IMPACTS OF AQUACULTURE ON WATER QUALITY AND ECONOMIC BENEFITS IN CENTRAL KENYA: A CASE STUDY OF GATUNDU SOUTH CONSTITUENCY

BY

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DECLARATION

This thesis is my original work and has not been submitted for a degree course in any other university

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DEDICATION

This thesis is dedicated to my beloved daughter Grace who has been a source of encouragement at every stage of this thesis. To my parents, brothers and sisters for a life well spent in seeing me through many hurdles in life including schooling.

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LIST OF ACRONYMS

AIEI	African Impact Evaluation Initiative
DO	Dissolved Oxygen
ESP	Economic Stimulus Programme
FAO	Food and Agriculture Organization of the United Nations
FFEPP	Fish Farming Enterprise Productivity Programme
FY	Financial Year
IE	Impact Evaluation
LIFDCs	Low Income Food Deficit Countries
PEV	Post election violence
PO_4-P	Orthophosphates
PSNP	Productive Safety Nets Programme
NACCEU	Network of Aquaculture Centres in Central and Eastern Europe
NEMA	National Environmental Management Authority
NO_3-N	Nitrate -Nitrogen
Mmt	Million metric tonnes
SSA	Sub-Saharan Africa
SPSS	Statistical Program for Social Sciences

ABSTRACT

In recognition of the importance of the aquaculture sector in Kenya, the government in the year 2008 increased its investment into the sector through Economic Stimulus Program (ESP). In executing the project, 200, 300 and 100 fish ponds were constructed per constituency in the first, second and final phase respectively. This unprecedent increase in aquaculture investment may result to increased production of fish and changes in water quality to the environment. Pollution of water resources by pond effluents is mainly the most complaint, and this concern has attracted the greatest amount of official attention in most countries. The characterization of fish farm effluents and the quantification of the impact they have on the environment will provide the much needed information and data for decision makers to formulate the necessary policies for safeguarding the environment.

As yet, the impact of the increased investment on environmental water quality and socio economic benefits remains to be evaluated. This study therefore determined the influence of increased aquaculture investments on water quality and economic benefits in Central Kenya using Gatundu South Constituency as a case in point.

The study determined the following in the study area: water quality parameters in the main rivers used as source of water for fish farming; changes in water quality due to effluent discharge in rivers; water quality parameters in the ponds and the socio-economic impact of ESP fish farming project. Sampling of water was done during the month of January and February 2014. Water quality data sampled from the rivers and ponds included: dissolved oxygen (DO), pH, water temperature, salinity, Nitrate-

Nitrogen concentration (NO_3-N) and Ortho-phosphate concentration. (PO_4-P) Survey data on the socio-economic benefits were collected in three areas in Gatundu South using questionnaires. Water quality data were presented as means and spatial differences analyzed using One-Way ANOVA. Frequency distribution and chi-square were used to analyze the socio-economic data. The results of water quality analysis indicated that most of the parameters analyzed were within the recommended range of water quality for most aquatic organisms.

There were significant differences in all the water quality parameters analyzed in the three rivers except for NO_3-N, One-Way ANOVA; $F = 0.624$, $df = 2, 6$, $P = 0.567$). The overall concentration of the NO_3-N ranged from 0.66 to 0.70 mg/l. ($p < 0.05$) reflecting variations in the location of the rivers. In the ponds, water quality parameters reflected low values of DO, and pH, with slightly higher values of salinity, NO_3-N concentration, and PO_4-P concentration. In areas of effluent discharge significantly (One-Way ANOVA, ($p < 0.05$) lower DO, pH and higher salinity, NO_3-N concentration, and PO_4-P concentration were recorded reflecting water quality effects of the effluents in the riverine waters. It was also noted that fish farms effluent contained pollutants that can affect water quality, but the pollutants magnitudes were within the NEMA water quality standards of effluent discharge were suspended solids is expected to be 30mg/l maximum and nitrate- 100mg/l maximum. The values were impacted more for farmers within the ESP programmes and this can be attributed to readily available inputs which they were not paying for, hence tended to misuse them.

Because the rivers in Gatundu serves as a source of water supply for drinking, washing, fishing and swimming, impacts of pond water discharge into natural systems should be closely monitored in order to avoid adverse effects like localised eutrophication and a change in the trophic structure.

There was a significant difference in all socio-demographic variables of the respondents who participated in this study. Also it was evident that farmers who participated in the Economic Stimulus Programme (ESP) had lower fish production cycles, higher production volumes and revenues and therefore resulted to higher margins compared to farmers without ESP support.

CHAPTER ONE

1.0 INTRODUCTION AND LITERATURE REVIEW

1.1 INTRODUCTION

1.1.1 Background of the study

According to Food Agricultural Organization of the United Nations (FAO) estimates, the global expansion of food demand is projected to increase by 50 million metric tones between the year 2000 and 2015 (FAO, 2013a) against an estimated increase of up to 2 billion people over the same period (Ayre, 2014). The fast increase in human population compared to increase in food production would therefore create food insecurity. Indeed, it has been noted that the problem of food insecurity is dire in the developing countries due to the declining food production owing to reliance on subsistence agriculture coupled with erratic climate and increasing populations (Population Council Inc. 2013). To remedy this situation, efforts aimed at increasing food supply have been considered as step gap measures in addressing the endemic food insecurity within these countries (World Economic Forum, 2014). Fish as a prominent food resource, has been considered as a step gap measure against chronic food insecurity in developing countries. Yet for some time now, most of the fish have been obtained from the wild stocks leading to declining yields and increase in food insecurity (Vince, 2012). This has seen the shift in focus to strategies that enhance increased fish production.

Aquaculture as a relatively new science in developing countries continues to contribute towards food security and is viewed as a panacea for continued reliance on wild fish stocks (Araki, 2008; UNFTP, 2012; Friend and Funge-Smith, 2012). It is the fastest growing food production sector for nearly two decades and has exhibited an overall growth rate of over 11% yearly since 1984; compared to 3.1% for terrestrial animals meat production and 0.8% for landings from capture fisheries (FAO, 2009; Garcia and Rosenberg, 2010; FAO, 2012a). Nearly 90% of the total aquaculture production comes from developing countries and a large proportion of this from Low Income Food Deficit Countries (LIFDCs) (World Bank and FAO, 2009; FAO, 2013a). As yet, the developing countries in Africa are currently performing very poorly in aquaculture (Kapetsky, 1994). In 2012, Sub-Saharan Africa (SSA) contributed a paltry 0.03% of the world's aquaculture production. By the year 2012, only Nigeria and Egypt were dominant countries in aquaculture production surpassing over 50% of total African production of farmed fish (Aguilar-Manjarrez and Nath, 1998; Machena and Moehl, 2011). Unfortunately, Kenya is classified in the latter category of poor performers in aquaculture.

Aquaculture development in Kenya dates back to the 1920s but has remained at subsistence level to-date (Ngugi and Manyala, 2004; Coche *et al*., 2008; Mbugua, 2008a). Serious attempts to introduce fish farming in Kenya were made in the early 1960s with the main objective of producing the much-needed animal protein for the rural populations but its potential has not yet been fully realized (Mbugua, 2008b; CIA, 2013). The sub-sector contributed 0.7% of the total annual fish supply from 1980 to 1998 and about 1% of the total national fish production (GoK, 2011) which was estimated at 0.5% of the GDP. The number of fish farmers in 2001 was 7688 with 16244 ponds covering an area of about 240 hectares. Because the government of Kenya through the Ministry of Agriculture, Livestock and Fisheries has focused on improving food security, earning higher incomes and improving economies in the rural areas through aquaculture, some growth is now being realized in the sector. In fact, fish farming has made much progress in the country between the year 2008 and 2012 (Hino, 2012). The sub-sector now provides livelihood support to 120,000 Kenyans directly and approximately 1.1 million others indirectly (GoK, 2011).

Practice of aquaculture in Kenya, relies on the culture of species that are simplistic in culture conditions, tolerant to prevailing water quality conditions and acceptable to the consumers (Mbugua, 2008b). This is based on the production of two species; namely, Nile tilapia (*Oreochromis niloticus)* forming about 90% of the farmed fish in Kenya (Kaliba *et al*., 2007) and the African catfish (*Clarias gariepinus*), which is polycultured with tilapine species to control prolific breeding (Okechi, 2004). Again other species such as Rainbow trout (*Oncorhynchus mykiss*) and largemouth bass (*Micropterus salmoides*) are cultured in cold environment (Otieno, 2012) However, the profitability of these species of fish has been decried for being too low and variable to spur the planning of commercial aquaculture (Kaliba *et al*., 2007).

It has been realized that most aquaculture takes place in the rural areas where there is huge potential for fish production due to conducive factors such as favourable weather conditions, land, and water resources (Mbugua, 2008b). However, it normally takes place at extensive and semi-intensive scale where minimal inputs of feeds, fingerlings and drugs are used, with tendency to concentrate on fish feeding lower in the food chain (Coche *et al*., 2008). More than half of the fish produced are consumed directly, bartered for other goods or sold in local markets (Neira *et al*., 2009). The domestic market for farmed fish is readily available in Kenya as there is consumer awareness on the health benefits of eating fish and quality assurance of the farmed fish. The combination of high demand and good prices has boosted aquaculture development in

Kenya. The distribution chain is short mainly at farm gate but the number of middlemen has increased especially in the fast growing bait fish market for catfish fingerlings (Kaliba *et al*., 2007).

1.1.2. Role of the economic stimulus programme fish farming project

The government has taken cognizance of the role of aquaculture and the endemic challenges faced by the sector and thus enhanced investments into the sector as a step gap measure to improve aquaculture productivity. This was achieved through Economic Stimulus Package (ESP) aimed to boost economic growth due to recession after the Post election violence (PEV), prolonged drought, an increase in oil prices and food prices and the effects of the 2008/09 global economic crisis (GOK,2009). Due to the concern, development of aquaculture was included as one of the projects under the Kenyan Economic Stimulus Program (ESP) (Economic Stimulus Programme, 2009-2012).

The government recognized the challenges and took note of the potential the aquaculture sub-sector has in poverty eradication, income generation, food security and general economic growth. The Economic Stimulus Programme (ESP) had a budget of Kenya Shillings (KES) 22 billion. Of the KES. 22 billion that was budgeted for ESP, KES. 1.12 billion Was awarded to the Fish Farming Enterprise Productivity Programme (FFEPP) in the first phase 2009/2010 Financial Year (FY) and KES 2.866 billion in the second phase 2010/2011 FY. As a result, FFEPP was launched in 2009/2010 FY from which, production of fish was projected to increase to over 20,000 tonnes in the short term and to over 100,000 tonnes in the medium and long terms providing close to Kshs. 6 billion (US$ 75 million) as direct earnings to farmers (www.thefishsite.com, 2010).

The target was to construct 48,000 fish ponds in the 160 parliamentary constituencies i.e. 200 fish ponds per constituency in the first phase and 20,000 fish ponds i.e. 300 fish ponds per constituency in 20 new constituencies and additional 100 fish ponds per constituency in the first 140 constituencies. Each recipient got a total of KES 34,023, where: KES 25,000 was for pond construction, 5,063 for feeds, 3,000 for seeds and KES 960 for manure (Economic Stimulus Programme, 2009-2012).

However, no studies have been done to evaluate the economic benefits of aquaculture to farmers under ESP fish farming project.

1.1.3 Impacts of increased investments in aquaculture

The practice of aquaculture may also have its unintended and negative consequences which, if not dealt with, may outweigh its positive impacts. The positive impacts of aquaculture include provision of rural livelihoods, better income and new or alternative employment, additional income from rice farming systems or subsistence staple cropping systems, food security and better nutrition, and development of rural areas (Foresight, 2011). Negative impacts of aquaculture arise due to the constant need to produce more by expanding the production area or by increasing the unit productivity.

During aquaculture practices, there is use of many inputs to enhance production ranging from the application of fish feeds, chemotherapeutants against disease outbreaks, fertilizers and other routine practices that may affect the quality of water.

Because of the unprecedented increase in fish production due to increased investments, water quality is likely to be affected due to discharge of the aquaculture wastes into the natural systems and environments. However, currently there is lack of information on how increased aquaculture activities affect the water quality in the riverine systems in Kenya.

1.2. Literature review

1.2.1. Status and trends of aquaculture production

Aquaculture is defined by the Food and Agriculture Organization of the United Nations (FAO) as "the farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants" (FAO, 2012b). Aquaculture has been a source of significant growth in the global production of fish since the late 1970s (World Bank, 2010). In the course of half a century or so, aquaculture has expanded from almost negligible levels to fully complex systems comparable with capture fishery production in terms of feeding people in the world (World Bank and FAO, 2009). Production from aquaculture has increased almost twelvefold, at an average annual rate of 11% compared to 3.1% and 0.8% for capture fisheries and terrestrial farmed meat production systems respectively since the 1990s. Aquaculture now accounts for almost 50% of total fish supply for human consumption in the world (FAO, 2010). In 2010, global production of farmed fish was 59.9 million tonnes with an estimated total value of US$119 billion. When farmed aquatic plants and non-food products are included, world aquaculture production in 2010 was 79 million tonnes, with a market value of US$ 125 billion (FAO, 2012a). Although these statistics present global totals, they are highly skewed by geographic regions.

The FAO (2008, 2009; 2010a and 2012a,b) statistics indicate that a high proportion of the total aquaculture production is from the developing countries in which Asia contributed between 86-91.3% (35.2-41.72 mmt), with a paltry 0.9-2.2% (0.54-1.31 mmt) of the total aquaculture production recorded from Africa between the years 2003 and 2012. In Europe, the share of production from aquaculture range between 5.2-5.3% (2.5 to 3.2 mmt) in the same period driven by marine cage culture of Atlantic salmon and other species. The rest come from America and the Caribbean who contributed between 6-8% although statistics from these regions are not readily available. Yet these statistics do not reveal the growth trends in aquaculture but just lumped total computed over a period of time using data provided by governments and some fisheries researchers.

An analysis of production by region for the period 1970–2010 shows that growth has not been uniform. China's aquaculture production increased at an average annual rate of 11.2% in the same period. However, recently, China's growth rate has declined to 5.8 % from 17.3 % in the 1980s and 14.3 % in the 1990s (FAO, 2010a). Other major producers in Asia are among the world's top producers; however fish production from these regions face negative growth trends. Similarly, production growth in Europe and North America has slowed substantially to about 1% per year since 2000. In the Americas, the share of freshwater aquaculture in total production declined from 54.8% in 1990 to 37.9 % in 2010. Also, in North America aquaculture has ceased expanding in recent years but in South America it has shown strong and continuous growth particularly in Brazil and Peru (FAO, 2012b). In France and Japan, countries that used to lead aquaculture development, production has fallen in the last decade. In terms of sustained growths, the Latin America and the Caribbean region shows the highest average annual growth (22.0%), followed by the near east region (20.0%) and the Africa region (12.7%). Also fish production in Africa depends mainly on omnivorous/herbivorous finfish such as carps and tilapia (99.3%) which normally feed at low levels in the aquatic food chain (De Silva, *et al*., 2009; FAO, 2012a).

In terms of volume and value in Africa; Nigeria, followed by Madagascar, South Africa, Uganda and Zambia are the five top farmed fish producing countries in the region amounting to 58,000 tonnes (80 % of SSA). The remaining 12 countries, including Kenya, only contributed 14,300 tonnes (< 20%). Kenya was ranked number 8 by volume and number 3 by value in 2003, a drop both in volume and value, from number 5 in 1990 though it improved from number 11 to 9 in 2000 (Coche *et al*., 2008). It is apparent that, while aquaculture output will continue to grow, the rate of increase may be moderate in the near future (CIA, 2013). Fish consumption per capita in sub-Saharan Africa is the lowest in all regions and is the only part of the world where it is declining. Since capture fisheries cannot meet the human demand for fish as food, aquaculture will have to play a crucial role. The Sub-Saharan region, despite its vast natural potential, continues to play a minor role in the world aquaculture production. To maintain the current consumption level of fish in Africa, the aquaculture sector would have to increase by 267% by 2020 (FAO, 2008). Consequently, it is necessary to promote the expansion of this sector. There is need therefore to intensify practice of aquaculture at all levels in these countries, which appear to lag behind for a long time now.

Although aquaculture has been practiced for over 50 years in Kenya, it has remained largely a subsistence level activity among the rural fish farmers. The blame for this is laid on the fact that aquaculture sub-sector was scarcely mentioned in planning documentation (Omondi *et al*., 2001). Kenya now has an official support for aquaculture development mentioned in planning documentation. During the preparation of the Poverty Reduction Strategy Paper in 2003, aquaculture development was identified as a core activity to be funded through the Medium Term Expenditure Framework (MTEF) budgeting system (Gitonga., Mbugua and Nyandat., 2004). The rationale is that it has the potential to play a major role in poverty reduction, improve rural income and increase rural protein supplies while reducing pressure on wild capture fisheries and to some extent promote exports.

Further, statistics indicates that aquaculture contributes less than 1.5% of the total fish production in Kenya (Mbugua, 2008a; Fisheries Department, 2012; Hino, 2012). These statistics provide pooled data of production from aquaculture; however private farms produced a total of 71,989.86 kg of tilapia and *C. gariepinus* valued at Kenya Shillings 6,788,011 from 7,890 individual fish farmers operating 10,038 fish culture units. The total area of the ponds for fish production was 1,838,809 m^2. Among the ponds 155 were stocked and the rest were not (GoK, 2011). During the same period (2012) there was an apparent increase in fish farming activities.

1.2.2. Financing of aquaculture sector

Aquaculture business enterprise, involves costs of purchasing the fixed assets of production (fixed costs), acquiring materials for business start up (business capital), obtaining inputs for the operations of the business (variable costs), supply of labour, and cost of other miscellaneous items (Nandlal and Pickering, 2004; Hishamunda and Ridler, 2006). Aquaculture farmers need loans to purchase or rent land, machinery and equipment, vehicles and aerators, to build ponds and/or cages as well as storage facilities, purchase of items such as seed, feed, fertilizers, chemicals and fuel, or to pay labour. An analysis of a sample of farms in sub-Saharan Africa (SSA) indicated that variable costs could cover between 51 to 98% in tilapia and catfish operations (Padiyar *et al.*, 2011; Otieno, 2012). Such large operating expenses typically require loans. Unfortunately, the lack of capital in general is a problem for development of many business enterprises in SSA (Ahmed, 2009; Machena and Moehl, 2011). Thus any effort that seeks to develop aquaculture in SSA has to understand and address the question of loans.

Commercial aquaculture farmers can get capital through own savings (own equity), which include family savings, borrowing, grants or through a combination of both. In the SSA, the majority of financing for any new, independent, business venture will be from the owner's personal assets (Otieno, 2012; Brakel and Ross, 2011). As a result, annual per capita investments in the SSA are very low (ADB, 2009). Such meagre investment in business enterprises imply that most or all investments profits will be consumed. Because a large percentage of the population lives below the poverty line in most countries, earnings from investments are often insufficient to cover family needs, which limit the possibility of business expansion (Nwanze, 2010; Friend and Funge-Smith, 2012). Thus, it can be argued that, with few exceptions, the marginal propensity to invest in SSA is at best close to zero. The likelihood for potential investors to build their own equity is also limited.

The lack of own equity suggests that most investors in SSA will depend on external funding to start a commercial aquaculture business; the leverage will be important. The common external source of funding to provide capital for commercial ventures is borrowing, mainly from banks (Hezell *et al*., 2013; IFAD, 2013). Unfortunately, in the case of aquaculture, so far financial institutions play a minor role in the provision of loans for the procurement of investment capital (Hishamunda and Ridler, 2006; Mbugua, 2008a). For aquaculture sector to develop in SSA, the issue of potential investors' access to loans needs to be addressed. Yet, access to loans by prospective commercial aquaculture farmers in SSA remains a serious concern (Neira *et al*., 2009; Padiyar *et al*., 2011; Kassam *et al*., 2011). Attempts to analyze the issue of loans in aquaculture in SSA by discussing the root causes of limited access to loans for capital investment in commercial aquaculture in the region is thus necessary.

Different lenders may have different types of loan repayment plans for different borrowers in aquaculture depending on the borrower's ability to repay the loan. There are two main types of repayment plans for aquaculture loans: single-payment plans and amortized-payment plans. Accordingly, aquaculturists can opt for single-payment loans where the payment of the principal is at once when the loan is due (Hishamunda and Ridler, 2006). Some intermediate-term loans that may require only annual interest payments, with the total principal due at the end of the loan are also included in this category of loans. However, amortized payment loans in which interest and principal payments are made periodically by instalments, generally monthly and include intermediate-term loans and long-term loans are also preferred by intermediate to large scale farmers (Brakel and Ross, 2011). These loan repayment methods are rarely used in SSA (ADB, 2009; Padiyar *et al*., 2011).

The Governments may enact policies that encompass lending money to the farmers to start business enterprises in situations where they want to boost economic development or jump start the economy. Examples in this category include financing of aquaculture development in Kenya through the economic stimulus programme (GoK, 2009). It was introduced through the 2009/2010 budget and aims to stimulate the growth of Kenya's economy through rapid creation of business opportunities and jobs. KES 22 billion (USD 284 million) were committed to the programme. However, many initiatives such as the ESP were doomed to fail due to corruption, poor project planning or failure to involve citizens in local organization and planning. By the end of 2010, some of the projects that were supposed to have been funded by ESP had either not commenced due to slow implementation and poor planning. Citizens' involvement in ESP projects was not adequately provided for by the ESP governance structure or there was low community involvement and awareness in the ESP funded projects. The poor information flow on the progress of the ESP projects also led to only a few people knowing about the existence of the fund. Also reported is consistent confusion between different sources of funding and that projects were misplaced and therefore did not meet the priorities of particular regions (TISA, 2010). Until now, there is scanty and fragmented literature on the role of government financing in aquaculture and the success of the initiatives among the smallholders aquaculture in the SSA region.

1.2.3 Socio-economic benefits of aquaculture

The socio-economic benefits of aquaculture is not clearly known because of the under representation of the sector towards national development agenda (FAO, 2010a). The sector's economic output provides important contributions to poverty alleviation and food security through three main, interlinked pathways: (1) nutritional benefits from the consumption of fish; (2) income to those employed in the sector and multiplier and spill over effects in fishery-dependent regions; and (3) through generation of revenues from exports, taxation, license fees and from payment for access to resources by foreign fleets or foreign investment in aquaculture (Corbin and Young, 1997). At present, data on the exact socio-economic contribution towards rural or urban economies is limited because of the difficulty of differentiating between the contribution of the wild fishery sector and that from aquaculture (Garcia and Rosenberg, 2010; Cai *et al*., 2011). Nevertheless, it is now clear that the economic contribution of aquaculture has been growing in many regions of the world.

Consumption of living aquatic resources is increasing to levels that cannot be sustained by our oceans and freshwater bodies (Dada, 2013). The rapid development of aquaculture has been a remarkable contributor to meeting this growing demand (Posadas and Bridger, 2012) and is widely forecast to grow further. The sector provides food security to over 800 million people, and is source of protein to about 1.2 billion people (Gabriel *et al*., 2007; FAO, 2012a). The gap between demand and supply is, however, increasing and the pressure is high necessitating aquaculture to develop even faster (Bridger *et al*., 2013). A marked increase in fishery exports was reported between 2000 and 2007, which coincided with an impressive global trade expansion and improvement of fish production from aquaculture (FAO, 2008; FAO, 2010a, b). However, this substitution effect of aquaculture on the capture fisheries in Kenya is not well understood.

Aquaculture sector also provide numerous jobs across the supply chains, in activities such as processing, packaging, marketing and distribution, manufacturing of fish-processing equipment, net and gear making, ice production and supply, construction of culture units and marketing, management, research and administration, which contribute substantially to the socio-economic wellbeing of those communities (Dada, 2013). This is estimated to support the livelihoods of 660 to 820 million people, or 10 to 12% of the world's population (FAO, 2012a). In most places, these employment opportunities have strengthened the economic viability of rural areas, often enhancing the status of women in developing countries, where more than 80 % of aquaculture output occurs (UNFTP, 2012). Interestingly, most of the socio-economic benefits for the smallholders accrue in more commercially oriented aquaculture undertakings (Kawarazuka and Bene, 2010; Otieno, 2012).

Land is required for establishing aquaculture farms and associated infrastructures. As far as the supply of aquatic protein is concerned, aquaculture can be a more economic way to utilize land and land- based resources in some cases, which is evident by the high productivity of both freshwater (e.g. carps and tilapia) and mariculture (e.g. shrimp and salmon) (Foresight, 2011). Aquaculture can also utilize land unsuitable for other agricultural activities and may complement other farming activities. In addition, nutrient-rich mud at the bottom of aquaculture ponds can be utilized to fertilize nearby agricultural land (FAO, 1997). Since SSA has large part of the land, which is not suitable for agriculture (CIA, 2013), it has not been established how much of this land can be used for aquaculture to enhance socio-economic benefits to the local community members.

Aquaculture development has been associated with stimulating the development of the rural communities by generation of greater economic activity with the establishment of support services. The sector also acts as an economic multiplier in marginal rural areas. Commercial-scale investment also spurs the government to provide or improve the infrastructure of an isolated area in the form of roads, bridges and often electricity (World Fish Center, 2005; Friend and Funge-Smith, 2012). The impact is even more pronounced if the farm is locally owned however small it may be, since income from sales of the harvest become part of the local cash flow, where the production centres dedicated to rural or small-scale aquaculture are mostly family owned (FAO/NACEE, 2006).

Although a number of field studies have observed or argued for the importance of cash income from aquaculture in boosting local economies, there is no explicit quantification of these linkage effects. For aquaculture, one of the few studies to quantify growth linkages relates to the shrimp farming industry in southern Honduras (Stanley, 2003). The study found that export-orientated commercial aquaculture exhibited low backward and strong forward linkages, but those were likely to be reduced with increased reliance on imported inputs as vertical integration and concerns for disease and quality management shaped the development trajectory of the industry. In Kenya, there is lack of information on the socio-economic benefits of aquaculture.

1.2.4 Impacts of aquaculture on water quality

During semi-intensive and intensive aquaculture (Dian *et al*., 1994a), rapid growth of fish is encouraged through pond fertilization, supplementary feeding (Diana *et al*., 1994b) and sometimes increased use of antibiotics to manage outbreaks of fish diseases (Rasowo *et al*., 2007; Magondu *et al*., 2011; Oyoo-Okoth *et al*., 2011) in the aquaculture facility. When ponds are fertilized to stimulate natural pond productivity, large amounts of nutrients are generated in the culture units (Iwama, 2009), feeds are rarely fully consumed by the fish (Gabriel *et al*., 2007), while the antibiotics are direct pollutants (Holmström *et al*., 2003). These substances tend to accumulate in the pond water during the culture period and are serious environmental concern, acting as aquaculture wastes (Gautier *et al*., 2009; Bergheim and Asgard, 2014). To re-use the water that has been used for aquaculture, conventional treatment is required to reduce the pollutant load in the water, which rarely occurs in many culture systems especially in the SSA.

Aquaculture practices also release wastes into the water body, which can lead to changes in water quality of the environments. The effluents may have serious negative effect on the quality of the receiving water if discharged without treatment (Mugg *et al*., 2007), depending on the effluent composition from the aquaculture units. These impacts have manifested in different ways such as changes in Dissolved Oxygen (DO) concentration, pH, salinity, conductivity, Total Dissolved Solids (TSS), total phosphorus (TP), total nitrogen (TN), total carbon(TC), biological oxygen demand (BOD), chemical oxygen demand (COD) etc (Corbin and Young, 1997; Svobodová *et al*., 2007; Mishra, 2008). In pond fish culture, the waste and the pollution from feed is more serious (Dong *et al*., 2000). In Lin Yongtai's research (Lin *et al*., 1995) about the influence of Heilongtan Reservoir cage fish culture on the water environment, the extent of leaching of total nitrogen (TN) content and total phosphorous (TP) from the feed to the environment is high. It is obvious that the feeds which have not been eaten seriously impact the water environment.

The discharges of organic and inorganic wastes produced by aquaculture have been identified to cause increased organic loads and the eutrophication in some natural environments, for example, as BOD increases, oxygen and oxidation-reduction potential will reduce (Midlen and Redding, 1998). Other influences include the acidification of pond soils, the decrease of biological diversity, the increase of pathogens, and the occurrence of algal bloom (Guangjun *et al*., 2010). In Kenya, studies by Kithiia (2006), Okoth and Otieno (2000) and Mavuti (2003) revealed degradation trends in water quality within the river system due to discharge of effluents from land use activities. However, they lumped up several of the activities without singling out the impacts of aquaculture.

Although aquaculture may cause negative impacts on the water body, some cases may even be beneficial, for example release of nutrients or organic waste by fish farms may increase the productivity of adjacent capture or culture fisheries (Furnas, 1999; Cai *et al*., 2011). However, while such externalities can easily be termed beneficial, they cannot simply be ignored since it is clear that the public are not indifferent to these environmental effects (Hasan, 2001; Brown, 2011; Gautier *et al*., 2009; Kithiia and Khroda, 2011). As such the growing concern over the environmental impact of aquaculture has prompted search for governance framework that can guarantee sustainably viable aquaculture industry in which the negative environmental impact is minimised (Kithiia, 1992).

Clearly, in order to avoid the dangerous consequences of serious water pollution, there is need to properly understand the volume of effluents to be discharged by any development projects planned for in a drainage basin (Kithiia and Ongwenyi, 1997)

Such information is rarely known in designing aquaculture projects in Kenya, leaving the water subject to degradation from the assiciated activities. The potential impact of ESP aquaculture project on water resource quality has not been studied in Kenya hence the procedures for regulating and monitoring the environmental impact of fish farming are not well understood. The paucity of site specific data on the effluent quality of fish farms and on their effect on the receiving streams and rivers is a major challenge on the establishment of regulatory framework. Therefore this study sort to assess the potential impact of the increased aquaculture investments through the ESP aquaculture program on the water quality of receiving waters in the rivers.

1.3. Problem statement

Kenya's ESP aquaculture project has been under implementation since 2009 with remarkable achievements including: improved access to inputs and enhanced capacity building of farmers through training on post harvest handling and group marketing. Even though the project has been in operation for four years with reported achievements and challenges, its impact on the income and environment remains unknown. The potential impact of fish farm effluents on water resources is not well studied in Kenya. Therefore the procedures for controlling, regulating and monitoring the environmental impact of fish farms are not well established. The lack of site specific data on the effluent quality of the farms and on their impact on the receiving streams and rivers is a major challenge on establishment of such regulatory measures and adaptation of appropriate waste management systems. This study investigated the economic and water quality impact of the ESP aquaculture project with a view of providing reliable empirical evaluations that will provide evidence on the impacts of the ESP to the farmer and the environment.

1.4 Justification and significance of the study

Aquaculture is a major contributor to Kenya's economy and has gained importance as a source of essential animal protein supplementing the wild fisheries stocks which have declined drastically. This sub sector contributed nearly 0.7% of the total annual fish supply from 1980 to 1998 in the country (Neira *et al*., 2009). After the government's intervention through the ESP between the year 2009 and 2012, the area under aquaculture has increased from 722 hectares to over 20,000 hectares and national aquaculture production rose from 4,220 metric tons to 12,154 metric tons which is about 7% of the national fish production. It was projected the production will increase to over 20,000 metric tonnes in the short term and over 100,000 metric tons in the medium and long terms. Therefore aquaculture will later contribute significantly to food security, rural development, employment and foreign exchange in Kenya. This study assessed the impact of the government's initiative to eradicate poverty and hunger through income generation among small scale fish farmers under ESP fish farming project. The results of this study are useful in evaluating the sustainability of ESP fish farming project. The water quality impacts of aquaculture, which is associated with discharge of effluents from culture units was also determined. Pollution of water resources by pond effluents is mainly the most complaint, and this concern has attracted the greatest amount of official attention in many countries. The characterization of fish farm effluents and the quantification of the impacts they have on the water quality has provided the much needed information and data for decision makers to formulate the necessary policies for safeguarding the environment.

1.5 Objectives of the study

1.5.1. Main objective

To determine water quality and economic impact of aquaculture development in Gatundu South Constituency, central Kenya.

1.5.2. Specific objectives

1. To determine the changes in water quality of water in fish ponds in Gatundu South Constituency.
2. To assess impacts of fish pond effluent discharge into natural streams in Gatundu South constituency
3. To establish the socio-economic benefits of ESP fish farming project in Gatundu South Constituency.

1.6. Hypotheses

1. Water quality parameters in the fish ponds remain the same.
2. Fish pond effluents have not changed the water quality parameters in the rivers.
3. There is no effect of ESP fish farming programme on the socio-economic status of fish farmers in Gatundu South Constituency

CHAPTER TWO

2.0 MATERIALS AND METHODS

2.1 Study area and sampling points

The study was conducted in Gatundu South constituency (Figure 2.1) in Kiambu County located in Central Kenya. It is located west of Thika about 29 Kilometres road distance through Mang'u and North of Kiambu about 44 Kilometres, road distance through Ruiru. Gatundu South Constituency has a surface area of 192 km^2 and lies at an average altitude of 1759 m above sea level. Temperatures range from a minimum of 12.8 °C to a maximum of 25.4 °C with an average of 18.7°C. The mean rainfall is just over 1000 mm annually. Long rains fall between the months of March to May while December to February are dry months, September to October are periods of short rains (https//en-wikipedia.org/wiki/Gatundu#location, the post updated on 31th May 2015 at02.51)

The population of Gatundu South Constituency is about 114,180 people. The main human activity within the study area is agriculture and includes crop farming and dairying in areas of rich volcanic soils (*Pers. Comm.*, Local communities). The main agricultural production in the area include: maize, horticulture, pineapples, coffee, tea, wheat, macadamia nuts, vegetables and assortment of fruits while poultry, cattle, pigs and fish are the main livestock in the area. Agricultural activities provide incomes for many households with other residents of the constituency working in other sectors such as processing and manufacturing sectors in both the county and the neighbouring Nairobi city. The main water sources are; rivers, streams, boreholes, tap water and rain harvested water (sasanews.com/Kiambu-county, posted by Sasanews on February 24th, 2012)

Three sites which are Ngenda, Kiamuu and Thaara locations were selected for this study for both the water quality assessment and economic surveys. The sampling points for each river were coded as (K1, K2, and K3) for river Kiamuu, (T1, T2, T3) for river Thaara and (N1, N2, N3) for river Ngenda. The study locations were based along the profiles of three rivers which had a concentration of 10 fish ponds for non-ESP and ESP fish farmers that were considered the independent variable for the current study. The three rivers were selected because they met the minimum selection criteria which was being the source of water for at least 10 ESP and 10 Non ESP fish ponds. A long each river the sampling points were identified at: Upstream (Point A), in the fish ponds (Point B), at the immediate pond effluent discharge area (Point C) and downstream after the ponds (Point D). Three replicate samples were taken at each point along the rivers while pond water samples were taken in 3 ESP and 3 non ESP Fish ponds.

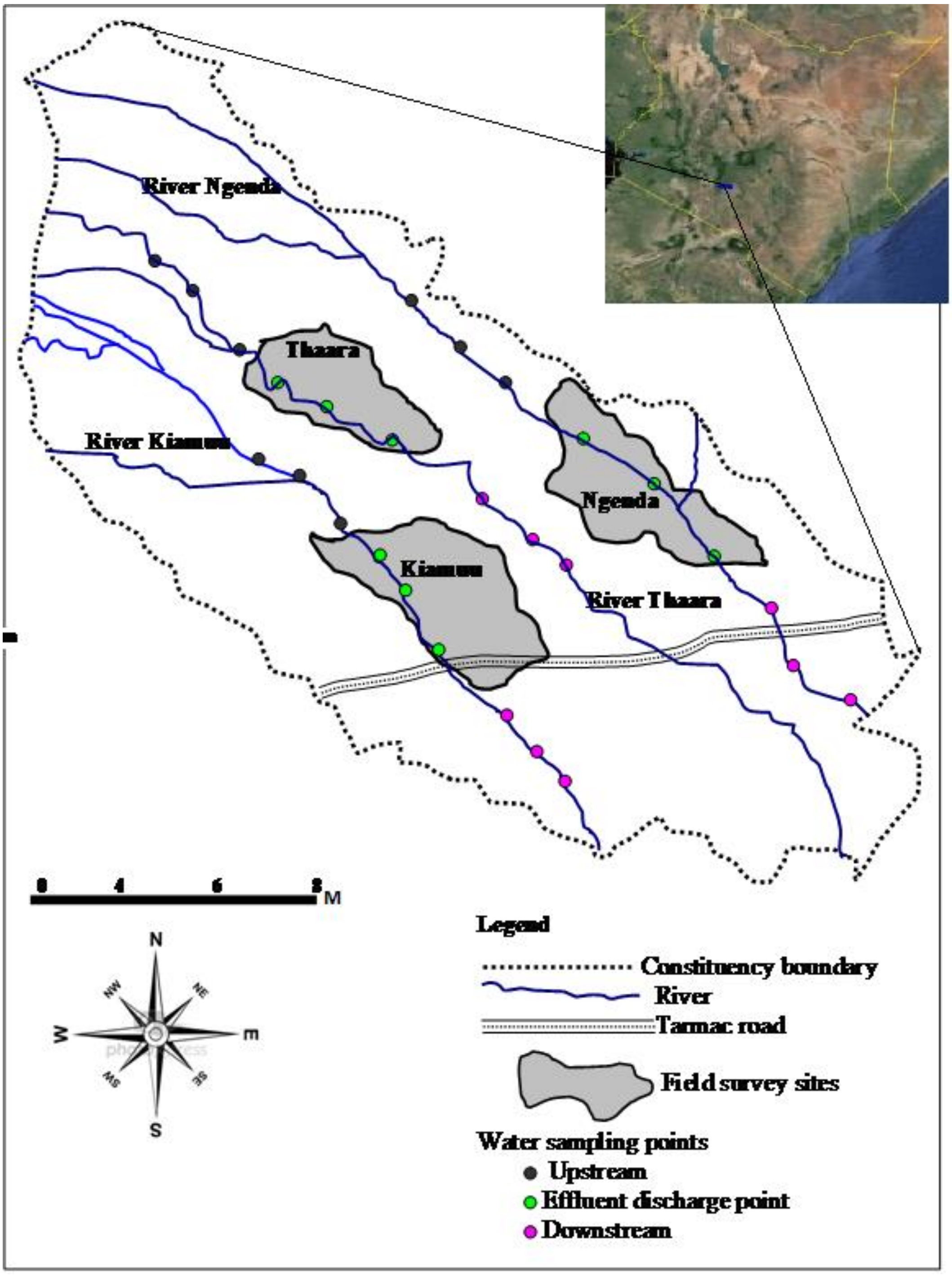

Figure 2.1: Map of Gatundu South Constituency showing position of rivers Kiamuu, Thaara and Ngenda and the sampling points

2.2. Collection and processing of water samples

Sampling of water was done during the month of January and February 2014. This period was the best because it is a dry season so there was no influence on water quality parameters from surface runoff which occurs during rainy seasons. The choice of the dry season justifies that the changes in water quality in the rivers and ponds was due to discharge of pond effluents back to the receiving rivers and fish farming practices carried out in the pond during the fish rearing period respectively but not other external factors. Water samples were drawn using plastic bottles in triplicate at the 12 sampling points along the three rivers (as shown in Figure 2.1). Three aliquots of 500 ml each were collected at each point by hand dipping the bottles beneath the water surface to fill them. 1ml/l of Sulphuric acid was used as a preservative during the transportation of the water samples. The filled bottles were capped immediately, packed in a 4 C̊ iced cooler box and transported to Chiromo campus Hydrobiology laboratory for further chemical analyses of nitrate-nitrogen (NO_3-N) and Orthophosphates (PO_4-P).

2.3. Water quality analyses

In situ measurements of dissolved oxygen (DO), pH, water temperature and salinity were recorded at each of the sampling locations at a depth of 20 cm using JENWAY 3405 electrochemical analyzer with probes for each of these variables. The choice for salinity was because some fish farmers were found to be using common salt as a traditional method of pest control so it was considered a more relevant parameter in order to assess if there was any change in water quality after it had been used. A minimum of three readings were recorded after the probe had stabilized at each location. Measurements were taken at a sensitivity of 0.01 for all parameters. D.O concentrations were measured in mg/l.

Nitrate nitrogen (NO_3-N) was determined using cadmium reduction methods as detailed in APHA (2001). The procedure involved preparation of a Standard nitrate solution were a stock solution was prepared by dissolving 7.22g of anhydrous KNO_3 in distilled water and the solution made up to 1 litre in a volumetric flask. 1 ml of the solution contained 1mg of NO_3-N. Absorbance of the standard solution which had a known concentration was determined using a spectrophotometer at 543 nm in a 1 cm cell. The water sample collected after passing the initial water sample through a column packed with cadmium was mixed with the reagents and its absorbance determined. A calibration graph for the standard solution concentration and its absorbance was prepared this graph was then used to determine the concentration of nitrate in the sample using the predetermined absorbance.

Orthophosphates was analyzed by standard ascorbic acid method after filtration of the sample through 45-μm pore membrane filter papers. The procedure involved preparation of a standard phosphate solution by dissolving 4.390g of potassium dihydrogen phosphate (KH_2PO_4) in distilled water and making up the solution to 1 litre such that 1ml contains 1 micro gram of Phosphate. The absorbance of the working solution was determined using a spectrophotometer at 680 nm at 4cm cell. A calibration graph was prepared using dilutions of the standard solution to determine the mean factor relating absorbance to concentration for concentration range of interest. The water samples were subjected to the reagents and their absorbance determined which was used to trace the concentration of orthophosphate in each replicate at the calibration graph.

2.4. Collection of socio-economic data

To obtain socio-economic data, an exploratory research design that examines the situation as it is from a section of the respondents through a survey technique was used. Such designs are efficient methods of collecting descriptive data regarding the characteristics of populations, current practices and conditions or needs (Kothari, 2005). The population for the current study were 1745 fish farmers, among which 617 obtained ESP support while the rest did not. The sample size selected in the current study was determined based on the formula by Mugenda and Mugenda (1999).

$$Nf = \frac{n}{(1+n)/N}$$

Where: Nf = The desired sample size when the population is less than 10,000

n = the desired sample size when the population is more than 10,000

N = the estimate of the population size.

A total of 162 fish farmers were selected for this study with up to 60% (n = 97) were among farmers who received ESP and the remaining 40% (n = 65) were not provided with any ESP support. The list of the ESP and non ESP farmers was obtained through snowballing techniques within the study area. The sample was stratified along the river profiles to get a representative sample. The tool for data collection was a structured questionnaire validated through a pilot study and tested through Spearman and Brown prophecy formula for reliability (Soujanya and Amarnath, 2013) The questionnaire targeted information on farm size and farming, household income and occupation and lastly household characteristics. Workshops were organized to train the fish farmers on how to approach the questions and how to respond to them. Later the questionnaires were administered to the fish farmers after each farmer was satisfied and confident to answer the questions. Out of the total of 162 fish farmers who were recruited in the current study, 142 completed and returned the questionnaires. Further; 136 questionnaires were used in the current analysis indicating a response rate of 84%. Forty six respondents in Ngenda, forty seven fish farmers in Kiamuu and forty three respondents in Thaara returned the questionnaires.

2.5. Data Analysis

All statistical analyses were performed with STATISTICA version 6.0 and SPSS version 17.0 statistical packages. In cases where data distribution deviated from normal distribution (heteroscedastic), Log (x + 1) data transformation was used to normalize all the data (Michael and Douglas, 2004). Data on physico-chemical parameters were calculated as means (± SEM) for each site on each sampling occasion. Mean differences in the physico-chemical parameters among sites were analyzed using a one-way ANOVA. Duncan's Multiples Range Test (DMRT) was used for Post-hoc discrimination between the means that were actually different from each other. The test was reliable because it uses student zed range of statistics to compare a set of means and also it protects against type 1 and 2 Error. The interaction between location and ESP support on the water quality was analyzed using Two-Way ANOVA.

Socio-economic data were summarized as frequencies and percentages. The significant differences among socio-economic attributes were analyzed using Chi-square (χ^2) test. An enterprise budget was used to determine the revenue, costs and returns of the ponds system with ESP and without ESP support. The short term profitability of the enterprise was analyzed using the net returns above variable costs while the sustainability of the projects was analyzed using net returns above total costs. All statistical analyses were done at 95% level of confidence.

CHAPTER THREE

3.0 RESULTS

3.1 Changes in River water Quality due to Fish pond Effluent Discharge.

Water quality parameters in rivers of Gatundu South Constituency in areas discharged by the ponds (EDP) were determined and compared to the water quality in the upstream and downstream points of the rivers.

Variation in the dissolved oxygen (DO) concentration (mean ± SEM) is provided in **Figure 3.1.** There were significant differences in the DO concentration upstream among the rivers in Gatundu during the study period (One-Way ANOVA; F = 5.715, df = 2, 6, $P = 0.041$). The highest concentration of DO was recorded in the water of river Kiamuu (7.76 ± 0.77 mg/l) followed by water in river Thaara (7.34 ± 0.71 mg/l) while the lowest DO level was recorded in water of river. Ngenda (6.37 ± 0.77 mg/l). DO was significantly lower at the effluent discharge points in the three sampling location ($P < 0.05$). Downstream DO was significantly different with highest levels recorded in water of river Thaara followed by river Ngenda and lowest in water of river Kiamuu ($P < 0.05$)

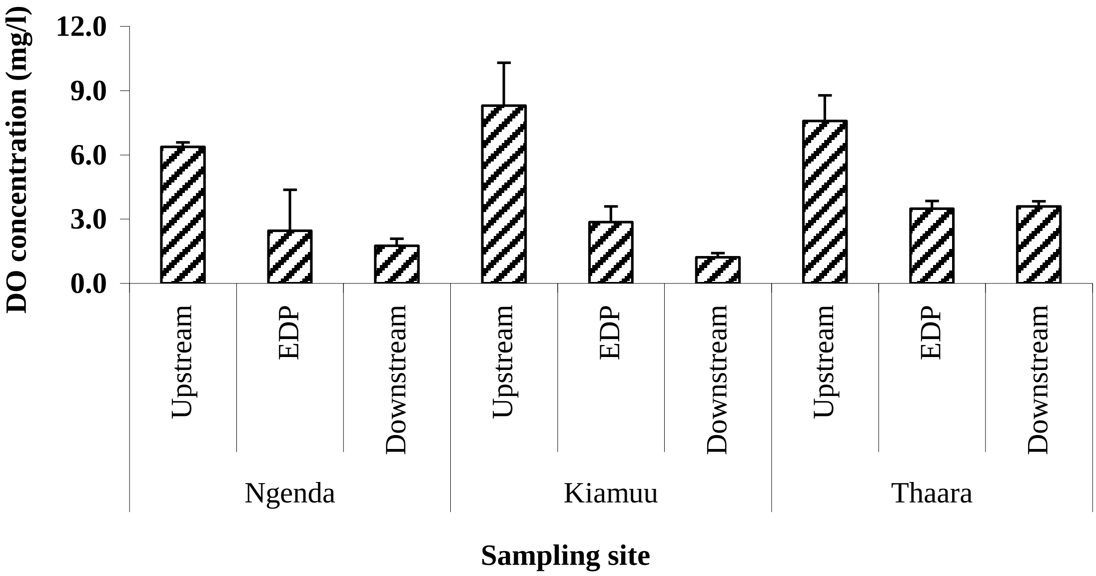

Figure 3.1: Mean (± SE) variation in the dissolved oxygen (DO) concentration at the upstream, Effluent Discharge and downstream points along three rivers studied in Gatundu South Constituency

Changes in the pH values (mean ± SEM) in the main rivers were also determined during the study **Figure 3.2.** There were significant differences in the pH concentration upstream among the rivers during the study period (One-Way ANOVA; F = 29.520, df = 2, 6, P <0.001). The highest pH value was recorded in River. Thaara (7.63 ± 0.13) that was similar to pH value of River. Ngenda (7.61 ± 0.25) while the lowest pH value occurred in River. Kiamuu (6.68 ± 0.14). pH value was consistently lower at the effluent discharge point in River Kiamuu compared to the other sampling points. There was no significant difference in pH value at downstream of the rivers in the three sampling locations

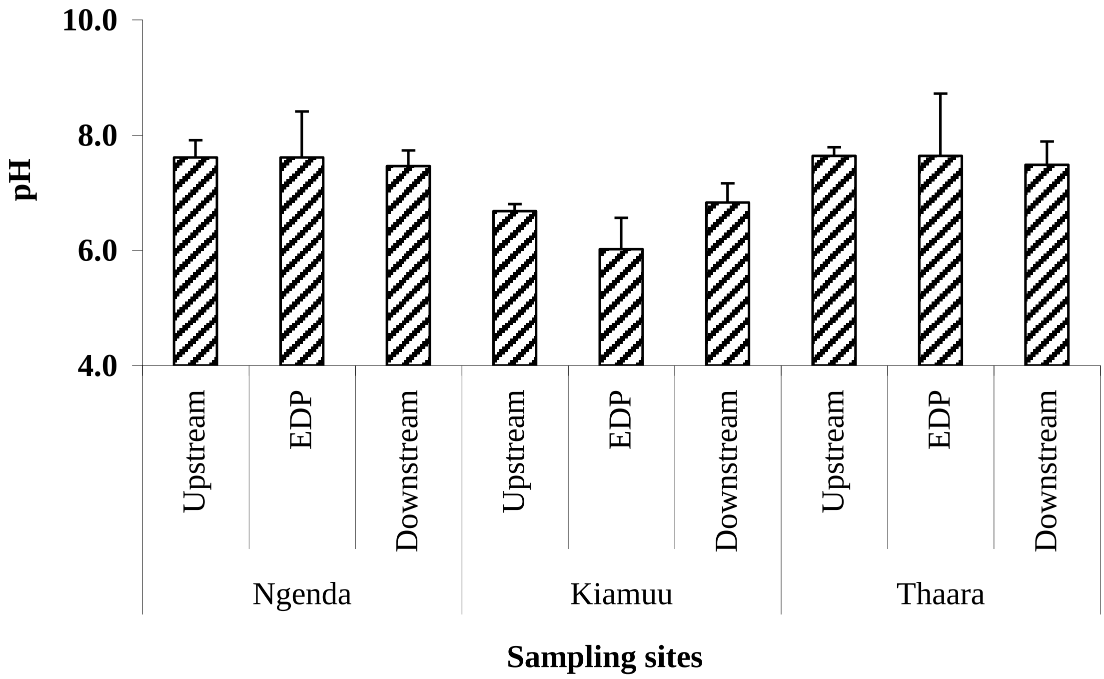

Figure 3.2: Mean (± SE) variation of pH at upstream, Effluent Discharge and downstream points along three rivers studied in Gatundu South Constituency

Values of water temperature in the main rivers are shown in **Figure 3.3**. Water temperature displayed marked variation during the study (One-Way ANOVA; $F = 163.418$, $df = 2, 6$, $P = 0.000$). The highest water temperature upstream occurred in River Kiamuu (23.09 ± 1.76°C) followed by water temperature in River. Thaara (20.52 ± 1.12°C) while the lowest water temperature occurred in River Ngenda (19.54 ± 0.31°C). At the effluent discharge point, the highest temperature occurred in river Kiamuu (23.09 ± 1.77) followed by River Thaaara (20.53 ± 1.13) and the lowest water temperature was for River Ngenda (19.55 ± 0.09). Water temperature downstream did not vary significantly with highest water temperatures at River Kiamuu followed by River Thaara and lowest at River Ngenda ($P>0.05$)

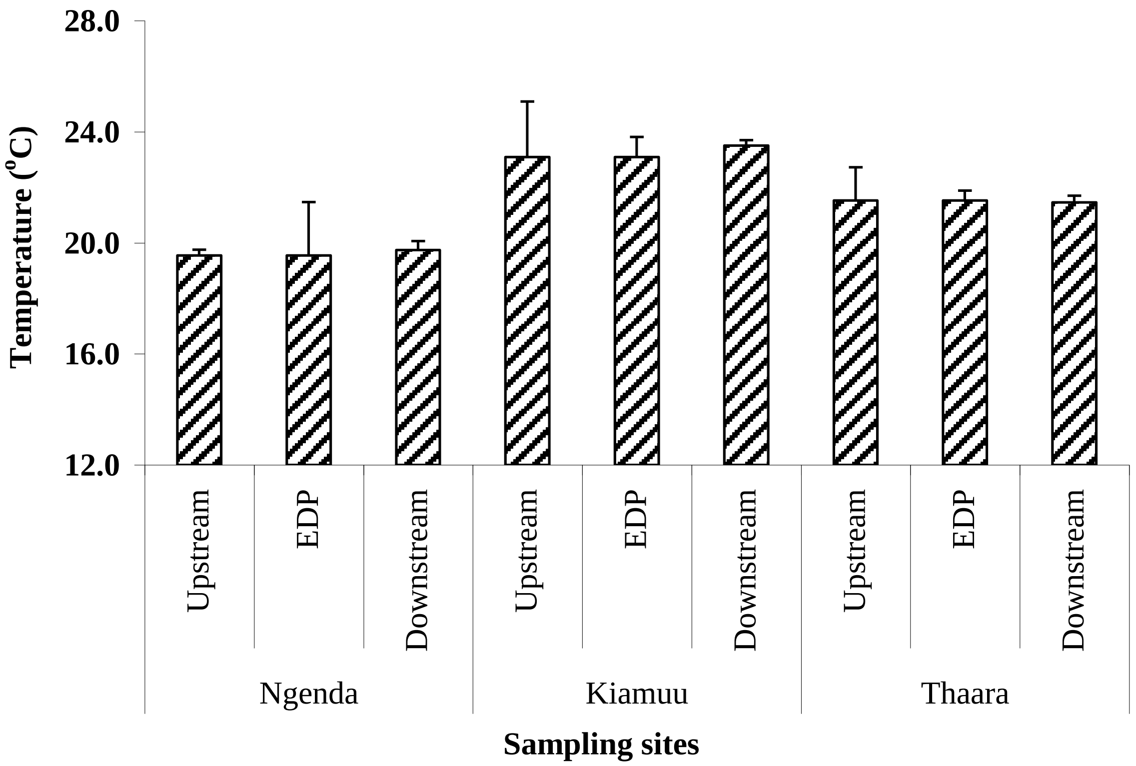

Figure 3.3: Mean (±SE) variation in the water temperature at the upstream, effluent discharge and downstream points along three rivers in Gatundu South Constituency.

Concentration of salinity (mean ± SEM) in the main rivers is presented in **Figure 3.4**. Salinity ranged from 4 to 23 ppm. There were significant differences in the concentration of salinity in the rivers in Gatundu during the study period (One-Way ANOVA; $F = 157.001$, $df = 2, 6$, $P = 0.000$). At the upstream points, the highest salinity values were measured in River Kiamuu (16.94 ± 1.84 ppm) followed by River Ngenda (11.34 ± 2.43 ppm) but was lowest in River Thaara (8.94 ± 0.67 ppm). At the effluent discharge points salinity was significantly lower ($P < 0.05$) while Salinity levels did not differ significantly at downstream sampling points in all the three rivers ($P > 0.05$)

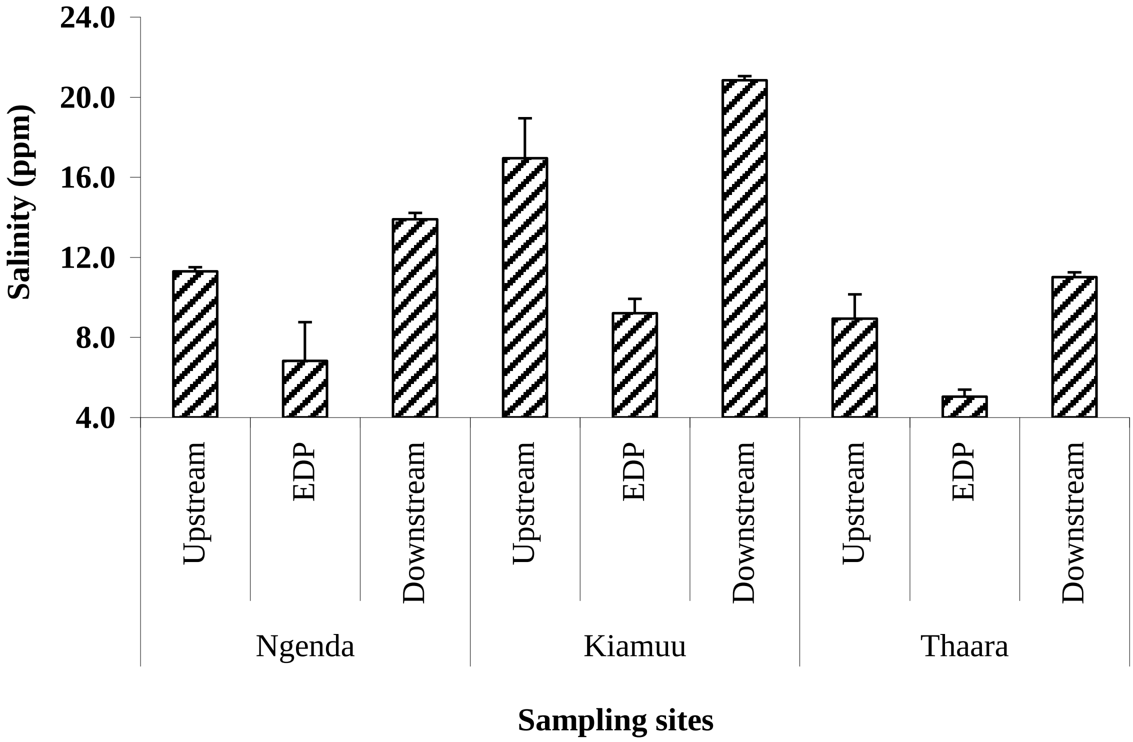

Figure 3.4: Mean variation in salinity levels (±SE) at the upstream, effluent discharge and downstream points along three rivers studied in Gatundu South Constituency

The concentration of NO_3-N (mean ± SEM) in the main rivers is presented in Figure 3.5. There were no significant differences in the concentration of NO_3-N among the analyzed rivers upstream (One-Way ANOVA; F = 0.624, df = 2,6, P = 0.567). The overall concentration of the NO_3-N ranged from 0.66 to 0.70 mg/l. However, NO_3-N concentration were significantly higher at the effluent discharge points compared to the upstream and downstream site in the three sampling points (P < 0.05).

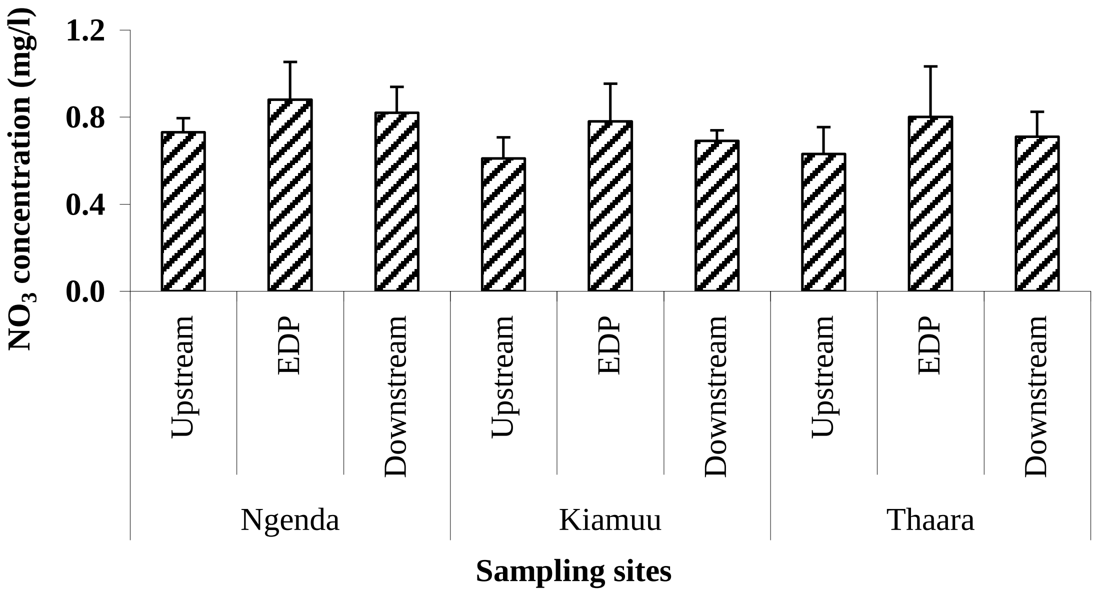

Figure 3.5: Mean (± SE) Nitrate (NO_3-N) concentration at the upstream, effluent discharge point and downstream along three studied rivers in Gatundu South Constituency

Variation in orthophosphate (PO_4-P) (mean ± SEM) in the main rivers is presented in **Figure 3.6**. The concentration of PO_4-P upstream differed significantly among the analyzed rivers in Gatundu South Constituency during the study (One-Way ANOVA; F = 4.786, df = 2,6 P = 0.014). The highest concentration of PO_4-P was recorded in water of River Thaara (0.53 ± 0.05 mg/l) which was significantly similar (P > 0.05) to PO_4-P levels of River Ngenda (0.51 ± 0.04 mg/l) with the least being PO_4-P of River Kiamuu (0.39 ± 0.08 mg/l). Discharge of effluents resulted in significantly lower PO4-P at the effluent discharge points (P < 0.05).

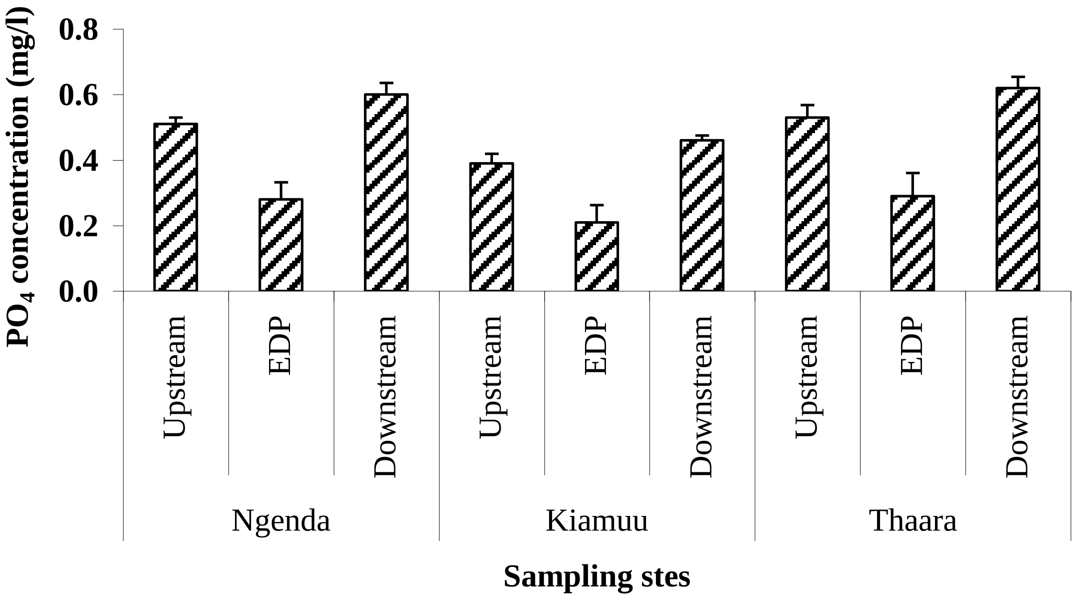

Figure 3.6: Mean (± SE) variation in Orthophosphate (PO_4-P) concentration at upstream, effluent discharge and downstream points along three rivers studied in Gatundu South Constituency

3.2. Influence of Fish rearing on water quality parameters in the Fish ponds in Gatundu South Constituency

Figure 3.7 provides a summary of DO levels in ponds at three sampling sites in Gatundu South Constituency among farmers receiving ESP against those who did not receive ESP support. There was a significant interaction between the location of the sampling sites and ESP support programme on the DO concentration of the water in the fish ponds (Two-Way ANOVA; F = 12.446, df = 4, P = 0.006). Simple main effects analysis on location showed that DO was highest in ponds at Thaara and similar in Ngenda and Kiamuu. Also main effects of ESP indicated that in ponds whose owners received ESP support had lower DO levels than ponds whose owners did not receive any ESP support.

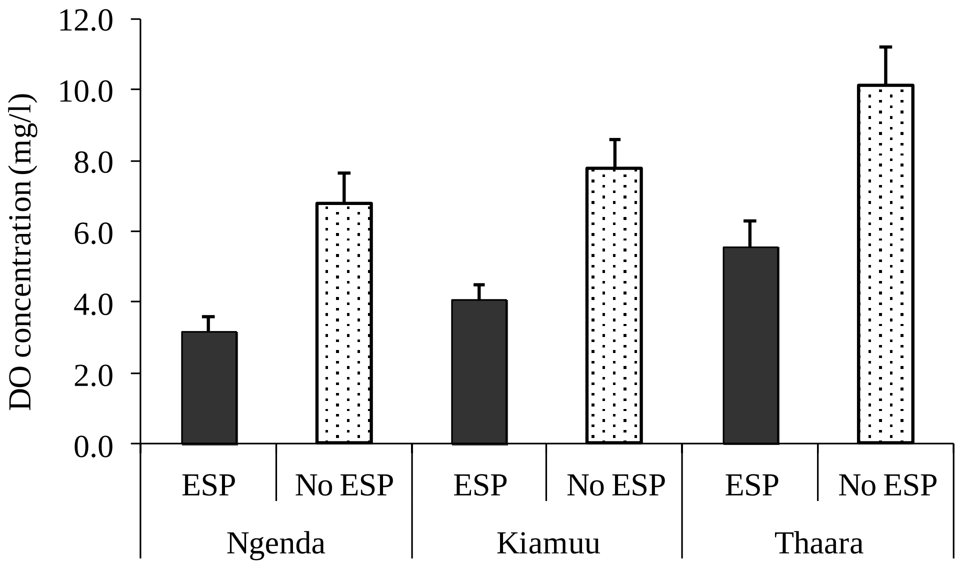

Figure 3.7: DO concentration in Fish ponds among farmers with ESP compared to those without ESP support

Variation in water pH levels in ponds at three sampling sites in Gatundu South Constituency among farmers receiving ESP against those who did not receive ESP support is shown in **Figure 3.8**. There was no significant interaction between the location of the sampling sites and ESP programmes on pH levels of water in the ponds (Two-Way ANOVA; F = 2.446, df = 4, P = 0.401). Main effects analysis on location indicated that ponds located in Thaara had the highest water pH followed by those in Ngenda while ponds near Kiamuu had the lowest pH. However, pH in ponds among farmers without ESP did not vary significantly with pH of ponds whose owners received ESP support.

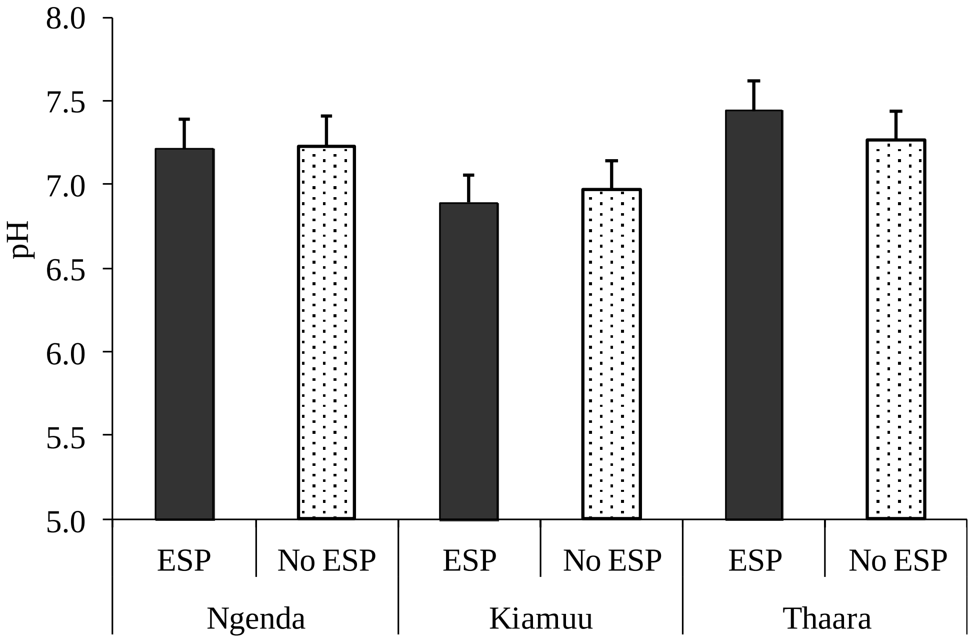

Figure 3.8: pH values in Fish ponds among farmers receiving ESP support compared to those without ESP support

Figure 3.9 provides a summary of temperature in Fish ponds at the three sampling sites among farmers receiving ESP support against ponds belonging to farmers who did not receive ESP support. There was no significant interaction between the location of the sampling sites and ESP programme on Fish pond water temperatures (Two-Way ANOVA; $F = 2.113$, $df = 4$, $P = 0.126$). Analysis of location showed that temperature was highest in ponds at Kiamuu, followed by temperature of ponds in Thaara and lowest in Ngenda regardless of the ESP status of the farmers.

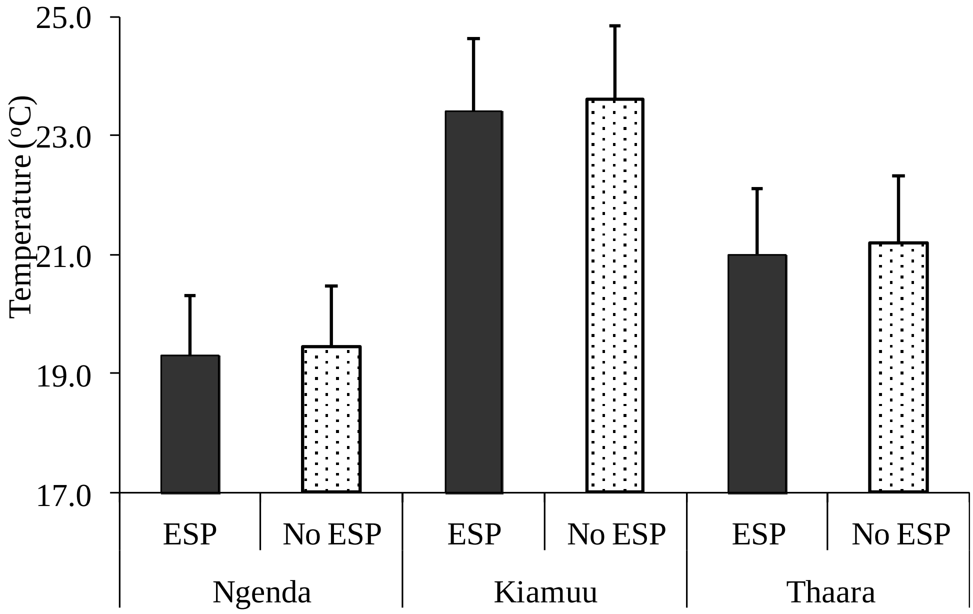

Figure 3.9: Temperature readings in Fish ponds among farmers receiving ESP support compared to those without ESP support

Figure 3.10 provides a summary of salinity levels in Fish ponds at three sampling sites in Gatundu South Constituency among farmers receiving ESP support against those who did not receive ESP support. Generally, salinity levels were significantly ($P < 0.05$) high in ponds whose owners did not receive ESP support. There was also significant interaction between the location of the sampling sites and ESP programme on salinity of the ponds water (Two-Way ANOVA; $F = 12.446$, $df = 4$, $P = 0.006$). For farmers without ESP support, salinity was highest in ponds located in Kiamuu compared to ponds in Ngenda and Thaara. However among farmers receiving ESP support, the highest salinity occurred in ponds located at Thaara followed by salinity in ponds at Kiamuu while salinity was lowest in ponds at Ngenda.

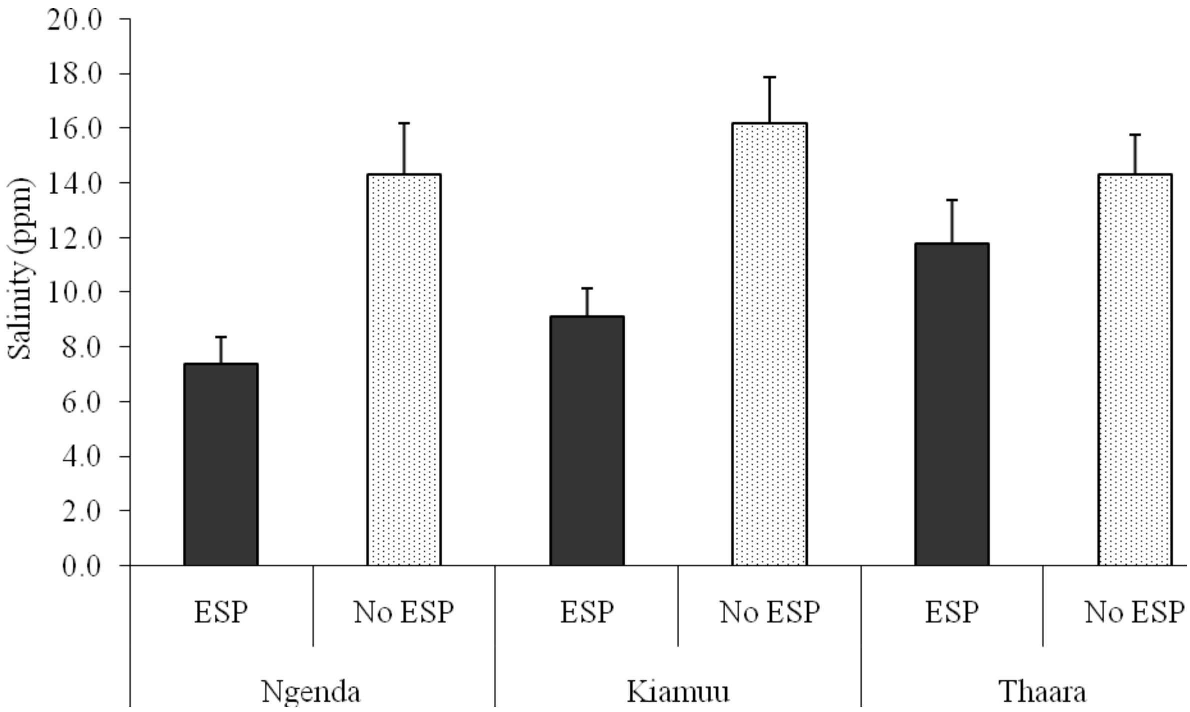

Figure 3.10: Salinity values in Fish ponds among farmers receiving ESP support compared to those without ESP support

Figure 3.11 provides a summary of NO_3-N levels in ponds at three sampling sites in Gatundu South Constituency among farmers receiving ESP support against those who did not receive ESP support. There was no significant interaction between the location of the sampling sites and ESP support programme among the farmers on NO_3-N concentration of the waters in the ponds (Two-Way ANOVA; $F = 2.025$, $df = 4$, $P = 0.456$). Ponds of farmers who received ESP support had higher mean NO_3-N concentration than those ponds whose owners did not receive any ESP support. However, changes in NO_3-N were not in tandem in ponds whose farmers received ESP support compared to the farmers whose owners did not receive ESP support. For farmers who received ESP support the NO_3-N was high in Ngenda, followed by Kiamuu and lowest in Thaara. On the other hand, farmers who did not receive any ESP support had highest NO_3-N in Kiamuu followed by Thaara and least in Ngenda.

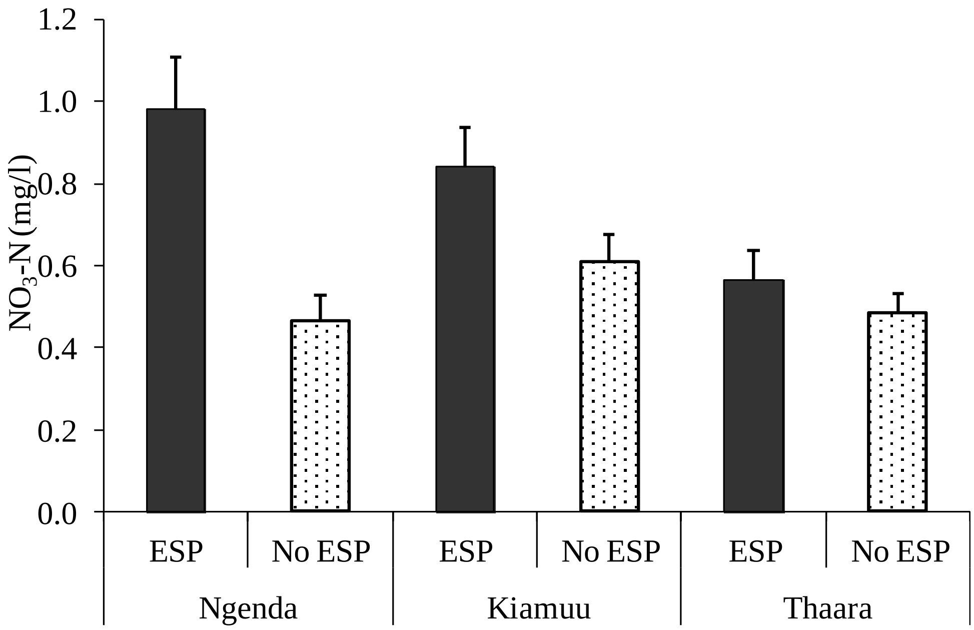

Figure 3.11: NO_3-N concentration in Fish ponds among farmers with ESP compared to those without ESP support

Figure 3.12 depicts a summary of PO_4-P levels in Fish ponds at three sampling sites among farmers receiving ESP against those who did not receive ESP support. Generally, ponds whose owners received ESP support had higher PO_4-P levels compared to ponds of farmers who did not receive any ESP support. There was no significant interaction between the location of the sampling sites and ESP among the farmers on PO_4-P levels (Two-Way ANOVA; $F = 2.411$, $df = 4$, $P = 0.092$). Regardless of the ESP support status, highest PO_4-P levels occurred in Ngenda followed by Kiamuu and lowest in Thaara.

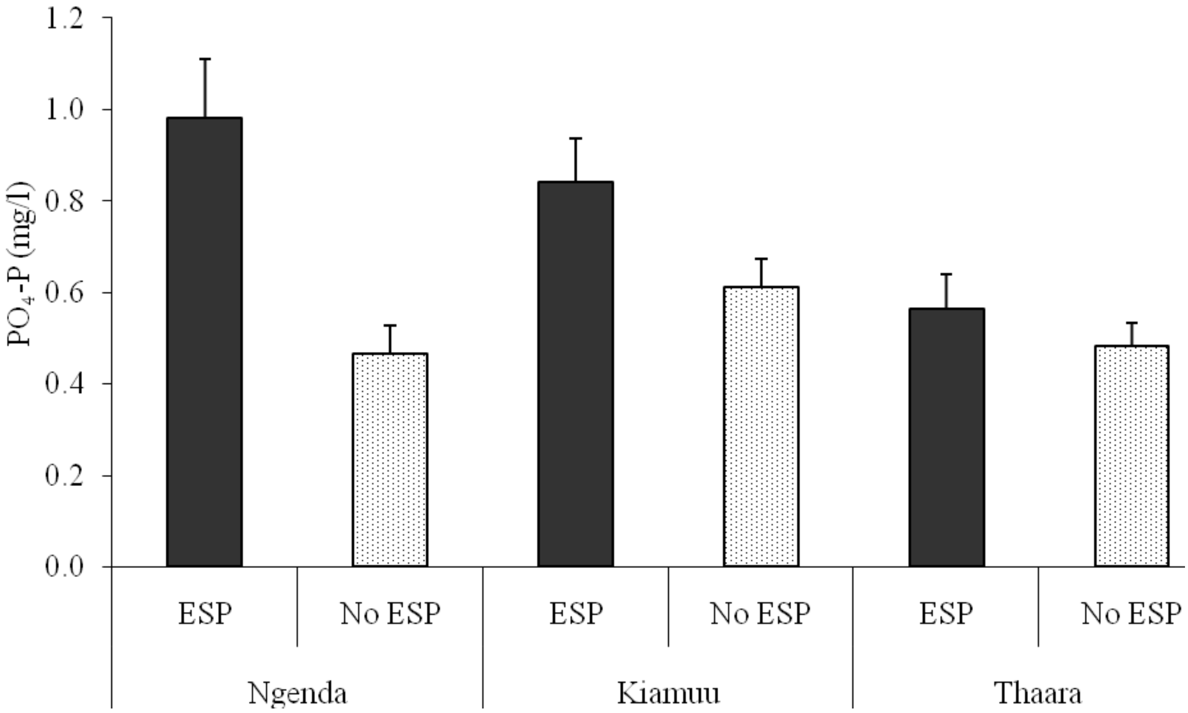

Figure 3.12: PO_4-P values in Fish ponds among farmers receiving ESP support compared to those without ESP support

3.3 Social and economic impacts of ESP project on fish farmers in Gatundu South Constituency

3.3.1 Characteristics and occupation of households

The socio-demographic variables of the respondents who participated in this study are shown in **Table 3.1**. Male farmers were significantly higher than female farmers at all the sampling locations (Chi-square; $P < 0.05$). Most of the respondents were aged above 50 years which was significantly higher than that of the other age groups in all the sampling points (Chi-Square; $P < 0.05$). A significant number of farmers in the three sampling points had primary level of education, followed in proportion by farmers having secondary level of education (Chi-square; $P < 0.05$). Monogamous family set ups characterised the families in the study area with a fairly significant number of single parents. The average household size ranged between 4 and 6 individuals. In terms of occupation, most of the fish farmers interviewed were fulltime farmers followed by teachers and students.

Table 3.1: The values of socio-demographic variables in the three locations sampled in Gatundu South Constituency.

Variable	Attributes	Ngenda (n =46)	Kiamuu (n = 47)	Thaara (n = 43)
Gender	Male	76.8	55.8	71.7
	Female	23.2	44.2	28.3
	Total	100	100	100
Age	18-35 yrs	24.5	22.6	19.3
	36-50 yrs	32.1	27.3	26.5
	>50	43.4	50.1	54.2
	Total	100	100	100
Levels of education	Primary	41.4	40.1	45.5
	Secondary	24.8	28.3	23.4
	College/University	22.1	9.5	8.2
	None	11.7	22.1	22.9
	Total	100	100	100
Family background	Monogamous	48.2	50.1	53.1
	Polygamous	21.1	27.4	23.4
	Single parents	30.7	22.5	23.5
		100	100	100
Mean household size		4.1	5.1	5.3
Occupation	Teacher	20.2	33.1	26.4
	Doctor/Nurse	2.3	0	4.8
	Administrator	12.3	22.9	18.7
	Students	20.2	14.2	14.2
	Farmers	40.1	20.1	21.8
	Business	4.1	5.8	8.7
	Plant operator	0.8	3.9	5.4
	Total	100	100	100

3.3.2. Farm size and farming

Land ownership, information on the land tenure and land allocated for fish farming among farmers receiving ESP against those without ESP support is provided in **Table 3.2.** Regardless of the ESP status, average land sizes ranged from 2.5 to 4.8 acres. This was significantly higher in Ngenda location and lowest in Kiamuu location. (One-Way ANOVA; F = 31.221, df = 2, P = 0.000.1). Most of this land (80-90%) was owned by the respondent with between 10-15% of the land being owned as family lands. Generally, farmers who received ESP dedicated a larger portion of their land to aquaculture than farmers who did not receive any form of support (One-Way ANOVA; F = 6.773, df = 2, P = 0.0002). It was further determined that farmers who received ESP support in Ngenda dedicated the highest proportion of the land to aquaculture which was significantly (χ^2 = 30.543, df = 2, P = 0.0009) higher than that of farmers in other locations.

Table 3.2: Land size/ownership and tenure among farmers in the study area and their ESP status

	Area	Size of farm (acres)	Personal ownership	Family land	Land leased	% of land for aquaculture
ESP support	Ngenda	4.4 ± 0.7	3.8 ± 0.8	0.4 ± 0.07	0.2 ± 0.08	58.1 ± 7.4
	Kiamuu	3.5 ± 0.2	2.2 ± 0.2	0.3 ± 0.04	1.0 ± 0.12	33. 2 ± 3.3
	Thaara	3.2 ± 0.3	2.4 ± 0.3	0.7 ± 0.09	0.1 ± 0.04	31.2 ± 3.4
No ESP support	Ngenda	4.5 ± 0.7	3.8 ± 0.8	0.4 ± 0.07	0.2 ± 0.08	18.1 ± 2.4
	Kiamuu	2.5 ± 0.2	2.2 ± 0.2	0.3 ± 0.04	1.0 ± 0.12	19.2 ± 3.3
	Thaara	3.2 ± 0.3	2.4 ± 0.3	0.7 ± 0.09	0.1 ± 0.04	13.2 ± 3.4

3.3.3 Sources of capital and initiation of aquaculture

The sources of capital for business start-ups and operations among farmers in the study area are shown in Figure 3.14. Based on the figure, most of the farmers obtained their finances from ESP grants followed by microfinance loans and family savings. Also some funds were obtained from cooperative societies though a few farmers obtained loans through that pathway.

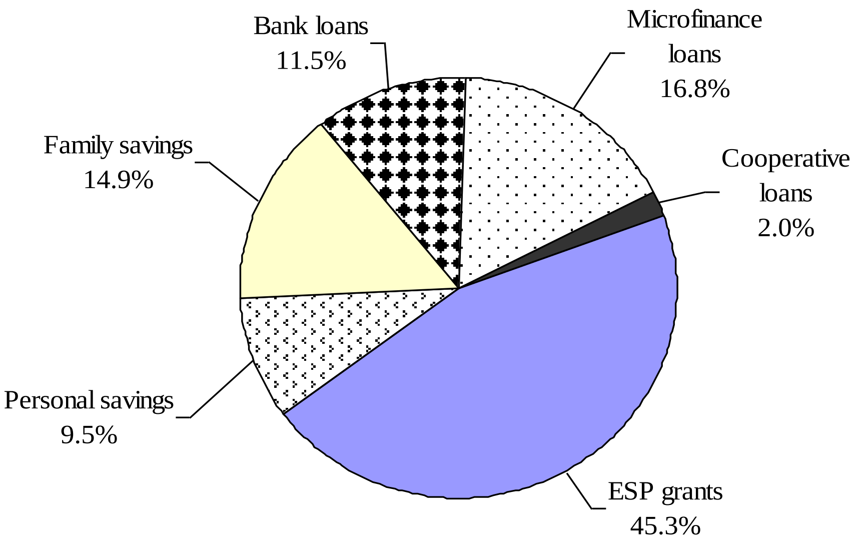

Figure 3.13: Sources of capital for aquaculture business for the farmers in Gatundu South Constituency.

Information on the year when fish farming started at the study area is provided in Table 3.3. This activity started in 2003 but higher numbers of fish ponds were constructed between 2009 and 2011 regardless of the farmers' location in the study area.

Table 3.3: Year fish farming started at the study area

		2003	2005	2006	2007	2008	2009	2010	2011	2012	Total
Area	Ngenda	1	0	2	0	0	8	10	26	9	56
	Kiamuu	0	1	0	2	5	4	20	19	0	51
	Thaara	4	0	0	1	1	13	10	27	4	60
Total		5	1	2	3	6	25	40	72	13	167

The study also determined the source of information to start fish farming among farmers in the study locations (Table 3.4). Based on the responses, most of the farmers were informed by the ESP programme to start fish farming activities. Others were also encouraged by other farmers while low proportions of the farmers were informed by NGOs and other development agencies to venture into the business of farming fish.

Table 3.4: Source of information on fish farming among farmers in the study locations in percentages

	Ngenda	Kiamuu	Thaara
Other farmers	21.4	26.9	6.7
ESP	73.2	48.1	80.1
NGO	1.8	3.9	0
Development agency	1.8	11.5	8.3

Types and number of Fish ponds owned by the farmers was also determined during the study (Table 3.5). Regardless of the sampling locations, most farmers had between 1 to 2 liner ponds in their farm. It was also determined that the number of farmers with one liner pond was high while concrete ponds were owned by very few farmers.

Table 3.5: Types and number of Fish ponds owned by the farmers in the sampling locations of Gatundu South Constituency

		Location					
	Number of ponds	Ngenda		Kiamuu		Thaara	
		ESP farmers	Non ESP	ESP farmers	Non ESP	ESP farmers	Non ESP
Earthen ponds	1	25	8	18	6	17	14
	2	2	6	1	5	1	3
	3	0	1	0	0	0	0
	4	0	1	0	1	1	3
Concrete	1	0	1	0	0	0	0
	2	0	1	0	0	0	0
Liner	1	10	11	12	9	14	10
	2	3	1	3	1	0	0
Total		45	43	38	31	37	42

The sources of water for aquaculture among residents in the sampling locations of Gatundu North Constituency are presented in **Figure 3.15**. Most of the farmers received water from rivers and streams. Wells and rain water were other important sources of water but for very few respondents in study area.

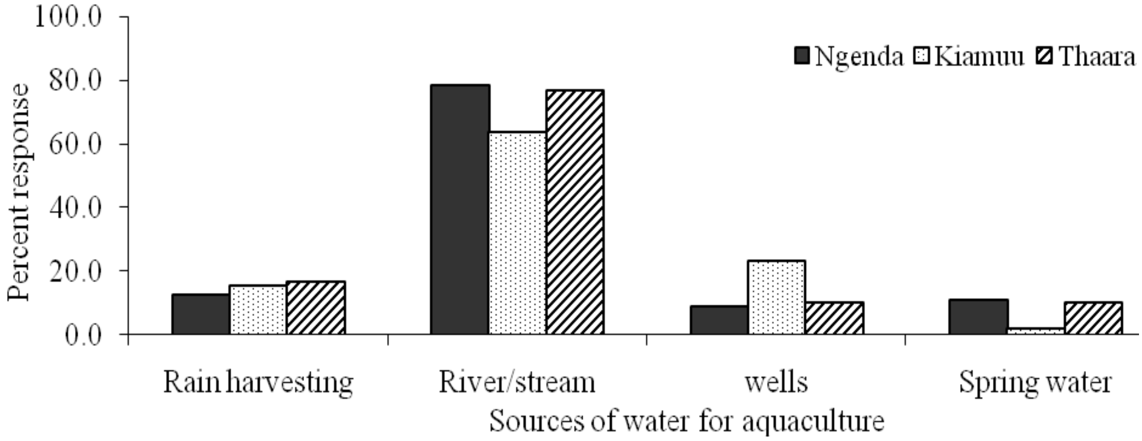

Figure 3.14: Sources of water for aquaculture in the study area

Labour on the farm among the fish farmers during the last production year is shown in **Table 3.6.** Labour among those farmers receiving ESP support concentrated more on the salaried labour with occasionally high number of casual labour but less of family labour. Significantly higher mean wages were also paid to salaried labour by farmers receiving ESP support than other forms of labour ($P < 0.05$).

Table 3.6: Labour cost per person on the farm among the Fish farmers during the last production year

		With ESP		Without ESP	
Sources of labour		Number	Wages (KES)	Number	Wages (KES)
Family labour	Ngenda	1	1400	2	1200
	Kiamuu	2	1500	2	1100
	Thaara	1	1000	1	500
Permanent labour	Ngenda	3	5500	1	1450
	Kiamuu	4	6000	1	1000
	Thaara	3	8000	1	1100
Casual labor	Ngenda	4	1200	2	2500
	Kiamuu	4	2000	2	1450
	Thaara	2	1200	1	600

The production cycles of commonly cultured fish in the study areas by the farmers is shown in **Table 3.7**. Most of the production cycles for tilapia ranged between 9 and 21 months while catfish production cycle ranged between 9 months and 16 months. However, it was established that farmers receiving ESP support had lower mean production cycle for tilapia (≈10 months) and catfish (≈ 11 months) which was significantly different compared to those without ESP support (tilapia = ≈16 months and catfish = ≈15 months).

Table 3.7: Production cycles of common cultured fish species in the study areas

	Area	Duration of the last production cycle for Tilapia (months)	Duration of last production cycle for Catfish(months)
Farmers receiving ESP	Ngenda	9.85 ± 0.32	10.82 ± 0.24
	Kiamuu	10.94 ± 0.29	12.21 ± 1.51
	Thaara	9.29 ± 0.31	11.38 ± 0.46
Farmers without ESP	Ngenda	14.44 ± 0.82	12.82 ± 0.89
	Kiamuu	13.91 ± 1.23	12.21 ± 1.21
	Thaara	13.77 ± 0.31	14.21± 0.96

3.3.3 Household Income

Production volumes and revenues from fish farming among farmers in the study area are provided in **Table 3.8.** There were significant interactions between location and ESP status on production volumes of Tilapia and Catfish as well as on the earnings from both stocks of fish (Two-Way ANOVA; $P < 0.05$). Production of tilapia among farmers who obtained ESP was (790 kg/cycle per fish pond) which was significantly higher than that of farmers without ESP (380 kg/cycle per fish pond) resulting in significantly higher earning for farmers with ESP (KES 225,800) as compared to farmers without ESP (KES 105,800). Similarly production of catfish among farmers who had access to ESP was (230 kg/cycle per fish pond) was significantly higher than those of farmers without access to ESP (100 kg/cycle per fish pond) and the earning reflected this trend by being higher for farmers who had access to ESP (KES 57,700) compared to those farmers without (KES 25,500).

Table 3.8: Production volumes and revenues from fish farming among farmers

	Area	Total annual production for Tilapia(Kg)	Total annual production for Catfish(Kg)	Total revenue from Tilapia (KES)	Total revenue of Catfish (KES)
Farmers receiving ESP	Ngenda	890.2 ± 15.02	313.7 ± 16.36	249,256	78,425
	Kiamuu	697.8 ± 10.79	69.2 ± 3.44	209,340	17,300
	Thaara	781.2 ± 11.53	309.7 ± 18.19	218,736	77,425
Averages		790	230	225,800	57,700
Farmers without ESP	Ngenda	510.2 ± 15.02	103.7 ± 16.36	142,856	25,925
	Kiamuu	293.8 ± 10.79	62.2 ± 3.44	82,264	15,550
	Thaara	341.2 ± 11.53	139.7 ± 18.19	95,536	34,925
Averages		380	100	105,800	25,500

The enterprise budget for fish production by farmers who obtained funds through ESP compared to those who did not get any funding is provided in **Table 3.9**. In terms of revenue, farmers who received ESP obtained more money through sales of fish ranging between KES. 226,640 and 327,681 per pond/production cycle compared to farmers without any ESP support (KES. 97,781 to 130,461), this was significantly different. As a result, farmers who obtained ESP support were able to spend more on the inputs resulting in better production and higher gross margins above the total cost.

Gross margin %= $\frac{\text{Revenue – Cost of goods sold}}{\text{Revenue}}$ (Farris. et al, 2010)

Farmers who received ESP support received double the amount of investments that ranged between 10 to 50% for farmers who did not have any monetary support.

Table 3.9: Enterprise budget analysis of Tilapia and Catfish per pond per production cycle in each area (Figures are in KES as at June 2014)

	Farmers receiving ESP			Farmers without ESP		
Parameters	Ngenda	Kiamuu	Thaara	Ngenda	Kiamuu	Thaara
Total revenue						
Sales of Tilapia	249256	209340	218736	142856	82264	95536
Sales of Catfish	78425	17300	77425	25925	15550	34925
Total revenue from Fish	327,681	226,640	296,161	168,781	97,814	130,461
Variable costs						
Fingerlings	5500	5100	5100	5700	5200	4350
Lime	200	700	450	500	350	400
Fertilizers	9750	6250	4750	6475	2000	1750
Feeds	25500	20400	23400	26250	17000	25800
Pumps	1250	1300	995	2000	0	930
Aerators	1500	985	1020	1500	950	910
Transport cost to the market	2000	2400	1200	2500	2100	1500
Field labour	8100	9500	10200	5200	3500	2050
Subtotal variable cost	53800	46635	47115	50125	31100	37690
Interest on operating cost	9684	8394.3	8480.7	9022.5	5598	6784.2
Total Variable Cost (TVC)	63484	55029.3	55595.7	59147.5	36698	44474.2
Fixed Costs						
Amortization	6000	6000	6000	6000	6000	6000
Pond construction	45000	45000	45000	45000	45000	45000
Interest on fixed cost	1080	1080	1080	1080	1080	1080
Total fixed cost	52080	52080	52080	52080	52080	52080
Total Cost (TC)	115,564	107,109	107,676	111,227	88,778	96,554
Net returns above TVC	264,197	171,611	240,565	109,634	61,116	85,987
Net Returns above TC	212,117	119,531	188,485	57,554	9,036	33,907
Margin above Total costs	***183.5***	***111.6***	***175.0***	***51.7***	***10.2***	***35.1***

CHAPTER FOUR

4.0. DISCUSSION

4.1. Water quality parameters in the rivers used as source of water for fish farming

Water quality is a major factor that affects the life of many aquatic organisms. Therefore before setting up a culture unit, farmers must be well aware of the quality of water available for use in their aquaculture facilities. Although many farmers in Kenya often start aquaculture units without prior knowledge of the water quality, it is prudent to understand the water quality parameters from rivers that are used as source of water for aquaculture. In this study therefore one of the objectives was to establish the water quality parameters of the main rivers that are used for aquaculture production to ascertain their suitability for aquaculture and understand the possible influence of fish farming downstream.

Like terrestrial animals, fish and other aquatic organisms need oxygen to live (McLoyd *et al*., 2012) but the transfer is efficient only above certain concentrations (Tenara and Richards, 2014). Therefore threshold concentrations are important in characterizing the aquatic environment. In this study, the dissolved concentration oxygen ranged between 6 mg/l to 8 mg/l similar to DO levels in many other rivers in Kenya (Raburu, 2003; Masese et al., 2009; Raburu et al., 2009; Nyakeya *et al*., 2009; Kilonzo et al., 2013). Mean levels of dissolved oxygen at all stations were higher than the minimum allowable limit (5 mg/L) for aquatic life. The current DO levels are suitable for respiration of fish and can enable fish to carry out all their biological functions (Chamber, 1996; Boyd, 1990). However, there were variations in DO values, where the highest concentration of DO was recorded in river Kiamuu, which could not be attributed to the location of the area situated in cooler environment. Although it has been shown that cold water can hold more oxygen, than warmer water since warmer water becomes "saturated" more easily with oxygen (Karr, 1999), the study point (Kiamuu) had higher temperature than other points. Therefore it is possible that higher rate of photosynthesis could be responsible for the higher DO in this site. There were also fewer human activities that could impact on the integrity of water and therefore may have resulted to less perturbations of the water hence not affecting the DO levels. The lowest DO levels were recorded in water of river Ngenda and this may be attributed to the presence of dense vegetation of putrefying leaves in the area. Presence of such vegetation may consume dissolved oxygen during respiration and decaying process.

Aquatic organisms exhibit optimal growth and survival at certain ranges of pH. Although each organism has an ideal pH, most aquatic organisms prefer pH of 6.5 to 8.0 (Kelly *et al*., 2004). Outside of this range, organisms become physiologically stressed. In this study, water pH ranged between 6.7 and 7.8 similar to findings from other studies in Kenyan rivers (Raburu *et al*., 2003; Nyakeya *et al*., 2009; Simiyu et al., 2009; Kilonzo et al., 2013), which is suitable for culture of many aquatic organisms including fish. It was noted that the pH range was within the acceptable limits for aquatic organisms (Ellis and Smith, 2012). The highest pH value was 7.63±0.13) recorded in river Thaara that was similar to pH value of river Ngenda while the lowest pH value was 6.68±0.14 in river Kiamuu. These differences may be attributed to the presence of photosynthesis in the areas. It has been reported that one of the main reason causing variations in the pH is the rate of photosynthesis (Heber et al., 2012). Photosynthesis uses up dissolved carbon dioxide which acts like carbonic acid (H_2CO_3) in water. CO_2 removal, in effect, reduces the acidity of the water and so pH increases. In contrast, respiration of organic matter produces CO_2, which dissolves in water as carbonic acid, thereby lowering the pH.

Often, oxygen and water temperature may be the single most important factors affecting the welfare of fish. Most aquatic organisms are poikilothermic - which means they are unable to internally regulate their body temperature. Therefore, temperature exerts a major influence on the biological activity and growth of their organisms. Aquatic organisms have preferred temperature ranges (Auckland Council, 2012). In this study water temperature displayed marked variation during the study ranging between 19°C to 23.4°C, which is suitable temperature range for many aquatic organisms (Water Management Plan, 2013). This range was below the limit of the WHO guideline of 27°C. The highest water temperature was 23.09 ±1.76^{o}C which occurred in river Kiamuu followed by water of river Thaara with 20.52 ± 1.12^{O}c while the lowest water temperature was 19.54 ± 0.31^{o}C in river Ngenda. The most obvious reason for temperature variations in the rivers was due to change in air temperature. Also it was observed that in river Ngenda, there was heavy shading by riparian vegetation and therefore preventing light penetration to the water bodies causing lower water temperature.

The salinity of water is an expression of, although not numerically identical to, the concentration of total dissolved solids (Wetzel, 2001). Salinity is actually the sum of the ionic composition of 8 major cations and anions in mass per litre. The concentration of the 4 major cations: Na^+, Ca^{2+}, K^+, Mg^{2+} and 4 anions e.g. Cl^-, HCO^-, CO_3^{2-}, SO_4^{2-} usually constitute the total ionic salinity of the water for all practical purposes. In the present study, salinity ranged between 4 to 23 ppm typical ranges for freshwater organisms (Dahl, 2006). Salinity is a limiting factor in the distribution of aquatic organisms. Nevertheless, there were significant differences in the concentration of salinity values in the three rivers in Gatundu South constituency during the study period. The highest salinity values were 16.94 ± 1.84ppm measured in river Kiamuu followed by salinity value of 11.34±2.43ppm in river Ngenda and the lowest was 8.94±0.67ppm in river Thaara. This may be due to the ionic influences of drainage, tributary inputs, influx of groundwater, variable evaporation rates, freshwater runoff with rainfall and exchange from the surrounding land, atmosphere and human activities (Xinfeng and Jiaquan, 2010).The basement rock at the source of the river as well as the rocks along the flow change the salinity regimes of water bodies and affect biota.

In the current study, the concentration of the NO_3-N ranged from 0.66 to 0.70 mg/l and did not exhibit any significant differences among the rivers sampled. It is possible that NO_3-N loading in the rivers originate from the same sources and therefore the nitrogen content that is in the rivers do not come from the allochthonous sources.

Phosphorus (P) is found in the form of inorganic and organic phosphates (PO_4) in natural waters. Inorganic phosphates include orthophosphate and polyphosphate while organic forms are those organically-bound phosphates. (Smith. 2005) Phosphorous is a limiting nutrient needed for the growth of all aquatic plants like algae. However, excess concentrations especially in rivers and lakes can result in algal blooms. (Quevauviller *et al*., 2008) The concentration of PO_4-P in the study ranged from 0.35 to 0.6 mg/l, Given that rivers with a concentration of PO_4-P below 0.01 mg/L is considered as oligotrophic, while concentrations between 0.01 and 0.02 mg/L are indicative of mesotrophy, and concentrations exceeding 0.02 mg/L are already considered eutrophic (Muller and Helsel, 1999), the PO_4-Plevels in the current study render the rivers to be hypertrophic. Among the common sources of phosphorous are wastewater and septic effluents, detergents, fertilizers, soil run-off (as phosphorous bound in the soil will be released), phosphate mining, industrial discharges, and synthetic materials which contain organophosphates, such as insecticides, which were all observed in the current study area. Also highest concentration of PO_4-P was recorded in water of R. Thaara and R. Ngenda which all appeared to have large amounts of human activities that may increase phosphorus in water.

4.2. Changes in riverine water quality due to effluent discharge from aquaculture ponds in Gatundu Constituency

An increasingly significant effect of intensive fish culture has been reported in several rivers/lakes receiving aquaculture effluent (Tumbare, 2008). The increased production of fish in aquaculture increases the amount of produced effluents. In the current study, discharge of effluents resulted in lower DO, salinity and P-PO_4 in the rivers, with higher NO_3 concentration. (Taeubert and Dortmund, 1979) in his study on evaluating the impact of shrimp farm effluent on water quality in coastal areas concluded that there were statistically significant differences in the concentration of DO, NO_3-N, PO_4-P among the three selected sampling stations and the levels of this parameters increased after the shrimp crop. The depleted dissolved oxygen levels recorded in this study, notably at the discharge points, could be attributed to the presence of high concentrations of degradable organic and inorganic matters in the aquaculture effluent (Utete *et a*l., 2013). This degradable material is more oxygen demanding, making oxygen less available to the desirable organisms including fish (Nizzoli *et al*., 2005). Low DO concentrations considerably affect the survival and behaviour of aquatic organisms (Utang and Akapan, 2012). Although the effect might not be prominent now the continued pollution in the rivers might mean some points become anoxic and may lead to hypoxia especially at turnover. The concentrations of Total Ammonium Nitrate (TAN), NO_3-N, and Total Phosphorus (TP) at the site directly receiving the farm effluent were higher than recommended for protecting aquatic ecosystems (Pulatsu. *et al* 2004). The differences in nitrate levels show that aquaculture effluent may be playing a prominent role in increasing nitrate levels in the rivers. Reduced phosphorus content was observed at the out let water in comparison to upstream station. The study concluded that fish farms effluent contains pollutant that can affect water quality, but the pollutants magnitudes were within the NEMA water quality standards of effluent discharge : Ph-6.5 to 8.5, nitrate- 100mg/l maximum (Environmental Management and co-ordination(water quality) Regulation,2006) and too low to put a significant impact on the rivers ecosystem. However if this discharge continues unabated and the number of aquaculture enterprises increase there could be negative implication on the river water quality with some parts of the river becoming eutrophic although this might be countered by the large river volume as per the study by Tumbare,(2008).

4.3 Water quality parameters in the Fish ponds in Gatundu South Constituency

Understanding water quality parameters in the ponds provides a measure of the effects that the effluents may have once discharged in the local water bodies such as rivers. Therefore this study sought to determine the water quality parameters in ponds near the rivers in Gatundu South Constituency. To evaluate the impact of increased investments in fish culture on the water quality, the current study also compared the water quality in fish ponds whose owners received ESP support against those whose owners did not receive ESP support. Water quality parameters that were measured were: DO pH, temperature, salinity, NO_3-N levels and PO_4-P levels.

Dissolved oxygen (DO) is one of the most important a biotic parameters influencing aquaculture production. Normally high DO is encountered in unpolluted areas, while at polluted areas levels of DO is very low (Bartram and Ballance, 1996). In the current study, the DO concentration ranged from 3.2 to 10.2 mg/l in the ponds for farmers in Gatundu South Constituency. A concentration level of at least 5 mg/L is desirable while values lower than this can put undue stress on the fish, while levels reaching less than 2 mg/L may result in death (but 3 mg/L to some species) (Utang. and Akpan. 2012). Tilapia can survive routine DO concentrations of less than 2 mg/L, considerably below the tolerance limits for most other cultured fish. Although tilapia can survive acute low DO concentrations for several hours, tilapia ponds should be managed to maintain DO concentrations above 1 mg/L (Popma and Masser, 1999). Metabolism, growth and, possibly, disease resistance are depressed when DO falls below this level for prolonged periods. Despite significant temporal variation in DO levels, it was noted that ponds whose owners received ESP support had lower concentration of DO compared to ponds owned by farmers who did not receive any ESP support. The lower DO levels in fish ponds of those receiving massive funding could be attributed to the higher stocking densities and increased use of feeds, the leftovers which are known to deplete oxygen in the ponds.

The pH variation ranged from 6.8 to 7.4, which is around neutral pH. In general, tilapia can survive in pH ranging from 5 to 10 but do best in a pH range of 6 to 9 (Masser. 2003) which suggest that the current pH ranges are suitable for culture of tilapia which is extensively done in Kenya. There were variations in pH among sites regardless of the ESP programme. It can thus be concluded that the higher acidic value in some sites is due to the chemical additives like; Oxidants, disinfectants, osmoregulators, algicides, coagulants, herbicides and probiotics (Boyd. And Massaut., 1999) applied to aquaculture pond with an objective of better production. Although during the study, it was not possible to determine the exact substance that caused a reduction in pH and thus subject to further research. It was also established that pH variation in the ponds was not affected by ESP status, suggesting that most of the fish farmers were using similar inputs with low acidity.

Temperature ranges in the ponds in the current study ranged from 19 °C to 24 °C equivalent to the most of the ponds in the tropical environment (Bronmark and Hansson, 2005). The high temperature in ponds is due to direct solar insolation which is highest at the equator that is close in proximity to the ponds in the study area. Despite the spatial differences in temperature caused by the elevation of the sites, ESP programmes did not affect temperature variations in the ponds because inputs into the ponds cannot control water temperature and none of the pond owners was found to have any form of warming the water before use in the ponds.

Salinity can be affected by aquaculture activities because of the utilization of salt during aquaculture for several activities (Herda. 2008). In the current study, farmers without access to ESP support had higher salinity because many farmers used common salt in managing diseases and pest in their farms. Farmers with ESP support could afford to buy drugs to manage any future disease outbreaks. There was a significant interaction between the location of the sampling sites and ESP programme on salinity of the pond waters. For farmers without ESP support, salinity was highest in ponds located in Kiamuu compared to ponds in Ngenda and Thaara. However among farmers receiving ESP support, the highest salinity occurred in ponds located at Thaara followed by salinity in ponds at Kiamuu while salinity was lowest in ponds at Ngenda.

In the current study nitrate (NO_3-N) concentration ranged from 0.4 to 1.1 mg/l suggesting increased nitrification process in the ponds. Nitrate is formed through nitrification process, i.e. oxidation of NO_2 into NO_3 by the action of aerobic bacteria. Nitrate not taken up directly by aquatic plants is denitrified in anaerobic sediments and micro zones (Chapman. 1992). In tropical systems, denitrification will be most intense in the following areas: (a) where detritus accumulates; (b) in water bodies subject to enhanced nutrient loading from pollution; (c) in water bodies with long residence times; and (d) in ecosystems subject to periodic drying, where oxygen inputs during drying periods stimulate coupled mineralization-nitrification-denitrification within organically rich sediments (Furnas, 1999). It is also possible that the high nitrate in the current study was due to uneaten feeds. In the eaten feeds, only 25% Nitrogen (N) is used for the growth of fishes, and other 75% N is removed out of the fishes as excrements. That means that only $^{1}/_{5}$ feeds are utilized effectively, and others are discharged to the environment as environmental pollutants (Okomoda., 2011) It was also determined that ponds which received ESP support had higher mean NO_3-N concentration than those ponds whose owners did not receive any ESP support, which may have been attributed to increased use of artificial feeds and other input like inorganic fertilizers that increase NO_3-N concentration in the pond water. Given that changes in NO_3-N were not in tandem in ponds whose farmers received ESP support compared to those who did not receive ESP support suggest that the enrichment of the ponds with NO_3-N was different among the farmers with ESP.

Generally, ponds whose owners received ESP support had higher PO_4-P levels compared to ponds of farmers who did not receive any ESP support, which could be attributed to use of more inputs containing phosphorus such as the use of inorganic fertilizers. The pattern of use of such substances containing phosphorus appeared highest in Ngenda, followed by Kiamuu and least in Thaara.

4.4 Impact of ESP fish farming project on farmers' income in Gatundu South Constituency

Aquaculture has traditionally played an important role in ensuring food security for humans and is often a component of rural development programmes to alleviate poverty. In this study, the socio-economic impacts of aquaculture investment through ESP were determined. Aquaculture expansion appeared to be restricted by the land size since land sizes rarely exceeded 5 acres that are not enough to enable large scale fish farming. Nevertheless most of the land was owned by individuals and therefore allowed for development of fish farming to be realized. The main problem attributed to the land in the region was competition from food crops. However, it was also observed that farmers who received ESP dedicated more of their lands (between 31 to 58% of land, Table 3.2) to aquaculture activity than farmers who did not receive any form of support (13 to 19%) for obvious reasons that they did not have enough money to spend in setting up fish ponds. Indeed the farmers indicated that most of the funds for fish farming were ESP grants as compared to other formal sources of loans from other financial institutions. The availability of these funds in the year 2009 allowed for many farmers to construct the ponds between the years 2009 to 2011 suggesting that availability of funds was a major factor limiting expansion of fish farming in the region. Also farmers in the study area cited ESP as the motivation to start fish farming activities. Therefore it is important to understand the benefits of this increased fish farming activity to the local economy.

Generally, farmers had one to two liner ponds in their farms from which they derived benefits. The ponds for both ESP and non ESP farmers have a standard size of 300 m^2 and ESP farmers had a total of 123 fish pond while non ESP farmers had a total of 111 fish pond (Table 3.5). Overall, aquaculture played an important role in income creation in all the surveyed households. However, the income from other income-creating activities (e.g. agriculture) was needed to sustain fish farming: On less than half of the surveyed farms, in all groups, aquaculture was self-supportive. Similar observations about the particular successfulness of combining agriculture and aquaculture were made by Kawarazuka and Bene, (2010). Only very few self-supportive aquaculture farms remain successful after donor-departure (Coche *et al.*, 2008). This initiates the thought that, the situation in Kenya's Lake Victoria region may get worse since ESP support was partially available until 2012.

The overall importance of salaries and pensions in income creation may have to do with the rather old group of fish farmers interviewed in this study. Farmers with no support relied mostly on aquaculture as their primary source of income: Possibly they may have had to drop, or reduce, other income creating activities in order to start fish farming. This is supported by the fact that farmers with no ESP support only had small, or no, shares in fishing, agriculture and business salaries. ESP support may have enabled farmers in the group to practise fish farming, agriculture, livestock farming and regular businesses. Farmers in the non funded group depended least on aquaculture as their primary source of income, but practiced agriculture and had the highest shares in fish farming and businesses to compensate.

Results of this study show that, significant level of employment was indeed created through aquaculture. However, small-scale aquaculture often does not create full-time employment all-year-round. Respondents stated that casual labourers were employed mainly during pond construction and harvest. Also, most labourers were not only working in aquaculture, but also in other sections of the farm. Important to note is that for some farmers of this study aquaculture seemed to represent mainly a supplementary activity. Labour among those farmers receiving ESP support concentrated more on the salaried labour with occasionally high number of casual labour but less of family labour. Significantly ($P < 0.05$) higher mean wages were paid to salaried labour by farmers receiving ESP support than other forms of labour.

Most of the production cycles for tilapia ranged between 9 and 21 months while catfish production cycle ranged between 9 and 16 months (Table 3.7). However, it was established that farmers receiving ESP support had lower mean production cycle for tilapia (≈10 months) and catfish (≈ 11 months) compared to those without ESP support (tilapia = ≈16 months and catfish = ≈15 months). Considering that ESP farmers were getting a lot of support from the government while non ESP farmers were not, the difference in the production cycles can be attributed to the quality and quantity of feeds used, the quality of water used, the training by the extension officers and the right stocking density.

There were significant interactions between location and ESP status on production volumes of tilapia and catfish as well as on the earnings from both stocks of fish. (Table 3.8) Production of tilapia among farmers who obtained ESP (790 kg/cycle per Fish pond) was higher than those farmers without ESP (380 kg/cycle per Fish pond) resulting in significantly higher total earnings for farmers with ESP (KES 225,800) as compared to farmers without ESP (KES 105,800). Similarly production of catfish among farmers who had access to ESP (230 kg/cycle per Fish pond) was higher than those of farmers without access to ESP (100 kg/cycle per Fish pond) and the earning reflected this trend by being higher for farmers who have access to ESP (KES57,700) compared to those farmers without (KES 25,500).

In terms of revenue, farmers who received ESP obtained more money through sales of fish ranging between KES. 226,640 to 327,681 per fish pond/year from 123 fish pond compared to farmers without any ESP support (KES. 97,781-130,461) from 118 fish ponds. As a result, farmers who obtained ESP support were able to spend more money on the inputs resulting in better production and higher gross margins above the total cost. Farmers who received ESP support received double the amount of investments that ranged between 10 to 50% more than for farmers who did not have any monetary support.

Even though local markets in the study area were available, market access was often difficult due to bad road conditions and the fact that most farmers did not have their own transport. Public transport is costly, thereby hindering farmers from selling the fish at the markets to increase their profits. The importance of not only market availability, but also accessibility, for increasing aquaculture profitability was stressed by Jagger and Pender, (2002). Other problems that may hamper market sales of cultured fish in the study area are the consumer's poverty and bad perception of cultured fish, both observed in the study area. Poverty of fish consumers was also identified by Jagger and Pender, (2002) as a constraint for market sales of cultured fish.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

The values of most of the water parameters measured in this study were significantly different compared to the control point which was the upstream sampling point where there was less disturbance/influence on rivers by human activities, showing that the aquaculture effluent is affecting the riverine water quality.

Although the mean values of pH, salinity, orthophosphate and temperature during the study were all within the acceptable local and international range, The higher values recorded at the discharged points relative to the control indicate that the aquaculture effluent at these points is distorting the riverine water quality.

There was a significant difference in the economic and social status between the fish farmers who were supported by the government through the ESP programme and those who did not benefit from the ESP programme. Fish farmers supported by the ESP programme had shorter production cycle, which means fewer expenses and fast production, higher production volumes and better earnings which enabled them to take care of their economic and social needs unlike the farmers who were not supported by the ESP programme.

5.2 Recommendations

Based on the findings of this study, the following are recommended:

1. Because the rivers in Gatundu serve as a source of domestic water supply for drinking, washing, fishing and swimming, continuous discharge of improperly treated aquaculture effluent should be stopped as this may cause localised eutrophication and a change in the trophic structure. The aquaculture waste should be thoroughly monitored and processed before discharging them into the rivers like by practice the best management practises which include: reuse of water or using the discharged water for irrigation of crops in the farms.
2. There is need for public awareness regarding the pollution problems and the consequences arising thereof in the rivers and basins investigated. There is need for an integrated Environmental Education (EE) programme within the basins. The programme should focus on the need for people living within the area to appreciate a cleaner environment. Farmers should be encouraged to treat the rivers as their friend and therefore protect its water quality for the present and future generations and to enjoy its aesthetic values.
3. The perception of farmed fish needs to be improved among rural communities.
4. Further encourage fish farmers to be members of fish farming groups and cooperatives to improve communication amongst fish farmers which may prove to be helpful in problem solving.
5. Testing of the suitability of the area and community setting before promoting aquaculture projects in order to avoid the building of ponds in unsuitable areas, i.e. areas where land and water availability are scarce.

6. The development of a suitable model for fish marketing mechanisms is necessary. This includes certain infrastructural facilities such as the availability of storage and cooling facilities and an improved road network.
7. Educate fish farmers on the use of loans and instruct commercial agricultural lenders to invest in the aquaculture enterprise.
8. The reliance of fish farmers on natural water resources needs to be alleviated, e.g. through the construction of boreholes, to secure water supply during droughts.
9. The results of this study can be used to draw some policy recommendations. The positive impact of the ESP programme on farmer's farm income implies that farmers should be well informed of any government or non-governmental support and what they need to do to be part of the programme. Therefore, policies which improve the likelihood of farmer's participation in ESP programme should be established. These policies include among others; improving top-down information flow. It is very clear from this study that the farmers who had access to information were more likely to benefit from the ESP programme.

10. From the results of this study, the ESP programme can be recommended to be fully implemented and monitored in most parts of Kenya since it has a positive impact on the farm incomes, better production, access to extension and access to credit among other benefits to the farmers. This will improve the living standards and the overall welfare of the people.

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APPENDICES

Research questionnaire

Hello,

My name is Carolyn Musyoki. I am undertaking a study to evaluate the impact of aquaculture development (Economic Stimulus Program) on income generation and environment in Gatundu south constituency. The information you provide will be used to make recommendations that inform policy makers on feasible ways to maximize the profitability of small-scale operations and formulate the necessary environmental safeguarding regulations. Thank you for cooperation.

Name of the Respondent ………............ Location……………

Phone No.………………… Date………………..

The following questions are designed to learn about your aquaculture operations

1. What is the size of your farm land? (Not just fish farm, but all farm land) ______________ acres

2. What is the land tenure arrangement for your farm?

#	**Land tenure arrangement**	**Total acres**
a.	Personal ownership	
b.	Family land	
c.	Community / communal land	
d.	Leasing / Renting	
e.	Other, specify _______________________	
	Total acres must add up to Q1 above	

3. If leasing/Renting, what is the cost per acre? ____________________

4. What proportion of the total land is used for fish farming? ____________ acres

5. When did you start fish farming? (*write year*) _________________________

6. How did you start fish farming?*Please circle one per row*

	Reason for starting Fish Farming	**Yes**	**No**
a	Motivated by a fellow farmer	1	0
b	Participated in the government initiative (ESP)	1	0
c	Participated in program by NGO	1	0
d	Participated in program by a development agency	1	0
e	Other, specify…………………………………	1	0

7. How many ponds do you have? (*please write the appropriate number for each pond type*)

	Pond Type	**Number**
a	Earthen	
b	Concrete	
c	Liner	
d	Other specify…………………………………	

8. What are the sources of water for your aquaculture operations? *Circle 1 for Yes or 0 for No*.

	Water source	**Yes**	**No**
a	Rain harvest	1	0
b	River/Stream	1	0
c	Borehole	1	0
d	Sub-surface (spring water, seepage in, etc.	1	0
e	Other, specify	1	0

9. On a scale (1- 5), describe the **reliability of quantity** of the water sources for fish culture.

Water Sources	1	2	3	4	5
	Very reliable	Reliable	Neither reliable nor unreliable	Unreliable	Very unreliable
Rain harvest					
River / stream					
Borehole					
Sub-surface					
Other ___					

10. How many species do you culture on your farm?

a. One
b. Two
c. Three
d. Indicate which ones…………………………………………..

11. What was the stocking density in your ponds for the last production cycle?................ In m^2

12. What was the duration of your last production cycle - from stocking to harvest?

	Tilapia	**Catfish**	**Other ___________**
Duration (months)			

13 .What was your total annual fish production (kilogams or tonnes) from your last year of production (*approximate or exact*)?

	Tilapia	**Catfish**	**Other, _________**
Production			
Unit: (Kg 1, tonnes 2)			

14. Sales volume, marketing and transportation cost

Fish type	Unit in Kg	Price per Kg	Value Ksh	Sales point	Distance to SPs	Transport cost (ksh)

*Codes for sales point farm gate…..1 local market…..2 urban markets….. 3cooperative…..4 other (specify)*_____________

Codes for mode of payment cash ….1 cash in advance …2 credit ….3in kind payment ..4 other specify _______________

15. How did you allocate your last production – indicate in percentages?(*must add to 100%)*

#	Allocation of production	Percent Allocation
a	Sold	
b	Home use	
c	Gift to others	
d	Other, specify …………………………	
e	**Total (must sum to 100%)**	

16. Labor on your fish farm during the last production year?

#	**Sources of Labour**	**1**	**2**	**3**	**4**
		Number	**Hours/day**	**Cost/day/worker**	**No. of days/week**
a.	Family workers				
b.	Hired Wage/Salaried workers				
c.	Casual (last year) workers				

17. Fixed input cost estimation for fish farming

Input	**Number owned**	**Purchase price of asset**	**Age of asset (years)**	**Current value of asset (Ksh)**
Pumps				
Ponds				
Aerators				
Vehicles (*for fish farming only*)				
Other specify……………				

18. Some other variable and operating cost in last production year

Input	**Used (Yes1 or No 0)**	**If yes, how much was used (*units*)**	**unit cost (Ksh)**
Fingerlings			
Lime			
Fertilizer			
Other specify …			

19. What type of feed do you use? (*Please circle either 1 for Yes or 0 for No per row*).

	Feed Type	**Yes**	**No**
a	Pelleted floating only	1	0
b	Pelleted sinking feed only	1	0
c	Local sinking feed only	1	0
d	Local floating	1	0
e	Other specify	1	0

20. How many times do you feed your fish in a day………

21. How much feed do you feed your fish in a day (kilos)……….

22. What was the total amount of feeds used from the beginning to the end in the last production cycle? (Bags/kilos)………………..

23. What is the cost of feed?

	Feed quantity	**Unit cost (Ksh)**	**Distance to farm (miles)**	**Cost of transportation**
10 kg bag				
20 kg bag				
50 kg bag				
Other, ____				

24. What was the **__initial source__** of capital for your farm? (***Please circle one per row)***

	Initial sources of capital	**Yes**	**No**
a	Grants	1	0
b	Personal savings	1	0
c	Family Loan	1	0
d	Bank Loan	1	0
e	Government Loan	1	0
f	Cooperative loan	1	0
g	Microfinance loan	1	0
h	Other specify……………………………………	1	0

25. What is your **__current source__** of funding for the business? (***please circle one per row)***

	Current sources of capital	**Yes**	**No**
a	Grants	1	0
b	Personal savings	1	0
c	Family Loan	1	0
d	Bank Loan	1	0
e	Government Loan	1	0
f	Cooperative loan	1	0
g	Microfinance loan	1	0
h	Other specify…………………………………….	1	0

26. On average what is the total value of credit you received in the past year for fish farming operations

	Sources of capital	**Amount received from source (Ksh)**
a	Grants	
b	Personal savings	
c	Family Loan	
d	Bank Loan	
e	Government Loan	

f	Cooperative loan	
g	Microfinance loan	
h	Other specify………………………	

The following questions are designed to learn about your socio-economic characteristics

27. What is your gender? Male 1 Female 0

28. What is your age (years)?________________________

29. What is your marital status Married 1 Single 0

30. What is your household/family size? ________________________________

Please complete the following table for each household member. You can use just the first name.

Household Bio-data

HH #	Name	Gender	Relationship to respondent	Education	Age	Work on farm? (Y/N)
HH1						
HH2						
HH3						
HH4						

31. Level of education of owner/director (*please circle only one answer*)

No formal education 1 Primary 2 Middle school 3

Secondary/High school 4

Tertiary/University 5 Other, specify____________________

32. On the average, what is your **total yearly** household / family income? Ksh ____________

33. Indicate the proportion of your total yearly household / family income as follows:

	Sources of income	Percentage (%) of total income
A	Fish farming	
B	Non-fish farming agriculture income	
C	Non-farm income	

34. How many years have you been involved in fish farming?________________

35. How many times did you meet a government extension officer within the last year? __________

36. Did you attend any fish farming training programs within the past year?

Yes 1 No 0

37. Are you a member of any farmers' association?

Yes 1 No 0

38. Do you keep records for all farm activities?

Yes 1 → why ___________________________________

No 0 → why not ________________________________

39. If yes, have you used your record keeping to secure a loan facility from a bank before? Yes 1 No 0

THANK YOU

END