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Fish Farming Management Practices as Determinants of Fish Yield in Kakamega County, Kenya

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ABSTRACT

This study established the association between fish farming management practices and fish yield in Kakamega County, Kenya. The results were that fish farmers who record the highest fish harvest of over 400 Kgs of fish output per 300 m^2 fishpond are those who check water quality at their ponds and apply corrective measures; and those who get their fingerlings from accredited sources. The success of fish farming as an economic livelihood activity in Kakamega County depends on the proper application and appropriate implementation of fish farming management practices. These include management of water and management of the production units through appropriate stocking, feeding and record keeping.

Introduction

Fish farming is an important economic livelihood activity for many communities around the world. An estimated 14% of the world's total fisheries are based on wild or aquaculture fisheries (Rossi, 2019). Fish farming is a source of employment, it provides a good alternative source of income to farmers a situation that alleviates poverty and improves living standards and it increases revenue to the governments (FAO, 2018). Wuyep and Rampedi (2018) also assert that small-scale fish farming is a viable source of food, employment opportunities and income and, therefore, can help reduce rural to urban migration.

In Kenya, the colonists were the first to begin fish farming in the early 1900s through the introduction of *Oncorhynchus mykiss* (trout) in rivers for sport fishing (Ngugi *et al*., 2007). Since then, fish farming has grown from mere sport fishing and is now a livelihood for many people and a source of food and especially protein to many families. Today aquaculture is one of the fastest developing food industry in Kenya with increased production since the Government initiated the Economic Stimulus Programme (ESP) in 2009 (Ojwala *et al*., 2018). Hand-dug earthen ponds dominate fish farming in Kenya although very few fish farmers have concrete tanks and raceways. Some of the fish farmers integrate fish farming with other farming enterprises such as rice farming and rabbit keeping. This integration is better than monoculture in terms of food supply and optimal utilization of land and environmental measures (Ahmed and Garnett, 2011).

Most Kenyan farmers' ponds are normally small, hardly exceeding 300 M^2 and producing not more than 0.15 Kg/M^2/year (GOK, 2010b). Changing technology in aquaculture has been the major driving force for increasing aquaculture production in the phase of dwindling open water stocks in Kenya (Bundi *et al*., 2018).

Fish farming households in Western Kenya mainly culture *Oreochromis niloticus* (Nile tilapia) *Clarias gariepinus* and (African catfish) (Nguka *et al*., 2017). In Kakamega County, majority of the fish farmers (75.6 %) have fishponds that are less than 300 M^2 (*Shitote et al*., 2013b). Despite efforts of several players to revitalize fish farming in Western Kenya, the development process is at a snag and is characterized by pond productivity that is low and not rising (Nguka *et al*., 2017). According to Shitote *et al*. (2013a), the major problems facing fish farmers in Western Kenya where Kakamega County is located are high costs of feed, shortage of quality fingerlings and feeds, flooding, poor security and poor fish farming practices. Other challenges that affect fish farming in Western Kenya are poor road infrastructure, poor pond management practices, limited sources of water, high costs of fish feed, poor location and construction of fishponds (Kundu *et al*., 2016).

Management of fish farming just like management of any other farming enterprise is very critical and needs the following considerations: the need to educate farmers, quality stocks of fish of known origins, high quality feeds, record keeping and quality extension support (USAID, 2010). Similarly, the promotion of integrated aquaculture production systems would be a critical dimension of intervention in the process of revitalizing fish farming in Kakamega County in order to check production (GOK, 2010a). A number of challenges, top of which is poor water quality resulting from the uncontrolled addition of inputs (fish feeds, inorganic fertilizers, and organic fertilizers) into the ponds affect fish production (Ojwala *et al*., 2018).

USAID (2010) reports that with increased knowledge and the dynamic development of fisheries, it was realized that living aquatic resources, although renewable, are not infinite and need to be properly managed if their contribution to the nutritional, economic and social well-being of the growing world's population is to be sustained.

Fish farming is an activity that requires a lot of inputs and work force especially in the initial stages of digging the pond than in the routine management of the pond after stocking including application of manure in the pond, feeding the fish and cleaning the pond (Akankali *et al.*, 2011). Reduced application of chemical-containing substances such as fertilizers and pesticides in ecosystems conserves a great variety of aquatic flora and fauna (Ahmed and Garnett, 2011). Surveys for suitable sites for fishpond establishment or evaluations of specific sites should first identify strengths and weaknesses of physical characteristics such as the suitability of the soil, topography and the availability of good quality water (Ngugi *et al.*, 2007).

Materials and Methods

The study was carried out in Kakamega County in Kenya with a focus in Lugari, Lurambi and Khwisero sub-counties. The main study population was fish farmers in fish farming households. Correlational research design was used. The study had the objectives of establishing the association between fish farming management practices and fish yield in the county.

Kakamega County has 12 sub-counties. Three sub-counties were purposively sampled to represent their ecological zones and the farming systems; Lugari and Lurambi from the Upper Medium (UM) ecological zone and Khwisero from the Lower Medium (LM) ecological zone. Lugari Sub-county also formed an important area of study because it had the highest number of fishponds in the county. Lurambi Sub-county has the Kakamega Fish Mini-processing Plant and, therefore, ready market for fish. Khwisero Sub-county had an active fish farmers' cooperative. In addition, it was important to concentrate on these sub-counties in order to allow in-depth exploration and understanding of the fish farms and thus increase the quality of data collected. The study employed multi-stage random sampling of fish farms. 384 fish farmers were sampled from three sub-counties selected in the entire Kakamega County. However, the sample size was added another 10 % to be 400 fish farmers in order to take care of non-response or lose of data during data collection process. The fish farmers were proportionately sampled in the three selected sub-counties in ratios relative to the total number of fish farmers in the sub-county.

Questionnaires containing closed and open-ended questions were administered to the fish farmers and/ or fish farm managers at the household level. During the visits at the fish farms, observable existing fish farming management practices were recorded and photographed as a way of supplementing the information collected on the questionnaires and these included: site of the fishpond, water quality, methods of controlling predators, methods of controlling diseases and method of controlling pests among others.

Three focus group discussions (FGDs) were organized for the fish farmers at major townships in the selected sub-counties; Kakamega Town, Lumakanda Township and Khwisero Township. Interviews were held with purposively selected key informants including the chairpersons for Kakamega County Fish Farmers Cooperative and Khwisero Fish Farmers Cooperative, one official from Aquaculture Association of Kenya (AAK) and the Fisheries Director, Kakamega County. Secondary data were obtained from farm records, documented reports in various offices that were visited and policy documents regarding fish farming in Kakamega County and Kenya.

Descriptive and inferential statistical analyses were done for the household data. The existing fish farming management practices that are water management, management of production units, stocking and fish feeding were summarized in tables, means, charts and graphs using Microsoft Excel and Statistical Packages for Social Scientists (SPSS) version 20. They were analyzed using descriptive and inferential statistics and qualitatively using narrative analysis. Inferential statistics included correlation and Chi-square tests of independence and association. The existing fish farming management practices were correlated with fish yield in order to determine if there were any relationships.

Results and Discussions

The study sought to examine the association between fish farming management practices in Kakamega County, Kenya and fish yield. These fish farming management practices include management of water; feeding; desilting and repair of the pond; stocking and selective removal of excess fish; and control of theft, predators and diseases.

Water Management

The main sources of water for fish farming in Kakamega County are streams and rivers. They are used by 83.40 % (n = 320) of the fish farming households for fish farming. Springs are sources to most streams that feed into rivers and, therefore, they act as important sources. Other sources of water for fish farming in Kakamega County are tap water from water supply companies that is used by 8.30 % (n = 31) of the fish farmers, borehole water by another 1.00 % (n = 3), harvested rainwater by another 4.40 % (n = 16) and protected springs by 2.90 % (n = 11) of the farmers. Figure 1 gives the percentages of the distribution of the various sources of water.

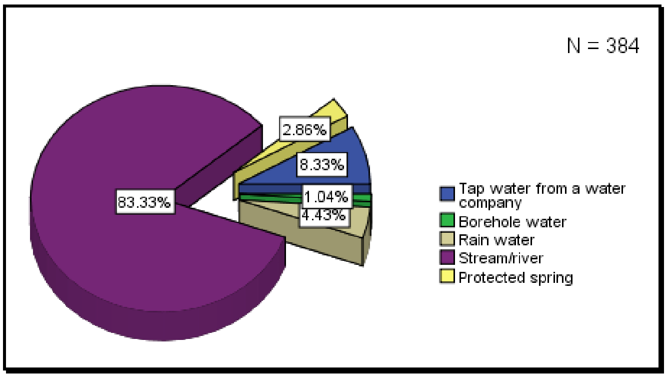

Figure 1. Main sources of water for fish farming in Kakamega County, Kenya

Source: Researcher (2018)

Very few farmers represented by 5.20 % (n = 19) pay for water that they use for fish farming. These are mostly farmers who use tap water from water supply companies. These farmers have limited or no access to the streams, rivers and protected springs. They also may not have installed adequate rainwater harvesting facilities.

The study investigated how management of water quality affects fish yield. Fish farmers who apply water quality management have their fishponds producing more fish compared to those that do not apply any water quality management. The common practices for water quality management by fish farmers in Kakamega County were checking turbidity and diverting muddy water away from the fishponds and also checking the pH of the fishpond water and treating the affected fishponds with manure or agricultural lime. Table 1 gives a comparison by fish yield for the different ways of managing water. The results show that fish farmers who record the highest fish harvest of over 400 Kgs of fish output per 300 m^2 fishpond are those who check water quality at their ponds and apply corrective measures.

Table 1. Comparison by fish yield for the different ways of managing water in fishponds in Kakamega County, Kenya

	Percentage of fish yield in Kgs/ hectare		
	Below 65,000	**65,000 to 13,000**	**Over 13,000**
Check turbidity to divert muddy water away from the pond	27.34 % (n = 104)	34.38 % (n = 132)	38.28 % (n = 146)
Neither check turbidity nor divert muddy water away from the pond	67.19 % (n = 258)	26.30 % (n = 100)	6.51 % (n = 24)
Check pH and treat the affected ponds with manure or agricultural lime	31.25 % (n = 120)	29.43 % (n = 113)	39.32 % (n = 150)
Neither check pH nor treat the affected ponds with manure or agricultural lime	80.21 % (n = 308)	17.71 % (n = 68)	2.08 % (n = 7)

Source: Researcher (2018)

The researcher was interested in finding more information about the fish farmers that were producing the highest fish harvests of 400 Kgs of fish output per 300 m^2 fishpond. A Chi-square test ($\chi^2_{6,\ 0.05} = 12.32$, $p = 0.044$) of association showed there was a significant ($p < 0.05$) relationship between fish yield and education and/ or training. This implies that fish farmers with high level of education and those with training related to fish farming, farm management and agriculture are more likely to have more fish yield than those who have lower levels of education and training or no training at all. Therefore, the study sought to establish the education levels and training of farmers who were producing the highest fish harvests of over 13,000 Kgs of fish per hectare (Table 2).

Table 2. Education and training of the fish farmers who apply water quality management and have over 400 Kgs of fish yield per 300 m^2 fishpond in Kakamega County, Kenya

Education level	**Water quality management applied and percentage under the education level**	
	Check turbidity and apply corrective measures	**Checks pH and alkalinity and apply corrective measures**
Short course related to fish farming	31.58 % (n = 46)	25.25 % (n = 38)
Tertiary level college with training related to fish farming and/ or agriculture	24.45 % (n = 35)	24.67 % (n = 37)
Tertiary level college	27.74 % (n = 40)	23.43 % (n = 35)
Complete secondary school	17.23 % (n = 25)	15.56 % (n = 23)
Complete primary school and incomplete secondary school	9.74 % (n = 14)	8.91% (n = 13)
Incomplete primary school	1.32 % (n = 1)	2.18 % (n = 3)
Never been to a formal school	0.00 % (n = 0)	0.00 % (n = 0)

Source: Researcher (2018)

Most of the fish farmers who were applying water management were fish farmers who have undertaken short courses related to fish farming and those who had tertiary education level and especially with training related to fish farming, farm management and agriculture. These had the highest fish production. None of the fish farmers who were applying water management had never been to a formal school. It is, therefore, imperative to say that education enables the fish farmers to get to appreciate the importance of water quality management and to understand how to manage water quality. However, the Knowledge, Attitude and Practice (KAP) of the educated or trained farmer determine this.

It was observed that fish farmers in Kakamega County capitalize on the available water resources for fish farming. These include protected springs that serve both the community as a source of potable water and the fishponds (Plates 1a and b).

Plates 1 (a and b). A protected spring as an important source of water for a fishpond in Khwisero Sub-county, Kakamega County, Kenya

Source: Researcher (2018)

No earthen fishponds was observed to have clear water. According to the farmers in all the focus group discussions (FGDs), the amount of water in their fishponds was adequate for their fish. These farmers said that they synchronize the intake and outlet so that the fishponds maintain the required level of water at all times as advised by their extension service providers. The fish farmers in all the focus group discussions (FGDs) said that tap water from water supply companies is expensive and, therefore, most farmers do not depend on it for their fish farming. Further information collected from the focus group discussions (FGDs) revealed that farmers discourage the use of tap water from water supply companies because of the high concentration of chlorine, which adversely affects fish. They, however, said that farmers who wish to use such water are advised to leave it settled in containers for at least one day before they can add it into their fishponds.

The focus group discussion (FGD) at Khwisero revealed that fish farmers who use water from boreholes, tap water from a water company, harvested rainwater and water fetched from protected springs in their fishponds are mostly those whose fishponds are located far away from streams and rivers. They added that they also include those fish farmers whose farm gradients do not permit free flow of water from the natural environment into the fishponds and that some of these farmers have PVC-lined fishponds, concrete fishponds and tanks. During all the focus group discussions (FGDs), farmers pointed out that clear water makes the fish vulnerable to predators such as birds of prey and even thieves. They even said that they sometimes have to induce fresh cow dung in the fishponds in order to repel snakes, which would prey on fish.

According to a Key Informant Interview (KII) with an Aquaculture Association of Kenya (AAK) official, the cost of digging a borehole/ shallow well is so high that most farmers have not invested in them. He added that rainwater is not reliable since there are months of the year when rainfall is very low and sometimes not there at all. These are December and January and due to climatic changes, this dry season has in some years extended to February and March. He however pointed out that rainwater supplements all the other sources because it directly fall into the fishponds. A Key Informant Interview (KII) with the County Director of Fisheries, Kakamega County pointed out that fish farmers are often encouraged to undertake some training related to fish farming or farm management even if they did not complete their formal education to the level that they expected.

These results are similar to the findings by Wuyep and Rampedi (2018) that all other things being equal, a pond with good water quality will produce more and healthier fish than a pond with poor quality. Water quality management aims to regulate environmental conditions so that they are within a desirable range for growth and survival of fish and largely this determines the success or failure of an aquaculture operation (Das *et al.*, 2015).

Stocking

The research revealed that a large percentage of the fish farmers represented by 80.50 % (n = 309) of the fish farming households interviewed get fingerlings for their fishponds from the accredited hatcheries that have been approved by the Kakamega County Department of Fisheries. These farmers know that in order to realize high production they have to use certified fingerlings of high quality.

Those farmers that get their fingerlings from other farmers accounted for 15.60 % (n = 59) while those that depend on their own hatcheries account for 3.90 % (n = 14). Fish farmers that get their fingerlings from these uncredited sources do not have financial capabilities and, therefore, cannot afford the cost of buying the fingerlings from accredited hatcheries. Currently, Kakamega County has 3 accredited hatcheries (Table 3).

Table 3. Accredited hatcheries in Kakamega County, Kenya

Name of hatchery	Sub-county	Ownership
Jafi Fish Farm	Lurambi	Private
Labed Cash Marine Enterprises	Malava	Private
Ilala Agencies and Fisheries	Shinyalu	Private

Source: Researcher (2018)

Some fish farmers in Kakamega County source their fingerlings from other accredited hatcheries outside the county. An example is LBDA in Kisumu County. Some farmers have their own hatcheries, which form important sources of fingerlings sources for them and some other fish farmers.

According to the field data, most farmers stock *O. niloticus*. These account for 57.60 % (n = 221) of the farmers. Those that stock *C. gariepinus* account for 22.70 % (n = 87) and those that stock both species in one pond represent 19.80 % (n = 76). Farmers that stock males only in one pond account for 83.60 % (n = 321) while those that stock females only in one pond account for 4.70 % (n = 18). Those that stock males and females in different ponds account for 7.80 % (n = 29) and those that stock both sexes in one pond at the same time account for 3.90 % (n = 14).

Farmers can also stock based on age of fish. In this study, 91.70 % (n = 352) of the farmers stock the same age in the same pond while only 8.30 % (n = 31) stock different ages in the same pond. All the interviewed fish farmers produce fish for consumption purposes only, either consumed by the family or sold at the market. Only about 10.20 % (n = 39) of the farmers interviewed integrate fish farming with other farming enterprises such as rabbit keeping.

Some farmers represented by 21.10 % (n = 81) of the farmers interviewed leave their fishponds un-stocked for at least one month between successive stockings. The study revealed that most farmers represented by 87.40 % (n = 193) of the *O. niloticus* farmers and 85.30 % (n = 74) of the *C. gariepinus* farmers follow the recommended stocking density. However, 9.30 % (n = 20) of the *O. niloticus* farmers and 8.10 % (n = 7) of the *C. gariepinus* farmers stock below the recommended stocking density while 3.30 % (n = 7) of the *O. niloticus* farmers and 6.60 % (n = 5) of the *C. gariepinus* farmers stock above the recommended stocking density.

A Chi-square test ($\chi^2_{1,\ 0.05}$ = 21.56, p = 0.023) of independence showed that fish yield in Kgs per hectare and source of fingerlings are significantly ($p < 0.05$) related. This implies that fish farmers who obtain their fingerlings from accredited hatcheries are more likely to have higher fish yield per hectare than those who obtain their fingerlings from their own farms and other farmers. The study compared fish yield by fish farmers based on their sources of fingerlings (Table 4).

Table 4. Comparison by fish yield for the different sources of fingerlings in Kakamega County, Kenya

Source of fingerlings	Percentage of fishpond yield in Kgs per hectare		
	Below 6,500	6,500 to 13,000	Over 13,000
Accredited sources	9.05 % (n = 27)	36.98 % (n = 114)	53.97 % (n = 166)
Own farms and other farmers	64.34 % (n = 48)	30.36 % (n = 22)	5.30 % (n = 3)

Source: Researcher (2018)

The study then sought to establish the experience and the education levels and training of the fish farmers and/ or fish farm managers from the fish farms that get their fingerlings from accredited sources and recording fish yield of over 13,000 Kgs per hectare. These are presented in Table 5. It is clear from Table 5 that the fish farming households that get their fingerlings from accredited sources and produce over 13,000 Kgs of fish per hectare are mostly the ones that have their household heads and fish farm managers having higher education levels and other trainings related to fish farming, farm management and agriculture. Their household heads and/ or fish farm managers too have experience of over three years in fish farming. This means that because of their many years of experiences they have learnt the importance of quality fingerlings that can only be found in accredited hatcheries.

It was observed that fish farmer leave their fishponds unstocked for some period between harvesting and the following stocking (Plate 2). The farmers said that this helps them to clean up the fishpond and prepare well for the next stocking.

The Fisheries Director, Kakamega County said that *O. niloticus* and *C. gariepinus* are the only cultured fish species in Kakamega County. He however pointed out that most farmers prefer to stock only *O. niloticus* because of its acceptability and marketability. Farmers also prefer to stock *O. niloticus* to *C. gariepinus* because *C. gariepinus* hides in mud and, therefore, makes it difficult to harvest.

Table 5. Experience, education levels and training of the fish farmers and/ or fish farm managers from the fish farms in Kakamega County that get their fingerlings from accredited sources and record over 13,000 Kgs of fish per hectare

Demographic characteristics	Percentage with fish yield of over 13,000 Kgs per hectare
Education level	
Short course related to fish farming	33.54 % (n = 55)
Tertiary level college with training related to fish farming, farm management and agriculture	30.65 % (n = 50)
Tertiary level college	20.25 % (n = 33)
Complete secondary school	13.95 % (n = 23)
Complete primary school and incomplete secondary school	1.10 % (n = 1)
Incomplete primary school	0.51 % (n = 0)
Never been to a formal school	0.00 % (n = 0)
Experience	
More than 5 years	79.65 % (n = 132)
Over 3 years – 5 years	19.24 % (n = 31)
1 – 3 years	1.00 % (n = 1)
Less than 1 year	0.11 % (n = 0)

Source: Researcher (2018)

Farmers stock either one or both species in one pond but when they intend to stock both species, they first introduces *O. niloticus* and later *C. gariepinus* after 3 months from the time of introduction of *O. niloticus* at the ration of 1:10 (*C. gariepinus* to *O. niloticus*). Here, *C. gariepinus* controls the population of *O. niloticus* by preying on their newborns. He also said that the mini-fish processing plant in Kakamega Town prefers *C. gariepinus* because of its large amount of flesh.

Plate 2. An unstocked fishpond in Lurambi Sub-county, Kakamega County, Kenya

Source: Researcher (2018)

The Fisheries Director, Kakamega County revealed that majority of the fish farmers stock males only in one pond because males especially of *O. niloticus* grow faster than females by about 30 %. These males end up having a relatively uniform size at harvest. He also said that sex is an important consideration in stocking fish and a farmer can stock either one sex only in one pond or both sexes in the same pond. He said that mono sex culture is important because the fish do not spend most of their time and energy in reproduction but these time and energy are spend in feeding and growth. He, therefore, said that some farmers adopt sex reversal mechanisms where they induce some chemicals into their fishponds in order to reverse the sex of any female fingerlings of Nile tilapia in stocked fishponds. He said that stocking the same age in the same pond controls cannibalism and ensures relatively uniform size at harvest that makes pond management and harvesting easier.

According to the Fisheries Director, Kakamega County, Kakamega County Department of Fisheries recommends fish farmers to the three accredited hatcheries in the county not only because they have good-quality fingerlings but also because of two other reasons. First, because they are found within the county and, therefore, near most fish farms and second as a way of promoting the local economy.

The Fisheries Director, Kakamega County also said that the recommended stocking density for *O. niloticus* is 3 fish per m^2 while that of *C. gariepinus* is 4 fish per m^2. With this stocking density, *O. niloticus* takes an average of 7 months to reach harvesting maturity while *C. gariepinus* may take slightly less months since it is a heavy feeder. Majority of the fish farmers, therefore, stock their fishponds only once in a year. He said that the Department of Fisheries of Kakamega County is looking for partners who will be able to supply farmers with bigger fingerlings in an effort to enable farmers harvest their *O. niloticus* after 6 months and thus encourage more farmers to have two breeding seasons in a year and this will increase the annual returns from fish farming.

Farmers in all the focus group discussions (FGDs) said that they have benefited from fish farming in many other ways other than fish as a source of food and as a source of income. They said that fish farming has ensured efficient use of wetlands and has provided employment to members of the family and, therefore, reduced idleness that often leads to vices such as theft and conflicts and sometimes crime. The farmers also said that they allow a period of at least one month between successive harvests in order to enable them clean up the fishpond, repair it where necessary and mobilize fingerling for the next season.

The findings here are similar to the findings by Debnath Biswajit (2011) that higher and proper fish seed stocking leads to higher production provided other inputs and management practices also support hand in hand. The selection of good-quality fingerlings is important in ensuring high fish yields (Ike and Chuks-Okonta, 2014). Agbei *et al.* (2016*)* reports that the quality of fingerlings determine fish adaptability, survival rates, growth rates, culture period, marketability and economic returns.

Management of Production Units

The study revealed that earthen ponds are the widely used fish production facilities in Kakamega County. They are used by 89.60 % (n = 344) of the fish farming households interviewed. This is because earthen ponds are cheap to establish. PVC-lined ponds are used by 8.10 % (n = 31) of the fish farming households interviewed, concrete tanks by 1.80 % (n = 6) and tanks by 0.50 % (n = 1). PVC-lined ponds are preferred because they prevent water loss through seepage.

The concrete tanks and tanks are expensive to establish and therefore not preferred by the fish farmers. These results go along the findings from the Kakamega County

Department of Fisheries that earthen ponds account for 90.00 % (n = 7,502), PVC-lined ponds for 8.0 % (n = 666) and each of the concrete fishponds and tanks for 1.0 % (n = 83) of all the fishponds in Kakamega County.

Most of the fishponds are located near rivers and streams. These fishponds represent 98.60 % (n = 378) of the fishponds in the households interviewed. This is because rivers and streams are free sources of water for fish farming in Kakamega County. Farmers construct their fishpond near rivers and streams in order to reduce the costs of piping or channeling water to the fishponds. Another 1.40 % (n = 378) of the fishponds are located away from rivers and streams. These were mostly concrete fishponds and tanks and a few PVC-lined fishponds. Fish farmers with these fishponds use pipes to get water into their fishponds.

Of the fishponds, only 1.30 % (n = 4) were located on steep slopes. Fish farmers do not prefer steep slopes because it is expensive to construct fishponds on steep slopes. It is also expensive to pump water to high levels. In addition, 48.50 % (n = 186) of the fishponds, are located on gentle sloping lands and 49.20 % (n = 188) on flat lands. Fish farmers prefer gentle sloping lands and flat lands that lie below the river level because it is easier to get water into these fishponds by gravitation free flow. There were no fishponds located as barriers on either rivers or streams. Fish farmers do not prefer to establish fishponds as barriers on either rivers or streams because of fear of fish being washed away when the rivers or streams floods.

There was no correlation between the type and location of fishpond and the fish production in yield per hectare. A Chi-square test ($\chi^2_{4,\ 0.05} = 12.29$, $p = 0.016$) of independence showed that annual returns per hectare from fish farming and size of fishpond are significantly ($p < 0.05$) related. This implies that a bigger fishpond or area under fishponds is likely to give more annual return per hectare than a smaller fishpond or area under fishponds. Only 20.57 % (n = 78) of the fish farming households interviewed had the highest fish production of 13,000 Kgs per hectare. The study then sought to establish the experience, the education levels, the training and the fraction of the average annual income of the household that farmers invest in upgrading fish farming of households that had this highest production. Table 6 presents these results. It is clear from the results that the fish farming households that record the highest production of over 13,000 Kgs per hectare are mostly the ones that invest bigger fractions of their average annual income in upgrading fish farming. These households also have their household heads and fish farm managers having higher education levels and other trainings related to fish farming, farm management and agriculture and too have experience of over three years in fish farming.

The farmers who keep records for their fish farming enterprises represent 86.20 % (n = 331) of the farmers interviewed. The records included records on stocking, feeding, harvesting and marketing. Keeping farm records is important because it helps the fish farmer to follow-up, monitor and evaluate the performance of the enterprise.

According to the Kakamega County Director of Fisheries, the recommended fishpond dimensions are 1.50 m and 1.00 m for the deeper and shallow ends respectively. The department also advices the fish farmers with earthen fishponds to make earthen embankments that rise at least 1 ft above the ground level to surround the fishponds and help prevent flooding that often carry away fish. They also must make overflow outlets. This Key Informant Interview (KII) also reported that earthen fishponds dominate the county because they are cheaper to construct. The PVC-lined fishponds, concrete fishponds and tanks are best for areas where water is inadequate. They are, therefore, best for fish farmers whose land gradient does not permit free flow of water from the natural environment into the fishponds and, therefore, locate their fishponds away from streams and rivers. These require heavy financial investments in water pumping and piping systems. A Key Informant Interview (KII) with an official from Aquaculture Association of Kenya (AAK) pointed out that farmers sometimes abandon their fishponds if they do not realize the income that they expected to make when they were starting fish farming.

Table 6. Experience, education levels, training and fraction of the average annual income of the household that the household invests in upgrading fish farming of the fish farming households that have the highest fish yield of 13,000 Kgs per hectare in Kakamega County, Kenya

Demographic characteristics	Percentage with fish yield of over 13,000 Kgs per hectare
Education level	
Short course related to fish farming	30.58 % (n = 24)
Tertiary level college with training related to fish farming, farm management and agriculture	29.21 % (n = 23)
Tertiary level college	23.21 % (n = 18)
Complete secondary school	14.90 % (n = 11)
Complete primary school and incomplete secondary school	2.10 % (n = 1)
Incomplete primary school	0.00 % (n = 0)
Never been to a formal school	0.00 % (n = 0)
Experience	
More than 5 years	37.32 % (n = 29)
Over 3 years – 5 years	29.24 % (n = 23)
1 – 3 years	16.88 % (n = 13)
Less than 1 year	16.56 % (n = 13)
Fraction of the average annual income of the household that is invested in upgrading fish farming	
Whole	1.45 % (n = 1)
More than ¾ but less than whole	27.32 % (n = 21)
More than ½ to ¾	25.45 % (n = 20)
More than ¼ to ½	15.56 % (n = 12)
Less than ¼	23.23 % (n = 18)
None	6.99 % (n = 5)

Source: Researcher (2018)

A Key Informant Interview (KII) with the Fisheries Director, Kakamega County revealed that the common diseases affecting fish in Kakamega County are white spot disease and fin rot also known as white cotton disease. These are fungal and bacterial diseases respectively and their major cause is poor water quality. He added that the department recommends keeping the fishponds clean and avoiding overcrowding through stocking as recommended as a preventive mechanism for these diseases. He continued that stress affects fish feeding and consequently growth. He however pointed out that since fish stays in water and farmers have very little interaction with them, they may not notice that any fish is sick unless it becomes week or dies and floats on water.

Farmers in an focus group discussion (FGD) at Khwisero pointed out that ESP, KAPP/ KAPAP and other government programmes that promoted fish farming in the county had their fish farming cross-margins based on a 300 m^2 fishpond.

These fishponds had a gently slanting bottom with the deeper side near the outlet and the shallow side near the inlet for ease of harvesting. The focus group discussion (FGD) in Lugari revealed that farmers abandon their fishponds due to challenges in management.

According to all the focus group discussions (FGDs), the location of the fishponds near rivers and streams is strategic in ensuring efficient supply of water since most of the farmers have inadequate resources to invest in water, water piping and water pumps. These focus group discussions (FGDs) also revealed that farmers do not establish their fishponds as barriers on rivers and streams because they have been informed that this is illegal and that the fishponds become prone to flooding during heavy storms which takes with it fish into the natural environment. The farmers in all the focus group discussions (FGDs) also pointed out that the location of their fishponds and the orientation of the fishpond bottom did not greatly affect the fish yield.

Farmers in all the focus group discussions (FGDs), named some of the main predators to their fish. They named birds, oaters, man, monitor lizard, snakes, other fish, tortoise, water beetles and frogs. Table 7 gives a list of these predators and some of the ways that the farmers use to manage the predators.

According to the focus group discussion (FGD) at Khwisero, children and trespassers are the most common thieves. The children often use hooks even in fenced off fishponds. One of the farmers (Participant 1 from Khwisero, July 6, 2017) during this interview stated that:

> "We sometimes have to seek assistance from wizards in order to acquire charms that can keep off thieves."

During all the focus group discussions (FGDs), farmers cited fungal infections as some of the notable diseases to fish. They attribute these fungal infections to entry of soapy water. Farmers, therefore, restrict washing clothes and other household items near fishponds and ensure the fishponds have embankments that prevent entry of surface run-off into the fishpond. Some farmers said that they use common salt instead of lime to prevent these infections.

It was observed that most of the locations of fishponds are flat and gentle sloping grounds that permit retention of water on the ground and that most of the fish farmers have adhered to the recommended dimensions of the deeper and shallow ends. It was also observed that farmers whose farms are irregular but need bigger ponds make more than one fishponds while those who have the sizes of their pieces of land too small to accommodate the size of fishpond that they need either lease land or end up having smaller fishponds.

It was observed that farmers in Kakamega County manage theft at their fishponds by fencing and regularly checking the fishponds to keep away thieves. It was also observed that some fishponds in Kakamega County are no longer operational due to abandonment. Plate 3 is a neglected PVC-lined fishpond at Luanda Dudi Secondary School in Khwisero Sub-county, Kakamega County, Kenya.

Akankali *et al.* (2011) reports that proper management of fish production systems is a perquisite for improved fish production. Shitote *et al.* (2013b) reported that 75.6 % of the farmers in Western Kenya have fishponds that are less than 300 m^2. Abiona *et al.* (2011) says that fishponds that are smaller than 300 m^2 are less economical. Fishpond location relative to topography and water source is an important factor in determining fish production because it determines how much the fish farmer will invest in sourcing water (Aurangozeb, 2019).

Table 7. Management strategies employed by fish farmers for the various predators of fish in Kakamega County, Kenya

Predator(s)	Species of fish	Management
King fisher, a bird of prey (*Namulobi* in Luhya)	Catfish and tilapia	• Keeping the water level high at all times so that it cannot easily spot the fish • Use of scarecrows • Use of predator net
Heron, a bird of prey	Catfish and tilapia	• Keeping the water level high at all times so that it cannot easily spot the fish • Use of scarecrows • Use of predator net
A unique duck that swims under water	Catfish and tilapia	
Black mamba snake	Catfish and tilapia	• Putting fresh cow dung in a manila sack and tying at the end and immersing near the walls of the pond so that the smell of the dung can repel the snake • Clearing bushes around the fishpond
Frogs	Fish eggs, fry, fingerlings and small fish	Controlled feeding
Tortoise	Fish eggs, fry, fingerlings and small fish	Controlled feeding
Other fish (catfish)	Tilapia	Introduce catfish fingerlings in the pond when tilapia has grown to a size that it will not be preyed on by catfish, three months after stocking with tilapia
Water beetles	Fry	

Source: Researcher (2018)

Plate 3. A neglected PVC-lined fishpond at Luanda Dudi Secondary School in Khwisero Sub-county, Kakamega County, Kenya

Source: Researcher (2018)

Fish Feeding

Majority of the fish farmers in Kakamega County representing 68.10 % (n = 261) of the fish farmers interviewed have semi-intensive aquaculture systems where they stimulate the growth of natural feed mostly phytoplankton through fertilization and liming and supplement them with household feeds and artificial feeds bought from local aqua-shops. Most of these farmers prefer this small-scale type of fish culture because it is easier to manage although it uses high amounts of inputs. These farmers have enough capital to purchase artificial feeds. The phytoplankton serve as a base of the food chain. Very few of these farmers represented by 11.20 % (n = 43) have intensive aquaculture systems where they depend entirely on artificial feeds bought from local aqua-shops. These farmers too have enough capital to purchase artificial feeds.

Other farmers represented by 20.70 % (n = 79) of the fish farmers interviewed have extensive aquaculture systems where they depend entirely on naturally growing or occurring feeds and sometimes some of them supplement these with household leftovers. These farmers have enough land to establish large fishponds and wish to economize on fish feed input due to constraints in accessing artificial feeds.

A Chi-square test ($\chi^2_{3,\ 0.05}$ = 11.46, p = 0.053) of association showed there was no significant ($p > 0.05$) relationship between culture system and fish yield. This implies that fish yield is not affected by the kind of culture system that the fish farmer uses provided the farmer uses the required fingerling and puts in place all other measures that will ensure the fishpond is properly managed.

Information collected from all the focus group discussions (FGDs) revealed that it is increasingly common among the fish farmers to apply commercial feeds in order to increase production above that which is achievable from natural productivity. The farmers apply these feeds once or twice a day in earthen ponds and slightly more than two times in tanks and PVC-lined ponds in order to ensure maximum consumption of commercial feed. In this case, there would be no wastage and leftovers. Leftovers often cause phytoplankton blooms and water quality deterioration. In all earthen fishponds, fish feed on naturally growing or occurring feeds therein because farmers do not remove them from the fishponds and, therefore, they are accessible to the fish.

Debnath Biswajit (2011) reports that different culture systems have different outputs, which depends on the other inputs and management practices that are applied. Usually an extensive or semi-intensive low-cost production technology appropriate to the available resource-base is applied (Edwards and Demaine, 1997).

Conclusion and Recommendation

The success of fish farming as an economic livelihood activity in Kakamega County depends on the proper application and appropriate implementation of fish farming management practices. These include management of water and management of the production units through appropriate stocking, feeding and record keeping.

There is need to develop and promote low-cost and economical production technologies among the farmers and provide them with suitable fish farming extension services.

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