DIFFERENCES IN GROWTH RATE OF AFRICAN CATFISH (*Clarias gariepinus*) AND PLANKTON DIVERSITY BETWEEN PONDS FERTILIZED BY ORGANIC AND INORGANIC FERTILIZERS

BY

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ABSTRACT

Aquaculture offers opportunity for safeguarding local and global food security in the face of declining capture fisheries. However, agrochemicals used in aquaculture negatively impact biodiversity through pollution effects such as eutrophication which is associated with fish kills. The main argument for the use of agrochemicals in aquaculture is to enhance productivity. However, evidence is lacking on whether use of inorganic fertilizers enhances fish productivity than organic fertilizers. Furthermore, effects of pollution from inorganic fertilizers have been demonstrated in aquatic ecosystems but not under aquaculture conditions. The main objective of the research was to investigate growth rate of *Clarias gariepinus,* an important aquaculture fish in Kenya, and plankton diversity between ponds fertilized by organic and inorganic fertilizers. Specific objectives of the study were to determine differences in growth rate of *C. gariepinus* and plankton diversity in ponds fertilized using chicken droppings and in ponds fertilized using Diammonium phosphate (DAP) and urea. Fish were raised in five ponds: two inorganic ponds were fertilized by DAP and urea, two organic ponds were fertilized by chicken droppings, and one pond was not fertilized and served as a control. Fish in all ponds were given supplementary feed at the same rate. Growth rate was determined by measuring weight (g) and total length (cm) fortnightly for four months. Average growth rate in length was higher in the organic pond at 0.06cm/day, followed by inorganic pond at 0.05cm/day and control at 0.04cm/day. Average growth rate in weight was higher in organic pond at 0.08g/day, followed by inorganic pond at 0.07g/day and control at 0.06g/day. Although differences in growth rate of fish in organic and inorganic ponds were not significant, fish in fertilized ponds were on average longer and weighed more than those in the control pond. These results suggest that pond fertilization is important but the argument that productivity is higher in ponds fertilized using inorganic fertilizers was not supported. Plankton identification was done using standard microscopic methods. Jaccard's similarity index for phytoplankton was highest (0.38) between organic and control but lowest (0.25) between inorganic and control suggesting that the use of chicken droppings did not shift nutrient balance in the ponds as did DAP and urea. Use of chicken droppings produced the highest diversity of zooplankton (Shannon-Weiner's H in organic pond = 1.886; inorganic = 1.044, and control = 0.935). The use of DAP and urea produced the highest proportion of phytoplankton species associated with pollution. In conclusion chicken droppings should be used to fertilize ponds for higher growth rate of *C. gariepinus* and to reduce pollution in aquaculture systems. Overall the study demonstrates that the use of Inorganic fertilizers is not associated with higher productivity than organic manure and may result in toxic algae thus the use of such fertilizers in aquaculture should be avoided.

CHAPTER ONE

INTRODUCTION

1.1. Background

Global aquaculture has grown steadily in the last several decades (FAO 2014). According to the United Nations Food and Agriculture Organization (FAO), sustainable agricultural practices offer opportunities to address projected shortfalls in food production in the face of climate change (FAO 2012). With the current decline in rate as well as quantity of global capture fisheries, aquaculture provides the means for mitigating the shortfall in fisheries products. One of the main reasons for the decline in capture fisheries is pollution by chemicals that are carried through runoff into aquatic ecosystems from agricultural and industrial activities (Munguti, *et al.*, 2014; Nicomedes, 2005). In addition to negatively impacting food security, such chemicals also threaten biodiversity in aquatic ecosystems.

Although aquaculture has potential to address shortfalls in capture fisheries, most aquaculture systems rely on use of inorganic fertilizers that have been shown to pollute the environment in ways that adversely affect biodiversity. According to Nicomedes (2005) and WHO (2011), when nitrogenous and phosphate fertilizers are washed by runoff water into freshwater bodies, they cause eutrophication that has been shown to negatively impact both human and wildlife health (Diana, 2012). In contrast, use of organic manure either cuts down the amount of agrochemicals or altogether eliminates the use of such chemicals. As such use of organic manures is more environmentally and economically sustainable and is a feasible economic option for both commercial and small holder farmers (Diana, 2009). Use of organic manures therefore lower threat to biodiversity compared to use of inorganic fertilizers (Kumar & Ayyapan, 1998; Shoko, *et al.*, 2011).

In addition to pollution issues associated with inorganic fertilizers, costs of agrochemicals are often high and thus prohibitive to subsistence fish farming (FAO 2012). Yet, as global growth in human population continues to exert pressure on natural resources including freshwater and marine fish populations (FAO 2014), innovative and affordable solutions are needed to ensure sufficient supply of safe and quality fish and other aquatic food to the world's population.

In Kenya, total fish production from aquaculture as of 2010 was 12,000MT/year, representing 7% of the total fish production and this statistic is from farms where ponds were fertilized mainly by inorganic fertilizers (Munguti, *et al.*, 2014; Ogello, *et al.*, 2013a). Although a large number of farmers use inorganic fertilizers apparently because they are assumed to have higher productivity than organic manure (Munguti, *et al.*, 2014; Ogello, *et al.*, 2013a), differences in productivity between the two fertilization regimens are largely unknown. Yet, despite the lack of evidence to support the assumption that productivity in ponds fertilized using inorganic fertilizers is higher than ponds fertilized by organic manures, and the extent to which use of inorganic fertilizers in aquaculture is associated with pollution that can negatively impacts biodiversity conservation are also largely unknown.

Mosha, *et al.* (2016), recommends use of either DAP fertilizers or chicken droppings for faster growth of *C. gariepinus* frys, at a stocking density of 5frys/m^2. In his document, a new guide to fish farming in Kenya, Ngugi, *et al.* (2007) also recommends use of both DAP and Urea and chicken dropping to fertilize fish ponds. According to Kuar, *et al.* (2015) chicken manure is effective to stimulate productivity in pond with conducive range of water quality. Several studies have been carried to show the influence of fertilization on growth rate of fish but mainly in Asian countries. Such statistics are missing in African countries such as Kenya more especially use of both DAP and Urea fertilizers.

In aquatic ecosystems, inorganic fertilizers directly affect fish by increasing nutrient level in water resulting in eutrophication that is associated with fish kill that is attributed in part due to proliferation of toxic algae species in the face of nutrient loads associated with inorganic fertilizers (e.g., Akankali & Elenwo, 2015). In addition to direct effects of agrochemicals on aquatic ecosystems, the chemicals used in aquaculture may also indirectly affect fish via their effects on other trophic levels in aquatic ecosystems (Kumari *et al.*, 2007). For instance, there are several species of phytoplankton that are associated with polluted waters such that their occurrence in an aquatic environment is indicative of the level of pollution (Kankal & Warudkar, 2012). However, differences in species diversity of phytoplankton and whether the use of inorganic fertilizers in aquaculture facilitates growth of phytoplankton associated with pollution is not known.

Aquaculture of *Clarias gariepinus* in Kenya is picking up, estimated at 21%, second only to that of *Oreochromis niloticus at 71%* (Munguti, *et al.*, 2014), both as food and as bait fish for Nile perch (Ngugi, *et al.*, 2007). The species is a generalist omnivore that is known to feed on natural foods in both its natural and aquaculture environments (e.g., Carballo, *et al.*, 2008). African catfish are of great importance as they grow quickly, attain large size with more flesh and few spines and are able to withstand wide range of environmental conditions increasing this taxon's potential to contribute to food security (El-Shebly, 2006; Ogello, *et al.*, 2013b). Ogello, *et al.*, 2013b reports that the species catch in Ugandan waters of Lake Victoria has been declining. Between the years; 1966-1967 the catch was 2237 metric tons, 1976-1977 the catch was 1620, 1986-1987 the catch was 655 and in 2000 that catch had reduced to 69. Also Boyd and colleagues (2005) evaluated the level of concern for *C. gariepinus* from use chemical in aquaculture to be of high negative influence.

Given its potential, the species is therefore an excellent candidate for evaluating any differences in productivity as a function of fertilization regimen.

1.2. Problem Statement

With the declining natural fish stock in the country's freshwaters such as Lake Victoria, aquaculture provides a mean of mitigating the shortfall by relieving the pressure on capture fisheries. However some of the aquaculture practices may be not sustainable such as use of agrochemicals like the inorganic fertilizers that are known to pollute the environment and therefore is a threat to biodiversity conservation. Although it is thought that fish productivity is higher under inorganic fertilization regimen, such statistics are largely unknown in most African countries such as Kenya. Although inorganic fertilizers are known to threaten biodiversity in other aquatic ecosystems through occurrence of phytoplankton associated with polluted waters, this has not been demonstrated under aquaculture systems.

1.3. Justification

It is largely thought that the current decline of capture fisheries in Lake Victoria can be addressed by aquaculture. However, the predominant form of aquaculture involves the use agrochemicals such as inorganic fertilizers that are known to cause pollution resulting for example in eutrophication, that is associated with direct fish kills or affect fish indirectly through other trophic levels such as plankton. In addition, use of inorganic fertilizers results in occurrence of toxic algae in aquatic ecosystems. In contrast, use of organic manure although less practiced is known to be environmentally safer and can help conserve fish and other biodiversity in aquatic systems. Empirical data on the effect of different fertilization regimen on growth rate in *Clarias gariepinus* are largely unknown and is lacking in Kenya. *Clarias gariepinus* is an important omnivorous fish, with the ability to withstand adverse environmental conditions. This is a native fish in Lake Victoria and current report show that it is declining in capture fisheries thus forms a suitable basis for research. Plankton forms primary productivity in any aquatic ecosystems therefore all other aquatic life forms depend on them as source of food. They are also good bio-indicators of aquatic pollution. If they are affected by fertilizers then this would be detrimental for aquatic life. It was thus important to identify phytoplankton genera associated with pollution under different fertilization regimen.

1.4. Study objectives

1.4. 1. General objective

The overall objective of the study was to determine differences in growth rate of *Clarias gariepinus* and plankton diversity between ponds fertilized by organic and inorganic fertilizers.

1.4.2. Specific objectives

The specific objectives of the study were:

1. To determine differences in growth rate between *Clarias gariepinus* raised in ponds fertilized using chicken droppings and those raised in ponds fertilized by DAP and urea.
2. To determine differences in plankton diversity and occurrence of Phytoplankton genera associated with pollution between ponds fertilized by chicken droppings and in ponds fertilized by DAP and urea.

1.5. Null hypotheses

1. There is no difference in growth rate between *C. gariepinus* raised in ponds fertilized using inorganic fertilizer and those raised in ponds fertilized by chicken droppings.
2. There is no difference in plankton diversity and phytoplankton genera associated with pollution between ponds fertilized using chicken droppings and ponds fertilized by inorganic fertilizer.

1.6 Significance of study

Results from the study are important to both individual farmers and environmental protection agencies such as National Environmental Management Authority and biodiversity conservation organizations such as the Kenya Wildlife Service and the Kenya Fisheries and Marine Research Institute. To the individual farmer raising *C. gariepinus*, the results of this study may have cost-saving and sustainability dimensions that together contribute to conservation of biodiversity. Results show that use of inorganic fertilizers in aquaculture is associated with pollution, which may negatively impact biodiversity thus at the agency level, the results and may guide formulation of policies and sustainable biodiversity conservation action plans.

CHAPTER TWO

LITERATURE REVIEW

2.1. Introduction

As the world's human population continues to rise, expected to reach 9.6 billion people by 2050, it is projected that the increasingly dwindling capture fisheries will not meet the human demand for fish and fish products (FAO, 2012). This shortfall poses a great challenge of feeding the global human population while conserving biodiversity (FAO 2014). Global aquaculture will thus need to continue growing in order to ensure sufficient supply of fish and other aquatic foods to meet the needs of the increasing human population (FAO 2012). Aquaculture therefore offers a means of addressing the challenges of both food insecurity and conserving biodiversity by relieving pressure on capture fisheries (Diana, 2009).

Global aquaculture production has been growing for the last several decades with a production level estimated at 70.5 million tonnes as at 2013 while world capture fisheries has been static (FAO 2014) or declining in some African countries such as Kenya (Munguti, *et al.*, 2014). Some of the reasons for the decline in capture fisheries in African countries are associated with unsustainable exploitation and pollution in aquatic ecosystems leading to a decline in biodiversity in such systems (Munguti, *et al.*, 2014; Ogello, *et al.*, 2013b).

Although aquaculture is promising to increase fish productivity, aquaculture systems predominantly practiced are neither economical nor environmentally sustainable (FAO, 2014). The most commonly practiced aquaculture relies on inorganic fertilizers to fertilize ponds whereas use of organic fertilizers is less practiced especially in African countries with statistics from such system lacking (Ogello, *et al.*, 2013a). Organic fertilizers are known to be environmentally safer thus provide a sustainable means for producing fish and conservation of biodiversity (WHO 2011). Consequently, use of organic fertilizers offers tremendous potential for food security and poverty alleviation in urban and periurban areas (Shoko, *et al.*, 2011). In addition, it has potential to augment agricultural production and improve rural economy (Kumar & Ayyapan, 1998) thereby relieving pressure on biodiversity in aquatic ecosystems.

Additionally, the rising cost of high protein fish and inorganic fertilizers use of organic manure, has the potential to simultaneously address globally important issues such as climate change adaptation, food security, and biodiversity conservation (Diana, 2009; Kaur, *et al.* 2015).

2.2. Status of aquaculture in Kenya

Global aquaculture production continues to grow but at a slowing rate than in the 1980's and 1990's (FAO, 2014). By 2013 the world fish production increased to 70.5million tonnes/year from 66.6 million tonnes/year excluding aquatic plants and non-food products (FAO, 2012). At the continent level, Africa has increased its contribution to global fish production from 1.2% to 2.2% in the past ten years (FAO 2012). By 2010, Egypt was the highest producer of fish contributing 71.3% of total African production followed by Nigeria at 15.57% then Uganda at 7.37 % (FAO 2014).

In Kenya, aquaculture began in the early 1900's during the colonial period when trout was the main aquaculture fish species and was reared for sport fishing along rivers (Ngugi & Manyala, 2009; Munguti, *et al.*, 2014). Pond production of tilapia, common carp, and catfish began in 1920's (Dadzie, 1992). Later in the 1960's the Kenyan government launched the "Eat More Fish" campaign to encourage rural communities to start fish farming (Ngugi & Manyala, 2009). As a result of the campaign, several small ponds were constructed particularly in central and western Kenya. However, the project was mostly unsuccessful due to insufficient training of extension workers and lack of quality fingerlings (Ngugi, *et al*., 2007).

Until the mid-1990s, fish farming in Kenya was still low, characterized by subsistence level of production but on recognizing aquaculture as a viable enterprise with potential to improve the country's food sector, the government in the year 2009 initiated the Economic Stimulus Program with the aim of injecting commercial principles into fish farming to stimulate economic development, alleviate poverty and spur regional development (Ngugi & Manyala, 2009). According to Munguti *et al*. (2014) and Otieno (2011) before the program, from 1950's to 2006, fish production through aquaculture was 2,000MT/year and after the program total aquaculture production increased to 12,000MT/year as at 2010 and is projected that fish production will continue to increase.

In Kenya the most farmed fish is *Oreochromis niloticus* at 71%, followed by *Clarias gariepinus* at 21%, and the remaining proportion is mainly farming of carp and trout (Otieno, 2011). Production of *O. niloticus* (Nile tilapia) through semi-intensive system of fish production (Ngugi & Manyala, 2009) is the major contributor to aquaculture in Kenya where ponds are fertilized using either or both chemical and organic fertilizers to enhance natural food productivity. Although, a few small-scale farmers have embraced integrated aquaculture, many farmers believe that use of inorganic fertilizer increases fish productivity. However, evidence on any differences in growth rate of commonly produced aquaculture fish species such as *C. gariepinus* under different fertilization regimens are not available.

2.3. Factors influencing growth rate of fish in aquaculture conditions

Several factors influence growth rate of fish under aquaculture: pond fertilization regimes, water quality, fish population density, and food supply (Hasan *et al.*, 2001). As long as these conditions are maintained at appropriate levels, fish will continue to increase in length and weight throughout its life span.

2.3.1. Fertilization of fish ponds

The ultimate goal for fertilizing fish ponds is to enhance primary and secondary productivity i.e., growth of phytoplankton and zooplankton (Diana, 2012; Carballo, *et al.*, 2008). Natural productivity of a pond can be greatly enhanced by the use of fertilizers that stimulate growth of organisms consumed by fish in addition to supplying essential elements that are often deficient in the pond (Bhatnagar & Devi, 2013). Fertilizer application in earthen ponds has been used as a low cost method for sustainable aquaculture production (Oyin, 2012).

The advantages of inorganic fertilizers over organic ones are that inorganic fertilizers have a definite chemical composition and are instantly soluble in water (Das & Jana, 1996). However nitrogen, phosphorus and potassium fertilizers are corrosive and therefore are not safe to handle using bare hands (Boyd & Massaut, 1999); farmers must therefore procure protective clothing including gloves, which ultimately increases the cost of non-integrated aquaculture. Commonly used inorganic fertilizers in aquaculture in Kenya include Di-ammonium phosphate (DAP) and urea (Ngugi, *et al.*, 2007).

Because chemical fertilizers are highly water soluble, they must be stored indoors so as to avoid accidental spills. Large spills of fertilizers on land or water have been associated with severe nutrient pollution in the surrounding areas (e.g., Boyd & Massaut, 1999). High phosphorus concentration, for example, is a major cause of environmental pollution and causes elevated levels of phytoplankton bloom in fish ponds (Das & Jana, 1996; Mizanur *et al.*, 2004). Nitrates in inorganic fertilizers also react with amines to form compounds such as nitrosoamines and nitroamides some of which may be carcinogenic or mutagenic (Das & Jana, 1996). In addition, inorganic fertilizers do not contain carbon (Liti & Munguti, 2015) that is an important element required by all organisms.

Unlike inorganic fertilizers, organic manure provides carbon in addition to phosphorus and nitrogen, support both autotropic and heterotropic food webs, increase the buffering capacity of a pond and are less expensive (Liti & Manguti, 2015). Research by Zahid *et al.* (2013) on the effect of artificial feed and fertilization on growth of tilapia indicated that enhancing natural food through manuring ponds resulted in higher contribution in fish nutrition and reduced the amount of supplemental feed requirement. Furthermore according to Boyd and Massaut (1999), some fish can digest specific components of manure such as bacteria, fungi and other organisms even though the manure itself may have no nutritional value. In addition, organic fertilizers are safe to handle and are relatively less harmful to the environmental compared to inorganic fertilizers. However organic manure are bulky and have been shown lower the level of oxygen in the pond compared to inorganic fertilizers thus their use can result in fish mortality (Elnady, *et al.*, 2010). Organic manures commonly used by fish farmers in Kenya are chicken droppings, cow dung, rabbit or duck waste (Ogello *et al.*, 2013a; Batterson & Mcnabb, 1993).

Studies on the effect of fertilizers on secondary production have often demonstrated that organic manures stimulate secondary production much more than inorganic fertilizers do (Diana, 2012). In addition, some studies have shown that growth rate of fish is higher in pond fertilized by organic manure than in pond fertilized by inorganic fertilizers (e.g., Elnady *et al.*, 2010). With regards to Mosha *et al.* (2016) *C. gariepinus* frys raised in tanks fertilized by chicken dropping from layers had 26.6% growth rate compared to 20.6% growth rate in tanks fertilized by DAP fertilizer. But according to Ekpenyong *et al.* (2012) *Oreochromis niloticus* had best growth in earthen pond limed and fertilized by NPK fertilizer than in earthen pond limed and fertilized by chicken droppings. In the aggregate, however, results of studies on effect of pond fertilization on fish growth rate remain inconsistent.

2.3.2. Food supply

Growth, health and reproduction of fish and other aquatic animals are primarily dependent upon an adequate supply of nutrients both in terms of quantity and quality irrespective of the culture system in which they are grown (Hasan, *et al.*, 2001; Marimuthu, *et al.*, 2011). Nutrition plays an essential role in the sustained development of aquaculture and therefore fertilizers and feed resources continue to dominate aquaculture needs (Hasan, *et al.*, 2001). Fish like other animals require carbohydrates, proteins, lipids, vitamins and mineral salts for growth. Supplementary feed is given to the fish to increase productivity and speedy growth (Ngugi, *et al.*, 2007).

In addition, mineral such as calcium and phosphorus are important for bone and muscle development. Also very important is crude protein in the feed, which the fish uses for growth and development and to synthesize animal protein. Studies in finfish, for example, have shown that fish need the same essential amino acids as do most animals (Hasan *et al.*, 2001). Although African catfish grows best on animal based diets, there is low availability of animal protein and fat sources of fish feed in developing countries (Fleuren, 2008). Consequently, other aquatic species are harvested and used in the production of animal-based feeds. African catfish are known to feed on natural food present in the pond thus different fertilizers are added to catfish ponds to increase food production (Carballo *et al.*, 2008).

2.3.3 Water quality

Water quality is an important but often overlooked aspect of pond management. Several physicochemical factors that influence water quality include temperature, pH, Ammonia, dissolved oxygen and turbidity. As poikilothermes, body temperature of fish closely follows the temperature of the surrounding medium. In aquatic environments, temperature exerts a major influence on the level of activity of the organisms (Myrick, 2005). For instance, temperature influences several control systems of the body including enzymatic reaction such that extreme temperatures can impair growth and increase susceptibility to diseases (Myrick, 2001). Indirectly, increase in temperature reduces the amount of oxygen in water, which may in turn affect key physiological functions including metabolism. Catfish can accommodate a temperature range of 16-30°C (Carballo, *et al.*, 2008).

Dissolved oxygen is probably the most critical water quality variable in fish culture. Fish requires adequate concentrations of dissolved oxygen for survival and growth. Photosynthesis by phytoplankton is the primary source of dissolved oxygen in fish culture system (Carballo, *et al.*, 2008; Ngugi, *et al.*, 2007). Fish breathe in oxygen for general body metabolism. Dissolved oxygen is needed to help breakdown harmful metabolic waste to less harmful forms such as ammonia to nitrites then to nitrates. Very low oxygen in a fish pond can result in fish fatality. In fish culture system more oxygen must enter or be produced in water by planktons than is used by the organisms. For salmonids, reduced level of dissolved oxygen affects fitness and survival by altering embryo incubation period, decreasing the size of fry, increasing the likelihood of predation and decreasing the feeding activity (Bjornn, 1991).

PH, the concentration of hydrogen ions in a solution and is important in aquatic environments (Ralph, 1978), is also an important physicochemical factor in aquatic environments. Fish have an average blood pH of 7.4 and thus the acceptable range in the pond is 6.5 and 9 (Ngugi, *et al.*, 2007). Fish becomes stressed and can die at the pH less than 5 or greater than 11. Reproduction also ceases at these levels. Increased carbon (IV) oxide at night interacts with water to form carbonic acid and thus lowering the pH. This limits the ability of fish blood to carry oxygen.

Ammonia is also an important factor in aquatic environments where it occurs in either the ionized but relatively nontoxic form or un-ionized toxic form. Water temperature and pH both affect the form at which ammonia occurs in an aquatic system (Floyd & Watson, 2006) and thus play an important role in both osmoregulation and excretion in fish. In small amounts, ammonia causes stress and gill damage (Floyd & Watson, 2006) such that fish exposed to low levels of ammonia over time are more susceptible to bacterial infections and generally exhibit poor growth. Higher concentration of ammonia can kill the fish. Ammonia plays an important part within the nitrogen cycle of aquatic environment, where it is converted by *Nitrosomonas* to nitrite (NO_2) then to nitrate (NO_3) by another bacteria called *Nitrobacter*. The resultant nitrate is important for synthesis of protein by phytoplankton, which ultimately consumed by fish.

Turbidity in fishpond is contributed by amount of phytoplankton and the sediments at the base of the pond. Increase in phytoplankton increases turbidity of the pond water thus lowering light penetration. Clay particles can clog fish gills or smother fish eggs. Turbidity also limits fish vision, which can interfere with social behavior (Berg, 1985), foraging and predator avoidance

(Gregory, 1993). According to Ngugi, *et al.*, 2007, the right turbidity should be allow you to see about 30-45cm into the water.

2.3.4 Population density and competition

Stocking density can significantly affect the growth, survival and feed conversion in fish (Jamabo & Keremah, 2009). However density effects depend on the type of fish as well as its foraging needs and behavior. For instance, according to Ngugi, *et al.* (2007) *C. gariepinus* can accommodate higher stocking density due to their ability breath outside water. According to Ronald, *et al.* (2014), at an appropriate stocking density before attainment of carrying capacity, fish grows well but beyond that, growth rate increases leading to competition for resources. Consequently, stocking too many fish in a limited space results in a large number of very small fish whereas stocking the right number gives many large marketable fish (Ngugi, *et al.*, 2007). Catfish fingerlings reared for market should be stocked at 2 to 10 per meter square in the ponds (Ngugi, *et al.*, 2007). With regards to Mosha, *et al.*, 2016 Catfish frys stocked at the rate of 5fry/m^2 had higher growth rate than the ones stocked at 10frys/m^2.

2.3.5 Sex difference in growth rate of fish

Information on sex development has been applied in fish culture to either initiate sexual change or improve growth of a particular sex. Among the tilapiine fishes, the male fish grow faster than the female ones such that growth rate varies with the sex of the fish. But according to research done by (Maithya, *et al.*, 2012), there was no significant variation in size at first maturity between the male and females of *O. variabilis* in different aquatic environments although females exhibited a much smaller size at fifty percent maturity than males. In contrast, female Nile perch grow to a larger size than their male counterparts but growth rate is the same for both sexes (Ogutu-Ohwayo, 1988). Growth rate is sometimes influenced by endogenous factors that may, for instance, involve the re-allocation of energy from growth to gonadal development (Boliver, *et al.*, 2008). According to (Blazquez, *et al.*, 1995) male sea brass divert energy resources into gonadal development while females use these resources for somatic growth thus grow faster hence the acquisition of all female stock is an attractive option for sea brass aquaculture.

2.4. Plankton diversity and Phytoplankton as indicators of pollution in aquatic ecosystems

The biological justification of fertilizing rearing ponds is to promote the development phytoplankton and zooplankton species that are natural food for fish. Phytoplankton and zooplankton are the main natural food in aquatic ecosystem. Apart from being food for fish they also good indicators of water pollution thus play a major role in pollution monitoring studies (Kankal & Warudkar, 2012). Several research studies have been carried out to establish diversity of the plankton in different fertilization regimens in fish pond mainly as food for fish but not for pollution monitoring studies.

According to Ekpenyong *et al.* (2012) both phytoplankton and zooplankton are more diverse in ponds fertilized with chicken droppings than with NPK chemical fertilizers. Begum, *et al.* (2007), also demonstrated that mean abundance for both phytoplankton and zooplankton was higher in earthen ponds which were treated with poultry manure, triple superphosphate and urea compared to earthen ponds treated with cow manure, triple superphosphate and urea. With regards to Mosha *et al.* (2016) Phytoplankton are known to be more abundance in DAP fertilizer applied tanks than in tanks fertilized by chicken droppings, while zooplankton are abundant in chicken manure applied tanks.

The Impact of pollution is directly reflected by the survival status of Phytoplankton and Zooplankton and fauna (Parmar *et al.*, 2016) therefore plankton diversity can indicate the level of pollution in aquatic ecosystem thus ensures biological monitoring of aquatic environment. Biological monitoring is thus a valuable method used in conservation studies to help preserve the biological integrity of natural ecosystem consequently preserves it (Kumari *et al.*, 2008). Biological monitoring involves assessing the survival status of flora and fauna thus, plankton are important bio-indicators of the health of aquatic ecosystems (Akankali & Elenwo, 2015). High levels of phytoplankton indicate high nutrient loads in the water (Das & Jana, 1996). According to Parmar, *et al.*, 2016, plankton react rapidly to ecological change thus are excellent indicators of water quality due to rapid rate of reproduction.

In a research by Zannatul *et al.* (2012) six genera of phytoplankton were found to be most abundant in River Buriganga in Bangladesh polluted with industrial effluent and these included *Crucigenia*, *Ankistrodesmus*, *Clostridium*, *Coelostrum*, *Scenedesmus* and *Nitzschia*. With regards to Kumari *et al.* (2008) Lake Phutala, a major lake for fisheries, had the highest number of pollution indicators and predominant one were *Oscillatoria*, *Fragellaria*, *Chlorococcum*, *Ankistrodesmus*, *Synedra* and *Selenastrum*, this was attributed to anthropogenic activities. However, the extent to which plankton are affected by fertilization regimen and in particular by the application of inorganic fertilizers in aquaculture is not known even though inorganic fertilizers are associated with pollution in aquatic ecosystems.

2.5. CONCEPTUAL FRAMEWORK

Growth rate of *C. gariepinus* and plankton diversity as dependent variables were determined in different fertilization regimen. The relationships between variables that are the focus of the present study are summarized in Figure 2.1.

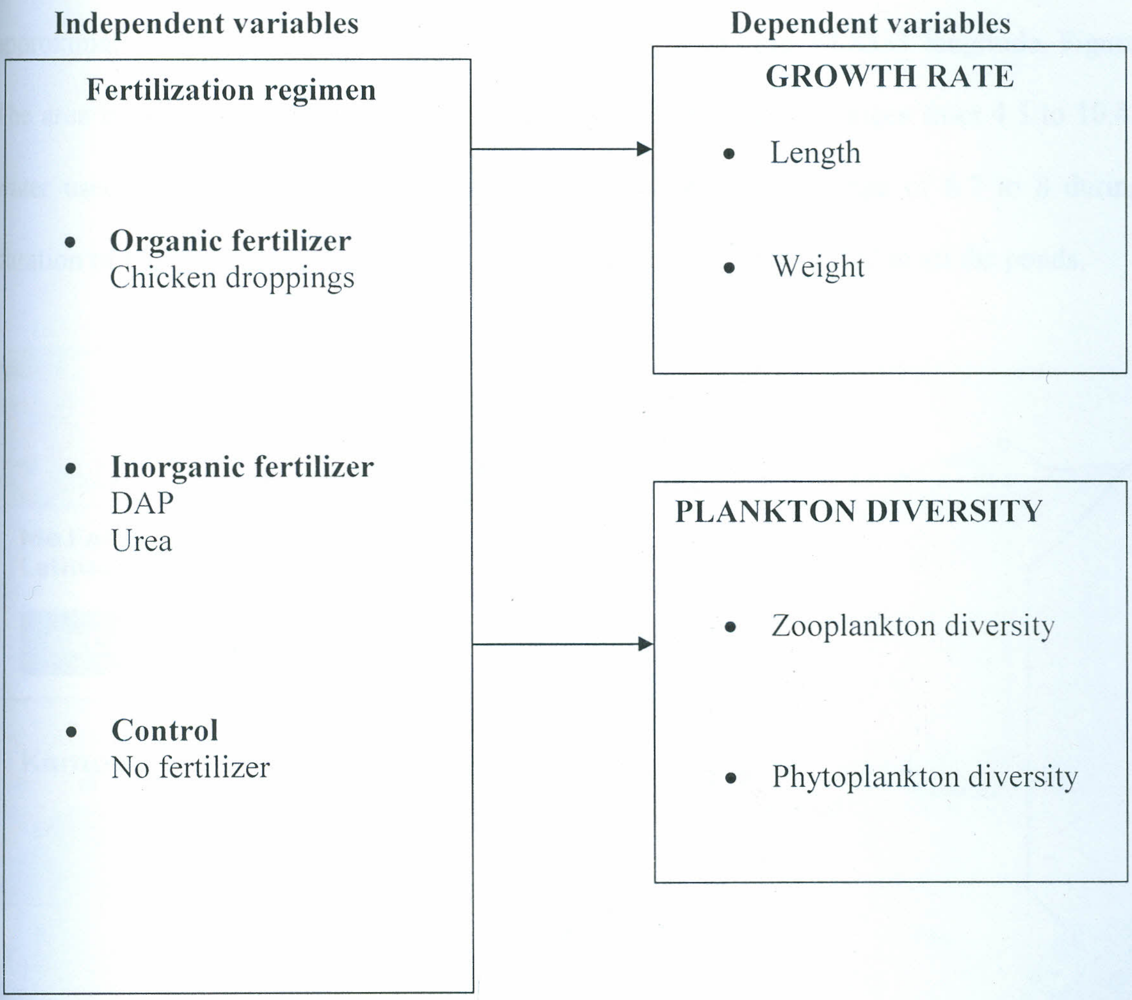


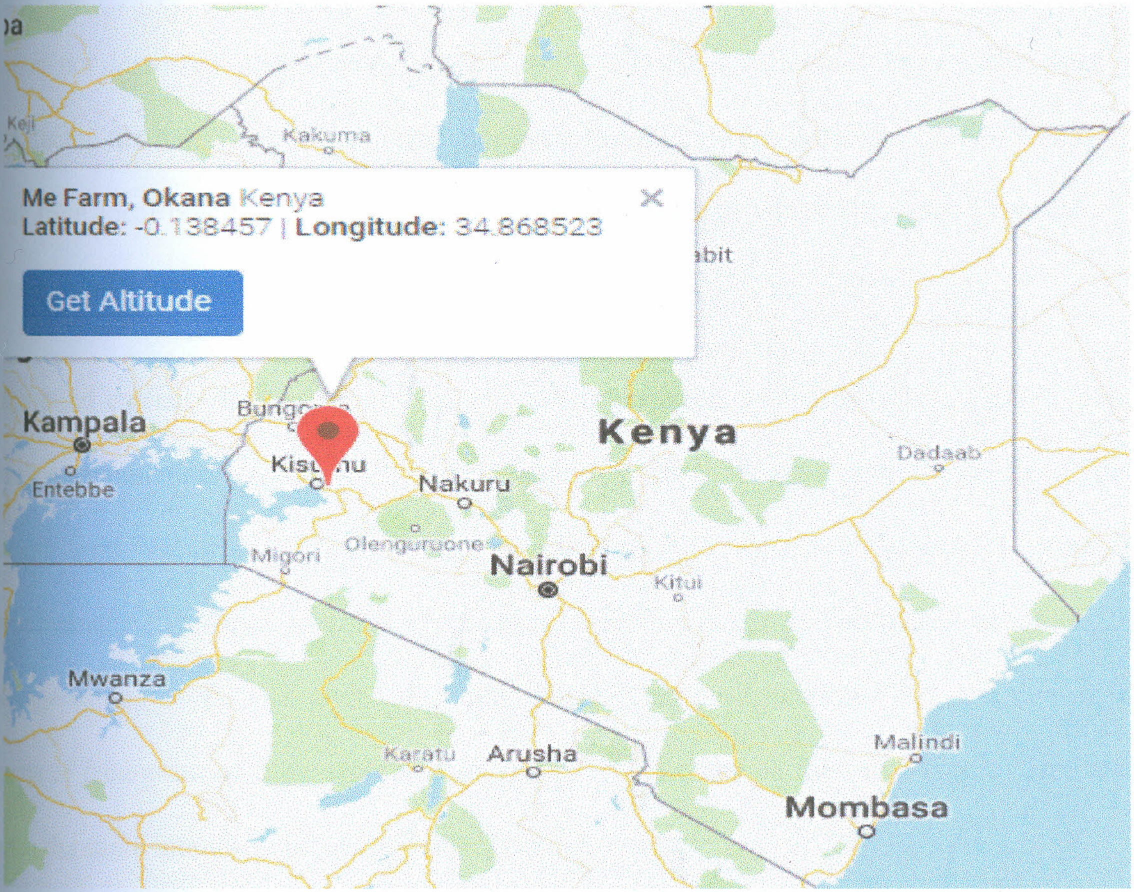
Figure 2.1: The conceptual framework showing association between independent and dependent variables

CHAPTER THREE

MATERIALS AND METHODS

3.1. Study site

The research was carried out at Me-farm which is situated along Kisumu- Nairobi Road approximately10 km from Kisumu Town at -0.138457° latitude, 34.8333°longitude, Figure 3.1. The area is characterized by clay loam alluvial soils with soil pH ranges from 4.5 to 10.4. The water used in the ponds was from underground and had a pH range of 6.7 to 8 during the duration of the study period. Water temperature varied from 26 to 27° C in all the ponds.



Me Farm, Okana Kenya
Latitude: -0.138457 | Longitude: 34.868523

Figure 3.1: Map of Kenya showing the location of Me-Farm. Source: Google Map © 2018

3.2. Experimental design

One month old fingerlings, weighing approximately 1g and measuring 6 cm in length, were bought from Mabro Fish Farm in Usenge Town and were transported in oxygen filled polythene bags to the experimental station at Me-Farm, a distance of approximately 100 km. Fingerlings were allowed to acclimatize to water temperature in the experimental and control ponds for 30 minutes before they were released into the ponds.

Fingerlings were raised in five experimental earthen ponds identified as A, B, C, D, and E. Each pond measured 2 x 2 x 1m. Ponds A and B were fertilized using chicken droppings at the rate of 200g/week/pond whereas ponds C and D were fertilized using inorganic fertilizers, DAP at the rate of 8g/week/pond and urea at the rate of 12g/week/pond following (Ngugi *et al*., 2007). Pond E was not fertilized and served as the control. Pond fertilization began one week before introducing the fish .Both organic and inorganic fertilizers were broadcasted. Chicken droppings were from local breed and were obtained from the Me-farm while DAP and Urea were bought from an agro veterinary shop in Kisumu town.

Each pond carried 7fish/m^2 according to recommendation by Ngugi *et al*., (2007). Fish were given supplementary commercially formulated fish feed of trade name 'Fish Feed' that was bought from Victoria Feed Company in Kisumu. The feed contained 35% protein, 20% carbohydrate, 10% lipid and 5% crude fibre. Feeding rate was calculated depending on the average weight of the fish and water temperature (Gertjan &Janssen 1996) the rate of 0.074% grams of feed/gram of body weight. Fish in each pond received the same type of feed and were fed at the same rate throughout the project period.

3.2.1. Determining growth rate of *Clarias gariepinus*

Length and weight measurements were carried out fortnightly in each pond. The total length of fish, from the mouth tip to the end of the tail fin, was measured using a 30 cm ruler. The weight of fish was measured to the nearest 0.1g using a portable digital battery-operated weighing balance, model CL 201J manufactured by OHAUS Corporation USA. Fish were randomly caught from the ponds using a seine net with a mesh size measuring 0.4 mm. Between 5 and 10 fish were measured from each pond on each sampling day. Data was collected for four months from June to September 2015.

3.2.3. Determining plankton diversity

Water was sampled fortnightly from three positions of all the ponds and taken to Kenya Marine and Fisheries Research Institute in Kisumu to analyse phytoplankton and zooplankton diversity. This was done for three months from July to September 2015. For phytoplankton analysis, a 20 ml vial was used for water collection. Each water sample was preserved in Lugol solution and then concentrated with distilled water to 100ml for clear vision of genera, after which 0.5 ml of concentrated water was placed in Utermohl cells and examined under a compound microscope (Leica Microsystems, Wetzier Gmbl) with magnification level between ×100 to ×150 using identification key according to UNESCO, 2006. Phytoplankton species were identified up to family and genus level. The genera of phytoplankton that were identified using utermohl technique are shown in Appendix 2. Phytoplankton species associated with polluted waters were separately examined and categorized by pond treatment according to Zannatul *et al.* (2012).

For zooplankton, 30 litres of water collected from littoral depth at three corners of each pond and was filtered then concentrated to a 20 mL using a 60μm zooplankton net. The concentrated water samples for zooplankton was obtained from the net cap were preserved in 5% formalin. A concentration of 1mL of the preserved zooplankton samples were introduced into a Sedwick Rafter counting chambers, Olympus BH2, OHAUS Corporation USA, for examination under a dissecting light microscope (Leica Microsystems, Wetzier Gmbl). Identification of zooplankton was done up to genus level.

3.3. Data analysis

Growth rates of *C. gariepinus* for each fertilization regimen were calculated and presented as mean increase in length and weight per day and calculated as Specific growth rate using the formula;

$$\text{Specific growth rate per day} = \frac{\text{Final mean Length/Weight} - \text{initial mean Length/weight}}{\text{Time (days)}}$$

Difference in length and weight across fertilization regimens were analysed using repeated measures analysis of variance.

Diversity of zooplankton under the two fertilization regimes as well as that in the control pond was analysed using the Shannon-Weiner Diversity (H) Index. The formula for H:

$$H = -\sum [(pi) * \ln(pi)]$$

where, pi = number of individuals of species i/total number of samples; H typically ranges from 1 to 4 such that the higher the index, the higher the species diversity. The Shannon Weiner diversity was then converted to effective species number for ease of interpretation as recommended by Joust (2006). Phytoplankton diversity was analysed using Jaccard's index, which is computed using the formula:

$$J = s_c / s_a + s_b + s_c$$

where, s_a and s_b are the numbers of species unique to samples a and b, respectively, and s_c is the number of species common to the two samples. Chi-square was used to determine pair-wise differences in phytoplankton and zooplankton diversity between the pond treatments. Descriptive statistics were used to summarize data on the occurrence of phytoplankton species associated with polluted waters. For all statistical tests, statistical significance was evaluated at $p \leq 0.05$. Statistical tests were performed in R version 2.14.1.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. Growth rate of *C. gariepinus*

Fish in the organic and inorganic ponds had comparable total lengths but were on average longer than those of fish in the control pond. The longest fish was from the organic pond with a total length of 14.2 cm, followed by inorganic pond at 14.1 cm and 12.3 cm from the control pond after 4 months. Mean total length was also higher in the organic pond. Mean total length of fish from organic, inorganic and control ponds were 9.39 cm, 9.16 cm, and 8.30 cm respectively; see Table 4.1.1 and Figure 4.1.

Table 4.1.1: Results on the mean Length and range measurement and total number of fish sampled for a period of 4 months in Organic pond, inorganic pond and control ponds.

	RANGE in Length in cm		Total number of	
Pond treatment	**Lowest**	**Highest**	**fish sampled (n)**	**MEAN total length (cm)**
Organic pond	5.5	14.2	107	9.39±0.23
Inorganic pond	5.7	14.1	107	9.16±0.19
Control pond	6.0	12.3	56	8.30±0.20

In reference to Table 4.1.2, average growth rate per day in total length was highest in the organic pond. This was followed by the inorganic pond and lastly the control.

The growth rates were in the order of; organic, 0.06 cm/day, inorganic pond 0.05cm /day then control 0.04 cm/day.

Table 4.1.2: Sampling date, average length and growth rate in length calculated per day in inorganic, organic and control ponds

TWO WEEK INTERVALS	Inorganic pond			Organic pond			Control pond		
Sampling Date	n	Av. Length (cm)	Growth rate (cm) Per day	n	Av. Length (cm)	Growth rate (cm) Per/day	n	Av. Length (cm)	Growth rate (cm) Per /day
11th June	21	7.11±0.18	0.00	17	7.09±0.23	0.00	10	6.70±0.15	0.00
25th June	20	8.09±0.28	0.07	20	7.46±0.32	0.03	10	7.00±0.18	0.02
9th July	20	8.71±0.22	0.04	20	8.31±0.25	0.06	10	7.70±0.24	0.05
23rd July	8	10.21±0.27	0.11	10	10.40±0.20	0.15	5	8.60±0.53	0.06
6th Aug	8	10.04±0.37	-0.01	10	9.68±0.57	-0.05	6	8.80±0.24	0.01
20th Aug	10	10.94±0.34	0.06	10	11.59±0.37	0.14	5	9.36±0.43	0.04
3rd Sept	10	11.42±0.42	0.03	10	12.19±0.38	0.04	5	9.94±0.44	0.04
17th Sept	10	12.14±0.41	0.05	10	12.73±0.39	0.05	5	10.64±0.53	0.05
Average Growth rate (cm)			**0.05**			**0.06**			**0.04**

Results of length analysis showed that the difference in mean total length was significant: $F_{2,264} = 24.06$, p = 0.0399 (Figure 4.1 and Appendix 1). Results of post-hoc Tukey HSD pairwise tests for total length are summarized in Table 4.1.1 and Appendix 1, and show that there was a significant difference in length between fish raised in ponds fertilized and those raised in the control pond (inorganic vs. control, p = 0.005; organic vs. control = 0.005) but not between fertilized ponds (p = 0.963) See Table 4.1.3.

Table 4.1.3: Pond treatment, mean differences in total length and significance level (P - Value) between the treatments.

Pond treatment	Mean difference (cm) in length of fish	P -Value
Organic pond vs. Control pond	1.090	0.005
Inorganic pond vs. Control pond	0.860	0.005
Inorganic vs. Organic pond	0.230	0.963

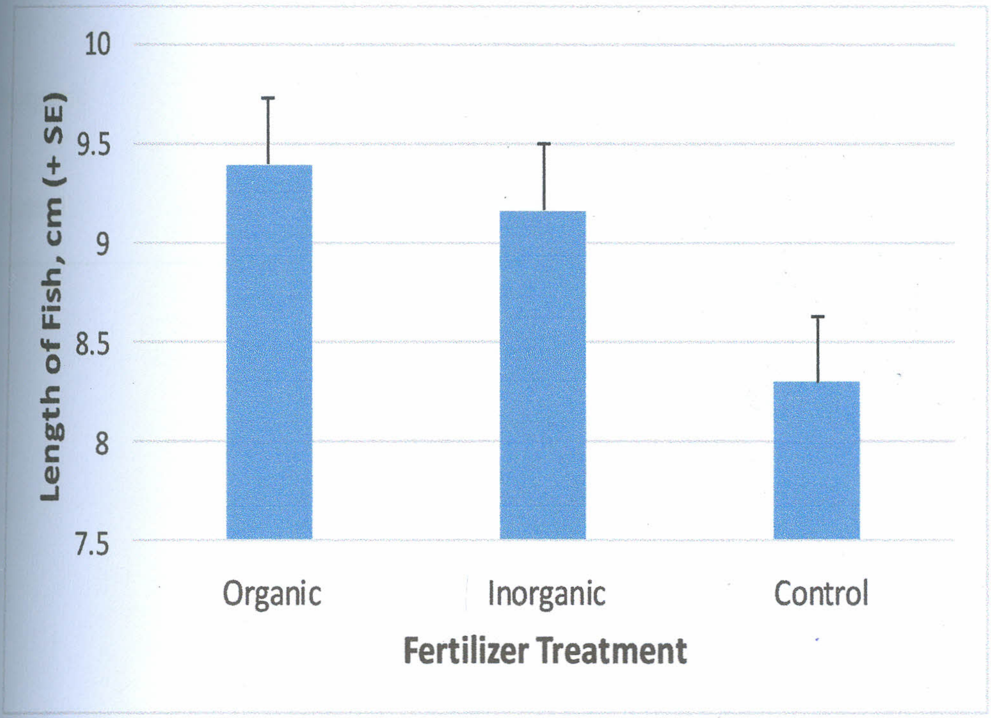


Figure 4.1: Mean length of C. gariepinus in ponds under different fertilization conditions for four months. Inorganic pond fertilized by DAP and urea, organic pond fertilized by chicken droppings and unfertilized pond, control. Error bar represent standard error of mean.

Mean weight of fish was higher in organic pond at 5.75 g, followed by 5.25 g in inorganic pond and 4.33 g in control pond (**Table 4.1.4**). In terms of maximum weight, fish with the highest weight was from the organic pond with a weight of 12.2 g, followed by one from the inorganic pond at 12.1 g, and lastly one from control pond at 9.5g.

Table 4.1.4: Mean weight and range in weight of fish in organic pond, inorganic pond and control ponds.

POND	RANGE in weight in grams		Total number of fish sampled. (n)	MEAN weight in grams
	lowest	Highest		
Organic	2.1	12.2	107	5.75±0.29
Inorganic	2.1	12.1	107	5.25±0.25
Control	2.1	9.5	56	4.33±0.26

Table 4.1.5: Average Weight and growth rate in weight per day in inorganic, organic and control ponds

	Inorganic pond			Organic pond			Control pond		
Sampling Date	n	Av. Weight (grams)	Growth rate (g) Per day	n	Av. Weight (grams)	Growth rate (g) Per day	n	Av. Weight (grams)	Growth rate (g) Per day
11th June	21	2.39±0.10	0.00	17	2.76±0.27	0.00	10	2.40±0.17	0.00
25th June	20	4.07±0.42	0.12	20	3.36±0.38	0.04	10	2.54±0.22	0.01
9th July	20	4.86±0.40	0.05	20	4.19±0.29	0.06	10	4.05±0.22	0.11
23rd July	8	6.83±0.56	0.14	10	7.20±0.43	0.22	5	4.36±0.39	0.09
6th Aug	8	6.06±0.55	-0.06	10	5.20±0.73	-0.14	6	4.80±0.27	0.03
20th Aug	10	7.30±0.43	0.09	10	8.64±0.51	0.25	5	6.32±0.64	0.11
3rd Sept	10	8.09±0.48	0.06	10	9.31±0.43	0.05	5	6.85±0.50	0.04
17th Sept	10	9.07±0.50	0.07	10	10.07±0.51	0.05	5	7.66±0.57	0.06
Average Growth rate (g)			**0.07**			**0.08**			**0.06**

In reference to table 4.1.5, average growth rate in grams per day was highest in the organic pond. This was followed by the inorganic pond and lastly the control. The growth rates were in the order of; organic pond at 0.08g/ day, inorganic pond at 0.07g/day and control at 0.06g/day.

The present results showed that mean weight was significantly different across fertilization regimens ($F_{2, 264}$ =20.89, p = 0.0457; Figure 4.2 and Appendix 1). Post-hoc pair-wise tests on mean weight are summarized in (Table 4.1.6); the results showed that mean weight between control vs. inorganic was not significant (p=0.070); control vs. organic was significant (p=0.025) and organic vs. inorganic was not significant (p=0.512).

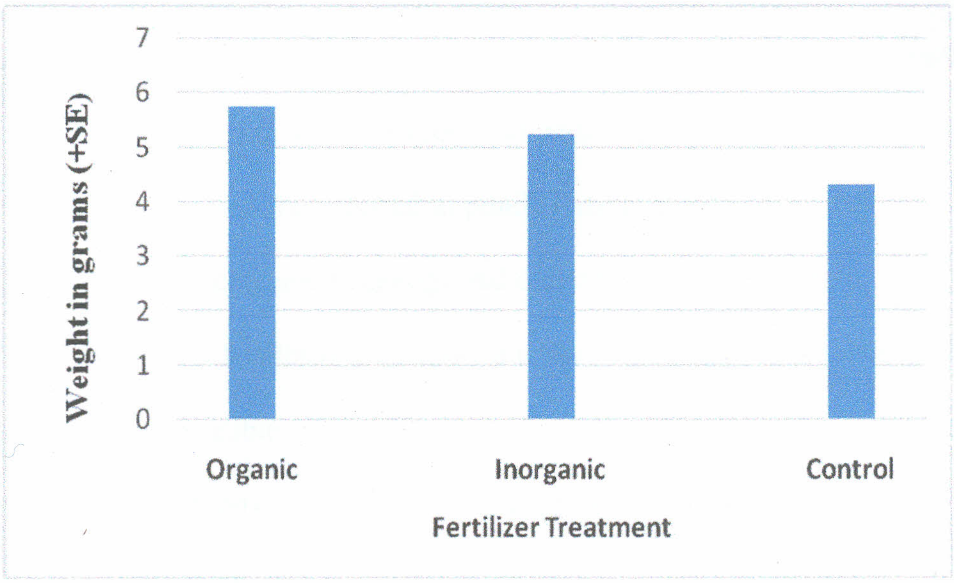


Figure 4.2: Mean weight of *C. gariepinus* raised under different fertilization conditions four months. Inorganic pond fertilized by inorganic fertilizers; DAP and urea, organic pond fertilized by chicken dropping and control pond not fertilized. Error bar represent standard error of mean.

Table 4.1.6: Pond treatment, mean weight differences between the treatments, P-value and significance level

Pond treatment	**Mean weight of fish difference (grams)**	**P value**
Organic pond vs. Control pond	1.420	**0.025**
norganic pond vs. Control pond	0.920	0.070
Inorganic vs. Organic pond	0.500	0.512

Results on growth measurements suggest that fish in fertilized ponds (treatment ponds) grew faster than fish in the unfertilized (control) pond. A notable point is that there were no significant difference P>0.05, in growth rate between fish raised in ponds fertilized by either inorganic fertilizer DAP and Urea and those raised in ponds fertilized by chicken droppings. However fish in the pond fertilized by chicken droppings had a marginally higher length and weight compared to those raised in ponds fertilized with inorganic fertilizers (Tables 4.1.1 and 4.1.2) Figure 4.1 and Figure 4.2). A possible explanation for the marginal difference in size of fish between organic and inorganic ponds is that fish in ponds fertilized with chicken droppings may have fed on zooplankton that were more diverse in organic pond. Furthermore, catfish are also an omnivorous fish whose main diet is zooplankton, whose population densities are higher in ponds fertilized by organic manures (Ngugi, *et al.*, 2007). It has been shown that ponds treated with organic manure improve fertility of the pond for primary productivity and provide direct nutrients which the fish can feed on (Knud-Hansen, *et al.*, 1993).

The results are consistent with those reported by Knud-Hansen *et al.* (1993), where use of chicken manure did not improve the net fish yield for Nile tilapia compared to use of inorganic fertilizers, urea and triple superphosphate. Gamal *et al.* (2008) showed that catfish had higher weight in ponds fertilized by chicken dropping than in ponds fertilized by urea and Mono-Superphosphate. Mosha *et al.* (2016) recommends use of DAP fertilizer or chicken droppings in raising catfish fry's. However, the results are inconsistent with findings from other previous studies. For example, according to Ekpenyong *et al.* (2012) *Oreochromis niloticus* had best growth in earthen pond limed and fertilized by NPK fertilizer than in earthen pond limed and fertilized by chicken droppings.

Several research studies have shown that organic manure has variable effect on fish growth depending on the animal source. For instance, according to Kangombe *et al.* (2006) *Tilapia rendalli* grew significantly faster in ponds fertilized by chicken droppings compared to ponds fertilized by pig or cattle manure. According to Orji and Udonwu (2006) organic manures are essential for plankton growth and enhance fish growth rate faster than compounded dry feed especially during the early stages of development of the fish. In an experiment carried out by El−sayed (1998), fish cultured in poultry manure ponds with supplementary feeding experienced the highest growth performance compared to those raised using supplementary feeds with or without cow manure.

4.2. Plankton diversity

4.2. 1. Phytoplankton diversity

The inorganic pond had the highest number of phytoplankton, 29 genera. This was followed by the organic pond that had 10 genera then lastly the control pond with 8 genera. (Appendix 3). Estimates of phytoplankton species similarity, Jaccard's index, between pairs of ponds are summarized in **Table 4.2.1.**

Table 4.2.1: Jaccard's similarity index of phytoplankton species and P-values between treatments. Organic vs. control had the highest similarity and inorganic vs. control had lowest similarity.

Pairwise comparisons	Similarity Index	P-values
Inorganic and control	0.25	**0.001**
Organic and control	0.38	0.639
Organic and inorganic	0.33	**0.002**

The results suggest that fertilization of pond using inorganic fertilizers induced more phytoplankton growth (**Appendix 3**) than pond fertilized by organic manure. Inorganic fertilizers such as DAP and urea have been shown to improve the level of phosphorus and nitrogen in the ponds thereby encouraging high phytoplankton growth

(Bhatnagar and Devi 2013).

Natural diet of most cultured fish consist of a wide range of phytoplankton species which include diatoms and flagellates thus have greater influence on growth rate of fish (Kwikiriza, *et al.*, 2016). The results showed that there was no significant difference in phytoplankton diversity between organic and control pond $P>0.05$ however there was significant difference in between inorganic and control and inorganic and organic ponds $P<0.05$; see **Table 4.2.1**.

4.2.2. Zooplankton diversity

Three groups of zooplankton genera were observed. These were Copepods, Cladocerans, and Rotifers as shown in **Table 4.3.** Zooplankton abundance across all ponds were in the order of Copepods>Rotifers> Cladocerans. Species diversity, based on Shannon-Wiener diversity index, and effective number for zooplankton species identified in the study are shown in **Table 4.4.**
The results showed that there was no significant difference in Rotifers across all the ponds, however there was significant difference in Copepods and Cladocerans in all the ponds

Table 4.3: Zooplankton numbers in treatment and control ponds. Note that the control pond had the least number of zooplankton compared to the treatment ponds.

Zooplankton group	No/ 1ml in Organic pond	No/1ml in Inorganic pond	No/1 ml in Control pond	P-value
Copepods	51	22	10	**0.001**
Rotifers	22	15	10	0.099
Cladocerans	3	10	2	**0.006**
Totals	76	47	22	

Table 4.4: A summary of Shannon-Wiener index and effective species number of zooplankton in organic pond fertilized by chicken droppings, inorganic pond fertilized by DAP and urea and control pond (not fertilized). Organic pond had the highest Shannon Weiner index; this was followed by the Inorganic pond and lastly Control pond.

Ponds	Number of Genera	n	Shannon-Wiener index (H)	Effective number of genera
Organic	3	76	1.886	6.59
Inorganic	3	47	1.044	2.84
Control	3	22	0.935	2.55

From the study ten families of phytoplankton namely Chlorophyceae, Cyanophyceae, Bacillariophyceae, Conjugales, Scenedemaceae, Desmids, Dinoflagellata, Tribophyceae, Volvocaceae and Chrysophyceae were identified **Appendix 3**. Results of the present study on phytoplankton diversity are consistent with those reported by Oparaku (2013) who also found that phytoplankton abundance was higher in pond fertilized by inorganic fertilizer NPK compared to ponds fertilized by either biogas sludge, or cow dung, or poultry manure. However, the results are not consistent with those of Begum *et al.* (2007), who demonstrated that mean abundance for both phytoplankton and zooplankton was higher in earthen ponds which were treated with poultry manure, triple superphosphate and urea compared to earthen ponds treated with cow manure, triple superphosphate and urea.

Concerning growth rate of fish, despite the results indicating that ponds fertilized with inorganic fertilizer had higher diversity of phytoplankton, fish growth rate was slightly faster in ponds fertilized by chicken droppings; however there was no significance difference in fish growth rate between the two ponds. Inorganic fertilizers NPK are known to stimulate faster growth of phytoplankton but slower growth of zooplankton (Ekpenyong *et al.*, 2012).

There was significant difference in Copepods and Cladocerans across all the ponds. However there was no significant difference in rotifers across all ponds. Organic pond had the highest number of Copepods followed by inorganic pond and lastly the control pond. According to Kangombe *et al.* (2006), chicken manure enhances proliferation of zooplankton than cattle or pig manure. Similarly, Mosha *et al.* (2016) found that zooplankton diversity was higher in tanks applied with chicken manure, followed by tanks fertilized with DAP and the least diversity recorded for unfertilized tank. To the extent that *C. gariepinus* predominantly feeds on zooplankton compared to phytoplankton (Elias, 2009; Dadebo *et al.*, 2014; Admassu *et al.*, 2015), the marginally higher growth rate reported for fish that were raised in ponds fertilized by chicken droppings may be attributed to the fact that organic manure enhances the growth of zooplankton than that of phytoplankton. Although ponds fertilized by inorganic fertilizers registered high phytoplankton species diversity, 100% of species that are associated with pollution aquatic environments species were found in ponds fertilized by DAP and urea. The results showing that even the control pond had 36% of such phytoplankton species associated with pollution suggesting that either the soil or underground water used in all the ponds already contained some level of nutrients that were conducive for phytoplankton growth. A list of phytoplankton genera associated with pollution that were identified in the current study are shown in Table 4.5. Worth noting is the fact that all the phytoplankton associated with pollution that were identified in the current study were found in the ponds treated with inorganic fertilizer, providing a clear evidence that such fertilizers may ultimately threaten biodiversity.

Table 4.5. Phytoplankton genera associated with pollution identified in the organic, inorganic and control ponds

Genus	Organic pond	Inorganic pond	Control pond
Scenedesmus	Yes	Yes	No
Ankistrodesmus	Yes	Yes	No
Navicula	Yes	Yes	Yes
Microcystis	Yes	Yes	Yes
Nitzschia	Yes	Yes	Yes
Fragilaria	Yes	Yes	No
Synedra	No	Yes	No
Amphora	No	Yes	No
Tabellaria	No	Yes	No
Asterionella	No	Yes	No
Coelostrum	Yes	Yes	Yes
Percentage genus associated with polluted waters	64%	100%	36%

Presence (Yes) or absence (No) in the ponds

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1. Summary

There was no significant difference in growth rate between fish raised in pond fertilized by chicken droppings and in pond fertilized by inorganic fertilizers, DAP and Urea. Fish in organic ponds registered a marginally higher growth rate than those in both ponds fertilized by inorganic fertilizers. Phytoplankton were more diverse in the inorganic pond fertilized by DAP and Urea than in organic pond fertilized by chicken droppings however ponds fertilized with DAP and Urea had higher percentage of phytoplankton associated with polluted waters fertilizers. Zooplankton were more diverse in the organic pond than in inorganic pond.

5.2. Conclusions

1. The claim that fertilization of ponds using inorganic fertilizers results in higher fish productivity than organic manure was not supported.
2. Fertilization of ponds using inorganic fertilizers is associated with pollution hence a potential threat to biodiversity in both ponds and those in downstream water ways.

5.3. Recommendations from the study

1. Since there was no significant difference in growth rate in fish raised in either organic or inorganic pond and inorganic fertilizers are known to be a threat to biodiversity therefore use of such fertilizers should be avoided.
2. Since phytoplankton pollution indicators were more in the inorganic ponds this shows that they are not suitable for use in aquaculture if we are to conserve aquatic biodiversity.

However, chicken droppings should be used to encourage zooplankton growth which is the preferred food for *C. gariepinus*.

5.4. Suggestions for future studies

There is still need for more research to:

1. Determine whether differences in growth rates reported in this study persist up to maturity of *C. gariepinus* and in other species of fish and whether they occur in other aquaculture species.
2. Determine plankton preferred by *C. gariepinus* so as to understand any links between growth rate and plankton diversity.
3. Determine whether fertilizers such as SSP and NPK that are also used in aquaculture also favour growth of phytoplankton associated with pollution so as to gain complete information on the role of inorganic fertilizer and pollution under aquaculture conditions.

REFERENCES

Admassu, D., Abera, L. & Tadesse, Z. (2015). The food and feeding habits of the African Catfish *Clarias gariepinus* (Burchell) in Lake Babogaya Ethiopia. *Gobal Journal of fisheries and Aquaculture*, 3,211-220.

Akankali, J., & Elenwo, E. (2015). Sources of marine pollution on Nigerian coastal resources: An overview. *Journal of Marine Science*, 5, 226-236.

Auta, J., Yashim, Y., Dambo A., & Tiamiyu, B. (2013). Growth responses of African catfish *Clarias gariepinus* fingerlings to imported and local feeds. *International Journal of Applied Biological Research*, 5, 55-61.

Batterson, T., & Mcnabb, C. (1993). The role of chicken manure in production of Nile tilapia, *Oreochromis niloticus*. *Journal of Agriculture and Fisheries Management*, 24, 483-493.

Begum, M., Hossain Y., Wahab, A., Amed, Z., Alam J., Shah, M., & Jasmine, S. (2007). Effects of iso-nutrient fertilizer on plankton production in earthen ponds of Bangladesh. *Pakistan Journal of Biological Sciences,* 10, 1221-1228.

Berg, L. (1985). Changes in territorial, gill-flaring, and feeding behavior in juvenile Coho Salmon following short-term pulses of suspended sediments. *Canadian Journal of Fisheries and Aquatic Sciences,* 42, 1410-1417.

Bhatnagar, A., & Devi, P. (2013). Water quality guide for the management of pond fish culture. *International Journal of Environmental Sciences*, 3, 6.

Bjornn, T. (1991). Habitat requirement of Salmonids in stream. In Meehem, W. Ed., Influences of forest and rangeland management on salmonid fishes and there habitat. American Fisheries Society Publication. 19, 83−138.

Blazquez, M., Piferrer F., Zanuy, S., Carrillo, M., Donaldson, M. (1995). Development of sex control techniques for European sea bass (*Dicentrarchus labrax* L) aquaculture: effects of dietary 17 α – methyltestosterone prior to sex differentiation. *Journal of Aquaculture* 135, 329-342.

Boliver, B., Boliver, L., Sacyo, V., Jimenez, T., Argueza, B., Dadag, L., Taduan A., & Borski J., (2008). Growth evaluation, sex conversion rate and percent survival of Nile Tilapia (*Oreochromis niloticus* L.) fingerlings in earthen ponds. 8th International Symposium on Tilapia in Aquaculture.

Boyd, E., & Massaut, L. (1999). Risk associated with the use of chemicals in pond aquaculture. *Journal of Agricultural Engineering*, 20, 113-132.

Boyd, E., MacNevin A., Clay, J., & Johnson, HM. (2005). Certification issues for some common aquaculture species. *Reviews in Fisheries Science*, 13, 231-279

Carballo, E., Eer, A., Schie T., & Hilbrands, A. (2008). A handbook on small-scale freshwater fish farming. Hilbrands, Digigrafii, Wageningen, the Netherland. ISBN Agromisa 978-90-8575-077-4.

Dadebo, E., Aemro, D., & Tekle-Giorgis Y. (2014). Food and feeding habit of African Catfish *Clarias gariepinus* (Burchell 1822) Pisces Clariidae in Lake Koka Ethiopia. *African journal of Ecology*, 52, 471-478.

Dadzie, S., (1992). Status of aquaculture in Kenya: An overview of aquaculture in Eastern Africa. *Hydrobiologia*. 232, 99-110.

Das, S., & Jana B. (1996). Pond fertilization through inorganic sources: An Overview. *Indian Journal of Fish*, 43, 137-155.

Diana, J., (2009). Aquaculture production and biodiversity conservation. *Oxford Journal of Bioscience*, 59, 27-38.

Diana, J., (2012). Some principles of pond fertilization for Nile Tilapia using organic and inorganic source. *John Wiley & Sons, Inc*.

Ekpenyong, E., Ada, F., & Idung, J. 2012. Growth performance of *Oreochromis niloticus* (Pisces: Cichlidae) in fertilized tropical earthen ponds. *Journal of Food, Agriculture and Environment*, 10, 1011-1013.

Elias, D., (2009). Filter- feeding habit of the African Catfish *Clarias gariepinus* (Burchell 1822) in Lake Chamo, Ethiopia. *Ethiopian Journal of Biology*, 8, 15-30.

Elnady, M., Alkobaby, A., Salem, M., & Abdel-salam M. (2010). Effect of fertilizer and low quality feed on water quality dynamics and growth performance of Nile tilapia (*Oreochromis niloticus*).*Journal of American Science*, 6, 1044-1054.

El-sayed, H., (1998). The use of organic manure in polyculture system for Tilapia, Mullet and Carp. *Egypt Journal of Aquaculture Biology*, 2, 133−147.

El-shebly, A., (2006). Evaluation of growth performance, production and nutritive value of the African Catfish *Clarias gariepinus* cultured in earthen ponds. *Egypt Journal for Aquatic Biology and Fish,* 10, 55-67.

FAO., (2012). State of the world fisheries and aquaculture. [Accessed 1 July *2014].http://www.fao.org/docrep/016/i2727e/i2727e.pdf.*

FAO., (2014). State of the world fisheries and aquaculture. Opportunities and challenges. Rome.

Fleuren, W., (2008). Reproductive and grow out management of African Catfish in Netherlands. Proceedings of the workshop on the development of a genetic improvement program for African catfish *Clarias gariepinus* in Ghana.

Floyd, F., & Watson, C. (2006). Total aquaculture health. The Fish site Article. Florida

Gertjan, G., & Janssen, J. (1996). A handbook on the artificial reproduction and pond rearing of African Catfish *Clarias gariepinus* in sub-Saharan Africa. Rome.

Gamal, O., Nabil A. & Mohamed, Y. (2008). Influence of fertilizer types and stocking density on water quality and growth performance of Nile tilapia – African catfish in polyculture systems. 8th International Symposium on Tilapia Aquaculture 157-171.

Gregory, S., (1993). Effect of turbidity on the predator avoidance- behavior of juvenile Chinook salmon. *Canadian Journal of Fisheries and Aquatic Sciences* 50, 241-246.

Hasan, M., Subasinghe, R., Bueno, P., Philips, M., Hough, C., McGladdery, S. & Authur J. 2001. Nutrition and feeding for sustainable aquaculture development in the millennium pp 193-219 Bangkok and FAO, Rome.

Jamabo, A., & Keremah, I. (2009). Effects of stocking density on growth and survival of the fingerlings of African walking Catfish. *Journal of fish Biology* 4 , 55 – 57

Joust, L., (2006). Entropy and diversity. Copyright © OIKOSISSN 0030-1299, 113, 363-375

Kangombe, J., Brown, J. & Halfyard, L. (2006). Effect of using different types of organic animal manure on plankton abundance and on growth and survival of *Tilapia Rendalli* (Boulenger) in ponds. *Journal Aquaculture Research*, 37, 1360-1371.

Kankal, C., & Warudkar, S. (2012). Biodiversity of phytoplankton, zooplankton and zoobenthos in east coast, bay of bengal near Nellore, Andhra Pradesh (India). *International Journal of Pharma Medicine and Biological*, 1, 273-285

Kaur, S., Masud, S., & Khan A. (2015). Effect of fertilization and organic manure on water quality dynamics a proximate composition of *Cyprinus carpio*. *Journal of Fisheries and Livestock Production,* 3, 1-6

Kwikiriza, G., Barekye, A., Bengana, A., & Orina, P. (2016). Performance of African catfish *Clarias gariepinus* fry fed on live Rotifers, formulated feed and a mixture of Rotifers and formulated diet. *International Journal Fisheries and Aquatic studies*, 4, 11-15

Knud-Hansen, C., Batterson, T. & Mcnabb, C. (1993). The role of chicken manure in production of Nile tilapia *Oreochromis niloticus* (L). *Journal of Aquaculture and Fisheries Management*, 24, 483-493.

Kumar, A. (2015). Studies on diversity and abundance of fresh waters diatoms as indicators of water quality in glacial fed Goriganga River India. *International Research Journal of Environment Science*, 4, 80-85.

Kumar, K., & Ayyapan, S. (1998). Integrated aquaculture in Eastern India DFID NRSP High Potential Systems, Working Paper Number 5 Prepared for the Integrated Aquaculture Research Planning Workshop, Purulia, India.

Kumari, P., Dhadse, S., Chaudhari, P., & Wate, S. (2008). A Biomonitoring of plankton to assess quality of water in the lakes of Nagpor city. Proceedings of Taal 2007; The 12th World Lake conference Pages 160-164.

Liti, D., & Munguti, J. (2015). Organic resources in fish farming. Publication Chapter 6, Research Gate/263234058.

Maithya, J., Harrison, C., Okeyo-Owuor B., Wangila, B., Ouma H., Orinda, C., Hoggren, M., Dannewitz, J., & Carlsson M. (2001). Aquaculture strategy for restoration of threatened Lake Victoria fishes: The case for *Oreochromis variabilis* (Boulenger, 1906) and *Labeo victorianus* (Boulenger, 1901).

Marimuthu, K., Umah, R., Muralikrishnan, S., Xavier R., & Kathiresan, S. (2011). Effect of different feed application rate on growth, survival and cannibalism of African catfish *Clarias gariepinus* fingerlings, *Journal of Food Agriculture* 23, 330-337.

Mizanur, R., Yakupitiyage, A., & Ramamukhaarachchi, S. (2004). Agricultural use of fish pond sediment for environmental amelioration. *Thammasat International Journal of Science*, 9, 1-12

Mosha, S., Kangombe, J., Jere, W., & Madalla, N. (2016). Effects or organic and inorganic fertilizers on natural food composition and performance of African Catfish *Clarias gariepinus* fry produced under artificial propagation. *Journal of Aquaculture Research and development* 7,441.

Munguti, J., Joeng-Dae, K., & Ogello, E. (2014). An overview of Kenyan Aquaculture: current status, challenges and opportunities for future developments. *Journal of Fish and Aquatic Science,* 17, 1-11.

Myrick, C., (2005). Effect of temperature on the growth, food consumption and thermal tolerance of age-0 Nimbus strain steelhead. *North America Journal of Aquaculture* 67, 324-330.

Ngugi, C., & Manyala, J. (2009). Assessment of national aquaculture policies and programmes in Kenya. A project report for Sustainable Aquaculture Research Networks in Sub-Saharan Africa.

Ngugi, C., Bowman, J., & Omollo, B. (2007). Anew Guide to Fish farming in Kenya. A Publication by a collaboration between Oregon University, Department of Fisheries and Aquatic Sciences, Moi University and Fisheries Department Ministry of Livestock and Fisheries Department, Government of Kenya, Oregon university, Oregon, USA pp 95.

Nicomedes, B., (2005). Environmental sustainability issues in Philippine agriculture. *Asian Journal of Agriculture and Development*, 2, 67-78.

Ogello, E., Mlingi, F., Nyonje, B, Charo Karisa, H., & Munguti J. (2013a). Can integrated livestock fish culture be a solution to East Africa's food security? *African Journal of Food Agriculture, Nutrition and Development*, 13, 8058-8076.

Ogello, E., Obiero, K., & Munguti, J. (2013b). Lake Victoria and the common property debate: is the tragedy of the commons a Threat to its Future? *Journal of Lakes Reservoirs and Ponds*, 7, 101-126.

Ogutu-Ohwayo, R., (1988). Reproductive potential of Nile Perch *Lates niloticus* and the establishment of species in Lake Kyoga and Victoria (East Africa). 162, 193–200.

Oparaku, F., (2013). Evaluation of different waste for use in plankton production. *North American Journal of Agriculture and Biology*, 4, 527-531.

Otieno, M. (2011). Fisheries value chain analysis; Background Report-Kenya. FAO, Rome, IT, pp 2-10.

Orji, R., & Udonwu, E. (2006). The Effect of Cow Dung and Poultry Droppings on Plankton abundance and growth of *Heterobranchus longifilis* ×*Clarias gariepinus* hybrid, reared in concrete ponds. *Animal production Research Advance*, 2, 197-201.

Oyin, O., (2012). The growth performance and survival of *Clarias gariepinus* fry raised in homestead concrete tanks. *Journal of Fisheries and Aquatic Science*, ISSN 1816-4927/ DOI: 10.3923/jfas. 2012.

Parmar, K., Rawtani, D., & Agrawal, K. (2016). Bioindicators: The natural indicators of environmental pollution. *Frontiers in Life Science*, 9, 110-118.

Prein, M., (2002). Integration of aquaculture in crop-animal systems in Asia. *Agricultural Systems*, 71, 127-146.

Ralph, L., (1978). Neutralizing of waste water by pH control. Instrument Society of American.

Shoko, A., Getabu, A., Mwayuli, G., & Mgaya, Y. (2011). Growth Performance, Yields and Economic Benefits of Nile Tilapia *Oreochromis niloticus* and Kales *Brassica oleracea* cultured under vegetable-fish culture integration. *Tanzania Journal of Science*, 37, 10-13.

United Nations Educational Scientific and Cultural Organization (UNESCO) (2006) Manual on aquatic cyanobacteria. A photo guide and a synopsis of their toxicology, Institute of Ecology/Limnology, Lund University, Sweden.

World Health Organization (2011). Global assessment of the state-of-the-science of endocrine disruptors. WHO/PCS/EDC/02.2.

Zahid, A., Khan, N., Nasir, M., & Ali, M. (2013). Effect of artificial feed and fertilization of ponds on growth and body composition of genetically improved farmed Tilapia. *Pakistan Journal of Zoology*, 45, 667 – 671.

Zannatul, F., Sumi, A., Mahamudul, H., Rawshan, A., & Reza, S. (2012). Phytoplankton diversity and abundance in relation to pollution levels in the hazaribagh tannery effluent sewage water of the river Buriganga. *Journal of zoology*, 40, 121-128