet, R., & Abban, E.K. (2009): *Producing tilapia in small cages in West Africa*. World Fish Center Technical Manual No. 1952. Penang : The World Fish Center, 16 pp.
- Phuong, N.T. (1998). Cage Culture of Pangasius Catfish in the Mekong Delta, Vietnam: Current Situation Analysis and Studies for Feed Improvement. (Unpublished Ph.D. dissertation). Toulouse : National Institute Polytechnique .
- Pillay, T.V.R. (1992). *Aquaculture and environment*. Cambridge: Blackwell Scientific Publications Inc.
- Pitta, P.I., Karakassis, M., & Zivanovic, S. (1999). Natural versus mariculture induced variability in nutrients and plankton in the Eastern Mediterranean. *Hydrobiologia*. 391:181-194.
- Sakyi, K.A. (2012). *Imperative of fish farming in Ghana*. Accra: Unpublished.
- Selock, D., & Swann, L. (1994). *Cage culture of fish in the North Central Region*. Iowa: Iowa State University. Pp. 1
- Spicer, A.V. (1997). *Water quality for aquaculture*. West Virginia: West Virginia University Extension.
- Storebakken, T., Shearer, K. D., & Roem, A.J. (2000). Growth, uptake and retention of nitrogen and phosphorus, and absorption of other minerals in Atlantic Salmon *Salmo salar* fed diets with fish meal and soy-protein concentrate as main source of protein. *Aquaculture Nutrition* 6: 103-108.

- The New Partnership for African Development (2005). *Proceedings of the NEPAP fish for all summit*. Abuja: Elias Modern Press.
- Tucker, C.S., Lloyd, S.W., & Busch, R.L. (1984). Relationship between phytoplankton periodicity and the concentrations of total and un-ionized ammonia in channel catfish ponds. *Hydrobiologia* 111:75–79.
- Tundisi, J. G., & Matsumura-Tundisi, T. (2008). *Limnologia*. São Paulo : Oficina de textos. p 631.
- Tundisi, J. G. (2003). Água no século 21: enfrentando a escassez. RIMA/IIIE, São Carlos, 247 p.
- Sumagaysay, N. S., & Chavoso, G. (2003). Nitrogen and phosphorus digestibility and excretion of different-sized groups of milkfish (*Chanos Chanos Forsskal*) fed formulated and natural food-based diets. *Aquaculture research* 34: 407-418
- United States Department of Agriculture (2009). *Managing Iowa state fisheries: Cage fish culture*. Iowa: Iowa State University.
- Vista, A., Norris, P., Lupi, F., & Bernsten, R. (2006). Nutrient loading and efficiency of tilapia cage culture in Taal Lake, Philippines. *Philipp Agric Sci.* 89:48-57.
- Water Resources Commission Act, 1996 (Act 522) p VII 4005-VII 4006
- Winsby, M., Sander, B., Archibald, D., Daykin, M., Nix, P., Taylor, F.J.R., & Mundy, D. (1996). *The environmental effects of salmon net-cage culture in British Columbia*. Victoria, BC : Ministry of Environment, Lands and Parks, Environmental Protection Dept. Industrial Waste/Hazardous Contaminants Branch.
- World Health Organisation (1993, 1998). *Guidelines for drinking water quality, Geneva*.
- WHO (1989). Health guidelines for the use of wastewater in agriculture and aquaculture: Report of a WHO Scientific Group. WHO Technical Report Series 778. World Health Organization, Geneva, Switzerland.
- Wu, R.S.S. (1995). The Environmental Impact of Marine Fish Culture: Towards a Sustainable Future, *Marine Pollution Bulletin*, 31, pp. 159–166.
- Ye, Y. (1999). Historical consumption and future demand for fish and fishery products: exploratory calculations for the years 2015/2030. Rome: FAO Fisheries Circular, No. 946. FAO. 50 pp.
- Yucel-Gier, G., Kucuksezgin, F., & Kocak, F. (2007). Effects of fish farming on nutrients and benthic community structure in the Eastern Aegean (Turkey). *Aquaculture Research* 38:256–267

## APPENDICES

## Appendix A: Water quality parameters at study areas (December, 2013)

Parameter	Site A	Site B	Site C	Site D	Site E (Control)/800m from Site D (Upstream)	Site F (Control)/800m from Site A (Downstream)
Total nitrogen (mg/L)	0.6	0.4	0.5	0.5	0.6	0.2
Total phosphorus (mg/L)	0.44	0.36	0.28	0.26	0.25	0.24
Ammonia – nitrogen (mg/L)	0.07	0.07	0.05	0.04	0.05	0.04
DO (mg/L)	3.5	3.21	3.92	4.1	3.97	4.02
TDS(mg/L)	31	30	31	29	30	32
Total Suspended solids (mg/L)	5	6	6	6	6	4
pH	7.1	7.3	7.3	7.3	7.4	7.6
BOD (mg/L)	2.25	1.75	1.82	2.23	1.8	1.6
Turbidity (NTU)	2	2	2	2	2	1
Conductivity	63	63	63	63	62	64
Temperature(°C)	30.12	29.93	30.17	29.6	29.8	29.9
Heavy metals (Cu) (mg/L)	0.07	0.05	0.05	0.07	0.05	0.02

**Appendix B: Water quality parameters at study areas (February, 2014)**

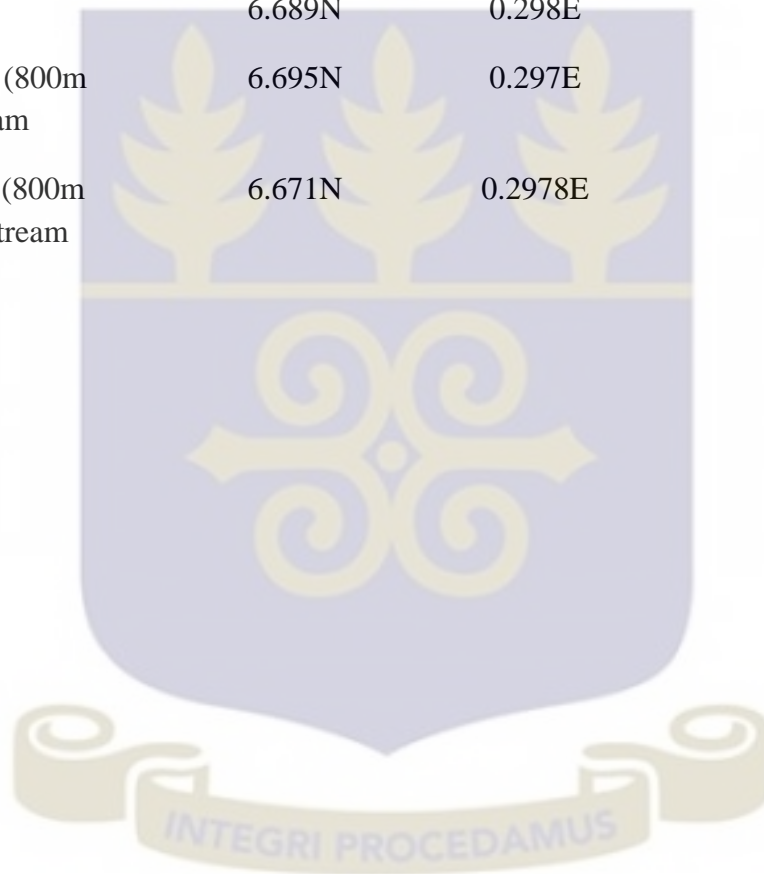
<b>Parameter</b>	<b>Site A</b>	<b>Site B</b>	<b>Site C</b>	<b>Site D</b>	<b>Site E (Control)/800m from Site D (Upstream)</b>	<b>Site F (Control)/800m from Site A (Downstream)</b>
Total nitrogen (mg/L)	0.7	0.6	0.7	0.3	0.7	0.6
Total phosphorus (mg/L)	0.46	0.32	0.42	0.36	0.39	0.42
Ammonia – nitrogen (mg/L)	0.01	0.04	0.01	0.01	0.05	0.05
DO (mg/L)	6.1	5.59	5.89	5.85	5.79	6.2
TDS(mg/L)	38	39	34	41	40	42
Total Suspended solids (mg/L)	1	3	3	2	3	5
pH	7.7	7.9	8.1	7.5	8.1	7.5
BOD (mg/L)	1.7	0.67	1.09	0.32	0.09	0.05
Turbidity (NTU)	3	3	3	3	2	3
Conductivity	78	79	78	83	80	83
Temperature (°C)	30.8	30.6	30.4	30.5	30.8	30.9
Heavy metals (Cu) (mg/L)	0.12	0.08	0.06	0.06	0.13	0.07

**Appendix C: Water quality parameters at study areas (April, 2014)**

<b>Parameter</b>	<b>Site A</b>	<b>Site B</b>	<b>Site C</b>	<b>Site D</b>	<b>Site E (Control)/800m from Site D (Upstream)</b>	<b>Site F (Control)/800m from Site A (Downstream)</b>
Total nitrogen (mg/L)	1	0.8	0.8	0.6	1.5	0.8
Total phosphorus (mg/L)	4.9	2.43	3.02	2.44	2.14	0.34
Ammonia – nitrogen (mg/L)	0.12	0.14	0.06	0.17	0.11	0.1
DO (mg/L)	6.9	7.9	7.5	7	7.2	7.1
TDS(mg/l)	30	28	29	29	29	29
Total Suspended Solids (mg/L)	7	5	9	7	8	6
pH	7.8	6.9	7.9	7.5	7.1	7.6
BOD (mg/L)	1.9	3.5	3.1	1.8	2.6	2.6
Turbidity	4	3	3	4	3	3
Conductivity	67	63	63	64	63	64
Temperature(°C)	32.3	31.9	32.2	32.6	32.9	32.3
Heavy metals (Cu) (mg/L)	0.13	0.12	0.12	0.11	0.19	0.11

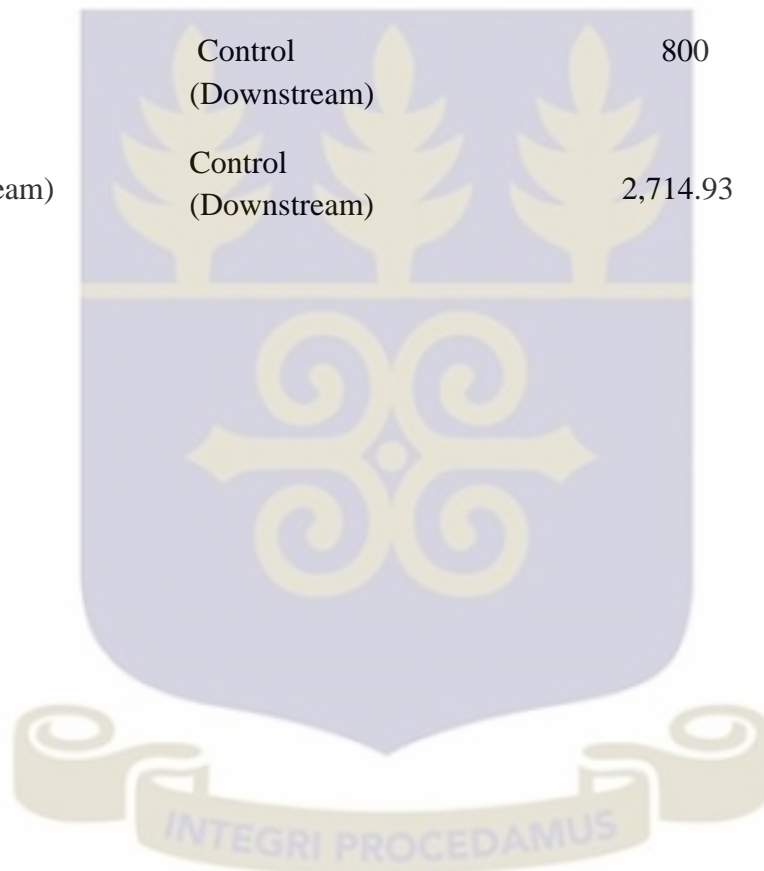
**Appendix D1: Global positioning system (GPS) model of sampling sites**

<b>Station</b>	<b>Latitude (°)</b>	<b>Longitude (°)</b>	<b>Av. Depth (in meters)</b>
Site A	6.6784N	0.301E	5.2
Site B	6.6754N	0.292E	19.5
Site C	6.6854E	0.294E	15.9
Site D	6.689N	0.298E	14.6
Site E/Control (800m away) Upstream	6.695N	0.297E	23.8
Site F/Control (800m away) Downstream	6.671N	0.2978E	20.0



**Appendix D2: Distances between sampling sites**

<b>From</b>	<b>To</b>	<b>Distance (in meters)</b>
Site A	Site B	1,065.16
Site B	Site C	1,187.11
Site C	Site D	642.6
Site D	Control (Upstream)	800
Site A	Control (Downstream)	800
Control (Upstream)	Control (Downstream)	2,714.93



**Appendix E**

**(Information on cage culture provided by a registered cage culture business entity)**

*This questionnaire is being administered to assess the financial viability of cage culture business on the Volta Lake. The study is purely for academic purposes and the information will be treated confidentially. Your genuine response is very much needed for the success of the exercise.*

Interview Date ..... Time .....

1. Name of organization .....
2. Position/Office of the respondent in the organization .....

**Average Production Cost, Revenues, and Returns on Investment in Cage Aquaculture**

**Business for a Single Cage per Production Cycle (for cost-benefit analysis)**

Item	Quantity	Unit Value GH¢	Item Value GH¢
Cage			
Fingerlings			
Transportation			
Feed (kg)			
Labour (person-month)			
Working Tools/Equipment		-	
Communal charge			
Marketing			
<b>Total cost</b>			
<b>Revenues</b>			-
Total Harvest (kg)			
Net Income			
Returns on Investment (%)			

Adapted from Ofori *et. al.* (2009)

**Appendix F**

**INSTITUTE FOR ENVIRONMENT AND SANITATION STUDIES**

**UNIVERSITY OF GHANA**

**(Information on cage culture impacts on the community)**

*This questionnaire/interview guide is being administered to assess the socioeconomic and environmental impacts of cage culture on the Volta Lake. This study is purely for academic purposes and the information will be treated confidentially. Your genuine response is very much needed for the success of the exercise.*

Interview Date ..... Time .....

*Tick (✓) where appropriate and provide answers to open ended questions*

1. Age bracket in years.
  - a. 18-35 ( )
  - b. 36-59 ( )
  - c. 60 and above ( )
2. Sex
  - a. Male ( )
  - b. Female ( )
3. Educational background
  - a. No formal education ( )
  - b. Primary school level ( )
  - c. JHS/Middle school ( )
  - d. Senior High/Technical education ( )
  - e. Tertiary education ( )
4. What is your main occupation or major economic activity?
  - a. Farming ( )
  - b. Fishing ( )
  - c. Fish Farming ( )
  - d. Trading ( )
  - e. Unemployed ( )
  - f. Other ( Specify ) .....
5. How long have you been in this community?
  - a. Less than one year ( )
  - b. One to five years ( )
  - c. Six to ten years ( )
  - d. Eleven years and above ( )

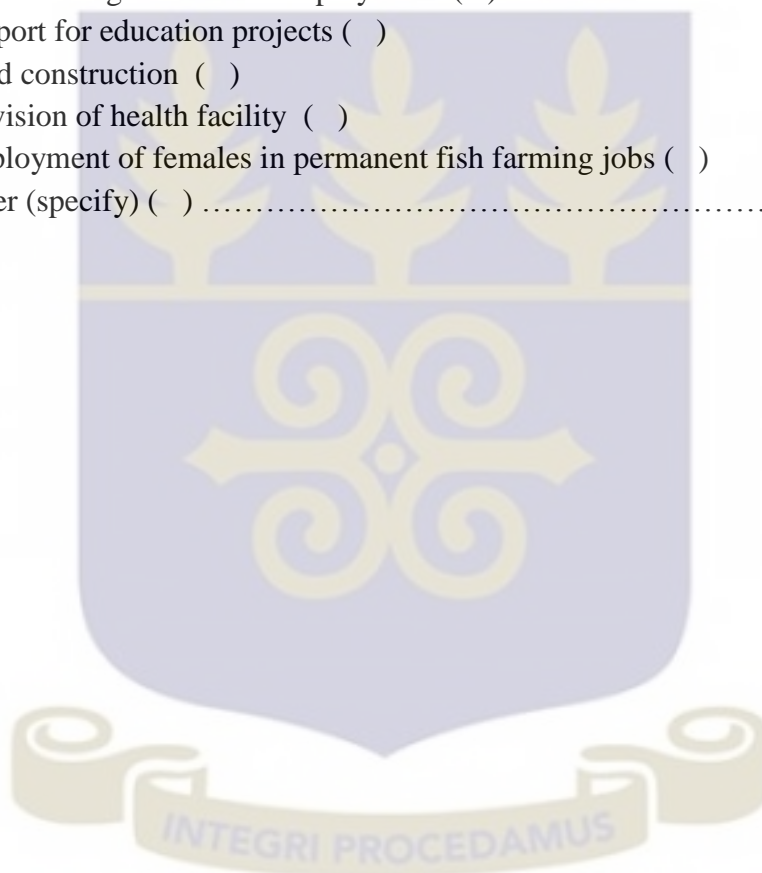
6. What are your main sources of water?
  - a. Pipe-borne water ( )
  - b. Lake water ( )
  - c. Rain water ( )
  - d. Other (Specify) .....
7. What do you mainly use the lake water for (if used)?
  - a. Drinking ( )
  - b. Washing ( )
  - c. Libation and worship ( )
  - d. Food preparation ( )
  - e. Irrigation ( )
  - f. Recreation ( )
  - g. Transport ( )
  - h. Other (Specify) ( ) .....
8. Are you in any way negatively affected by the cage culture business in your area?
  - a. Yes ( )
  - b. No ( )
  - c. Not certain ( )
9. If yes to 8, in what way(s) does it affect you?
  - a. Water quality effects ( )
  - b. Water transport ( )
  - c. Recreation ( )
  - d. Fishing activities ( )
  - e. Religion ( )
  - f. Occupation ( )
  - g. Other (Specify) ( ) .....
10. Do you think cage fish farming practices pollute the lake water?
  - a. Yes ( )
  - b. No ( )
  - c. Not certain ( )
11. What is your assessment of fish cage farmers' attitude towards the water environment?
  - a. Good ( )
  - b. Average ( )
  - c. Poor ( )
  - d. Not certain ( )
12. What are the benefits of the cage culture business to the community?
  - a. Employment/Income ( )
  - b. Revenue for the community ( )
  - c. Food fish for household level consumption ( )
  - d. Trade ( )
  - e. Social amenities ( )
  - f. Others (Specify) .....

13. In what way(s) do you personally benefit from the cage culture business in the community?

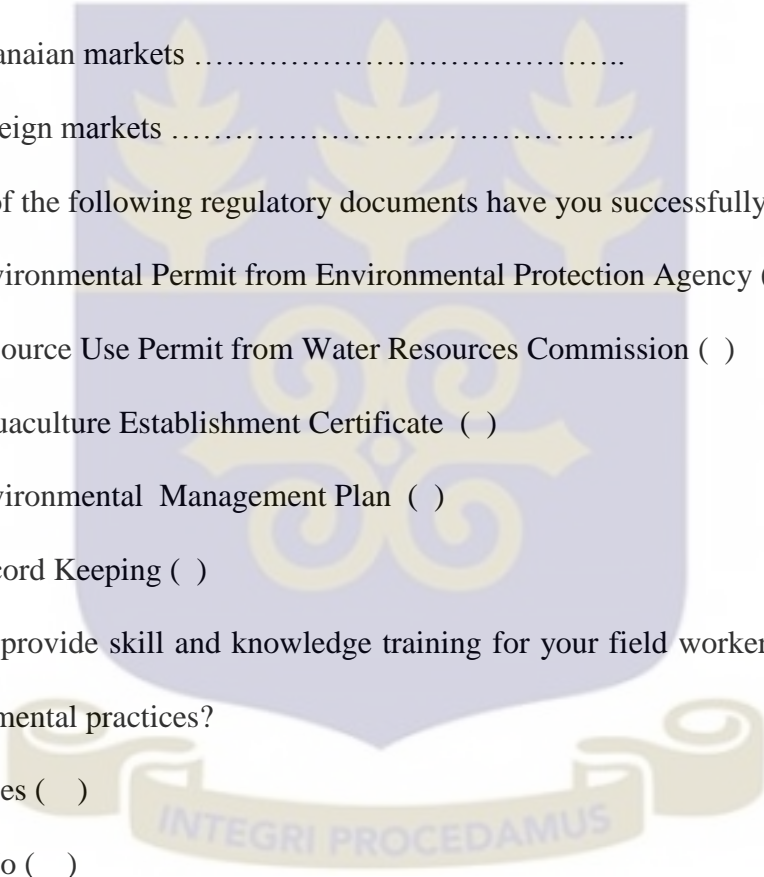
- a. Permanent Employment/Income ( )
- b. Temporal Employment/Income ( )
- c. Food fish for household level consumption ( )
- d. Trade ( )
- e. None ( )
- f. Others (Specify) .....

14. What do you expect cage farmers to do to improve living conditions in your community?

- a. More fish cages for more employment ( )
- b. Support for education projects ( )
- c. Road construction ( )
- d. Provision of health facility ( )
- e. Employment of females in permanent fish farming jobs ( )
- f. Other (specify) ( ) .....

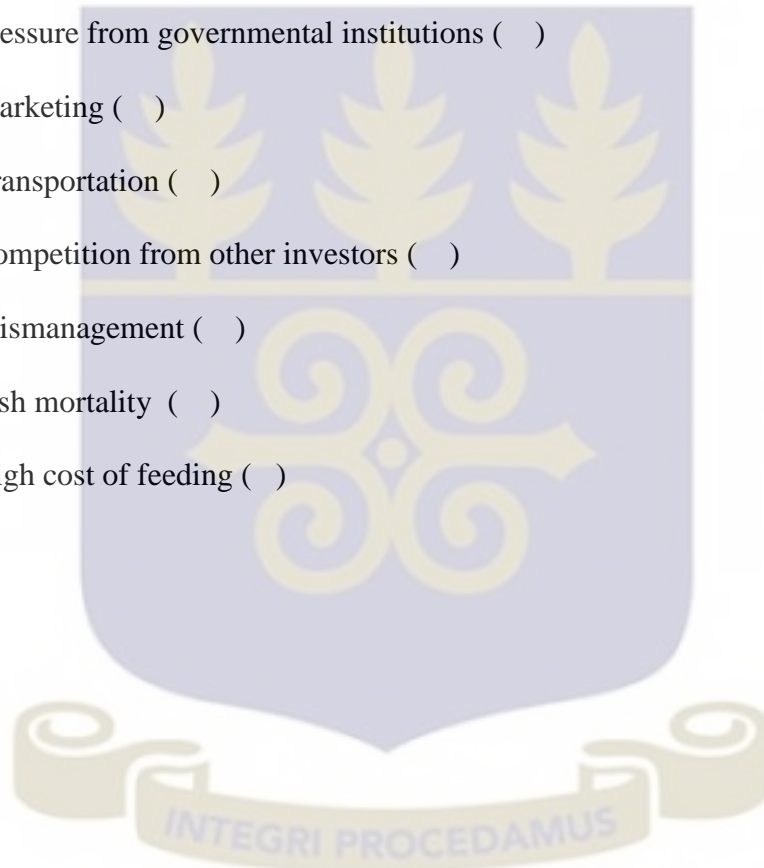




8. Is cage aquaculture business financially viable?
    - a. Yes ( )
    - b. No ( )
    - c. Not certain ( )
    - d. Other (Specify) .....
  
  9. Do you invest part of your profit back into cage farming?
    - a. Yes ( )
    - b. No ( )
    - c. Sometimes ( )
  
  10. What is/are your market(s) of your products/harvests (in percentages)?
    - a. Ghanaian markets .....
    - b. Foreign markets .....
  
  11. Which of the following regulatory documents have you successfully dealt with?
    - a. Environmental Permit from Environmental Protection Agency ( )
    - b. Resource Use Permit from Water Resources Commission ( )
    - c. Aquaculture Establishment Certificate ( )
    - d. Environmental Management Plan ( )
    - e. Record Keeping ( )
  
  12. Do you provide skill and knowledge training for your field workers to ensure good environmental practices?
    - a. Yes ( )
    - b. No ( )
- 
- The image contains a large, semi-transparent watermark of the University of Ghana logo. It features a shield with three golden leaves at the top, a central golden emblem, and a banner at the bottom with the Latin motto "INTEGRI PROCEDAMUS".

13. What are the challenges that face fish farming business in Ghana? Please, number in order of magnitude with 1 representing the most identified challenge and 10 the least – 1,2,3,4,5,6,7,8,9,10 etc. Ignore areas with no serious challenges.

- a. Capital for investment ( )
- b. Taxation ( )
- c. Poaching ( )
- d. Biofouling or algal formation on fish nets ( )
- e. Pressure from governmental institutions ( )
- f. Marketing ( )
- g. Transportation ( )
- h. Competition from other investors ( )
- i. Mismanagement ( )
- j. Fish mortality ( )
- k. High cost of feeding ( )



**Table 7: Comparing mean values at sampling sites with WHO and GSA guidelines on drinking water quality**

Parameter	A	B	C	D	E	F	WHO	GSA
NO3 (mg/L)	0.7	0.6	0.6	0.4	0.9	0.5	10	0-10.0
Ph	7.5	7.3	7.7	7.4	7.5	7.5	6.5-8.5	6.5-8.5
PO4 (mg/L)	1.9	1.0	1.2	1.0	0.9	0.3	< 3.0	
Cu(mg/L)	0.1	0.08	0.07	0.08	0.1	0.06		0-1.0
Conductivity	69	68	68	70	68	70	700	400
Turbidity(NTU)	3	2.6	2.6	3.0	2.3	2.3	5	0-5.0



**Appendix H1: ANOVA Table**

		Sum of Squares	df	Mean Square	F	Sig.
TEM P	Between Groups	.288	5	.058	.035	.999
	Within Groups	19.586	12	1.632		
	Total	19.874	17			
pH	Between Groups	.280	5	.056	.395	.843
	Within Groups	1.700	12	.142		
	Total	1.980	17			
DO	Between Groups	.177	5	.035	.011	1.000
	Within Groups	38.274	12	3.190		
	Total	38.452	17			
EC	Between Groups	14.278	5	2.856	.030	.999
	Within Groups	1140.667	12	95.056		
	Total	1154.944	17			
TDS	Between Groups	16.500	5	3.300	.104	.989
	Within Groups	380.000	12	31.667		
	Total	396.500	17			
TUR B	Between Groups	1.333	5	.267	.369	.860
	Within Groups	8.667	12	.722		
	Total	10.000	17			

**Appendix H2: ANOVA Table**

		Sum of Squares	Df	Mean Square	F	Sig.
TSS	Between Groups	5.778	5	1.156	.198	.957
	Within Groups	70.000	12	5.833		
	Total	75.778	17			
NO3_N	Between Groups	.429	5	.086	1.104	.408
	Within Groups	.933	12	.078		
	Total	1.363	17			
PO4	Between Groups	4.021	5	.804	.369	.860
	Within Groups	26.141	12	2.178		
	Total	30.162	17			
NH3_N	Between Groups	.003	5	.001	.240	.937
	Within Groups	.032	12	.003		
	Total	.035	17			
BOD	Between Groups	1.604	5	.321	.277	.917
	Within Groups	13.886	12	1.157		
	Total	15.489	17			
CU	Between Groups	.007	5	.001	.793	.575
	Within Groups	.022	12	.002		
	Total	.029	17			