CHARACTERIZATION OF SMALLHOLDER AQUACULTURE SYSTEMS AND GROWTH PERFORMANCE OF THE AFRICAN CATFISH (*Clarias gariepinus*) IN HIGH ALTITUDE AREAS OF KENYA.

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DECLARATION AND RECOMMENDATION

Declaration

This thesis is my original work and has not, wholly or in part, been presented for an award of a degree or diploma in any university

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DEDICATION

This work is dedicated to my family (Vincent, Consolater, Nancy and Grace Ochieng') and my academic mentor Dr. Ojango Julie

ABSTRACT

Aquaculture in Kenya is diverse with uncharacterized fish strains under varying production and management systems. This study characterized the smallholder aquaculture systems and analyzed the growth and survival of the African catfish (*Clariasgariepinus*) fingerlingsin the former Eastern Province of Kenya. The study also mapped the smallholder aquaculture value chain and identified the main challenges therein. Information on the value chain, fish production and management was collated from 198fish famers, 13 traders' and3 key informants. Descriptive and inferential statistics were used to analyze the data.The predominant species of fish reared was the Nile Tilapia (*Oreochromis niloticus*), followed by the African Catfish (*C.gariepinus*). Good growth rates and survival of fish were noted to be the most important traits of economic importance to the farmers. Fish produced was mainly sold to the local community and within local markets. Traders, however, indicated that the demand for fish was much higher than the supply, hence also sourced fish from lakes in the country for sale. Strains of fish selected for improved growth and reproduction were not available for aquaculture.132 families of the African catfish sourced from Sagana River were thus monitored for growth and survival over a period of 60 days. Growth and survival of the fingerlings were significantly affected by the stocking density and sire group. Survival rates within sire group ranged from 10.7 – 90%, while average daily gain and specific growth rate had means of 0.06±0.04g/day and 2.30±0.88g respectively. Weight gain at 60 days had a mean of 3.34±2.32g. The highest final length at 60 days recorded was 9.63cm while the highest final weight recorded was 8.78g. Sires of 551-650g at a stocking density of 41-70 fry/hapa produced fingerlings with the highest mean growth rates. The study showed that the smallholder aquaculture value chain (VC) in Eastern Kenya is still rudimentary. There are few brood stock and fingerling suppliers who not yet able to meet the demand of the farmers. Feed manufactures are also few and the feeds are expensive hence farmers opt for home-made feeds. Main extension services are provided by the government through the fisheries department; however, personnel are not enough to reach all farmers in the area. The farmers don't target export markets and very few produce fish for urban markets. Challenges experienced along the VC present an opportunity for further development of the sector and for selective breeding of the African catfish.

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LIST OF ABBREVIATIONS AND ACCRONYMS

CLOFFA	Check List of the Freshwater Fishes of Africa
DO	Dissolved Oxygen
ESP	Economic Stimulus Program
FAO	Food and Agricultural Organization of the United Nations
FCR	Food Conversion Ration
GDP	Gross Domestic Product
GoK	Government of Kenya
IGFA	International Game Fish Association
IIRR	International Institute of Rural Reconstruction
KNBS	Kenya National Bureau of Statistics
MoFD	Ministry of Fisheries Development, Kenya
MoLFD	Ministry of Livestock and Fisheries Development, Kenya
MSL	Maximum Sustainable Level
TDS	Total Dissolved Solids
VC	Value Chain

CHAPTER ONE
GENERAL INTRODUCTION

1.1 Background information

Fish comprises about 11% of the average daily protein consumption in Kenya, with the per capita consumption of fish estimated at 2.8 kilograms (FAO, 2007, GlobalFishAlliance, 2010)This is below the global per capita consumption which is estimated at 16 kg (FAO, 2012). Kenya however has a high demand for fish and is endowed with both freshwater and marine fish resources. A high proportion of the fish produced in the country is however exported to other countries, rather than used for food security at the subsistence level (EPZ, 2005). To meet the increasing global demand for fish and fishery products, production needs to increase by 50 million Metric tons by the year 2050 (Tacon and Forster, 2001).

Fish production in Kenya is divided into two sectors; capture fisheries and aquaculture. Capture fisheries is mainly practiced in the Indian Ocean and major natural lakes and rivers and contributes 98% of the total national fish production while aquaculture contributes 2%(MoLFD, 1999). Aquaculture, contributes substantially to the livelihoods of rural communities living beside rivers and river floodplains in East Africa (FAO, 2007, Mbugua, 2008). The main fish types reared under aquaculture and used for household consumption are the Nile tilapia (*Oreochromis niloticus*), and the African Catfish (*Clarias gariepinus*) (Charo-Karisa*et al.,* 2007).

The African Catfish (*C. gariepinus)* is a sub-species of the Catfish, genus *Clarias* which originated in Africa and the Middle East(Teugels, 1984). It is the most popular of the Clarias species' reported in East Africa which also include *Clarias liocephalus* (carsonii), *C. werneri* and *C. alluaudi* (Greenwood, 1966, Teugels, 1984, CLOFFA, 1986) and has a ubiquitous distribution in rivers, streams, dams and lakes of Kenya(Charo-Karisa*et al.,* 2007). Successful culture and captive breeding of *C. gariepinus* has been carried out and fingerlings reared for small scale fish farming (Campell*et al.,* 1995, Macharia*et al.,* 2002). The fingerlings are also used as bait for the Nile perch fish in Lake Victoria since they are able to endure extreme environmental conditions (Okechi, 2004).

In a bid to improve the livelihoods of communities that live beside rivers and river floodplains as part of a poverty reduction strategy defined in a vision for the next thirty years, the

Government of Kenya launched an Economic Stimulus Programme (ESP) to improve the use of inland water resources through the adoption of commercial aquaculture (GoK, 2010).Increasing aquaculture productivity however requires a transformation from traditional subsistence type of fish production to modern commercial practice. This involves both technical change, the use of more commercial inputs, finance, and improved marketing systems to deliver to consumers a product at a competitive price(Brummett*et al.*, 2008). In order to develop a vibrant aquaculture sector within the country, the whole value chain for producing the end product, fish must be taken into account.

To date, most efforts in aquaculture production in the country have focused on developing capacity to manage and feed fish, with little characterization of existing fish strains(Ponzoni*et al.*, 2008) and few studies on the most economic production rates for various cultured fish strains within the different environments. Existing and developing markets and market players at different levels within the fisheries sector are not well mapped out and understood. Additionally, there is a paucity of improved fish strains, and insufficient quantities of fish seed available for the stocking of ponds within areas targeted for aquaculture(Brummett*et al.,* 2008, Ponzoni*et al.,* 2008).

1.2 Statement of the problem

Fish comprise a nutritionally important part of the human diet, and make a vital contribution to the survival and health of the population(Mbugua, 2002). Development of sustainable aquaculture within riparian communities of developing countries would greatly enhance national efforts to improve the nutrition and livelihoods of these communities. However, supportive research to address the aquaculture value chain, the diverse production and marketing systems and the quality of fish reared to support the growth of the industry is required. The aquaculture sector in Kenya, mainly dominated by smallholder farmers is growing and has a huge potential for further development. Fish production and off take levels are however low, resulting in low incomes for the farmers. In order to improve the livelihoods of those adopting aquaculture, the characteristics of the production systems need to be evaluated and optimal interventions identified. Additionally, among the species of fish identified for production under smallholder conditions, there is little selection and strain improvement implemented for the African catfish. Characteristics of populations of the fish obtained from diverse wild environments and used for production of fingerlings to be reared by farmers are not well defined. Breeding lines to produce fish that would meet the demands and preferences of the market need to be identified and multiplied through selective breeding programmes.

1.3 Objectives

1.3.1 General objective

The overall objective of this study is to contribute to the development of sustainable aquaculture within riparian communities of Kenya to improve the nutrition and livelihoods of these communities.

1.3.2 Specific objectives

The specific objectives are:

1. To characterize fish production and marketing systems under the smallholder aquaculture in Eastern province
2. To evaluate the growth and survival of a strain of African catfish under semi-intensive aquaculture production.
3. To describe the smallholder aquaculture value chain in Eastern Province in relation to the development of a sustainable breeding programme.

1.4 Research questions

1. What are the characteristics of the fish production and marketing systems for smallholder aquaculture production in Eastern province?
2. How variable is the growth and survival of African catfish strains from the Sagana river under semi-intensive aquaculture production systems?
3. What is the nature of the smallholder aquaculture value chain and how can it be influenced by a sustainable fish breeding program?

1.5 Justification

Fish farming is a growing food production system within Kenya, greatly supported by the government through the economic stimulus programme. This has resulted in a high demand for fingerlings. The lack of proper programmes for seed dissemination results in farmers using unimproved species and strains collected from rivers, dams and lakes as a source of seed and brood stock. The fish genetic resources and production systems being used by the farmers have not been adequately characterised. Characterization of fish genetic resources and the requisite production systems would help to determine the productivity of fished populations and their adaptability to both the systems and environmental changes as a result of climate change. Mapping the value chain assists in understanding the importance of selective breeding as a primary driver for aquaculture.There is little point in providing ideal water conditions and optimum feed quality to fish that do not have the potential to grow faster and be harvested in a timely manner. A value chain approach to selective breeding of fish is therefore important for the development of sustainable aquaculture in Kenya, and would contribute to national efforts to improve the nutrition and food security.

1.6 Scope of Study

The study was carried out through three main activities within the former Eastern Province of Kenya and at Sagana Aquaculture Centre which is the main center for aquaculture production within the province. As characterization is an important initial step in the development of any breeding programme, the first activity involved characterization of the production practices of small-holder aquaculture farmers in select sites of the Province. This is outlined in Chapter 3 of this thesis. Chapter 4 of this thesis presents a study on the performance of a sample of the source population at the Sagana Aquaculture Centre that is used for breeding the African catfish (*C. gariepinus*) for use by the small-holder aquaculture farmers. While in Chapter 5 a description of the aquaculture value chain within the province is presented. This information is critical in guiding the nature of selective breeding pertinent to improving production of African catfish (*C. gariepinus*) in Eastern Province. The final chapter of the theses presents a general discussion on the results obtained and conclusions from the study.

CHAPTER TWO
LITERATURE REVIEW

2.1 Overview of fish production in Kenya

2.1.1 History of fish farming in Kenya

In Kenya fish farming dates back to the early 20th century when trout was introduced as sport fish for stocking rivers between 1910 and 1921(Okemwa and Getabu, 1996). The rearing of the African cichlids has been carried out in ponds since 1924 with some experiments in tilapia rearing. It is thought that serious fish farming started in 1948(Balarin, 1985) with the establishment of Sagana and Kiganjo fish culture stations. Nyanza and Western provinces are estimated to have had more than 30,000 fishponds by 1980 (Zonneveld, 1983). Marine culture was introduced in the late 1970's with the establishment of the Ngomeni Prawn Farm pilot project. Kenya started to export fish in the early 1980's, when fish processing factories were established around Lake Victoria. Since then, the fisheries sub-sector gradually evolved from a domestic consumption oriented industry to an export oriented industry with value added processing being adopted.

Despite the long history, aquaculture production has only seen an increase in uptake in recent years (2007-2011), as illustrated in Figure 1. At present, the number of fish farmers is estimated to be between 7,500 and8, 000 with over 10,000 individual ponds (MoFD, 2012). Although aquaculture is yet to become commercial in Kenya, strong interest by the private sector is increasing the prospects for commercialization of aquaculture activities. The Government, through the economic stimulus program, is also supporting construction of fish ponds (GoK, 2010).

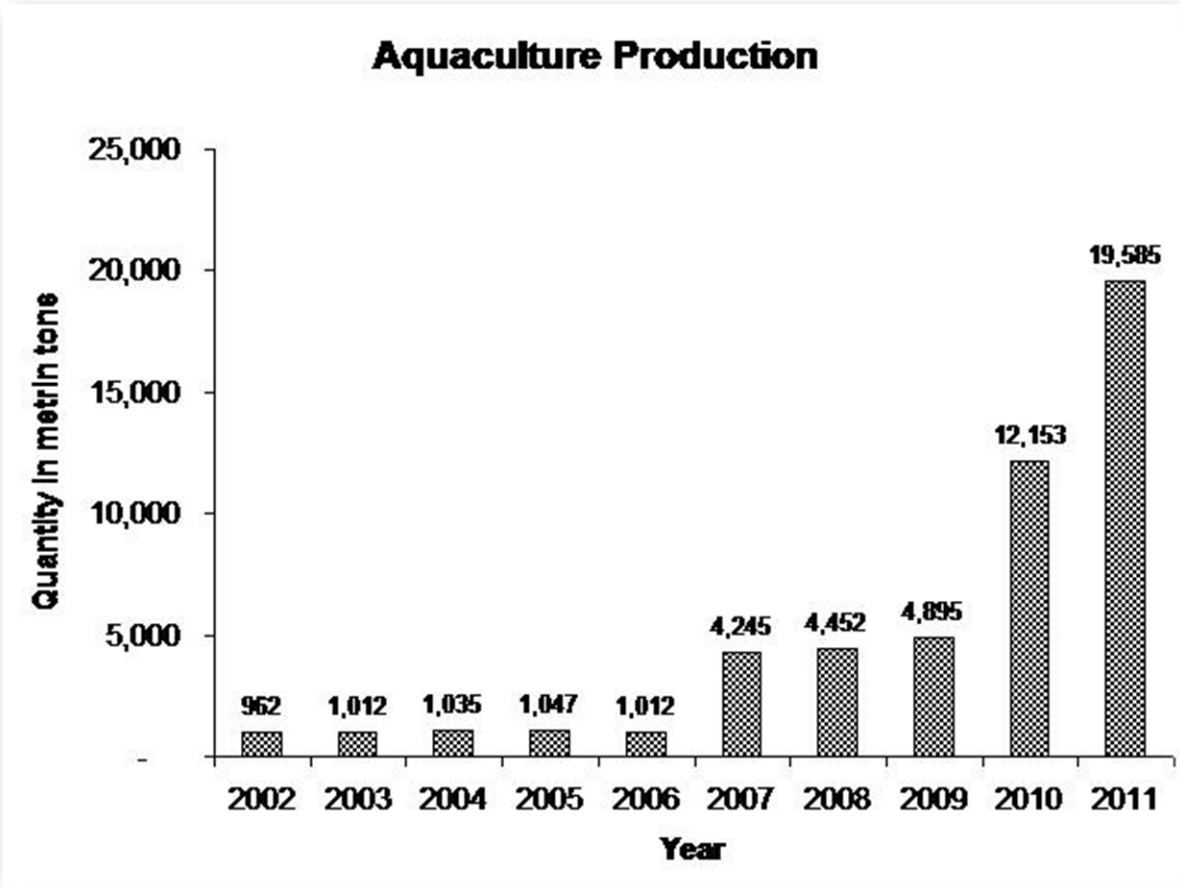


Figure 1: Trends in quantity of fish produced from aquaculture in Kenya (Source: FAO 2006b)

The species largely utilized for pond culture are Nile Tilapia (*Oreochromis niloticus)* and the African Catfish (*Clarias gariepinus*). Other exotic fish species also raised under aquaculture but in low quantities include the Largemouth Bass (*Micropterus salmoides*), Trout (*Salmo trutta* and *Salmo gairdneri*) for river and lake stocking and *Oreochromis spirulus niger*(Balarin, 1985).

2.1.2 Fish industry in Kenya

The fisheries sub-sector provides employment and income to over 500,000 Kenyans engaged in fish production and related enterprises. In terms of contribution to the gross domestic product (GDP), Kenya's fishing industry accounted for 0.5% of GDP in 2011(KNBS, 2012). Kenya’s total fish production increased to 167,700 Metric tons valued at about KShs. 19.5 billion in 2011 from 150,000 MT valued at 15 billion in 2010 (MoFD, 2012, Figure 2). This was an increase of 19% in quantity and 27% in ex-vessel value compared with 2010 figures. The increase in quantity can be attributed to increase in farmed fish and *Rastrienobola argentea* (Omena) catches from Lake Victoria, while the increase in ex-vessel value can be attributed to the ever increasing value of fish due to the high demand for the same. Kenya's aquaculture potential amounts to about 1.4 Million hectares of which only 2% is exploited. This implies a capacity to produce 11 million tons of fish worth well over KShs. 50 billion annually(MoFD, 2012).

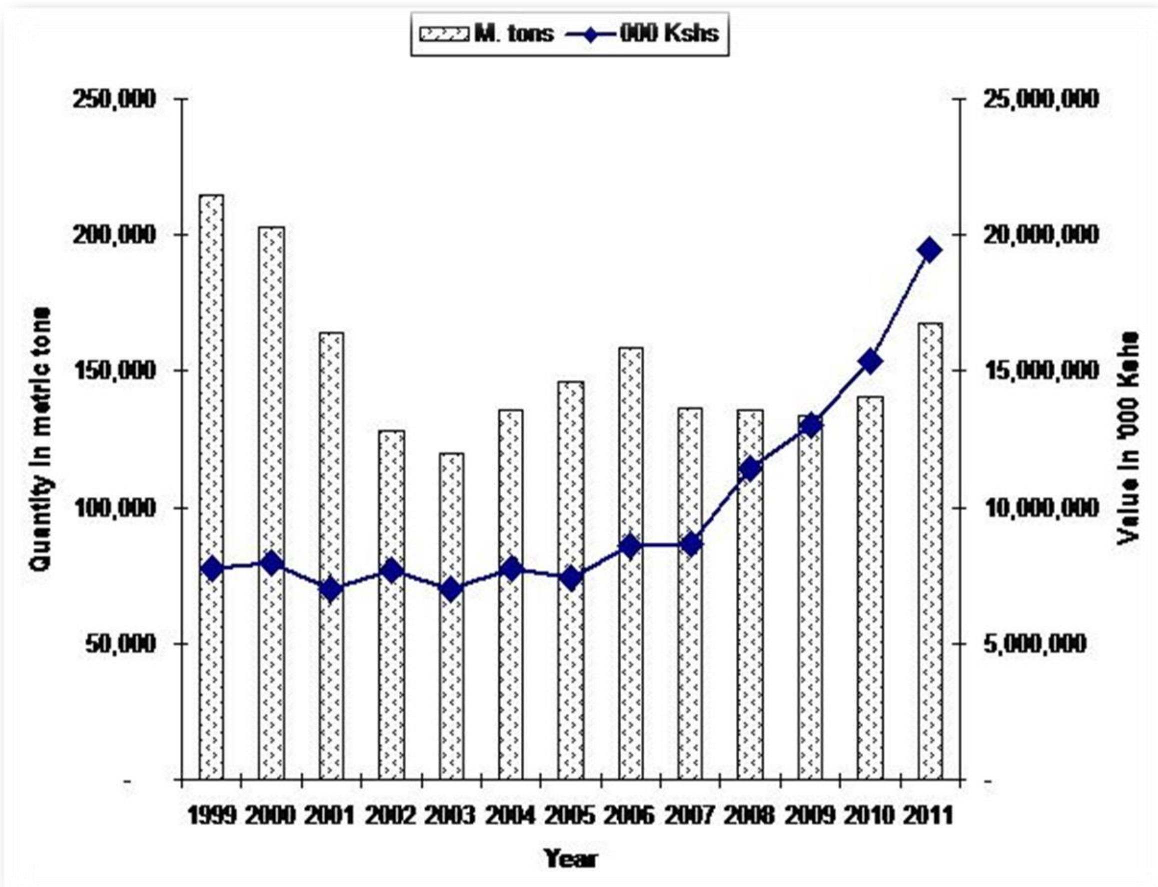


Figure 2: Fish production trends and value 1999 – 2011(Source: Ministry of Fisheries Development, 2012)

Kenya's freshwater fishery resources include major lakes like Victoria, Naiveté, Turkana, and Baringo; smaller ones like Jipe, Challa, Kanyaboli and Kenyatta; dams such as the Tana River dams, and a variety of both cold and warm water rivers across the country. Inland capture fisheries contributed 83% of Kenya's total fish production in 2011(MoFD, 2012). Lake Victoria is the principal fishery in Kenya which accounted for 133,801 metric tons or 80% of the country's total annual fish production in 2011(MoFD, 2012). Fish species found in the different lakes of the country are presented in Table 1.

Table 1: Fish species found in various lakes and rivers of Kenya

Inland water Body	**Fish species**
Victoria	*Alestes spp, Bargus docmak, Barbus spp, Clarias spp, Rastrineobola argentea, Haplochromis spp, Labeo victorianus, Lates niloticus, Momyrus spp, Proptopterus aethiopicus, Schilbe mystus, Synodontis spp, O. niloticus, and Other tilapia*
Turkana	*L. niloticus, Tilapias, Labeo spp, Bargus spp, Citharinus spp, Disticodus spp, Clarias spp*
Naivasha	Black Bass, Crayfish*, O. leucostictus, Tilapia zilii, Cyprinus carpio*
Baringo	Tilapia, Protopterus, Clarias, Barbus
Tana River	Tilapia, *Common Carp, Clarias spp, Barbus spp, Labeo spp,* Eels, *Momyrus spp*
Nairobi river	*Alestes affinis, Amphilius uranoscapus, Anguilla bengalensis, Barbus intermedius, Barbus jacksoni, Barbus kersteni, Clarias gariepinus, Clarotes laticeps, Cyprinus carpio carpio, Labeo cylindricus,*

Source: Ministry of Fisheries Development, 2012

2.2. Systems of fish farming adopted in Kenya

Aquatic organisms under culture include a wide variety of taxa and species each with specific biological characteristics and diverse environmental requirements (Barg*et al.*, 1997a). Major differences in culture practices generally depend on the feeding behavior of the species cultured. Diversity in the farming systems exists with regard to the intensity of use of resources, such as land, water, seed, feed and fertilizer inputs. Most global production is based predominantly on extensive and semi-intensive systems and on culture-based fisheries, producing affordable finfish for domestic rural markets and subsistence (Tacon*et al.*, 1995). The farming approach employed by developing countries has been geared towards management for fish survival, whereas the farming approach used in developed countries is geared more towards management for profit (Tacon, 1996). In Kenya aquaculture is practiced at varying intensification using different types of holding units as presented in Table 2.

Table 2: Characteristics of holding units used for aquaculture production in Kenya

Type of holding	Characteristics	Fish species cultivated
1. Pond culture	Earthen ponds are the most common and form the bulk of aquaculture production. Comprise still water earthen ponds for either intensive or semi-intensive aquaculture. .	Tilapia, Catfish, Common Carp
2. Raceway culture	Typically long, narrow, rectangular ponds through which water flows continuously. Either made of concrete or of earth. Earthen raceways are the most common. Unit allows for high stocking densities because of the high water exchange rate.	Trout
3. Tank culture	Circular structures with a central outlet. The circular shape makes self-cleaning effective because the wastes are flushed out in the resulting vortex toward a central drain. Mainly made of concrete.	Tilapia and Trout

2.3.1 Extensive system

Extensive aquaculture systems have a low level of management with practically no external inputs directed into the production. Fish are stocked in floating cages, earthen ponds and other water impoundments and left to fend for themselves. These systems depend on the natural productivity of the fish and the physical conditions of the water. The stocking densities therefore depend on the carrying capacity of the environment. These systems are characterized by low yields ranging between 0.05 and 0.15 kg/m^2/year(Mbugua, 2008). The main species cultured in this manner are the *Oreochromis niloticus, Tilapia zilli, Clarias gariepinus* and *Cyprinus carpio*. In Kenya, these systems contribute 10% or more of the total country's aquaculture production(Mbugua, 2008).

2.3.2 Semi-intensive system

Semi-intensive aquaculture production is the main system of production in Kenya. Fish here are reared in earthen ponds fertilized using chemical and organic fertilizers at varying proportions to enhance the natural productivity. Exogenous feeding using rice, maize or wheat bran is carried out to supplement pond productivity. Production in these systems ranges between 0.5 and 1.5 Kg/m^2/year(Mbugua, 2008). Polyculture is often practiced with various combinations of *Oreochromis niloticus, Tilapia zilli, Clarias gariepinus* and *Cyprinus carpio*.

2.3.3 Intensive systems

In intensive aquaculture systems, more fish are produced per unit area by substituting the natural food web with external inputs. These systems employ raceways and various types of tanks as holding units. The units allow for high stocking densities because of the high water exchange rate and provision of a complete diet for the fish. These systems can be divided into:

i. Flow through systems where water flows through the production units supplying oxygen while removing wastes. The water is then released back into the environment. This type of system has been implemented for trout production in Kiganjo, Bagureti, Tamtrout and Ndaragwa(Mbugua, 2008).
ii. Bio-filter recycle systems: here water from the production units is passed through a screen filter that sieves out most suspended solids. The water is then pumped through a bio-filter where bacterial action detoxifies the water. The water is then aerated before being pumped back to the production units. This system is employed by the Baobab fish farm in Mombasa and the Kitengela aqua farm for the production of tilapine fish (Mbugua, 2008).

2.4 Challenges to fish production under natural environments

Fishery resources utilized for human consumption in the world are reported to be exploited at their Maximum Sustainable Level (MSL) with many exceeding that value(FAO, 2000e). Apart from over-fishing, in Eastern Africa, factors such as pollution and invasive weeds such as the water hyacinth, have led to environmental degradation resulting in a decline of catches from Lake Victoria(Okechi, 2004). Indiscriminate agricultural practices in the catchments also threaten the lake and other water bodies leading to additional problems of nutrient loading and siltation. While capture fisheries production remains at a fixed level, aquaculture production continues to expand. Changing climatic conditions, pollution and reduction in surface water availability however continue to threaten capture fisheries. Aquaculture on the other hand is set to remain one of the fastest-growing animal food-producing sectors, and in the next decade, total production from both capture fisheries and aquaculture is anticipated to exceed production of beef, pork or poultry(FAO, 2012).

2.5 Value chain analysis and aquaculture

The current trend in research and development efforts for different production systems is to use a value chain perspective(FAO, 2012). Value chain analysis provides an excellent 'lens' for:

- Focus on distributional issues, growth and global linkages
- Benchmarking of changes over time and assessing the relative importance of factors affecting competitiveness, and the costs and earnings for those involved in the value chain;
- Identifying gaps/weaknesses in value chain performance in addition to 'levers' and targeted action programmes to 'upgrade' and improve performance of a value-chain.

A value chain is a sequence of related enterprises (operators) conducting activities (functions) so as to add value to a product from its primary production, through its processing and marketing to the final sale of the product to consumers(Macfadyen*et al.,* 2011). The functions of each link in the chain involve sourcing inputs, producing, and then delivering products to the next link in the chain. Best practice value chain analysis is composed of a number of both descriptive and analytical steps. First, the overall market within which the specific value chain operates is described followed by the operators and functions. Analytical steps in the process involve benchmarking the performance of the value chain both so as to consider changes over time, and potentially also to compare with international competitors. The main steps in a value chain are presented in Figure 3.

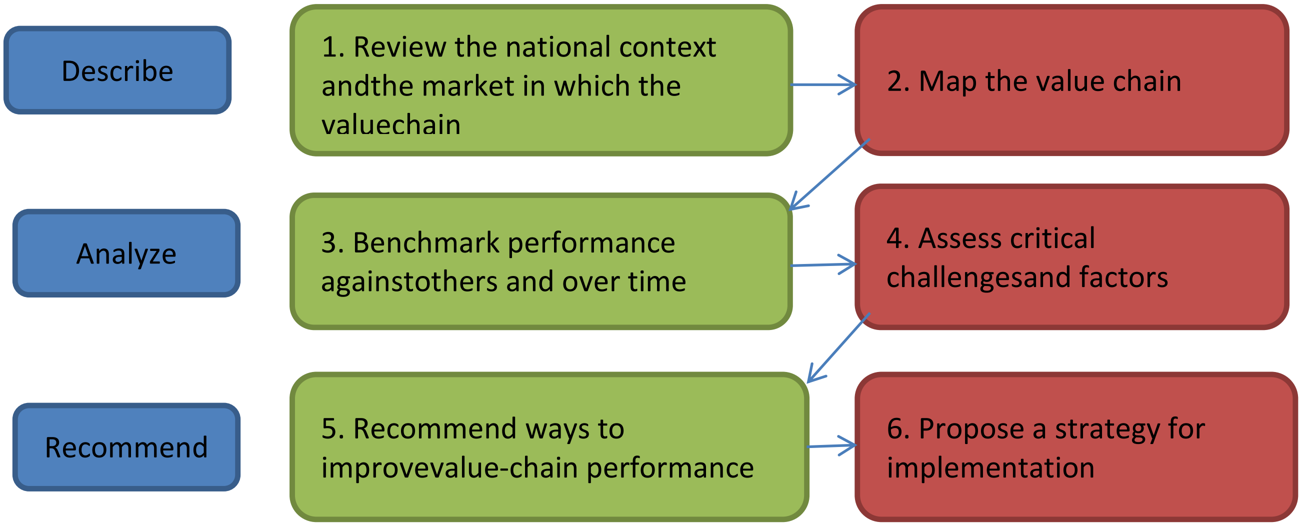


Figure 3: Steps involved in value chain analysis (Source: Macfadyen *et al*, 2011)

Performance of a value chain can be improved through reducing costs, increasing outputs, and/or increasing the prices of their products. Typically mechanisms to do so involve improving efficiency and the quality of products moving to the next link in the value chain. Improvements in a value chain performance can also be supported by governments and other parties external to the value chain. Policies, institutions and infrastructure all impact on the ability of actors in the value chain to source inputs, engage in various activities, and to sell and deliver products to customers.

Aquaculture has been noted to be the fastest-growing animal-food-producing sector in the world. Given the economic inefficiency of fisheries in several developing countries and the importance of fishing to the world's poor, understanding the value chain plays an important role in the production of fish and fish related products (Wilkinson, 2006).Improved integration of various actors within the value chain is necessary particularly in systems where little of the money attained within the fisheries sector goes to the primary producers who often remain poor (Ponte, 2007).

2.6 Water quality in aquaculture

The quality of water available for aquaculture determines to a great extent the success or failure of a fish cultural operation"(Piper*et al.*, 1982). Productivity of a given body of water is determined by its physical chemical and biological properties. Environmental properties of water need to be conducive for growth and survival of fish as the population density of organisms in water systems varies according to the physio-chemical factors such as hydrogen-ion concentration (pH), dissolved oxygen (DO), conductivity, nutrients and temperature and light(Abolude, 2007).

Water temperature is one of the major environmental factors that affects and controls food utilization at all levels and stages of fish growth. Temperature has a pronounced effect on the rate of chemical and biological processes in water (Adeniji and Ovie, 1990). It also influences the dissolved Oxygen (DO), for instance, fish require twice as much oxygen at 30^{o}C than at 20^{o}C.DO in water is essential to life in the aquatic environment as it affects the physiology and distribution of the aquatic organisms. The ideal range of dissolved oxygen in the water must be at least 5mg/l to sustain fish and other aquatic life in a water body (Adakole, 2000). Insufficient DO in a water system tends to cause anaerobic decomposition of organic materials thereby leading to the production of obnoxious gases such as carbon dioxide, hydrogen sulphide and methane. Both organic and inorganic particles in water tend to screen out light from the bottom of a water body (Abolude, 2007)). Additionally substances including carbonate, bicarbonate, chloride, sulphate, nitrate, calcium and sodium when in suspension cause turbidity in the water thus reduce photosynthesis leading to a reduction in the of DO. Inadequate DO negatively affect fish as it leads to reduced feeding, impaired growth, stress and increased susceptibility to diseases.

The hydrogen-ion concentration (pH) as a measure of the acidity or alkalinity of the water should range between 6.5 - 9.0 for fish culture(Adeniji 1986, Auta, 1993). An increase in acidity and alkalinity of a water body beyond these ranges results in a change in the toxicity of that water for aquaculture. Solar radiation and high temperatures accelerate photosynthesis, which in turn increases carbon dioxide absorption thus altering the bicarbonate equilibrium and producing OH. This raises the pH and poses a threat to aquaculture(Branco and Senna, 1996).

2.7 The African catfish

2.7.1 Distribution and biodiversity

Catfishes of the genus Clarias (*Siluroidei, Claridae*) are widespread in tropical Africa and Asia. Having evolved in the Pliocene epoch (upper Tertiary period) some 7–10 million years BC(Sudarto, 2007), there are now 58 species all living in freshwater but able to tolerate salinities up to 2.2 ppt recognized in Fish Base(Clay, 1977). The African catfish (*Clarias gariepinus)* is a typical air-breathing catfish with a scale-less, bony elongated body with long dorsal and anal fins, and a helmet like head (Figure 4). Colour varies dorsally from dark to light brown depending on the water conditions, and is often mottled with shades of olive and grey while the underside is a pale cream to white (Skelton, 2001). The fish can grow very large with a maximum reported length of 170 cm (IGFA, 2001) and weight of 60 kg (Robins*et al.*, 1991).The genus Clarias was reviewed in the 1980s, resulting in several widespread species being synonymized under the name *Clarias* (*Clarias capensis* of southern Africa, *C. mossambicus* of central Africa and *C. lazera* of West and North Africa(Teugels, 1986).

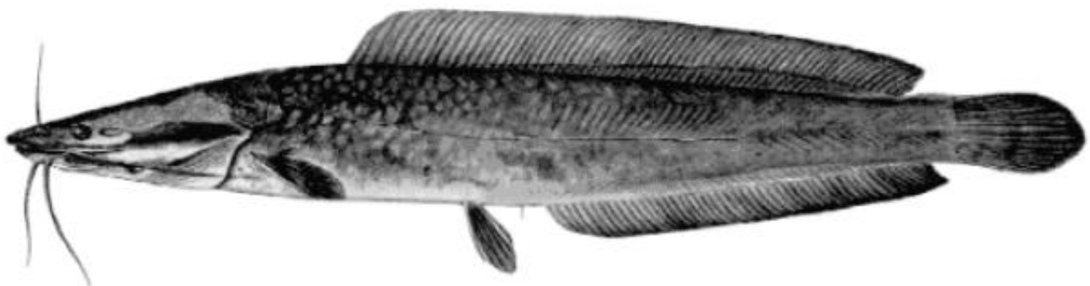


Figure 4: Lateral view of *Clarias gariepinus* (Source: FAO, 2012).

The native range of *C.gariepinus* covers most of the African continent, with the exception of Maghreb, Upper and Lower Guinea, and the Cape provinces of South Africa (Picker and Griffiths, 2011). According toSkelton (2001) it is probably the most widely distributed fish in Africa. *C.gariepinus* is widely tolerant of many different habitats, even the upper reaches of estuaries, but is considered to be a freshwater species. It favours floodplains, slow flowing rivers, lakes and dams. It can tolerate waters high in turbidity and low in dissolved oxygen, and is often the last or only fish species found in remnant pools of drying rivers(Safriel and Bruton, 1984, Van der Waal, 1998).

2.7.2 Performance and behaviour of the African catfish

Diet and feeding

Clarias gariepinus is considered to be omnivorous displaying both scavenging and predatory behaviour (Bruton, 1979a). It is known to have an extremely varied diet comprising fruits and seeds, all types of aquatic invertebrates and small vertebrates, small mammals and even plankton (Bruton, 1979a, Skelton, 2001). Larger individual fish show a specific dietary shift towards other fish as they grow bigger (Willoughby and Tweddle, 1978). However, inactive foods are generally preferred (Bruton, 1979a, Skelton, 2001).*C. gariepinus* can be an efficient predator and are seen to hunt in ‘packs’ where they herd shoals of small fish against submerged aquatic vegetation before devouring them (Merron, 1993). Solitary feeding, social hunting and coordinated pack-hunting behaviour in addition to feeding migrations have been observed in *C. gariepinus*populations (Bruton, 1979a, Merron, 1993).

Growth potential

C. gariepinus is considered to have a rapid growth rate depending on the ambient conditions and habitat (Bruton and Allanson, 1980, Hecht and Appelbaum, 1987, Britz and Pienaar, 1992). Growth has been found to be positively density dependent with individuals recorded to reach 200 mm length within a year (Bruton and Allanson, 1980, Skelton, 2001). In females, the growth rate decreases after 3 years resulting in the males reaching larger sizes (Skelton, 2001). Individuals of this species are known to live for eight or more years(Bruton and Allanson, 1980).

Reproduction in the wild

Shoals of the fish migrate upstream or to the shores of still water bodies prior to breeding (De Moor and Bruton, 1988). Courtship, spawning and egg laying takes place at night often after rain (Bruton, 1979b). Eggs usually adhere to vegetation of either aquatic or terrestrial origin that is submerged sometimes as a result of seasonal rises in water levels. Hatching of the eggs occurs usually within 24 to 36 hours of spawning(Bruton, 1979b). There is no parental care of the young (Hecht*et al.,* 1988). The average fecundity of *C. gariepinus*in Lake Sibaya has been reported to be 45 000 eggs for a 2 kg fish (Bruton, 1979b)

Reproduction in ponds

For artificial rearing under aquaculture production systems, *C. gariepinus* are propagated using artificial means in restricted hapas. Artificial reproduction of the fish is achieved by inducing the breeding of females using hormone treatment followed by artificial fertilization using the milt from males that are knocked out. Eggs thus fertilized are incubated to hatch, and then grown till they achieve fingerling size before being introduced into larger ponds for maturation. The development of a reliable method for the production of *C. gariepinus* fingerlings is one of the priorities in aquaculture research in Africa. Hormone-induced reproduction of the African catfish using deoxycorticosterone acetate, human chorionic gonadotropin and common carp pituitaries has been carried out successfully(Hogendoorn, 1979). The practice of artificially breeding and growing *C. gariepinus* to a fingerling size results in better rates of fertilization and hatching, protection against predators and unfavorable environmental conditions and better conditions for growth and survival.

Environmental tolerance ranges

C. gariepinus can endure extremely harsh conditions (Skelton, 2001). They tolerate very low oxygen concentrations and even survive for considerable periods out of water, via the use of a specialized suprabranchial organ (Safriel and Bruton, 1984, Hecht*et al.*, 1988). Water temperatures between 8°C and 35°C, salinities of 0 to 10‰ and a wide pH range are all tolerated (Safriel and Bruton, 1984). *C. gariepinus* exhibits high growth rates between 25 and 33 °C, with optimum growth recorded at 30°C (Britz and Hecht, 1987). The ability of the fish to tolerate these extreme conditions allows it to survive even in moist sand and in borrows with an air-water interface (Bruton, 1979c, Van der Waal, 1998).

2.7.3 Genetic diversity in cultured stocks

Captive holding of Catfish on fish farms has resulted in a certain amount of genetic change in *C. gariepinus*. The mean heterozygosis in a captive population of *C. gariepinus was* reported to be of less magnitude than in a wild Population. Wild *C. gariepinus* grew 15–43% better under culture conditions than populations that had been held on-farm. Reviews of genetic variability in *C. gariepinus* have reported strong evidence of inbreeding, founder effects and genetic drift in most captive populations.(Van der Bank*et al.*, 1992, Van der Walt*et al.*, 1993a, Grobler*et al.*, 1997, Van der Bank, 1998).

Selective breeding and management of the genetic diversity can reverse negative consequences of domestication and even improve performance. Van der Bank *et al.,* (1992) showed that outcrossing to other captive stocks and with wild fish raised mean heterozygosity of a farmed population to 7.6%. Similarly, populations of *C. gariepinus* that were found to have been purposefully outcrossed among research stations were significantly more heterozygous than fish held in isolation on a single station(Teugels*et al.,* 1992). Among *C. gariepinus* stocks, significant variation in growth indicates that selection for better performance in aquaculture is possible (Van der Bank, 1998). A well-maintained experimental line of *C. gariepinus* was shown to outperform both wild strains and a population held on a local hatchery(Van der Walt*et al.,* 1993a). In Southeast Asia, hybrids between *C.gariepinus* and *C.batrachus* or *C.macrocephalus* have been widely produced, reportedly combining the faster growth of the African catfish with the more appealing culinary attributes of the fish strains from Asia(Uraiwan, 1993).

2.7.4 Opportunities for selective breeding and genetic improvement of *C.gariepinus*

Since the 1970's *C.gariepinus*has been considered to hold great promise for fish farming in Africa (CTFT, 1972, Micha, 1973, Jocque, 1975, Kelleher and Vincke, 1976, Hogendoorn, 1979, Richter, 1979). Selective breeding occurs when individuals or families that display a certain performance level for a specific trait are chosen in efforts to increase the performance of that trait in the next generation (Tave, 1993). In terrestrial animal and plant species, selective breeding programmes have made a substantial contribution to agricultural productivity and viability. In contrast, with the exception of a few fish species, aquatic animals have undergone a limited amount of genetic improvement or domestication, and most aquaculture stocks in current use in developing countries are genetically similar or inferior to wild, undomesticated stocks(Gjedrem, 2000, Brummett*et al.,* 2004, Ponzoni*et al.,* 2011). This contrast raises two important differences between fish and terrestrial species in the context of conservation and use of genetic resources. Firstly, an enormous potential exists to improve aquaculture productivity through the application of selective breeding programmes that capitalize on the broad genetic diversity present in many wild fish populations. Secondly, the conservation of fish genetic resources should emphasize the application of appropriate genetic management to ensure that cultured populations remain viable and productive. However, there is need for monitoring and managing impacts of cultured fish on wild populations and the preservation of habitats where (unique) wild populations reside(Lind *et al.,* 2012).

Aquatic animals allow the implementation of several approaches to genetic improvement. These include hybridization and cross-breeding, chromosome manipulation, sex control, transgenesis and selective breeding. These are almost always mentioned in aquaculture genetics reports, papers and meetings without making a judgment about their relative cost efficiency (FAO, 2008). Selective breeding offers the opportunity of continued genetic gain that can be transmitted from generation to generation. Gains achieved in a nucleus can be multiplied and expressed in thousands or millions of individuals in the production sector (Ponzoni *et al.,*2007, Ponzoni *et al.,*2008).

The failure of some attempts to achieve genetic improvement with aquatic animals that have been reported may have been more duet weaknesses in the base population than to the selection method utilized. Irrespective of the method of choice, continued genetic improvement hinges upon an adequate balance between high selection intensity and the maintenance of a low inbreeding rate(Lind*et al.,* 2012). Whereas there is evidence of response to selection in traits such as growth rate, monitoring unfavorable correlated responses also needs to be done. For instance, there are likely alterations in behavior as a consequence of selecting for growth rate(Olesen *et al.*, 2011). Higher growth hormone levels in faster growing fish have also been correlated with increased aggression in some fish (Jonsson *et al.,* 1998) which may have environmental consequences in the event the farmed fish are re-introduced in the wild. From an economic viewpoint, investment appraisal studies indicate very favorable benefit-to-cost ratios for genetic improvement programmes for both Nile tilapia(Ponzoni *et al.*,2007)and common carp(Ponzoni *et al.*,2008). This has been shown to occur even in situations where there was genotype by environment interaction (Ponzoni*et al.,* 2008). Limitations and constraints during the implementation of genetic improvement programmes in fish often occur particularly in developing countries. Challenges are commonly related to financial resources, and to a paucity of human capacity in the field of aquaculture. Other constraints include technical issues related to individual identification of fish; however these can be overcome with a relatively small investment.

The first breeding program implemented by the WorldFish Center in Egypt to improve growth performance of *C. gariepinus* in 2005 reported significant genetic variation in various morphometric traits (Ponzoni and Nguyen (2008). The World Fish center has since proposed a value chain approach sensitive to different environmental conditions as the most sustainable way to selectively breed *C. gariepinus.*

CHAPTER THREE

CHARACTERIZATION OF FISH PRODUCTION AND MARKETING PRACTICES UNDER SMALLHOLDER FISH FARMING SYSTEMS OF EASTERN KENYA

3.1 Introduction

To improve the livelihoods of the communities dependent on aquaculture as part of a poverty reduction strategy defined in a vision for the next 30 years(GoK, 2010), the Government of Kenya launched an Economic Stimulus Programme to improve the use of inland water resources through the adoption of commercial aquaculture. The programme aimed to construct 200 fish farming ponds in each of the one hundred and sixty constituencies found in the country. The ponds were to be stocked with appropriate fingerling determined by the different communities(GoK, 2010). Information on the farm environmental characteristics, potential aquaculture production rates and behaviour of the species targeted within different environments is however scarce. Part of this study thus aimed to characterize fish production and marketing practices under smallholder farming systems found in the Eastern province of Kenya and determine the traits of economic importance for fish production in order to inform planned selection and breeding programmes for improvement.

3.2 Materials and Methods

3.2.1 Description of study site

The study was carried out in Meru Central, the first district in Eastern Province where aquaculture was introduced under the Economic Stimulus Programme. The district lies to the east of Mt. Kenya covering a total area of 2,982 km^2 of which 1,952 km^2 is for human settlement (Figure 5). Most of the agro-ecological zones described in Kenya are found in Meru District. The climate and rainfall is greatly influenced by Mt. Kenya and the Nyambene Hills. Rainfall varies from 2 600 mm annually in the upper highlands of Mt. Kenya to 500 mm in the lower parts of the district. The area has two rainy seasons, March to May and from October to December (Kenya Meteorological Service, 2013). Most of the farmers are smallholder farmers. The farmers had limited land size, low production and practised mixed farming, i.e., crop cultivation, animal husbandry and aquaculture.

The system of aquaculture recommended through the ESP in this area is semi-intensive with a stocking density of 3 fingerlings per m^2 in ponds of 300 m^2 under a monoculture of *Oreochromis niloticus*.

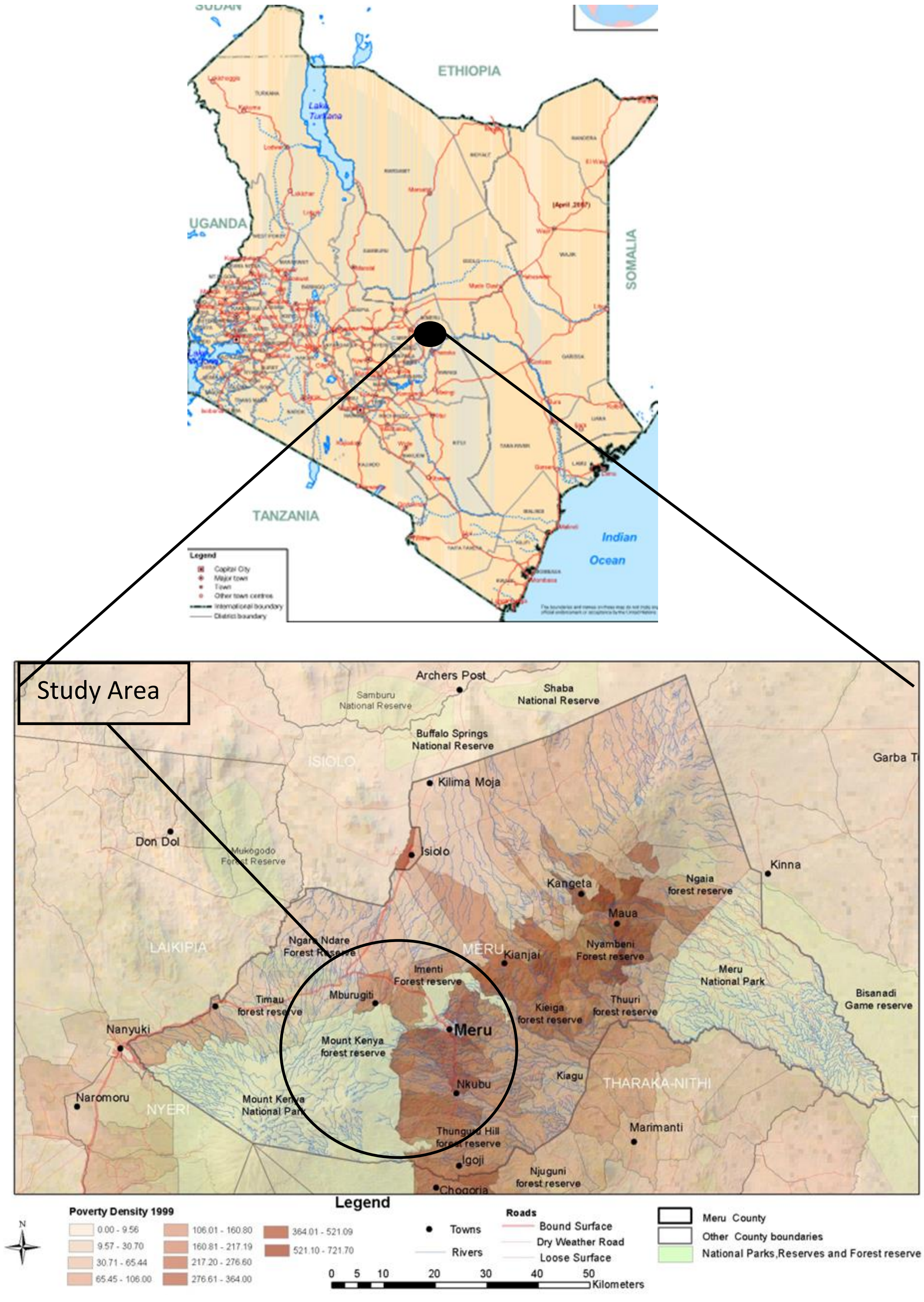


Figure 5: Map of Kenya indicating the Study area

3.2.2 Data collection and analytical procedures

Stratified random sampling techniques were used to identify households within the community to provide information on aquaculture. Farmers were grouped depending on the nearest major town within each division then randomly sampled for questioning. Various players in the aquaculture production system were categorized into three broad categories; farmers, service providers and traders. The District and Divisional fisheries officers, together with the chiefs, provided key information on aquaculture practices within the area. Semi-structured questionnaires and participatory appraisal within the community were used to obtain information from respondents. The information collected included the farmer characteristics and the fish farming practices. Information on the fish production traits perceived to be of economic importance to the farmer and the marketing of the fish and fish products were also collected. A total of 198 famers (112 from Meru, 42 from Nkubu and 44 from Mburuguti); 13 traders and three key informants provided information.Qualitative and quantitative data analysis techniques were used to evaluate information collated on aquaculture from the target area. Results are presented using descriptive and inferential statistics. Differences between observations were tested using analysis of variance, and the Least Significant Difference (LSD) was used to test significant differences between means while the Pearson correlation coefficient was used to present the relationship between variables. The SPSS Version 11.5(SPSS, 2007) and GenStat 14 (Payne*et al.*, 2009) computer software were used for analyses.

3.3 Results

3.3.2 Characteristics of the fish farming systems

Characteristics of the farming systems in the study area are presented in Table 3. In all the towns, farmers reared fish mainly to obtain higher incomes and for food security. Fish were reared mainly by individual farmers with a few ponds managed by groups mostly under semi-intensive production. Groups rearing fish were mainly institutions and women groups. Most of the individual farmers were males and they practiced monoculture. However, in Meru town, six percent of the farmers practiced polyculture. Nile tilapia (*O. niloticus)* was the predominant species under monoculture followed by the African Catfish (*Clarias gariepinus),* while a combination of the two species were reared under polyculture.

Table 3: Description of the fish farming systems within the study area

	Towns		
Characteristic	**Meru**	**Nkubu**	**Mburuguti**
Number of farmers (N)	112	42	45
Pond ownership*			
Individual	103 (92%) [a]	38 (90.5%) [a]	41 (80.5%) [a]
Group	9 (8%) [a]	4 (9.5%) [a]	4 (8.9%)[a]
Farmers' gender *			
Male	73(70.9%)[a]	30(78.9%)[a]	33 (80.5%)[a]
Female	30 (29.1%)[a]	8 (21.1%)[a]	8 (19.5%)[a]
Management system[ns]			
Extensive	2 (1.8%)	0 (0%)	1 (2.3%)
Semi-intensive	109 (98.2%)	42 (100%)	43 (97.7%)
Culture system[ns]			
Monoculture	105 (93.8%)	42 (100%)	44 (100%)
Polyculture	7 (6.25%)	0 (0%)	0 (0%)
Fish species reared*			
O. niloticus	111 (94.1) [a]	42 (100%)	44 (93.6%) [a]
C. gariepinus	7 (5.93%) [a]	0 (0%)	3 (6.38%)[a]
Source of water*			
Wells/canals	8 (7.3%)	3 (7.1%)	6 (9.5%)
Streams/Springs	34 (30.9%)	6 (14.3%)	8 (18.6%)
Rivers	47 (42.7%) [a]	15 (35.7%)	18 (42.9%) [a]
Piped water	21 (19.1%) [a]	18 (42.9%)	5 (11.6%) [a]
Type of fertilizer[ns]			
Organic fertilizer	17 (15.7%)	7 (19.4%)	19 (48.7%)
Inorganic fertilizer	30 (27.8%)	12 (33.3%)	4 (10.3%)
Combination	61 (36.5%)	17 (47.2%)	16 (41.0%)

**differed significantly within the group characteristic and across the towns ($p<0.05$),*

ns-did not differ significantly within the group characteristic and across the towns.

[a] - Parameters significantly differed between the towns and within the group characteristic

In all the areas, water from the ponds was obtained mainly from the rivers. The respective municipal councils also provided piped water to the farmers which in some instances was used as the main source of water for aquaculture. There was, however, no relationship between the source of water and the management system adopted for aquaculture. The type of fertilizer used by the farmers, however, differed significantly ($p<0.05$, LSD) depending on the source of water (Table 4).

Table 4: Types of fertilizer used in ponds supplied by different sources of water

Source	**Inorganic fertilizer**	**Organic Fertilizer**	**Inorganic and Organic fertilizer**
Wells*	3 (6.7%)[a]	2(4.8%)[a]	11(11.8%)[a]
Stream/Spring*	5(11.1%)[b]	9(21.4%)[b]	32(34.4%)[b]
River*	28(62.2%)[ab]	23(54.8%)[ab]	29(31.2%)[ab]
Piped water[ns]	9(20.0%)	8(19.0%)	21(22.6%)

**differed significantly across fertilizer type ($p<0.05$),*

ns-did not differ significantly across fertilizer type.

[a, b] *- Parameters with the same letter differed significantly within fertilizer type*

Feed management

Most famers (66%) used only commercial feeds which were supplied by the government (Table 5). Additionally, farmers that had greater access to natural sources of water (rivers, streams and springs) tended to use more of commercial feeds than organic wastes (Table 6).

Table 5: Types of feed used for the cultured fish

Species	**N**	**Commercial feed only**	**Organic waste feeds only**	**Commercial feeds and Organic waste**
*O.niloticus**	185	123(66.5%)	61(33.0%)	1(0.5%)
C.gariepinus	10	0	10(100.0%)	0
O.niloticus & C.gariepinus [ns]	7	4(57.1%)	3(42.9%)	0

**differed significantly across feed types ($p<0.05$),*

ns- did not differ significantly across feed types

Table 6: Type of feeds used for the different water sources

	Commercial feeds only	**Organic waste only**	**Commercial feeds and organic wastes**
Wells*	14(11.2%)[a]	3(4.6%)[a]	0
Stream/Spring*	38(30.4%)[a]	8(12.3%)[b]	0
River*	47(37.6%)[a]	37(56.9%)[ab]	1(100.0%)
Tap water	26(20.8%)	17(26.2%)	0

**differed significantly across feed types (p<0.05).*

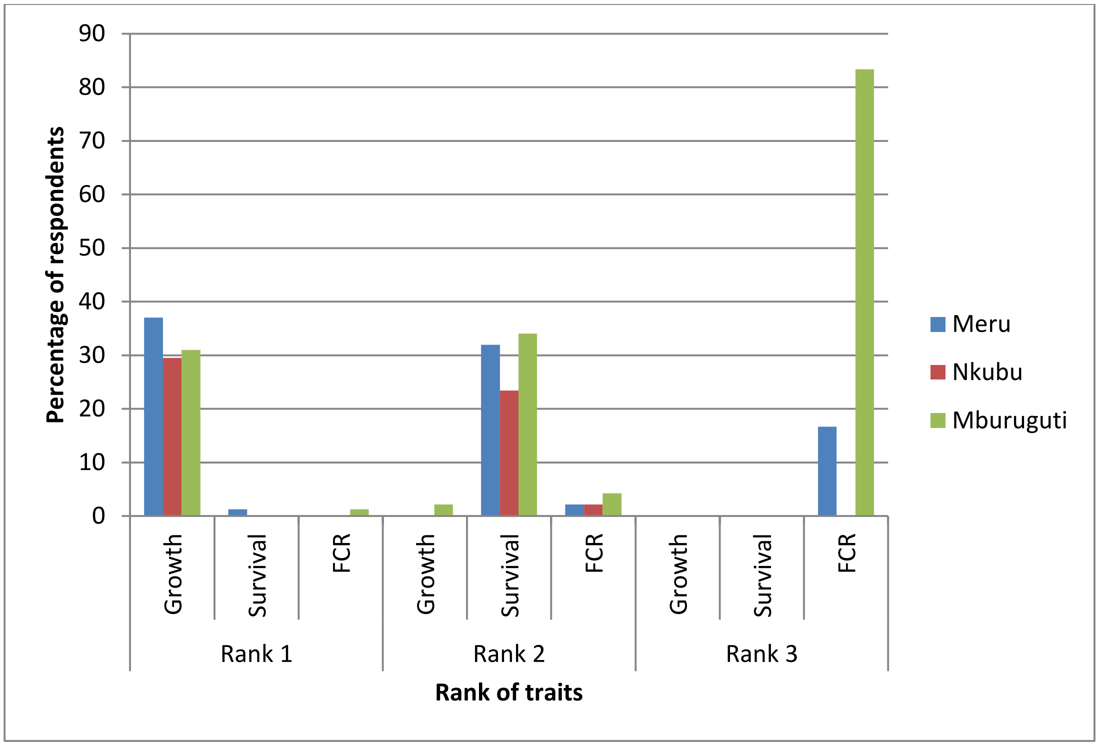
[a, b] *- Parameters with the same letter differed significantly within feed type*

Fish health

In all the areas studied, only six percent of the respondents indicated that they encountered challenges of fish diseases in their farms. However, aside from indicating that the condition of the fish reared changed when they were unhealthy, no farmer specified a type of disease for the fish. Those who experienced diseases consulted the Fisheries Department for advice and treatment. There was no correlation between the source of water, or type of fertilizer used with the occurrence of disease.

3.3.3 Traits of economic importance in fish farming

In fish rearing, farmers have target traits of economic importance for the market, which later they hope to turn into profit. In the areas studied, growth, survival and feed conversion ratio (FCR) were the traits the farmers considered economically important. Farmers were requested to rank the traits in order of importance for the fish species reared (Figure 6). In all the areas, for both *O. niloticus* and *C. gariepinus,* high growth rate was most desired trait (Rank 1), followed by survival (Rank 2).



Rank 1 – Most important, Rank 2 – Second in importance, Rank 3 – Third in importance.

FCR- Feed Conversion Ratio

Figure 6: Ranks of fish traits perceived to be of economic importance by the farmers

3.3.4 Markets and marketing

Market outlets for farmed fish

The various outlets for marketing of fish and their related products in the area studied are presented in Table 7.Most farmers in all the towns (90%) sold their fish to the local communities and within local markets.

Table 7: Market outlets for fish in Meru Central district

	Meru	Nkubu	Mburuguti
Type of market			
Local community	68 (68.0%)	19(57.6%)	28 (65.1%)
Local markets	22 (22.0%)	11(33.3%)	11 (25.6%)
Hotels/Restaurants/Schools	4 (4.0%)	1 (3.0%)	3 (7.0%)
Urban markets	1(1.0%)	1(3.0%)	0 (0%)
Local & Urban markets	5(5.0%)	1(3.0%)	1(2.3%)

A large proportion of the farmers had a ready market for the fish reared (52.5%), while for 47.5% of the farmers, marketing of their fish varied with the prevailing consumer demand. Most of the fish from the farms (95%) was sold fresh and whole. The target sale weight for the African catfish (*C. gariepinus*) was 1.72 ± 0.45 kg, while that for the Nile tilapia (*O. niloticus*) was 0.45 ± 0.14 kg.

Fish traders and their sources of fish

The fish traders at the markets were of mixed gender, 61.5% (n=8) male and 38.5% (n=5) female. The main source of fish sold by the traders was fish from Lake Victoria in Nyanza, with some fish coming from the farms within the study area. The traders dealing with farmed fish collected the fish from the farms although they preferred farmers bringing the fish to them. A major concern was the irregular supply of farmed fish and the preference of "wild" fish by consumers rather than cultured fish, as this was deemed to taste sweeter that cultured fish. *O.niloticus* was the most preferred fish species for sale while *L. niloticus* was the second most preferred fish species (Figure 7).

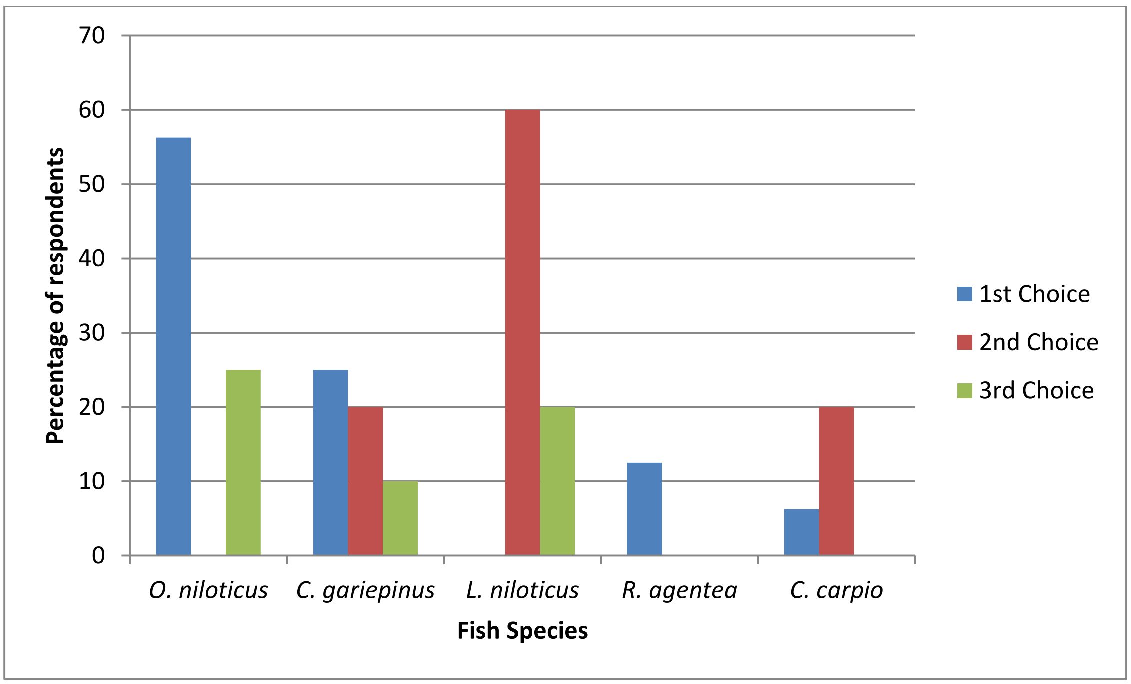


Figure 7: Preference for species of fish marketed by traders in the study area

Fish on the market was sold either whole (23.07%), in fillet form (46.15%) or fried (30.76%). Of the species sold at the market, *L. niloticus* was reported to sell faster when sold as whole fish due to its "sweet" taste, however, it was also noted that this fish was highly bony. Nile Tilapia (*O.*

niloticus) was the main farmed fish that was sold by the traders. The traders indicated that the demand for fish in the area was higher than the supply.

3.3.5 Suggestions for improving fish farming

Farmers from the different areas had different suggestions for the improvement of fish farming as presented in Figure 8. In all the areas, a high proportion of respondents suggested improving fish marketing and availing of credit facilities to support aquaculture as the most important interventions desired for improving fish productivity. Provision of extension services and availability of quality feeds and seeds were also considered important.

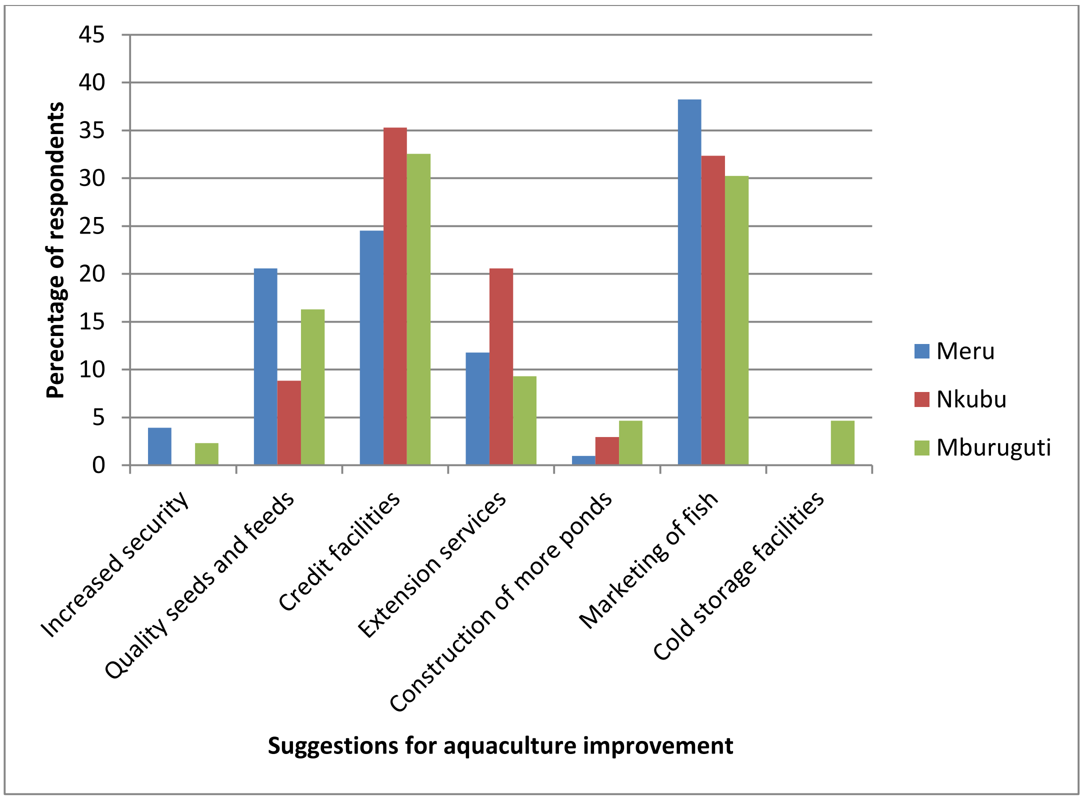


Figure 8: Suggestions by farmers for improving fish farming

3.4 Discussion

Small-scale fish farming has been widely adopted by farmers within the Meru Central District. Though the ownership of ponds was said to be for men in the households, women played a significant role in routine fish management and culture activities, cleaning ponds and providing security to the ponds during day time. Similar roles by different gender in the management of smallholder fish farming in West Africa have been reported by Singh *et al.*, (2008) and Lawal (2002).

3.4.1 Species reared and management practices adopted

The Nile tilapia (*O.niloticus)* was the most common cultured warm water species in areas of the Meru Central district. *Oreochromisniloticus* and its hybrid have been cited as the most important cultured fish species in the tropics under semi-intensive smallholder farms (Mbugua, 2002, Charo-Karisa*et al.,* 2006). The African Catfish was not reared by many farmers although it is known to be versatile under differential water qualities, and to have a high flesh to bone ratio(Charo-Karisa*et al.,* 2008). Okwu (2011)showed that in Nigeria, Catfish is cultured by a large number of farmers because of its good marketability, resistance to harsh environmental conditions and survival in diverse water conditions.

It was evident that farmers in the present study strived to implement the management practices specified in the ESP. This was a semi-intensive system of managing fish with limited external inputs. Practices adopted by farmers were not different in relation to the diverse sources of water used for fish farming. The main practice implemented in all the areas to try and boost off-take, was the use of both organic and inorganic fertilizers to promote the growth of plankton, one of the main fish feeds. Fish farmers in other regions have been able to increase fish yields in ponds by using inorganic or chemical fertilizers and organic fertilizers or manures, which help maintain the nutrient status of ponds (Brunson*et al.,* 1999, Bocek, 2009).

Diseases were not noted to be a common occurrence in the study areas. However, the greater challenge was the loss of fish through predators like fish eating birds (e.g. kingfishers); frogs and reptiles (snakes and monitor lizards) and man. The communities would need to collaboratively determine measures for pond security with the most optimal management of time in order to enhance fish production in the area.

3.4.2 Feeds and feeding practices adopted in Meru Central

Farmers in the study sites were provided with formulated fish feeds by the government at a subsidised cost. However, due to limits in the supply, farmers provided the feed in small portions to enable the feed last to the next supply and this affected fish growth. Fish were also given vegetables and kitchen wastes and no mineral and vitamin supplements were provided. Feeds manufactured for fish by the private sector within the area were available, but the farmers indicated that the prices were too high. This had a great impact on the growth and development of the fish. Fish nutrition and feeding are critical for growth, reproduction and health in fish populations. Availability of adequate feeds also greatly influences the response of fish to the physiological environment and to various pathogens. Fish willingness to spawn and the quality of sperm and eggs produced is greatly affected by the quality of feed. Selective breeding for growth improvement in fish also improves feed retention and FCR (Thodesen*et al.,* 1999, Neely*et al.,* 2008).

More efficient use of by-products from the fishing industry could serve to enhance fish nutrition. Bacterial protein meal produced using natural gas (methane) as a carbon source, has been shown to be an excellent substitute for fish meal in fish feed (Aas*et al.,* 2006). Feed for carnivorous fish like the catfish can to a large extent be substituted with grain protein and oils instead of animal protein and fat (Gatlin*et al.,* 2007). Algae and aquatic macro types are good feed sources for farmed fish but should not exceed 15-20% of dietary requirements (Hasan and Chakrabarti, 2009).

3.4.3 Traits of economic importance in smallholder fish farming

Farmers received fingerlings from the government through the ESP and hence were not involved in the breeding and multiplication of fish. Fast growth rate and good survival rates were noted to be of most importance to the farmers when rearing the fish supplied. There was, however, no information available on the genetic potential of the fish reared within the environments targeted by the ESP. Reproductive performance and growth rate have been noted to be of primary importance for increased productivity when rearing tilapia strains (Ponzoni*et al.,* 2011). Other traits of importance include mothering ability, survivability, adaptability and resistance to parasites and diseases. Due to the high fecundity and short generation intervals of fish, selective breeding programmes when implemented have shown rapid genetic gains (Ponzoni*et al.,* 2011, Gjedrem*et al.,* 2012). Information from studies conducted in other tropical environments should be adapted and used to inform the development and implementation of a breeding and improvement programme for smallholder fish production as part of the ESP.

3.4.4 Marketing of Fish from the smallholder farmers in Meru Central

Most fish produced on the smallholder farms was sold directly within the local community, either to individuals or to the nearby markets. The production practices introduced by the ESP mean that farmers tend to harvest their fish in large batches resulting in periodic gluts and lower prices. Prices offered for fish in the local markets also tend to be low as middlemen involved in transactions pass on the costs of transportation to the farmers. The marketing of fish was dominated by male traders, contrary to what has been reported in fish markets found in other parts of the country. Women have been reported to dominate fish marketing in Lake Victoria regions of Kenya, and in several urban centres (Ikiara, 1999). According to Kristyn and Sergio (2005), fish is the most heavily traded food commodity and the fastest growing agricultural commodity in the international market. In Nigeria, demand for fish has been reported to be doubling as alternative sources of animal protein become expensive due to the ever-increasing human population and high production cost of the protein sources (Akolisa and Okonji, 2005).

Traders in the local markets of Meru district collect fish from several sources then transfer these to other larger urban trading centres for more profit. Most of the traders in the urban centres, however, obtained fish they sold from Lake Victoria. A high fishing pressure on Lake Victoria due to demand from other parts of the country has been noted by the Fisheries Department in Kenya (Mbugua, 2002).

Farmers tended to focus more on the production and management of fish than on issues related to the markets and marketing of fish. There was some misconception that the ESP which introduced the fish would also be a key supporter in the marketing of fish produced. A challenge for those implementing the ESP is to manage the expectations of communities targeted in development. There is also need for development and strengthening of fish markets and marketing of fish products in Meru Central for farmers are to obtain better incomes from aquaculture.

3.5 Conclusion

There is great potential for smallholder aquaculture in Meru Central, however, research is needed to develop, manage and market the most optimal strains of fish for the prevailing environments. Fish farming is capable of creating employment, improving food security and hence uplift the living standards of the people. Necessary inputs such as feeds and water and unavailable capital/credit to start fish farming should be made available at a reasonable cost. Additionally, well established marketing channels are critical for farmers to actualize their investment in fish farming. In implementing the ESP, the great willingness and determination of farmers to adopt and implement the practices introduced as a way of improving their livelihoods should be harnessed through development and introduction of fish strains with good potential for growth and survival in order to improve their incomes from aquaculture

3.6Recommendations for developing smallholder fish farming in Kenya

Aquaculture is fast growing within the food production industry globally, with the vast majority of aquaculture products being derived from Asia (Gjedrem*et al.,* 2012). Compared with farm animals, fish are more efficient converters of energy and protein. It is estimated that at present less than 10% of aquaculture production is based on improved stocks, despite the fact that annual genetic gains reported for aquatic species are substantially higher than that of farm animals (FAO, 2006). There is an inadequate supply of improved strains of fish for small-scale producers in Kenya. Efforts need to be enhanced in the selective breeding and multiplication as the market grows. The marketing of fish products is central when promoting aquaculture enterprises.

Further research and capacity development is required in the area of fish feeds and the management of feeding for optimal outputs. The costs of feeds were perceived to be high relative to the anticipated returns from the investment. Therefore, alternative and economical sources of feed using locally available materials need to be explored. There is a need for further research and information on alternative sources of raw materials for fish feeds. The area studied had readily available natural water sources; however, information on the quality of the water was not available. Water plays an august role in fish production; hence understanding the physical and chemical qualities of water is critical for successful aquaculture.

CHAPTER FOUR

GROWTH PERFORMANCE AND SURVIVAL OF THE AFRICAN CATFISH (*Clarias gariepinus*) UNDER SEMI-INTENSIVE AQUACULTURE SYSTEMS IN CENTRAL KENYA

4.1 Introduction

The application of genetic tools in aquaculture mainly in more developed countries has led to increased fish production, improvements in production efficiency, product quality and financial profitability of aquaculture enterprises and industries (Akinwande*et al.*, 2009). Several successful genetic improvement programmes of cultured aquatic species have been developed over the last four decades achieving genetic gains of between 10% and 20%per generation for economically important traits(Ponzoni*et al.,* 2013).

Development of improved catfish strains and the application of "best practice" aquaculture techniques that are compatible with available resources and sustainable over time can result in up to 70 percent increases in production(Ponzoni and Nguyen, 2008). Using artificial propagation techniques, it is possible to ensure a regular supply of African catfish seed to support fish farming enterprises. Currently however, there are no improved strains of the African catfish available in Kenya, and cultured stocks exhibit low productivity. Successful selective breeding programmes on growth of African catfish in Egypt and Nigeria have resulted in its profitable farming, achieving market weights of 600-700 g in 6 months and 1.5 kg in 12-15 months(Ponzoni and Nguyen, 2008). This study was thus undertaken to generate preliminary information on the characteristics of a base population of an African Catfish strain that is being developed at the Sagana Aquaculture Center (SAC) in Kenya. The study presents information on the growth performance and survival rates of *C. gariepinus* during the early rearing stages in hapa-in-pond nursing conditions.

4.2 Materials and methods

Description of the study site

The study was undertaken at the SAC located in Kirinyaga County, central Kenya. The center is located at a global position of -0° 39' 40.76", +37° 11' 58.33" and occupies 20.5 hectares of land on which it has established 73 fishponds for experimental activities. The topography of the county is generally gentle sloping with mostly volcanic soils, and an average annual rainfall of between 1100 and 1250 mm. Water to support the aquaculture at SAC is obtained by gravity via an open canals from the Ragati River, a tributary of the larger Sagana River. Daily temperatures in the area range from a minimum of 12°C to a maximum of 26°C with an average of 20°C. These cool temperatures result from the high altitude of the region (1000 – 1200m above seas level), and its proximity to Mt. Kenya.

Selection and management of the experimental population

The experiment was carried out in one pond measuring 1500m^2 in which 88 hapas, each measuring 3m^3 were set up. 132 mature African Catfish, 44 males and 88 females, sourced from the African catfish population at SAC and were selected based on their external morphological features as described byViveen*et al.*,(1985) to serve as base parents for the study. Female fish were selected on the basis of ovarian biopsy (Legendre*et al.,* 1992) and mated randomly with the males, while the males were selected on the basis of their weight. The sires were grouped according to their body weight to form four sire groups (SG), each with eleven sires as follows: SG1 (400-550g), SG2 (551-650g), SG3 (651-750g) and SG4 (>750g). Each male was mated to two females to produce 88 full-sib and 44 half-sib families. Each hapa was stocked with fry from individual females in a completely randomized design. There were differential stoking densities (SD) depending on the number of fry hatched across the sire family groups. For purpose of the analysis, the stocking densities were grouped as follows: SD1 (10 – 40 fry/hapa), SD2: (41 – 70 fry/hapa), SD3: (71 – 100 fry/hapa) and SD4: (101 - 130 fry/hapa).

The full sib-family groups of fry were reared in separate hapas to the fingerling stage following protocols outlined by FAO (1987). Briefly, hatched larvae were fed on Artemia for the first two weeks, then provided with increasing quantities of finely ground fish meal as their anticipated rate of growth changed. To avoid fouling of the hapas by algae, the hapas were cleaned every 2 weeks. Ten fry from each hapa were sampled and their average wet weight recorded every two weeks over a two month period. Sampling started when the fish were four weeks old. Measurements were taken until the fish reach a fingerling size, the stage at which they are sold from SAC to farmers to rear for the market.

Water quality

Dissolved oxygen (DO), temperature, pH, total dissolved solids (TDS) and salinity of the pond in which the hapas were maintained were measured every two weeks, twice a day (0600hrs and 1400hrs) using a multi-parameter measuring kit. These water quality parameters were taken a day before the sampling of fry for weighing was carried out.

Traits evaluated

a) Growth parameters

The growth performance of the fish over the two months was evaluated as the specific growth rate (SGR), weight gain at the end of two months (WG) and the average daily gain (ADG). These were calculated using equations 1-3 presented below.

$$\boldsymbol{SGR = 100 * (LnTW_f - LnTW_o)/t}$$ ………..Equation 1

Where -SGR is the overall growth rate (%per day), *Ln*: natural logarithm, TW_f final mean weight in grams, TW_o: initial mean weight in grams, and *t*: time (days)

$$\boldsymbol{WG = W_f - W_o}$$ ……………..Equation 2

WG is weight gain at the end of two months, W_f is the final bodyweight and W_o is the initial bodyweight.

$$\boldsymbol{ADG = (W_2 - W_1)/T}$$ …………Equation 3

Where *ADG* is the average daily gain, W_2 is the mean final weight, W_1 is the mean initial final weight and *T* is the rearing period in days.

The mean final weight (**FW**) and the mean final total length (**FTL**) of the fish within sire groups and for different stoking densities were also calculated.

b) Survival

The survival rates after each day of sampling within each sire group and stocking density was calculated as:

$$S_{t_i} = (\boldsymbol{N_{t_i} / N_{t_0}}) \times \boldsymbol{100}$$ ………..Equation 4

Where S_{ti} is the survival rate from the time of stocking (t_0), to the time the fry reach the fingerling stage (t = 32, 46 and 60days) And N_t is the number of fry in a hapa at the different time intervals as defined above.

Data analysis

Quantitative procedures were used to analyze the information collated and the results are presented using descriptive and inferential statistics. The differential growth rates between sire groups and for different stoking densities were analyzed using the following model:

$$y_{ijk} = \mu + SG_j + SD_k + e_{ijk}$$

Where Y_{ijk}, is the weight of fry at time intervals (t); μ, is the population mean weight at time t, SGj is the sire group (j=1-4) and SD_k is the stoking density (k= 1-4).

Resultant adjusted mean weights were used to plot growth curves.

Differences in the means between growth parameters and survival rates between sire groups and between stocking densities were tested using Least Significant Difference (LSD) at $P<0.05$. The Pearson rank correlation between the various traits at $P<0.01$ was also obtained. SPSS Version 20 and SAS Enterprise 4.3 were used to carry out various analyses.

4.3 Results

4.3.1 The experimental population and water quality

Characteristics of the experimental population and water parameters measured are presented in Table 8. Variation in the phenotypic characteristics of the mating population was quite high (>32%). The heaviest sire weighed 1322g while the heaviest dam weighed 918g. The mean number of fingerlings was lower than that of fry, mainly attributed to cannibalism as no dead fry were present in the hapas.

Table 8: Mean measurements (± standard deviation) of the experimental population and water quality parameters

Parameters	Mean±SD	%CV
Sire weight (g)	642.3±333.04	34.45
Dam weight (g)	538.48±164.77	32.01
Egg weight (g)	56.95±23.62	48.69
Number of fry	23.68±28.26	43.23
Number of fingerlings	20.39±11.29	55.39
Water quality parameters		
Dissolved Oxygen (mg l^{-1} Morning)	3.08±1.31	42.55
Dissolved Oxygen (mg l^{-1}, Afternoon)	5.41±5.44	100.55
Temperature (°C, Morning)	23.30±0.69	2.96
Temperature (°C, Afternoon)	25.90±3.13	12.08
pH (Morning)	8.86±1.15	13.00
pH (Afternoon)	8.99±0.97	10.78
Salinity(Morning)	0.04±0.01	15.75
Salinity(Afternoon)	0.04±0.02	43.30
TDS (mg l^{-1}, Morning)	47.67±19.43	40.75
TDS (mg l^{-1}, Afternoon)	46.00±16.46	35.79

CV – Coefficient of variation (%); SD – Standard deviation; TDS- Total Dissolved Solids

Differences in water parameters taken in the mornings and afternoons were not significant (Table 9). The lowest temperature recorded in the morning was 23°C while the highest recorded in the afternoon was 29°C. The experiment was carried out within one season, hence no differences in water quality was experienced due to variation in precipitation at the station.

4.3.2 Growth performance

The least square means and standard deviations for the growth parameters of the ten fingerlings sampled in various sire groups are presented in Table 10. Differences were evident in the weight gain and average daily gain across the sire groups, however these were not significant. Differences in the final weight, final total length and specific growth rate were significant ($p<0.05$, Table 9). The stocking density didn’t significantly affect the average daily gain (ADG) and the specific growth (SGR). Stoking density significantly affected the final weight (FW). The hapa with the highest FW (SD4) had the highest final weight of fingerlings sampled, however, these fingerlings were shortest in length (FTL, $p<0.05$).

Table 9: Mean measurements (± standard deviation) of growth parameters for the sire groups (SG) and stocking densities (SD) of the *C.gariepinus* from fry to fingerling stage

		FW (g)	FTL (cm)	WG (g)	ADG (g)	SGR (g)
Sire groups	SG1	3.53±2.99[a]	6.45±0.58[a]	2.48±2.46	0.04±0.04	1.81±0.47[a]
	SG2	5.06±3.77[b]	5.00±1.91[b]	3.85±3.53	0.06±0.06	2.15±1.39[ab]
	SG3	4.79±1.75[c]	6.87±2.85[c]	3.96±1.93	0.07±0.03	2.89±1.04[b]
	SG4	4.18±2.31[c]	7.16±1.80[d]	3.17±1.95	0.05±0.03	2.33±0.42[ab]
Stocking Density	SD1	3.95±2.85[a]	6.70±1.59[a]	2.95±2.28[a]	0.05±0.04	2.21±0.43
	SD2	4.22±2.47[b]	6.79±2.42[a]	3.19±2.41[b]	0.05±0.04	2.24±1.01
	SD3	3.68±1.89[a]	6.10±2.31[b]	2.64±2.10[a]	0.04±0.04	2.12±1.18
	SD4	5.76±3.31[d]	6.08±2.10[b]	4.72±2.82[d]	0.08±0.05	2.67±1.05

a,b,c,d– means with different letters significantly differed ($p<0.05$) across groups; means with the same letter did not significantly differ across the groups
FW *- Final weight;* ***FTL*** *- Final total length;* ***WG*** *- Weight gain;* ***ADG*** *- Average daily gain;* ***SGR*** *- Specific growth rate.*

Growth curves presenting the average growth performance for the different sire groups are shown in Figure 9. Progeny of sires with average weight (SG2 and SG3) showed the highest growth rates while progeny of the lightest (SG1) and heaviest sires (SG4) showed significantly lower growth rates ($p<0.05$).

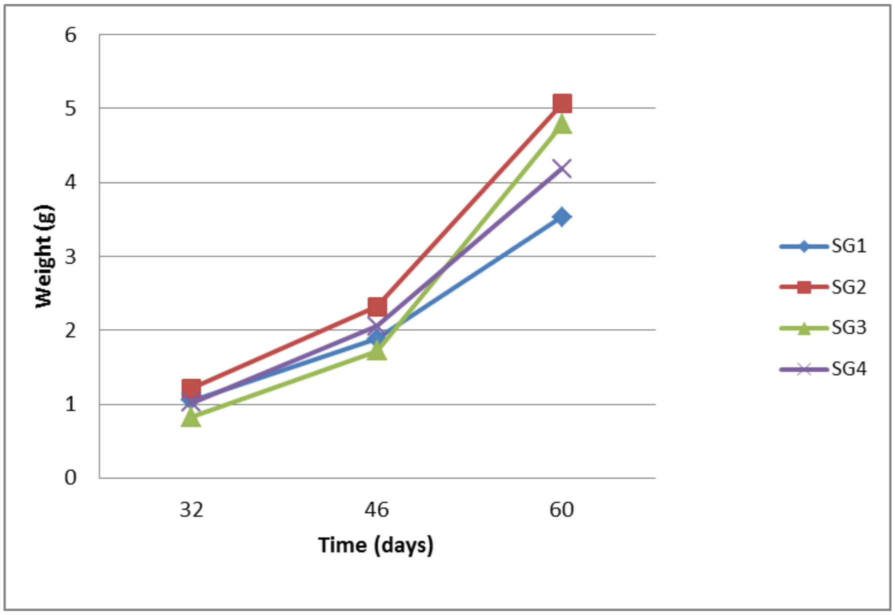


Figure 9: Growth curves of the African catfish from fry to fingerling for the different Sire Groups

4.3.3 Survival

Mean survival rates did not differ significantly between sire groups but differed significantly between the highest stocking densities (SD3 and SD4) and the lowest stocking densities (SD1 and SD2) (Table 10).

Table 10:Mean survival rates (%) of the various stocking densities (SD) of the African catfish from fry to fingerling stage

		S1	S2	S3
Stocking density	SD1	100%	96.55%[a]	90.83%[a]
	SD2	100%	92.30%[a]	84.84%[b]
	SD3	100%	90.73%[b]	88.51%[ab]
	SD4	100%	95.00%[b]	91.49%[a]

a,b– means with different letters significantly differed (p<0.05) across the sire groups; means with the same letter didn't significantly differ across the sire groups and stocking densities
S1-Survival rate at day 32, S2- survival rate at day 46 and S3- survival rate at day 60

Figure 10 shows the survival curves from fry to fingerling stage for the various sire groups. Progeny of sires weighing between 650 and 750g (SG3) had the highest survival rates while progeny of sires with lower weights (SG1 and SG2) had the lowest survival rates.

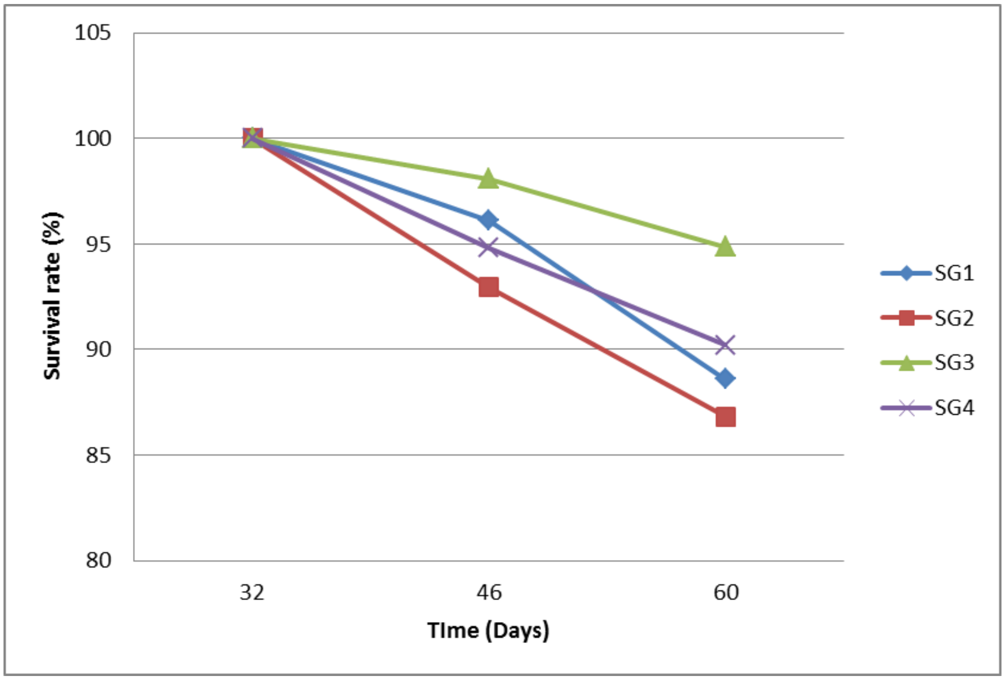


Figure 10: The cumulative survival rate (%) curves of *C.gariepinus* from fry to fingerling

4.3.4 Correlations between parameters

Correlations estimated between the various parameters are presented in Table 11. A positive and strong (0.615) correlation was found between the dam weights (DW) and the egg weight (EW), with heavier dams producing more eggs. Positive and strong correlations also existed between the growth parameters (FW, WG, ADG, and SGR).

Table 11: Correlation matrix of sire group, growth parameters and survival during the culture period

	DW	EW	FW	FTL	WG	ADG	SGR	Surv
DW								
EW	.615**							
FW	.129	.130						
FTL	-.233	-.111	-.383					
WG	.185	.114	.984**	-.443				
ADG	.185	.114	.984**	-.443	1.000**			
SGR	.297	.041	.670**	-.369	.785**	.785**		
Surv	.156	.013	.387	.028	.402	.402	.398	

***correlations is significant at p<0.01; Surv – Survival*

***FW** – Final weight, **DW**-Damn weight, **FW**- Final weight, **FTL** – Final total length, **WG**-weight gain, **ADG** – Average Daily gain, **SGR** – Specific Growth rate, **Surv**- Survival*

4.4 Discussions

4.4.1 Water quality

Water is a vital component and fish breeding system can be improved by managing its physical, biological and chemical parameters. Quality of water available for fish farming must be described for any proper-prepared plan for aquaculture. In the present study, the water quality parameters observed were within the non-toxic range to fish life in ponds(Boyd and Litchtkoppler, 1979) and were within the accepted range for catfish growth as described by FAO(2006b). Varying the water quality parameters has an impact on fish growth and several studies have shown that temperature has an effect on fish growth (Tidwell *et al.,* 1999, Person-LeRuyet *et al.,* 2004, Mciwem, 2006, Kling *et al.,* 2007, Okamura *et al.,* 2007, Handeland *et al.,* 2008, Sahoo *et al.,* 2008).

4.4.2 Growth performance and survival

Improving the growth rate is a main objective in aquaculture. Increased growth rate results in shorter production cycles thus reducing economic and biological risks of aquaculture operations. Growth rate is also favourably correlated to increased feed conversion efficiency(Thodesen *et al.*, 1999, Thodesen *et al.,* 2001, Ogata *et al.,* 2002, Silverstein *et al.,* 2005). Genetic improvement of feed conversion efficiency therefore relies on indirect selection for improved growth(Quillet *et al.*, 2007). Good prediction of growth is important for efficient production and contributes to a more profitable sustainable aquaculture. Growth rate can be expressed as average daily gain (ADG) or specific growth rate (SGR) (Dumas *et al.*, 2010). Within this study, the SGR significantly varied across the sire groups and stocking densities. According to and Van der Waal (1998) a considerable growth variation has been exhibited in African Catfish both in aquaculture and in the wild. Unfortunately, due to lack of prior information on the characteristics of the parent population, the weight of the sire in this study could not be attributed to its' age or its' genetic potential for growth. A stocking density of 41-70 fry/hapa at fry stage proved to be more optimum for growth performance. Stocking density is one of the main factors determining the growth and the final biomass harvested(Boujard *et al.,* 2002). Under crowded conditions at higher stocking densities, fish suffer stress as result of aggressive feeding interaction and eat less, resulting in growth retardation (Bjoernsson, 1994). Barua (1990) noted that successful aquaculture required careful selection of species, appropriate feeding and water quality management also in addition to density at which the fish are stocked.

Survival is not usually considered a major concern in the culture of *C.gariepinus* as the fish can live under highly variable conditions of water quality, stress and some diseases (Kestemont *et al.,* 2007). From the parents sourced from the Sagana River to breed, there was a high rate of mortality in larval stages. The larvae often exhibit strong cannibalism, which results in low survival rates in hatcheries. Survival rate in the African catfish is usually related to cannibalism. The species is highly cannibalistic when substantial differences in the size of fry occur (Baras and Jobling, 2002). The population studied exhibited cannibalism irrespective of the regular feed that was supplied within the hapas. Marimuthu *et al.,* (2010)noted that an increase in the feed application rate did not reduce cannibalism and increase the survival of African Catfish. The heterogeneity in size of fry within a hapa often leads to social dominance, which results in aggressive behaviour and cannibalistic responses (Hecht and Appelbaum, 1988). Other studies have also demonstrated that increased stocking density has a negative effect on survival and growth (Schram*et al.,* 2006). Cannibalism in the African catfish could therefore be influenced not only by environmental effects but also genetic effects. When rearing fingerlings for multiplication in aquaculture, cannibalism is undesirable, hence should be selected against when implementing a breeding program.

4.5 Conclusion and recommendations

The variation exhibited in the *C. gariepinus* studied is a clear indicator of great potential for selective breeding and genetic progress in a breeding program. The results obtained indicate that the characteristics of the sire greatly influence the survival of its offspring. However as the sample size was small, phenotypic and genetic characterization needs to be carried out at a wider scale in order to provide a basis for selection. Major developments in molecular genetics and genomics offer means of improving selection accuracies and selection intensities for many traits. Good growth rates and survival of fish are the most important traits of economic importance to the fish farmers in the communities studied.Selective breeding for both growth and survival has great potential in the development of a national genetic improvement program for the African catfish given the ease of getting broodstock and a suitable environment. The long-term sustainability of aquaculture sectors critically depends on the development and use of genetically improved stocks for cost-effective production.

CHAPTER FIVE

THE SMALLHOLDER AQUACULTURE VALUE CHAIN OF EASTERN KENYA

5.1 Introduction

Fish produced in smallholder aquaculture production systems are strategically important for nutritional security and for improved economic status of those who raise and market them. Smallholder production and marketing systems offer means to increase access to fish as a source of food through creating sustainable linkages between the farmers and the markets. Linking farmers to markets is widely viewed as a milestone towards promoting economic growth and alleviating poverty (Pica-Ciamarra*et al.,* 2011). Through the ESP, approximately 48,000 fish ponds were constructed in 2010 and 2011 spread across 160 constituencies in the country. The annual growth of the aquaculture sector changed from 7.4 percent to 8.8 percent, however there is still a potential to produce more fish through its farming in ponds. A Value chain (VC) approach to understanding the market structure is important to sustainable smallholder fish production. Outlining the VC also aids in understanding and identifying opportunities and constraints in the aquaculture sector. This section aims to outline the VC for aquaculture in Meru in relation to the development of sustainable breeding programmes.

5.2 Methodology

The study was carried out in Meru Central the first district in Eastern province where aquaculture was introduced under the ESP. Key actors involved in aquaculture production within the community were determined and stratified random sampling techniques used to identify the key informants to provide information on:

- Market opportunities
- Policies and legal frameworks
- Input supplies (Feeds and fingerlings)
- Business know-how
- Capacity building and supportive services (Credit facilities and extension services)

Information was generated using questionnaires, participatory appraisal and focused group discussions to identify key constraints to aquaculture development within the community. The exercise of mapping the VC involved identifying different players and their roles, and the flow of the product from brood stock supply to the final consumers of fish. A total of 198 famers provided information: 112 from Meru, 42 from Nkubu and 44 from Mburuguti. 13 traders and 10 key informants also provided information. A general industry/market assessment based on existing literature and available secondary data was also carried out. Descriptive data was analyzed using the SPSS (Version 20) computer software.

5.3 Results and discussion

5.3.1 Description of value chain participants

The main actors identified in the aquaculture value-chain in Meru central are presented in Table 12.

Input suppliers

Broodstock and fingerling supply: The main source of seed to the farmers were government hatcheries such as the Kenya Marine and Fisheries Research Institute (KEMFRI), Sagana Aquaculture Centre, Lake Basin Development Authority (LBDA) and private farms notably Dominion farm (Table 12). The hatcheries obtained broodstock for fingerling production from the wild and also from some cultured fish. Wild broodstock were used as replacement stock for the cultured broodstock in order to reduce inbreeding.

Feed supply: Fish feeds have been developed by some feed companies; however, they are not readily available. The feeds were generally procured by the government on behalf of the farmers through the ESP. Even though some farmers produced their own feeds through mixing various ingredients, they were not aware of the requirements for quality feeds for good growth.

Table 12: Main actors in the aquaculture value chain in Meru central and their proportionate contribution within the sites

	Proportion of respondents accessing different services		
Value chain actors	**Meru**	**Nkubu**	**Mburuguti**
Input supplier(*broodstock & fingerlings***)**			
Dominion farm	45%	0	2.3%
Small-scale hatcheries	2.4%	9.5%	11.5%
Wild	1.8%	0	0
Government hatcheries	72.4%	90.5%	86.3%
Input supplier (*feeds***)**			
Manufactured feeds	91 (87.5%)	40 (95.2%)	37 (88.1%)
Own formulated feeds	13 (12.5%)	2 (4.8%)	5 (11.9%)
Extension service provider			
Gov't extension agents	89 (100%)	28 (100%)	40 (100%)
Markets			
Local community	68 (68%)	19 (57.6%)	28 (65.1%)
Local market	22 (22%)	11 (33.3%)	11 (25.6%)
Institutions/hotels	4 (4%)	1 (3%)	3 (7%)
Urban markets	1 (1%)	1 (3%)	0
Local & Urban markets	5 (5%)	1 (3%)	1 (2.3%)

Fish farming inputs primarily seed, feeds and fertilizer, have an enormous potential to leverage the efforts of hard-working farmers. Used appropriately, they determine the difference between a good and a poor harvest.

Extension services: The extension services were provided by the fisheries officers from the District Fisheries Office (DFO). 80.9% (n=152) of the farmers interviewed received extension services while 19.1% (n=36) didn't receive any extension services. Non-Governmental organisations (NGOs) and Research Institutes were not involved in the provision of the extension services.

Traders

The range of wholesalers, retailers and other middlemen in the fish distribution chain was diverse; however, there was no active organized marketing body. Most traders in the district are small entrepreneurs serving local markets, having limited knowledge of market demand, and using very basic means of transport (bicycles, and motor-bicycles), storage, and trading. Lack of cold storage, affects the fish quality and lowers the bargaining power of fish farmers as they have to sell their fish at reduced prices at the end of the day to avoid losses resulting from spoilage. Additionally, the farmers did not have direct contracts with processing plants and/or exporters. There existed a range of different type of customers for fish (e.g. hotels and schools); however the majority of local production was consumed within the District.

5.3.2. The Value chain

The VC showing the different actors and the flow of fish and fish products is presented in Figure 11. Three main stakeholder groups were identified in the VC before the fish reach the consumers: Fish farmers, input providers and traders. There was no export of farmed fish.

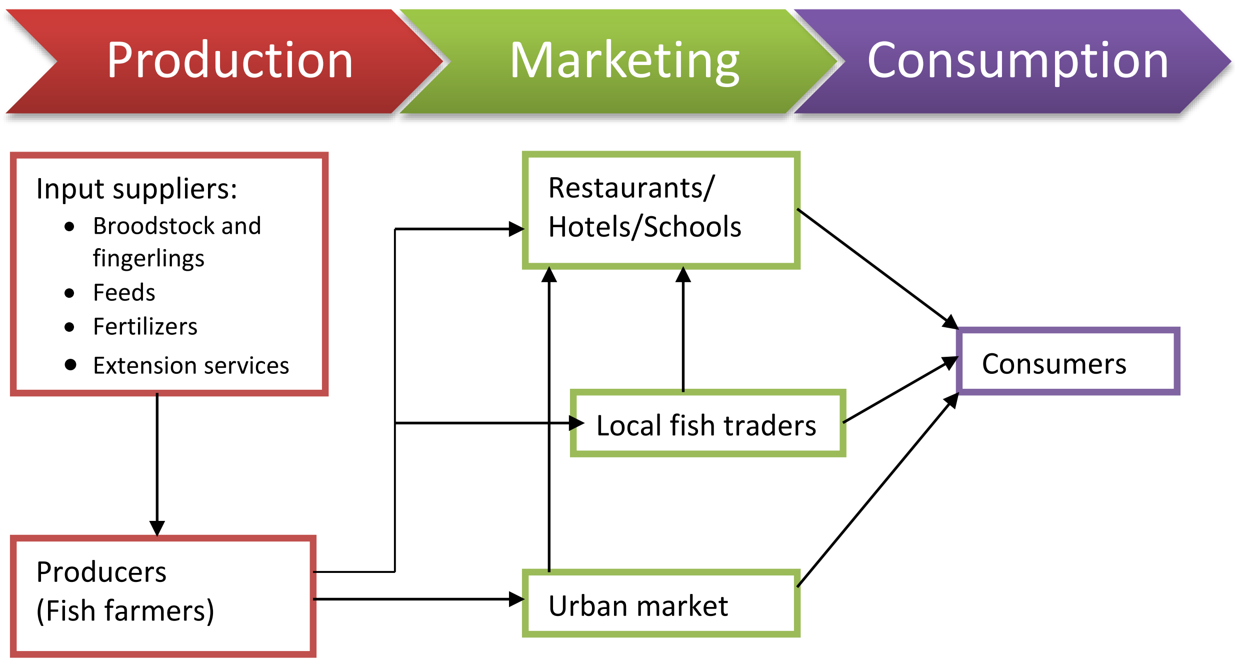


Figure 11: Schematic presentation of the smallholder aquaculture value chain

Roles of different actors in the value chain

The different roles identified for various actors in the VC are presented in Table 13.

Table 13: Roles of the different actors in the value chain

Actor	Chain position	Roles
Hatcheries e.g. Sagana Aquaculture Centre	Production	• Broodstock selection • Fingerling production and selective breeding
Input Suppliers e.g.Unga feeds	Production	• Supply of farm inputs e.g. fertilizers, nets, feeds etc. • Machinery, tools and production equipment
Fish farmers	Production /Marketing / Consumption	• Fish rearing • Fish marketing • Transportation of the harvest to the market
Extension service providers	Production / Marketing	• Provision of extension servicese.g. good feeding practices and pond management services
Traders	Marketing	• Selling fish • Convenient packaging and value addition • Marketing and advertisements of the products
The government	Production/ Marketing	• Provision of fingerlings to farmers under ESP • Provision of feed to farmers under ESP • Provision of extension service • Making of policies relevant to the fisheries sector • The lead federal department for the sustainable management of fisheries and aquaculture. • To ensure that the legislative and regulatory framework for aquaculture is responsive to the public's and industry's needs • Building the confidence to invest • Improving public support • Capitalising on research and innovation • Increasing market revenues
Consumer	Consumption	• Purchase fish from fish farmers and fish traders • Taste and preferences dictates market trends

5.3.3. Key constraints in the value chain and possible solutions

The key constraints that were identified along the VC and their possible solutions are presented in table 14.

Table 14: Key constraints and possible solutions along the aquaculture value chain

Key constraints	Possible solutions
Poor marketing system: Farmers and hatchery lack communication links to necessary market information for their produce. Poor infrastructure, lack of aquaculture product diversification.	• Develop a good marketing system (domestic and international) to provide the producer a remunerative price. • Develop a market information system • Promote and facilitate value addition for aquaculture products • Develop market infrastructure (e.g. roads) • Develop investment in aquaculture through public private participation.
Lack of access to credit and business know how: Microfinance can help the poor meet their financial needs to engage in aquaculture. The initial investment capital for aquaculture (pond construction, production costs, including seed and feed) requires access to credit or other sources of financial capital.	• Provide formal credit facilities to farmers • Develop business oriented extension services.
Inadequate certified quality seeds and low outputs: This is a major problem facing most parts of the country. Most farmers are forced to rely on each other for seeds. Such seeds are sometimes of poor genetic quality.	• Breeding programmes to expand access to improved aquaculture genetic material • Promoting an integrated aquaculture production system • Promote diversification of aquaculture products through recruitment of new aquaculture species. • Enhance collaboration and linkages with relevant research institutions/stakeholders to undertake a demand driven research.
Inadequate training programmes for extension agents and farmers: Training programmes to equip extension agents with necessary and current knowledge and technologies on aquaculture are lacking hence farmers lack the know-how.	• Train extension agents in current aquaculture related technologies and effective means of extension service provision. • Production of technological extension package for both farmers and extension agents.

	• Adequate funding of the extension departments
Lack of affordable good quality feeds: This forces farmers to use poor quality feeds that result in poor production.	• Develop standards for fish feeds • Promote best practices in processing and storage of feedstuffs • Research on using locally available feed materials for feed formulation and production of affordable feeds
Poor record keeping by farmers: Inefficient statistical data collection has impeded information dissemination on viability of aquaculture.	• Farmers should be trained on record keeping and its importance
Weak policies and legal framework: The sector operates without a comprehensive policy and legislation. This has reduced management and research effectiveness, discouraged investment and constrained production and growth.	• Revise the existing aquaculture policy and strategies

5.3.4 Sustainable aquaculture breeding programmes

Aquaculture has overtaken capture fisheries as the main source of food fish (FAO, 2010). World aquaculture production attained an all-time high in 2010, at 60 million tonnes (excluding aquatic plants and non-food products), with an estimated total value of US$119 billion. Africa has increased its contribution to global production from 1.2 percent to 2.2 percent in the past ten years, albeit from a very low base. In 2010, Kenya contributed 0.94% (12,154 tonnes) to the total aquaculture production in Africa (FAO, 2012). Aquaculture production in Kenya is still insignificant on a global scale though there is a great potential for aquaculture activities that are not yet fully explored. However, this potential cannot be explored when the fish farming systems in the country are still underdeveloped and practiced at low levels of intensification. In order to exploit the potential of aquaculture in the country, sustainable fish breeding programmes should be put in place. For the breeding programmes to be successful and sustainable, meeting the needs of the various stakeholders in the aquaculture sector, a VC approach should be adopted.

A VC approach will help in addressing the various problems or challenges along the value chain that would help boost the efficiency in this subsector. Value Chain Analysis (VCA) can assist in identifying ways in which the end user can benefit through creation of value (Bett et al, 2012). This procedure can also inform many different kinds of interventions whether or not their overall aim is to enhance performance of the chain through addressing of specific constraints and market failures (Ashley and Mitchell, 2008).The improved fish species through breeding programmes have their challenges and specificities as to how they can be delivered to their end users. A VC approach in the implementation of the breeding programmes will be able to create vital links between the science component with the other components of the VC like policies, gender, knowledge management/capacity development and markets, hence making the breeding programmes sustainable.

5.4 Conclusion

The government as an institution promoted the development of aquaculture through the ESP. Through the Ministry of fisheries development, aquaculture has been continuously promoted as an alternative source of proteins and income in the rural areas. More can be done through strategic interventions at various points along the smallholder aquaculture VC and creating strong links between actors. Concerted efforts are thus required to improve aquaculture production through the development of sustainable breeding programmes and marketing for it to have a greater impact on the regional economy. Sustainable breeding programmes cannot succeed on their own. There is need for links between the farmers, markets, policy makers and other stakeholders. These necessary links can be created through a VC approach. The development of sustainable breeding programmes through a VC approach will ensure proper utilization and conservation of the fish genetics resources by informing the different kinds of interventions needed to enhance performance of the chain through addressing specific constraints and market failures. On the other hand, a well-developed VC based on the local improved strains cannot only generate new sources of income, but also build skills of the local people and empower them in relation to the outside world.

CHAPTER SIX
GENERAL DISCUSSION

6.1. Objectives of the study

The aim of this study was to describe the smallholder aquaculture VC for the development of sustainable fish breeding programmes, generate knowledge on the production practices of the smallholder fish farmers and analyse the performance of the African catfish during its early stages under a semi-intensive production system. A VC approach is important for any successful development and can as well be used to ensure the successful development and implementation of fish breeding programmes in the Kenya. This will ensure the necessary interventions are implemented. Designing breeding programmes require sufficient knowledge on the production systems and practices. The African catfish (*Clarias gariepinus*) is a hardy species that thrives well under harsh production environments compared to other aquaculture species. Its ability to grow fast and survive, coupled with minimal husbandry requirements and optimum production in tropical environments make *C. gariepinus* a very important fish species for aquaculture production in Kenya. A study on the traits of economic importance related to the *C. gariepinus* for a given production system will aid in the development of a sustainable and appropriate breeding program.

6.2. Study methodology

The methods applied in this study were based on a cross-sectional survey conducted on smallholder fish farmers, key informants and fish traders to understand fish farming systems, fish species reared, production practices, and the fish marketing practices in the study area. Descriptive and inferential statistics were used to analyze the data. Growth rates between sire groups and for different stoking densities were analyzed using a general linear model. The resultant adjusted mean weights were used to plot growth curves. Differences in the means between growth parameters and survival rates between sire groups and between stocking densities were tested using Least Significant Difference (LSD) and the Pearson correlation estimated between the various traits. A qualitative approach of focus group discussions was used to generate information on the roles of various actors, the key constraints and opportunities along the VC.

6.3 Aquaculture production

Aquaculture in the area studied was mainly carried out by individual farmers under semi-intensive production systems as presented in Table 4. Such systems are common within different countries of sub-Saharan Africa e.g. Ghana, Liberia and Nigeria(NEPAD, 2005). Hecht (2006) noted that fish farming technologies in sub-Saharan Africa ranged from simple low input-low output pond systems to high-density re-circulating systems found in Nigeria and South Africa. The overall contribution of aquaculture to Gross Domestic Product (GDP) in the sub-Saharan Africa countries has been noted to be quite low, ranging from 0.001 to 0.715 percent (Hecht, 2006).It was evident from Chapter 3 that aquaculture as an industry in the high altitude areas studied was still in a very infantile stage and had not yet attracted larger players to avail inputs and influence the quality of fish availed through the system. Although the African Catfish had been identified as a main species of interest in the area studied (GoK, 2010), most farmers reared the Nile tilapia as presented in Table 4. Feed availability, quality, distribution and a low food conversion ratio remain major constraints to the fish farmers.

Figure 6 showed that the farmers practicing aquaculture desired to rear fish that would grow fast hence bring good returns from the market when sold. However due to an unclear selection and breeding strategy to guide the production of fingerlings being distributed to the farmers, it was not possible for them to have any certainty on the quality of the end product. In a bid to improve productivity of the Nile Tilapia reared under aquaculture systems, a collaborative research project widely known as 'Genetic Improvement of Farmed Tilapias (GIFT)' was conducted by the WorldFish Center in cooperation with The Institute of Aquaculture Research in Norway (AKVAFORSK) and a number of national research institutions in the Philippines from 1988 to 1997. The GIFT project demonstrated the potential of using selective breeding to genetically enhance the production performance of Nile Tilapia. After five generations of selection, the growth performance of the GIFT strain was improved by more than 80 per cent compared with the base population (WordFish, 2004). Transfer of the improved strains from Asia has however not been undertaken because of concern over the potential adverse impact of the GIFT strain on naturally occurring Tilapia strains in Africa. The genotype by environment interaction of the GIFT strain within different environments of Africa has also not been tested (Rezk *et al.,* 2001). Institutions managing the uptake of aquaculture in Kenya should understudy the GIFT project and adopt practices that yielded the most desirable results in order to hasten their own impacts on national aquaculture.

6.4 Selective breeding and genetic improvement of the African catfish

It is estimated that less than 10% of the current world aquaculture production is based on improved stocks (Gjedrem and Baranski, 2009). Results from well-designed selection programmes are generally manifested in rapid improvements in fish productivity leading to very significant and sustained reductions in production costs (Rye*et al.,* 2010). Chapter 4 of this thesis indicates a great diversity in performance of offspring from different parent lines. There is thus potential for genetic improvement of the species through selective breeding. In other regions, research programmes for aquaculture improvement have used hybridization (Legendre*et al.,* 1992, Nwadukwe, 1995, Senanan*et al.,* 2004); gynogenesis and androgenesis (Na-Nakorn*et al.,* 1993, Bongers*et al.,* 1995); cytogenetics (Teugels*et al.,* 1992, Nagpure*et al.,* 2000a, Nagpure*et al.,* 2000b) and biochemical and molecular markers (Agnese and Teugels, 2001, Sukmanomon*et al.,* 2003, Poompuang and Na-Nakorn, 2004, Senanan*et al.,* 2004, Islam*et al.,* 2007). Results and experiences from these studies should inform the development of a program for *C. gariepinus* breeding in Kenya.

Genetic improvement programmes implemented in aquatic animal species can have the same positive effect they have had in livestock and crops. The GIFT strain of the Nile tilapia (*Oreochromis niloticus*) and Jayanti Rohu (*Labeo rohita*) are two examples of genetically improved strains of fish where the resulting improvements in growth and survival have proved both appealing and valuable. Strains of fish reared have an impact on the final product available at the market, time it takes to rear the fish to the desired market weight and the inputs it will require. Various fish genotypes as a fish farming input greatly contribute to economic gain or loss of an enterprise. New strains can form a nucleus population for a long-term national breeding program designed to deliver superior strains of farmed fish.

As a first step in a genetic improvement programmes, priority should be assigned to genetically distinct populations, which may be identified through characterization at the molecular level prior to sampling for parent stocks if resources permit. Before assembling the foundation populations, a well-designed experiment should be carried out to evaluate performance of locally (regionally) available fish stocks. This can result in gains equivalent to a few generations of selection, thus saving time and resources (Ponzoni*et al.,* 2008). Depending on availability of experimental facilities and resources, four or five different fish stocks in a complete diallel cross can sufficiently capture abundant genetic variation in a population for future selection (Holtsmark*et al.*, 2006). Such a strategy has proved successful in farmed aquaculture species such as Atlantic salmon (Gjedrem*et al.,* 1991), Nile tilapia (Eknath*et al.,* 2007) and Indian rohu carp (Mahapatra*et al.*, 2006). Profitability through selective breeding of fish was illustrated by Gjerde and Olsen (1990) who estimated that for a genetic gain of 10% per generation in growth rate and 3% for age at sexual maturation, the corresponding profit would be US $0.13 and $0.08 per kg fish produced.

The implementation of effective breeding programmes has been slow in many developing countries of Sub-Saharan Africa. According to Ponzoni et al (2008), through selective breeding programmes in Egypt and Ghana, two fast-growing strains of the Nile tilapia (*Oreochromis niloticus*), an economically important fish that is native to much of Africa, have been developed for farmers: the 'Abbassa' and 'Akosombo'. In Malawi, selective breeding techniques have been successfully used to improve the breeding stock of *Oreochromis shiranus*, a popular aquaculture species in Malawi. The improved strain performs 30% better than local ones, thrives in all ecological zones, can boost production to 6 tons/ha/cycle (5 times higher than current yields) and can potentially increase fish production from the present level of 1,500 tons to 7,500 tons (WordFish Centre-Malawi, 2010). In Chapter 3 (Figure 6), growth and survival were identified as the most important traits of economic importance. The results in Chapter 4 show diversity in growth and survival of the African Catfish fingerlings, therefore there is potential for selective breeding for these traits of economic importance.

Growth and survival in the early phases of *C. gariepinus* influence the production potential of many commercially important fish stocks. According to Adebayo and Popoola (2008) the continuous growth of aquaculture is hinged on the production of fish seeds with high fertilization and survival rates, high feed conversion efficiency, and high growth rate among other factors. Selective breeding for these traits would therefore play a significant role in growing the aquaculture sectors. The availability of quality fingerlings constitutes a major obstacle in the development of the commercial farming of African Clariid fish such as *C. gariepinus*(Ponzoni and Nguyen, 2008)

6.5 Sustainable fish breeding through a value chain approach

The aquaculture value chain within the area studied had relatively few actors and the scale of operation was quite small (Chapter 5). As the ESP has been implemented over a relatively short time period (2 years) it was evident that the value chain for aquaculture is still developing. There was an unmet demand for fish in the areas, however in order to respond to this the quality of the end product would need to be more consistent. The market pays for what it gets and there was little incentive for stratification. Though fish are a species able to multiply and grow very rapidly and thus offer a cheaper option for good quality protein, this is not exploited for aquaculture in Kenya. Prices of fish and fish products on various markets in the country remain high, rendering it uncompetitive relative to other animal source proteins such as meat and poultry (Karuga and Abila 2007).

The nutritional status of populations in developing countries that use fish has been shown to improve through fish consumption. In Zambia, a local small freshwater pelagic fish, kapenta (*Limnothrissa miodon*) when included in the diets of people living with HIV/AIDS, resulted in a reduction in opportunistic infections and improved chronic wound healing (Kaunda et al., 2008). Kumar and Dey (2006) also showed that in India, households engaged in small-holder farming with additional income from aquaculture were generally less undernourished than households without aquaculture. In Malawi, Aiga et al(2009) noted that the prevalence of malnutrition among children (6 – 59 months) was lower in fish farming households compared to non-fish farming households.

The role played by the government in Kenya to implement an ESP to help improve livelihoods of small holder farmers is a positive boost to food security in the region. There is however a need for supportive infrastructure primarily in terms of improved road networks to ease transportation of products. Working with private and development partners within the sector, the government could play a lead role in enhancing the capacity of farmers within communities to manage and rear fish, and could help in raising the profile for the marketing of fish to an expanded consumer base. This could serve as a catalyst to stimulate a demand by the producers for better quality fingerlings. Information generated through the value chain approach strengthens the need for increased support to the selective breeding program at the Sagana Aquaculture Centre. Fish breeding in response to demands evident in a VC expands options for integrating new technologies, improving delivery systems at different levels, and developing partnerships and innovation capacity for aquaculture production.

6.6 Conclusion

Small-holder aquaculture in highland areas of Kenya provides a unique opportunity to increase household incomes and improve the nutritional status of the communities. There is however a lack of improved strains of various fish species demanded by the market, leading to very variable supply of fish. A main cause of variability in quality of fish is the sourcing of breeding stock to produce fingerlings for farmers from the wild. Selective and sustainable breeding programmes with training of farmers on improved aquaculture practices at the main aquaculture centers in the region are critical to boost the developing sector. Through improved production and breeding larger size fish with more uniform characteristics can be availed on the market. This would provide a setting for integrating new technologies and improving delivery systems for aquaculture products to consumers. Linkages among stakeholders in the aquaculture sub-sector should be encouraged to drive development and improve incomes for primary players in the sector.The growth of the aquaculture sector in the country can be achieved by developing sustainable fish breeding programmes through a value chain approach.

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APPENDICES

Appendix 1: Farmers Questionnaire

DEPARTMENT OF ANIMAL SCIENCES
EGERTON UNIVERSITY, NJORO, KENYA

ENUMERATOR NAME ________________________ ENUMERATOR CODE: [_________]

DATE OF INTERVIEW (DD/MM/YY/) /__/__/20__

QUESTIONNAIRE IDENTIFICATION

To be filled by enumerator prior to the interview	
Project Area	
Province	
District	
County	
Location	
GPS	**XY**

RESPONDENTS NAME ____

RESPONDENTS POSITION IN THE HOUSEHOLD [____]

NAME OF HEAD OF THE HOUSEHOLD _______________________________________

1=Head, **2**=spouse, **3**=Daughter/daughter in-law, **4**=son/son in-law, **5**=Hired farm manager, **6**= Head/Spouse' parent, **7**=other, specify

CONTACT INFORMATION

Physical Address:	
Mailing Address:	
City or town [if urban]:	
Village [if rural]:	
Nearest Town [if rural]:	

1. GENERAL HOUSEHOLD CHARACTERISTICS

1.1Details about the household head

Sex {Code: **1**=Male, **2**=Female}	[____]
Age (years)	[____]
Years of farming experience	[____]
Level of education	[____]
Formal training in agriculture/fish farming {Code: **1**=Yes, **2**=No}	[____]
Major occupation	[____]
Level of Education: 1=No formal education, **2**=Primary, 3=Secondary, **4**=Post=secondary **Major occupation: 1**=Farming, 2=Off-farm, specify	

1.2 Legal Status of pond (individual or group) [____]

Legal status: 1=proprietor, **2=**Group

1.3 If Individual, fill the table below:

Number of Ponds	
Sizes of the ponds (Range)	
Date of Construction	___/___/_____

1.4 If group, fill the table below:

Name of group	
Number of members	
Date of Registration	____/____/______
Number of Ponds	
Sizes of the ponds (Range)	
Date of Construction	____/____/______

1.5 What is the total area of your farm [________ ha]

1.6 Land use patters

Land use		**Size (ha)**
Arable land		**[___________]**
Forest land		**[___________]**
Grazing land		**[___________]**
Un-utilized land		**[___________]**
Other types of land available		**[___________]**
		[___________]

1.7 Does your household have any livestock? {Code: **1**=Yes, **2**=No} **[____]**
(If YES fill the table if NO go to section 2)

Livestock		**Number owned**	**Reasons for rearing (code)**
Chicken		**[____]**	**[____]**
Ducks		**[____]**	**[____]**
Rabbit		**[____]**	**[____]**
Pig		**[____]**	**[____]**
Cattle	Local	**[____]**	**[____]**
	Exotic	**[____]**	**[____]**
	Crosses	**[____]**	**[____]**
Goat		**[____]**	**[____]**
Sheep		**[____]**	**[____]**
Donkey		**[____]**	**[____]**
Reasons for rearing: 1=Home consumption, **2**=Sale of milk, **3**=Sale of adult animals, **4**=Sale of young stock, **5**= Wool/hair, **6**=Religious sacrificial animals,**7**= Sale of breeding animals, **8**=Livestock as social status symbol, **9**= Wealth status, **10**=Raising animals for export, **11**= other, specify			

2 FISH FARMING PRACTICES

2.1 What species of fish do you rear?

Species	Stocking Density	Number of males	Number of females
[____]	_____Females per Male	[_____]	[_____]
[____]	_____Females per Male	[_____]	[_____]
[____]	_____Females per Male	[_____]	[_____]
[____]	_____Females per Male	[_____]	[_____]
[____]	_____Females per Male	[_____]	[_____]
[____]	_____Females per Male	[_____]	[_____]
Species: 1=*O.niloticus*, **2**=*O.esculentus*,**3**=*O.variabilis*,**4**=*Labeo*, **5**=*C.gariepinus*(African catfish),**6**=Goldfish			

2.2 What type of management do you practice (according to feeding system)? [____]

Management system: 1=Extensive system, **2**=Semi-intensive system, **3**=Intensive system

2.3 What is the major source of water for the fish ponds? [____]

Water source: 1=Wells, **2**=hand pump, **3**=Stream, **4**=Canal, **5**=River**, 6**=Tap water, **7**=Rain water, **8**=other specify

2.4 Who provides labour in the fish farm? [____], [____], [____], [____]

Source of Labour: 1=Family, **2**=Hired labourer, **3**=Communal, **4**=Other joint (specify codes), **5**=Other, specify

2.5 What's your fish culture system? [___]

Culture system: 1=Monoculture, **2**=Polyculture

2.6 If Polyculture, specify the species? [____],[____], [____],[____]

Species: 1=*O.niloticus*, **2**=*O.esculentus*,**3**=*O.variabilis*,**4**=*Labeo*, **5**=*C.gariepinus*(African catfish),**6**=Goldfish

2.7 Do you fertilize your pond(s) {**Code: 1=**Yes, **2=**No} [____]

2.8 If yes, what type of fertilizers do you use? [____]

Fertilization: 1=Inorganic fertilizers, **2**=Organic manure, **3=**Both

2.9 Do you keep any records? {Code: **1**=Yes, **2**=No} **[____]**

2.10 If YES, tick as appropriate

Record	Tick
Stocking records	
Mating records	
Weight at harvest records	
Time of harvest records	
Sales records	
Feeding records	
Other, specify	

3 FISH FEEDING PRACTICES

3.1 How do you feed your fish?

Species	Feeding mode
[____]	[____]
[____]	[____]
[____]	[____]
[____]	[____]
[____]	[____]
[____]	[____]
Species: 1=*O.niloticus*, **2**=*O.esculentus*,**3**=*O.variabilis*,**4**=*Labeo*, **5**=*C.gariepinus*(African catfish),**6**=Goldfish **Feeding Mode: 1**=Feed given, **2**=Left to fend for themselves	

3.2 Where do you get feed from? [____]

Source of feed: 1=Self-made, **2=**feed factory, **3=**Both

3.3 What type of feed do you give your fish?

Species	Feed type
[____]	**[____],[____],[____],[____],[____],[____],[____],[____],[____]**
[____]	**[____],[____],[____],[____],[____],[____],[____],[____],[____]**
[____]	**[____],[____],[____],[____],[____],[____],[____],[____],[____]**
[____]	**[____],[____],[____],[____],[____],[____],[____],[____],[____]**
[____]	**[____],[____],[____],[____],[____],[____],[____],[____],[____]**
[____]	**[____],[____],[____],[____],[____],[____],[____],[____],[____]**
Species: 1=*O.niloticus*, **2**=*O.esculentus*,**3**=*O.variabilis*,**4**=*Labeo*, **5**=*C.gariepinus*(African catfish),**6**=Goldfish	

Type of feed: 1=Grains, **2**=vegetable, **3**=Minerals, **4**=Brans (Maize, wheat, rice etc), **5**=Cakes(Cotton seed cake, simsim, sunflower, etc), **6**=fish meal, **7**=Vitamins, **8**=Kitchen wastes, **9**=Animal wastes, **10**=Other, specify

3.4 How frequently do you feed your fish?

Species	**Time of day**	**How much(g)**
[____]	**[____]**	
[____]	**[____]**	
[____]	**[____]**	
[____]	**[____]**	
[____]	**[____]**	
[____]	**[____]**	
Species: 1=*O.niloticus*, **2**=*O.esculentus*,**3**=*O.variabilis*,**4**=*Labeo*, **5**=*C.gariepinus*(African catfish),**6**=Goldfish **Time of day: 1**=Morning, **2**=Afternoon, **3=**Morning and Afternoon		

4. BREEDING PRACTICES

4.1 Fill the table below

species	Foundation stock	Replacement stock	Sex ratio	Average egg production per average sized female	Average hatchability of eggs in percentage	Mortality rate of fry to fingerling stage(%)	Mortality rate of fingerling to mature stage(%)	Time the fish is kept till harvest	Breeding method
O.niloticus	[____]	[____]	[____]						[____]
O.esculentus	[____]	[____]	[____]						[____]
O.variabilis	[____]	[____]	[____]						[____]
Labeo	[____]	[____]	[____]						[____]
C.gariepinus	[____]	[____]	[____]						[____]
Goldfish	[____]	[____]	[____]						[____]

Sex ratio: 1=1male:1female, **2=**1male:2female, **3=**1male:3females

Breeding method: 1=Natural breeding, **2=**Artificial breeding, **3=**Both natural and Artificial

Foundation stock:1=Wild, **2=**Purchased, **3=**Own farm production

Replacement stock:1=Wild, **2=**Purchased, **3=**Own farm production

Sex Ratio: 1=1male:1female, **2=**1male:2female, **3=**1male:3females

Breeding method: 1=Natural breeding, **2=**Artificial breeding, **3=**Both natural and Artificial

4.2 Do you practice sex reversal (androgenesis/ gynogenesis) in your farm? {**Code: 1=**Yes, **2=**No} [___]

4.3 Which traits are of importance to you? List and rank them in order of importance in the table below.

Species	Trait	Rank
O.niloticus		
O.esculentus		
O.variabilis		
Labeo		
C.gariepinus		
Goldfish		

5. FISH HEALTH

5.1 Do you experience serious disease outbreaks?[Code: **1**=Yes, **2**=No] **[____]**

5.2 What do you do when your fish show signs of sickness? **[____]**

Fish treatment: 1=Do nothing, **2=**Treat them myself, **3=**Call a veterinary doctor, **4=**Kill them immediately, **5=**consume them immediately, **6=**Sell them immediately, **7=**Other, specify

5.3 Describe the 2 common diseases you have experienced in your fish stock

Disease 1	
Symptoms	
Susceptible spp and age	
Favourable seasons	
Severity	
Treatment/Control	
Disease 2	
Symptoms	
Susceptible spp and age	
Favourable seasons	
Severity	
Treatment/Control	

5.4 Describe the 2 common parasites that affect you fish stock

Parasite 1	
Symptoms	
Susceptible spp and age	
Favourable seasons	
Severity	
Treatment/Control	
Parasite 2	
Symptoms	
Susceptible spp and age	
Favourable seasons	
Severity	
Treatment/Control	

5.6 Name the common fish predators in your farm

Predator	**Species of fish preyed**
[____],[____],[____],[____],[____],[____]	**[____],[____],[____],[____],[____]**
[____],[____],[____],[____],[____],[____]	**[____],[____],[____],[____],[____]**
[____],[____],[____],[____],[____],[____]	**[____],[____],[____],[____],[____]**
[____],[____],[____],[____],[____],[____]	**[____],[____],[____],[____],[____]**
[____],[____],[____],[____],[____],[____]	**[____],[____],[____],[____],[____]**
[____],[____],[____],[____],[____],[____]	**[____],[____],[____],[____],[____]**
Predator: 1=Humans, **2=**Frogs, **3=**Snakes, **4=**Dogs, **5=**Birds, **6=** Other, specify **Species: 1**=*O.niloticus*, **2**=*O.esculentus*,**3**=*O.variabilis*,**4**=*Labeo*, **5**=*C.gariepinus*(African catfish),**6**=Goldfish	

6 MARKETING DYNAMICS

6.1 What's your target market weight?

Species	Target market Weight (g)
[____]	
[____]	
[____]	
[____]	
[____]	
[____]	
Species: 1=*O.niloticus*, **2**=*O.esculentus*,**3**=*O.variabilis*,**4**=*Labeo*, **5**=*C.gariepinus*(African catfish)	

6.2 How long do you rear the fish to your target market weight?

Species	Time for rearing (Months)
[____]	**[____]**
[____]	**[____]**
[____]	**[____]**
[____]	**[____]**
[____]	**[____]**
[____]	**[____]**
Species: 1=*O.niloticus*, **2**=*O.esculentus*,**3**=*O.variabilis*,**4**=*Labeo*, **5**=*C.gariepinus*(African catfish)	

6.3 Where/what are your major markets

Species	Market or market characteristics
[____]	[____], [____], [____], [____]
[____]	[____], [____], [____], [____]
[____]	[____], [____], [____], [____]
[____]	[____], [____], [____], [____]
[____]	[____], [____], [____], [____]
[____]	[____], [____], [____], [____]

Species: 1=*O.niloticus*, **2**=*O.esculentus*,**3**=*O.variabilis*,**4**=*Labeo*, **5**=*C.gariepinus*(African catfish),**6**=Goldfish **Market: 1=**Local market, **2=**Near urban market, **3=**Distance urban market, **4=**Export

7. NETWORKING STRATEGIES

7.1 How many fish farmers do you know who are in this village?				
7.2 How many fish farmers do you know that are in this location				
7.3 Do you consult on common strategies?	1. Yes		2. No	
7.4 What do you consult about?				
7.5 Do you have any potential buyer(s) who is/are ready to buy your fish when you harvest	1. Yes		2. No	
7.6 What form of fish/product does he want?	1. Fresh/whole	2.smoked	3.Filleted	
7.7 What kind of arrangements have you made with him/her/them?				
7.8 How many fish does he/she want?				
7.9 How will you deliver the fish?				
7.10 Do you expect to meet their demands?	1. Yes		2. No	
7.11 If NO, Why?				
7.12 Where does he live/come from?	1. This village	2.Town-----------------------	3 Town ----------------------	
7.13 How many times have you sold your fish to them/him/her?				
7.14 What was the gross income before costs?				
7.15 Do you sometimes take fish from the pond for food for your family?	Yes	1	No	2
7.16 If "Yes" How often do you do that?				
7.17 How much does that cost?				
7.18 Do you ever give fish to relatives or friends				
7.19 How much does this cost you				
7.20 Please now tell us about the costs during marketing in the last sales that you had				
Harvesting costs				
Packaging				

Transport	
Municipal charges	
Other charges (Specify)	
7.20 Problems of pond Management and Predators	
What are the major pond problems that you have encountered (List)	1.
	2.
	3.
	4.
	5.

8. SERVICE PROVIDERS

Name of supplier of seed	
Telephone:	
Fax or E-Mail:	
Name supplier of feeds	
Telephone:	
Fax or E-Mail:	
Name of technical advisor	
Telephone	
Fax or Email	
Designation	**[1=Vet Doc, 2=Fisheries officer, 3=Technician]** **[_____]**
Where based	

9.OTHER GENERAL ISSUES

9.1 What's your reason for keeping fish? **[____]**

Purpose of rearing fish: **1=**For pleasure, **2=**as a business, **3=**For food, **4=**for research

9.2 Do you and your family consume fish? [Code: **1**=Yes, **2**=No] **[____]**

9.3 If yes, how often? **[____]**

Consumption rate:1=Daily, **2=**Thrice a week, **4=**twice a week, **5=**once a week, **6=**twice a month, **7=**once a month

9.4 Are there any extension services you receive? Code: **1**=Yes, **2**=No] **[____]**

9.5 If yes who offers the services? **[____], [____],[____], [____]**

Extension service provider: 1=Gov't, **2=**NGO's, **3=**Research Institutes, **4=**Farmers Associations

9.6 What type of service do they offer**?** **[__________]**

Extension Service provider	**Extension services provided**
Government	**[____], [____], [____], [____], [____], [____]**
Non-Governmental organisations (NGOs)	**[____], [____], [____], [____], [____], [____]**
Research institutes	**[____], [____], [____], [____], [____], [____]**
Farmers Association	**[____], [____], [____], [____], [____], [____]**
Extension services being offered: 1=Breeding services, **2=**fish health services, **3=**Feeding management services, **3=**financial management services, **4=**pond construction and management, **5=**marketing services, **6=** other, specify	

9.7 Do you intend to expand fish production?Code: **1**=Yes, **2**=No] **[____]**

9.8 If yes, why? **[____]**

Reasons for expanding fish farming: 1=For increased profits, **2=**For increased food security

9.9 List five important things that you think should be done to improve fish farming

i. ____

ii. ____

iii. ____

iv. ____

v. ____

Appendix 2: Key Informant Questionnaire

Please kindly tell us about the development of aquaculture in your area of jurisdiction. Kindly fill the following information as indicated below.

Name of the respondent________________________ Date of Interview__________

1. District of responsibility _______________________________
2. Number of locations __________________________________
3. How many Ponds do you have in your area? _________________
4. How many ponds are currently stocked with fish? _____________________________
5. Please kindly tell us about the species that have been stocked in this area using the key provided as follows:

Species	Number of ponds	Stoking density	Total No. of fish
Species: 1=*O. niloticus,* **2**=*O.esculentus,***3**=*O.variabilis,***4**=*Labeo (ningu),* **5**=*C. gariepinus*(African catfish),**6**=Goldfish			

6. How many ponds are in your area that have not been stocked? ___________________
7. What is the reason for them not getting stocked?

____

8. How many ponds have been developed privately without involving the Economic Stimulus Program **(ESP)?** ____
9. What are the major challenges in involving aquaculture development in this area?
   1.____
   2.____
   3.____
10. What can be done on the above problems?
    1. ____
    2. ____
    3. ____
11. Was there a problem with the ESP? **1**. =Yes. **2**. = No

12 If “Yes” What was the problem?
   1. ____
   2. ____
   3. ____

13. How were the problems overcome? _______________________________________

____

THANK YOU.

Appendix 3: Marketing Agent/Traders Questionnaire

This Questionnaire will deal with the fish products in the market, fish traders and market dynamics in relation to aquaculture fish

ENUMERATOR NAME: ______________________ ENUMERATOR CODE: [__________]

DATE OF INTERVIEW (DD/MM/YY/): /_____/_____/20_____

TIME STARTED [__________] TIME ENDED [_________]

Questionnaire identification To be filled by enumerator prior to the interview	
Market Name	
Province	
District	
Location	
County	
GPS	**XY**

1. Gender of respondent {**Code: 1=**Male, **2=**Female} [____]
2. Position of the respondent in the household [______]

1=Husband, **2**=Wife, **3**=Head's father, **4**=Head's mother, **5**=Son/son in-law, **6**=Daughter/daughter in-law, **7**=Other joint (specify codes), **8**=Hired worker, **9**=Other (specify)

3. What's your type of market? [____]

Type of market: 1=Retail, **2=**Wholesale, **3=**Middleman

4. What species of fish do you deal with and why?

Species	**Tick as appropriate**	**Reason for choice of species**
O.niloticus	[____]	[____], [____], [____]
O.esculentus	[____]	[____], [____], [____]
O.variabilis	[____]	[____], [____], [____]
C.gariepinus(African catfish)	[____]	[____], [____], [____]
Trout,	[____]	[____], [____], [____]

Goldfish	[____]	[____], [____], [____]
Nile perch	[____]	[____], [____], [____]
Reason for choice of species: 1=High on demand, **2=**Affordable to buy for sell, **3=**Profitable,		

5. Where do you get your fish from and at what cost?

Species	**Source of fish**	**Cost of fish/Batch**
O.niloticus	[____], [____], [____], [____], [____],	
O.esculentus	[____], [____], [____], [____], [____],	
O.variabilis	[____], [____], [____], [____], [____],	
C.gariepinus	[____], [____], [____], [____], [____],	
Trout	[____], [____], [____], [____], [____],	
Goldfish	[____], [____], [____], [____], [____],	
Nile perch	[____], [____], [____], [____], [____],	
Source of fish: 1=FarmedFish **, 2=**Lake Victoria, **3=**Lake Turkana, **4**=Lake Baringo, **5=**Lake Naivasha, **6=** Other (Specify)		

6. In what form do you sell your fish?

Species	**Product type**
O.niloticus	[____],[____],[____],[____],[____],[____]
O.esculentus	[____],[____],[____],[____],[____],[____]
O.variabilis	[____],[____],[____],[____],[____],[____]
C.gariepinus(African catfish)	[____],[____],[____],[____],[____],[____]
Trout,	[____],[____],[____],[____],[____],[____]
Nile perch	[____],[____],[____],[____],[____],[____]
Product type 1=Fresh, **2=**Fried, **3=**Smoked, **4=**Dried. **5**.=Salted **6.=**Filleted	

7. Of the products you sell, which one sells fastest and why?

Species	**Product type**	**Reason for selling fast**
O.niloticus	[____]	[____],[____],[____],[____]
O.esculentus	[____]	[____],[____],[____],[____]
O.variabilis	[____]	[____],[____],[____],[____]
C.gariepinus(African catfish)	[____]	[____],[____],[____],[____]
Trout,	[____]	[____],[____],[____],[____]
Nile perch	[____]	[____],[____],[____],[____]

Product type 1=Fresh, **2=**Fried, **3=**Smoked, **4.=**Dried. **5**.=Salted **6.=**Filleted
Reason for selling fast: 1=Its affordable to consumer, **2=**Its most preferred due to taste,**3=**It's easy to easy to prepare,**4=**Other, specify

8. Of the products you sell, which one is difficult to sell and why?

Species	**Product type**	**Reason for difficulty in selling**
O.niloticus	[____]	[____],[____],[____],[____]
O.esculentus	[____]	[____],[____],[____],[____]
O.variabilis	[____]	[____],[____],[____],[____]
C.gariepinus(African catfish)	[____]	[____],[____],[____],[____]
Trout,	[____]	[____],[____],[____],[____]
Nile perch	[____]	[____],[____],[____],[____]

Product type 1=Fresh, **2=**Fried, **3=**Smoked, **4.** =Dried. **5**.=Salted **6.=**Filleted
Reason for selling fast: 1=Its not affordable to consumer, **2=**Its less preferred due to taste,**3=**It's not easy to prepare,**4=**Other, specify

9. How regularly do you buy fish? [Every _____ months]
10. Generally, how is the supply of fish like in this market? [____]

Supply of fish: 1=Not enough, **2=**Just enough, **3=** More than enough

11. Is there a family member/anybody who helps you in this business?{**Code:1=**Yes, **2=**No} [____] (*If NO go to question 15*)

12. If yes above, who is it? [____]

Helper: 1=Spouse, **3**=Head's father, **4**=Head's mother, **5**=Son/son in-law, **6**=Daughter/daughter in-law, **7**=Other joint (specify codes), **8**=Hired worker,

13. Do you pay for the helper? **Code:1=**Yes, **2=**No} [____]
14. If yes how much? [Ksh____________ /Month]
15. What determines the price of fish that you trade in? [____],[____]

Price determinant: 1= Weight, **2=** Age, **3=** color, **4=** Quality of flesh, **4=**Demand

16. For how long have you dealt with farmed fish? [____ months]
17. How is the fish delivered to you? [____]

Mode of delivery: 1=in an ice box, **2=**in an open basket, **3=**other, specify

18. How would you like it delivered to you? [____]

Preferred mode of delivery: Mode of delivery: 1=in an ice box, **2=**in an open basket, **3=**other, specify

19. Who are your customers? [___],[___],[___],[___],[___],[___],[___]

Customers: 1= Hotels**, 2=** other traders**, 3=** Local market**, 4=** hawkers**, 5=** export market**, 6=**Nearest urban market**, 7=**Distance urban market, **8=**Schools

20. What kind of sizes do your customers prefer and at what cost?

Species	Weighted category	Price (Ksh)
Tilapia Species	<250g	
	250g	
	300g	
	350g	
	400g	
	450g	

Catfish Species	<250g	
	250g	
	300g	
	350g	
	400g	
	450g	
	<250g	
Nile perch	<250g	
	250g	
	300g	
	350g	
	400g	
	450g	
	<250g	

21. When is the demand for fish highest and lowest?

Species	Highest Demand months	Lowest Demand months
Tilapia Species	[___],[___],[___],[___],[___],[___]	[___],[___],[___],[___],[___],[___]
Catfish Species	[___],[___],[___],[___],[___],[___]	[___],[___],[___],[___],[___],[___]
Labeo Species	[___],[___],[___],[___],[___],[___]	[___],[___],[___],[___],[___],[___]
Nile Perch	[___],[___],[___],[___],[___],[___]	[___],[___],[___],[___],[___],[___]
Months:1=Jan, **2**=Feb, **3**=Mar, **4**=Apr, **5**=May, **6**=Jun, **7**=Jul, **8**=Aug, **9**=Sep, **10**=Oct, **11**=Nov, **12**=Dec		

22. Who delivers the fish to you in the market? [____],[____]

Who delivers fish: 1=on my own, **2**=The fish farmer, **3**=Other traders, **4**=Middlemen

23. How do you judge the quality of fish that you buy? [____],[____]

Mode of judging fish quality: 1=by pressing, **2=**looking at gills, **3=**by color, **4=**other____

24. What are the general costs of the business?

Item		**Ksh**
Transport		
Municipal fee		
Other costs		

25. What are the problems related to marketing/trading of Aquaculture fish? [___],[___],[___]

Problems in catfish marketing: 1=Unstable prices, **2=** Poor sales (demand, seasonality), **3=** Lack of market place, **4=** Poor infrastructure (road, market), **5=** Preference of other species, **6=** other, specify

26. Do you belong to any Marketers/Traders organization? [**1**=Yes, **2**=No] [____]

27. If yes, what's the name of the organization?

____

28. How do you rate fish business?

Fish Business: 1= slightly profitable, **2=** Profitable, **3=** Very Profitable

THANK YOU