CHARACTERIZATION OF FISH FARMING SYSTEMS IN KIAMBU AND MACHAKOS COUNTIES, KENYA

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DECLARATION

This thesis is my original work and has not been presented for award of a degree in any other university.

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Dedication

This thesis is dedicated to my parents Paul and Esther who taught me important virtues in life and to my lovely wife Damaris and son Jeremy.

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ABBREVIATIONS AND ACRONYMS

CRSP	Collabourative Research Support Program
ERPARDP	Recovery, Poverty Alleviation and Regional Development Programme
ESP	Economic Stimulus Program
FAO	Food and Agricultural Organization of the United Nations
FFEPP	Fish Farming Enterprise Productivity Programme
GOK	Government of Kenya
HACCP	Hazard Analysis and Critical Control Point
KSHS	Kenya shillings
MFD	Ministry of Fisheries Development
MT	Metric tons
NGO	Non-governmental organization
NH_3	Ammonia gas
NH_4^+	Ammonium ion
USAID	United States Agency for International Development
WHO	World Health Organization

ABSTRACT

Kenyaös fisheries sector has the potential to contribute significantly to the national economy through employment creation, earning foreign exchange, poverty reduction and food security provision. The purpose of this study was to characterize the fish farming and marketing practices in Kiambu and Machakos Counties in Kenya. To achieve this a cross-sectional survey design targeting fish farmers was conducted in Kiambu and Machakos Counties in Kenya. The areas were selected because the two Counties border Nairobi Metropolitan area which is an important fish market and they have no long history of fish farming.

A semi-structured questionnaire was used to collect data from 250 respondents selected randomly from the sampling frame provided at the District Fisheries Office and the area under study in each County was selected purposively from the sampling frame. Data were collected on socio-economic characteristics of fish farmers, pond management practices and fish feeding practices. The role of the ESP in funding input supply and service delivery, fish harvesting, marketing and consumption was also evaluated. The data were analyzed for descriptive statistics using SPSS program.

The results showed that majority of fish farmers in Kiambu and Machakos County respectively, had attained atleast primary level of education. Majority of the farmers (over 70%) were men who controlled most of the income generating activities. The employment status of fish farmers in Kiambu and Machakos Counties showed that majority of the respondents (79.3% and 54% in Kiambu and Machakos County respectively) were self-employed in agriculture, while the others were engaged in non-agricultural activities in Kiambu and Machakos Counties. Fish farming was practiced by a relatively large proportion of farmers below 50 years of age in Kiambu Machakos Counties. The average land size was

2.5±3.47 and 4.27±4.78 acres in Kiambu and Machakos Counties respectively. The means were not statistically different between the two Counties(p=0.05). Additionally, the study showed that farmers practiced mixed farming fish farming into crop farming where water from the ponds was used for watering ponds were located near vegetable plots. The study also showed that in Kiambu and Machakos Counties majorityof ESP and self-funded farmers respectively kept fish mainly for commercial purposes.

Of the 250 respondents interviewed, 85.3% and 75% in Kiambu and Machakos Counties respectively were recruited through the ESP. The main source of information on fish farming was government extension agents as reported by 93.8% and 92% of ESP farmers in Kiambu and Machakos Counties respectively . Stocking of Nile tilapia in mixed sex tilapia in monoculture was the most dorminant culture method and fish were mainly stocked in earth ponds. There were no differences in the species of fish farmed and the culture method between ESP and self-funded farmers. Majority of the fish farmers under the ESP programme (84.4 and 68 percent) in Kiambu and Machakos County, respectively were provided with fingerlings by the government.

Farmers in Kiambu and Machakos Counties used complete or formulated commercial feeds for feeding the fish. Formulated fish feeds were mainly supplied by the government. Farmers purchased inorganic fertilizers and supplementary feeds like maize bran and fish meal from the local agrochemical stockists. The average amount feed fed to 1000 fish per day from the age of 3 months was found to be 2.18±2.51kg in Machakos County and 1.44±1.29 kg in Kiambu County. Majority of the fish farmers (67.2%) in Kiambu and (70.7%) in Machakos County refilled their pond when water fell below a certain point. A relatively larger farmers (42.1%) fertilized their ponds at least once per production cycle and used manure from their farms. These results were significantly different between the two categories of farmers(P=0.05).

Majority of the ESP farmers (64.8% and 78.7%) in Kiambu and Machakos Counties respectively relied on government extension to provide information on pond management. About 90% and 65% of the ponds observed in Kiambu and Machakos Counties respectively had green water, an indication of algae growth. Further, 8% of ponds in Kiambu and 15% in Machakos County had brown water. The results also indicate high Permanganate Values (PV) in the ponds especially in Machakos County.

Machakos County had higher levels of toxic ammonia especially ponds along Athi river. Other ponds in both Machakos and Kiambu County had low levels of ammonia, which may also be harmful to fish if they are exposed for long periods of time. Results indicate high Permanganate Values (PV) in the ponds especially in Machakos County which implies high amounts of organic matter load which can influence the amount of dissolved oxygen.

It was observed that most farmers in the two Counties used poor fishing gears such as mosquito nets and wire mesh to harvest fish. The average pieces of fish harvested in Kiambu and Machakos Counties were 231.15 (34.67Kgs) and 418.36 (62.75Kgs) per the main harvest respectively. In Kiambu County 80 percent of the fish were sold to local consumers as compared to 22 percent in Machakos County. The average farm gate price for tilapia in Kiambu County was KShs 180.8 while in Machakos it was KShs 131.4. This was statistically different between the two Counties (p=0.05). The study also showed that there were few cases of fish diseases in this region.

The study recommends provision of capacity development approaches through training and credit initiatives to fish farmers in order to improve on pond management and feeding, conduct extensive baseline survey and feasibility studies before introduction of fish farming in different parts of the country and train farmers on the importance of determining the pond water quality at certain intervals and before stocking the pond to ensure that the water parameters like ammonia are within the required range.

CHAPTER ONE: INTRODUCTION

1.1 Background

Kenyaǿs fisheries sector has the potential to contribute significantly to the national economy through employment creation, earning foreign exchange, poverty reduction and food security provision. In 2010, the sector supported a total of 76,263 people directly as fishers/farmers deriving their livelihood from various fishery resources in the country(Semberya, 1998). Of this number, 14,120 were fish farmers while the rest were fishermen. In the same year, the sector supported about a million people directly and indirectly, working as fisher folk, traders, processors, suppliers and merchants of fishing accessories.

In 2010 the total national fish production was 140,751 metric tons (MT) valued at KShs 15.4 billion and about KShs. 4.1 billion (approximately US $ 54 million) worth of fish was exported to Europe and other countries (Semberya, 1998).Fish production in the country has been declining since 1999 when the highest quantity (214,709 MT) of fish was landed. The value of fish products have been increasing steadily due to increased demand and decrease in supply(Semberya, 1998).

Capture fisheries in Kenya has been rapidly declining as result of both environmental degradation of the main water bodies and increasing fishing pressure leading to over-fishing. Concurrently, maximum annual output from marine fisheries has remained stagnant at about 7 MT (despite the estimated potential annual yield of 150,000MT) (Semberya, 1998). Additionally, the most valued fishery species in Lake Victoria, the Nile Perch, is threatened with extinction and has been decreasing in numbers in recent years (Boshnakova, 2010).

Under the National Oceans and Fisheries Policy the Ministry of Fisheries Development (now state department of fisheries) identified the development of fish farming as one of its core activities. This is because it reduces fishing pressure on the oceans, lakes and rivers and enhances food security, creates employment, creates wealth, and healthy living for our people (FAO, 2010).

Aquaculture is one of the fastest growing food production sectors in the world. Fish production has increased in developing countries, while the numbers of species cultured have also increased. Despite this increase, fish farming in many countries is still dominated by a few species, such as carp in India and China, pink shrimp in South America, oysters and mussels in Japan, France and Korea, milkfish in the Philippines and Indonesia and tilapia in Africa (FAO, 2010).

Aquaculture in developing countries has been viewed as a means of improving food security and supplementing income for rural families. In many countries, particularly in Africa, aquaculture is done at subsistence level and the little surplus production is sold in the rural markets (Subasinghe et al., 2012). In Kenya, The state department of fisheries has been at the forefront of aquaculture policy development aimed at diversifying fisheries resource production .The increase in awareness among farmers in Kenya about the viability of fish farming as an alternative agricultural enterprise has led to increase in fish farming activities in the Western, Central, Eastern, and Rift Valley regions . This increase has also been as a result of initiatives by some Non-Governmental organization on technology transfer programs towards improving fish farming. For example, the USAID-funded Aquaculture Collabourative Research Support Program (CRSP) in Kenya in the 1990s played a significant role in promoting new fish production technologies (Kwamena, Ngugi, & Amisah, 2010).

In many developing countries, especially those in sub-Saharan Africa, the problem of a rapidly increasing human population coupled with an increasing need for inexpensive sources of protein have justified the need to develop aquaculture rapidly and urgently. In view of the stagnating or declining catches of fish from inland natural lakes (FAO, 2010)fish farming has recently received increasing attention among governments and development agents.

In the 1960s rural fish farming was popularized by the Kenya Government through the ñEat more fishò campaign; as a result of this effort, tilapia farming expanded rapidly, with the construction of many small ponds, especially in Central and Western Provinces (FAO, 1996). However, the number of productive ponds declined in the 1970s, mainly because of inadequate extension services, lack of good quality fingerlings, and insufficient training for extension workers (Mwamuye, Cherutich, & Nyamu, 2012). Until the mid-1990s, fish farming in Kenya followed a pattern similar to that observed in many African countries, characterized by small ponds, subsistence-level management, and very low levels of production.

Following the renovation of several government fish rearing facilities, the establishment of research programs to determine best practices for pond culture, and an intensive training program for fisheries extension workers, there is renewed interest in fish farming in Kenya. Farmers in suitable areas across the country are turning to fish farming as a way of producing high quality protein, either for their families or for the market, and for (earning extra income). On-farm research trials carried out in Kenya and elsewhere in the world have enabled farmers to apply appropriate techniques and good management which result in high yields and a good income (Ngugi, Bowman, & Omolo, 2007).

1.2 Problem statement

The aquaculture sector was one of the sectors selected by the Government of Kenya to benefit from the Economic Stimulus Program (ESP) in 2010 in order to contribute to economic recovery for the attainment of Vision 2030 (WHO, 2010). There have been other such programs started by development agents in the past, but they lacked sustainability and collapsed as soon as the donor funding was withdrawn. During 2009/2010 financial year, the government of Kenya spent KShs 1.12 billion on aquaculture. The money was used to construct 200 fish ponds per constituency, purchase of fingerlings and feeds, improve hatcheries and revamp aquaculture extension services (WHO 2010). It has been four years since the inception of the ESP but no systematic evaluation has been done to date to assess the influence of this programme on fish farming in the study areas. In particular, there is little comprehensive information on fish farmersô management practices such as the fish species kept, type and sources of feed used, common fish diseases, and opportunities and challenges faced by fish farmers. There is also no adequate and updated information on the quality of water and feeds used in fish farming. Such information is useful for farmers to improve on their practices and for policy makers to design programs which address the challenges faced by the farmers and exploit the opportunities available. This study aims to fill this gap. The study also aims to carry out comparison of fish farming management practices in the two Counties in order to bring out the challenges and opportunities in the sector.

1.3 Objectives of the study

The overall objective of this study was to characterize fish farming systems in Kiambu and Machakos Counties in Kenya. The specific objectives of the study were to:

1. Evaluate socio-economic characteristics of fish farmers in Kiambu and Machakos Counties of Kenya.

2. Determine the impact of the economic stimulus program on service delivery and fish management practices in the two Counties.
3. Assess the quality of water and feeds used by farmers in the two Counties
4. Characterize the marketing of farmed fish in the two Counties.
5. Map out diseases and challenges experienced by farmers in the two Counties.

1.4 Research questions

The study was guided by the following research questions:

a) What are the main socio-economic characteristics associated with fish farming in Kiambu and Machakos Counties?

b) What are some of the impacts of the ESP on service delivery and fish management practices in the two Counties?

c) What is the suitability of the quality of water and feeds used for fish farming?

d) What are the main markets and what is the demand for the farmed fish?

e) What are the main diseases and challenges experienced by farmers in the two Counties?

1.5 Justification of the study

Traditionally, most of the fish in Kenya is produced from inland fresh water lakes, particularly Lake Victoria which produces over 85 percent of the total fish consumed and exported from Kenya. Lake Victoria however is experiencing problems with water hyacinth, pollution, eutrophication, and loss of fish biodiversity (Semberya, 1998). In the meantime, the demand for fish in Kenya is increasing due to growth in incomes and as consumers become more health conscious. The gap between per capita fish demand and supply can only be met by increasing production from fish farming.

Per capita fish consumption in Kenya is 5kg which is three times lower than the world average of 16 kg (C. Ngugi et al., 2007). Fish farming is fast becoming established in Kenya as a strategy for food security, employment creation and poverty reduction through income generation. The Department of Fisheries has been at the forefront of aquaculture policy development aimed at diversifying fisheries resource production. The emphasis of most of the government aquaculture policy initiatives has been on social objectives, such as improved nutrition in rural areas, generation of supplementary income, diversification of activities to reduce risk of crop failures, and creation of employment in rural communities (Kwamena et al., 2010).

With the government intervention in aquaculture through the ESP, fish production is bound to increase and therefore this study is relevant in that it will provide information on current management practices adopted by fish farmers which will form a basis for future improvements.

The information generated by this study will enable policy makers to formulate policies to promote aquaculture development by addressing the challenges faced by farmers and exploiting the opportunities available in the sector. The government can also use the information to develop funding programs and incentives to support fish farmers. Funding agencies can also use this information to plan and fund programs that address farmersô problems. On the other hand, farmers will use the information generated by this study to improve on the management of their fish farming enterprise.

CHAPTER TWO: LITERATURE REVIEW

2.1 Aquaculture in Kenya

Commercial aquaculture in Kenya involves the production of *Orechromis niloticus ,Clarias gariepinus* (African catfish), and *Oncorhynchus mykiss*(rainbow trout) (Mwangi, 2007). Tilapia and catfish are mainly produced as mono- or poly-culture under semi-intensive production systems while the rainbow trout is produced in intensive production systems using raceways and tanks(Mbugua, 2002). While all the species are produced for the food fish market, there has been increasing demand for baitfish for the capture of Nile perch in Lake Victoria (Mwangi, 2007). Several entrepreneurs have started producing catfish juveniles for the market.

Fish farming in Kenya began in early 1920s (FAO, 2010). However, rural fish farming dates back to 1940s when farmers in Central and Western Kenya constructed fish ponds to culture Nile tilapia (FAO, 2000). In spite of several decades of fish culture, Kenyaøs aquaculture remains a young industry, practiced mainly on a small scale using *Oreochromis niloticus* (Nile tilapia) and *Clarias gariepinus* (African catfish) to produce approximately 12,000MT of fish annually (FAO, 2010).

The African catfish is the most widely distributed fish in Africa (Skelton, 1993). It can endure adverse conditions using its accessory breathing organ, and it is highly omnivorous, with a fast growth rate. Research into the culture potential and the artificial propagation of the fish species began in the 1970s (De Kimpe and Micha 1974) (Ngugi *et al.*, 1984).

According to Balarin and Hatton (1979), the major factors limiting production of farmed tilapia in Kenya are stunting, resulting from over-reproduction, and inadequate and affordable commercially available feeds. Although it has been difficult to solve the feeds problem, restricted growth has been overcome to some extent through the use of hybrids (Balarin and

Hatton 1979), monosex culture and by polyculture of tilapia fingerlings with a carnivorous fish species such as *Clarias gariepinus* (FAO, 1974).

2.2 Fish production in Kenya

According to the Ministry of Fisheries Development 2010 report fish produced from farming in that year was 12,153 MT valued at KShs 2.6 million. Nile tilapia contributed 75 percent (or 9,115 MT) of the total fish produced while African catfish contributed 18 percent (or 2,188 MT). On the other hand, Common carp accounted for six percent (or 729 MT) of total production while Rainbow trout made up a mere one percent (or 122 MT) (Figure 2.1). This production was from 23478 ESP ponds, 8,399 non ESP ponds, tanks and dams. The production was from an area of 14,931,621m^2 (or 14932 Ha)

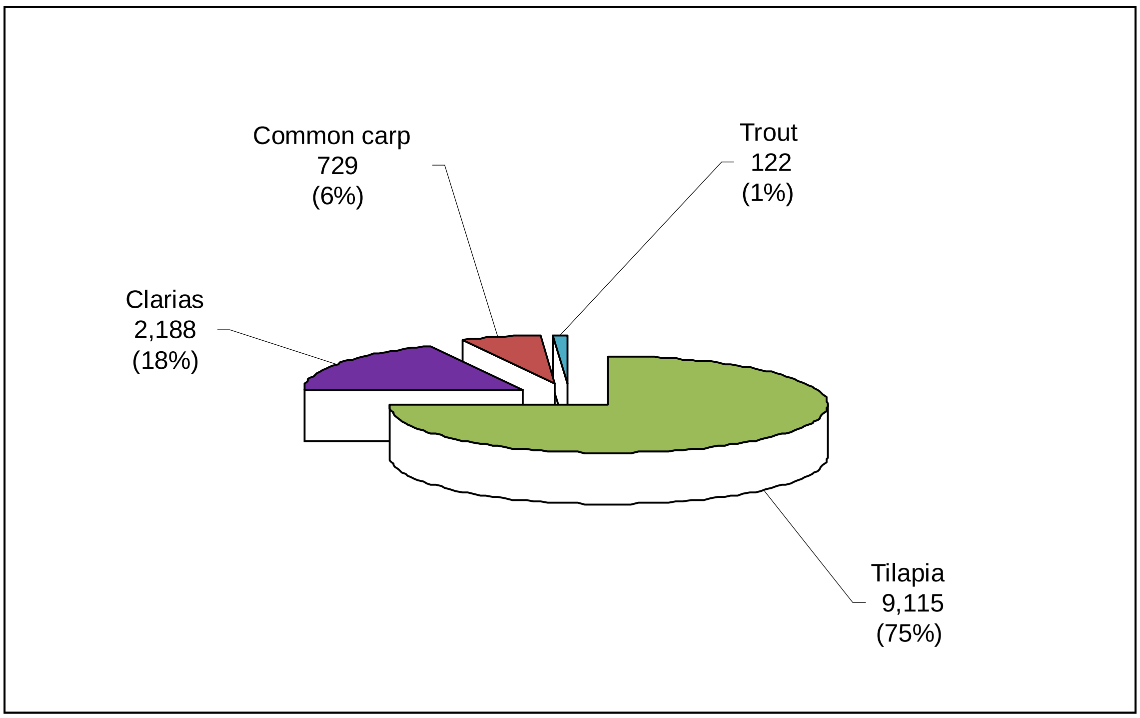


Figure 2.1: **Aquaculture production in metric tonnes by species in 2010**

Source: (NALEP, 2010).

2.3 Fresh water fish production systems

Fish production systems are typically classified according to type of fish, biomass density and feeding practices. The division based on water flow rates provides a fundamentally more useful way of describing water quality process that control fish production (Krom and Neori 1989). Wijkstrom and Macpherson stated that large scale and intensive aquaculture enterprises are often beyond the means of most farmers in Africa, but small scale aquaculture with a commercial orientation could be a profitable economic activity (Wijkstrom and Macpherson 1990). Green *et al.,* reported that economic considerations are the main driving factors in the selection of appropriate aquacultural production systems. Such considerations include potential for economic returns, economic efficiency and access to operating capital (Green *et al*., 2002).

2.3.1 Extensive production system.

In extensive production systems farmers use naturally available feeds to feed the cultured fish. Ponds are routinely fertilized with droppings from domesticated animal or tender leaves as compost manure. Feeds used vary depending on availability. Kaliba *et al.,* in a study in Tanzania observed that feed supplements such as rice, maize bran, and kitchen left overs were occasionally used in this system (Kaliba *et al.*, 2006).

Terchert-Coddington and Green (1997) and Ramnarine (2000) noted that the main fish holding units were small earthen ponds with no inputs, relying mainly on natural plankton and detritus present in water and soil (Teichert-Coddington and Green 1997). They also observed that families typically consumed most of the fish and only a small portion was sold. Watanabe *et al.,* (2002) reported that mixed sex culture tilapias were often cultured at low stocking densities and yields were usually low (Watanabe *et al*., 2002). In addition, Alceste (2000) noted that in most developing countries, farmers who used this system had a low social cultural and economic status and limited access to technology, markets and credit. Fitzsimmons (2000b and Fonticiella and Sonesten, (2000) working in the Dominican Republic noted that extensive tilapia culture has helped the rural poor to improve their household nutrition and raise their standards of living (Fonticiella and Sonesten 2000).

2.3.2 Semi-intensive production system

Terchert-Coddington and Green (1997) defined this system as one where production is done in earthen ponds with nutrient input limited to manure and supplemental feeds with no aeration or water exchange (Teichert-Coddington and Green 1997). Lovshin (2000) working in Brazil noted that semi-intensive pond culture of tilapia was typically integrated with agricultural or animal husbandry activities because pond fertilization with organic (e.g., crop residues or manures) fertilizers could promote natural pond productivity in addition to being consumed directly by tilapia. The researcher observed that ponds which were integrated with pig husbandry had high yields (Lovshin, 2000).

Production in developing countries such as Kenya occurs mainly in semi-intensive ponds, where cheap feed supplements and fertilizers are applied to produce low cost fish (DM Liti & Munguti, 2007). The suitability of *Orechromis niloticus* for semi-intensive culture stems from their ability to utilize feeds from a wide range of materials including plants (Moriarty 2010; Moriarty and Moriarty 1973; Getachew 1987; Getachew and Fernando 1989).

2.3.3 Intensive production system

Hanley (2000) described this system as practiced in cages, ponds, raceways and tanks with large amounts of flowing water from rivers or streams. In the United States of America, tilapia is cultured in cages placed in abandoned phosphate mining pits in Florida and in watershed ponds in Alabama (Popma and Rodriquez 2000). Fitzsimmons (2000a) noted that cages vary widely in construction from simple bamboo enclosures to complex steel and plastic designs.

(Alceste, 2000) noted that this system is practiced by companies who produce fish for export. In addition to complete water exchange supplemental aeration with paddlewheels or air injection is usually applied.

Michielsens *et al.,* (2002) in a study to characterize carp farming systems in Asian countries used 12 variables in the classification. The variables included the type and area of aquaculture facility (pond, cage/pen or raceway), ratio of aquaculture facility area to total farm area. Other factors used in the characterization included water added during the culture period, use of inorganic fertilizers, total organic fertilizer, and ratio of organic fertilizer collected on or off the farm to total organic fertilizer used. Feeding systems used were total feed added (purchased and collected on or off farm), ratio of feed collected on- or off-farm to total feed added. The number of fish species cultivated, stocking density, total labour (family labour plus permanent or casual hired labour), and ratio of family labour to total labour were also used. They came up with six clusters which included Intensive systems based in pens/cages, raceways. Specialized semi-intensive systems which were exclusively pond-based systems were located mostly in India. It was characterized by polyculture of 3ï 10 carp species at low stocking densities and high inputs of fertilizers and feeds.

2.3.4 Integrated production system

An integrated farm is one in which the wastes from each farming enterprise are recycled into other enterprises, thus raising the economic and ecological efficiency of all enterprises.

In a study in Malawi, Brummett and Chikafumbwa (1994) found that farmers practice integrated crop-fish farming where there are crops planted around the ponds**.** The researchers also noted that integrated farm ponds enabled farms to spread the risks due to crop failure on seasonal crop lands by retaining water on the farm.

According to Chimatiro and Scholz (1995) the average fish productivity of integrated Malawian small holdings was higher than that in non-integrated fish holdings. They noted that the difference was due to the range of available pond inputs and the location of the pond relative to other farm enterprises. They also established that integrated farms produce almost six times the cash generated by typical Malawian small holder farmer.

Brummett (1997) noted that on integrated farms, ponds are generally located near vegetable gardens or vegetable gardens develop around the fish pond to take advantage of emergency irrigation water and wastes from the garden, which are used to feed fish. The researcher established that these wastes amount to 3,700 kg of dry matter per year and the material is generated in close proximity to the pond, minimizing the work involved in transportation. He also noted that non integrated farms use maize bran which is produced in the house often far from the pond. Maize is also a possible emergency food for humans whereas vegetable garden wastes are typically burned if not used in the pond.

Lightfoot and Noble (1993) and Lightfoot and Pullin (1995) found that small scale integrated farming systems are more efficient at converting feeds into fish and produce fewer negative environmental impacts than purely commercial fish farms. The combination of aquaculture, crop and livestock production in integrated agriculture-aquaculture systems is often considered a sustainable agricultural model for small holders in developing countries (Lightfoot *et al*., 1993; Prein 2002)

Elsewhere, Li 1987 (1987); Richards *et al*., (1989); Luu *et al.*, (2002) and Pant *et al.*, (2002) noted that integrated agriculture-aquaculture farming is a traditional and well developed practice in China and Northern Vietnam. The integrated agriculture-aquaculture system is almost completely closed with a small environmental impact due to strong nutrient linkages between integrated agriculture-aquaculture components.

Nhan *et al.*, (2007) noted that farmers use on farm resources in pond culture to produce fish and reduce environmental impacts of farming activity. The main aim of integrated agriculture-aquaculture farming is to increase the whole farm productivity while reducing nutrient discharges (Edwards, 1998). Luu *et al.*, (2002) in a study in Mekong Delta found that intensive pig production is practiced where pigs are fed commercial feeds and farmers get high fish yields from pig manure.

2.4 Species cultured

Nile tilapia *(Oreochromis niloticus*) is one of the widely farmed tilapia species in tropical countries. This is because they feed low in the food chain and also consume a wide variety of materials (De Silva, 1993). Production in developing countries such as Kenya occurs mainly in semi-intensive ponds, where inexpensive feed supplements and fertilizers are applied to produce low cost fish. At low levels of production, fertilizers are applied to increase fish yields (Green et al., 1989; Knud-Hansen et al., 1993) while at high levels, feeds-only or feeds combined with fertilizers are applied to optimize fish yields (Diana et al., 1991; Diana et al., 1994)

Polyculture of tilapia with the African catfish *(Clarias gariepinus)* is often done to control the prolific breeding of the former. Some exotic species, including the *Cyprinus carpio* (Common carp), *Oncorhynchus mykiss (*rainbow trout) and *Micropterus salmoides* (largemouth bass) have been introduced in Kenya for aquaculture purposes. The rainbow trout was introduced in Kenya during colonial period mainly for sport fishing.

Clarias gariepinus (African catfish) is one of the most important fish species currently being cultured both within and outside its natural range of tropical and subtropical environments

(Adewolu et al., 2008). Its resistance to diseases, high fecundity and easy larvicidal production in captivity makes it of commercial importance (Hogendoorn 1979; Haylor 1991; Kestemont et al., 2007)

2.5 Holding Structures

Fish farming is practiced at varying degrees of intensification using the following holding units (Mbugua, 2002):-

(i) Pond culture: Mainly use earthen ponds for extensive or semi-intensive aquaculture. Mostly for the culture of tilapines, catfish and common carp.

(ii) Raceway culture: These are rectangular ponds through which water flows continuously. They are either concrete or earthen, although the latter is more common in Kenya. These units allow for high stocking densities because of the high water exchange rate and provision of a complete diet for the fish. Raceway culture is used mostly in trout farms. Examples include Kiganjo Trout Hatchery and Ndaragwa Trout Farm

(iii)Tank culture: Tanks are usually circular concrete structures with a central outlet. This system deploys continuous water flow and complete feeding with formulated feeds.

Machena and Moehl (2001) in a review of aquaculture pontetial in Africa noted that production occur in a variety of production structures such as cages, ponds, tanks and raceways. These structures are used in small, medium and large scale operations and at various levels of intensity. The researchers also noted that earthen ponds are the dominant production structures in Africa.

Trout is traditionally produced in inland flow-through systems without water re-use. The water residence time in the rearing unit is usually in the range of minutes (Lawson, 1995). Lawson (1995); Wheaton and Singh (1999) noted that the inflowing water can be used once when the units are parallel grouped or up to several time when grouped in series.

Timmons et al., (1999) observed that rearing units of fish are either earthen or concrete raceways or tanks. Elsewhere, Lukowicz (1994) noted that trout culture in freshwater is mainly determined by the amount and quality of water available, limiting the maximum production capacity at a location. (Bowman et al., (2007) outlined the following physical factors: land area, the water supply, and the soil as important to consider when evaluating and selecting sites for earthen fish ponds.

2.6 Feeding management in fresh water fish aquaculture

Fish reach marketable table size (250g for tilapia) in six monthsô time in a well-managed fish pond. Some management practices influence fish growth, these include:- pond fertilization, feeding the fish with feeds enriched with proteins and management of water quality parameters. Fertilizing the pond encourages growth of algae which aerates the pond. In addition, growth of zooplanktons is enhanced by fertilization of the pond. Natural food in the pond can also be supplemented with commercial feeds (semi-intensive system) to reduce competition for food and enhance growth (Ngugi et al., 2007). Fertilizer plays two major roles in semi-intensive production of tilapia: (i) it improves fish nutrition through stimulation of natural food (Schroeder et al., 1990), and (ii) it provides oxygen through photosynthesis, while ammonia levels are reduced through assimilation by phytoplankton (Boyd, 1990).

Feed is the most costly item in fish production and accounts for over 50 percent of the total operating costs (Shang, 1992). According to Liti et al., (2005), Semi-intensive culture of *O. niloticus* in Kenya has been based on feeds formulated for intensive production. This practice has led to increased production costs and cosequent reduction in profits. The nutrient requirements shared among different species generally include protein, lipid, amino acid and water-soluble vitamins. Further, carbohydrate utilization by closely related species or species groups falls within a narrow range. Similarly, the differences in the requirements of most of the micronutrients, such as amino acids, vitamins, minerals and fatty acids show marginal variation between cultured species (De Silva & Anderson, 1995). Therefore, general nutritional principles can be applied, and reliable data from closely related species can be utilized as and when appropriate. The use of such nutritional strategies will strengthen sustainability of the production system as a whole.

Little or no information exists on the dietary requirements under farming conditions for many of the species cultured in Kenya. To a large extent, this is due to the difficulties of quantifying the contribution of naturally available food organisms to the overall nutritional budget of pond-raised finfish or crustaceans (Tacon, 1993).

Orechromis niloticus is one of the most important species among the commercially farmed tilapias. Under natural conditions, the adults of this species consume large quantities of plant materials, which are largely dominated by live algae, detritus and the associated bacteria (Dempster et al., 1993; Moriarty and Moriarty 1973) Tilapia offspring produced during grow-out compete with initial stock for food, resulting in a lower yield of marketable fish and little economic value. Therefore, pond management strategy should attempt to achieve efficient utilization of nutrient inputs and minimize potential for the production of tilapia offspring during grow out period (Green *et al.*, 2002). Availability of feeds is a major constraint to aquaculture in developing countries. Peri-urban aquaculture benefits from the use of domestic wastes, while a wide range of polycultures and integrated agriculture-aquaculture systems (for example, fish in association with rice, pigs, or ducks) offer feed options for rural areas (The World Bank, 2006).

Herwig et al., (2006) reported that feeding rate and pond fertilization significantly increased fish growth, profitability and water quality. Green (1992) working in Egypt found that young tilapia grew rapidly during initial 60 days of culture in ponds in which natural productivity was stimulated by pond fertilization.

Green *et al.,* (2002) also working in Egypt noted that feeding fish commercial feeds without fertilization led to poor performance of fish because the young fish cannot consume the pelleted commercial feed. Feeding commercial feeds to fish after 59 days increased their growth substantially because the fish can consume pelleted feeds (Green, 1992).

Diana *et al.,* (1994), demonstrated that ponds receiving a combination of feed and fertilizer were more efficient in the production of *O. niloticus* than feed-only ponds, and attributed the superior growth of tilapia in the fertilizer-feed treatment to improvement in water quality in the fertilized ponds.Green (1992) also observed better growth of tilapia in the treatment combining supplemental feeding with fertilization.

Diana *et al.,* (1994) working in Thailand found that the net tilapia yield in ponds fertilized with high rate of chemical fertilizer was high. Knud-Hansen *et al.,* (1993) working in Honduras found that chemical fertilization of ponds effectively stimulate primary productivity. Production of *O. niloticus* in fertilized ponds largely depends on natural pond productivity (Knud-Hansen *et al*., 1991; Diana *et al*., 1991), but feeds may be added into the ponds to increase fish yields (Green 1992; Diana *et al*., 1994). Yields between 2500 and 4000 kg ha-1 of *O. niloticus* have been reported from fertilized ponds (Diana and Lin 1998; Diana *et al*., 1991). Liti *et al.,* (2005) working in Kenya found that formulated feeds produced higher yields than pig pellets and wheat bran but wheat bran had higher economic returns. In another study Green (1992) found that yields from organically fertilized ponds were significantly higher than yields from chemically fertilized ponds.

2.7 Water quality management

Several water quality parameters affect fish production; these include temperature, oxygen concentration, pH and turbidity. Bisson and Bilby (1982) and Lloyd (1987) noted that total suspended solids can cause a reduction in fish fry survival and gill damage. Elsewhere, Summerfelt (1999) determined that total suspended solid concentration should not exceed 80 mgl^{-1} for optimal fish health in fresh water.

Schäperclaus (1992) noted that elevated ammonia (NH_3) concentration can lead to blood ammonia intoxification or autointoxification in fish. According to Twitchen and Eddy (1994) high ammonium (NH_4^+) concentration leads to ionic imbalance in the blood and acid-base disturbances. Environmental pollution ï mainly eutrophication from nitrogen and phosphorus in effluents from aquaculture facilities ï also can limit the growth of aquaculture and negatively impact natural ecosystems (Håkanson *et al.,* 1998; Lemarie *et al*., 1998)

Ammonia is the major end product in the breakdown of proteins in fish. Fish digest the protein in their feed and excrete ammonia through their gills and in their feces. The amount of ammonia excreted by fish varies with the amount of feed put into the pond or culture system, increasing as feeding rates increase. Ammonia also enters the pond from bacterial decomposition of organic matter such as uneaten feed or dead algae and aquatic plants (Durborow *et al*., 1997). According to Hargreaves and Craig (2004), ammonia is toxic to fish if allowed to accumulate in the fish pond. When ammonia accumulates to toxic levels, the fish cannot extract energy from feed efficiently. If the ammonia concentration gets high enough, the fish will become lethargic and eventually fall into a coma and die. In properly managed fish ponds, ammonia seldom accumulates to lethal concentrations. However, ammonia can have the so-called ñsub lethalò effects - such as reduced growth, poor feed conversion, and reduced disease resistance at concentrations that are lower than lethal concentrations.

Tiews (1981) observed that in an open system in which oxygen and carbon dioxide can be exchanged across the air-water interface in the USA, unionized ammonia was the most limiting factor. Depletion of dissolved oxygen has been observed to be a serious problem in many pond systems and may be caused by daily fluctuations in dissolved oxygen due to photosynthesis and respiration and the sudden die-off of algae (Tucker *et al*., 1979). Management problems with ponds also include high pH and off flavor which could lead to death of fish.

2.8 Fish pond management

2.8.1 Carrying capacity

Achieving maximum growth is a common goal in fish aquaculture. Production units in fish farming are stocked with young fish whose growth rates are influenced by feeds and other environmental factors. As feed availability and/or water quality conditions become limiting, the rate of growth rate slows down until it gets to the point whereby growth reaches zero and the biomass remains stable (Diana, 1997). At this stage, the pond is said to have reached its carrying capacity; because the nutrients and/or water culture conditions in the pond are inadequate to foster growth. The reason why there is a limit on how much production can be sustained at different management levels is because of limits in access to feed, feed quality and water quality.

2.8.2 Management Level 1 – Unfertilized Pond

According to Isyagi *et al.,* (2009) unfertilized ponds are the lowest, most extensive level of fish production management in ponds. At this level, the amount of food available to the fish for production depends entirely on how much can be produced by natural productivity.

The amount of natural productivity depends on soil fertility, water depth, etc. Ponds at management level 1 should be therefore managed as ‗static water'. If water is allowed to continuously flow-through such ponds, the natural food generated gets washed out. At this management level, food quantity is the first limiting production factor.

2.8.3 Management Level 2 – Fertilized Ponds

In fertilized ponds, extra nitrogen, phosphorus, lime and possibly organic material like manure are added to the pond to enhance natural productivity. The ponds are managed as ‗static water' to avoid washing away the nutrients added and plankton produced. Such ponds are able to generate much more plankton as food for the fish than unfertilized ponds (Diana, 1997). Therefore, more kilograms of fish can be sustained in the pond to the point whereby, the fish start consuming the plankton produced at a rate faster than it can be regenerated. At this management level, the amount of plankton that can be produced is usually the first limiting production factor. Catfish do not consume phytoplankton, but they can consume zooplankton and insects (Isyagi *et al.,* 2009).

2.8.4 Management Level 3 - Supplemental Feed

At this level of management, feed rich in energy is added to supplement the food produced through natural production. Supplementary feeding is often done on combination with fertilization as documented by (Diana, 1997). The strategy is to provide an alternative source of energy to the fish, while the plankton provides the fish with their protein and vitamin requirements. Supplementary feeding is often done on combination with fertilization Isyagi *et al.,* (2009). However, because the farmer has no physical control over how much plankton as well as how much protein and vitamins the plankton can produce, the first limiting factor to increased production is feed quality.

2.8.5 Management Level 4 - Complete Feed

At this level of management, the fish are provided all their nutritional requirements through a nutritionally complete feed pellet. The commercial feed pellets used in this case may either be sinking or floating. The biomass of fish produced in this case is limited by the effect of feed metabolism on water quality. As the amount of feed increases, the water quality starts to deteriorate. Dissolved oxygen (D.O.) is usually the first water quality parameter to drop, and become the limiting factor for fish production (Diana, 1997).

2.8.6 Management Level 5 - Aeration

According to Diana (1997), at this level of management, fish are fed nutritionally complete feeds but the limiting effect of feed metabolism on dissolved oxygen levels is overcome through aeration. Therefore, a higher biomass can be supported up to the point whereby the accumulation of ammonia in the system, as a form of protein metabolism by the fish, becomes the limiting factor.

2.8.7 Management Level 6 - Partial Water Exchange

At this level of management, the fish are fed nutritionally complete feeds and the limits of feed metabolism on dissolved oxygen levels can be overcome through aeration, while ammonia accumulation is managed through partial water exchange to wash out and dilute wastes (Isyagi *et al.*, 2009). If aeration is not involved, the water exchange rate must be increased. According to Diana (1997), in management level 6, the accumulation of wastes is physically managed by removing a proportion of the pond water with high nutrient load and replacing it with good quality water. This results in a reduction of the concentration wastes in the water. At this management level, it is up to the manager to decide how much water and how often water should be exchanged, to achieve the desired levels of water quality. Hence, the upper limits on how much can be produced for this level, depend not just on the feed, but on the water resources the manager has a hand as well as the costs of using this water effectively.

2.8.8 Management Level 7 - Flow through Water Exchange

At this level of management, the fish is fed high quality nutritionally complete feeds because there is no other source of nutrients available to the fish. The limits of feed metabolism and feeding on dissolved oxygen levels, ammonia and organic loading, are overcome by continuously allowing good quality water to flow through the pond. This dilutes and washes away wastes before they accumulate to levels that reduce water quality for production. Fish density at this level can be extremely high. However, the amount of fish that can be raised in such a system is limited by what flow rates are required to effectively wash out wastes and replenish water quality (Isyagi *et al.*, 2009).

2.9 Diseases and parasites

A large number of parasites infect fish but only a few are zoonotic. Humans acquire these fish borne parasitic zoonoses through the consumption of infected raw, undercooked or inadequately preserved fish (Slifko *et al.*, 2000). Helminths in the following families Opisthorchiidae and Heterophyidae (Class Trematodea, subclass Digenea), Anisakidae and Gnathostomidae (Phylum Nematoda), and Diphyllobothridae (Class Cestoda) are of major concern.

In a recent review of evidence linking fish farming to human pathogenic diseases, Lima dos Santos & Howgate (2011) found that several parasitic diseases can be transmitted from fish to humans and that control and prevention measures should be put in place. Some of these diseases include diseases caused by the following pathogens: *Salmonella spp, Campylobacter spp, Mycobacterium spp* and *Cryptosporidium* (Nemetz *et al*., 1993). One way of preventing transmission of diseases and parasites from farmed fish to humans is through the implementation of the Hazard Analysis and Critical Control Point (HACCP) system. The implementation of this system is more feasible in cases of medium and large sized farms but this is also applicable in small subsistence fish ponds (Lima dos Santos and Howgate 2011).

In an assessment of small-scale fish farming in Malawi and central Mozambique, Hecht (2006) found that diseases and parasites were of little consequence in small-scale fish farming. Serious infections have only been reported in those countries in which aquaculture is reasonably developed and where rainbow trout and common carp are being cultured. These include Nigeria, South Africa, Zambia and Zimbabwe.

2.10 Fish Marketing.

Fish marketing is essential for the development of aquaculture because it influences the profitability and sustainability of the enterprise (Huisman, 1990). Small-scale aquaculture development efforts in the past have emphasized the importance of aquaculture for food security without focusing on the commercial dimensions of fish farming (Jamu & Brummett, 2004).

Gupta & Acosta (2004) showed that consumers in Kenya prefer larged sized whole fish to smaller fish. Size is mainly influenced by management practices used especially species stocked, feeding and aeration of ponds.

Kwamena *et al*., (2010) reported that most fish produced by small-scale farmers in Kenya was sold at the farm gate. The study also found that the fish marketing channel was short involving producers, retailers and consumers with low and inconsistent supply. The researchers also noted that the buyers included institutions such as schools and restaurants and private individuals from the local community. There was no group marketing. The fish sold was fresh but some low cost preservation technologies such as smoking and deep frying were used to add value to the products.

2.11 Economic stimulus program

The Economic Stimulus Program was initiated by the Government of Kenya in 2009 to boost economic growth in response to the 2008-2010 global economic recession. The ESP was introduced in the 2009/2010 budget speech in parliament by the then finance minister. Its aim was to jumpstart the Kenyan economy towards long term growth and development, after the 2007/2008 post-election violence that affected the Kenyan economy, prolonged drought, a rally in oil and food prices and the effects of 2008/2009 global economic crisis (GoK, 2010). The ESP was made necessary by the decline in economic growth rate from 7.1 percent in 2007 to 1.7 percent in 2009 (GoK, 2010). In 2010, the Ministry of Fisheries Development rolled out the Fish Farming Enterprise Productivity Programme (FFEPP) under the ESP and the Economic Recovery, Poverty Alleviation and Regional Development Programme (ERPARDP). Phases I and II of the FFEPP were implemented in 2010 under the ESP and ERPARDP, respectively (Maina *et al.*, 2014).

The main activity of both phases was the establishment fish ponds in selected regions in the country in order to promote commercial aquaculture. This was executed through the provision of extension services and fingerlings as well as farmer training. The African catfish and Nile tilapia were the main species promoted by the ESP throughout the country.

The current study will build on the existing literature on characteristics of the fish farming enterprise in terms of management practices and challenges in the sub-sector. The study will focus on the fish farming enterprise to document the socio-economic characteristics of the fish farmers, management practices adopted by the farmers, marketing of the farmed fish and challenges experienced by the fish farmers. The study will also document the influence of ESP funding on fish farming and also analyse the quality of water and feeds used by farmers. The study will therefore provide information on the characteristics of fish farming enterprise in Kenya. Information will further be provided on the influence of ESP on management and service delivery and also quality of water and fish feeds used by farmers. These information will guide farmers in fish farming management and inform formulation of projects targeting fish farmers in Kenya.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Study area

The study was carried out in Kiambu and Machakos Counties in Kenya. The area was chosen because of the following reasons: (i) the two Counties border the Nairobi metropolitan area which is an important fish market; (ii) the two Counties had a short history of fish farming, (iii) in both Counties, the farmers practice mixed farming, and (iv) for comparison purposes: Machakos County is drier than Kiambu County.

Kiambu County is located in former Central Province of Kenya, where fish farming and consumption are not traditional practices. The area borders Nairobi where is a lucrative market for fish. The County covers an area of 1,323.9 Km². It borders Nairobi city and Kajiado County to the south, Nakuru County to the west, Nyandarua County to the northwest and Machakos County to the east. The County lies between latitudes 0°75Nĝand 1° 20Nĝsouth of Equator and longitudes 36° 54Nĝand 36° 85Nĝeast (figure 3.2).

On the other hand, Machakos County is in a semi-arid agro-ecological zone with no history of fish farming. The County border the city of Nairobi and Kiambu, Murangĝa and Embu Counties to the northwest, Kitui County to the east, Kajiado County to the west and Makueni County to the south.. It stretches from latitudes 0º 45ô south to 1º 31ô south and longitudes 36° 45ôeast to 37° 45ô east (figure 3.1). The two Counties were among those that received funds for the implementation of the FFEPP under the ESP(GOK 2010).

Figure 3.1**: Map of Machakos County showing sub Counties**

Source : Kenya Bureau of Statistics (2009)

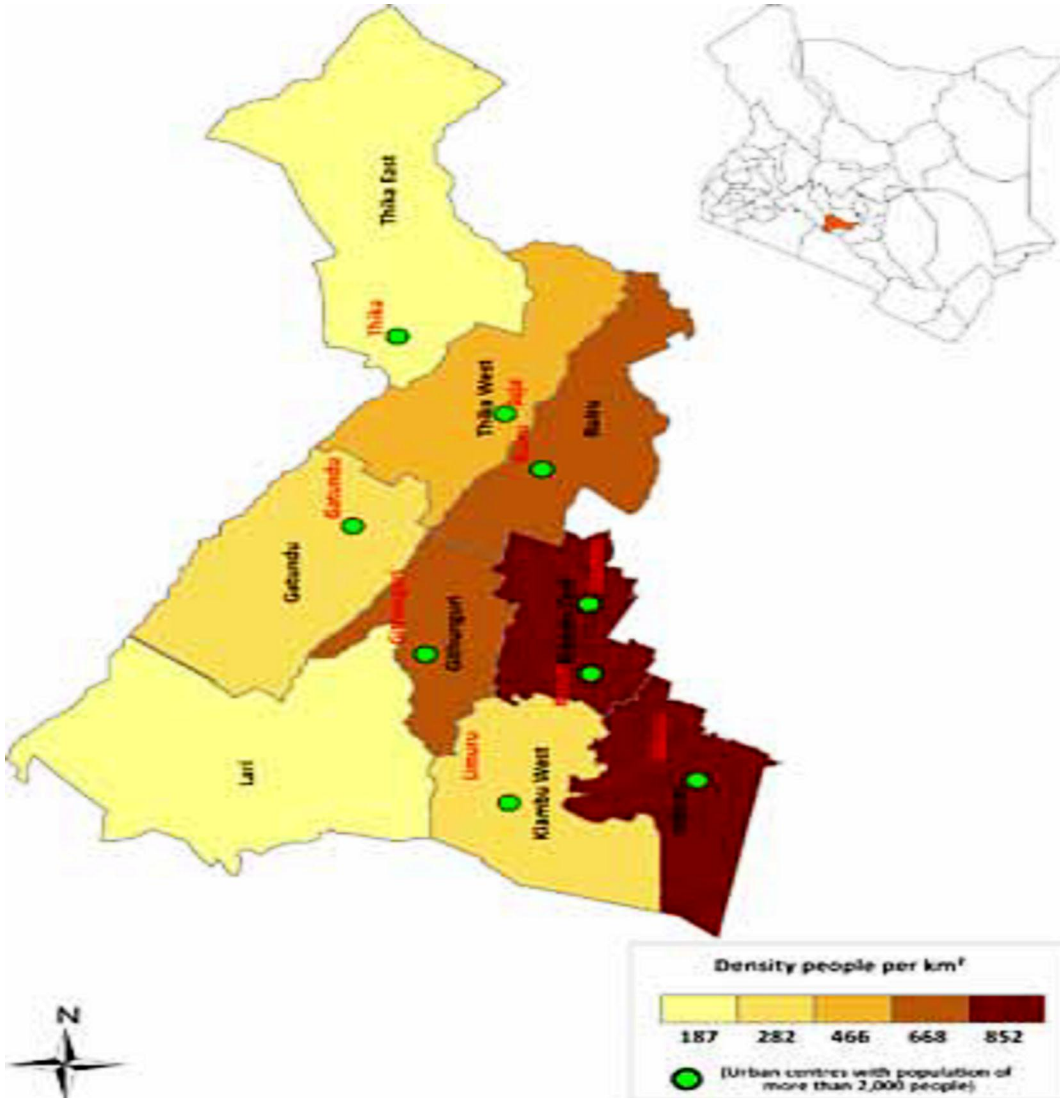


Figure 3.2**: Map of Kiambu County showing sub Counties.**

Source: Kenya National Bureau of Statistics (2009)

3.2 Sampling procedure and sample size

Households were the sampling units used in the study. Samples were purposively drawn from the sampling frame provided by District Fisheries Officers in the respective study areas.
The area of study within the County was purposively chosen according to the sampling frame provided by the district Agricultural Officer.

The sample size was calculated using the formula shown below (Yamane (1967).

$$n = \frac{N}{1 + N(\epsilon)^2}$$

Where n is the sample size,

N is the population size

e = is sampling error, which is approximately 10%

According to Ministry of Fisheries Development Kiambu and Machakos Counties had approximately 666 and 598 fish farmers respectively in 2011 and therefore the sample size is calculated as follows:-

$$n = \frac{1264}{1+1264(0.1)^2} = 100$$

The minimum sample size calculated was

farmers were selected for the study.

A semi-structured questionnaire was prepared and given to aquaculture experts to check content and validity (see appendix A). After incorporating expertsô comments, it was pre-tested, and then a final version incorporating the pre-test results was produced. All questionnaires were administered through face-to-face interviews by the researcher with the help of five enumerators.

3.3 Data collection procedure

3.3.1 Management practices used by fish farmers in Kiambu and Machakos Counties in Kenya

Both primary and secondary data were collected. Secondary data were collected from published literature, government projects and other reports. The collection of secondary data involved paying visits to libraries of government institutions (Ministry of Fisheries Development and Kenya Marine and Fisheries Research institute) as well as to documentation centers of NGOs and the private sector organization involved in aquaculture.

The questionnaire gathered the following information:

(i) Respondentsô socioeconomic characteristic relevant to explaining adoption of fish farming was collected including age, gender of household head, marital status, level of education, occupation and farm size.

(ii) Data on fish management practices included: Stocking rates, farm size in acres, pond size, type and number of fingerlings stocked, type of pond and number of ponds and fish species stocked. Pond management practices were assessed using data on pond fertilization and topping up of water in the pond. Observations were also made on the colour of the pond water and analysis done to determine the suitability of water for fish farming. Data on pond fertilization were also collected including the type of fertilizer used and the frequency of fertilization. Percentage of ponds using a certain kinds of fertilizer and manure were determined and correlated with the type of feeds in order to determine the level of intensification and integration. Data were collected on type of feed fed to fish, amount fed daily and the number of times feeding is done, source of fertilizer, type and frequency of fertilization. Feed samples were obtained for sigma feeds which was supplied by government, king feeds and any other type of feed fed to the fish by the farmers. This was obtained purposively from farmers who were willing to give some small amount of the feed. Water samples were taken from 30 randomly selected fish ponds in each County between 9 am and 10 am using a 2 litre water bottle and analyzed for chemical properties.

(iii) To show that fish farming is mixed with other farm enterprises data were collected on the other crop and livestock enterprises existing on the farm, location of the fish pond, source of manure, source of home made fish feeds and whether the pond water was used for irrigation or not.

(iv) To evaluate fish marketing, data were collected on types of markets, Farm-gate prices, Source of market information, Products marketed, and quality standards for farmed fish.

3.3.2 Water sample analysis

The water samples were analyzed for pH, nitrites, ammonia, phosphates and permanganate value. The pH was tested using the pH test kit. Ammonia was analyzed using the Nessler method according to the association of official analytical chemists. To determine the amount of un-ionized ammonia present, the fraction of ammonia that is in the un-ionized form for a specific pH and temperature from the table (Appendix B) is multiplied by the total ammonia nitrogen present in a sample to get the concentration in ppm (mg/L) of toxic (un-ionized) ammonia (Emerson *et al.,* 1975).

Nitrites, phosphates and permanganate value where analyzed using the standard analytical methods as per the Association of official Analytical chemists at the Government chemist laboratories in Nairobi (AOAC 2005).

3.3.3 Feed sample analysis

Proximate analysis of the feeds was done at the Kenya Industrial Research Institute (KDRI) using the standard analytical methods as per the Association of official Analytical chemists (AOAC 2005).

3.3.4 Influence of the Economic Stimulus Program on service delivery management practices and fish yields in the two Counties

To determine the influence of the ESP on fish farming, data were collected on :

(i) Pond establishment date, number of ponds, source of funding, sources of fingerlings and feed, sources of information on aquaculture, whether farmer was recruited by the government, frequency of contact with government extension staff, type of advice received and the amount and quality of fish harvested.

(ii) Source and type of labour and capital: Information was collected and analysed to determine whether the hired labour was funded by the ESP. Data were also collected on sources and amount of capital for pond establishment including source of funds for purchase of liners.

3.3.5 Marketing of farmed fish in the two Counties

To evaluate fish marketing, data were collected on types of markets, farm-gate prices, sources of market information, products marketed, quality standards for farmed fish and demand for fish.

3.4 Statistical analysis

All the data were capture, stored analyzed using SPSS Version 16. Two analyses were made: descriptive analyses (by use of means, modes, standard deviations, variance, percentages, and frequencies) and the inferential analyses (by use of t-test). The former provided the descriptive and documentation of the state of affairs as they were, while the latter indicated statistically significant relationships between the variables and in the testing of the specific objectives. The variables tested included, time of harvesting, Farm gate price in Kenya shillings, land size and frequency of pond refilling, price of harvested fish and number of fingerlings stocked. Means, standard deviation and p values were used to test differences that existed. All this were tested at the probability level of p=0.05

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Socio-economic characteristics of fish farmers in Kiambu and Machakos Counties

4.1.1 Distribution of respondents and response rate

The study covered a total of 250 fish farmers in both Kiambu and Machakos Counties with 150 fish farmers from Kiambu County and 100 fish farmers from Machakos County. The fish farmers interviewed were unevenly distributed in the divisions depending on the number in the sampling frame provided by the fisheries officer. In Kiambu County, the respondents were distributed as follows: Kiambu central (55), Githunguri (50), Kabete (10), Kikuyu (25) and Ndeiya (10). In Machakos County the distribution was as follows: Machakos Central (35), Kathiani (20), Athi-river (6), Kangundo (10) and Matungulu (29).

4.1.2 Gender of respondents

Table 4.1 shows that the majority of the fish farmers in Kiambu and Machakos Counties were men (80 percent, 74 percent, respectively). This is in agreement with the findings by Ellen and Gardner (2009) on the challenges facing women in Burkina Faso.

Table 4.1 Distribution of respondents by gender in Kiambu and Machakos Counties

	Kiambu County		**Machakos County**	
Gender	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Male	120	80	74	74
Female	30	20	26	26
Total	**150**	**100**	**100**	**100**

4.1.3 Age of respondents

Table 4.2 shows the age of fish farmers in the two Counties. The mean age of fish farmers interviewed was 45.7±13.19 years in Machakos County and 48.4±11.99 years in Kiambu County. The Table further shows that fish farming was practiced by a relatively large proportion of farmers below fifty years of age ï 61.7 percent in Kiambu and 69.4 percent ï both categories combined in Machakos Counties respectively under the ESP. Wetengere (2009) reported that younger farmers in Tanzania were more likely to try new technologies and were capable of doing labourious activities like pond construction, pond repair and total harvest. The mean ages obtained have important implications on future adoption of fish farming as a commercial enterprise since the youth are more likely to practice it over a longer period of time than the older farmers.

Table 4.2 Distribution of age of the respondents in Kiambu and Machakos Counties

		Kiambu County		
	ESP		**Self-funded**	
Age category(years)	**Frequency**	**Percentage**	**Frequency**	**Percentage**
26 ï 40	36	28.1	8	36.4
41 ï 50	43	33.6	4	18.2
51 ï 60	30	23.5	7	31.8
Above 60	19	14.8	3	13.6
Total	**128**	**100**	**22**	**100**
		Machakos County		
	ESP		**Self-funded**	
Age category(years)	**Frequency**	**Percentage**	**Frequency**	**Percentage**
26 ï 40	34	45.4	9	36.0
41 ï 50	18	24.0	8	32.0
51 ï 60	13	17.3	4	16.0
Above 60	10	13.3	4	16.0
Total	**75**	**100**	**25**	**100**

ESP- Economic Stimulus Program

4.1.4 Employment status of fish farmers

Table 4.3 shows the employment status of fish farmers in Kiambu and Machakos Counties. Majority of the respondents (79.3 percent and 54 percent in Kiambu and Machakos County respectively) were self-employed in agriculture, while 20.7 percent were self employed in non-farm enterprise such as formal employment, domestic work and casual labour in Kiambu County. Machakos County had similar trends having 46 percent self employed in non-farm enterprise. These results tally with what is reported in the 2010 Government of Kenya

Development Plan (Republic of Kenya, 2011) which shows that over 70 percent of Kenyans are employed in the informal sector, particularly agriculture.

In this study, it was also observed that respondents aged over 60 years who had retired from formal employment had settled in farming, and particularly fish farming. This corroborates the results obtained by Oseni *et al.*, (2011) who reported similar trends in Nigeria.

Table 4.3 Employment status of fish farmers in Kiambu and Machakos Counties

	Kiambu County		**Machakos County**	
Main occupation	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Self employed in agriculture	119	79.3	54	54
Self employed in non-farm enterprise	31	20.7	46	46
Total	**150**	**100**	**100**	**100**

4.1.5 Education level of fish farmers

All the fish farmers had formal education (Table 4.4). Only 23.8 percent and 16 percent of the fish farmers in Kiambu and Machakos County respectively, did not complete primary education. 25.2 percent and 45.3 percent of the farmers in Kiambu and Machakos Counties respectively, had attained a minimum of primary school education. The results presented in table 4.4 show the percentage who had at least primary level of education was highest for farmers who did fish farming under the ESP. The results show that only 13 and 3 percent of fish farmers under ESP and Self funded respectively in Kiambu County had not completed primary education. In Machakos County only 3 percent of farmers in both categories had not completed primary level of education. This could be due to the fact that fish farming was a relatively new venture and only farmers who had ready access to information and were willing to take risks, had adopted it since farmers with higher levels of education are more responsive to new technologies. This observation was in agreement with that of Kimenye (2005), who showed that increase in farmerõs level of formal education increased the probability to plant an improved crop variety. The fact that majority of the fish farmers had formal education imply that dissemination of information on fish farming is likely to yield positive results in terms of better management and improved productivity. The farmers who were recruited by the government to do fish farming had higher levels of education. This shows that the recruitment of the farmers might have been biased. Shitote *et al.,* (2013) reported that fish farming in Western Kenya was practised by farmers with at least primary level of education.

Table 4.4 Level of formal education among respondents in Kiambu and Machakos Counties

Kiambu County				
	ESP		Self-funded farmers	
Education level	**Frequency**	**Percentage**	**Frequency**	**Percentage**
University/college	3	2.3	2	9.1
University/college student	11	8.6	2	9.1
Secondary	87	68.0	8	36.4
Technical/polytechnic	5	3.9	3	13.6
Primary	9	7.0	4	18.2
Never completed primary	13	10.2	3	13.6
Total	**128**	**100**	**22**	**100**
Machakos County				
	ESP		**Self-funded**	
Education level	**Frequency**	**Percentage**	**Frequency**	**Percentage**
University/college	3	4.0	2	8.0
University/college student	10	13.4	5	20.0
Secondary	28	37.3	12	48.0
Technical/polytechnic	3	4.0	1	4.0
Primary	28	37.3	2	8.0
Never completed primary	3	4.0	3	12.0
Total	**75**	**100**	**25**	**100**

ESP- Economic Stimulus Program

4.1.6 Total farm size and land use

The average land size was 2.5±3.47 and 4.27±4.78 acres in Kiambu and Machakos Counties respectively. This was not statistically different between the two Counties (p=0.05)(Table 4.12) Land was primarily used for crops and livestock production. The major crops grown in the two Counties were maize, beans, vegetables and fruits. Both Counties had cash crops which included coffee and tea(in Kiambu County). In Kiambu County 5.3 percent of the farmers grew nappier grass as cattle feed for the zero grazed dairy cows (Table 4.5). Vegetables were grown mainly for commercial purposes in KiambuCounty and to a small extent in Machakos. Fruits were also grown in both Counties but results show that Machakos County had a larger percentage of fruit farmers than Kiambu County. The type of crops grown in both Counties had no influence on fish farming except that most farmers doing fish farming also grew vegetables under irrigation.

Table 4.5 Crops grown by respondents in Kiambu and Machakos Counties

	Kiambu County		**Machakos County**	
Crop enterprise	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Maize and beans	22	14	54	54
Vegetables	71	48	33	33
Coffee	29	19.3	6	6
Fruits	4	2.7	7	7
Tea	16	10.7	0	-
Napier grass	8	5.3	0	-
Total	**150**	**100**	**100**	**100**

4.1.7 Livestock enterprises

The main livestock species kept in Kiambu County were dairy cattle, goats, poultry, pigs and rabbits (Table 4.6). Cattle and goats were kept by 66.6 percent and 83 percent of farmers in Kiambu and Machakos Counties, respectively. Farmers practiced mixed farming of fish and other livestock species where manure from livestock was used to fertilize the fish ponds. Pigs and rabbits were only reported in Kiambu County which is close to the city of Nairobi which provides a ready market for pig and rabbit meat.

Table 4.6 Livestock enterprises among respondents in Kiambu and Machakos Counties

	Kiambu County		**Machakos County**	
Livestock enterprise	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Cattle and goats	100	66.6	83	83
Poultry	38	25.3	17	17
Pigs	8	5.4	0	-
Rabbits	4	2.7	0	-
Total	**150**	**100**	**100**	**100**

4.2 Influence of the Economic Stimulus Program on fish farming in Kiambu and Machakos Counties

4.2.1 Distribution of respondents under ESP and Self- funded fish farmer categories

Of the 250 respondents interviewed, 85.3 percent and 75 percent in Kiambu and Machakos Counties respectively were recruited through the ESP (Table 4.7). The rest of the farmers (14.7 percent in Kiambu and 25 percent in Machakos) started fish farming using their own funds and were doing it before the onset of the FFEPP. This study also established that 89.3 percent and 80 percent of the fish ponds in Kiambu and Machakos respectively were established between 2009 and 2010 financial years which is the period when the Economic Stimulus Program was rolled out.

These findings are consistent with reports by the Ministry of Fisheries Development which gave the number of stocked fish ponds to be 666 and 598 ponds in Kiambu and Machakos districts respectively, in its ESP implementation report of January 2011 (GoK, 2010). Musa *et al.,* (2012) indicated that 92% of ponds in Western Kenya were stocked in the year 2010 in comparison to four percent in 2009. The researcher pointed out that the high number of ponds stocked in 2010 may be attributed to the FFEPP which supported farmers in constructing and stocking of the ponds with ESP funds from the Government of Kenya (Musa *et al*., 2012).

Table 4.7 Distribution of respondents with respect to ESP in Kiambu and Machakos Counties

	Kiambu County		**Machakos County**	
Category of farmer	**Frequency**	**Percentage**	**Frequency**	**Percentage**
ESP funded	128	85.3	75	75
Self-funded	22	14.7	25	25
Total	**150**	**100**	**100**	**100**

4.2.2 Respondents' motivation for engaging in fish farming

In Kiambu County 79.6 and 91 percent of ESP and self-funded farmers, respectively kept fish mainly for commercial purposes while in Machakos County it was 56 and 72 percent respectively (Table 4.8). Another 7.8 and 4.5 percent for ESP and self funded farmers, respectively in Kiambu County and 38.7 and 20 percent in Machakos County kept fish for home consumption. The rest (6.3 percent in Kiambu and 4 percent-both ESP and self funded categories combined in Machakos) started the enterprise because it was a government initiative under the ESP. Charo-Karisa and Gichuri (2010) reported that the FFEPP started in mid-2009 aimed at increasing production of farmed fish from 4000 MT to over 20,000 MT in the medium term and over 100,000 MT per year in the long term. The latter observation suggests that some of the farmers did not own the government-driven fish farming enterprise. However, majority of the fish farmers in both Counties believed that fish farming was profitable and could contribute to their income.

Table 4.8 Motivation of respondents engaging in fish farming in Kiambu and Machakos Counties

	Kiambu County			
	ESP farmers		Self-funded farmers	
Motivation	**Frequency**	**Percentage**	**Frequency**	**Percentage**
To generate income	102	79.6	20	91.0
Hobby	8	6.3	1	4.5
Home consumption	10	7.8	1	4.5
Governmentøs initiative	8	6.3	0	0
Total	**128**	**100**	**22**	**100**
	Machakos County			
	ESP		**Self-funded**	
Motivation	**Frequency**	**Percentage**	**Frequency**	**Percentage**
To generate income	42	56.0	18	72.0
Hobby	1	1.3	2	8.0
Home consumption	29	38.7	5	20.0
Governmentøs initiative	3	4.0	0	0
Total	**75**	**100**	**25**	**100**

ESP- economic stimulus program

4.2.3 Source of initial information on fish farming

The main source of information on fish farming was government extension agents as was reported by 93.8 percent and 92 percent of ESP farmers in Kiambu and Machakos Counties respectively (Table 4.9). In both Kiambu and Machakos Counties the major source of information on fish farming management among farmers in the ESP programme was government extension services.

Non-governmental, neighbours and mass media also played a significant role in the delivery of fish farming technologies among self funded farmers in both Counties (Table 4.9). Jacobi (2013) in a study in Western Kenya reported that 58 percent of the farmers obtained information from extension officers and 23 percent from mass media.

Table 4.9 Sources of information to start fish farming in kiambu and machakos Counties

		Sources of Information (Percentage)			
County		**Government extension**	**Mass Media**	**Neighbours**	**NGOs**
Kiambu	ESP	93.8	2.3	2.3	1.6
	Self-Funded	22.7	18.2	27.3	31.8
Machakos	ESP	92.0	5.4	1.3	1.3
	Self-Funded	96.0	-	4.0	-

4.3 Influence of ESP on Pond management and fish farming inputs

4.3.1 Labour sources and use

The FFEPP supplied farmers with fingerlings, fish feeds and hired labour for the construction of the ponds through the ‗*Kazi Kwa vijana'* Programme. In both Kiambu and Machakos Counties, the average quantity of labour hired for construction of one pond was 9.1 ± 2.43 persons while the average cost of construction of a pond was KShs 21,680 ± 14534.18. However, not every farmer in the ESP benefited from government funding to hire labuor to dig the ponds. About 37 and 31 percent of ESP farmers in Kiambu and Machakos Counties respectively used their own labour to dig the ponds (Table 4.10). In Machakos County self funded farmers were also funded by the government to construct the fish ponds. All the non-ESP farmers hired their own labour. The cost of labour has important implications in terms of future adoption of fish farming and the size of the pond farmers construct since the larger the pond the higher the cost of labour.

Table 4.10 Sources of labour used for pond construction in Kiambu and Machakos Counties

		Source of Labour			
		ESP		Self-funded	
County	**Labour source**	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Kiambu	Government hired	81	63.3	3	13.6
	Hired by the farmer	47	36.7	19	86.4
	Total	**128**	**100**	**22**	**100**
Machakos	Government hired	52	69.3	15	60.0
	Hired by the farmer	23	30.7	10	40.0
	Total	**75**	**100**	**25**	**100**

Table 4.11 independent t test for variables influenced by ESP funding

Variable	**ESP funded farmers**	**Self-funded farmers**	**p-value**	**SEM**
Frequency of topping up	1.84	1.98	.611	.268
Frequency of fertilization	2.37	2.79	.032*	.192
Age of respondent	47.20	47.57	.853	2.033

Values with asterisk (*) denote significant different of the variables between the two categories of farmers at p=0.05

Table 4.12 independent t test for variables different between the two Counties

Variable	**Kiambu County**	**Machakos County**	**p-value**	**SEM**
Land size(acres)	4.27	5.93	.215	1.33
Frequency of topping up water	2.03	1.62	.052	.212
Number of fingerlings stocked	1066.53	876.29	.003*	64.349
Time of harvesting(months)	9.50	6.88	.000*	.321
Farm gate price (Ksh)	180.8	131.90	.000*	9.555

Values with asterisk denote significant different of the variables between the two Counties at p=0.05

4.3.2 Sources of fingerlings in Kiambu and Machakos Counties

Majority of the fish farmers under the ESP programme (84.4 and 68 percent) in Kiambu and Machakos County respectively were provided with fingerlings by the government (table 4.13). Many of the self-funded farmers in Machakos County were provided with fingerlings by the government which was not the case in Kiambu County. Musa *et al.,* (2012) noted that one of the principal activities of the FFEPP was to revamp fish hatcheries across the country to ensure sufficient production of fingerlings to stock the ponds. Other sources of fingerlings included; private hatcheries, rivers and supply by NGOs supporting fish farming.

Table 4.13 Sources of fingerlings in Kiambu and Machakos Counties

Kiambu County				
	ESP		**Self-funded**	
Sources of fingerlings	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Government supplied	108	84.4	3	13.7
Purchased	20	15.6	18	81.8
Borrowed from neighbors	-	-	-	-
River	-	-	-	-
Supplied by NGO	-	-	1	4.5
Total	**128**	**100**	**22**	**100**
Machakos County				
	ESP		**Self-funded**	
Sources of fingerlings	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Government supplied	51	68.0	10	40.0
Purchased	20	26.7	11	44.0
Borrowed from neighbors	3	4.0	1	4.0
River	0	-	3	12.0
Supplied by NGO	1	1.3	0	0
Total	**75**	**100**	**25**	**100**

ESP- Economic stimulus program

4.3.3 Supply of fish feeds and pond liners

Formulated fish feeds were mainly supplied by the government. Majority of farmers however complained of lack of feeds implying that the government was not a reliable source. Farmers purchased inorganic fertilizers and supplementary feeds like maize bran and fish meal from the local agrochemical stockists.

Lining of ponds is done to reduce seepage in porous soils. Pond liners were from dealers who are mainly in Nairobi. The major challenge in acquiring the liners was that they were very expensive costing KShs. 30,000 for a 300m^2 liner and many fish farmers could not afford them.

4.3.4 Sources of extension services to fish farmers

Majority of the ESP farmers (64.8 and 78.7 percent) in Kiambu and Machakos Counties respectively (table 4.14) relied on government extension services to provide information on fish farming. Among self-funded farmers, neighbours played an important role as source of information on fish farming. This was particularly evident in Machakos County. There was disparity in sources of information for the self-funded farmers. 18.2 percent in Kiambu and 72 percent in Machakos County of the self-funded farmers indicated that they obtained information on fish farming from the government. This category of farmers also relied on information obtained from other sources like neighbours and mass media.

Table 4.14 Sources of extension services to fish farmers in Kiambu and Machakos Counties

	Kiambu County			
	ESP		**Self-funded**	
Source of information	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Government extension	83	64.8	4	18.2
Neighbors	18	14.1	8	36.4
Seminars	20	15.6	7	31.8
Mass media	7	5.5	3	13.6
Total	**128**	**100**	**22**	**100**
	Machakos County			
	ESP		**Self-funded**	
Source of information	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Government extension	59	78.7	18	72.0
Neighbors	4	5.3	4	16.0
Seminars	3	4.0	1	4.0
Mass media	9	12.0	2	8.0
Total	**75**	**100**	**25**	**100**

ESP- Economic Stimulus Program

Seminars played a role in transmission of fish farming technologies especially in Kiambu County. The farmers indicated that most of the seminars were organized by government extension officers. The farmers who started fish farming prior to the ESP programme obtained information from neighbours and friends, mass media and NGOs. According to Quagrainie *et al.,* (2009), the increase in awareness among farmers in Kenya about the viability of farming fish as an alternative agricultural enterprise was as a result of initiatives by some Non-governmental organization in technology transfer programs toward improving fish farming.

4.3.5 Fish species and culture method

The most popular species stocked in Kiambu County by both ESP and self-funded fish farmers was tilapia which was by 96.1 percent and 90.9 percent of farmers under ESP and self-funded categories, respectively. In Machakos County, ESP farmers formed 94.6 percent for those who stocked tilapia. De Silva (1993) noted that *O. niloticus* is one of the widely farmed tilapia species in tropical countries because it feeds low in the food chain and also consumes a wide variety of materials.

Tilapia/catfish polyculture was done by 9.1 percent and 12 percent of farmers in Kiambu and Machakos Counties, respectively among self-funded category of farmers (Table 4.15). Machakos County had a higher percentage of farmers practicing catfish monoculture because of market preference for that species and also because fingerlings were easily obtained from river Athi.

The average price of a tilapia fingerling supplied by the government was KShs 3 although most of the farmers were supplied with fingerlings by the government. Crayfish was only found in Kiambu County where it was grown by 0.8 percent of the farmers interviewed. The study also found that the average pond area in Machakos and Kiambu County was $300M^2$ and that 1000 fingerlings were stocked per pond giving a stocking rate of approximately 3 fingerlings per square meter. The numbers of fingerlings stocked was statistically different between the two Counties (p=0.05) (Table 4.12). Musa *et al.,* (2012) also reported similar findings in western Kenya except for crayfish.

Availability of fingerlings is one of the pre-requisites of fish farming. This was supported by the fact that over 50 percent of farmers in the two Counties cited availability of the fingerlings and recommendation by the government as the main reason for their choice of fish species. In both regions, the practice was to introduce a few mature cat fish into tilapia ponds after 4 months of stocking tilapia to control the population of tilapia which reproduce very fast after reaching sexual maturity which is as early as 3 months (Diana et al., 1996).

Table 4.15 Type of fish culture practiced in Kiambu and Machakos Counties

		Kiambu County		
	ESP		**Self-funded**	
Type of culture	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Tilapia monoculture	123	96.1	20	90.9
Tilapia/catfish polyculture	0	0	2	9.1
Catfish monoculture	4	3.1	0	0
Cray fish	1	0.8	0	0
Total	**128**	**100**	**22**	**100**
		Machakos County		
	ESP		**Self-funded**	
Type of culture	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Tilapia monoculture	71	94.6	14	56.0
Tilapia/catfish polyculture	2	2.7	3	12.0
Catfish monoculture	2	2.7	8	32.0
Cray fish	-	-	-	-
Total	**75**	**100**	**25**	**100**

ESP- Economic Stimulus Program

About 51 and 28 percent of farmers in Kiambu and Machakos Counties respectively stated that the main reason for choosing to rear a certain fish species was because it was promoted by the government which also guaranteed the availability of the fingerlings for those farmers who were under the ESP. With regard to ESP farmers, 13.6 and 16 percent in Kiambu and

Machakos Counties stocked tilapia because it was promoted by the government. However, fish farmers in Kiambu County seemed to have already made up their minds to keep tilapia monoculture, which shows that fish farming and consumption might not have been as new as it was in Machakos County.

Over 40 percent of farmers in both Counties preferred tilapia culture due to its consumer preference the species. A relatively large percentage of farmers (28 percent in Machakos County) reared tilapia because of its early maturity compared to only 2.3 percent in Kiambu County (Table 4.16). On average, tilapia in Machakos County reached table size at 6 months compared to 9 months in Kiambu County because of the higher water temperatures in Machakos. This was statistically different between the two Counties (p = 0.05) (Table 4.12)

Table 4.16 Reasons for preference of tilapia to other fish species in Kiambu and Machakos Counties

Kiambu County				
	ESP		**Self-funded**	
Reason	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Recommended by government	65	50.8	3	13.6
Market preference	51	39.9	16	72.8
Decision by NGO	0	0	1	4.5
Availability of fingerlings	9	7.0	2	9.1
Early maturity	3	2.3	0	0
Total	**128**	**100**	**22**	**100**
Machakos County				
	ESP		**Self-funded**	
Reason	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Recommended by government	21	28.0	4	16.0
Market preference	29	38.7	11	44.0
Decision by NGO	-	-	-	-
Availability of fingerlings	16	21.3	6	24.0
Early maturity	9	12.0	4	16.0
Total	**75**	**100**	**25**	**100**

ESP- Economic Stimulus Program

4.3.6 Fish holding structures

The most common type of pond was the earth pond where Kiambu County had 74.2 percent and Machakos County had 42.7 percent among the ESP farmers. Machakos County had the highest number of liner ponds at 56 percent against 25 percent in Kiambu County (Table 4.17). However, 59.1 percent of self-funded farmers in Kiambu County had liner ponds possibly indicating the willingness of these farmers to invest more in fish farming. The liner ponds were more common in Machakos County because of the scarcity of water in this region, low amounts of rainfall, high rates of evaporation and the poor water holding capacity of soils in the County. Therefore, the liners were used as a strategy of conserving the pond water. In a similar survey in Western Kenya, Musa *et al.,* (2012) found that most farmers had earthen ponds. The prevalence of earthen ponds showed that the soils in western Kenya have good water retention or that farmers were poor and could not afford pond liners.

Earth ponds lose a lot of water through seepage and the problem of water scarcity makes refilling of the pond difficult hence the trend of moving towards investment in liner ponds. The soils in Machakos were also poor compared to Kiambu in terms of water holding capacity and there was a high rate of evaporation. However, on average, earth ponds were the most common pond types compared to liner, concrete ponds and tanks. This finding is consistent with that of Machena and Moehl (2001) who noted that earth ponds are the dominant fish holding structures in Africa.

Table 4.17 Pond types used by fish farmers in Kiambu and Machakos Counties

Kiambu County				
	ESP		Self-funded	
Pond type	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Liner pond	32	25.0	13	59.1
Earth pond	95	74.2	7	31.8
Concrete pond	-	-	-	-
Tank culture	1	0.8	2	9.1
Total	**128**	**100**	**22**	**100**
Machakos County				
	ESP		**Self-funded**	
Pond type	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Liner pond	42	56.0	11	44.0
Earth pond	32	42.7	12	48.0
Concrete pond	1	1.3	2	8.0
Tank culture	-	-	-	-
Total	**75**	**100**	**25**	**100**

Key: ESP- Economic Stimulus Program

4.3.7 Pond stocking

The average number of fingerlings stocked per pond in Kiambu County was 1064.57±541.96 fingerlings and 876.29±421.28 in Machakos County. This was mainly because most of the farmers got the fingerlings from the government which supplied 1000 fingerlings for a 300m^2 fish pond. In this study, only 10 percent of the fish farmers stocked less than 1000 fingerlings and these were self-funded who procured the fingerlings using their own resources.

4.3.8 Fish production cycle and systems

The average production cycle was 9.36 months in Kiambu and 6.88 months in Machakos. The means were significantly different between the two Counties (p=0.05)(Table 4.12). This difference could be due to differences in water temperatures in the two Counties since harvesting in the two Counties is informed by fish size. This was also supported by the fact that 31 percent of the farmers in Kiambu County harvest after 12 months while in Machakos 53 percent of the farmers harvest at 6 months of age. Tilapias reach table size maturity (180 ï

200) grams between 6 ï 7 months with the right temperature and good management and the right species (Popma & Rodriquez, 2000).

Terchert-Coddington and Green, (1997) defined semi-intensive system as one where production is done in earthen ponds with nutrient input limited to manure and supplemental feeds with no aeration or water exchange.This fish production system was the most common in both Counties with 98.4 and 46.7 percent of ESP farmers in Kiambu and Machakos Counties practising it respectively (Table 4.18). This production system was characterized by keeping fish in ponds which were fertilized with organic manures (especially crop residues and livestock manure) with little or no use of commercial fertilizers. Supplementary feeding was done using complete or home made feeds. Lovshin, (2000) working in Brazil noted that semi intensive pond culture of tilapia was typically integrated with agricultural or animal husbandry activities because pond fertilization with organic fertilizers promotes natural pond productivity in addition to being consumed directly by tilapia.

A relatively large percentage of ESP farmers (1.6 and 42.7 %) in Kiambu and Machakos Counties practiced extensive fish production where ponds are fertilized using plant remains and animal droppings and fish fed on cereal by products such as maize and wheat meal with some fish meal. Kaliba *et al.,* (2006)observed that in extensive fish production systems in Tanzania fish were fed on rice and maize bran, kitchen left overs and garden remains. Very few farmers practiced intensive fish farming system where pond fertilization and fish feeding are done using inorganic commercial fertilizers and formulated fish feeds respectively.

Table 4.18 Fish production systems in Kiambu and Machakos Counties

	Kiambu County			
	ESP		**Self-funded**	
Production level	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Extensive	2	1.6	2	9.1
Intensive	0	0	0	0
Semi-intensive	126	98.4	20	90.9
Total	**128**	**100**	**22**	**100**

Machakos County				
	ESP		**Self-funded**	
Production level	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Extensive	32	42.7	2	8.0
Intensive	8	10.6	0	0
Semi-intensive	35	46.7	23	92.0
Total	**75**	**100**	**25**	**100**

ESP- Economic Stimulus Program

4.3.9 Pond filling

Most of the ponds in these two Counties were located in valleys due to closeness to the water source mainly rivers, wells and boreholes. Most ponds in Kiambu County (52 percent) were filled by gravity where furrows were dug from the water source mainly a river and water was directed to the pond. The remaining 48 percent of the farmers pumped water to fill their ponds which increased the cost of production due to the high cost of fuel. In Machakos County methods such as ferrying water using donkey were also grouped under pumping.

Rivers formed the greater percentage of water sources in Kiambu County because there are more permanent rivers and streams than in Machakos County. Fish farmers in Machakos County used different sources of water such as shallow wells (35 percent), borehole (30 percent) and rivers (27 percent) (Table 4.19). It was therefore expensive and tedious to fill ponds in Machakos than in Kiambu. This study further showed that over 15 percent of ponds in Machakos County had dried which may imply that this region was not suitable for fish production. Results also showed that 89.6 percent of farmers in both Counties did not experience any conflict in accessing water for filling the ponds while 10.4 percent experienced some conflict such as complaints of using a lot of water by neighbours located downstream. In Machakos County there were also fish farmers that drew a lot of water from the community boreholes.

Table 4.19 Sources of pond water

	Kiambu County		Machakos County	
Source of water	Frequency	Percentage	Frequency	Percentage
Borehole	31	20.7	30	30
Well	11	7.3	35	35
River	93	62	27	27
Dam	3	2	4	4
Rain	10	6.7	4	4
Tapped	2	1.3	0	-
Total	**150**	**100**	**100**	**100**

4.3.10 Frequency of re-filling the fish ponds with water

The frequency of topping up pond water affected the quality of water in terms of turbidity and levels of dissolved oxygen. Majority of the fish farmers (67.2 percent) in Kiambu and (70.7 percent) in Machakos Counties refilled their pond when water fell below a certain point, usually a point or level which was shown to them by government extension officers (Table 4.20). This further showed the important role played by ESP which facilitated extension officers who trained farmers on pond management. The findings showed that self-funded farmers followed a similar regime of pond refilling. A small percentage 10.2 percent of the farmers in Kiambu County had continuous flow of water in their ponds due to availability of water. This is not a good management practice because it does not allow time for growth of phytoplankton which is the natural feed for the tilapia fish. The results were not significantly different between the two Counties ($p = 0.05$) (Table 4.11). Isyagi *et al.,* (2009) in a study in Uganda noted that water should only be added to top up water levels and to correct water quality problems. The reduced frequency of pond refilling in Machakos County can be explained by the problem of water scarcity and seasonality of rivers.

Table 4.20 Frequency of refilling the fish pond with water in Kiambu and Machakos Counties

	Kiambu County			
	ESP		Self-funded	
Frequency of refilling	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Water falls below a certain point	86	67.2	12	54.5
Once a month	15	11.6	4	18.2
Once a week	8	6.3	2	9.1
Continuously	13	10.2	-	-
After 3 weeks	2	1.6	-	-
After 5 months	0	0	2	9.1
Twice a month	4	3.1	2	9.1
Total	**128**	**100**	**22**	**100**
	Machakos County			
	ESP		**Self-funded**	
Frequency of refilling	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Water falls below a certain point	53	70.7	18	72.0
Once a month	5	6.7	2	8.0
Once a week	14	18.7	5	20.0
Continuously	1	1.3	-	-
After 3 weeks	-	-	-	-
After 5 months	1	1.3	-	-
Twice a month	1	1.3	-	-
Total	**75**	**100**	**25**	**100**

ESP- Economic Stimulus Program

4.3.11 Pond draining

Pond draining is also an important aspect of pond management in that it influences the quality of water in terms of dissolved oxygen, fish health and primary productivity of the pond (Ngugi et al., 2007). Draining should be done at the end of each production cycle to get rid of accumulated chemicals which may be toxic to the fish. Majority of the farmers (86 percent and 65 percent in Kiambu and Machakos, respectively) did not drain their pond at all (Table 4.21). This is not good because leaving the pond water for too long without draining increases organic wastes which decreases the amount of dissolved oxygen which can lead to death of the fish.

Isyagi *et al.,* (2009) noted that the accumulation of wastes can be physically managed by removing a proportion of the pond water with high nutrient load and replacing it with good quality water. A relatively large percentage (10.7 and 26%) in Kiambu and Machakos Counties respectively drained their ponds once and this was usually during harvesting for farmers who did complete harvesting. Balance should be found in pond draining because draining of the pond too often allows no time for phytoplankton to grow which is the natural feed for the fish. It also causes fluctuations in water temperature which is not good for the fish.

Table 4.21 Frequency of pond draining

	Kiambu County		**Machakos County**	
Frequency of pond draining	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Never drained	129	86	65	65
Once	16	10.7	26	26
Twice	2	1.3	4	4
After 4 months	3	2	5	5
Total	**150**	**100**	**100**	**1f00**

4.3.12 Pond fertilization

Farmers in both Kiambu and Machakos Counties used farm yard manure for pond fertilization with only few farmers using both manure and chemical fertilizers. The chemical fertilizer used was mainly diammonium phosphate (DAP) and it was used once during first stocking. Majority of the farmers in Machakos County (59 percent) had only fertilized their ponds only once since the pond was established (Table 4.22). These ponds had poor water colour indicating that there was no primary productivity of algae. These findings are consistent with results by Diana and Lin (1998), who reported that in ponds that were fertilized once tilapia had low growth rates in Thailand. In these ponds, nutrients were quickly utilized and primary production and growth rates of fish declined dramatically. Farmers in Kiambu County fertilized their pond more frequently compared to those in

Machakos County. Consequently, 90 percent of ponds in Kiambu County had green water due to proper fertility management. The manure used was mainly from cattle, poultry and pigs showing a high level of integration between fish farming and other enterprises on the farm.

Farmers lacked information on when to add manure to their ponds because the decision to fertilize the pond should be informed by the colour of pond water. The frequency of fertilization is very important in pond management because fertilization enhances the primary productivity of the pond which positively influences fish growth. However, Knud-Hansen and others noted that fertilization frequencies varying from daily to once every three weeks had no effect on primary productivity of the pond (Knud-Hansen et al., 1993).

These findings agree with results by Nhan *et al.,* (2007) who noted that farmers used on-farm resources to produce fish and reduce environmental impacts of farming activity. They however lacked information on when to add manure to their ponds.

Table 4.22 Frequency of pond fertilization in Kiambu and Machakos Counties

	Kiambu County		**Machakos County**	
Frequency of pond fertilization	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Only once since pond was established	46	30.7	59	59
Once a month	60	40.0	28	28
After 3 months	9	6.0	0	0
Twice a month	32	21.3	13	13
After 2 months	3	2.0	0	0
Total	**150**	**100**	**100**	**100**

4.3.13 Fish feeds and feeding management

According to Tacon and De Silva (1997) feed and fertilizers represent about 60-80 percent of the total cost of production in fish farming. In view of this understanding feed management strategies and their implementation is of major importance.

Results showed that all the farmers in Kiambu and Machakos Counties used complete or formulated commercial feeds for feeding the fish. Most the feeds were supplied by the government through ESP as shown in table 4.23. Majority (50% in Kiambu and 64% in Machakos) of self-funded fish farmers also obtained fish feeds from the government. In Kiambu County farmers were supplied with feeds from Unga Feeds Ltd while in Machakos County the feeds were purchased from Sigma Feeds Ltd.

Farmers in both Counties also used homemade formulations based on shrimp meal and omena while other farmers also used supplementary feed such as wheat and maize bran to feed the fish. Kitchen left overs and vegetable residues were also used as fish feed. The latter materials acted more as organic fertilizers than feed due to their raw nature which may have led to high organic loading as indicated by the high permanganate value.

Table 4.23 Source of formulated fish feeds in Kiambu and Machakos Counties

		Kiambu County		
	ESP		**Self-funded**	
Source of feed	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Supplied by government	112	87.5	11	50
Purchased by farmer	16	12.5	11	50
Total	**128**	**100**	**22**	**100**
		Machakos County		
	ESP		**Self-funded**	
Source of feed	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Supplied by government	54	72.0	16	64.0
Purchased by farmer	21	28.0	9	36.0
Total	**75**	**100**	**25**	**100**

ESP- Economic Stimulus Program

The disparities in the sources of feeds between Kiambu and Machakos Counties can be explained by several reasons. One is distance between farms and the Fisheries Office where farmers were supposed to collect the feeds. This influenced the ability of the farmer to get feeds from the government due to the cost of transporting the feeds to the pond. In Kiambu County the Fisheries Offices were not far from most of farmers. Hence, it was relatively cheaper for farmers to pick the feed from government offices. The County also has better transport network compared to Machakos thereby enabling farmers to transport feeds to their farms with ease.

The procedure of distributing fish feeds to the various fisheries offices across the country was lengthy and inefficient. This made some farmers to neglect fish farming due to lack of funds to purchase feeds. There also were reported cases of corruption where farmers complained that only farmers who bribed government officers got the free fish feeds. This assertion was however difficult to verify during the time of the survey.

The average amount feed fed to 1000 fish per day from the age of 3 months was found to be 2.18±2.51kg in Machakos County and 1.44±1.29 kg in Kiambu County (Table 4.24a and 4.24b). The results were significantly different between the two Counties (p=0.05) (Table 12). In both Counties the minimum number of times the fish were fed was once per day and a maximum of three times per day.

These results showed a gap in the information needs of the farmers because the amount of feed fed to the fish should be determined from their weights at various stages of development. The frequency of feeding should also be determined by the rate of intake of feed by the fish because excess feed, decays, thereby increasing the concentration of ammonia in the pond that may lead to low oxygen. Hasan (2010) noted that some of the potential pollutants from aqua feed are phosphorus, nitrogen and organic matter. Ideally, feeding rates should be determined by pond ecology (which varies considerably with season and location), in addition to fish biomass (Hasan, 2001).

Table 4.24a Fish feeding practices in Machakos County

Variable	Average	Standard deviation	Minimum	Maximum
Number fingerlings per pond	913.59	390.50	35	3000
Amount of feed per day per pond(Kg)	2.184	2.51	0.001	20
Number of feeding times per day	1.67	0.51	1	3
Pond size (M^2)	270.78	137.58	12	680

Table 4.24b Fish feeding variables in Kiambu County

Variable	Average	Standard deviation	Minimum	Maximum
Number fingerlings per pond	1064.57	541.96	200	5000
Amount of feed per day per pond(Kg)	1.44	1.29	0.1	10
Number of feeding times per day	1.39	0.51	1	3
Pond size (M^2)	311.24	190.8	50	2100

4.4 Quality of water and feeds used by farmers in Machakos and Kiambu Counties

4.4.1 Pond colour

About 90 and 65 percent of the ponds observed in Kiambu and Machakos Counties respectively had green water (Table 4.25) (Plate 1). This was the recommended water colour because it showed that there was adequate growth of algae which serves as food for the fish and also increases oxygen content in water due to photosynthesis (Ngugi et al., 2007). The ponds had low water levels which increased turbidity. Further, 8 percent of pond in Kiambu and 15 percent of ponds in Machakos County had brown water. This indicated high turbidity of the water which is not good for fish rearing because it leads to reduction in fish fry survival and gill damage (Bisson and Bilby 1982; Lloyd 1987). The prevalence of brown pond water in Machakos could be attributed to the fact that most of soils in Machakos are loose soils which causes sedimentation of the ponds (Plate 4.2). In Machakos County, 6.4 percent of the ponds were dry due to scarcity of water (Plate 4.3). This showed that fish farming may not be economically viable in the ASAL Counties of Kenya due to lack of water especially for farmers located far from the water sources like rivers and community boreholes.

Table 4.25 Pond water colour

	Kiambu County		Machakos County	
Pond water color	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Green	135	90	65	65
Brown	12	8	15	15
Clear	3	2	4	4
Dry	0	-	16	16
Total	**150**	**100**	**100**	**100**

Plate 4.1: A fish pond with green water in Matungulu, Machakos County.

Plate 4.2: A fish pond with brown coloured water Machakos County.

Plate 4.1: A dry fish pond in Machakos County.

4.4.2 Assessment of fish pond water quality

The water quality parameters assessed in this study were: pH, temperature, phosphates, nitrites and turbidity. The pH of the pond water varied between 5.9 and 9.4 (Table 4.26). Wurts and Durborow noted that fish can survive at pH levels between 6.5 and 9.0. However, fish and other vertebrates have an average blood pH of 7.4. The pH levels in the pond were influenced by other parameters in the water such as carbon dioxide and ammonia concentrations. Carbon dioxide concentration lowers the pond pH due to its reaction with water to form carbonic acid while ammonia increases the pH due to its alkaline ion NH_4^+ (Wurts and Durborow 1992)

Table 4.26 Results of labouratory analysis of fish pond water samples from Kiambu and Machakos Counties

Sample no.	County	Location	pH	Nitrite(mg/l)	PV(mg/l)	Ammonia (mg/l)
1	Machakos	Kinanie	8.1	Not detected	135	25.4 (1.45)
2		Athi River	7.3	Not detected	31.5	11.5 (0.11)
3		Kimutwa	8.3	Not detected	4.5	2.0 (0.17)
4		Kinanie	6.9	Not detected	20.0	6.1 (0.03)
5		Tala	7.0	1.3	17.5	7.3 (0.04)
6		Kangundo	6.6	Not detected	18.0	13.7 (0.08)
7		Kathiani	6.8	Not detected	9.5	13.3 (0.07)
8		Mumbuni	7.7	Not detected	49.0	27.1 (0.63)
9	Kiambu	Kiambu	8.5	Not detected	3.8	Not detected
10		Lari	8.1	Not detected	11.6	Not detected
11		Kiambu	8.1	Not detected	4.0	Not detected
12		Kikuyu	7.8	Not detected	8.4	Not detected
13		Kikuyu	8.4	Not detected	1.2	Not detected
14		Githunguri	5.9	Not detected	2.0	0.546 (0.002)
15		Kiambu	7.1	0.0394	5.6	Not detected
16		Kiambu	9.4	Not detected	6.2	0.336 (0.16)
17		Githunguri	7.0	Not detected	0.6	Nil
18		Githunguri	7.4	Not detected	0.6	1.0592 (0.01)
19		Githunguri	6.9	Not detected	Not detected	0.2296 (0.00)
20		Githunguri	7.2	Not detected	Not detected	Not detected

PV- Permanganate value

Mg/l- milligrams/litre

*[1]The numbers in brackets give the concentration of toxic (unionized) ammonia in ppm (mg/l) .These numbers are calculated from data in Emerson *et al.,* (1975) which gives the fraction of toxic (unionized) ammonia in aqueous solutions at different pH values and temperatures. The average water temperature for Machakos County was 26^{0}C while that of Kiambu County was 20^{0}C.

As shown in Table 4.24 most ponds in Kiambu and Machakos Counties (except two) had no nitrites. According to Durborow *et al.,* (1997) nitrites are toxic to fish in concentration above

0.3 mg/l. The nitrite (NO_2) ion affixes itself to the haemoglobin and inhibits oxygen transport in the blood. High concentrations of nitrites may exist in densily populated ponds, especially newly established ones where nitrifying bacteria have not developed (Durborow et al., 1997).

Total ammonia nitrogen (TAN) is composed of toxic (un-ionized) ammonia (NH_3) and nontoxic (ionized) ammonia (NH_4^+). Only a fraction of the TAN exists as toxic (un-ionized) ammonia ($NH_{3)}$, and a balance exists between it and the nontoxic ionized ammonium (NH_4^+). The proportion of TAN in the toxic form increases as the temperature and pH of the water increase. For every pH increase of one unit, the amount of toxic unionized ammonia increases about 10 times (Durborow et al., 1997). The amount of toxic unionized ammonia in the ponds was determined by calculating from the fraction of TAN that is in the toxic form which is based on water temperature and pH (Emerson et al., 1975).

Results presented in table 4.26 showed that ponds in Machakos County had higher levels of toxic ammonia especially ponds along Athi river. Other ponds in both Machakos and Kiambu County had low levels of ammonia, which may also be harmful to fish if they are exposed for long periods of time. Durborow *et al.,* (1997) observed that Chronic exposure to toxic un-ionized ammonia levels as low as 0.06 mg/L (ppm) can cause gill and kidney damage, reduction in growth, possible brain malfunctioning, and reduction in the oxygen- carrying capacity of the fish. These observations could explain the findings that most fish in the ponds were small sized fish even after attaining the maturity age which might be due to continuous exposure to low levels of toxic ammonia or other factors.

The results indicate high Permanganate Values (PV) in the ponds especially in Machakos County which implies high amounts of organic matter load which can influence the amount of dissolved oxygen. Permanganate Value (PV) is a method of determining the efficiency of biodegradation, by estimating the strength and oxidisability. A decrease in PV indicates high (potential) efficiency.

4.4.3 Fish feed quality

According to Hasan (2001), Growth, health and reproduction of fish and other aquatic animals are primarily dependent upon an adequate supply of nutrients, both in terms of quantity and quality, irrespective of the culture system in which they are grown. Supply of inputs (feeds and fertilizers) has to be ensured so that the nutrients and energy requirements of the species under cultivation are met and the production goals of the system are achieved.

In this study fish feeds supplied by Sigma feeds Ltd which were provided by the government through the ESP had a protein content of 19.4 percent which was far less than the recommended protein requirement for tilapia fish (Table 4.27).

According to Hepher (1988), Tacon (1993), De Silva and Anderson (1995), the protein requirement for *O.niloticus* is 30 percent of the total dry matter of feed. This feed also had high crude fibre content (14.6 percent) which diluted the protein and other nutrients. The omena fishmeal used by some of the farmers had low percentage of protein (25.3 percent) and an abnormally high percentage (60.7 percent) of ash indicating that it had been contaminated by sand (silica). The fish meal also had low lipids and nitrogen free extract with 0.36 percent and 5.21 percent, respectively.

The results of proximate analyses of some feeds used by farmers in the two Counties are presented in Table 4.27

Table 4.27 Proportion of nutrients in different fish feeds samples collected in Kiambu and Machakos Counties (Air-dry basis)

Parameters (percentages)	Feed 1 (own feed)	Feed 2 (Sow weaner Kiambu	Feed 3 (Omena)	Feed 4 (Sigma feeds)	Feed 5 King Feeds Nakuru)
Protein	43.5	19.54	25.32	19.4	21.21
Moisture	10.94	11.19	5.53	10.51	11.32
Ash	36.39	20.96	60.70	8.86	6.68
Crude fibre	8.46	11.76	6.68	14.67	9.21
Lipids	1.23	0.02	0.36	3.17	4.08
Phosphorus	-		2.09	1.11	0.76
Nitrogen free extract	10.92	47.72	5.21	53.9	58.82

4.5 Evaluation of Consumption and marketing of farmed fish in Kiambu and Machakos Counties

4.5.1 Fish harvesting

It was observed that most farmers in the two Counties used poor fishing gears such as mosquito nets (Plate 4.3) and wire mesh (Plate 4.4) to harvest fish and this could have led to injury of fish. It could have also resulted in harvesting under-sized fish and contamination of the pond water by the chemicals contained in the mosquito nets. The tendency to use poor fishing gear was attributed to the fact that the cost of hiring fishing net from District Fisheries Office was KShs 200 per day which was out of reach of many fish farmers. In most cases the office was far from many of the farmers. Some farmers also felt that it was expensive to hire the net individually because fish farmer groups were not well established in the study areas.

The average pieces of fish harvested in Kiambu and Machakos Counties were 231.15 (34.67Kgs) and 418.36 (62.75Kgs) during a major main harvest, respectively. However, this might not be very accurate because majority of the fish farmers did not keep records especially on harvesting.

Plate 2.4: Fish harvesting using mosquito net in Machakos County, Letter A shows a mosquito net being used for harvesting

Plate 4.3: Fish harvesting using wire mesh in Matungulu. Machakos County

4.5.2 Determinants of time of fish harvesting for market

Majority of the farmers in Machakos County (62 percent) harvested their fish at 8 months after stocking and 88.8 percent did partial harvesting where only the numbers required are harvested and the rest were left to continue growing (Table 4.28).

In Kiambu County majority of farmers (31.3 percent) used fish size to determine the time of harvesting because fish took longer to mature in Kiambu County compared to Machakos County because temperatures were lower for most of the areas. The remaining (11.2 percent) of respondents practiced complete harvesting strategy where they drained the water and harvested all the fish. This is the recommended practice in tilapia farming (Ngugi et al., 2007).

According to Diana (1997), Achieving maximum growth is a common goal in aquaculture. Production units are stocked with young fish, which grow to their maximum weight until food and other environmental (water quality) parameters become limiting. As food availability and/or water quality conditions become limiting, the rate of growth slows down to the point where growth rate reaches zero and biomass remains stable. At this stage, the pond is said to have reached its maximum carrying capacity; because the nutrients and/or water culture conditions in the pond are inadequate to promote further growth (J. Diana, 1997).

Majority of farmers noted that their fish were not attaining the desirable marketable size even with proper feeding. This can be explained by the fact that most of the ponds had reached their maximum carrying capacity or there was stunted growth of the fish. These findings are further supported by observations by Diana (1997) in Uganda where the researcher noted that many farmers had experienced the state of carrying capacity often before fish had reached market size. This could be due to high rate of sexual reproduction of tilapia when stocked in mixed sex (J. Diana, 1997).

Table 4.28 Determinants of time of fish harvesting in Kiambu and Machakos Counties

	Kiambu County		**Machakos County**	
Determinant	**Frequency**	**percentage**	**Frequency**	**percentage**
Maturity age	57	38	62	62
Size	47	31.3	3	3
Market demand	46	30.7	35	35
Total	**150**	**100**	**100**	**100**

The average farm gate price for tilapia in Kiambu County was KShs 180.8 per piece while in Machakos it was KShs 131.4 per piece. This was statistically different between the two Counties (p=0.05) (Table 4.12). Prices were fixed using criteria such as the size, weight and demand for fish. These results are similar to those obtained by Quagrainie et al., (2009) who reported that prices as high as KShs 140 (US $1.87) per kg in major cities such as Eldoret and other parts of the country. In both Counties size was estimated by physical inspection and this was used to determine the price of fish (Table 4.29). Only 2.7 percent of farmers in Kiambu and 11 percent in Machakos used weight to set the price for selling the fish. These results show that marketing of fish is not fully developed because majority of the farmers should have been able to fix the prices using the weight of the fish which can be measured.

Table 4.29 Criteria for setting price of fish by fish farmers in Kiambu and Machakos Counties

	Kiambu County		**Machakos County**	
Criteria used	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Size	94	62.8	68	68
Demand	52	35.3	21	21
Weight	4	2.7	11	11
Total	**150**	**100**	**100**	**100**

4.5.3 Fish markets

The main markets for fish in Kiambu and Machakos Counties were local small scale traders, large scale traders and local consumers (Table 4.30). In Kiambu County 80 percent of the fish were sold to local consumers as compared to 22 percent in Machakos County (Table 4.30). This showed that there was a high demand for fish in Kiambu by the local population. This County is peri-urban with people from different parts of the country who have different experiences in fish eating. In Machakos County there was low demand by local people due to lack of experience in fish preparation and to some extend fish eating. This showed that the government under the ESP did not do enough to sensitize and educate farmers in this on the importance of fish in nutrition and further provide them with information on how to prepare fish. In Machakos County 70 percent of the fish was sold to local small scale traders who took the fish to big towns like Machakos and Nairobi. The results also showed that 70.7

percent and 47 percent of farmers in Kiambu and Machakos Counties respectively were able to sell all the harvested fish.

These findings are in agreement with those by Shitote *et al.,* (2013) who reported that most fish farmers in Western Kenya had ready market where fish were locally sold either at the farm gate or at the local market. The method of disposing the surplus fish included consumption and them to neighbours. Some of the fish got spoilt because farmers did not have proper storage facilities (Shitote et al., 2013).

Table 4.30 Main fish buyers in Kiambu and Machakos Counties

	Kiambu County		**Machakos County**	
Main fish buyer	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Local consumers	121	80	22	22
Local small scale traders	29	20	70	70
Large scale traders		-	8	8
Total	**150**	**100**	**100**	**100**

4.5.4 Source of market information

The survey established that 66 percent of the farmers in Kiambu County were aware of prices of fish in other markets and 83.3 percent indicated that this information helped them to set prices for their fish (Table 4.31). This is mainly due to the proximity of Kiambu to the capital city of Nairobi and the role played by mass media in giving market information. A relatively large percentage of farmers (68 percent) in Machakos County were not aware of prices of fish in other markets mainly because most of them were rural farmers whose access to market information was limited. The main sources of market information in both Counties were market visits, mass media and information from friends and neighbors.

In both Kiambu and Machakos Counties it was noted that no market information came from the government extension officers. This showed that the government did little to enhance the marketing of fish in the two Counties. Provision of market information would enable farmers to determine where to sell the fish and price per piece.

Table 4.31 Sources of market information in Kiambu and Machakos Counties

	Kiambu County		**Machakos County**	
Source of information	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Market visits	55	36.7	25	25
Mass media	22	14.7	1	1
Friends and neighbors	23	15.3	7	7
n/a	50	33.3	67	67
Total	**150**	**100**	**100**	**100**

4.6. Diseases and other challenges experienced by fish farmers in Kiambu and Machakos Counties

4.6.1 Fish diseases

Majority of farmers (84 percent) reported that they had not experienced high mortalities in the ponds due to diseases. However, 16 percent of the farmers noted that they observed high mortalities which occurred after stocking and immediately after harvesting. Farmers observed that gulping of air on the surface of the water was the main symptom observed which led them to conclude that the death of fish was due to lack of oxygen and not diseases. Only one case of sudden fish deaths was observed in Kikuyu constituency. The farmer reported there was extensive use of insecticides on vegetable farm around the ponds prior to the fish deaths. These results are therefore consistent with findings by Hecht (2006) in Malawi and Mozambique who reported that diseases and parasites were not widespread in small-scale fish farms.

4.6.2 Challenges in fish farming

The main challenge as reported by fish farmers was predators (41.3 percent and 39 percent of farmers in Kiambu and Machakos Counties, respectively) (Table 4.32). Shitote *et al.,* (2013) reported predation was a major challenge in Western Kenya. Lack of feeds was not a major challenge in the two Counties because most the fish feeds were provided by the government through the ESP. However, farmers reported high mortality of fingerlings due to lack of oxygen during the first few hours of stocking and delay in delivery of fingerlings as challenges which they experienced (Shitote et al., 2013). The problem of scarcity of water was experienced by 41% of farmers in Machakos County and 2 percent in Kiambu County mainly in Lari constituency which the driest part of Kiambu. In a study in Kisumu and Homa Bay Counties, Jacobi (2013) reported similar findings where the main challenges in fish farming were predators, water scarcity, marketing and poor management.

Only 19.2 percent of respondents had not experienced the problem of predators on their fish farms. Kingfisher was the main predator bird reported by 68.4 percent of farmers while 10 percent reported that vultures were the main predator. Frogs also formed 2 percent of total cases of predators where they created competition for feed with the fish leading to stunted growth of the fish. Farmers employed different methods of controlling predators including use of screen nets, scarecrows and using strings and wires strung (Plate 4.6) across the pond to prevent the birds from diving into the water to get fish.

The picture below shows a pond in Machakos County where the farmer had tied barbed wire across the pond to control kingfisher and vultures.

Plate 4.6: A fish pond lined with barbed wire to control predator birds in Kinanie, Machakos County.

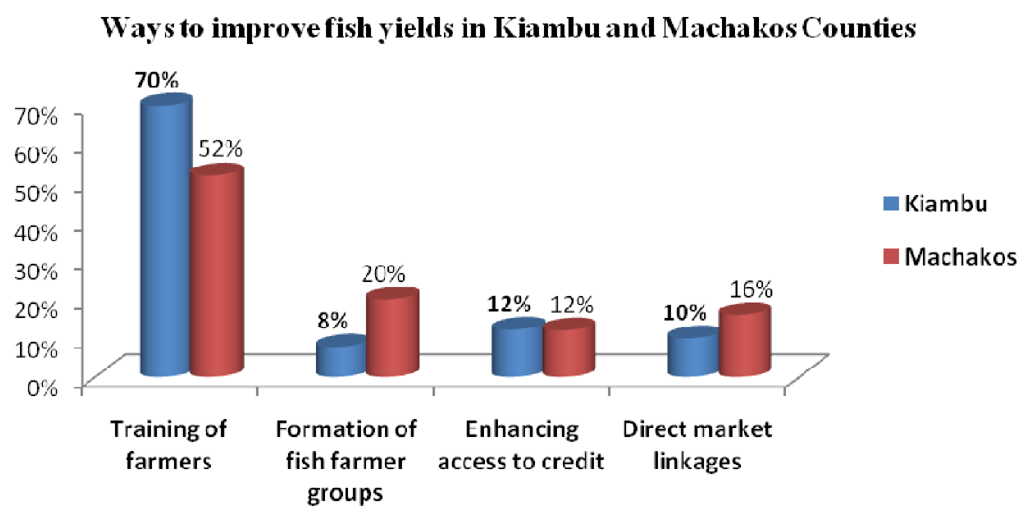
Table 4.32 Challenges faced by fish farmers in Kiambu and Machakos Counties

	Kiambu County		**Machakos County**	
Type of challenge	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Predators	62	41.3	39	39
Lack of feeds	9	6	0	-
High mortality of fingerlings	34	22.7	20	20
Pond leakage	12	8	0	-
Scarcity of water	3	2	41	41
Lack of management information	22	14.7	0	-
Delay in delivery of fingerlings	8	3.2	0	-
Total	**150**	**100**	**100**	**100**

4.6.3 Ways to improve fish productivity

The respondents interviewed were asked to note in their own view what they thought should be done to improve fish productivity. On average the farmers stated training of farmers on fish farming and organization of fish markets, formation of farmer groups, enhancing access to credit and direct linkages to fish markets as ways they thought would help improve their productivity. Training of farmers was seen as the most important way to help improve productivity with 70 percent and 52 percent of farmers in Kiambu and Machakos County respectively (Table 4.313). Formation of fish farmer groups was also relatively important forming 7.8 percent in Kiambu and 20 percent in Machakos County.

Figure 4.1 Ways to improve fish yields in Kiambu and Machakos Counties



CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATION

5.1 Conclusions

The following conclusions are drawn from the findings:

Majority of the respondents (79.3 percent and 54 percent in Kiambu and Machakos County respectively) were self-employed in agriculture, while 20.7 percent were self employed in non-farm enterprise such as formal employment, domestic work and casual labour in Kiambu County. Machakos County had similar trends having 46 percent self employed in non-farm enterprise.

Fish farming was practiced by a relatively large proportion of farmers below 50 years of age ï 79% in Kiambu and 54.6% ï both categories combined in Machakos Counties. The average land size was 2.5±3.47 and4.27±4.78 acres in Kiambu and Machakos Counties respectively. The study also showed that in Kiambu County 79.6 and 91% of ESP and self-funded farmers respectively kept fish mainly for commercial purposes while in Machakos County it was 56 and 72% respectively.

Of the 250 respondents interviewed, 85.3% and 75% in Kiambu and Machakos Counties respectively were recruited through the ESP. The main source of information on fish farming was government extension agents as reported by 93.8% and 92% of ESP farmers in Kiambu and Machakos Counties respectively. Stocking of Nile tilapia in mixed sex monoculture was the most dorminant culture method and fish were mainly stocked in earth ponds.

Majority of the fish farmers (67.2%) in Kiambu and (70.7%) in Machakos County refilled their pond when water fell below a certain point. Water quality was poor as indicated by the high percentage of farmers (86% in Kiambu and 65% in Machakos) who never drained their ponds at the end of the production cycle and pond water colour which was brown or clear in many cases. Most farmers (42.1%) fertilized their ponds at least once per production cycle and used manure from their farms. The study also showed that there are no fish diseases in this region because 84% indicated that they had not seen any massive fish deaths.

Additionally, the study showed that there was mixed fish farming and crop farming where water from the ponds was used for watering vegetable plots usually located near the ponds (48% in kiambu and 33% in machakos County). In Kiambu, 79.6% and 91% of ESP and self-funded farmers respectively kept fish mainly for commercial purposes while in Machakos County it was 56% and 72% respectively. It was observed that most farmers in the two Counties used poor fishing gears such as mosquito nets and wire mesh to harvest fish. The average pieces of fish harvested in Kiambu and Machakos Counties were 231.15 (34.67Kgs) and 418.36 (62.75Kgs) per the main harvest respectively.

In Kiambu County 80 percent of the fish were sold to local consumers as compared to 22 percent in Machakos County. The average farm gate price for tilapia in Kiambu County was KShs 180.8 while in Machakos it was KShs 131.4. This findings were statistically significant between the two Counties ($p = 0.05$)

Majority of the ESP farmers (64.8% and 78.7%) in Kiambu and Machakos Counties respectively relied on government extension to provide information on fish farming. About 90% and 65% of the ponds observed in Kiambu and Machakos Counties respectively had green water, an indication of algae growth. Further, 8% of ponds in Kiambu and 15% in Machakos County had brown water. The results also indicate high Permanganate Values (PV) in the ponds especially in Machakos County.

The main challenge as reported by fish farmers was predators (41.3 percent and 39 percent of farmers in Kiambu and Machakos Counties, respectively).

On average the farmers stated training of farmers on fish farming and organization of fish markets, formation of farmer groups, enhancing access to credit and direct linkages to fish markets as ways they thought would help improve their productivity.

5.2 Recommendations

Based on the findings of this study, the following recommendations were made:

1. There is need to provide training to the fish farmers in order to improve on pond management and feeding. The farmers also need to be organized into fish farmer groups for them to receive this training and be able to bargain for higher prices for their produce and obtain inputs on credit.
2. Policy makers need to include provision for credit to purchase pond liners and screen nets to control predation in future funding programs.
3. Extensive baseline survey and feasibility studies should be conducted before introducing fish farming initiatives like in the case of Machakos County that experienced many dry ponds attributed to lack of water.
4. There is need for fish farmers in water scarce areas to be trained or facilitated to have multiple water sources for sustained supply.
5. There is need to develop farmersô capacity on the importance of determining the pond water quality at certain intervals and before stocking the pond to ensure that the water parameters like ammonia are within the required range. The government should find ways of providing the water test kits at the local Fisheries Office so that farmers can access them.
6. In order to maximize production, there is need to develop basic understanding of nutrient dynamics, specifically the role of fertilization and natural productivity. Such under-standing will allow us to ensure that cost-effective diets are developed that take

into account nutritional requirement differences between species, natural productivity of the water bodies and the location-specific availability of inputs. Feeding rates or ration size need to be determined by pond ecology (which varies considerably with season), in addition to fish biomass.

7. There is need for progressive documentation and profiling of case studies, lessons and success stories for knowledge sharing and propagation of best practices across the country.
8. There is need for gender mainstreaming in fish farming and promotion of fish farming for home consumption.

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APPENDICES

APPENDIX A: Survey questionnaire

UNIVERSITY 0F NAIROBI

CHARACTERIZATION OF FISH FARMING QUESTIONNAIRE

SECTION A: QUESTIONNAIRE IDENTIFICATION (To be completed before the start of the interview)

NO.	QUESTIONS	ANSWER CATEGORIES
A.01	Serial number of the questionnaire	
A.02	Name of the enumerator	
A.03	County	
A.04	District	
A.05	Division	
A.06	Sub-Location	
A.07	Village	
A.08	Date of Interview	[ ]/[ ]/[2011]

SECTION B: HOUSEHOLD CHARACTERISTIC

S/ No.	Name	Relation to HH head (a)	Marital status (b)	Gender (c)	Age	Highest level of Education (d)	Main occupation current year (e)
B.01							

APPENDIX A continued…

a) 1-household head (hh), 2-spouse, 3-son or daughter, 4-father or mother. 5-grandchild, 6-grandparents, 7-other relative, 8-non-relative

b) 1-single, 2-married, with spouse permanently present in the hh, 3-married with spouse migrant, 4-widow or widower, 5-divorced or separated

c) 1-men, 2-femen

d) 1-in primary, 2-never completed primary, 3-completed primary, 4-technical school/polytechnic, 5-in secondary, 6-never completed secondary, 7-completed secondary, 7-in college/university, 8-completed college/university.

e) 1-self employed in agriculture, 2-self employed in non-farm enterprise, 3-student, 4-casual worker, 5-salaried worker, 6-domestic worker, 7-unemployed, looking for job, 8-unwilling to work or retired, 9-not able to work (handicapped)

SECTION C: RESOURCE UTILIZATION AND PRODUCTION

C.01	Approximate size of land (in acres)	Number of acres
C.02	In which year did you establish your first fish pond?	
C.03	What was your source of information in inland fish farming?	Government extension agents ☐ Mass media ☐ NGOs ☐

		Neighbors/friends Others (specify)
C.04	Could you please inform us the motivation behind venturing into fish farming business?	
C.05	Indicate the type of holding unit by inserting the total number per each category in the space provided.	Earth pond Raceway culture Tank culture Liner pond Concrete pond Others (Specifyé é é é é é é é é é é)

Pond (C.06)	Date Established (C.07)	Size (C.08)	Species (C.09)	Source of water (C.10)	Ownership (C.11)
Pond 1					
Pond 2					
Pond 3					
Pond 4					

Species Codes	**Water source**	**Ownership Codes**
1=Tilapia monoculture 2=Cat/mud fish mono-culture 3=Tilapia and catfish poly-culture 4=Others (specify) To accept local names.	1=River 2=Well 3=Borehole 4=Dam 5=Others (specify)	1=Own 2=Leasehold 3=Freehold

SECTION D: MARKETING AND CONSUMPTION

D.01	What is the current farm gate price of fish?	
D.02	How do you decide at which price to sell?	

	(Grading according size/weight, demand, quantity harvested, dictated by buyers, haggling etc)	
D.03	Are you aware of fish prices in major markets, (such as in Nairobi, Nakuru) in the country? (If YES, proceed to question D.04 and NO go to D.05	Yes ☐ No ☐
D.04	Would you please indicate the source of information and what are the prices at the moment?	
D.05	Do you think knowledge of prices elsewhere would have assisted you and if so, how?	
D.06	For what species do you get the highest and lowest prices on average?	<table><tr><td>Species</td><td>Price (KShs/Kg)</td></tr><tr><td></td><td></td></tr><tr><td></td><td></td></tr><tr><td></td><td></td></tr></table>
D.07	Are you able to sell all fish you harvest? (If NO, proceed to question D.08)	Yes ☐ No ☐

<table>
<tr><td>D.08</td><td>If unable to sell all fish harvested, how do you dispose the surplus?
(Consume, give away freely, gets spoilt etc)</td><td></td></tr>
<tr><td>D.09</td><td>Who are the MAIN buyers of your produce of the species you rear in your farm?
1=Consumers (neighbors/passersby)
2=Taking the nearby markets/vending
3=Local small scale traders
4=Middlemen/brokers from large towns, such as Nkr, Nrb
5=Exporters
6=Processors
7=Large scale traders
8=Others
(Specify
é é é é é é é é é é é é é é é é)
9=None</td><td>
<table>
<tr><td>Species</td><td>Main significant buyer</td><td>2nd significant buyer</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
</table>
</td></tr>
<tr><td>D.10</td><td>Do you sell fingerlings?
(If yes, go to question D.11)</td><td>Yes ☐
No ☐</td></tr>
<tr><td>D.11</td><td colspan="2">Where do you sell them?
<table>
<tr><td></td><td>When</td><td>Amount</td><td>Price</td></tr>
</table>
</td></tr>
</table>

	Where				
D.12	In what form do you sell fish?	Fresh ☐ ☐ Processed			
D.13	If fish is processed as in the above question, what techniques are used? (Tick where appropriate)	Salting ☐ Sun-drying ☐ Smoking ☐ Refrigeration ☐ Freezing ☐ Cooling ☐ Deep frying ☐			
D.14	What are your main marketing and operation costs?				
D.15	Please tell us your rating of the **Quality** of the	1=Very poor			

Nature of cost	Value (KShs)

	fish you sell? (If 1,2 or 3 go to question D.16)	2=Poor 3=Fair 4=Good 5=Very good
D.16	If the **Quality** of your fish is **NOT** as good as you would want, what is the main reason for the low quality?	
D.17	How would you rate the market that you have for your fish produce?	1=Very poor 2=Poor 3=Fair 4=Good 5=Very good
D.18	**IF NOT FULLY SATISFIED,** what are the **MAIN** problems?	1=Prices offered too low 2=Buyers not coming at the right time (when produce is ready) 3=Buyers do not take all the produce 4=Donǿt like taking my produce to the market 5=Un-assured market (not sure will sell my produce) 6=Un-predictable prices 7=Poor roads to the market

		8=Other (specifyé é é é é é é é é é é .)
D.19	**ON OVERALL,** what do you see as the KEY ways through which inland fish enterprise can be developed in your area?	1=Training of farmers to adopt good agronomic practices 2=Farmers, access to credit for needed inputs 3=Organization of farmers into groups for production & marketing 4=Assistance in getting direct market linkages 5=Establishment of capacity for processing (semi/fully) 6=Improved access roads to markets 7=Other (Specifyé é é é é é é é é é é ..)
D.20	**On overall,** approximate percentage of your total household income is generated through fish farming?	

Appendix B: Fraction of toxic (un-ionized) ammonia in aqueous solutions at different pH values and temperatures. Calculated from data in Emerson, et al., (1975).

	Temperatures (o^{C})												
pH	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**
7.0	.0013	.0016	.0018	.0022	.0025	.0029	.0034	.0039	.0046	.0052	.0060	.0069	.0080
7.2	.0021	.0025	.0029	.0034	.0040	.0046	.0054	.0062	.0072	.0083	.0096	.0110	.0126
7.4	.0034	.0040	.0046	.0054	.0063	.0073	.0085	.0098	.0114	.0131	.0150	.0173	.0198
7.6	.0053	.0063	.0073	.0086	.0100	.0116	.0134	.0155	.0179	.0206	.0236	.0271	.0310
7.8	.0084	.0099	.0116	.0135	.0157	.0182	.0211	.0244	.0281	.0322	.0370	.0423	.0482
8.0	.0133	.0156	.0182	.0212	.0247	.0286	.0330	.0381	.0438	.0502	.0574	.0654	.0743
8.2	.0210	.0245	.0286	.0332	.0385	.0445	.0514	.0590	.0676	.0772	.0880	.0998	.1129
8.4	.0328	.0383	.0445	.0517	.0597	.0688	.0790	.0904	.1031	.1171	.1326	.1495	.1678
8.6	.0510	.0593	.0688	.0795	.0914	.1048	.1197	.1361	.1541	.1737	.1950	.2178	.2422
8.8	.0785	.0909	.1048	.1204	.1376	.1566	.1773	.1998	.2241	.2500	.2774	.3062	.3362
9.0	.1190	.1368	.1565	.1782	.2018	.2273	.2546	.2836	.3140	.3456	.3783	.4116	.4453
9.2	.1763	.2008	.2273	.2558	.2861	.3180	.3512	.3855	.4204	.4557	.4909	.5258	.5599
9.4	.2533	.2847	.3180	.3526	.3884	.4249	.4618	.4985	.5348	.5702	.6045	.6373	.6685
9.6	.3496	.3868	.4249	.4633	.5016	.5394	.5762	.6117	.6456	.6777	.7078	.7358	.7617
9.8	.4600	.5000	.5394	.5778	.6147	.6499	.6831	.7140	.7428	.7692	.7933	.8153	.8351
10.0	.5745	.6131	.6498	.6844	.7166	.7463	.7735	.7983	.8207	.8408	.8588	.8749	.8892
10.2	.6815	.7152	.7463	.7746	.8003	.8234	.8441	.8625	.8788	.8933	.9060	.9173	.9271

Source: Emerson, K., R.C. Russo, R.E. Lund, and R.V. Thurston. 1975. *Aqueous ammonia equilibrium calculations: effect of pH and temperature*. Journal of the Fisheries Research Board of Canada. 32:2379-2383.