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DEPARTMENT OF FISHERIES AND WATERSHED MANAGEMENT

OPPORTUNITIES AND CONSTRAINTS OF FISH FARMING IN GHANA

(A CASE STUDY OF ASHANTI REGION)

Thesis submitted for the degree of Master of Philosophy

in

Aquaculture Management

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DECLARATION

I hereby declare that this Thesis has been composed out of my own research work and it has not been submitted in any form elsewhere for the award of any other degree.

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DEDICATION

The Thesis is dedicated to my mother, Fatou Saine and wife, Adama Gaye, my children Fatou, Binta, Mariama and Baboucar and all that contributed towards the success of this work.

In memory of, my late father, Baboucar Mboge. May the Almighty God through his infinite mercy allow him enter paradise.

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ABSTRACT

The study was conducted in Ashanti Region of Ghana to examine the opportunities and constraints for environmental best practices of fish farming. The study examined resources available at farm levels, farm operations, farming systems, sustainability of fish farming and roles of stakeholders.

A systems approach was used as a guide for data collection. A structured questionnaire survey targeted fish farmers. Farmers‘ selection was based on their ability to provide records and information on their fish farming activities. It also involved farmers who participated in Aquafish Collaborative Research Support Programme, 2009 - an initiative of KNUST and some USA Universities. Secondary data was also collected from the Regional Fisheries Office in Kumasi.

Farming systems ranging from semi-intensive to extensive systems were encountered. The farm practices included polyculture, monoculture, mono-sex culture and integration. The study showed that the fish farmers have resources and experiences in fish farming but still lack appropriate technologies for the utilization of their resources; for increased production without compromising environmental protection.

Some of the opportunities include availability of land, water, feed ingredients, manure and infrastructures. Major constraints were generally lack of appropriate management techniques: water quality control, effluent control and proper record keeping. Poor site selection was linked with restriction of pond drying due to underground water trend.

Therefore, farmers' sensitisation, technical assistance and financial support will become suggestions to develop solutions to these confrontations.

The potential for fish farming to improve is enormous as the opportunities are vast. Government and non-governmental support will continue to be needed to overcome constraints imposed on the industry.

ACRONYMS

ACRSP Aquafish Collaborative Research Support Programme

CSIR Council for Scientific and Industrial Research

DO Dissolved oxygen

IAB Institute of Aquatic Biology

MOFA Ministry of Food and Agriculture NVRI

National Veterinary Research Institute pH

Concentration of hydrogen ions in liquid

PRA Participatory Rural Appraisal

WRI Water Research Institute

KNUST Kwame Nkrumah University of Science and Technology

RAS Recycle Aquaculture Systems

IRS Integrated Recycling System

AEA Agricultural Extension Agent

FRNR Faculty of Renewable Natural Resources

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CHAPTER ONE

1.0 INTRODUCTION

Ghana is located on the west coast of Africa between latitude 4^{o} 30‘ N and longitudes 1^{o} 10‘ E to 3^{o} 15‘ W and 1^{O}E. The country is bounded by Burkina Faso to the north, Cote d‘voire to the west, Togo to the east and the Gulf of Guinea to the south (BODFAM, 2003). The country covers an area of approximately 238,500 km square and is well inundated by river systems (Dankwa *et al*. 1999).

The fisheries resources of Ghana supply 60-70% of natural animal protein to the people. Generally, many Ghanaians are encouraged to take more of this fish protein than meat, since fish is more nutritious and healthy (Asmah, 2008). Moreover, fish is recognized as the most important source of animal protein in Ghana (Aggrey-Fynn, 2001). Among the various sources of protein, fish stand out as the most important in terms of food security because its price, relative to the price of other high quality protein sources such as milk, meat and eggs is very competitive. Furthermore, fish have been found to have self life which is readily enhanced through low-cost sustainable technologies such as smoking, drying and salting (FAO, 2000, 2009). On the other hand, fish is good in terms of gross body weight gain and protein gain per unit of feed intake (Hastings and Dickie, 1972). The feed conversion ratio (wet weight gain per unit of dry feed intake) of fish has been found to be in the range 1:1 to1:1.25 and the protein efficiency ratio (weight gain per unit of protein intake) is either equal to or higher than that for poultry, swine, and sheep and steers (Hastings and Dickie, 1972).

Unfortunately, there is growing evidence that the fishery is being exploited beyond its sustainable limit. This has caused a decline in its fishing trend (Owusu *et al.* 1990). Consequently, the 1970 average fish consumption declined by 25 percent to reach 22 kg/caput/year in 1997 (Owusu *et al*. 1999) while it was previously estimated at 20kg per caput fish consumption in 1993 (Ofori, 2000). Although, subsistence fisheries have become the sole means of survival, there is limitation in the country‘s ability to meet the domestic demand. As a result, this has threatened the economy and food security of many Ghanaians (UN, 2009). Subsequently, the government of Ghana, as early as the 1950s, decided to promote aquaculture and culture-base fisheries (Owusu *et al*. 1999). This initiative was taken in order to prevent the extinction of species as well as contribute to fisheries management and policy; reduce the pressure and offer the sustenance of overall supplies (Pillay, 1990).

Fish farming is the principal form of aquaculture which involves raising fish commercially in tanks or enclosures, usually for food, (Wikipedia, 2009). This includes different farming systems: extensive, semi-intensive, intensive, integrated and recycling (Swift, 1993). Collectively, in these systems several operations are performed in order to produce fish in a pond: stocking with fingerlings, feeding, applying fertilizers, monitoring growth performance and harvesting the fish (Delincé, 1992). However, the most important factor that determines the feasibility of viable operation is the right selection of sites for pond construction (Pillay, 1990). At these sites, the management of ponds is concerned with the water supply and maintenance of healthy environment for optimum growth and minimum mortality of the cultured fish (Swift, 1993). Relatively, the most important fish species raised by fish farmers are salmon, carp, tilapia, catfish and cod (Wikipedia, 2009).

Conventional fish farming started in Ghana in the 1950s (Amisah and Quagrainie, 2007). During this period the number of fish farmers rose to about 1000 with over 2000 earthen fish ponds with a surface area of about 350 hectares. Collectively, these ponds were managed within 1300 farms (Asmah, 2008). Technically, semi-intensive fish farming systems were commonly practised in earthen ponds either as monoculture of tilapia or polyculture of tilapia and catfish. In recent years, newly introduced culture systems are cage and pen culture (BODFAM, 2003). These involve five multinational companies in larger scale aquaculture production on the Volta lakes. Meanwhile, over 100 mediumscale farmers are found in Ashanti and Eastern regions using fish ponds (GIPC, 2009).

Fish farming is geared towards the improvement of nutritional standards of the people and to create self- employment opportunities for Ghanaian communities. Secondly, fish farming has become more appropriate to developing countries because of the opportunities for waste recycling and integration with crops and animal farming (Pillay, 1990). These opportunities have not been fully utilized in Ghana where fish is most needed. This is because the increasing population places pressure on the demand for fish supply (Hiheglo, 2008).As a result, the national fish requirement has grown from 676,000 tonnes in 1975 to 840,000 tonnes in 2007 (GIPC, 2009). Similarly, the national demand for fish in 2007 was

913,992 tonnes but the country was able to supply only 511,836 tonnes (Hiheglo, 2008). Therefore, the fisheries sector requires additional fish production through fish farming in order to offset the annual deficit of about 400,000 metric tonnes of the country's fish requirements (Asmah, 2008). In Ghana, fish farming is regarded as a means to counter observed decline in fish availability (Ofori, 2000). Therefore, deficit between fish requirement and production becomes a prime motivation in the development of aquaculture in Ghana (GIPC, 2009).

Although, works have been done in fisheries aquaculture in Ghana, there is need for further research on the management systems practised by fish farmers to assess the opportunities and constraints. This is because farmers have been advised to discuss their problems and challenges for better ways in order to be able to contribute to fish deficit supply of about 400,000 metric tonnes as expected (Asmah, 2008). Secondly, research priorities have been set by the Water Research Institute (WRI) through consultations conducted internally as well as with other stakeholders while keeping in mind issues such as problems faced by fish farmers (FAO, 2000, 2009). These are plans for better utilization of the country's potential to increase its fish production and availability through aquaculture as well as integrating with agriculture (Ofori, 2000). Furthermore, it has been commented that all fish farmers in Ghana could double their current production purely through better management (FAO, 1990a). Asmah *et al*. (2008) suggested that the current 400,000 mt shortfall in domestic fish production can be achieved by 2020 by increasing overall aquaculture production by 60% per annum. In relation to this, Asmah (2008) recommended a further study in the area and incorporate crops that can be used to produce by-products for fish feeds. Other recommendations include situations of water, soils, feed and fertilizer source, market access and other social economic factor (Asmah, 2008).

Therefore, this work was undertaken to explore the opportunities and constraints for fish farming in Ghana, as well as the management systems practised at local levels including the small-scale farmers. Generally, small-scale farmers' aquaculture projects provide more employment opportunities per unit of capital investment than those with larger farms (Pillay, 1990). In addition, they have the advantage of being more widely distributed geographically and are locally owned, enabling income distribution among the population (Pillay, 1990).

In order to have a holistic coverage of farms and stakeholders, aspects of the Systems Approach (Phillips *et al*. 2001) was adopted in data gathering and analysis. This approach recognizes the diverse factors affecting fish farmers and it is a multi-factorial and multidisciplinary approach that attempts to analyse how different factors affect fish farming and develop solutions to problems based on an understanding of how the farming systems operate (Phillips *et al.* 2001).

Application of this approach has more potential for success on the typically diverse small-scale farms that are operated in developing countries. According to the recommendations of the Bangkok Millennium Conference, systematic approach should be taken in the development of aquaculture and aquaculture research because it allows the proper understanding and analysis of problems and opportunities as well as resourcebase of the farms, and the farmers' perceptions of their needs (Phillips *et al*. 2001).

1.1 STATEMENT OF THE PROBLEM

Despite all the enormous potential, Ghanaian fish farmers and fishers are unable to meet the fish requirements of the country, leading to a deficit in fish supply (Asmah, 2008). According to Ofori (2000), pond production forms an insignificant proportion of the national fish supply, contributing only about 5 tonnes yearly. Neither farmed fish products nor fish seed are exported from Ghana because production is low (FAO, 2000, 2009).

Although many works had been done which involved government farms, large-scale farms and NGO farms, there is still the need to study in detail the systems and management practices at farm-level. Therefore, this work will take a systematic approach to gather information about the management systems, especially individual small-scale farmers and suggest ways to improve their productivity, and to enable them to contribute to the annual deficit of about 400,000 metric tonnes of the country's fish requirement (Asmah, 2008).

1.2 RESEARCH QUESTIONS

Ghana has great potential for fish farming but there is still need to strengthen the practice. Therefore, answers to the following questions will help to provide management strategies and policy direction.

a. What are the opportunities for fish farming in Ghana?

b. What are the constraints for fish farming in Ghana?

c. What are the systems of fish farm practised at the local level?

d. Do the farmers have background knowledge of practical experiences of fish farming?

e. Do they solely depend on their locally acquired or traditional knowledge?

f. What are the management strategies of these fish farmers?

g. How can these be improved to become more appropriate to the local conditions of farmers in order to increase their production?

h. What are the roles and contributions of stakeholders in development of aquaculture in Ghana?

1.3 OBJECTIVE

The main objective of the study is to determine the management practices of fish farmers as well as their constraints and opportunities in order to help improve upon production systems that are more appropriate to the local conditions and their resource-base.

1.3.1 Specific Objectives:

- Examine the main constraints to fish farming in Ghana.
- Identify the opportunities to further promote fish farming in Ghana.
- Examine the management practices of fish farmers and how these can be enhanced

CHAPTER TWO

LITERATURE REVIEW

2.0 *Historical background of Aquaculture*

The practice of aquaculture started in Asia, Ancient Egypt and in Central Europe. In Asia, it was around 500 BC by a Chinese politician (Ling, 1977). In Egypt (Africa), tilapia as a native, was raised in ponds around 2500 BC.

The earliest species of fish cultured was the common carp (*Cyprinus carpio*), by a native of China (Ling, 1977). In addition, Indian carp culture existed in the 11th Century AD (Pillay, 1990). Similarly, aquaculture started in Europe from the middle Ages with the introduction of common carp culture in monastic ponds. Subsequently, during the 14th century, the propagation of trout was introduced in France and the monk Don Pinchot and, discovered in the same period; the method of artificial impregnation of trout eggs (Davies, 1956). Furthermore, commercial trout culture in freshwater was developed in France, Denmark, Japan, Italy and Norway (Pillay, 1990). Specifically, the British introduced trout as sport fisheries in their Asian and African Colonies. Moreover, the development of fish culture in North America became possible through the propagation of trout Salmon and Black bass. In the Czech Republic, these fishes were cultured in large ponds which were built from around 1650 and are still in use (Wikipedia, 2009). Originally, other culture facilities such as pens and cages were used to grow catfish in Cambodia. While, the earliest brackish- water farming originated in Indonesia during the 15th Century AD (Pillay, 1990). Atlantic Salmon also were cultured in cages in

Norwegian fjords (Pillay, 1990).

In West Africa, The Gambia started aquaculture in the 1970s‘ in the form of trials using tilapia culture in rice fields (Jawo, 2007; Jallow, 2009). Later on, in 1982, a company known as West African Aquaculture limited started the culture of *Peneaus monodon* in the coastal region (Jallow, 2009). This company became well established in The Gambia in 2000. Similarly in 1988, two fish farms were operated in Western Region by Scan Gambia limited (Jallow, 2009).

Fish farming started in Ghana in 1953 by the former Department of Fisheries. Thus, it served as hatcheries to support the then culture-based reservoir fishery development programme of the colonial administration. In 1957, the government of Ghana adopted a policy to develop fish ponds for farming within all irrigation schemes in the country (FAO, 2000, 2009). There was a boost in early 1980s, following a nation-wide campaign by then military government. Subsequently, the first experimental fish farm was established in the Upper West Region in 1985. During the period of 1982 to 1985, the number of fish ponds increased from 578 to 1,390. Gradually, the number rose to 1,400 in 1986; covering an average surface area of 685 m square (Amisah and Quagrainie, 2007). In order to increase further, research collaboration between International Centre for Living Aquatic Resources Management (ICLARM) and the Institute of Aquatic Biology (IAB), Accra, Ghana, began in 1991 to investigate the development of aquaculture on smallholder farms (Pullin and Prein, 1994).

At the beginning of 1994, pond fish production was estimated at 500 tonnes involving

1000 fish farmers (Amisah and Quagrainie, 2007). In 1997, the Fisheries Sub-Sector Capacity Building Project estimated 3330 ponds with a total pond area of 242.7 hectares; with yields of 700 tonnes per year (Amisah and Quagrainie, 2007). In the period between 1990 and 2004, the technology of fingerlings production improved tremendously but there were neither marine nor brackish water aquaculture establishment in the country. The major species grown were *Oreochromis niloticus, Clarias gariepinus and Heterotis niloticus.* The majority of farmers were small-scale operators using extensive fish farming systems (FAO, 2000, 2009).

2.1 *Fish farming in Africa*

Sub-Saharan Africa started aquaculture in the 1950s with the main objectives of food security, income and creation of jobs for the rural poor families (Hecht, 2006; Lazard *et al*. 1991). Eventually, it began to drop after 4 decades as compared with Asia. The proof was that, Africa realized a sum of US $72.5 million from 1978 to 1984 while Asia and the Pacific recovered US $171.3 million (Lazard *et al.* 1991). However, it is also discovered that the African continent is environmentally friendly with the farming of tilapia, African catfish and carps (Ridler and Hishamunda, 2001). Despite the potential, the Region contributes less than 1% to world aquaculture production. Consequently, this has caused a high pressure on capture fishery due to the growing population of Africa that depend on fish protein. According to Asmah (2008), an increment of fish supply, from 6.2 to 9.3 million tonnes per year will help to reduce the pressure. Muir (2005) further explained that more than 8.3% of the total tonnage is needed from aquaculture on annual average production in 2010 in Sub- Saharan Africa alone. In support of this, FAO, UNDP, World

Bank and France funded projects in countries like Cameroon, Cote d‘voire, Kenya, Madagascar and Zambia (Lazard *et al*. 1991).

However, in West Africa, countries such as The Gambia, Senegal and Guinea Bissau, have considered many projects for the integration of fish/shrimps and rice (Trottier, 1987; Jawo, 2007; Jallow, 2009). Furthermore, Senegal women in the Basse Cassamance also practised traditional, integration of rice fish culture. Another example was reported in Gabon where women practised traditional form of fish culture through the collection of fingerlings from the wild and stocked them in ponds owned by their husbands (Trottier, 1987). In addition, fish farmers in Gabon also practised cage culture. Also, in Nigeria, pond culture is widely spread in the fadamas of Sokoto state (Trottier, 1987).

Specifically, women participate extensively in all phases of work performed in fish farms throughout West Africa but few of them are recognised because of lack of ownership of resources (Trottier, 1987). In Tanzania, women raise ducks near their husbands‘ ponds which automatically serve the purpose of integration. Generally, women feed their fish with kitchen wastes. Although, women participate in farm labour such as pond draining as well as harvesting but they are not given the entire farm responsibility because of their low level of training experience. Normally, in African countries fish farm labour is a task given to boys and youths or hired labour. It is reported that in Africa credit is one of the opportunities for fish farming but this has exempted women who are identified to be the best practitioners, since they are normally patient meticulous and diligent (Trotteir, 1987).

The promotion of fish farming in Africa, should involve the participation of women and their ownership pattern which is also a constraint in the Region. Generally, land ownership is a constraint to both men and women. Although, full-time employment is offered in large fish farms but the other constraints include difficulties in hiring labour and obtaining credit for the farm (Trottier, 1987). However, the most significant constraints to women in fish farming are lack of access to extension and training.

2.2 *Fishery resources of Ghana*

The fisheries resource is broadly divided into marine and inland fishery (BODFAM, 2003 and Owusu *et al.* 1999). The marine fishery cover a coastline of nearly 550 km long (Kapetsky, 1991; BODFAM, 2003). Between 1993 and 2000, the annual domestic production from the marine fisheries was 358,000 metric tonnes which is about 80% of the overall fish supply (FAO, 2004).The inland fishery is mainly part of the Volta river basin (fresh water) which include the largest artificial lake in Africa, known as Lake Volta (BODFAM, 2003). The fishery includes a fish fauna of 157 species of which 81 are used as food (Dankwa *et al.* 1999). In this fishery, the fish production was estimated at over 70, 000 tonnes of fish in 2002. This has represented about 16% of the total domestic production and 85% of inland fishery output (Asmah, 2008).

2.3 *Fish farming in Ghana*

Between the 1950s and the early 1970s, the country started stocking fish in small reservoirs and dugouts (Prein and Ofori, 1996). Generally, the types of fish farming practices include small-scale subsistence farming and commercial farming in larger farms. Majority of farmers are small-scale farmers that practised extensive farming systems and semi-intensive farming systems (FAO, 1990a; FAO, 1991). Within the various systems some practised polyculture while others practised monoculture and mono-sex culture (FAO, 1990a). In these culture systems, farmers reared different types of fish species, example tilapias and Clarias sp. being the most common. The maintenance of these fish highly dependent on manufactured feeds and farm made types using local ingredients (FAO, 1990a).

Generally, the farming units are very small and highly dispersed with various earthen pond sizes from 15 m^2 to about 0.48 hectares (FAO, 2000, 2009). Normally, these ponds are maintained on schedule maintenance and drainage (FAO, 1990a). Naturally, their water sources include rivers, streams, underground and rainfall (FAO, 2000, 2009). However, the fertility of these ponds is maintained mainly through the use of organic manure and inorganic, in rare cases (FAO, 2000, 2009).

Similarly, in extensive system practice, some farmers apply a shovel full of poultry manure every day (FAO, 1990a). Other small-scale farmers apply together both poultry droppings and pig wastes as their organic fertilizers while few chose the inorganic fertilizers, NPK and urea (FAO, 2000, 2009).

Usually farmers that practise semi-intensive systems give oil palm kernel cake to their fish as supplement (FAO, 1990a). Within the systems, some fish farmers in the Eastern Region, Tema and Greater Accra practise polyculture of *Sarotherodon galilaeus, Oreochromis niloticus, Tilapia zilli, Tilapia discolor Tilapia busumana, Heterotis niloticus, Clarias gariepinus* and *Ophiocephalus spp* (FAO, 1990a). These fish are normally fed with wheat bran (c. 800/25-30 kg bag) and spent grain, brewery waste (c. 700/truck load); at 2 bags of wheat bran supply to 4 ponds every week (FAO, 1990a). Similarly, at Golinga irrigation scheme (Northern Region) the Department of Fisheries is managing ponds that are stocked with *O niloticus* and *T galilaeus*; which are also fed with rice bran. In this farm close monitoring of water quality is established through the use of Secchi disc readings on daily records (FAO, 1990a).

Furthermore, the farmers also practise rice-cum-fish culture through the integration of the two after broadcasting the rice fields with appropriate seeds and stock three weeks later with about 8 to 10 cm tilapia fingerlings at a density of about 700 per hectare. Conveniently, the water depths in the rice fields are maintained between the range of 15 and 45 cm (FAO, 1990a). Subsequently, fish in these rice fields are fed with rice bran at the same rate as those in the ponds and, both rice and fish are harvested together, about 120 days after seeding (FAO, 1990a). Similarly, other farmers at the irrigation schemes in Central Region stock their rice fields at 500 fingerlings in 1.6 acres (780 fingerlings/ha) and give rice bran at a rate of 15-20 kg per day for every pond (FAO, 1990a). Unlike other farmers, some of them harvest their fish only once every year (FAO, 1990a).

Systematically, farmers in the Western Region stock catfish in reservoir and use to feed them with a mixture of chopped paw-paw (*Casica papaya*), cocoyam (*Colocasia esculenta*) leaves and wheat bran, twice daily (FAO, 1990a). Sometimes, fish farmers use feeds that are made of wheat bran mixed with cassava leaves. In addition, some used food leftovers, papaya leaves and even palm kernel waste (FAO, 1990a).

However, commercial fish farmers in Volta Region produce their own fish seeds through the incubation of fertilized eggs in re-circulating troughs which are also structured as tanks. Later, the fry are recovered from these troughs and reared in concrete tanks to produce fingerlings up to 10 grams before stocking (FAO, 2000, 2009). Normally, their parent tilapias or brood stock are confined in hapas in earthen ponds (FAO, 2000, 2009).

Fish farming in Ghana is based largely on earthen ponds where rainfall, ground water and stream are the main sources of water while cage culture systems are found in commercial farms in the Volta lakes and irrigation dams in Akuse (Asmah, 2008).Naturally, most of the Ghanaian fish farmers depend on seepage of water from the pond bottom to fill the ponds (FAO, 2000, 2009). Although, series of attempts are made to control the flow but the most effective is the use of chicken and pig wastes (FAO, 1990a). The use of this manure is attributed to physical blockage of soil pores, with secondary biological clogging due to slime-forming microorganisms (FAO, 1990a). Technically, farmers use plastic seals and layers of clay compacted on the bottom of the ponds but these are washed away during draining operations (FAO, 1990a).

During the maintenance of these ponds, the farmers clean the bottom and do the levelling; uproot the weeds and repair the dikes together with their inlets and outlets as well as cutting grasses on dikes (FAO, 1990a). Normally, such ponds are drained only once every 3 years (FAO, 1990a). Some of the labour force come from the family members as well as hired labourers (FAO, 1990a).

2.3.1 *Fisheries and aquaculture statistics of Ghana*

According to Asmah et al., (2008), the mean production of pond-based farms ranged from 1,436 kg per hectare per year to 4,423 kg per hectare per year while the medium sized intensive commercial pond farms produced 45,999 kg per hectare per year. Similarly, FAO (2000, 2009), reported that the culture-based fisheries in reservoir; produce an average of 150 kg/ha/yr whereas production from the small-scale pond operators is estimated at 2.5 tonnes/ha/yr. Furthermore, Department of Fisheries, in 2004 survey, estimated aquaculture production at 950 tonnes (FAO, 2000, 2009). In addition, it is estimated that aquaculture production in October, 2009, is 212.56m/t; for Ashanti Region (Appendix 1). Other details are indicated in table 2.1 which is shown as follows.

Table 2.1: Domestic Fish Production in Ghana from 2001 - 2007

Descriptive	Year	Year	Year	Year	Year	Year	Year	Year
Marine	2001	2002	2003	2004	2005	2006	2007	2008
Canoes	236,355	200,769	238,796	267,910	218,872	231,681	199,948	
Inshore Vessels	7,606	7,785	13,319	6,331	7,591	9,877	7,933	
Industrial Vessels	19,644	13,900	9,943	14,011	12,494	17,419	14,641	
Shrimp Vessels	310	249	296	292	443	299	344	
Tuna Vessels	88,807	66,046	65,153	62,742	82,226	63,252	69,407	
Industrial Vessels FW/PT	13,020	1,260	3,906	1,120	1,164	1,090	1,125	
Sub Total	365,741	290,008	331,412	352,405	322,790	323,619	293,398	
Volta Lake	75,000	75,000	74,500	74,500	74,500	74,500	74,500	
Rivers & Dams	7,000	7,000	7,000	7,000	7,000	7,000	7,000	
Sub Total	82,000	82,000	81,500	81,500	81,500	81,500	81,500	
Aquaculture ponds	1000	1000	950	950	1,154	1,668	3,257	5,595
Total Domestic Catch	453,741	378,008	413,862	434,855	405,444	406,787	378,155	

Source: Fisheries Commission, Ghana 2010

2.3.2 *Stakeholders and aquaculture potential in Ghana*

The Department of Fisheries (D o F) now Directorate of Fisheries is the lead agency vested with the administrative control of aquaculture. The department is also responsible for planning and development in the aquaculture sub section. The other responsibilities include the implementation of fisheries policies and programmes as well as facilitating the increment of fish production from marine, inland waters and aquaculture (FAO, 2000, 2009).

The Water Research Institute (WRI) of the Council for Scientific and Industrial Research (CSIR) is mandated to carry out aquaculture research while CSIR is an umbrella of the organizations in Ghana (FAO, 2000, 2009). In addition, the Institute of Renewable Natural Resources of the Kwame Nkrumah University of Science and Technology is collaborating with the Fisheries Directorate and Institute of Aquatic Biology. Its plans are to train more technicians and farmers as well as provide extension services. According to FAO (2000, 2009), by then the Institute offers training in aquaculture at the BSc level only. Presently, the Faculty of the University is offering MPhil and PhD programs in the area of Aquaculture. The Department of Oceanography and Fisheries University of Ghana also trains students and research in Aquaculture.

Ashiaman Agriculture Demonstration Centre is also offering training programme for students, farmers and its staff members. In addition, the institute produce fingerlings for the fish farmers. Its institutional collaborators are the Department of Biological Sciences, ARDEC, Directorate of Fisheries and the Faculty of Renewable Natural Resources, KNUST.

Asmah *et al*., (2008) reported that interests in fish farming continue to grow with an overall annual average growth rate of 16% since 2000. This is because the government motivate people through opportunities of trainings, free extension services, capacity building of farming agents and provision of fingerlings for sale (FAO, 2006). The existing farms, 1,300 in number were however very small with a mean farm size of 0.36 ha and a median 0.06 ha of which commercial farms accounted for less than 3%. Through GIS study, it has been stated that, 2% (3,692 km2) and 0.2% (313.8 km^2) of the country‘s available land is most suitable for subsistence and commercial farming, respectively. In addition, there are another 97.4% of land for subsistence farming and 84% of land for commercial purpose while potential areas for cage culture are in the southern and middle part of the country (Asmah *et al.* 2008).

Furthermore, there are irrigation schemes and dams for aquaculture agriculture in Upper Region, Upper West Region. Other projects include World Bank funded Pilot aquaculture centre in Kona-Tano Odumasi, fingerling production in Ashaiman Fisheries Station, water supply from irrigation dam at a rice project in Dawhenya and ARDEC Akosombo WRI/CSIR in Eastern Region (Owusu *et al.,* 1999).Besides, potential areas for cage culture are in the Greater Accra, Western , Eastern and Ashanti Regions. The specific areas are Lake Bosomtwi, Atwima, Kwamwoma district, Weija reservoir, Dawhenya irrigation reservoir (Kapetsky *et al*. 1991). In addition, the most suitable areas for culturebased fisheries are Northern, Upper East and Upper West. The advantage of these areas is the availability of their artificial water while rainfalls are very low (Kapetsky *et al*. 1991).

Fish species of culture importance in Ghana include *Oreochromis niloticus, Lates niloticus Heterobranchus longifilis* and *Chrysichthys nigrodigitatus*, (Dankwa *et al.*, 1999). In addition, small-scale farmers produce various species of tilapia such as *Tilapia zillii, Tilapia discolor, Tilapia busumana, Sarotherodon galilaeus and Hemichromis fasciatus, Heterotis niloticus* and *the catfishes: Clarias gariepinus* and *Heterobranchus bidorsalis* (FAO, 2000-2009; FAO, 1990a). Normally, women buyers demand to buy the harvested fish from farm gates because of their low costs (FAO, 1990a).

2.3.3 *Livestock and crops inputs for fish production in Ghana*

It is reported that solid contents of pigs and poultry manure are 268-509 grams dry weight per day per animal (Whetstone *et al*. 1974). The quality value of manure as a substrate for microbial growth is directly related to the feed the animal received. Generally, the value of manure, in increasing order is: cattle, sheep, goat, pig, chicken and ducks (Huque, 1992).

Cattle, pig and poultry manures are those of principal interest in Ghana. In this country, cattle population is estimated as 1.12 million in 1986. Collectively, their total manure produce is in the range of 10 to 15 million tonnes per year; because one cow produces about 16 tonnes of manure per year (FAO, 1990b). About 9 tonnes of this manure is required for one hectare of pond in order to obtain 2,150 kg of tilapia over a six month period. Similarly, continuous supply of manure from 100 pigs into one hectare of water, for a period of one year; was reported to result in ten tonnes of tilapia (all-male) per hectare per year (FAO, 1990b). Categorically, one chicken produces about 19 kilograms of droppings per year while 12 tonnes of droppings is applied to produce 1.5 tonnes of fish per hectare per year; meaning that droppings from 421,000 chickens will achieve 1,000 tonnes of tilapia production (FAO, 1990b).

Economically, in Ghana the wastes from both animals and plants are prepared into compost for use as fertilizer in fish ponds. Examples of these are grasses, spoiled fruits, waste from soaked cassava as well as cattle and chicken manure (FAO, 1990b). Satia and

Vincke (1989), identified crop wastes as feeds or feed ingredients for potential fish farmers; which include slaughter-house wastes, fish meal, residues of wheat and rice milling, brewery waste, waste products from sugar manufactured, vegetable oil cakes, cocoa and coffee waste and, animal feeds. Although, it is stated that molasses (from sugar factory) is not suitable as a single feed, but in combination with rice bran at 60% molasses and 40% rice bran will give a conversion of 8 (FAO, 1990b). In Ghana, oilpalm is another source of cake which is not suitable for fish feed; but also reported to have a conversion coefficient of 8. In this country, fish farmers use the freshly pressed fibres as tilapia feed. Furthermore, coffee hulls have a conversion rate of 40 and are used as single-feed while the pulp can be used in mixtures up to 25% of fish diets (FAO, 1990b).

2.3.4 *Land and water for fish farming in Ghana*

Generally, the extensive land areas used for land-based aquaculture are wetlands and agricultural lands. Example, Indian farmers practice the conversion of unproductive agricultural land into aquaculture land (Pillay, 1958).

In Ghana, a vast area of land is reserved for forestry and wildlife parks which make it difficult to develop fish farming in these areas (FAO, 1991). The reserve land covered 46,000 km^2 (19% of the country's surface) which include the water surface of Lake Volta and lagoons. The remainder of about 193,000 km^2 is the land that can be developed for fish farming (FAO, 1991). Similarly, FAO (1990a) reported that 2,480 ha of land are used for irrigation in Tano (Northern Region) and an area of over 60 ha is allocated for aquaculture development. However, the other constraint on the land issue is the availability of suitable soils for pond construction. Considering the landscape and soil texture and permeability, FAO (1991) identified the unsuitable soils to be the alluvial soils adjacent to rivers and streams with an estimated width of one kilometre.

Water is the culture environment that gives physical support to fish and other aquatic organisms (Delince, 1992). Water has a number of sources some of which are rainfall, streams, groundwater and agricultural irrigation schemes (Behrendt, 1994). According to Pillay (1992), the water abstracted from rivers, streams, lakes and irrigation schemes is commonly used in land-based fresh water aquaculture; while the pumped groundwater is most preferred for hatchery purposes. Normally, areas with low rainfall result to low water tables during the summer and many lakes become shallow; allowing the water temperature to remain above 20 degrees centigrade for longer period (Behrendt, 1994). On the other hand, water temperature at the surface is influence by changes in air temperature. Water bodies less than 1 metre deep can reach 40 degrees centigrade or more under direct sunlight (Delince, 1992). In such water, temperatures of 30 to 35 degrees centigrade are tolerated by fish, but beyond these, aquatic life is threatened. Similarly, temperature variations in shallow ponds are wider and affect the water mass to a greater extent than in deep ponds (Delince, 1992).

Economically, water is used in rice-cum-fish culture, where it is required in limited quantity (Pillay, 1992). In West Africa, The Gambia with high potential for aquaculture; is an example where tilapia is cultured in rice fields, under controlled water levels (Jawo, 2007; Jallow, 2009).

In Ghana, some of the factors that influence the availability of water include annual rainfall and evaporation (FAO, 1991). According to Dankwa *et al* (1999), source of rivers water is the Volta basin which includes Oti, Pru, White Volta, Black Volta and the Asukawkaw. The Pra basin is formed by Pra, Offin and Birim while other rivers such as Tano, Bia, Ankobra and Densu flow as individual rivers into the Atlantic Ocean. The Volta basin covers an area of about 8,482 km square. In addition, Lake Bosumtwi is the most important natural lake. Basically, the drainage of these river systems is determined by the Kwahu Plateau (Dankwa *et al*.1999). Physically, the most suitable water quality is obtained from the river basin: pH 6.0-8.0, temperature (^{0}C) 25-32 and DO (mg/l) 5.0-10.0. This was a research conducted under ―Ghana raw criteria and guidelines‖ (Asmah, 2008). Asmah (2008) further explained that the river basin is most suitable for fish farming in Ghana because the oxygen concentration is generally within the range of 5 mg/l; which is considered as the minimum for proper growth and development of fish.

2.3.5 *Human Resource for aquaculture in Ghana*

Human resource is considered to be very important in the development of aquaculture. The few that are discussed in this area include the role of research and researchers, the role of extension field agents and farmers' involvement.

In Ghana, research on the health status of the ponds of some small-scale operators is being analyzed by Water Research Institute. In the result, some of the disease causative agents include *Myxosporidia* (Boil disease), *Piscicola sp*. (Leech), *Trichodina sp*. (*Trichodiiasis*) and *Ichthyophthirius sp.* (White spot). Other research and documentation of the genetic characteristics of *O niloticus* from the Volta Lake are also being carried out to be able to select the fast growing strains for fish farming (FAO, 2000, 2009). Water Research Institute is the main aquaculture research institution that carries out such studies in the country, although other institutes also carry out some research into aquaculture.

These other institutes include Kwame Nkrumah University of Science and Technology; University of Ghana; University of Cape Coast and Kwadaso Agricultural College (FAO, 2000, 2009).

In addition, the University of Science and Technology (KNUST) and Virginia Tech & State University under the project of Aquafish Collaborative Research Support Program (ACRSP), carried out a research on Aquaculture and Environment in Ghana. The research findings addressed the best management practices on effluents, biodiversity, feeds and nutrients.

According to ACRSP (2009), pond sediments are allowed to settle down before the release of the effluent. Secondly, the cleaner water normally passes through top-release standpipes which also disallow the release of solid loads. On the other hand, the recycling of pond water will also prevent the release of the effluent (ACRSP, 2009). Furthermore it is stated that, vegetated ditches have the ability to filter sediments as well as reduce nutrient content. Similarly, wetlands are also used for the removal of sediments from effluents (ACRSP, 2009).

The project also discovered that, uneaten feed in a pond will increase the nutrient level which could lead to algal blooms. Usually, algal blooms consume a lot of oxygen in a pond which may lead to fish losses (ACRSP, 2009). Furthermore, nutrient-rich ponds encourage rapid growth of aquatic plants that can also block water channels (ACRSP, 2009). Therefore, the precautions include the avoidance of over feeding and excess application of fertilizers and, close monitoring of feeding patterns (ACRSP, 2009). However, more attention is focused on the selection of fish species that are native to the culture environments as well as prevent them from escaping into rivers (ACRSP, 2009).

2.3.6 *Aquaculture extension service in Ghana*

In Ghana, the Directorate of Fisheries and the Ministry of Agriculture provide free extension services and other technical services to fish farmers which include the production of fingerlings for sale at government-operated fish hatcheries. In addition, non-governmental organizations and universities have also provided some technical assistance to fish farmers in effort towards the development of aquaculture in Ghana (Quagrainie *et al*. 2009).

However, the Fisheries Directorate, are represented at the farmer contact level by Agricultural Extension Agents (AEA). This is because, Fisheries extension capacity for aquaculture activities; was very weak because this area was not part of the curriculum of the agricultural colleges (FAO, 2000, 2009).

2.4 *Socio-economic importance of fish farming in Ghana*

In 2004, Ghana Directorate of Fisheries estimated aquaculture fish production for human consumption, at 950 tonnes (FAO, 2000, 2009). Specially, among the fish produced, both tilapia and North African catfish sell at 1 cedi and 50 pesewas ($1.63) per kilogram in Kumasi, as the second largest city. In Accra, cage culture farm sells tilapia at 3 cedis and 50 pesewas ($3.80) per kilogram at its sales outlets, while Clarias sells for 5 cedis ($5.44) per kilogram. On the average, from the farm gate, farmed fishes are sold at 1 cedi and 50 pesewas ($1.63) per kilogram (FAO, 2000, 2009).

Usually, the majority of small-scale fish farm operators depend on these sales for their income and also provide jobs for their family members (FAO, 2005). However, information and data are not available on the contributions of fish farming to food security, employment and poverty alleviation in Ghana (FAO, 2000, 2009).

2.5 *National Aquaculture policy for fish farming in Ghana*

The preparation of strategic framework for aquaculture development was completed with the involvement of all stakeholders (FAO, 2000, 2009). The Fisheries Act of 2000 (Act 625) is the main legislative instrument that governs the practice of aquaculture in Ghana. The relevant sections are stated as follows:

Section 60 is on licenses for aquaculture and recreational fishing. This section stipulates that a license is required for an aquaculture project > 1 ha, an application for which must be made to the Fisheries Commission and accompanied by an environmental impact assessment.

Section 93, i.e. the requirement for a Fisheries Impact Assessment: Subsection (1) makes it compulsory for anyone undertaking any activity other than fishing, and which is likely to have a substantial impact on the fishery resources or other aquatic resources of Ghana, to inform the Fisheries Commission prior to the commencement of the planned activity. Subsection (2) empowers the Commission to prepare or commission reports and make recommendations that must be taken into account in the planning of the activity and in the development of means of preventing or minimizing any adverse impacts. Subsection (3) adds that this requirement is additional to any other requirements of the Environmental Protection Agency.

Section 139 stipulates that the Minister may, on the recommendations of the Commission and by law, establish regulations relating to aquaculture. This option has yet not been used. The Act is not explicit on legal rights, protection against other resource users and ownership and tenure. It does not contain anything on fish health, quality assurance or product safety.

In exercise of the powers conferred on the Minister responsible for the environment under section 28 of the Environmental Protection Agency Act 1994 (Act 490) i.e.L.I.1652, and on the advice of the Environmental Protection Agency Board, regulations were made for the conduct and submission of environmental reports and impact statements. Schedule 2, regulation 3 of the Environmental Assessment Regulation, 1999, prescribes land-based

aquaculture as one of the undertakings for which an environmental impact assessment (EIA) is mandatory, In the same legislative instrument, schedule 5, regulation 30(2) contains the provisions to regulate the activities associated with fish cage culture. It characterizes water trapped for domestic purposes, water within controlled and/ or protected areas and that water which supports wildlife and fishery activities as environmentally sensitive areas the use of which is governed by
EIAs.

The Food and Drug law, 1992, prohibits the sale of unwholesome, poisonous or adulterated and unnatural substances and lays down penalties for breaching the law (FAO, 2000, 2009). In the development plans, the Government aim to promote small-scale pond farming through the integration of aquaculture into agriculture. Furthermore, culture-based fisheries are introduced within communities living close to irrigation dams for their livelihood opportunities (Owusu *et al.* 1999). In addition, government propose to convert 5% of all irrigated areas into small-scale fish farms. Also, there are plans for further research in aquaculture agriculture which will be facilitated through the reinforcement of institutional collaboration (Owusu *et al*. 1999). The institutions include Department of Fisheries, Institute of Renewable Natural Resources, the Crop Research Institute,
University of Development studies, the Irrigation Development Authority and various NGOs. In addition, Water Research Institute collaborates with ICLARM, GTZ, the World Bank and FAO (Owusu *et al*. 1999).

2.6 *Constraints of fish farming in Ghana*

Constraints of fish farming are considered as any factor or subsystem that works as a bottleneck to restrict the fish farmers from achieving their potentials (BD, 2010).

Initially, some of the constraints were poor site selection, bad pond designing and construction, inefficient pond management, shortages of fingerlings, lack of fertilizers, feeds, lack of harvesting strategies, marketing and processing (Prein and Ofori, 1996). Owusu *et al.* (1999) highlighted the major constraints of Ghanaian fish farmers as: inadequate extension service, lack of fish seeds, inadequate manufactured feeds, lack of capital for expansion and lack of biotechnical information. Furthermore, Vincke M.M.J and Awity L.K.A selected 24 farms where a research was conducted on Description and Assessment of Fish Farms in Ghana (FAO, 1990a). In the findings, the constraints were: lack of credit for pond construction, lack of technical information, high cost of equipment, lack of fingerlings of *Clarias gariepinus* and *Heterobranchus bidosalis*, poaching by villagers and lack of nets for harvesting (FAO, 1990a).

As regard to the pond harvesting, farmers faced additional costs on hiring beach seine nets from the Department of Fisheries at c 3,000 per day (FAO, 1990a). Furthermore, those who use machines (bulldozer) for pond construction, pay at a daily rate of c. 30,000 per day (FAO, 1990a). It is also reported by FAO (2000, 2009) that majority of fish farmers depend on the water seepages to fill their ponds which become a challenge for the drying of these ponds. On the contrary, few farmers have ponds that do not hold water due to serious seepages (FAO, 1990a). Furthermore, in certain areas of Ghana; during the rainy season, the ponds and rice fields are sometimes flooded for periods of 2 to 3 days and even up to about a month (FAO, 1990a).

Other challenges explained that, tilapia fish seeds are often obtained from less desirable sources such as fish production ponds of other farmers that have not been drained for several years and other common sources are reservoirs and rivers (FAO, 2000, 2009). Normally, these fingerlings are of very poor quality because most of them are stunted due to their long stay in the ponds while chosen as seeds for culture. Biologically, fish caught as fingerlings from rivers and reservoirs are either mature or of poor genetic quality and health or are undesirable species (FAO, 2000, 2009).

It is also reported that the flow of information between some of the farmers and the researchers becomes difficult because these farmers cannot remember the stocking densities, feeding rates and the days of certain operations on the farm (FAO. 1990a).

2.7 *Other uses of fish farming*

In some Asian countries, fish are integrated with rice as biological control against weeds, pest and diseases; which is geared towards the increment of grain production (Cagauan, 1994). In similar integration, sludge collected from settlement ponds is used as fertilizer for agricultural crops. On the other hand, sludge is digested in septic tanks for the production of biogas (Pillay, 1992). Apart from this, in Taiwan and Yugoslavia, commercialized fish farms are operated in conjunction with restaurants, motels and holiday homes for the provision of fresh fish depending on their customers' choice (Pillay, 1992).

In the USA and in some European countries, ranch fish ponds serve as source of wholesome food and recreation. Thus, in many European countries there is usually a high demand of carps and eels for the Christmas season (Pillay, 1992). Also, in parts of India, carps (*Labeo rohita*) are the choice of fish for exchange during wedding ceremonies (Pillay, 1992).Similarly , in some parts of Malawi and Cameroon, fish farming is considered as a prestige for the farmers which also provide gifts to their special visitors (Nji, 1986).

Generally, fish farming has contributed to fill the gabs in the supply of preferred species that capture fisheries cannot provide (Pillay, 1992). In addition, the breeding of ornamental fish and aquarium-keeping cause a lot of benefits to the culture, education and business of many people in the World. This has resulted to a lot of benefits: income generation, employment opportunities, improved nutritional status and overall improvement of the living standard of rural people in many developing countries (Pillay, 1992).

2.8 *Fish seeds and fingerlings production*

Fish seed is either collected from the wild or produce by inducing the fish to spawn under farm conditions. The best known fish that spawn easily in a pond are tilapias. Carp form an example half-way between the tilapia and the trout, because they spawn in a farm pond and the eggs and fry can be reared in the pond (Swift, 1993). In Europe, one of the modern methods for seed production is the introduction of early-spawning females to photoperiods in order to facilitate their ovulation. Similarly, sex-reversal females, when subjected to the same condition, will result to all-female eggs (Mussion, 1994). Other techniques include the use of hormones from the pituitary gland; which automatically control the maturation of the fish gonads. In this way, fish become ripe without having to undergo spawning migration (Swift, 1993). Normally, sexually matured fish are given injections of either whole fish pituitary gland or of pituitary hormones to facilitate spawning. Furthermore, cryopreservation technique has been developed in order to preserve viable fish sperm at very low temperatures for long period (Swift, 1993).

2.9 *Site selection for fish farm establishment*

Site selection for a fish farm, includes a lot of factors for consideration. Examples of these factors are: topography, availability of quality water and condition of the water table, suitable soil types for pond construction, level of seepage, ideal pond position, surrounding vegetation, access road, land size and ownership as well as the meteorological and hydrological information about the area.

In selecting a site, one should consider the volume of water available, level of the land in relation to the water possibilities of flooding, vehicular access, electricity supplies, and proximity to potential markets (Woods, 1994). Other meteorological and hydrological information about the area are temperature, rainfall, evaporation, sunshine, speed and direction of winds. In land-based aquaculture where earthen ponds are normally used, ease of filling and drainage by gravity are basic consideration. So, it would be advantageous to select land with slope not steeper than 2 percent (Pillay, 1990). Secondly, it is advisable to make discrete enquiries about ownership of the land or swamp and if the owner is prepared to sell for a reasonable sum (Woods, 1994).

However, a good irrigated agricultural land may be the best for fish ponds. Asia is an example, where farmers utilized rice fields for fish farming (Pillay, 1990). In other areas, before designing a fish farm, a survey is carried out on the site using few trial holes dug to establish the type of terrain as well as taking advantage of the feature of the land (Woods, 1994). This is important because a place with high ground water level may create problems in the farm operation, as drainage will become difficult and expensive. Woods (1994) concluded that selection of suitable site will depend on the culture system
to be adopted.

2.9.1 *Suitable soils for fish pond structures*

Soils are the joint products of rocks, climate and vegetation (Quayson, 1999). Soils are considered due to their suitability for dike construction. Suitable soils for pond construction include sandy clay to clayey loam, clay, clayey silt and silt clay loam. This is because of their additional advantages: retain nutrients for organic production in ponds; resistant to erosion and other damages (Pillay, 1990). These soils are determined by sample collection through the use of anger on regular pit (1.0-2.0 m deep, 0.8 m wide and
1.5 m long) while touch and feel are used to determine the texture (Pillay, 1990).

2.9.2 *Pond construction for fish farming*

The Institute of Science in Society, I-SIS (2005), described most ponds as rectangular shaped, 0.4 to 0.6 ha in area and 2 to 3 meters deep whiles dykes are usually 6 to 10 meters wide with extension of 0.5 to 1.0 meter above the pond surface. According to Swift (1993), ideal position for a pond is one where it can receive water supply under gravity and discharge the used water under gravity. It is also believed that fish pond located under a tree will encourage a lot of shed leaves (drop into the pond) that can result to pollution and need constant removal (Lee, 2006).

Generally, the excavated material is used to form the dyke whereby impermeable soil is preferred for a central core of about 50 cm thick in case of permeable soil. The slope of the inside of the dyke should be 1:2 or decrease to 1:4 in large ponds; where wave action is greater. On the other hand, the slope outside the pond is 1:1 or 1:1.5 (Swift, 1993).

On completion, the pond bottom is compacted and drainage ditches are dug into it. The main ditch is about 50 cm wide and the side slope is about 1:1.5 (Swift, 1993). In front of the pond outfall is constructed as a collection basin sunk below the level of the pond bottom, lined with concrete, and form a firm base for the collection of fish. Generally, pond inlets are structures which enable water supply to be turned on and off at the same time prevent the entrance of unwanted organisms into the pond. The outlets of the pond are formed by a structure known as monk (Swift, 1993).

Pillay (1990) further suggested that ponds could be constructed and operated without disturbing the acid soils, allowing a non-acidic layer of sediment on the bottom.

Secondly, at the designing stage, one should also consider that a fish pond with an average depth of 1.5m required 15000 m^3 of water per every hectare. It is also recommended that, before filling the ponds with water, further preparation is done through clearing, cleaning and applying fertilizers such as quick lime, tea-seed cake and livestock manure (I-SIS, 2005).

2.9.3 *Infrastructural services for fish farmers*

These are facilities such as hatcheries and irrigation schemes which serve as source of fish seed for fish farmers.

Hatchery production is used to stabilize the supply of improved seeds for better growth and fish production. This involve the rearing of brood stock, spawning or stripping and fertilization of ova, incubation of fertilized eggs and rearing of larvae; which are later transferred to nursery enclosures (Pillay, 1990).

Equipments in a hatchery, include tanks and scoop nets for catching brood stock as well as jars, troughs or other containers, net cages or _hapas' (mesh cloth tanks) for incubation of fertilized eggs; food dispensers; larval rearing tanks and aeration systems (Pillay, 1990). In addition, trough-type incubators that are used in trout and salmon hatcheries have egg baskets fitted in trays with perforations which are of the same shape and sizes to retain the eggs; but allow the hatchlings to fall through to the bottom of the trough. On average, the sizes of such troughs is 3m x 0.5m x 0.25m (Pillay, 1990).

Generally, 20-30 degree centigrade is maintained for warm water fish species while the dissolved oxygen level can be slightly lower than the range from 3 to 4 mg per litre of the water (Pillay, 1990). Normally, hatcheries with small fries use around 300 gallons of water per minute (Halls, 1994). While larger fish use a maximum of 700 gallons in every hour. Usually, these are stocked at low density in order to achieve quality fish (Halls, 1994). Also, irrigation systems are potential sites for fish grow-out or nurseries. Some of the examples are: large irrigation reservoirs, extension network of irrigation canals and irrigated fields (Fernando and Halwart, 2000). Fernando and Halwart (2000) further stated that, high densities of fish in irrigation systems will enhance the crop yields, alleviate the pressure of both terrestrial and aquatic pest to lower the population of vectors of diseases of man and domestic animals.

2.10 *Management of fish enclosures for fish rearing*

Pond is one of the enclosures where management is concerned with the water supply and to maintain the environmental conditions required for the optimum growth and minimum mortality of the pond‘s fish population (Swift, 1993). After each harvest the pond is drained and the bottom is allowed to dry out. Excess mud and detritus are removed while the soil is ploughed and then treated with lime and manure as required. Normally, the water flow is controlled in order to adjust the temperature and oxygen content of the water (Swift, 1993).

Repeated draining and filling of a pond may result to desiccation of the entire embankment, causing cracks and entry of water into the structure. Eventually, the crack faces become saturated and the moisture penetrates into the interior by capillary action (Pillay, 1990). Gradually, greater amount of water flows through the cracks, resulting into the development of gully or tunnel erosion (Szilvassy, 1984). Secondly, siltation may become a problem but this will depend on the annual volume of sediment entering the pond. Where the water turbidity is undesirably high, separate sedimentation tanks are required to reduce it (Pillay, 1990).

Generally, ponds filled from natural bodies of water create entry of extraneous fish and other eggs or larvae of organisms even whereas inlet protection made of small-meshed screens are provided (Pillay, 1990). Swift (1993) further explained that, concrete-lined ponds are used in systems where the entire food supply for the fish is placed in the pond by the farmer. Such ponds are meant for the intensive production of high-priced fish (example trout) in intensive systems.

Normally, pond management becomes easier and most economical with shallow type (3 to 6 feet & 1 to 10 acres) ponds with drainage systems. Pond draining is necessary in order to harvest all of the fish; after which the pond bottom is allowed to dry for the eradication of any fry or fingerlings that may interfere with the next production cycle (Rakocy and McGinty, 1989).

Usually, ponds are drained two or three times yearly, and the mud is added onto the dykes, thereby raising and repairing the dykes as well as restoring the depth of the pond (I-SIS, 2005). Ponds are also sealed by pudding which is a process where fine particles are used to clog the most permeable parts (Pillay, 1990). Furthermore, Nilson and Wetengere (1994) recommended cleaning of pond slopes, three times every year while harvesting twice per year and pond construction and maintenance, in the months after the rainy season. Furthermore, planting some water plants around the pond edges will help to manage and absorb some of the nutrients in the fish pond in order to control the presence of algae (Lee, 2006). It is also suggested that, plastic lining can be used in a pond in other to separate the ground as well as control the debris and soil nutrients (Lee, 2006).

However, fish tank is also another enclosure which is maintained through regular cleaning of the filtration system as well as the interior of the tank (Stevens, 2007). Usually, a partial water change of about 20% is needed during fish tank and aquarium maintenance. This is a continuous replacement after each cleaning of an aquarium. During the process, algae scrubber is used to remove a little amount of algae off the front viewing panel of the aquarium and as well scrape any algae off both the front and sides of the tank (FishLore, 2007). Consequently, the filter media is given a special care and rinse with discarded tank water. This is because beneficial bacteria load needed for the aquarium nitrogen cycle are concentrated at the filter media (after draining) and rinsing it in tap water with chlorine can kill some of these bacteria. Therefore, the tank is refilled with de-chlorinated water as the same temperature as the remaining water (FishLore, 2007). Stevens (2007) further registered that, cleaning the filter of fish tank is usually a monthly task while the entire tank is clean at least once a week or once every fortnight.

Normally, salt water aquarium is cleaned once a week whereby the algal built up on the front and side of the glass are scrubbed out completely. Subsequently, the water is replaced but freshly mixed salt water can be fairly toxic to fish. Thus, a day is allowed to prepare the mixture in order to dissolve properly; prior to the need. At this moment salinity is determine using the hydrometer (FishLore, 2007).

2.10.1 *Seepage in fish ponds*

Pillay (1992) stated that seepage in fish ponds depend on soil conditions, area of pond surface and dike construction. Example, loss through seepage and evaporation in an arid climate is estimated at 1-2 cm per day or more. Therefore, the minimum quantity required for filling and topping under such situation is estimated between 35000 m^3 and 60000 m^3 per hectare per year (Pillay, 1990). In Europe, the range of such losses is reported to be about 0.4-0.8 cm per day. Technically, seepages are reduced through compaction of soils during pond construction. This is supported with other elements that cause natural sealing or colmatation include decaying debris, pond wastes and algal growth (Pillay, 1990). Naturally, seepage water losses can be reduced by proper site selection and adequate pond construction (Pillay, 1992).

2.10.2 *Water quality in fish farms*

This section will discuss water quality measures for the maintenance of healthy water for fish farming. Basically, these include turbidity, acidity and alkalinity, dissolved oxygen and salinity.

High turbidity of water by suspended solids affects both productivity and fish life. It reduces light penetration into the water and as a result primary production decreases (Pillay, 1990). The suspended solids also clog the filter-feeding apparatus and as well injure gills of fish. This occurs when the water contains about 4% by volume of solids (Pillay, 1990). However, these solids are reduced through the use of settling tanks with different types of filters and repeated application of gypsum (200 kg per 1000 m^3, followed by additional application of 50g per 1000m^3).

The best conditions for a fish pond are a stable pH with a level between neutral and alkaline (Swift, 1993). Pillay, (1990), clearly stated that the most suitable pH of water for aquaculture farms lie in the range of 6.7 to 8.6 while below or above inhibit growth and production. Normally, water of low pH is commonly found in freshwater areas with soils that are low in calcium and rich in humic acids (Pillay, 1990). Occasionally, acidic water (pH range of 5.0-5.5) is harmful to eggs and fry of most fish. Therefore, it is advisable to take pH measurement on daily bases as productive water is prone to reach higher pH values of 9-10 due to the uptake of carbon dioxide during (photosynthesis) the day.
Beyond that level, even pH level of 11 may be lethal to fish (Pillay, 1990).

Photosynthesis, respiration, exchanges at the air-water interface, and supply of water to the pond controlled the amount of oxygen dissolved in water (Krom *et al*. 1989b; Erez *et al.* 1990). The source of dissolved oxygen in water is partly from the air and mainly photosynthetic activities.

In Israel, Milstein *et al.* (1989) reported that the impacts on water quality of reservoirs use for fish farming is primarily the result of algal activities, followed by decomposition processes, and, finally, wind action. In the epilimnion, algae produce oxygen, while in the hypolimnion, they consume oxygen. Furthermore, in the metalimnion, consumption and production are balanced (Chang & Ouyang, 1988). Generally, the principal source of oxygen consumption in ponds is heterotrophic respiration (include all animals) while the autotrophs react during the night (Delince, 1992).

Therefore, in the early afternoon, at the peak of production, oxygen saturation can reach 250%, and this is towards release of oxygen into the air (Delince, 1992). Normally, the level of dissolved oxygen varies from 14.6 mg/ litre at 0 degrees centigrade to 7.6 mg/litre at 30 degrees centigrade. Thus, over the temperature range of 0 to 30 degrees centigrade the amount of oxygen contained in the water is halved. The required oxygen varies with species, example salmon require 9 mg/litre; carp 6 mg/litre, but can withstand levels as low as 3 mg/litre. Tilapia can also withstand low levels of oxygen below 6 mg/litre (Swift, 1993).

However, salinity is the sum of all solid substances in solution in 1 kg of water (measured with salinometer), when all carbonate ions have been converted to oxide ions, all bromide and iodide ions are replaced by chloride ions, and all organic matter oxidized (Spotte, 1979). Similarly, in temperate freshwater, calcium and magnesium are the most abundant ions while in African waters, sodium and magnesium are often dominant (Delince, 1992). Furthermore, Weninger (1985) stated that the water in tropical humid areas are commonly dominated by calcium and bicarbonate ions and become alkaline.

2.11 *Common fish diseases in fish farms*

Viral, fungal, bacterial and parasitic diseases are all water-borne that can be carried from pond to pond either by the introduction of new fish or by the farmer and his equipment (Swift, 1993). Farmers in such conditions like the European, small-scale producers in restricted water areas are more vulnerable to diseases and encounter higher cost than larger growers (Halls, 1994). Furthermore, high fish densities suffered more risks of infections by parasites like fish lice, fungi (*Saprolegnia species*), intestinal worms (*nematodes* or *trematodes*), bacteria (*Yersinia spp.*, *Pseudomonas spp*.), and protozoa (such as *Dinoflagellates*) (Wikipedia, 2009).

Most of these diseases are distributed worldwide. Example, Furunculosis affect both cold and warm water of many fish species worldwide (Pillay, 1990). Similarly, Bacterial gill disease also affect all ages of fish. Normally, such contagious diseases are highly fatal and very destructive in an endemic area (Swift, 1993). This has caused heavy losses in many infected fish farms. Some of the predisposing factors include the types and conditions of the fish species. Fry types or fingerlings are highly susceptible to viral diseases (Moeller, 2007). Normally, such diseases are not curable and very difficult to eradicate. Similarly, fungal diseases (Saprolegniasis) cause a lot of irritation which eventually disturb the feeding habit of the infected fish. Consequently, the pond becomes loaded with uneaten feeds that may lead to pollution. The feeds load also increase the nutrient level of the ponds which indirectly affect the water quality through the encouragement of algal growth. Eventually, poisons develop from the algae; which also reduce the oxygen level in the pond water (Swift, 1993).

Generally, large-scale intensive farming suffers severe problems with fish diseases. However, vaccines have been used successfully against bacterial diseases. Some are administered by oral, injections, high pressure spray or by immersion. Recent technology allows fish to swim in vaccine solution for about 2 hours, and the protection last for about 5 to 7 months (Swift, 1993). Preventive measures include the avoidance of infected sources and quarantine stock before the introduction into the ponds (Pillay, 1992).

2.12 *Record keeping in fish farms*

Record keeping is the most important tool used to keep information about the fish farm. Some of this information include inventory of farm facilities such as ponds, tanks, pens, cages and others. Usually, records are divided into different schedules: personnel records, dates of project activities and records of other farm operations (SM, 2008). Behrendt (1994) also stated that farmers keep pond books which enable them to accurately predict the number of fish stocked in each pond. Without reliable farm records, not much progress can be made on the farm (Pillay, 1990).

Stamp (1978), stated that computers are used for planning, budgeting, keeping records and accounting at shrimp farming in the USA. Already, Jaffa (1994) discovered the use of computers in farm offices, in Scotland, for keeping track of large amount of information on a daily basis; which are automatically updated after every entry in order to examine the current performance of a farm. Technically, the system is built to suit farmers who have no experience in computer operation. Ingram (1994) further stated that, a cumulative record of normal situation at farm levels as well as water and stock analysis will strengthen a claim on a disaster relief.

2.13 *Fish farming systems*

Basically, these are the farming systems that are practiced throughout the World. The five main types are intensive, semi-intensive, extensive, integrated and recycling.

2.13.1 *Intensive fish farming systems*

In intensive fish farming systems, fresh water, sufficient oxygen and food are provided through integration of massive water purification system in the fish farm as well as the combination of hydroponic horticulture and water treatment. Normally, there is tight monitoring of water quality (oxygen, ammonia, nitrite, etc.) and a high level of expertise of the fish farmer (Wikipedia, 2009). Similarly, commercial fish farmers in Ghana undertake intensive fish farming practices and feed their fish with balanced diets which are locally prepared (FAO, 2000, 2009).

Generally, fish are fed with higher level of protein (up to 60%) which is a consequence of the higher food conversion efficiency: FCR—kg of feed per kg of animal produced (of aquatic animals). For example salmons have FCR‘s in the 1.1 kg of feed per kg of salmon range (Wikipedia, 2009). Relatively, in indoor, intensive fish farming systems, fish may be fed as many as 5 times per day in order to maximize growth at optimum temperatures (Craig and Helfrich, 2002).

One of the intensive systems is known as recycle aquaculture systems (RAS) where control over all the production parameters are being used for high value species. The water is recycled such that very little quantity is used per unit of production (Wikipedia, 2009). Economically, RAS is for high products: brood stock for eggs production, fingerlings for net pen aquaculture operations, sturgeon production, research animals and some special niche markets like live fish (Wikipedia, 2009).

However, the other farming system is the integrated recycling system (IRS) where large plastic fish tanks are placed in a greenhouse while a hydroponic bed is placed closer, above or between them (Wikipedia, 2009). The tank water is slowly circulated into the hydroponic beds where the tilapia waste feeds a commercial plant crops. At the same time, the tanks are properly fertilized in order to encourage algal growth which is feed upon by the raise fish (example tilapia). Automatically, cultured microorganisms in the hydroponic beds convert ammonia into nitrates while the plants are fertilized by the nitrates and phosphates (Wikipedia, 2009). On the other hand, wastes are strained out by the hydroponic media, which doubles as an aerated pebble-bed filter. This system is advantageous of adapting to almost all temperate climates and may also adapt to tropical climates, since it is based in a greenhouse (Wikipedia, 2009). Usually, the discharged water is salted in order to maintain the fishes' electrolyte balance. Scientifically, some veterinary authorities suggested that, ultraviolet ozone disinfectant system (widely used for ornamental fish), may play a vital role in keeping tilapia healthy with recycled water

(Wikipedia, 2009).

2.13.2 *Semi-intensive fish farming systems*

In Tanzania, semi-intensive fish farming is defined as a practice where feeds are given 23 times a week or even once a week while fertilizer is applied at least once per week (Nilson and Wetengere, 1994). Normally, the feeds are supplements added to the available natural nutrients in the ponds. The feeds include maize, rice bran, vegetable leaves, kitchen wastes, local brew leftovers, and manure (cattle, goats and chicken)
(Nilson and Wetengere, 1994).

Similar systems are irrigation ditches or farm ponds that have the potential to retain water, possibly with an above-ground irrigation system while others use buried pipes with headers. In the smaller systems fish are often fed with commercial fish food, and their wastes products are used to fertilize the fields. Naturally, grown water plants and algae are use as fish food in larger ponds whereby water quality is closely monitored
(Wikipedia, 2009).

2.13.3 *Extensive fish farming systems*

In this system, food is supplied by natural sources: zooplankton feeding on pelagic algae or benthic animals. Biologically, almost all available food sources in the pond are tap by fish species which occupy different places in the pond ecosystem: tilapia (filter algae feeder), carp or catfish (benthic feeder), various carps (zooplankton feeder) and grass carp as submerged weeds feeder (Wikipedia, 2009).

Ranching is a similar type practice in Asia, USA and Scandinavia. These are areas where young salmon are released into the river to return to the sea to complete their growth phase. This is a system where the fish are reared on the farm to a certain age and are then released without control or additional food (supplement) into large bodies of natural water, lakes and oceans, where they complete their life cycle and grow to maturity (Swift, 1993).

2.13.4 *Fish culture systems practice*

These are techniques used to culture fish in different types of enclosures: ponds, tanks and cages. As mentioned before, different farm practices are carried out using these enclosures. There importance is to enable the manipulation of the rearing environmental conditions.

Pond culture is the most popular method of growing tilapia. Naturally, the fish are able to utilize available nutrients. On the other hand, the management of tilapia ponds ranges from extensive systems, which uses only organic or inorganic fertilizers; to intensive systems, using high protein feeds, with aeration and water exchange (Rakocy and McGinty, 1989).

Fry rearing is also done in tanks and troughs with much control over ambient conditions (Pillay, 1990). Trout and other sport fish are often raised from eggs to fry or fingerlings, in long shallow concrete tanks, filled with fresh stream water as well as supplied with commercial fish food in pellets (Wikipedia, 2009).

However, cage culture is a system where cages are placed in open water resources to contain and protect fish until they can be harvested (Wikipedia, 2009). Generally, many types of water can be used in cage system: rivers, lakes and filled quarries. While different types of fish can be raised, example *Giant gourami* in central Thailand. Simultaneously, this type of fish farming can co-exist with sport fishing and other water uses (Wikipedia, 2009).

Normally, wooden cages of 8m square are stocked with Salmons from their original hatchery and remain in fresh water for about nine months (Halls, 1994). This is a condition where artificial feeds are given to the fish (Wikipedia, 2009). At the same time some farmers allowed their loch to lie fallow for two months between generations. Subsequently, the on growing is taken to sea cages, a system known as cage to cage culture (Halls, 1994).

Similarly, the cage culture facility in Ghana has 8 cages, each with a diameter of 15 m, and depth of 4 m. Each cage is stocked with 50,000 fingerlings of *O. niloticus* at 30 grams which are cultured for six months. In addition, fingerlings of 10 grams in weight are stocked in cages for culture (FAO, 2000, 2009).

2.13.5 *Fish culture practices*

Normally, these are culture practices that accommodate single or special combination of fish species for a particular purpose. Examples are monoculture and polyculture, likewise, sexes are also considered as mono-sex or mixed-sex culture.

In monoculture only one species of fish (catfish or trout) is reared in the pond. Purposively, this is used in expected high levels of production with a support of supplementary feeds.

Specifically, there is a monoculture practice which involves two species of fish, commonly practised for the control of overpopulation of tilapia in ponds (Swift, 1993).

Similarly, in male mono-sex culture, all-male fingerlings are obtained by three methods: hybridization, sex-reversal and manual sexing. Only the single sexes are reared in tanks with high quality water (Rakocy and McGinty, 1989). The stocking rate for male monosex culture varies from 4,000 to 20,000 per acre while a stocking rate of 8,000 per acre is frequently used. Normally, a culture period of 200 days or more are needed to produce fish weighing close to 500 grams (Rakocy and McGinty, 1989).

In mixed-sex culture, tilapias are usually stocked at low rates to reduce competition for food and promote rapid growth. Fry of one month old (1 gram) are stocked at 2,000 to 6,000 per acre into grow-out ponds for 4 to 5 months culture period. Usually, supplemental feeds with 25 to 35 percent protein are given. At harvest, their average weight is approximately 220 grams or 0.5 pounds (Rakoci and McGint, 1989).

However, in polyculture practice several species of aquatic animals are stocked simultaneously to take advantage of the different food niches available in the pond environment (Wurts, 2001). Rakocy and McGinty (1989), further explained that polyculture is the type where tilapias are commonly cultured together with other species to utilize the available natural foods in ponds and as well as to control tilapia recruitment.

This is a control that involves the use of predatory fish, such as largemouth bass (*Micropterus salmoides*). Similarly, small sized predators are also stocked when tilapia begin their breeding season, because this would prevent the elimination of the original tilapia stock and the recommended predator/prey ratio is one largemouth bass to 15 tilapias (Rakocy and McGinty, 1989). It is also reported by Wikipedia (2010) that Snakeheads (*Channidae*) are used in polyculture as fish predators and as well considered as valuable food fish. Usually, younger snakeheads feed on plankton, aquatic insects and molluscs while the adults feed on bigger fish example, carps or frogs. In rare cases, small mammals example, rats are also preyed (Wikipedia, 2010).

Similar combination in China and India, usually involve carps with other species and, include at least one scavenging species that feeds on the faecal matter of other species. This is done in order to reduce wastes load in the ponds (Pillay, 1992). Technically, this type of culture, improves the water quality through the creation of a better balance among the microbial communities in the pond (Pillay, 1992).

2.13.6 *Feeding in fish farming systems*

Normally, feeding rates are affected by factors such as time of the day, season, water temperature, dissolved oxygen levels, and other water quality variables (Craig and Helfrich, 2002). Therefore it is not advisable to feed fish (grown in ponds) early in the morning when the dissolved oxygen level becomes very low. This is with exception to recirculating aquaculture systems where oxygen supply is continuous (Craig and Helfrich, 2002).

The efficiency of the feeding rates by fish is monitored through the consideration of factors such as feed application rates, number of feeds per day and the duration of each feeding (Talbot, 1994b). The suggested approach for this is to relate diameter of the type of pellet to the appropriate fish size and estimate the average number of pellets to satisfy (satiation) the particular fish for its daily ration. Automatically these calculations are used to examine effect of number of daily meals, the duration of each meal and the feed application rates (Talbot, 1994b). The outcome of this provide a guideline to be able to divide daily meals into different numbers of feedings (feeding frequency) at a given feeding rate; example, 1 kg fish at 1% body weight per day needs 31pellets per day (Talbot, 1994b).

The feeding frequency is another factor which is highly dependent on labour availability, farm size, and the fish species and sizes of fish grown (Craig and Helfrich, 2002). It is also believed that, growth and feed conversion increase with feeding frequency (Craig and Helfrich, 2002). Generally, such feeds are quality feeds with the required ingredients to become more acceptable, palatable and digestible. However, a combination of such improved diets and low stocking densities will reduce the risk of water quality (Halls, 1994).

2.13.7 *Fertilizer application in fish ponds*

Sewage effluents and properly treated animal wastes are used as fertilizers to increase growth of food organisms in aquaculture farms (Pillay, 1990). Other types are artificial fertilizer mixtures, such as potash, phosphorus, nitrogen and micro-elements which are also use to fertilize ponds in order to increase their photosynthetic production (Wikipedia, 2009). Normally, the type of phosphorus use at high level is liquid polyphosphate (13-380); which is applied at a rate of 20 pounds per acre (2.4 gallons/acre) (Rakocy and McGinty, 1989).

It is also stated that organic fertilizers (manure) such as pig, chicken and duck wastes increase fish production more than cow and sheep manure (Rakocy and McGinty, 1989). The rates to apply such manure from chicken, cattle and pigs is 20,000 kg per hectare, to be placed on the bottom of the pond in small heaps in order to allow free oxygen circulation (Swift, 1993).

2.13.8 *Liming in fish ponds*

Liming is a method use to neutralize low pH (acidity) as well as high calcium bicarbonate (Ca $(HCo_3)_2$). Examples of lime are: quicklime (calcium oxide, Cao), slaked lime or agricultural lime (Calcium hydroxide, Ca $(OH)_2$) and limestone (Calcium carbonate, $CaCo_3$) (Pillay, 1990). Lime is added when the pH of the water is low, when the alkalinity is low, when the pond bottom is muddy, when the organic content of the pond is too high and when there is a threat of disease in the pond (Swift, 1993). Liming is also used to activate the mud bottom and prevent the water becoming too acidic (Behrendt, 1994). The lime requirement for low pH is in the proportion of 1:1; while, 5:2 is recommended for high chemical content (Pillay, 1990).

For example, for normal routine maintenance; calcium oxide is directly applied into the water at the rate of 200 kg /ha while 200 to 400 kg/ha is used on the pond floor (Swift, 1993). This application is increased to 1000 kg/ha (on pond bottom) for the eradication of fish parasites and 1000 kg/ha when combating conditions of low pH in the pond (Swift, 1993). Usually, drained ponds are treated with quicklime at 2,000 kg per hectare; before the bottom dries out (Behrendt, 1994).

2.13.9 *Weed control measures in fish farms*

Weeds are of different types: succulent and, fibrous and woody. The succulent types include duck weed *(Lemna sp., Spirodela sp., and Wolffia sp.), Azolla spp*., pond weeds *(Potamogeton spp.*), *Hydrilla verticillata, Najas spp., Chara spp., Myriophyllum sp.* and *Eleocharis spp*. The fibrous and woody weeds are the water hyacinth *(Eichhornia sp.), Pistia sp.* and *Sagittaria spp*. (Cagauan, 1994). According to Behrendt (1994), in the United Kingdom, ―Canada weeds‖ *(Elodea Canadensis*) or ―water pest‖ can choke pond, lake or river within a short period.

In this country, farmers control weeds through the use of large black polythene sheets place under the water surface. Eventually, the weeds are killed in about three to four weeks after which their roots are eliminated three months later (Behrendt, 1994). Similarly, in Sweden, a large wooden raft is used to smother under water weeds while the raft is constructed with closely-boarded; at the same time excluding light from the environment. Eventually, all weeds beneath it died off (Behrendt, 1994).

It is recommended that selected weed killers are effectively used to control such weeds (Behrendt, 1994). Other methods include the drying of ponds together with the weeds. In addition, the most wasteful method is to cut them during the summer. Specially, bushes on the banks of the ponds are cut in order to discourage reed beds. Furthermore, the grass carps are also used as a control measure (Behrendt, 1994).

2.13.10 *Sustainability of fish farming*

Wurts (2000) suggested that it is more practical and efficient to recycle nutrient (converting nitrogen back to protein) through different polyculture systems than controlling or treating the effluents. Secondly, the culture of channel catfish with paddlefish and some species of freshwater mussels could be another option. Wurts (2001), noticed that on a dry weight bases, plankton can account for almost half of the standing biomass in a culture pond (900 to 1000 kg/ha).

Technically, for sustainability in such a pond with plankton rich water, the kind of plankton harvest uses filter feeders which are placed in a series arrangement (Wurts, 2001). In order to compartmentalize various sizes of particles, different planktivores are introduced in the order of largest planktons feeders first followed by smallest particle feeders. Secondly, in a systematic method, the pond water can be pumped repeatedly, from one enclosure into the next; through a series of floating or land-based chambers which remove the plankton sequentially. However, it is a strong believed that careful selection and segregation of filter feeders would recycle waste nutrients indirectly through the planktivores (Wurts, 2001).

The assurance of the availability of feeds through integrated livestock-cum-fish farming, is also contributing in sustainability because the animal manure fertilizes the ponds and encourages the growth of plankton that feed the fish (Pillay, 1992). In addition, most dyke crops, such as elephant grass are fed directly to the fish (grass carp) or else to the livestock (I-SIS, 2005). The bottom feeding activities of fish like the common carps *(Cyprinus carpio*) result to turbid condition which reduces the light penetration for the control of photosynthetic activity in water quality (Cagauan, 1994).

2.13.11 *Effluent control and waste treatment in fish farms*

Normally, the cage culture systems, encounter low dissolved oxygen levels as well as the release of hydrogen sulphide and methane. In order to control these, the University of Stirling *et al*. (1990), reported that Atlantic salmon cage farms in Scotland undergo fallowing for periods ranging from 4 to 51 weeks; to allow the dilution of nutrient wastes and to recover the sediments.

Although, many ways such as sand filtration, microstraining and air flotation had been tried for the treatment of effluents from fish ponds, but simple sedimentation has proved to be more cost-efficient in commercial farms (Pillay, 1992). Subsequently, the accumulated detritus at the pond bottom are removed after harvest; for the preparation of the next cropping (Pillay, 1992). Boyd (1985) gave an example that, well-managed channel catfish ponds were found with no accumulation of nitrogen and organic matter in their sediments; due to the control over feed wastages.

CHAPTER THREE

3.0 MATERIALS AND METHODS

Study Area:

The study was carried out in Ashanti Region. The region was selected because it forms the highest potential area for aquaculture in Ghana (FSCBP, 1997). A district-wise assessment (in 1991) on the availability of land, water, rice bran and organic manure; found that part of Ashanti is among the suitable places for the viability of fish farming development. Ashanti Region is an area where water is not a constraint for fish farming (FAO, 1991). Generally, the whole area is inundated by rivers and streams which serve as water source for fish farming (Dankwa *et al*. 1999).

Ashanti Region has 644 of the estimated 966 fish farms in the country (Asmah, 2008). The most suitable areas for subsistence fish farming were identified on the 2004 Fish Farm Census as Ashante and Eastern Regions. Some of the notable districts are AsantieAkim South, East Akim, Adansi East, Amansie East, Sekyere East, Fantenkwa, Bosomtwi, Atwima-Kwanwoma and Akwapim North (Asmah, 2008)

The types of fish farming systems practised in this region are the same as those practised in other parts of the country: small-scale subsistence farming and commercial farming in larger farms. Although, their farming units are very small but they are highly dispersed, while the pond sizes vary from 15 m^2 to about 0.48 hectares (FAO, 2000, 2009).

Ashanti Region occupies an area of 24,389 sq km with a population of 2,762,400 (Quayson, 1999). The vegetation is predominantly, moist semi-deciduous forest as well as Guinea savannah woodland. The soils in this area are mainly forest ochrosols and forest ox sols; which are well drained and fertile (Nabila and Kofie, 2001).

The weather condition of this area is moderately humid which increases towards the southern part. This condition favours the farmers of this area to cultivate crops and vegetables as well as trees for palm oil, timber, cocoa and others. In the 1984 census, Ashanti Region had 50% of the estimated area (125,000 ha) planted with oil palm trees in Ghana; which are good source of agro-industrial by-product for animal feeds (FAO, 1990a). Although, the farmers took the task in keeping animals such as cattle, sheep, goats, pigs, poultry and others as additional farming yet they are found among the 1.6 million small-scale farmers that produce the highest amount of cocoa in the country (ENAG,2009).

It is an advantage for fish farmers in that the area is endowed with both agriculture and fisheries institutions which also collaborate with the Department of Fisheries and Watershed Management of the Kwame Nkrumah University of Science and Technology (FAO, 2000, 2009). The availability and collaboration of these institutions have encouraged more farmers in this region to engage in fish farming. According to research findings, five districts in Ashanti Region that have been identified with better chances of commercial success in fish production and the best farming opportunities are clustered in this area (FAO, 1991). Therefore, further research on the opportunities and constraints as well as the systems practise; will help to identify ways for improvement in order to boost the production of fish farmers in this area.

In this research, the proposed method is the administration of questionnaires through the ‗Systematic approach'. This is a tool that was used to examine the ways fish farming systems are operated at farm-levels, in the study area. Relatively, the current understanding of fish farming systems and management practice are based on system approach (Phillips *et al*. 2001). This approach was also used to define institutional responsibilities in fish farming in the country, because they are recognized as the primary facilitators of aquaculture in any country (NACA/FAO, 2000). This approach has considered the importance of institutions as stakeholders that highlight the need for training and to set a legal and policy framework to underpin sustainable development of aquaculture (FAO, 1995).

3.1 Methodology

A purposive, systematic approach was used during the field research work. As a case study, 25 farmers were selected from 323 fish farmers in Ashanti Region (Appendix 1). These farmers were interviewed with a predesigned questionnaire administered to 25 respondents in order to obtain the required information about fish farming in the region (Appendix 3). The exercised was carried out in an interactive atmosphere. In addition, four stakeholders were contacted: Ashanti Regional Fisheries Department, Department of Fisheries and Watershed Management (KNUST), Ashiaman Aquaculture Demonstration Centre and Institute of Water Research in Akosombo (Appendix 4).

The purposive approach was used to target fish farmers; who were selected based on a list of contact farmers, provided by the Aquafish Collaborative Research Support Programme (ACRSP) project (Appendix 2). The criteria for selection were based on the farmers' experiences, their locations and their abilities to give the required information about the systems practised in fish farming and other resources as in other parts of the country. Moreover, most of these farmers have a comprehensive knowledge of fish farming in the region. In addition, the categories of these farmers were both small-scale and larger scale; who own at least one or more enclosures for fish rearing. These farmers also handle about 25% (210) of the total number (808) of ponds in Ashanti Region
(Appendix 1).

These ponds were located in 14 districts in the region (Appendix 5). Each of these places was visited during the interviewing of the selected farmers. This was started in the month of July 2009; when most of the fish farmers were available at their farms. The questionnaires used during this period were semi-structured; designed with predominantly closed as well as few open types while their components included demography; available resources; status of natural resources; challenges faced by fish farmers; opportunities of fish farming and the systematic approach to management practices (Appendix 3). Data was collected through the assistance of Research Assistants from the Department of Fisheries and Watershed Management (KNUST).

During the exercise, all 25 farmers were interviewed at their various farm sites (Table 3.1). Simultaneously, observations were made and pictures were taken from the same sites where, all the necessary data was collected using the same questionnaires (Appendix 3); which were accomplished with information from stakeholder institutions. These were specific (interrelated) questionnaires administered on stakeholders (Appendix 4); accompanied with special request for secondary data collection. Most of this data was collected through desk studies at the Fisheries Regional Office in Kumasi. Information was also obtained from farmers who were feasible through telecommunication media. This information was also double checked during field visits. Sample questionnaires are presented in Appendix 3 and Appendix 4.

Table 3.1: Locations of fish farmers and their farm sites in Ashanti Region

No. of farmer interviewed	Village	District
1	Kubease	Ejisu
1	Kwaokrom-Konongo	Ashanti Akim North
1	Konongo YMC Junction	Ashanti Akim North
1	Domeabra	Ejisu-Juaben
1	Mpasatia	Atwima Mponua
1	Kona-Odumasi	Sekyere South
1	Jamasi	Sekyere South
1	Biansa No. 2	Ahafo A South
1	Kunsu	Mankranso
1	Tseransa	Amansie East
1	Safi-Sefwi	Amansie Central
1	Terobabi	Amansie
1	Anwiankwanta	Bekwai
1	Brofoyedru	Atwima-kwanwoma
1	Feyiase	Bosomtwi Atwima Kwanwoma
1	Esieso/Esaso	Bosomtwi Atwima Kwakroma
1	Esreso	Bosomtwi Atwima Kwakroma
1	Hemang	Mamponteng
1	Wamasi	Kwabre
1	Kukaasi	Kwabre
1		Mamponteng
1	Oyoko	Bosomtwi
1	Darban	Atwima Mponua
1	Abuontem	Bosomtwi
1	Ayeduasi	Kumasi

Source: Survey of fish farmers in Ashanti Region, 2010

3.2 Data analysis

The data were analysed using Microsoft Excel 2007 and Microsoft Access 2007. Furthermore, all files were systematically transferred into SPSS version 16.0 for the final analysis. In this SPSS software, a summary of all the files was arranged as a single complex file known as Syntex file which provided or served as a source of all the information required for a comprehensive analysis. Before analysis, all responses/respondents were coded serially: farmer 1 to farmer 25. Each farmer was assessed with the various factors and disciplines which were based on the system approaches.

In this analysis, opportunity variables are considered as the available places (lands) or suitable combination of conditions that are favourable for executing fish farming activities (BQ, 2010). Others include availability of resources such as water, organic manure (livestock wastes), vegetables and other crops (FAO, 1990b; Satia & Vincke, 1989), brood stock, fingerlings, other facilities (ponds, tanks, hatcheries, feed mills, stores and biogas plant). In addition, the equipments (aerators & nets) use during farm operations as well as feed ingredients and feed types (floating & sinking) are all considered as opportunities. Finally, collaboration of others, infrastructure services, creation of employment, income generating and food for consumption and production types (fingerlings & market sizes) are also termed as available chances (Hecht, 2006).

Example, the first file, labelled as _Assets‘, contained some of the available places such as land, fish ponds and tanks. These were identified as part of the opportunities based on their sizes as well as the land spaces for future expansion. From this file, total land area was analysed as descriptive analysis in order to obtain their maximum, minimum and other values. Furthermore, these results were integrated with the pond and tank sizes to check for the possibility of future expansion within the farm premises. The constraints were examined through ranking of their frequencies and included the different kinds of land (agricultural, residence, wetland) as well as their topography and soil types.

Available land for future expansion was determined as:

TAL-(TAP+TAT) = PE of the farm

Where: TAL, means total area of all lands of the selected farmers

TAP, means the total area of all the ponds in their various farms

TAT, means the total area of all the tanks in the various farms

PE, means space for future extension

Generally, the frequencies of the rest of the opportunity variables are compared in percentages; in order to determine their levels of availability.

However, the constraints are considered as any factor or subsystem that works as a bottleneck to restrict the fish farmers from achieving their potentials (BD, 2010). The discoveries of these constraints are: the kinds of land (agricultural, residential, wetland), topography, soil types, water sources, cultured fish species, source of brood stock and fingerlings, source of feeds and feed preparation methods (FAO, 2000, 2009; Owusu *et al*. 1999). Others are the most destructive factors such as natural disasters (floods, erosion, drought and seepage), aquatic pests, effluents, fish diseases; weed infestation and theft cases (ACRSP, 2009; FAO, 1990a). Finally, the pond construction methods, estimated yearly investment, harvesting intervals, record keeping and other major problems have been found to be part of the farmers‘ weaknesses (FAO, 1990; Prein & Ofori, 1996).

Categorically, all the variables are analysed based on their values as demographic information, opportunities, constraints, resource-base and systems practice.

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter presents the findings of the study as presented in the preceding chapter. The presentations of the results are tabulated and further expressed in charts. Generally, the results are divided into five different sections: socio-demographic characteristics, farm resources, farm operations, farming systems and sustainability. The overview consists of socio-demographic characteristics of the fish farmers in Ashanti Region, the opportunities and constraints of fish farming and the management practices.

4.1 Socio-Demographic Characteristics

This section gives an overview of the socio-demographic characteristics. The characteristics include sexes, main protein source, educational levels, associations‘ membership, land ownership, formal trainings and their experiences on disease detection.

Table 4.1 demonstrates that 96% of the fish farmers in Ashanti region were males with only 4% being females. About 56% of the farmers are members of Associations and 8% belong to their family groups while the rest of the 36% are independent farmers.

Table 4.1: Socio-demographic characteristics of fish farmers in Ashanti Region

Description	Frequency	Percentage
Number of male farmers	24	96%
Number of female farmers	1	4%
Fish as main source of protein	22	88%
Farmer with secondary education	13	52%
Farmer with tertiary education	11	44%
Farmer with secondary occupation	12	48%
Farmer belonging to Association	14	56%
Farmer in a family group	2	8%
Independent farmer	9	36%
Personal ownership of the farm	19	76%
Parent ownership of the farm	2	8%
Group ownership of the farm	1	4%
Government ownership of the farm	2	8%
NGO ownership of the farm	1	4%
Trained in general aquaculture practice	3	12%
Trained in fish farming	7	28%
Trained in pond construction	4	16%
Trained in integration practice	0	0%
Ability to detect diseases	12	48%

Source: Survey of fish farmers in Ashanti Region, 2010

The educational levels of the farmers are tertiary and secondary education, 44% and 52% respectively. For capacity building, 12% of them are trained formally in the area of General Aquaculture, 28% are trained in Fish Farming, 16% are trained in Pond Construction and none is trained in Integration Practice. From the knowledge gained together with their experiences, 48% of these farmers are able to detect fish diseases.

About 76% of the farmers owned their farms while the rest were owned by parents (8%), government (8%) and, NGOs and groups ownership are 4% each. The personal ownership of farm land for fish farming is an advantage because when selecting site for farming it is advisable to get the land involved (Woods, 1994). The ownership will allow the fish farmer to develop the land for future use because fish farming provide more of long term benefit.

At present, 88% of the fish farmers depend on fish as their main protein source because fish are more nutritious and healthy (Asmah, 2008). Apart from fish farming, 48% of the farmers are engaged with other occupations. Parts of their earnings are used to support the farming activities which are also a contribution in the sustainability of fish farms.

4.1.1 *Farmers' experiences in fish farming*

Experiences has been considered in this study because is one of the criteria for the selection of the fish farmers. Secondly, it is believed that reliable information at farmer‘s level should come from experienced farmers. This category of farmers, are more exposed to new discoveries at farm levels which are of great concern in field research.

In Table 4.2, majority of elderly farmers are over 50 years and have practised fish farming for up to 20 years conferring on them considerable expertise. Generally, both elderly farmers and younger ones are classified as those with experiences from 4 years to 23 years. Therefore, the farmers‘ ages have influences over their experiences. Younger farmers have been in practice between 4-10 years.

Table 4.2: Ashanti farmers‘ experiences in fish farming

Description	Frequency	Percentage	Minimum	Maximum
Periods of farmers' experiences in fish farming			*Age range (yrs)*	
<1yr to 1yr	5	20%	34 years	55 years
2 years	4	16%	31 years	65 years
3 years	2	8%	52 years	52 years
4 years	4	16%	34 years	60 years
5 years	2	8%	57 years	60 years
7 years	1	4%	31 years	31 years
9 years	1	4%	41 years	41 years
10 years	2	8%	49 years	75 years
11 years	1	4%	52 years	52 years
18 years	1	4%	46 years	46 years
20 years	1	4%	70 years	70 years
23 years	1	4%	51 years	51 years

Source: Survey of fish farmers in Ashanti Region, 2010

4.1.2 *Fish farmers age grouping*

The farmers in the study area are aged between 31 years and 75 years old. These ages are arranged into groups. The youngest range is 31-41 years being 20% of the farmers, 42-49 years (28%), 51-57 (32%) and the oldest representing 20% of the farmers are 60-75 years. This grouping is important because in this study it is used to determine trend of the labour force.

4.2 Farm resources

Farm resources include land and other resources that are available with the fish farmers. In this region land is acquired differently: inherited, bought, borrowed and remain under the responsibilities of the fish farmers. Furthermore, these lands have different locations, topography and soil types. The facilities available on these lands are mainly fish ponds, tanks and reservoirs. The fish farmers keep their culture fish in these facilities. However, reservoirs are also part of the water bodies found in the Region. These water bodies serve as the main source of water supply for fish farming in the area.

In the area, other resources include the types of manufactured feeds that are commonly used by the fish farmers. Secondly, the farmers give additional local feed ingredients obtained from their vegetable gardens and field crops. Subsequently, tree products from moringa, palm oil and cocoa are also given as fish feeds (FAO 1990b). Apart from crops, the farmers keep livestock and use their manure to fertilize the fish ponds (FAO, 1990b), and this was observed on some farms. The availability of these resources enables the farmers to practise effective fish farming in the region.

4.2.1 *Farm land sizes with the enclosures*

The availability of land has been found to be very important in fish farming (Pillay, 1958). Table 4.3 has indicated the land that is available for fish farming in the study area. Minimum means the smallest land size while maximum is the largest land size. The mean gives the average area of land each farmer should have. At least 0.4 ha is the smallest size of land while 80 ha becomes the largest land.

Table 4.3: Sizes of lands, ponds and tanks used by Ashanti fish farmers

Descriptive	Minimum	Maximum	Mean	Total
Size of all farm lands	0.4 ha	80 ha	14.15 ha	325.4 ha
Number of ponds	1	36	8.40	210
Size of smallest pond	0.0013 ha	0.6858 ha	0.10433 ha	2.295256 ha

Size of largest pond	0.015 ha	1.28016 ha	0.38666 ha	9.279724 ha
Area of all ponds	0.03 ha	4.572 ha	1.185305 ha	28.45 ha
Number of tanks	2	24	11	55
Size of smallest tank	0.0004 ha	0.004 ha	0.0019 ha	0.0095 ha
Size of largest tank	0.0012 ha	0.04 ha	0.01014 ha	0.0507 ha
Area of all tanks	0.006 ha	0.094356 ha	0.02947 ha	0.15 ha
Size of reservoir	0.025 ha	0.025 ha	0.025 ha	0.03 ha

Source: Survey of fish farmers in Ashanti Region, 2010

Collectively, the entire area of land occupied by these farmers is 325.4 hectare; with 28.63 ha (9.6%) as the used land for the ponds and tanks including reservoir. The remaining 296.77 hectare is the empty land without these facilities which is an opportunity for future expansion. Furthermore, it allows the farmer to change sites for pond construction or undergo fallowing for disease control as well as other maintenance activities (Spencer, 1994). In addition, farmers with such land sizes have the potential to develop infrastructures at their farms and introduce other farming systems for integration.

Generally, each of the farm land accommodates at least one pond while the highest is 36 ponds. As a result, 210 ponds are found in the total area of farm lands. The farm lands include 55 fish tanks which are shared among 5 farms or farmers only; with an average of 11 tanks per farmer.

4.2.2 *Land Acquisition*

The kind of land used by most farmers (68%) is primarily for agriculture (Table 4.4). Only a minority of 24% used lands that was meant for residence and categorised as wetlands due to their water logging. Naturally, 96% of these farm lands were wetlands.

These lands were bought by 80% of the farmers and became their personal properties. Furthermore, 16% acquired their lands through inheritance while 4% borrowed the land.

Table 4.4: The kinds of lands acquired for fish farming in Ashanti Region

Description	Frequency	Percentage
Kind of land		
Agricultural land	17	68%
Residential	6	24%
Wetland	24	96%
Acquisition of the land		
Inherited	4	16%
Bought	20	80%
Borrowed	1	4%

Source: Survey of fish farmers in Ashanti Region, 2010

Although, agricultural land is most suitable for fish farms but it is advisable to make thorough enquiries about the land and if possible try to obtain ownership of the land itself (Pillay, 1958; Woods, 1994). However, the major factor to consider is the terrain of the land because a place with high water table will make pond drainage to become a challenge for the fish farmer (Woods, 1994).

4.2.3 *Land locations, topography and soil types*

Almost all the fish farmers (92%) have lands that are located in lowland areas while 44% owned lands along the river banks (Table 4.5). Those with lands in upland areas were only 8% of the farmers. Although, lands in the lowland areas are most common but there are many disadvantages. Normally, in such environments the underground water is closer to the surface which makes it favourable to parasites such as fish lice. Secondly, such places are more exposed to floods and during the processes the runoffs wash wastes from grazing animals as well as chemicals from the surrounding fields. Eventually, these places become very fertile which are normally breeding grounds for fish lice (Behrendt, 1994).

Table 4.5: Locations, topography and soil types of fish farms in Ashanti Region

Description	Frequency	Percentage
Upland	2	8%
Lowland	23	92%
River bank	11	44%
Flat plain	1	4%
Low hill	17	68%
Depression	5	20%
Gentle slope	1	4%
Undulating	1	4%
Sandy soil	22	88%
Clay soil	21	84%
Sandy clayey	7	28%
Loamy soil	4	16%

Source: Survey of fish farmers in Ashanti Region, 2010

These lands are of different topographic conditions which are managed by individual fish farmers. The farm lands in flat plain, gentle slope (Plate 4.1) and undulating conditions are each owned by 4% of the fish farmers. On the other hand, farms with low hill landscape are owned by 68% of the farmers while 20% of them have their farms in valleys or depressions lands. Generally, the largest area of the total farm lands is predominantly low hill where water supply is normally through gravity force and easier to control.

Plate 4.1: Deep water pond in Feyiase (Bosomtwi Atwima Kwanwoma); at a lowland rift-valley area, surrounded by teak trees and other vegetations.

Most of these lands (88%) are predominantly sandy soils while 84% are clay soil type. The mixture of sand and clay was found in farms belonging to 28% of the farmers. Only, loamy soil was found in places of 16% of farmers. Loam soil alone is not recommended.

Among these soils, the best types are clay or sandy clay because they are considered suitable for pond construction. Furthermore, they have adhesive properties and can retain nutrients for organic production in the ponds (Pillay, 1990).

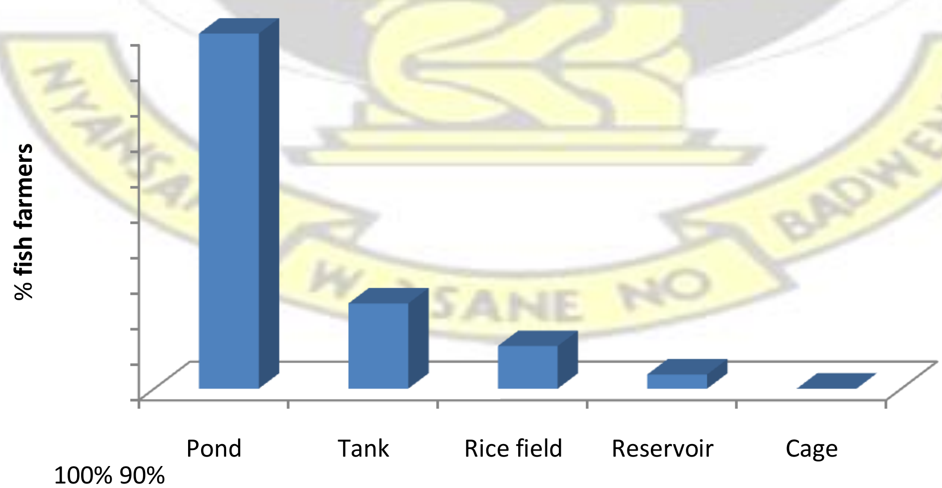
4.2.4 *Facilities for fish farming*

Generally, in Table 4.6 all the selected farmers (100%) use ponds for fish culture. Furthermore, within the farms other facilities; such as tanks, are used by only 24% of the farmers. Hapas (Plate 2) are also used by 16% of the farmers while 12% have rice fields for integration (Plate 4.11). At least, 4% of these farmers culture fish in reservoir and none of them practice cage culture.

Table 4.6: Facilities used by fish farmers in Ashanti Region

Description	Frequency	Percent
Pond	25	100%
Cage	0	0%
Tank	6	24%
Hapas	4	16%
Rice field	3	12%
Reservoir	1	4%

Source: Survey of fish farmers in Ashanti Region, 2010



80%
70%
60%
50%
40%
30%
20%
10% 0%

Culture facilities

Figure 4.1: Culrure facilities used by fish farmers in Ashanti Region

Generally, all the ponds are earthen which were either dug by machines or manually made by hand. The nature of these ponds, provide the required environments to accommodate lot of plankton and other natural nutrients for the survival of the fish. These have favoured the fish farmers because majority of them culture tilapias which strive well in earthen pond conditions (Rakocy and McGinty, 1989). In these ponds, few of the fish farmers confined their brood stock by the use of hapas (Plate 4.2) which can still allow them to benefit from the pond bottom. Similarly, reservoir is an enclosed water body that is commonly used as reserve water for the ponds while, fish are also kept in reservoir for recruitment. Furthermore, fish are also cultured in rice fields for integration. Rice fields, normally have shallow water where both the fish and rice plants benefit from the available nutrients.

Plate 4.2: Confinement of fish using hapas, in Domeabra

Although, tanks are enclosures for rearing fish they are either made of cement or fibre material. Therefore, they do not encourage the growth of plankton and other organisms that are necessary for the production of fish nutrients. However, tanks are commonly used as hatcheries and to keep fingerlings that are supplied with the necessary feed nutrients.

4.2.5 *Brood stock for fish farming*

In Table 4.7, a few number (28%) of the fish farmers keep brood stock for breeding purpose. These include species such as *Oreochromis niloticus* (7 farmers), *Clarias gariepinus* (4 farmers), *Heterotis niloticus* (2 farmers) and *Chrysichthys nigrodigitatus* (2 farmers).The availability of brood stock (Plate 4.3 & 4.4) enhances conservation of the indigenous species which multiply in large numbers (ACRSP, 2009). Therefore, the availability of brood stock is a good opportunity to enhance seed production for fish farmers.

Plate 4.3: Tilapia brood stock being returned into a in concrete tank in Kona-Odumasi

Plate 4.4: Clarias brood stock, in a fish farm Abuontem

Table 4.7: Species of brood stock in fish farms in Ashanti Region

Description	Frequency	Percentage
Brood stock for breeding	7	28%
Oreochromis niloticus	7	28%
Clarias gariepinus	4	16%
Heterotis niloticus	2	8%
Chrysichthys nigrodigitatus	2	8%

Source: Survey of fish farmers in Ashanti Region, 2010

4.2.6 *Feeds for fish farming*

Usually, 88% of the fish farmers used floating types of feed while 36% use the sinking type. Consequently, 76% supply manufactured feeds to their fishes. In addition, some of the fish farmers prepare their own feeds locally.

Although, 72% of these farmers produced their feeds locally some (8%) still buy from others who also produced their own feeds (Table 4.8). Furthermore, kitchen waste and leftovers were used by 12% and 8% of the farmers, respectively (Nilson and Wetengere, 1994). Agro-industrial by products was also used by 8% of the farmers. However, 8% of the farmers were not giving feeds to their fish in the ponds; instead the fish depended on the natural available nutrients. Therefore, those were the farmers that practised extensive systems while the rest practised semi-intensive using supplementary feeds.

Table 4.8: Feeds used by farmers in Ashanti Region

Description	Frequency	Percentage
Manufactured feed	19	76%
Floating type	22	88%
Sinking type	9	36%
Produce locally by the farmer	18	72%
Produce locally by others	2	8%
Kitchen waste	3	12%
Leftovers	2	8%
Agro-industrial by product	2	8%
Natural nutrients	2	8%

Source: Survey of fish farmers in Ashanti Region, 2010

4.2.7 *Feed ingredients*

According to the results in Table 4.9, 76% of the farmers use groundnuts husks as fish feed. In addition, 44% use rice bran while 32% use wheat bran. Furthermore, 16% use maize and cassava, soya beans, fish meal are each utilized by 12% of the fish farmers. The rest such as blood meal, cotton seed and moringa are used by 8%, 4% and 4%, respectively. Also, 68% prepare the fish feed by hand mixing while 20% use the milling machine.

Table 4.9: Feed ingredients used by the farmers in Ashanti Region

Description	Frequency	Percentage
Cassava flour	3	12%

Maize bran/meal	4	16%
Rice bran	11	44%
Wheat bran	8	32%
Soya bean meal	3	12%
Fish meal	3	12%
Cotton seed cake	1	4%
Groundnut husks	19	76%
Blood meal	2	8%
Moringa leaves	1	4%
Methods of preparing the above ingredients		
Farmer use milling machine	5	20%
Farmer use hand mixing	17	68%

Source: Survey of fish farmers in Ashanti Region, 2010

Majority of the fish farmers (76%), used groundnuts husks as supplementary feeds. A reasonable number of these farmers (44%) gave rice bran in order to supplement the available feeds in the ponds (FAO, 1990b). Secondly, rice bran is a source of feed which is also use to facilitate the expansion of fish farming in Ghana because the supply is widely distributed (FAO, 1990b). In addition, wheat bran was used by 32% of the farmers while maize bran/meal was also used by 16% and, cassava flour, soya beans meal and fish meal were each used by 12% of the farmers (FAO, 1990a; FAO, 1990b). Furthermore, cotton seed cake and blood meal were used as feed ingredients and the farmers concern in these areas were 4% and 8% respectively. In rear cases, the farmers (4%) incorporated moringa leaves into the fish feeds.

The results in the same Table 4.9 indicate that, there are varieties of feed ingredients for fish farming in the country. These ingredients are prepared locally (FAO, 1990b). Some of the farmers (20%) milled their feeds locally while 68% of them prepared fish feeds through hand mixing. This kind of preparation might have effect on the palatability of the feeds because hand mixing does not have controlled over the sizes of feed particles.

Secondly, large feed particles will depress feeding and even choke some of the fishes (Craig and Helfrich, 2002). Eventually, the accumulation of uneaten feeds will lead to waste loads and finally pollute the water in the ponds which is of great concern in the control of effluents (ACRSP, 2009; Boyd, 1985). Therefore, this can be a big challenge for the fish farmers.

4.2.8 *Livestock keeping and arable crops cultivation*

Table 4.10 shows that, some of the selected fish farmers practise mix-farming. About 40% of them keep poultry at a minimum of 14 birds each farmer and to a maximum of 100,000; with an average of 15,315 birds. In addition, goats, pigs, rabbits, sheep and cattle followed; as 32%, 24%, 24%, 20% and 8% of farmers respectively. Consequently, 2 farmers own a maximum of 16 cattle while 5 farmers and 8 farmers rear maximum of 76 sheep and 46 goats, respectively. Furthermore, 6 farmers own a maximum of 240 pigs and another number of 6 farmers keep a maximum of 35 rabbits. The wastes from these animals were used as manure for the fish ponds.

Table 4.10: Livestock keeping by fish farmers in Ashanti Region

Description	Frequency	Percentage	Minimum	Maximum	Mean
Cattle	2	8%	3	16	9
Sheep	5	20%	6	76	21
Goats	8	32%	3	46	17
Pigs	6	24%	90	240	154

Poultry	10	40%	14	100000	15315
Rabbits	6	24%	4	35	14

Source: Survey of fish farmers in Ashanti Region, 2010

Livestock Figure 4.2: Trend of

livestock keeping by Ashanti fish farmers

The total manure produced by the number of 16 cattle is estimated at 256 tonnes per year which can fertilize 28.44 hectares of ponds to produce 16,155.55 kg (16 tonnes) of tilapia every 6 months (FAO, 1990b).Likewise, the continuous supply of manure from 240 pigs (at 100 pigs/ha of ponds) will produce 24 tonnes of all-male tilapia every year (FAO, 1990b). Furthermore, 100,000 birds will produce 1,900 tonnes of droppings yearly which is enough to supply 158.33 hectares of ponds to produce 237.5 tonnes of fish per year (FAO, 1990b). Consequently, the quantity of manure produced by the livestock will provide organic fertilizer for the fish farms. This is an opportunity because only the cattle manure was enough to fertilize all pond culture systems in the region, for 6 months (Table 4.3 & Table 4.10). This depends on the proper management of the manure and if well distributed; without which it may lead to algal blooms (Plate 4.9).

Apart from the manure produced, some of the fish farmers own gardens where varieties of vegetables were grown as additional farming (Table 4.11). Among them the most popular was garden eggs which were produced by 28% of the fish farmers. Furthermore, okra and tomatoes were the second choice of 24% of the farmers. Other vegetables were pepper, onions, lettuce and cabbage which were also farmed by 20%, 16%, 8% and 8%, respectively.

Some of these vegetables reached the fish through the leftovers. Therefore, vegetables were part of the local fish diets which were given to the fish indirectly.

Table 4.11: Vegetable cultivation by the fish farmers in Ashanti Region

Description	Frequency	Percentage
Garden eggs	7	28%
Onions	4	16%
Tomatoes	6	24%
Pepper	5	20%

Lettuce	2	8%
Cabbage	2	8%
Okra	6	24%

Source: Survey of fish farmers in Ashanti Region, 2010

In this Region, 72% of the fish farmers grow maize as an additional farming (Figure 4.3). Furthermore, plantains are cultivated by 40% of the fish farmers. Cassava and cocoyam are cultivated by 24% of the farmers each while rice and beans are also grown by 12% of the farmers. Finally, groundnuts and sugarcane are grown by 4% only.

From the results, the main field crops grown in this area included maize, plantain, cassava and cocoyam. This is because they were cultivated by the range of number of farmers from 6 to 18. On the other hand, the rest of the crops (rice, beans, groundnuts, sugarcane) were engaged upon by few of the farmers: 3, 3, 1 and 1, respectively.

Some of the farmers used part of their waste products as fish feeds (Nilson and Wetengere, 1994; Satia and Vincke, 1989). The farmers with these opportunities had resources that were used for the integration of crops and fishes (FAO, 1990a).

Sugarcane

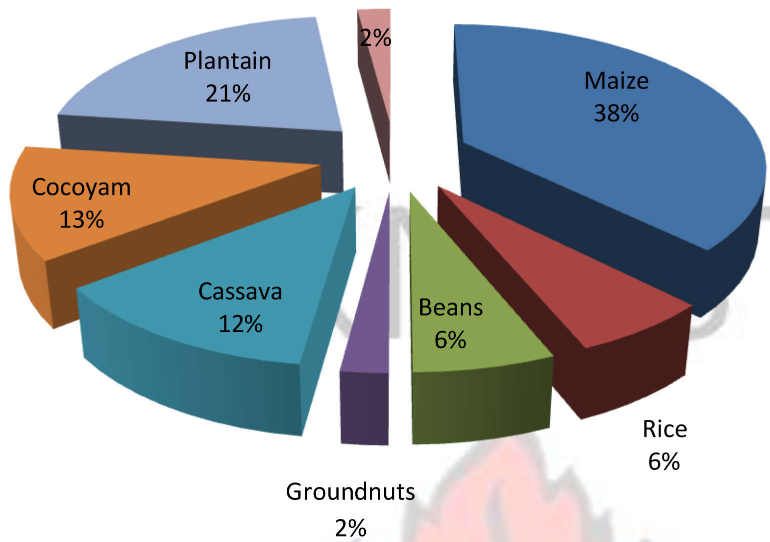


Figure 4.3: Crops grown by fish farmers in Ashanti Region

Tree crops were also discovered with many fish farmers (40%) who managed palm trees as part of their agricultural practices. Other trees such as citrus, cocoa, mango, teak, moringa and pawpaw were found in farm lands that belong to 28% of the farmers, 20%, 16%, 16%, 12% and 8%, respectively (Table 4.12).

Some of these tree products were used as fish feeds. Although palm oil cake is not recommended to use as fish feed but the freshly pressed fibre is used as tilapia feed (FAO, 1990b). Furthermore, waste products from cocoa are used as fish feed (Satia and Vincke, 1989). Although, pawpaw was grown by few farmers it was also used as fish feed (FAO, 1990a).

Table 4.12: Trees grown by the selected fish farmers in Ashanti Region

Description	Frequency	Percentage
Palm tree	10	40%
Citrus	7	28%
Cocoa	5	20%
Mango	4	16%
Teak	4	16%
Moringa	3	12%
Pawpaw	2	8%

Source: Survey of fish farmers in Ashanti Region, 2010

4.2.9 *Water bodies in the area*

In this result 84% of the fish farmers have rivers as water bodies for the provision of water supply. Eight percent have reservoir and 4% have spring.

The study area is inundated with water bodies, which have given the opportunity of rivers within the vicinity of 84% of the fish farmers. Other water bodies like reservoir and spring were available in the areas of 8% and 4% of the farmers, respectively. Some of the fish farmers in this area used the river water to fill their fish ponds (Pillay, 1992).

Furthermore, reservoirs were used as culture-based systems (FAO, 1990a).

4.2.10 *Water sources for fish farms*

Water source of 92% of the farmers is underground and 72% is stream (Plate 4.5). Rainfall is a water source for 56% while 40% have boreholes. Rivers and wells serve 8% of farmers each. Reservoirs were used by 4% of the fish farmers. Twenty percent of the farmers also use their water bodies for domestic purpose.

Plate 4.5: Water source for fish farming in Mamponteng

Nearly all of the fish farmers (92%) were benefiting from underground water supply while 72% received from streams and 56% used the rainfall runoff (Wikipedia, 2009; Pillay, 1992). Similarly, boreholes were used by 40% of the farmers and only 8% had well water. Although, rivers are found in many parts of the region only 8% used the water as an additional source (Wikipedia, 2009; Pillay, 1990). Furthermore, only one farmer added reservoir which is also used for culture-based (FAO, 1990a).

Generally, this area has great potential in terms of water source for the fish farms. At least, every farmer tapped water from two or more sources and even 20% of them used the source for domestic purpose.

Table 4.13: Water sources for fish farming in Ashanti Region

Description	Frequency	Percentage
Underground	23	92%
Stream	18	72%

Rainfall	14	56%
Borehole	10	40%
River	2	8%
Well	2	8%
Reservoir	1	4%
Domestic purpose	5	20%

Source: Survey of fish farmers in Ashanti Region, 2010

4.3 Farm operations

In Ashanti Region fish farms were operated in relation to their resources at farm levels. These resources included water from water bodies which were supplied to the farms through different mechanisms. In the farms, the water was managed through drainage intervals for its replacement. In the process, the sediments were allowed to settle on the pond bottom; before they were released as effluents. Lime and fertilizers were also applied in order to neutralize the pH and increase the productivity of nutrients in the ponds. The periodic pond harvests were other opportunities for the farmers while weed control became one of their major constraints. However, the possibilities of the farm activities were dependent on the availability of farm materials; example fishing gears and equipments.

Generally, most of these farms used culture fish that were indigenous species which normally thrive well when stocked in ponds and tanks at the most appropriate densities. Initially, the fish stocks were either brood stock or fingerlings which were obtained from different sources. These fish were supplied with feeds at different intervals because they were reared according to the different production types, market sizes or fingerlings.

4.3.1 *Mechanisms of water supply*

Naturally, groundwater flows directly into the ponds without any technical support. This existed in 84% of the fish farms. Despite, some of the farmers (48%) used pumping machines while 28% of them relied on the gravity force by nature. Other means included runoffs from rains and spring; which supplied 20% and 8%of the farm, respectively (Table 4.14).

However, gravity can also facilitate the movement of runoff but as the force accelerates there are chances of high silt contents (Pillay, 1990). Secondly, the ground water supply makes it rather impossible to be able to dry the ponds (FAO, 1990a). It is necessary to dry the ponds after every harvest in order to prepare for the next crop (Pillay, 1990).

Therefore, this became a challenge for 21 farmers who were not able to dry their ponds (FAO, 1990a).

Table 4.14: Mechanisms water supplies to fish farming in Ashanti Region

Description	Frequency	Percent
Ground water	21	84%
Machine	12	48%
Gravity	7	28%
Runoff from rainfall	5	20%
Runoff from spring	2	8%
Ground water & machine	9	36%
Ground water & gravity	5	20%
Spring & rainfall	1	4%
Ground water & rainfall	1	4%
Gravity & rainfall	1	4%
Ground water, rainfall & machine	1	4%
Ground water, gravity & machine	1	4%

Source: Survey of fish farmers in Ashanti Region, 2010

4.3.2 *Cultured fish species*

Although, there are several other fish species culture in other parts of the World but these are found to be most common in Ghana. Categorically, 100% of the fish farmers cultured *Oreochromis niloticus* and 80% of them cultured *Clarias gariepinus*. *Heterobranchus longifilis* and *Heterotis niloticus* were among the species cultured by 20% and 16% of the farmers, respectively (Dankwa *et al*. 1999). In addition, other species included *Snakehead (Channidae), Chrysichthys nigrodigitatus, Sarotherodon galilaeus* and *Tilapia zillii;* which were also cultured by 12%, 8%, 8% and 4% of farmers respectively (Figure 4.4).

Table 4.15: Types of fish species culture in Ashanti Region

Description	1	2	3	4	5	6
Oreochromis niloticus	100%	88%	84%	50%	50%	100%
Clarias gariepinus	80%	60%	64%	17%	17%	100%
Heterobranchus longifilis	20%	12%	12%	17%	17%	100%
Heterotis niloticus	16%	4%	12%	0%	0%	0%
Snakehead (Channidae)	12%					
Chrysichthys nigrodigitatus	8%	8%	4%	0%	0%	0%
Sarotherodon galilaeus	8%	0%	4%	0%	0%	0%
Tilapia zillii	4%	0%	4%	0%	0%	0%

Source: Survey of fish farmers in Ashanti Region, 2010

1 *Types of fish species cultured by 25 fish farmers/farms in the study area*

2 *Fish species culture by 25 fish farmers/farms in small ponds*

3 *Fish species culture by 25 fish farmers in large ponds*

4 Fish species culture by 6 fish farmers/farms in small tanks

5 Fish species culture by 6 fish farmers/farms in large tanks

6 Fish species culture by 6 fish farmers/farms in a reservoir

Majority of farmers (88%) cultured *Oreochromis niloticus* in their smallest ponds while 84% of them cultured theirs in larger ponds (Dankwa *et al*. 1999). *Clarias gariepinus* were most popular in larger ponds than in smaller ponds (Table 4.15). This is because, 64% of the farmers cultured them in larger ponds while 60% kept them in their smallest ponds (Dankwa *et al*. 1999). *Heterotis niloticus* and *Heterobranchus longifilis* were equally reared in larger ponds by 12% of the farmers each whereas, *Heterobranchus longifilis* and *Chrysichthys nigrodigitatus* were cultured in small ponds by 12% and 8% of the farmers, respectively (FAO, 2000, 2009; FAO, 1990a). Furthermore, only 4% of the farmers kept *Heterotis niloticus* in small ponds leaving out *Tilapia zillii* and *Sarotherodon galilaeus* as 0%. Although, *T zillii* and *S galilaeus* are not considered in small ponds but 4% of the farmers include them in their larger ponds (FAO, 2000, 2009; FAO, 1990a). Furthermore, in fish tanks, *Oreochromis niloticus* were cultured by 50% of the farmers. Secondly, *Clarias gariepinus* and *Heterobranchus longifilis* were kept in the same type of enclosure by equal number of farmers (17%) (Dankwa *et al*. 1999).

Generally, *O niloticus* are most popular because they are affordable and strive in conditions with or without supplements; due to their dependant on natural nutrients.

Furthermore, they are tolerant to environmental stress and have very fast growth rate (FAO, 2000, 2009; Swift, 1993). Moreover, *O niloticus* multiply in pond conditions without any induce spawning. Although, *Clarias ganiepinus* and *Heterobranchus longifilis* are species with high qualities but very few farmer can keep them. As carnivorous, they depend mainly on high protein diets and take longer rearing periods. Normally, these species do not spawn easily under pond condition and therefore, they are induced for spawning (Swift, 1993). Other species such as *T zillii*, perform well in integration with rice cultivation where they are use to control weeds (Cagauan, 1994;

Cagauan, 1989). In this region, only few farmers have rice fields for such practices. Finally, Snakeheads *(Channidae/Channa sp*.) have not been mentioned specifically in any of the enclosures, but they were included in the culture systems by 12% of the farmers. Normally, these species are less popular because they serve as fish predators.

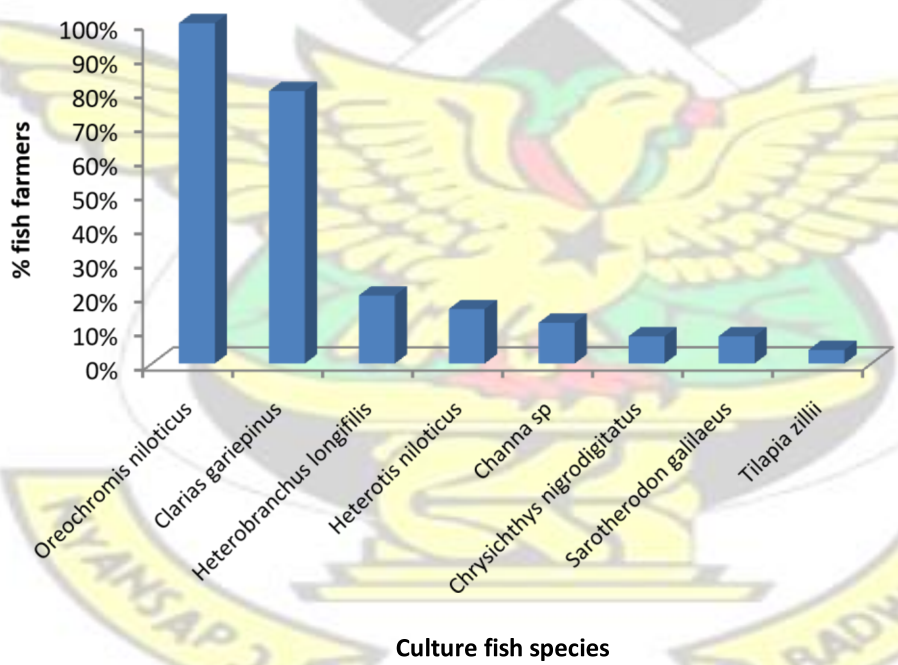


Figure 4.4: Fish preferences for culture in Ashanti Region

4.3.3 *Fish sources*

Those who buy brood stock are 28% of the farmers. The other 12% collect from the wild and 4% import brood stock. The fingerlings are bought by 72%. Furthermore, 16% propagate artificially and 12% got theirs from brood stock. Only, 4% collect fingerlings from the wild (Table 4.16).

This result proves that 28% of the farmers have brood stock which they bought from others. Among them, 12% also collected from the wild while 4% of them imported brood stock. Biologically, 12% of the farmers bred their brood stock for the production of fingerlings while 16% propagated eggs that were collected from brood stock in order to produce fingerlings.

Although, majority of the fish farmers (72%) bought fingerlings but 4% of them also collected theirs from rivers, reservoirs or even abandoned ponds. The brood stock or fingerlings are normally exposed to many hazards in the wild. The most specific ones are the disease carriers that are capable of spreading diseases when introduce to the fish farms. Furthermore, fingerlings of fast growers (tilapia) become stunted due to their long stay in the wild and some even have undesirable traits that can contaminate the fish stock (FAO, 2000, 2009).

Table 4.16: Sources of brood stock and fingerlings for Ashanti fish farmers

Description	Frequency	Percent
Source of brood stock		
Farmer buys brood stock	7	28%

Collect from the wild	3	12%
Farmer import brood stock	1	4%
Source of fingerlings		
Farmer buys fingerlings	18	72%
Propagate artificially	4	16%
Brood stock produce fingerlings	3	12%
Farmer collects fingerlings from the wild	1	4%

Source: Survey of fish farmers in Ashanti Region, 2010

4.3.4 *Fish stocking densities in ponds*

In Table 4.17 the minimum number of fish stocked in small ponds (0.10 ha), are 200 while the maximum is 20,000. Automatically, this makes a stocking density of $1/m^2$ minimum and $230/m^2$ maximum, with an average of $23/m^2$. Eventually, this stocking density may lead to congestion as the fish grow bigger. In this condition, other problems will arise, such as disease spread, high feeding competition and poor water quality. As a result, fish are produced with very low grades. This can be avoided by considering the type of fish species and its production type and the sizes of the enclosures.

Table 4.17: Ranges of fish stocking densities in fish ponds in Ashanti Region

Description	Minimum	Maximum	Mean
Number of fish stocked in small ponds	200	20,000	4,784
Stocking densities in small ponds	$1/m^2$	$230/m^2$	$23/m^2$
Number of fish stocked in large ponds	100	35,000	11,456
Stocking densities in large ponds	$1/m^2$	$10/m^2$	$4/m^2$
Number of fish stocked in reservoir	3000	3000	3000
Stocking density in reservoir	$12/m^2$	$12/m^2$	$12/m^2$

Source: Survey of fish farmers in Ashanti Region, 2010

A better stocking density, is the case of large ponds, 0.38666 ha (Table 4.3) which are stocked at $1/m^2$ minimum and $10/m^2$ maximum, with an average of $4/m^2$ (Rakocy and McGinty, 1989). In this situation, the impact of the waste load has a little effect on the water quality. Secondly, space is provided for the fish to grow to their required sizes. Another example is a culture-based reservoir where fish are stocked at $12/m^2$ on average. The effects of this system will depend on the types of fish culture and the purpose of their production.

4.3.5 *Fish stocking densities in tanks*

Fish tanks are usually stocked with fry or fingerlings which are supposed to be transferred to grow-out ponds (FAO, 1990a). Normally, the minimum number of fingerlings stock in small tanks (0.0019 ha) was 6 while the maximum was 15,000 and an average of 15. Relatively, the stocking densities in small tanks became a minimum of

$1/m^2$ to a maximum of $3750/m^2$ and with an average of $3760/m^2$. Furthermore, large tanks (0.01014 ha) were stocked with a minimum of 12 fish to a maximum of 30,000 fish and an average of 30. Similarly, the minimum density was $1/m^2$ while the maximum density being $75/m^2$ and an average of $84/m^2$ (Table 4.18).

Normally, fry or fingerlings are not kept long in tanks because of that their stocking densities became remarkably high when compared with the ponds. In such situations, farmers closely monitor the levels of the dissolved oxygen. Therefore, it is advisable to aerate fish tanks when highly stocked with fry or fingerlings.

Table 4.18: The ranges of stocking densities in fish tanks in Ashanti Region

Description	Minimum	Maximum	Mean
Number of fish stocked in small tank	6	15,000	15
Stocking density in small tank	1/m^2	3750/m^2	3760/m^2
Number of fish stocked in large tank	12	30,000	30
Stocking density in large tank	1/m^2	75/m^2	84/m^2

Source: Survey of fish farmers in Ashanti Region, 2010

4.3.6 *Feeding intervals in fish farms*

Pond morning feedings were more frequently carried out by 68% of the farmers. Secondly, 52% of the farmers supplied feeds in the evenings. Afternoon feedings were done by 12% of the farmers. Throughout the study, only one farmer combined the three times on a daily bases. Other 14 farmers maintained two times daily while 2 farmers gave once daily (Table 4.19).

However, these excluded 16% of the farmers who normally feed every hour because they practised mono-sex culture. Such practice provides the fish with adequate feed supply, especially during the early stages of their lives (Craig and Helfrich, 2002). On the contrary, 4% of the farmers fed their fish only once in a day or occasionally; depending on the availability of feeds. Eventually, such practice may lead to under feeding which seriously affect fish performances and result to very low production.

Table 4.19: Ponds and tanks feeding intervals in fish farms in Ashanti Region

Description	Frequency	Percentage	Description	Frequency	Percentage
Pond feedings			Tank feedings		
Morning	17	68%	Afternoon	5	83%
Evening	13	52%	Evening	5	83%
Afternoon	3	12%	Morning	4	67%
Every hour	4	16%	Every 3 hours	4	67%
Once daily	1	4%	Every 2 hours	3	50%
Occasional	1	4%	Every hour	1	17%

Source: Survey of fish farmers in Ashanti Region, 2010

The pond feeding intervals are different from tank feeding because this facility does not have additional nutrients; which also serve as supplementary feed. Therefore, tanks receive more time on feeding than ponds which have nutrients for supplements. In tank feeding, 83% of the farmers combined more than one time of feeding because of the fingerlings present. Furthermore, morning and every three hourly feeding were carried out by 67% while every two hourly feeding interval dominated 50% of the farmers (Table 4.19). Normally, fingerlings are reared in tanks before they reach maturity for the growout ponds. During the process, a scheduled feeding calendar should be followed and the most tedious is every hour which was only practised by 17% of the farmers (Craig and Helfrich, 2002). Probably, this has contributed to the limited use of fish tanks but it is very important in the development of fish farms.

In Figure 4.5, specific pond feeding intervals are adopted by fish farmers. The specific adoption, include feeding both morning and afternoon which involve 8% of the farmers. Whiles, both morning and evening feedings are practised by 52% of the farmers. The farmer, combining morning, afternoon and evening feeding is 4% while 8% feed only in the mornings. Furthermore, 16% of the farmers feed every hour and 4% feeds once every day. However, 4% is feeding occasionally and another 4% does not feed the fish.

Generally, the farmers that combined feeding intervals with either morning and afternoon or morning and evening were giving more feeds than the ones feeding in the mornings only. This may lead to over feeding as well as feed loads in some of the semi-intensive systems where stocking densities are very low (Pillay, 1992; Moeller, 2007). Otherwise, it is advisable in polyculture practice where feed competition is high while, it is a challenge in monoculture where feed competition is very low (Pillay, 1992). On the other hand, the one daily meal may lead to under feeding or appropriate; depending on the stocking density.

Normally, the ones feeding on hourly basis rear fry or fingerlings in their ponds. Consequently, close monitoring is undertaken in order to prevent over feeding as well as uneaten feed loads (ACRSP, 2009). However, only one of the farmers was feeding occasionally and this is defined as extensive system practice because it might take months without feeding likewise, the one that doesn‘t feed at all. These are the only two farmers that allowed their fish to depend on the natural nutrients available in the ponds.

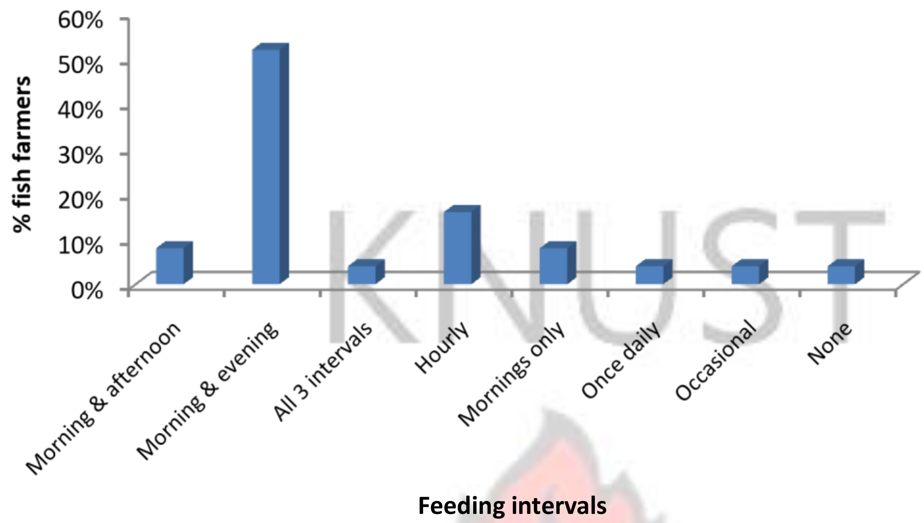


Figure 4.5: Combination of pond feeding intervals in Ashanti Region

The fish farmers have adopted three different ways of feeding their fry or fingerlings in tank environments (Figure 4.6). The farmer that supplies feeds in the afternoon, evening and every three hours is most reasonable because the waste is lesser compare to others. Similarly, majority of farmers feeding in the morning, afternoon, evening and every two hours cause less problems when compare to the farmer that feeds morning, afternoon, evening and every one hour.

Normally, fish tank operators feed their fry at high rates because at this stage the fish require more nutrients for their growth rate and feeding rates are reduced as the fish grow bigger (Craig and Helfrich, 2002). Therefore, feeding intervals in tanks are more frequent and need more attention.

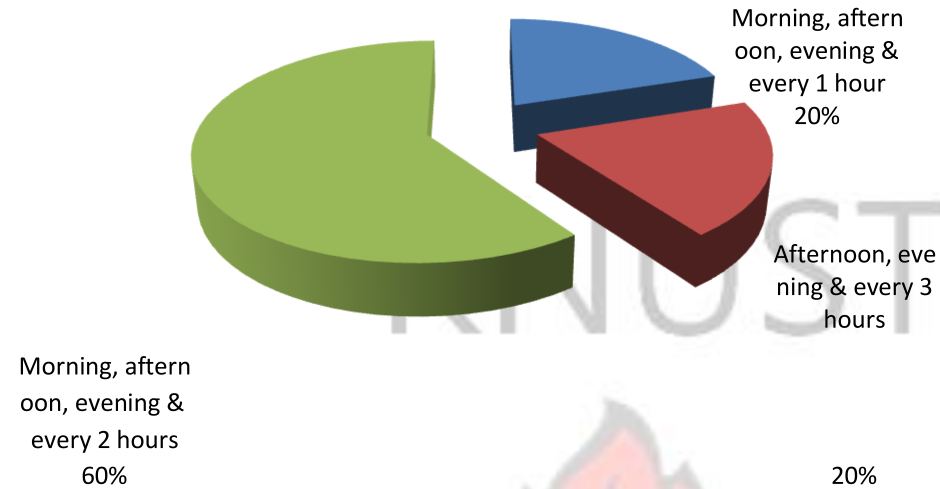


Figure 4.6: Daily feeding intervals in fish tanks in Ashanti Region

4.3.7 *Fish feeding*

In the results, farmers that estimate their feed supplies formed 64% and 28% feed according to body weights, while only 4% fed by satiation.

Generally, 64% of the farmers supplied feeds through their estimations and this was common among those that were unable to determine the number of stock in their enclosures (FAO, 1990a). This can lead to a serious challenge in the productivity of farm fish. Secondly, fish that are managed in such a way are either under fed or over fed. The under fed stock will not perform and the over fed ones create a lot of waste loads. The waste loads directly affect the water quality which may lead to disease outbreaks
(ACRSP, 2009; Moeller, 2007).

Therefore, farmers (28%) with the knowledge of the statistics of their fish population; fed according to body weights (Talbot, 1994b). Example, 5 farmers fed at 5%BW while others included 1%, 3%, 4% and 10%BW. Although, some farmers preferred to supply more feed but only 4% was able to feed to satiation.

4.3.8 *Fish production types*

Every fish farmer rear fish for a special purpose: commercial, subsistence or both. In order to achieve any of these, fish are produced with different qualities, at different stages. As most of the fish farmers are commercial farmers; 76% of them produced market sizes. Furthermore, 40% of the fish farmers produced all-male tilapia through sexreversal while 4% did manual sorting. In addition, 28% of them were fingerling producers (Table 4.20).

Majority of the fish farmers used these fingerlings as fish seeds. Similarly, the all-male tilapias are popular for their fast growth within a shorter period of rearing. Although, allfemale sex-reversal are carried out for the same purpose but a minority of 12% got the interest.

On the other hand, 12% of the fish farmers produced brood stock, which were normally used by 8%, for induce spawning in catfish production (Pillay, 1990). Usually, 8% of the farmers include these catfish in a polyculture with tilapia where they are allowed to spawn naturally.

Table 4.20: Types of fish production by Ashanti fish farmers

Description	Frequency	Percent
Production of market size	19	76%
All-male sex-reversal	10	40%
Fingerling production	7	28%

Production of brood stock	3	12%
All-famale sex-reversal	3	12%
Induce spawning	2	8%
Natural spawning	2	8%
Manual sorting for all-male	1	4%
Manual sorting for all-female	0	0%

Source: Survey of fish farmers in Ashanti Region, 2010

4.3.9 *Materials for fish farming*

In fish farms of Ashanti region, most of the materials used for fish pond harvesting, were drag nets and cast nets. Similarly, seine nets and other materials were used. Among these materials, drag nets were the most active gears used in larger ponds and because of their sizes, a lot of effort was needed for the operations. Although, the cast net was more portable but others used other materials such as hook and lines in deep water ponds.

One of the most important equipment for fish farming is an aerator (Plate 4.6). Usually, 16% of the farmers maintained or supplied oxygen into their ponds through aeration. Most of these ponds were highly stocked with fish where a lot of microbial activities coupled with high oxygen demand could lead to its depletion. As a result, the oxygen depletes and can lead to fish losses. Despite the risk of oxygen depletion, majority of farmers were not using aerators as well as water quality readers. Therefore, these materials should be a necessity for most of the farms so that the oxygen levels can be maintained as required (Swift, 1993).

Plate 4.6: Pond culture system with an aerator, in Safi-Sefwi (Amansie Central)

4.3.10 *Farm Water Management*

Normally, 88% of the farmers drained their ponds during harvesting and maintenance (FAO, 1990a). At times 12% of the farmers top the water levels of their ponds and tanks. This is carried out in order to replace water that had been lost due to seepages or evaporation (FAO, 1991). On the other hand, 8% of them replaced water when it is suspected to be contaminated (Table 4.21); which is normally detected through water quality or evidence of dead fish in the water.

During these processes, there are high risks of escapees of aquatic organisms but these are controlled through the use of filters (ACRSP, 2009). Only 8% of the farmers filter water flowing through from their sources. This has the advantages to prevent the entry of wild species as well as disallow the culture stock escape into the wild (ACRSP, 2009).

This has become another challenge which is not realized by majority of fish farmers. Therefore, the importance of water filtering needs to be given a great attention; in fish farming, in this area.

Table 4.21: Water management on fish farms in Ashanti Region

Description	Frequency	Percentage
Water in ponds and tanks		
Drain water	22	88%
Top water level	3	12%
Filter water flowing through	2	8%
Replace water	2	8%

Source: Survey of fish farmers in Ashanti Region, 2010

4.3.11 *Drainage Intervals*

Fish farmers of this area drained their ponds on different periodical intervals (Table 4.22). A minority of 44%, drained on yearly basis while 28% drained theirs every six months. According to recommendations, a pond should be drained at least once every seven years but it is not also advisable to drain so often; because this will encourage damages on pond dykes (Pillay, 1990). Although, 4% of the farmers drained their ponds once every two years or three years and more but those draining on weekly and monthly bases did more harm than good (FAO, 1990a; Pillay, 1990). Apart from fish harvesting, water draining allows the farmer to dry the pond bottom for the eradication of pests as well as to enable lime and fertilizer application (Rakocy and McGinty, 1989; Behrendt, 1994)).

However, 33% of the farmers had water flow-through tank culture systems at their fish farms (Swift, 1993). This will improve their water quality because there is continuous dilution as well as encourage the availability of dissolved oxygen (Swift, 1993). Only 16% of the farmers drained their tanks occasionally (Plate 4.7) and every fort night (Steven, 2007). These are carried out during their scheduled maintenance and for the harvesting of fish to be transferred to the grow-out ponds.

Plate 4.7: Tank drainage system in a fish farm at Abuontem (Bosomtwi)

Table 4.22: Drainage intervals of ponds and tank water in Ashanti fish farms

Description	Frequency	Percentage	Description	Frequency	Percentage
Pond drainage interval			Tank drainage interval		
Yearly	11	44%	Flow-through	2	33%
Every 6 months	7	28%	Every forth night	1	16%
Monthly	2	8%	Occasional	1	16%
Weekly	1	4%			
Occasional	1	4%			
Once every 2 years	1	4%			
Once every 3years or more	1	4%			

Source: Survey of fish farmers in Ashanti Region, 2010

4.3.12 *Pond Sediments management*

From the findings, farmers that removed sediments formed 68% while 44% dried the sediments. Twenty four percent left the sediments to remain throughout and 4% used the sediments as manure on their field crops (Table 4.23).

Normally, earthen ponds accommodate lot of sediments continuously for long periods and as a result siltation develops. In such situation, farmers (68%) remove the sediments from the ponds but only 4% used it to fertilize field crops. On the other hand, 44% of the farmers allowed these sediments to dry in the ponds (ACRSP, 2009). However, some of the farmers (24%) were unable to remove the sediments because they could not drain the ponds due to underground water flow. Therefore, sediments remain in the ponds throughout.

Table 4.23: Ponds sediment management in Ashanti fish farms

Description	Frequency	Percent
Farmer remove sediment	17	68%
Pond sediments allow to dry	11	44%
Sediments remain throughout	6	24%
Sediments use as manure on field crops	1	4%

Source: Survey of fish farmers in Ashanti Region, 2010

4.3.13 *Lime application and effluent control*

Lime application was carried out after construction by 47% of farmers. Yearly application was done by 36% and 15% never apply any (Table 4.24). The effluent was drained away by 95% and 4% allowed sedimentation (Plate 4.8). Farmers apply lime immediately after pond construction in order to neutralize the level of acidity in the pond bottom (Pillay, 1990). For the same purpose, some fish farmers apply lime directly to the pond water (Swift, 1993). In this area, 47% of the farmers were able to carry out the same procedure; for the establishment of safe ponds for fish farming. Secondly, this liming method will help to eradicate fish parasites. Although, 15% of the farmers never apply lime but 36% of them followed the yearly application.

This application usually takes place during pond maintenance and warrants for effluent draining. Usually, this effluent is drained away by 92% of the farmers. Eventually, it will contaminate water bodies downstream and cause lot of problems in the water quality as well as the biodiversity (ACRSP, 2009). The control of such effluent is a concern for the sustainability of aquaculture in any country (ACRSP, 2009; Wurts, 2000). However this has been prevented through sedimentation (Plate 4.8), by 4% of the fish farming population (ACRSP, 2009).

Plate 4.8: Effluent sedimentation at a fish farm in Abuontem (Bosomtwi) which has been drained directly from fish tanks

Table 4.24: Lime application and effluent control in fish farms in Ashanti Region

Description	Frequency	Percentage	Description	Frequency	Percentage
Lime application			Effluent control		
After construction	9	47%	Drain away	23	92%
Yearly	7	36%	Sedimentation	1	4%
None	3	15%			

Source: Survey of fish farmers in Ashanti Region, 2010

4.3.14 *Fertilizer application*

Poultry manure was used to fertilize ponds by 80% of the fish farmers (Rakocy and McGinty, 1989). Furthermore, pig waste was used by 12% and cattle manure by 8% of the fish farmers. Only 8% used NPK and 4% applied urea. However, 88% did not use inorganic fertilizers (Table 4.25).

Organic fertilizers include sewage effluents and compost of both animals and crop wastes (FAO, 1990b). Normally, these are use to directly or indirectly increase fish productivity. It is indirectly, because such fertilizers increase growth of food organisms in pond environments. It is directly because some of these fertilizers serve as food for the culture fish. Example is poultry droppings which were used by 80% of the farmers of this area (FAO, 1990a). Furthermore, pig wastes and cattle manure were used by 12% of the farmers and 8% of them, respectively (FAO, 2000, 2009). However, it is believed that excess fertilizers can lead to algal blooms (Plate 4.9).

Plate 4.9: Fish pond in Esreso, showing weeds and algal blooms

Basically, inorganic fertilizers are chemicals or mineral fertilizers which are also used to increase productivity (Rakocy and McGinty, 1989). Although, chemical fertilizers react quickly their withdrawal periods should be closely monitored. Economically, they are expensive and health-wise are risky to handle without safety guides. Therefore, few of farmers (8% & 4%) were able to apply NPK and Urea, respectively.

Table 4.25: Fertilizers use on fish farms in Ashanti Region

Description	Frequency	Percentage	Description	Frequency	Percentage
Organic fertilizer			Inorganic fertilizer		
Poultry manure	20	80%	None	22	88%
Pig waste	3	12%	NPK	2	8%
Cattle manure	2	8%	Urea	1	4%

Source: Survey of fish farmers in Ashanti Region, 2010

Generally, majority of the fish farmers practised organic agriculture aquaculture. This is because in this region 88% of the farmers avoided the application of inorganic fertilizers. This can also help to sustain the practice of fish farming in the area

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4.3.15 *Pond harvesting intervals*

Weekly harvest was carried out by 36% of the farmers while 31% were harvesting occasionally and 10% yearly. Twice in a year and monthly basis are each carried out by 5% of the farmers. Only 10% are yet to harvest (Table 4.26).

Fish farmers in this region have different times of harvesting and most of them rarely harvest their fish. This has become a challenge for these farmers. The fortunate ones formed 36% who usually harvest every week, which is likely a multiple harvest (Wurts, 2004). Similarly, 31% were harvesting occasionally as the clients demanded as well as domestic use while only 5% harvested theirs on monthly and every six months (Nilson and Wetengere, 1994). The most unfortunate ones were those (10%) harvesting once every year and even none throughout the year (FAO, 1990a).

Table 4.26: Pond harvesting intervals in fish farms in Ashanti Region

Description	Frequency	Percentage
Weekly harvest	7	36%
Occasional	6	31%
Yearly	2	10%
Not yet	2	10%
Monthly	1	5%
Twice in a year	1	5%

Source: Survey of fish farmers in Ashanti Region, 2010

Certainly, pond harvesting intervals depend on various factors: availability of fishing gears, market demand, market size and weather conditions. The gears involved in this exercise include seine nets (by hand pulling), drag nets (more hands or boat, vehicle), cast nets and hooks and lines at very rear cases (Wurts, 2004). Also, the market demand is very important because it is directly related to the time of harvest, species preference and sizes to be caught. Furthermore, the weather conditions determine the time most appropriate for harvesting and one of the examples is cool weather which will give the assurance of quality and fresh fish for longer period. Secondly, it is a natural way of preservation (Wurts, 2004).

4.3.16 *Weed control in fish farms*

The percentage of farmers that use cutlasses to remove weeds is 68%. Furthermore, herbicides are used by 24% and 8% uproot the weeds. The mower is used by only 4% and burning is done by 4%. Only, 12% do not remove the weeds (Table 4.27).

Weeds are unwanted plants that are commonly found in fish farms especially during the rainy season when they appear in large volume (Plate 4.10). Naturally, the moist conditions at farm levels encourage a lot of weed even without the rains. Biologically, such conditions favour pest and parasites as well as predators all of which cause high losses to the farm produce (Behrendt, 1994). Farmers have been using different measures to control weeds but due to different condition, restrictions are limited to the users.

Table 4.27: Weeds control on fish farms in Ashanti Region

Description	Frequency	Percentages
Farmer use cutlasses to remove weeds	17	68%
Farmer use herbicides	6	24%
Farmer do not remove weeds	3	12%
Farmer uproot weeds	2	8%
Farmer use mower	1	4%
Farmer burn weeds	1	4%

Source: Survey of fish farmers in Ashanti Region, 2010

Usually, majority (68%) of farmers in this area removed weeds with their cutlasses (Behrendt, 1994). Selective aquatic herbicides were used by 24% of the farmers while 4% of them used mowers. Furthermore, 8% were uprooting the weeds while burning was carried out by 4%; during the dry periods. Apart from this explanation, 4% of the farmers used both mower and herbicides while 12% used both cutlasses and herbicides. Furthermore, 8% solely depended on herbicides (Behrendt, 1994). Those who used only cutlasses to weed their fish farms formed 52% while 8% practised uproot only. Also, 4% of these farmers, burn the grasses after cutting with cutlasses.

Categorically, weed control is a task that demands for lot of labour force. Therefore, some of the farmers (12%) without the opportunity of labour have never removed the weeds on their farms (Plate 4.10). Such farms are at high risks because the weeds provide hiding grounds for many pests that can spread diseases in the fish ponds.

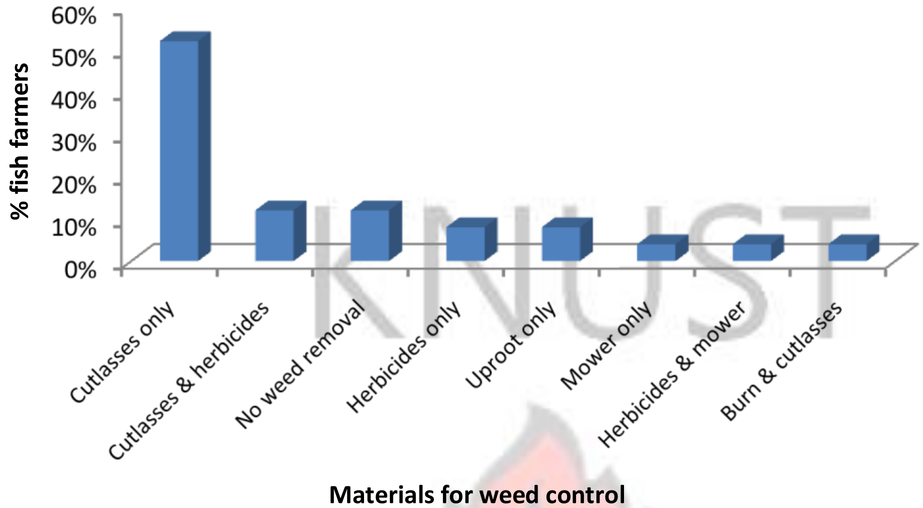

Figure 4.7: Weed control methods in fish farms in Ashanti Region

Plate 4.10: Fish ponds in Konongo, showing weed infestation

4.4 Fish farming systems

The fish farmers practised semi-intensive farming and extensive systems. This is because the majority of them are small-scale commercial and subsistence fish farmers (FAO, 1990a). Subsequently, the types of farming systems practise in the region determine the types of farm practices. Secondly, as discussed in the previous section, the rearing facilities and fish species also reflect in the adoption of the type of farming systems. Therefore, these criteria can be considered as important factors for the expansion of fish farming in the area.

Economically, fish farming has grown to become a business venture. It generates a lot of foreign exchange. In this country fish farmers do not export their produce because of the low production (Ofori, 2000). Their produce is sold to local consumers who preferred fish proteins as their major diets. In trying to meet their demand 68% of the fish farmers, turn to commercial farming.

However, the fish farmers do not only engage in commercial farming but some (28%) combined it with subsistence farming while 36% considered subsistence farming only. According to them subsistence farming is a way to secure food for their households and as well improve their nutritional status. As a result their livelihood becomes socially acceptable.

4.4.2 *Fish farming systems*

In this study, fish farming systems include semi-intensive, extensive, recycling and culture-based. From the findings, semi-intensive is practised by 92% of the fish farmers. In addition, extensive, recycling and culture-based systems are practised by 8%, 4% and 4% respectively.

Table 4.28: Fish farming systems in Ashanti Region

Description	Frequency	Percentage
Semi-intensive	23	92%
Extensive	2	8%
Recycling	1	4%
Culture-based in reservoir	1	4%
Intensive	0	0%
Semi-intensive & extensive	1	4%
Semi-intensive & recycling	1	4%

Source: Survey of fish farmers in Ashanti Region, 2010

The majority of the fish farmers (92%) that practised semi-intensive systems only provided supplementary feeds in order to compliment the natural available nutrients in the ponds (FAO, 1990a). Most of the time they culture tilapia and catfish which depended on these nutrients but also needed supplements to increase their productivity. These supplements included manufactured feeds, field crops, vegetable ingredients and agroindustrial by-products (FAO, 1990a). Other farmers (8%) practised extensive systems (Plate 4.11) because they did not add any feed to their ponds (FAO, 1991). Therefore, the fish took the natural available nutrients which are also increased through the application of organic manure or chemical fertilizers. Similarly, culture-based in reservoir stock with tilapias, may not need feed to be supplied because the fish depend on the nutrients which have less competition. This has an exception where some farmers give supplements because they rear catfish in reservoirs (FAO, 1990a). Such system was used by 4% of the farmers for fish rearing and recruitment. Also, farmers without reservoir or with limited water supply prefer to conserve it by recycling (Wikipedia, 2009). Only 4% of the farmers used their water in the same manner.

However, none of the farmers practised intensive systems because the culture fish are supposed to be given complete balanced diets throughout. Normally, such systems are found in large commercial farms, where the water quality is closely monitored. The most common species produced in these systems are carps, salmon and catfish, some of which are not cultured in this area (Wikipedia, 2009).

Plate 4.11: 0.82 ha pond in Oyoko (Bosomtwi) under extensive fish culture system

4.4.3 *Fish farm practices*

Majority of the fish farmers (84%) practised polyculture (FAO, 1990a). This type of practice gives the farmers opportunity to control the overpopulation of tilapias through the introduction of catfish (Rakocy and McGinty, 1989). Secondly, their feeding habits will take advantage of the different niches available in ponds (Wurts, 2001). Also, through the introduction of other aquatic organisms, effect of waste loads is limited (Pillay, 1992). Therefore, polyculture is recommended for the sustainability of fish farming as stated by Wurts (2000).The farmers under this type of practice have a little to contribute on protein feeds because the catfish consume some tilapias; which serve as source of proteins.

Similarly, tilapias or catfish were cultured separately by 48% of the farmers; as monoculture practices whereby, only one species was kept in an enclosure (FAO, 1990a). This is associated with a single sex of tilapia cultured in a separate environment obtained through sex-reversal which results to all-male tilapia, example *Oreochromis niloticus (*Rakocy and McGinty, 1989). Consequently, overpopulation is under full control by the farmer who also realizes high performances from the culture fish within a short period.

Table 4.29: Fish farm practices in Ashanti Region

Description	Frequency	Percentage
Poly-culture	21	84%
Monoculture	12	48%
Mono-sex culture	7	28%
Integration	5	20%
Monoculture & poly-culture	8	32%
Mono, poly & mono-sex culture	5	20%
All types of farm practices	1	4%

Source: Survey of fish farmers in Ashanti Region, 2010

Although, 28% of the farmers practised mono-sex culture 20% of them also practised the combination of monoculture, polyculture and mono-sex culture within the same farm. In addition, monoculture and polyculture were practised by 32% of these fish farmers while only 4% practised all types of fish farming practices. The combination of these farm practices exposed the farmers to gain more experiences and able to produce more in order to meet the fish demand.

However, the sustainability of fish farm practices depends on the availability of enough feeds supply among others. This is achieved through the integration of fish and rice (Plate

4.12) or fish and livestock or the combination of all (FAO, 1990a). The farmers under this practice formed 20% of the population studied.

Plate 4.12: Integration of fish in rice field in Domeabra, Ejisu

4.5 Sustainability

Generally, in the Sub-Region of Africa where the fishery pressure has become a challenge; aquaculture has been suggested to stand as a solution (Owusu *et al*. 1999; Pillay, 1990). However, in this country where fishery production cannot meet the demand; sustainable fish farming is chosen as a means to counter decline in the availability of fish (Ofori, 2000).

The sustainability of fish farming in Ashanti Region has been linked with the availability of infrastructures and infrastructure services, example markets and marketing of fish with reasonable prices. In addition, mechanisms have been set by the fish farmers which included employment and other investments for the increment of outputs. Although, some of the farmers were self-employed but they had collaborators and also held membership in different Associations where problems are normally discussed. Some of the problems include fish predators, diseases, poaching and natural disasters.

In order to sustain fish farming, it is necessary to take preventive measures against these challenges. Although, unexpected disasters are difficult to prevent; but they can be avoided during sites selection (Woods, 1994, Pillay, 1990). Normally, general farm records as well as the history of other occurrences are kept for future claim on disaster relief (Ingram, 1994). Therefore, improper records keeping can be an obstacle to the sustainability of fish farms in the region and elsewhere.

4.5.1 *Infrastructures and infrastructure services*

In this Region, feed store has been found to be one of the major infrastructures that belonged to 76% of the fish farmers (Table 4.30a). Although, some of these farmers (24%) had farm houses but cold stores and resident lodges were owned by only 8% of them. Despite, there limited numbers, they can be considered as opportunities, because they provide shelters at farm levels as well as other uses.

In addition, transportation was included as one of the major infrastructural services which benefitted 80% of the fish farmers. Also, the electricity supply provided the energy requirement for 60% of the farms/farmers. This electricity supply is a necessity at farms where hatcheries are operated. Hatcheries were available with only 28% of the farmers who produced fingerlings through artificial propagation (Table 4.30a). These facilities require a lot of attention because water quality is normally monitored in order to produce quality fish seeds (Pillay, 1990). Subsequently, they are well protected against predators as well as other environmental hazards

Table 4.30a: Major infrastructures and infrastructure services for fish farming in Ashanti Region

Description	Frequency	Percentage
Transport	20	80%
Feed store	19	76%
Electricity supply	15	60%
Farm house	6	24%
Cold store	2	8%
Lodges for residence	2	8%
Feed mill	2	8%
Bio-gas plant	1	4%
Farmer has none of the facilities mentioned above	2	8%
Hatchery	7	28%
Farmer access main road	25	100%
Farmer access main market	8	32%
Farmer access main store	7	28%

Source: Survey of fish farmers in Ashanti Region, 2010

Generally, these facilities are considered as opportunities in the area of infrastructure service while constraints included feed mill (8%), bio-gas plant (4%) and 8% of the farmers who had none of the facilities mentioned. However, other facilities that are considered in site selection included the opportunity of all fish farmers' accessibility to main roads (Woods, 1994). Other opportunities were enjoyed by 32% of the farmers who accessed markets while 28% benefitted from main stores. According to the trend, the accesses to markets and stores have excluded the majority of the farmers who also needed these facilities. Therefore, they become a common threat to the promotion of fish farming in the area.

4.5.2 *Infrastructure services*

The infrastructure services provide main roads for communication, places to market farm produce and facilities to store the farm produce (fish). These were the main services available for the fish farmers of the region.

The distance to the main road is a minimum of 10 meters and a maximum of 11 km. Distance from the farm gate or main market is 3 meters minimum and 8 km maximum. Furthermore, the distance from the main store is a minimum of 50 meters and maximum of 3.050 km (Table 4.30b).

Main roads provided opportunities for easy communication between the commercial farmers and their clients. Normally, the farmers use these opportunities to transport equipments, other goods or fish from and into their farms. Usually, some of these goods are kept in main stores which were also accessed by 6 out of 7 fish farmers in the region (Table 4.30b) because one of them could not give estimate of the distance. Similarly, 6 out of 8 farmers sold their produce at their farm gates or main markets.

Table 4.30b: Estimates of distances to infrastructure services in Ashanti Region

Description	Frequency	Minimum	Maximum	Mean
Distance from road	25	10 meters	11,000 meters	1,528 meters
Distance from market or farm gate	6	3 meters	8,000 meters	3,083 meters

Distance from main store	6	50 meters	3,050 meters	1,275 meters

Source: Survey of fish farmers in Ashanti Region, 2010

4.5.3 *Marketing Strategies*

The marketing strategies of the fish farmers included export and sales by retail or whole sale. These farmers advertised to their customers, fish that were sold through weighing. Their marketing places included road side, the farm gates or trading centres. Other modes included supply personal hotel, institution or school and families. However, fish were also preserved through smoking, salting and drying (Table 4.31a).

Fish farmers have different ways of marketing their produce. Therefore, in this region, 64% of the fish farmers sold their fish by retail while 20% sold theirs by whole sale. Among the sellers, 36% of them advertised to their customers and only 48% of them weighted the fish for sale. These sales were made at the trading centres by 28% of farmers, other 20% of them used their farm gates and 4% sold theirs by the road side.

Only 4% exported some of the fish produced.

Apart from the fresh fish sold in the markets, 12% of the farmers processed their remaining fish through smoking, salting and drying (Table 4.31a). Fish under these conditions are preserved for longer periods. These kinds of preservations allowed 4% of the farmers to use some of their produce to feed the families. On the other hand, 8% of the farmers supplied their personal hotels and 4% supplied their school where the farm was located; for their feeding program. Therefore, marketing strategies do not only facilitate the opportunity of fish business but also contribute to subsistence uses.

Table 4.31a: Marketing strategies for farmed fish in Ashanti Region

Description	Frequency	Percentage	Description	Frequency	Percentage
Sold by retail	16	64%	Farmer weights	12	48%
Sold at trading centre	7	28%	Farmer advertise	9	36%
Sold by whole sale	5	20%	Process fish	3	12%
Sold at farm gate	5	20%	Hotel supply	2	8%
Exportation	1	4%	School supply	1	4%
Sold at road side	1	4%	Family supply	1	4%

Source: Survey of fish farmers in Ashanti Region, 2010

4.5.4 *Fish prices*

Commercial fish farmers sold their produce mainly in two different ways. One of them was the cost of kilogram of market sizes for minimum prices at GHC 2.50, maximum GHC 5.0 and average of GHC 3.20 (FAO, 2000, 2009). This kind of selling involved 15 fish farmers representing 60% of the population studied. The other 4 farmers produced fingerlings which they sold at 0.08p minimum, 0.25p maximum and an average of 0.14p per piece of fingerling (Table 4.31b).

However, these two ways of pricing fish had been developed so that the fish became more affordable to consumers. Secondly, the strategy enabled customers to select fish according to different sizes and species preferences. This pricing attracted number of customers in Kumasi, the capital city of the region where marketing opportunity is not a problem (FAO, 1991).

Table 4.31b: Prices of fish produced by fish farmers in Ashanti Region

Description	Frequency	Minimum	Maximum	Mean
Cost per kg of market size	15	GHC 2.50	GHC 5.0	GHC 3.20
Cost per piece of fingerling	4	0.08p	0.25p	0.14p

Source: Survey of fish farmers in Ashanti Region, 2010

4.5.5 *Employment in fish farms*

Fish farming provide employment opportunities for many people. Every employee contributes towards the achievement of the farmer‘s out puts. In three of the farms, a minimum of one technician to a maximum of four were employed (Table 4.32). In these farms, the farmers gained lot of technical knowledge from the employees; which improved their skills in fish farming. Five farmers also included managers who supervised the daily activities of their farms. These managers also kept the farm records as well as taking care of all the financial transactions of the farm business.

However, fish farming requires a lot of labour force. Therefore, 56% of the farmers employed a maximum of 40 labourers and a mean of 7 labourers each. Other employees included the casuals who normally work as hired labourers. Such tasks involve clearing of grasses, pulling of nets during pond harvesting and other general maintenance. This also includes taking care of the healthy conditions of the environments. Therefore, 56% of the farmers employed on average one caretaker each and the farms with the largest number of caretakers have a maximum of 3 caretakers. Although, caretakers also contributed towards the security of these farms but some (32%) owners decided to employ watchmen on average of one each.

Table 4.32: Employment statistics on fish farms in Ashanti Region

Description	Percentage	Minimum	Maximum	Mean
Labourers	56%	1	40	7
Other employees	8%	1	13	7
Technicians	12%	1	4	2
Caretakers	56%	1	3	1
Managers	20%	1	1	1
Watchmen	32%	1	1	1

Source: Survey of fish farmers in Ashanti Region, 2010

4.5.6 *Estimates on fish farm expenses*

Fish farming has become a business entity for the farming community in the area. In order to make it more productive, some of the farmers decided to invest in their areas of interests. These areas included, labour force, equipment, transportation, brood stock, fish seeds and feeds and others activities. Relatively, the moneys involve are estimated in Table 4.33.

According to the statistics on the estimated farm expenditures, farmers spent more on feeds than equipments which gave six times of what was paid for labour. In addition, GHC 1,502 was invested on seeds; which is about four times the cost of brood stock. The farmers also spent GHC 720 on transportation and GHC 840 on fuel for their machines, which are estimated at GHC 7200 and GHC 8400, respectively. The expenditure on other activities covered a maximum estimate of GHC 200.

Generally, these estimates of expenses were higher on those engaged on businesses. Secondly, expenditures on all items had zeros as minimum because there were none expenditure on each of them (Table 4.33). Although, some of the farmers could not give estimates because they did not keep the proper records; the trend has depicted the rates of expenditures.

Table 4.33: Estimates on yearly expenses (Ghana cedis) in Ashanti fish farms

Description	Frequency	Minimum	Maximum	Mean
Investment on feeds	23	0	GHC 27274	GHC 1185.82
Equipment	17	0	GHC 9254	GHC 544.35
Labour	22	0	GHC 4000	GHC 181.82
Seeds	21	0	GHC 1502	GHC 71.52
Fuel	16	0	GHC 840	GHC 52.5
Transportation	15	0	GHC 720	GHC 48
Brood stock	19	0	GHC 315	GHC 18
Other activities	15	0	GHC 200	GHC 13

Source: Survey of fish farmers in Ashanti Region, 2010

4.5.7 *Mechanisms for sustainability*

In this study, fish farming can be defined as a long term project because it serves for life when properly managed. Therefore, its sustainability is the only way forward. Some of the mechanisms for sustainability included self financing, sales revenue, loan from others, government‘s support and groups‘ contributions (Table 4.34)

Most of the farmers (88%) financed themselves in order to sustain their farms. Although, 48% of them used their sales revenue 20% also received loans from other people. Other

16% farmers were supported by the government while 4% depended on their groups' contributions.

Normally, some of these loans are given in different forms which also depend on the facilitators. Despite their individual choices, 36% of the farmers received moneys while 4% were given equipment. Unfortunately, the majority of farmers (64%) did not receive any loan.

Table 4.34: Mechanisms for sustainability of fish farming in Ashanti Region

Description	Frequency	Percentage
Self financing	22	88%
Sales revenue	12	48%
Loan from others	5	20%
Government's support	4	16%
Groups' contributions	1	4%
Kinds of loans		
Farmer receives no loan facility	16	64%
Farmer receives money as loan	9	36%
Farmer receives equipment as loan	1	4%

Source: Survey of fish farmers in Ashanti Region, 2010

4.5.8 *Farmers and collaborators*

Farmers in this region collaborate with many stakeholders in different areas of interests. The areas of interests include the provision of loan facilities, sponsorship on formal training programs, dissemination of information through workshops, research, technical assistance and many other supports to develop fish farming in Ghana. The stakeholder institutions include government of Ghana, NGOs, individual partners, universities and colleges (Table 4.35a).

The government of Ghana is collaborating with 64% of Ashanti fish farmers. The collaboration is channelled through governmental institutions and one of them is the Department of Fisheries; which is responsible of policies and development activities in the areas of fisheries and aquaculture (FAO, 2000, 2009). This Department is collaborating with 52% of the fish farmers. Agricultural extension and Water Research

Institute also collaborate with 20% of the farmers. In addition, the Ministry of Food and Agriculture collaborates with 4% of the fish farmers. Furthermore, Kwame Nkruma University of Science and Technology, through the Faculty of Renewable Natural Resources; collaborate with 12% of these fish farmers. Collectively, other universities and colleges also collaborate with 8% of the fish farmers (FAO, 2000, 2009).

This collaboration has also included NGOs in working closely with 16% of fish farmers. Moreover, among these farmers, 16% of them collaborate with their individual partners. Unfortunately, 32% of them are not collaborating with any of the collaborators. However, the trend shows that majority of the fish farmers have a lot of collaboration opportunities. This will motivate the farmers and strengthen the practice of fish farming in the country.

Table 4.35a: Ashanti fish farmers' collaboration network

Description	Frequency	Percentage	Description	Frequency	Percentage
Farmer's collaborators			Governmental collaborators		
Government	16	64%	Dept of Fisheries	13	52%
None	8	32%	Agric extension	5	20%

NGO	4	16%	Research	5	20%
Individual partner	4	16%	KNUST	3	12%
Universities & colleges	2	8%	MOFA	1	4%

Source: Survey of fish farmers in Ashanti Region, 2010

4.5.9 *Farmers Associations and employment status*

Generally, farmers in this area form different Associations all over the country. In this study, all the farmers belong to Agricultural and Fisheries Associations. The Associations provide fora whereby farmers meet and discuss their problems and the way forward (Asmah, 2008). The most popular one is Ashanti Fish Farmers Association where 44% of the farmers are registered. Next is the Mamponteng Fish Farmers Association with a membership of 12%. The other fisheries body is the Central Youth Fish Farming Association; which also accommodate 4% of the farmers. The only agricultural body is the Poultry Farmers Association where 4% joined as members (Table 4.35b).

The farmers' membership status, have given them the opportunity to share their experiences as well as contribute financially towards their future developments. The membership to Associations, have lot of advantages whereby funds would be raised among the farmers themselves.

Table 4.35b: Existing Associations and farmers' employment status in Ashanti Region

Description	Frequency	Percentage
Membership status		
Ashanti Fish Farmers Association	11	44%
Mamponteng Fish Farmers Association	3	12%
Central Youth Fish Farming Association	1	4%
Poultry Farmers Association	1	4%

Employment status		
Self-employment	20	80%
Farmer is an employer	18	72%
Farmer is an employee	5	20%

Source: Survey of fish farmers in Ashanti Region, 2010

4.5.10 *Record keeping in fish farms*

In this study, farm records are the information about the fish farms. This information includes staff profile, inventory of the farm, daily operations and other financial transactions (SM, 2008). The inventory and daily farm operations also contain the number of fish stock in the enclosures, feeding rates and other occurrences (Behrendt, 1994). Normally, farm records are kept and managed by the farm manager for future references.

Generally, 92% of the farmers kept their farm records in books while 24% of them used computers (Table 4.36). Among the farmers, 24% of them combined the two. The remaining 8% of the farmers did not keep records. So, these farmers were not able to give all information about their farms (FAO, 1990a). Book keeping was most popular among the farmers while computers can keep larger information which is easily retrievable (Jaffa, 1994). Such record keeping facilitate effective flow of information between the farmers and the researchers. This was one of the encounters during this field research because some of the farmers could not give all the information needed (FAO, 1990a).Subsequently, this is related to the commitment on data entries because what is not entered cannot be retrieved. Therefore, proper farm record keeping is very important in the development of fish farming (Ingram, 1994).

Table 4.36: Record keeping at fish farm levels in Ashanti Region

Description	Frequency	Percentage
Book records	23	92%
Computer records	6	24%
Farmer does not keep record	2	8%
Computer and books	6	24%

Source: Survey of fish farmers in Ashanti Region, 2010

4.5.11 *Poaching in fish farms*

Poaching is an act of stealing animals that are kept in isolated places. This is most common in cage culture systems and seldom occurred in earthen ponds. However, poaching is identified as a cause to fish losses in fish farms.

Fish poaching is not a common problem in the region because 64% have not experience any case. Three or more poach cases occurred in 16% of the farms. Only 12% of the farmers encountered two poach cases and 8% experienced it once (Table 4.37a).

Table 4.37a: Occurrence of poaching of cultured fish in Ashanti fish farms

Description	Frequency	Percentage
No poach case	16	64%
Three & more poach cases	4	16%
Two poach cases	3	12%
Occurred once	2	8%

Source: Survey of fish farmers in Ashanti Region, 2010

4.5.12 *Fish farm predation*

Fish predators prey on small fish such as fries and fingerlings. Although, there are many kinds of predators but few are reported as pests in the area. These included snakes, frogs and wild birds. The wild birds were reported by 68% of the farmers. The other 48% of the farmers reported snake attacks while 32% received a lot of frogs at their farms. Only 16% are free from predator attacks (Table 4.37b).

Predator freedom is a good blessing for a fish farmer because they cause more harm than good. On average some of these predators can consumed about 10 small fish in a day (Behrendt, 1994). Secondly, predators also contribute in disease transmission, example the Kingfishers which also serve as a definitive host for metacercaria of Digenetic fluke (Moeller, 2007).

The overview has shown that predator attacks are causing losses to the fish farmers in the area. It is even worst with 12% of the farmers that suffered from all the predator attacks. Generally, 40% are exploited by attacks from two different predators. So it is a concern to consider this as a threat to fish farming in the area. The preventive measures vary according to literature; which are also dependent on the types of predators.

Table 4.37b: Fish farm predators in Ashanti Region

Description	Frequency	Percentage
Wild birds	17	68%
Snakes	12	48%
Frogs	8	32%
Snakes & wild birds	6	24%
Free from predator attacks	4	16%
Snakes, wild birds & frogs	3	12%
Snakes & frogs	2	8%
Wild birds & frogs	2	8%

Source: Survey of fish farmers in Ashanti Region, 2010

4.5.13 *Natural disasters in fish farms*

Collectively, 60% of the fish farmers in Ashanti encountered disasters while the remaining 40% did not experienced any disaster (Table 4.38a). The farmers that suffered from both floods and erosions (Plate 4.13) have lands situated in low hills and depressed areas. On the other hand, drought and storm occurred in a farm located at a flat plain. Normally, such environment lacks the required number of trees to serve as wind breakers. Therefore, it is necessary to include the meteorological information about an area during site selection (Woods, 1994; Pillay, 1990).

Plate 4.13: Fish pond showing the effects of flood and erosion in Biansa No 2

Flood is one of the most destructive disasters. Some of the destructions include fish escapees, deposits of silts and alluvial soils as well as disease spread. Similarly, farmers that encountered erosion suffered from weak dykes which also resulted to fish escapees. The effects of fish escapees are two ways because those entering the ponds will either cannibalize the stock in the ponds or spread diseases while, escapees into the wild are threats to the sustainability of natural resources (ACRSP, 2009).

Table 4.38a: Natural disasters in fish farms in Ashanti Region

Description	Frequency	Percentage
Flood	12	48%
No natural disaster	10	40%
Erosion	8	32%
Storm	1	4%
Drought	1	4%
Erosion & flood	6	24%
Drought & storm	1	4%

Source: Survey of fish farmers in Ashanti Region, 2010

4.5.14 *Suspected disease cases*

Culture fish are susceptible to many kinds of diseases. These diseases include viral diseases, bacterial diseases, fungal diseases, protozoan diseases and other parasitic diseases (Moeller, 2007; Wikipedia, 2009).

In this study, the diseases that were suspected to occur in four different farms are Harpesvirus disease, Bacterial gill disease, Columnaris or Saddlepatch disease and Saprolegniasis (Moeller, 2007; Swift, 1993). Each of these diseases was suspected to have occurred in one of the farms which were based on symptoms showed by affected fish. However, only 8% of the farmers could not identify the cause of death at their farms (Table 4.38b).

Columnaris or Saddlepatch disease is caused by bacteria and is highly communicable. The most susceptible fish include catfish and many other fish (Moeller, 2007). Such disease can spread easily when conditions are more favourable. Similarly, Bacterial gill disease can be very infectious to all ages of fish. On the other hand, Harpesvirus is a viral disease common in fries or fingerlings of channel catfish. Also, Saprolegniasis is aquatic fungal disease that affects all species and age of fresh water fish.

Although, the level of disease cases was very low because 76% of the farms were disease free but the few can spread within a short period. Therefore, there is need to eradicate these diseases through many measures including pest or predators.

Table 4.38b: Suspected fish farm diseases in Ashanti Region

Description	Frequency	Percentage
Disease free	19	76%
Cannot identify diseases	2	8%
Harpesvirus disease	1	4%
Bacterial gill disease	1	4%
Columnaris or Saddlepatch disease	1	4%
Saprolegniasis	1	4%

Source: Survey of fish farmers in Ashanti Region, 2010

4.5.15 *Fish farmers' problem ranking*

In the problem ranking, the highest score is financial constraint; which was claimed by 68% of the farmers. Therefore, this has become a major problem in this farming community. The second position is marketing (48%) which is also followed by feeds (28%) including feed ingredient shortages (8%), cold store (20%) and security 16% (Table 4.39).

However, farms affected with weak dykes were located in low hill areas which are prone to erosion and floods, and contributed to dyke problems of 16% of the farmers. Relatively these farmers with such problems need additional maintenance. Despite, another 12% are also faced with predator attacks. In addition, road accessibility became one of their difficulties.

Other difficulties included technical knowledge faced by 12% of the farmers. Despite, the importance of technology, only 4% complained about technical assistance (FAO, 1990a). As a result, 4% of the farmers could not prevent escapees' invasion at their farms. Secondly, 8% were not able to control weeds because they lack labour force which was also faced by 16%. Other technical problems included pond construction claimed by 4%. In addition, 4% also requested for construction engineers. However, 4% was not able to locate good site for fish farm. As a result of such, 4% also reported siltation which was due to eroded deposits. Furthermore, another health hazard was raised as pollution which occurred in one of the fish farms.

Occasionally, fish farmers attempted to remove their pond deposits and used them to fertilize their field crops. The continuity of such practice will eventually lead to deep water which was faced by 8% of the farmers. Similarly, such deep water ponds are difficult to harvest and unfortunately 8% faced the same condition. However, 8% of the farmers who could not posses their own fishing gears will not be able to harvest ponds with similar situations.

Table 4.39: Ranking of other challenges faced by the Ashanti fish farmers

Description	Frequency	Percentage
Financial constraint	17	68%
Marketing	12	48%
Feeds	7	28%
Cold store	5	20%
Lack of labour	4	16%
Lack of security	4	16%
Weak dykes	4	16%
Pond maintenance	3	12%
Floods	3	12%
Predator attacks	3	12%
Road accessibility	3	12%
Lack of technical knowledge	3	12%
Feed ingredients	2	8%
Lack of fishing gears	2	8%
Weed control	2	8%
Deep water levels	2	8%
Pond harvesting	2	8%
Invasion of escapees	1	4%
Pollution	1	4%
Pond construction	1	4%
Lack construction engineers	1	4%
Site selection	1	4%
Siltation	1	4%
Lack of technical assistance	1	4%

Source: Survey of fish farmers in Ashanti Region, 2010

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

Opportunities and constraints are identified in order to understand the fish farming operations in Ashanti Region and to be able to suggest better ways for the environmental best practice for fish farming in Ghana. Although, the practice of fish farming started in this country in the 1950s the production is still below expectation while a lot of challenges are faced with high fish demand and over exploitation of the fishery resources. Consequently, the government of Ghana, targeted fish production through farming in order to counter the current fish deficit supply. This has become the main agenda of this research which examined details of the socio-demographic characteristics of fish farmers, their resource-based, their ways of farm operations, farming systems and mechanisms for sustainability.

The fish farm business in the region is dominated by males who constitute about 96%. This appears to relate to accessibility of land which is not easy for women (Trottier, 1978). Despite, women can be recommended to be given support and encouragement in fish farming because they are more committed to animal rearing. The only female fish farmer has attained within the age range of 24-39 years which is the least age when some of the fish farmers started their fish farm operations. This has given them the opportunity of gaining more than 20 years experiences. Therefore, fish farming in this area has become a life-long activity to sustain food security.

A large proportion of farms is occupied with earthen ponds (8.74%) leaving a verse land which can serve for future expansion (Table 4.3). Therefore, land for fish farming is not a problem in Ashanti Region; especially agricultural land and wetland which formed greater part of the farm lands. However, one of the challenges in these areas is the high water table because most of the fish farms are located in the lowland where underground water is abundantly available (Table 4.5). Thus, it becomes difficult for farmers to dry their ponds; which is another measure to control weeds (Behrendt, 1994). Therefore, the farmers in this area should consider looking for better sites within their empty space of lands for the constructions of other ponds. Before any intervention, it is advisable to understand the terrain of the land (Woods, 1994). Although, the most common water body in the area is river which is most suitable for fish farming but only few of the fish farmers used it as water source for their fish ponds (Pillay, 1992; Asmah, 2008). Nearly all the farmers relied on the underground water supply and therefore were not able to dry their ponds during maintenance (Table 4.13). On the other hand, majority of these farmers drained away their pond water without consideration of effluent control measures (Table 4.24). It is also discovered that water quality and pond pH were not monitored by many farmers. Secondly, during the rainy season weeds are very difficult to control especially those without labour force (Table 4.27).

The common culture species in these operation systems include Tilapia sp. and Clarias sp. (Table 4.15). Besides, the most appropriate fish species to culture in this region are the source from the indigenous species (Table 4.7). However, farmers in this area have not given much attention towards fish stocking densities (Table 4.17 & Table 4.18).

Secondly, most of the farmers supplied feeds through estimation because they lack proper records of the fish populations. Subsequently, most of them combined feeding intervals which were predominantly mornings and evenings (Table 4.19 & Figure 4.5). Also, majority of the fish farmers in this region feed their fish using manufactured feeds which are combined with local made at their farms (Table 4.8 & Table 4.9). Among those producing feeds locally, only very few of them used milling machines while a larger percentage used their hands to mix the feed ingredients. This has been integrated with livestock keeping which provided a lot of manure for the fish farmers. Therefore, this has motivated the fish farmers to concentrate more in organic farming. Generally, the availability of these resources became an opportunity for the fish farmers that are engaged in semi-intensive farming systems. Thus, the majority of these farmers were able to practise polyculture and monoculture within the farming systems. Although, it is an opportunity for the minority that keep their brood stock; the idea should reach the rest of the fish farmers because it can motivate them to increase their production. The brood stock signify the seed store for fish farming and a farmer without viable seeds will always face the problem of low productivity. Thus, seeds are normally expensive and risky to buy. Therefore, availability of brood stock can be included in the suggestions to solve the problem of fingerlings scarcity.

Throughout the study, sustainability has been considered as a factor to increase fish production because fish farming is also a life-long activity for food security in the area. The infrastructures and infrastructure services were fairly good but not well distributed. However, the farmers have developed various marketing strategies in order to attract more clients (Table 4.31a). As some of the farmers have secondary occupations; they were able to use part of their earnings for self financing (Table 4.1 and Table 4.34). In addition, associations were used as focal points for collaborators. The collaborators include government agencies, NGOs and farmers among themselves.

From the findings, the Department of Fisheries is mandated to promote all fisheries related activities. Its operation areas included the support of fish farmers and their associations. The support includes extension services, formal training, facilitate access to credit, supervision of pond construction, provision of subsidized fingerlings and harvesting of ponds. The Department also have training opportunities for capacity building in the area of aquaculture and the employment opportunities include farm managers and technicians for commercial fish farms. It also established link through the collaboration with MOFA, WRI, Food and Drug Board, universities, agric colleges and
Water Resource Commission.

Other stakeholders, such as Ashiaman Aquaculture Demonstration Centre train fish farmers, and provide fingerlings and give technical supports in sampling and harvesting. It also collaborates with Fisheries Department and strengthened the employment of fisheries officers. Secondly, the Institute carry out research in order to produce local feeds for fish farmers. WRI has also been engaged in a lot of research in order to distribute fast growing strains to the fish farmers (FAO, 2000, 2009). On the other hand,
the Department of Fisheries and Watershed Management of KNUST produced remarkable number of graduates (undergraduates & postgraduates) to promote fisheries and aquaculture. Furthermore, a collaborative research was conducted in partnership with

Virginia Tech & State University in order to examine best management practice for fish farming in the area.

Recommendations

Fish farmers in the area have been given considerable support but their operations still lack the appropriate techniques to improve productivity. Generally, resources are available but are not properly utilized by the fish farmers. Although, fish farmers in the region have background knowledge of practical experiences some of the fish farmers still need to adopt environmental best practices of fish farming in the area. Therefore, the following recommendations will help the fish farmers to be able to improve their management strategies in relation to the local conditions and resource-base.

- Farmers should locate better sites within their empty space of farm lands to enable them practise pond fallowing for pond maintenances. Secondly, the impacts from the difficulties of pond drainage and drying will be minimal.

- The fish farmers should be encouraged to culture more of the indigenous fish species and avoid over stocking, over feeding as well as under feeding. Therefore, farmers should closely monitor the populations of their fish stocked. Further research should be carried out in the form of a PRA to involve the farmers in full participation in the introduction of improved practices to solve these problems.

- The farmers should be trained on how to utilize available resources such as crop residues and ingredients, organic manure and keeping their proper records for future references. This should include regular flushing of pond water in order to dilute the waste loads as well as put under sedimentation for effluent control. Furthermore, the idea of preparing feeds through hand mixing should be discouraged because of the implications which can lead to future pollutions.

- The fish farmers in the region also practised mixed-farming and therefore, need to integrate their fish farming. Especially, with rice because the condition of water is favourable and additional control of the nutrient levels will be assured. This can be further suggested that, integration may have an effect in controlling algal bloom. Therefore, this work will further recommend a study in the area of integration.

- Although, some fish farmers used part of their earnings from secondary occupations they could not cater for all the requirements. As a result, the general expenditure became insufficient (Table 4.33). According to the problem ranking, financial constraint and marketing were the most urgent (Table 4.39). Therefore, further support is needed in these areas.

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APPENDICES

Appendix 1: Ashanti Region Aquaculture Database

- Statistics as at October, 2009

• Number of districts covered	-	18
• Total number of farm(er)s	-	323
• Number of ponds	-	808
• Total surface area of ponds	-	123.01ha
• Species cultured	-	Tilapia, Catfish, Heterotis and Snakehead
• Major pond type	-	Earthen
• Estimated production	-	212.56m/t

Source: Fisheries Regional Office (2010)

Appendix 2: List of selected farmers (ACRSP)

Ministry of Fisheries Pilot	Ministry of Fisheries	0242116134 (Francis	0244353755 (Richard-caretaker)	Ashanti	Kona	Afigya Sekyere	21
Aquaculture Center	Mr. Effah	Adjei -manager)		Ashanti	Sefwi-	South	
Effah	Gyan Fosu	0246536076	0244812805 (Pastor Robert Obeng-	Ashanti	Domenase	Amensie East	13
Plantation	Dr. Mrs. Grace Ababio	0243321341(Godfred	caretaker) 0241185714 (B. F.	Ashanti	Anwiankwanta	Bekwai	
Limited Gyan	Mr. Kofi Oti	Adioo-manager)	Boateng)	Ashanti	Bosomponso-	Offinso	3
Fosu Farms	Akyeampong	0244355789/021233846 (Dr.		Ashanti	Akomadan	Asanti-Akim	13
		Mrs. Grace Ababio)		Ashanti	Konongo	North	

Amponsah-Ababio	Mr. Lorrep	0243576657	Ashanti	Mpasatia	Atwima	6
Farm	Kyei Boateng	0243725798	Ashanti	Asokore	Mponua	6
Shallom Farms			Ashanti	Ahisan		4
TTYAC	Mr. Clifford Boateng	0244052525	Ashanti	Kuntenase	BAK	3
Wofa Guy			Ashanti	Burofoyedu	BAK	8
Ziloboat Farms			Ashanti	Esereso		5
Sagoe Farms			Ashanti	Chirapatrae		5
Opoku Ware Girls	Mr. Ebenezer Obeng	0244607264	Ashanti	Tiwobabi-	Adansi North	10
Vocational School	Dompreh	0244476806	Ashanti	Obuasi	Atwima	
Asumadu Farm	Elizabeth Adu Dankwa	0243239377	Ashanti	Darbaa	Mponua	
Obdoms Farms	Emmanuel Boakye	0243179092	Ashanti	Obuasi	Adansi	
Enterprise	Mrs. Afrifa		Ashanti	Krobo-	Central	
Cici Yaa Farms	Mrs. Esther Adu-		Ashanti	Mampong	Sekyere West	
Agyadu Farms	Gyimah	0243837574		Effiduase	Sekyere East	3
Powell Fisheries	S.S. Agyemang			Manso	Amensie West	3
Adu-Gyimah	Obolo (farm	0247676788		Akropong		
Farms	supervisor)	0277012568		Kyeranse		
Agro Na Me Pe	Mr. Amoah Appiagyei			Akomadan-		
Farms	Abraham Kinte			Afrancho		
County Farms	Mr. Asare (Senior			Manhyia		
Kaho Bio Farms	Housemaster -			Adum		
Royal Valley Farms	caretaker)					
Limited						
Armed Forces Senior		0277752012				
High School						
	Mr. Armah					
Department of						
Fisheries Kumasi						

Appendix 3: Questionnaire (Village Interviewee)

1. **Personal details**:

Name:

Sex: F or M Age: Region: Village: District:

Contact: Marital status:

Occupation:

Membership status:

a. Association Which?

b. Group

c. Family

d. Independent

Which of these do you eat more than the other? i. Meat ii. Fish flesh Why or why not?

2. Educational background**:**

(1) What is your educational level?

(11) Have you been trained in any of these areas:

a. Fish farming

b. General aquaculture practice

c. Pond construction

d. Rice-fish integration

e. Crop-livestock and fish integration

f. All of the above

g. None of the above

(III) How long have you been engaged on fish farming?

General information on the availability of resources

3. Which kind of land do you access?

i. Agricultural land ii. Residential land iii. Wetland iv. Others………………………

a. What is the ownership pattern?

i. Personal ii. Community iii. Guardian iv.government v.parents

b. Where is it located?

i. Upland ii. Lowland iii. River bank iv. Others:

4. Do you own a garden? If yes, give vegetable types

5. Do you own livestock? If yes, give the species and population

6. Do you own a rice field? If yes, what are the varieties?

7 What is the type of water body in your area?

a. Lake
b. Lagoon
c. River
d. Reservoir
e. Mining pool
f. Irrigation canal
g. Others (sea)

Constraints on natural resources

LAND

8. What is the land topography?

a. Flat plain b. low hill c. depression d. gentle slope

9. Which types of soils are found in your area? If more than one, which is the most predominant?

a. Sand b. clay c. loam d. silt e. mix

10. What is the land size? Estimate the area

How did you acquire the land?

a. Hired
b. Inherited
c. Bought
d. Borrowed

WATER

11. What is the water source?

a. stream b. river basin c. rainfall d. borehole e. wells f. underground/water table

12. What are your domestic uses and other activities carried out in this water body?

13. What is the type of irrigation or water supply used at your farm?

a. Seepage b. Machine pump c. Runoff (rain fed) d. Spring

e. If rainfall, how long does it take?

14. How do you access the water source?

a. By foot
b. Motorcycle
c. Pedal bike
d. Boat
e. Animal power
f. Others (specify)

15. Did you experience any natural disaster? If yes, which of the following:

a. Flood
b. Erosion
c. Drought
d. Other

16. Do you have pests or predators in your area?

a. Yes / No
b. Which of the following do you have in your area: snakes, crocodiles, or wild birds?

Challenges faced by fish farmers

17. How much did you invest in running your farm; on cost of?

VARIABLES	COST
a. Feeds	
b. Seeds	
c. Brood stock	
d. Equipment (specify)	
e. Labour	
f. Fuel	
g. Transportation	
h. Others	

18. Which are the culture species?

19. Have you ever had any disease incidence? If yes, what diseases and what measures did you take?

20. Which equipment do you use at your farm on the following?

a. Pond construction	
b. Aeration	
c. Seining (netting)	
d. Feeding	
e. Hatchery	
f. Others (specify)	

21. Where do you acquire brood stock?

a. Collection from the wild b. Artificial propagation c. Importation

d. If ―a‖ where are they commonly found? Water bodies, rice fields, irrigation canals or ponds

e. Buy from others (specify)

22. How do you acquire fingerlings? …………………………………………………………………...

If self acquired, which of the following:

a. Brood stock
b. Artificial propagation
c. From the wild

23. i. How do you acquire feeds?

a. Buy b. Produce locally c. Natural available nutrients d. Kitchen waste e. Animal waste f. All of the above

ii. How do you prepare your feeds?

a. Grind b.Pound c. Mill by machine d. Mix by hands e. Others

24. How do you market your produce?

25. Do you encounter theft cases? If yes, how often?

26. If a crop farmer, which of the following do you cultivate?

a. Sesame b. Groundnuts c. Maize d. Millet e. Rice

f. Cotton g. Beans h. Others:

Opportunities for fish farming

27. Who is/are your collaborator/s?

a. NGO b. Government c. Other groups………………………………………………….

d. Individual partner e. All of the above f. None of the above

28. What is your type of farming? i. Commercial ii. Subsistence iii. Both

a. If commercial farming, estimate your income:

b. If subsistence farming, what are the outputs and other benefits

i. Household food security ii. Improve nutritional status iii. Others

29. What is your employment status?

a. Self- employed b. Employer c. Employee

30. How many people do you employ in your farm?

a. Caretaker
b. Watchman
c. Manager
d. labourer
e. Others:

31. How many ponds do you have?

32. What are their sizes? **Refer to excel sheet**

33. Have you ever practice monoculture? a. Yes b. No If yes, which of the following methods:

	Species	sexes
Sex-reversal		
Manual sorting		
Hybridization		
Others		

34. Do you have a brood stock? a. Yes b. No If yes,

Type of species	Age

SYSTEMATIC APPROACH TO PRODUCTION MANAGEMENT

35. Which of the following are you practicing?

a. Monoculture b. Polyculture c. Monosex culture

d. Integration e. Combination of all

36. What is the system under practice?

a. Intensive b. Semi-intensive c. Extensive d. All of the above

37 Do you give supplement feeds? If yes,

Give types	Ingredients involve

38. How often do you feed your fish?

a. Morning

b. Afternoon

c. Evening

d. All times

39. What is the feed source?

a. Readymade (Factory made) b. Locally made by someone c. Farm made (By myself)

d. Kitchen waste e. Leftovers from personal meals

40. Do you measure your feed? a. Yes b. No If yes, what are the measurements?

41. How do you supply the feeds? Estimate or ad libitum

42. Which type/types do you use? Floating, sinking, or both

43. Where do you rear your fish or aquatic organisms? Chose any applicable

a. Ponds b. Pens c. Cages d. Tanks

e. Rice paddies f. All

44 Do you realize any of the following?

a. Seepage b. Precipitation c. None

45 How do you manage the water?

Manage	Timing
a. Filter	
b. Disinfect	
c. Drain	
d. Replace	
e. Other treatments	

46 How do you manage the pond sediments?

a. Allow to dry

b. Remove

c. Recycle in crop fields

d. Recycle within the farm

e. Other

47. Where do you store your water?

	Period
a. Ponds	
b. Tanks	
c. Reservoir	

48. How often do you drain your ponds?

a. Weekly b. Fortnightly c. Monthly d. Yearly

e. None

49. How often do you harvest the ponds?

a. weekly b. Occasionally c. Yearly d. Not yet e. monthly f. Twice in a year

50. How do you control the effluent?

a. Drain away b. Allow to evaporate c. Treat d. Other

51. Do you apply fertilizers? If yes,

a. Inorganic: NPK, urea or other

b. Organic: Poultry Waste, Cattle Waste, Sheep, or Goat Waste, Pig Waste

52. How often do you apply lime into the ponds?

a. After construction b. Yearly c. None

53. How do you control weeds on the farm?

a. Cut with cutlasses b. Apply herbicides c. Use mower d. Uprooting e. none

54. What is your production type?

	Volume
a. Fry	
b. Fingerlings	
c. Brood stock	
d. Market size	
e. Others	

55. What are the mechanisms for sustainability?

a. Self-financing b. Project support c. Government support

d. Group contributions e. Sales revenue f. Loan from others

56. How do you keep your farm records?

a. Books b. Computer c. None

57. Which of the following do you collaborate with?

a. Agriculture Extension b. Research c. Other agency

58. Do you have any loan facility? If any, specify money or equipment:

59. Do you have any infrastructure service?

a. Transport b. Stores c. Electricity supply

b. Others:

60. Which of the infrastructures are accessible in your area? Estimate distances.

a. Main market

b. Main road

c. Storage facility

d. Others

61. Are you aware of any government policy or strict municipal ordinance that may perceive barriers to entry? If yes, who are responsible?

a. Area council b. Department of Fisheries c. Dept. of Forestry

d. Department of Wildlife e. National Environment Agency

f. Others………………………………………………………………………………………………

62. Which is the affected area?

a. Land use b. Water body c. Forest zone

d. Fisheries ecology e. Others………………………………………………..

63. Is there any community-based aquaculture committee?

64. Is there any aquaculture association?

65. Are you a member?

66. What are your major problems?

Remarks:

Excel sheet

Pond number	Size	Source of Input	Species Present	Density of Each Species	Reuse Water

Appendix 4: QUESTIONNAIRE (Institute Desk Survey)

Background information (tick where necessary)

1. What is the name of the institute?

2. What is the kind of institute?

3. What is the mandate of the organization/institute?

4. Where are the operational areas?

5. Which institution do you collaborate with?

6. Who are the support groups or individual farmers? List below

7. How are they supported?

General information on the availability of resources

7. Which kind of land does the institute access?

8. What is the ownership pattern? Government, institute, community or others

9. What is the size of the land? If more than one, please specify

10. Where is it located? Upland, lowland, inland or river bank

17 What are the types of water bodies in the area used for aquaculture?

18. What organisms are found in the water bodies? Give species and habitat

a. When are they most common?

19 Which kinds of infrastructure does the institution have? Give locations and number where necessary

20 What is the institute's human resource capacity? Trained persons, areas and their levels **General information about the opportunities: tick where necessary**

21 What are the training opportunities? For senior staff, extensionists, farmers and other

22 What are the employment opportunities?

23 What are the areas of Research activities?

24. Are there conserved areas?

25. If practicing fish farming, what is the outcome (income)?

26. Does the institute advocate for networking through the invitation of farmers in order to adapt their technology?

27. Which of the following facilities does the institute provide for farmers? Loan, grant, subsidized material, all or none

General information about the major constraints (tick where necessary)

32. What are the volumes of catches on each type, on seasonal bases (3-5 year period?)

33. Does the institute invest in aquaculture activities?

a. What is the outcome? Successful, pending or failure

b. Does the institute or government import fishes?

42. Which are the common diseases?

43. What are their ways of treatments and prevention?

Development of management plan and policy

48. What is the organizational structure and linkages with various institutes?

49. What is the policy on environmental pollution and land use for aquaculture?

51. How does the institute utilize her trained persons? Extension activities, monitoring small scale projects, farmers training, surveillance agent and others

52. Is there a research station for the institute?

53 Has any fish stock assessment been done in the last three years?

54. Does the institute have a copy of national aquaculture development plan? Yes or no

55. Who are those involved in aquaculture practices? Rice growers, other crops growers, fishermen, fish mongers, women groups, trained farmers or trained staff

58. Does the institute provide any infrastructure service for the communities? Transports, stores, electricity supply, roads, markets or others

59. Identify the places affected and specify the kind of service provided?

60. Does the institute have any role to play in government policy in the areas of fisheries, aquaculture and environmental protection?

61. Would these encourage the fish farmers?

Appendix 5: Map of Ashanti Region showing study area

Source: 2000 Population and Housing Census

Report – Ghana Statistical Service, March 2002.