EFFECTS OF PREDATION ON AQUACULTURE PRODUCTION IN KITUI COUNTY

ERIC MUSYA KAINDI, BSc

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DECLARATION

I understand that plagiarism is an offense and declare that this thesis is my original work and has not been presented to any other institution for any other award.

Signature: …… Date: …….

Eric Musya Kaindi, BSc

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This thesis has been submitted for examination with our approval as the University supervisors.

Signature..... Date: ……...

Prof. Titus I. Kanui, PhD.

Professor, South Eastern Kenya University

Department of Agricultural Sciences

Signature: .....… Date: …….

Dr. Grace M. Mutia, PhD.

Lecturer, South Eastern Kenya University

Department of Hydrology and Aquatic Sciences

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DEDICATION

I dedicate this work to my family. Their support throughout my academic journey has been priceless yet greatly valued. Special recognition to my Late Wife Francisca Wanza Musya who encouraged career progression through education all the time. I wish to thank my two young men for persevering with me through the entire period. I acknowledge the sacrifice and patience of my two supervisors throughout the research period.

TABLE OF CONTENTS

CHAPTER THREE

CHAPTER FOUR

CHAPTER FIVE

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABBREVIATIONS AND ACRONYMS

ASDSP	**:**	Agriculture Sector Development Support Programme
CIDP	**:**	County Integrated Development Plan
ESP	**:**	Economic Stimulus Programme
FAO	**:**	Food and Agriculture Organization
GDP	**:**	Gross Domestic Product
GOK	**:**	Government of Kenya
IFPRI	**:**	International Food Policy Research Institute
NAFIS	**:**	National Farmers Information Services
NGO	**:**	Non-Governmental Organizations
SPSS	**:**	Statistical Packages for Social Sciences
SSA	**:**	Sub-Saharan Africa
USDA	**:**	United States Development Agency

ABSTRACT

Recent developments in the agricultural field have led to the intensification of fish farming in Kenya. The value of fish in the modern-day diet has developed a market that has always been in short supply due to the high demand for fish products. However, the sector faces a major challenge of predation affecting farm productivity, which has seen some farmers dry up their ponds and look elsewhere for profitable ventures. Despite fish farmers in Kitui County experiencing challenges of predation, there is very scarce information on the types of predators, their effects, and successful control measures in the county. This study therefore sought to assess the prevalence, socio-economic impacts, and control measures of predators in fish farming in Kitui County with the most active ponds being in Kitui South and Kitui West Sub Counties, Kenya. Data was collected from 110 ponds in 7 sub-counties in Kitui County. The data collection involved the administration of questionnaires, key informant interviews, and field observations. Collected data was analyzed using both descriptive and inferential statistics whereby inferences were made informing the study objectives and making conclusions. The study found that fish predation is at 93% level, with major predators being birds, reptiles, domestic animals, and wild animals like mongoose, with birds being considered the worst predators. The study found that 86% of the fish farmers have various predator control measures, overhead nets, fences, and scarecrows in the place where 57% of men operate them while women constitute 27%. The various predator control measures employed are only 37.9% effective leading to 69.5 % of the fish farmers experiencing financial losses. Farmers in Kitui County employ various measures to control fish predation including fencing, the use of overhead nets, and the use of scarecrows; which means they are able to integrate separation, exclusion, and deterrent techniques of predator control in their farms. Due to predation, the study confirmed that fish farmers face deteriorating socio-economic conditions as a result of the losses and costs incurred in predator attacks and control. The study recommends that County Government of Kitui should integrate predator control training in their extension programs and prepare farmers getting into aquaculture to be ready to integrate predator control measures. Predator control innovations should also be developed to reduce the costs of controlling fish predators in the region. Further study should be undertaken to allow the application of the study outcomes in other counties in Kenya.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

Fish is an important resource as it is widely linked to food security, income generation, employment and foreign currency earnings globally (FAO, 2019; Halasi, 2018). With the dwindling returns from large-scale fishing (within natural fish sources such as rivers lakes, and oceans), fish farming (aquaculture) has been widely considered an important economic undertaking (Munguti, *et al.*, 2022). Fish production is rated the fifth most important agricultural activity accounting for 7.5% of total world food production. In addition, it is estimated that about 1 billion people in developing countries depend on fish products as the primary source of animal proteins (FAO, 2019). Recent developments in food and nutrition have raised the demand for fish as it enhances access to the provision of an alternative source of animal proteins. Additionally, capture fish (from lakes and seas) is low and facing a decline, while human population has been increasing over the years (Nyanjui, 2020). This has led to the growing popularity of aquaculture as an agricultural production method with fish farming becoming a lucrative venture due to the rising demand and the ready market.

Fish farming offers an alternative source of protein and income to many communities, particularly women and the youth, since it can be integrated with other existing farming systems (Taconet, *et al.*, 2019). The global fish production is estimated to be 148.5 million tonnes per year of which capture fisheries accounts for 88.6 million tonnes and aquaculture 59.9 million tonnes per year (FAO, 2022). The Food and Agriculture Organization (FAO) of the United Nations has estimated that more than 30% of all fish used for human consumption originates from aquaculture comprising mainly of herbivorous species, such as tilapia, carp and carnivorous cat fish. Production of fish in fresh water stands at 60% of the world fish output, (FAO, 2022). This comprises water tanks and ponds with other forms of fish farming such as cage farming, mostly found in Asia and China. In countries with abundant water resources and fish protein demand, fish farming has been faced with steady growth in production (FAO 2018).

Globally fish production of fish products is 214 million tonnes with 178 million tonnes of aquatic animals and 36 million tonnes of Algae,130.9 million tonnes are produced from Aquaculture and 79 million tonnes from marine capture (SOURCE: FAO. 2024. FishStat: Global aquaculture production 1950–2022. [Accessed on 29 March 2024]. In: FishStatJ. Available at: www.fao.org/fishery/en/statistics/software/fishstatj.Licence:CC-BY-4.0.) Asian countries produce 83million tonnes but, the Sub-Saharan Africa (SSA) contributes 7.7 million metric tonnes (Kawarazuka & Bene, 2020). Freshwater fish in SSA provide important animal proteins for the populace. Farmed fish is increasingly becoming a main source of fish protein under intensive and semi-intensive conditions. The SSA human population is increasing at a steady rate of 4% per annum and requires improved nutrition from food resources like fish for high-quality proteins (Nora, 2018). In East Africa, aquaculture is increasing rapidly, with Tilapia and Catfish being the most farmed fish. (Mwamuye, *et al.,* 2021).

According to Hetland (2018), the economic viability of fish farming became widely recognized as observed in countries like Israel where more than half the fish eaten in the country are produced from fish farms. Similarly, 25% of fish in China and India, 11% in the USA, and 10% in Japan of fish consumed are aquaculture products. In developing countries, fish farms not only improve a nation's diet but also bring income to small-scale farmers and create employment, especially within rural areas. Fish culture has been proven successful in improving rural farmers' living standards in Asia, where fish culture has a long tradition (Shinn, *et al.,* 2018). Pérez Roda *et al.,* (2019) noted that more recently, a new wave of optimism for aquaculture in Africa had been observed with several privately funded tilapia farming projects showing promise.

Fish farming in Kenya began in the 1920s, initially raising Nile Tilapia and later including the Common Carp and the African Catfish. In the 1960s, the Kenya Government popularized rural fish farming with the stocking of dams, rivers, and other water reservoirs. Later construction of many small ponds of 300 meters square each were initiated through the ESP project in 2015. As a result of this effort, tilapia farming expanded rapidly in Kenya’s Central and Western Provinces (Mwamuye *et al.,* 2015).

However, the number of productive ponds declined in the 1970s, due to inadequate extension services, a lack of quality fingerlings, high fish losses from diseases and predators, and insufficient training for extension workers. Until the mid-1990s, fish farming in Kenya followed a pattern similar to that observed in many African countries, characterized by small ponds, subsistence-level management, and very low levels of production (Ngugi *et al.,* 2017). The establishment of the Economic Stimulus Programme (ESP) in 2010 revitalized aquaculture in Kenya, leading to the renovation of several government fish-rearing facilities, the establishment of research programs to determine best practices for pond culture, and an intensive training program for fisheries extension workers, leading to renewed interest in fish farming (Munguti *et al.,* 2014). The government rolled out in the first phase Ksh.1.12 billion to support fish farming activities in the country and constructed 200 Fish ponds in each of the 140 constituencies to reduce poverty through the Economic Stimulus Programme (GOK, 2015).

Fish farming led to improved nutritional status among vulnerable people, more prospects for work and income, and regional development in rural areas over the past ten years (Cheserek et al., 2022). Increasing from 12,152 tonnes in 2010 to 22,140 tonnes in 2022, aquaculture production now represents 12.7% of the nation's total fish output. The Kenyan government allocated KES 3.986 billion for the Fish Farming Enterprise Productivity Project (FFEPP) under the Economic Stimulus Program (ESP) in two phases for pond construction, the supply of fingerlings and pond stocking, the acquisition and supply of fish farming inputs and specialized equipment, as well as capacity building and extension support services (Musa *et al*., 2012). Growing from 12,152 tonnes in 2010 to 22,140 tonnes in 2022, aquaculture production now represents 12.7% of the nation's total fish output.

The sector supports about 1.5 million people, including their dependents, are directly and indirectly supported by the industry as fishermen, traders, processors, suppliers, and merchants of fishing accessories (GoK, 2022). In all, 174,000 tonnes of fish were produced in the nation through capture fisheries and aquaculture in 2022, amounting to KES 37.5 billion (KNBS, 2023). Aquaculture contributed 31.1 billion of the production

overfishing, biodiversity loss, and pollution, particularly in the territorial seas, are causing the wild catch, on which the fishing industry is overly dependent, to be caught less frequently. Due to a production base of 180,000 to 240,000 tonnes, the sector is unable to meet Kenya's yearly demand for fish, which is now anticipated to be between 550,000 and 600,000 tonnes (Obiero *et al*., 2019b). Between predicted demand and domestic fish production, there is a sizable gap that is only partially filled by fish imports. Nile Tilapia (*Oreochromis niloticus*) and Cat Fish (*Clarias gariepinus*) species are the main fish species reared in ponds within Kenya. The two fish species have developed to be a major source of food for humans globally. *O. niloticus* makes up the bulk of Kenya's aquaculture fish production while *C. gariepinus* is the second most commonly produced fish in Kenyan aquaculture (Blaha, 2017).

Both are usually produced in semi-intensive static ponds with the optimal water temperature for the culture of African catfish being 30°C and that of *O. niloticus* being between 20˚C and 35°C (Gachucha *et al.,* 2019). Fish farming is mainly in the form of rural subsistence farming with few large-scale commercial operations undertaken. Different fish culture systems are employed ranging from extensive, semi-intensive, intensive, monoculture, polyculture, mono-sex culture, and mixed-sex culture depending on farmer resources, site characteristics, environmental conditions, socioeconomic factors, technical knowledge- how, and market demand (Ngugi *et al.,* 2017).

Nevertheless, despite the increasing production and rising demand for fish and its products, fish farming faces challenges, just like in other agricultural production. Fish predation is currently a major concern to fish farmers and fingerling producers, affecting not only the farm productivity but also the value of the investment due to additional control measures installations. In a study on the state of fish farming in arid and semi-arid regions, Musyoka & Mutia (2016) found that more than 35% of the respondents thought that fish predators were a major issue. King Fisher, pelicans, toads and frogs, snakes, and monitor lizards were mentioned as some of the most common fish predators. They observed that 73% of the ESP-funded fish ponds in Makueni County have so far been completely abandoned, while 11.3% are partially abandoned, with only 15.3% being

functional, a key cause of this being predator attacks. Similarly, Oloo (2019) found that aquaculture farmers in the ESP faced challenges in terms of predatory animals while one of the greatest costs keeping farmers away from fish farming was noted to be predator control installations at the fish farm. However, fish farming retains the greatest potential for reducing the national fish deficit, hence to benefit from the high fish demand, the presence and management of predators ought to be understood to avoid and minimize the occurrence of losses.

1.1.1 Fish Farming in Kitui County

Kitui County is in the lower eastern part of Kenya and towards the southeastern side of the Kenyan capital city, Nairobi. The County has a population of 1,136,187 as per the 2019 census and an area of 30,429.6 km^2. The county is considered arid and semi-arid with poverty levels of about 47.5% according to the Kenya Bureau of Statistics 2016. Indeed, alternative sources of food more so protein-rich foods are required. The County Integrated Development Plan (CIDP, 2018-2022) has widely observed the need and planned for the development of fish farming as an economic undertaking and as one of the poverty alleviation mechanisms. Nile Tilapia and African catfish are the two most important farmed fish in Kitui County. According to the Kitui County Reports (2022), the fish production from ponds ($300M^2$ each) in the County has been estimated to be 18 tonnes, valued at Ksh. 26,532,800.

In anticipation of the growing world market for fresh and frozen fillets, it is necessary to safeguard their production by preventing possible losses due to predation by known and unknown predators in the region. Kitui County has a conducive environment for producing both Tilapia and African catfish. Still, fish predation information, which is not currently available, is necessary for farmers and planners to be informed on possible scenarios during production planning. Though faced with many challenges such as water availability and lack of equipment, the fish production sector in the County is growing with subsequent support from the county government. Kitui County having individual poverty levels of 35% needs new avenues for farm investment like aquaculture (Figure 1)
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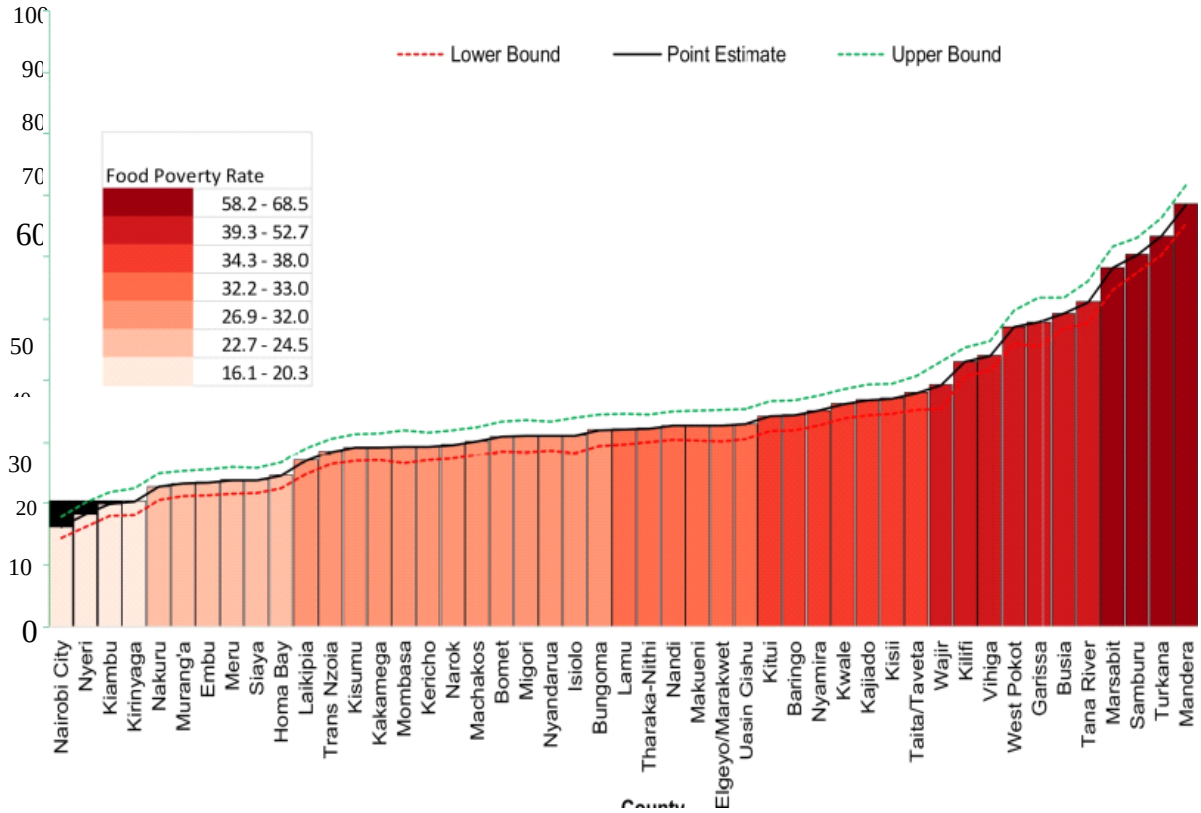

Figure 1: National individual poverty levels: Source KBS 2021

1.2 Statement of the Problem

Information on fish predators is scarce, at the regional and local levels even for the known high-production areas like Sagana and Western Kenya regions. Predator problems may be localized since predators living in certain areas are unique to those regions. Studies have not been carried out to inform planners and investors about the distribution and impact of fish predators in Kitui County. Farmers and extension staff need to be informed on the dangers of predator attacks, economic impacts, and their control mechanisms within the region in a bid to improve production and economies of scale. This study, therefore, sought to establish if predators have a significant effect on aquaculture production in Kitui County. The study was done in Kitui County and offers a baseline for the type of fish predators prevalent in the county, where the areas selected are the ones with active fish ponds in the year 2019 to 2023.

1.3 Objectives of the Study

The main objective of the study was to establish the impacts of predation on aquaculture production in Kitui County.

The specific objectives of the study include:

i. To Determine the prevalent types of fish predators within Kitui County;
ii. To establish the predator control measures applied in Kitui County;
iii. To determine the socio-economic impacts of predation among the fish farmers.

1.4 Research Questions

The study seeks to find answers to the following questions:

i. What are the prevalent types of predators attacking fish in fish farms within Kitui County?
ii. Which methods are used for predator control by fish farmers in Kitui County, if any are in use?
iii. What is the socio-economic impact of fish predation to fish farmers within Kitui County?

1.5 Significance of the Study

This study provides information on the impact and prevalence of predators in farmed ponds in Kitui County. This information is beneficial to the fish farmers in the entire Kitui County. Predators eat away the productivity of fish farming ventures and therefore their control and management would widely be of benefit to fish farmers. The study offers fish farmers vital information related to predators within the county and the available options to control them which they can apply in their farms.

The study informs the policy makers and extension workers within the aquaculture industry in Kenya on the extent of fish predation in Kitui County. The study provides information that can be used to influence the fish farming policies, operations within the country and therefore contribute towards policy framework, informing policy makers within the sector. Policy makers can use the information from this study to come up with

relevant policies and regulations to curb and mitigate losses caused by fish predators in Kitui County and in other parts of Kenya.

The study provides an independent and impartial assessment of the prevalence of fish predators within Kitui County. Future studies can utilize the findings of the study as the basis for further research and Policy decisions in the sector in Kitui county. The findings also offer solutions leading to increased food production as alternative protein sources in the County.

1.6 Limitations

The study covered seven sub-counties out of the eight sub-counties of Kitui. Kitui East sub-county ponds were not available as they had dried up due to lack of water.

1.7 Scope of the Study

The respondents of the study were from within the Kitui Central, Kitui South, Kitui Rural, Mwingi West, Mwingi Central, Mwingi North Sub Counties, Fisheries extension staff from the county headquarters and the eight Sub Counties formed part of the information source. 120 fish ponds formed the 110 households that were interviewed as respondents. These formed the active and stocked ponds.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Global Status of Aquaculture

At the global scale, fish and fish products are the most important sources of protein. Over the past three decades, aquaculture has developed to become the fastest-growing food-producing sector in the world. It is estimated that more than 30% of fish for human consumption comes from aquaculture (Håstein *et al.,* 2016). A large proportion of fish products come from small-scale producers in developing countries. More than 80% of global aquaculture products are produced in fresh water (FAO, 2019). From its early development in Asia, aquaculture has undergone development and is today highly diversified. Asia and Latin America are currently the two major producing regions while Sub-Sahara Africa has the least global production (FAO 2022). The production of fish from the African continent totaled approximately 79,500 metric tons in 2008; 57% of this was produced by three countries bordering the Mediterranean, with Egypt producing the most (i.e. 43,000 tons). Thirty-three sub-Saharan countries produced the remaining 34,000 metric tons, of which 93% can be attributed to 6 countries, which include Nigeria (16,700 tons), South Africa (4,500 tons), Zambia (4,100 tons), Zimbabwe (3,800 tons), Namibia (1,300 metric tons) and Kenya (1,100 tons) (Hetland 2018).

Fish farming in the world has evolved into a profitable enterprise. It feeds millions of people daily and sustains many through employment in services related to fish and fish products. The nutritional attributes of fish are high, as it is rich in essential amino acids, has high-quality vitamins and its fatty acid fraction have well-established health benefits (anti-thrombotic activity) (FAO 2013). Therefore, fish availability in many developing countries enables significant access to a healthy and balanced diet. It is estimated that around 60% of the population in many developing countries derive over 30% of their animal protein supplies from fish, while almost 80% of the population in most developed countries obtain less than 20% of their animal protein supplies from fish (FAO, 2022). The role of aquaculture in food production, economic development and food security is

therefore increasingly becoming important in the developing countries and the whole world in general.

The International Food Policy Research Institute, IFPRI (2020), which carried out annual consumption forecasts, observed that seafood consumption will increase to about 1.5 kilograms (Kgs) per person per year by 2020. This is an indication that the demand for seafood products will be considerably higher in the near future than it is now, with more than 10 million metric tons of additional seafood being consumed each year (assuming no increase in the human population). Over the same time period (2010 – 2030), FAO (2019) postulated that the harvest from natural fish stocks will remain static or decline due to worsening environmental conditions, poor fishing methods and overfishing. Fish and fish products are the most traded food commodity. World fish trade has developed rapidly in the last three decades, increasing from a US$8 billion in 1976 to US$101.8 billion in 2008 (FAO 2021). In real terms (adjusted for inflation). fish exports increased by 104 percent between 1985 and 2008, including a 50 percent increase in the period between 1998 and 2008 (FAO 2021). Indeed, more than one-third (39 percent live weight equivalent) of total annual production enters into the international trade.

About 50 % (US$50.6 billion) of that international fish trade by value originates in developing countries, where it represents an important source of foreign exchange earnings and employment opportunities. Net fish exports (i.e. the total value of exports less the total value of imports) from developing countries have increased significantly in recent decades, growing from US$1.8 billion in 1976 to US$26.5 billion in 2008 (Hetland, 2018). Aquaculture is therefore observed to harbor a great potential for growth and has been seen to improve significantly over the years. Though there is an emerging possibility of a future decline due to challenges arising in the sector, such as diseases, parasites and predator attacks which eat away on the gains from the venture.

2.1.1 Fish Farming in Kenya

Although aquaculture has been the fastest growing food-producing sector globally, its contribution to Kenya’s total fish production is still insignificant (Karimi, 2021). Dismal

aquaculture production coupled with declining catches of indigenous fish species (Wild catches) has increased the gap between supply and demand of fish in Kenya. Unlike the indigenous fish species that were easily harvested by the local fishers, the fishery of the alien Nile perch that dominates the Lake Victoria catch require some expensive gear and crafts for harvesting this large species of fish (which majority of fisher folk cannot afford). Much of the Nile perch catches go for processing. The supply of fish and fishery products in this region is declining while compared to the demand (Njeru, 2016). For food security and improved nutrition there is a need to develop a sustainable aquaculture industry through production of high quality, indigenous wild catch fish to supplement capture fisheries.

Kenya has a great potential for pond-based aquaculture of *O. niloticus and C. geriepinus.* It is estimated that 2 million metric tonnes of fish are harvested annually in Africa accounting for 2.6 % of the global aquaculture production (Akoll & Mwanja, 2022). However, in 2008 this potential was by no means fully explored despite about 30 years of various aquaculture extension services (Ngugi *et al*., 2017). The future of aquaculture is bright considering that many people are increasingly turning to fish as a source of their animal protein. With this increase in demand for fish and the decreasing catches from natural sources, aquaculture is destined to become an important alternative to traditional agricultural practices.

Support for aquaculture development in Kenya comes from the Government of Kenya (GoK) and county governments, also from within the industry, the private sector and a number of Non-Governmental Organizations (NGOs) (Rothuis *et al.,* 2019). In the year 2006 alone, the fisheries sector contributed 0.5% of the Kenyan GDP while in the year 2005, it registered a 4.1% growth in the sub - sector (Mbugua, 2018). In 2009, the development of aquaculture became part of the GoK's Economic Stimulus Programme (ESP), to commercialize this subsector of Kenya's economy (Manyala, 2011), and improve the nutritional situation of the farmers and create employment (TISA, 2010). Fish pond construction costs as well as the costs for feeds and fingerlings were subsidized through the programme. Additionally, governmental infrastructure supporting the

aquaculture sub-sector, i.e. trainings, research farms and extension officers, is in place (Hino, 2021). This program led to an increase in the number of farmers engaged in fish farming as well as to increased fish production (FAO, 2013). On a global scale, however, Kenyan aquaculture production is still insignificant (Rothuis *et al.,* 2019).

Top-down government support policies for aquaculture development sometimes prove to be unsuccessful in terms of increasing production (Russell *et al.,* 2020). Traditionally the major fish consumers have been the Luo ethnic group, inhabiting areas around Lake Victoria. The demand for fish has increased fast because more and more people have embraced fish on their household menus and aquaculture production is widespread throughout the country (Rothuis, *et al.,* 2019). Owing at least partially to aquaculture development, significant improvements in livelihoods were recorded between 2004 and 2011 among fish farmers (Nora, 2013). The aquaculture sector provides employment and income to over 500,000 Kenyans engaged in fish production, fish trade, industrial fish processing, and related enterprises.

2.2 Predators in Fish Farming

Fish farming produces fish and fish products for markets under controlled conditions or semi controlled conditions. The success of fish farming business has also attracted predators. Rothuis *et al.,* (2019), noted that the controlled or semi controlled conditions are conducive to the survival of predators. Fish predators are hard to control as some of the control measures fail to deter predator attacks. Fish predators have both direct (such as instances where they attack and kill fish in the pond) and indirect (such as cases where they transfer diseases to the ponds) effects. Losses due to fish predator attacks is particularly high in the tropics where mitigative intervention is limited. The risk of losing profits due to predator attacks is already manifesting in many fish farms especially in areas where there is extensive fish farming and conditions for the thriving of predators are manifested (Akoll & Mwanja, 2022).

Direct damage results when the fish or other cultured organism is killed or seriously maimed by the predator and is therefore lost from production. Indirect damage is highly

variable and includes: non-lethal wounding of fish; chronic stress with a consequent reduction in feeding efficiency or health; transfer of harmful disease-causing organisms, including bacteria, viruses and parasites; and sometimes even physical damage to the animal enclosure system leading to escape. Often, the indirect damage caused by a predator can result in a greater economic loss than that caused by direct damage. For example, a mongoose which tears a hole on the net cage and eats a few fish is a small loss compared to the pending escape of potentially large numbers of the remaining fish. In addition, the loss of "disease free" status of a farm because of transfer of an exotic pathogen by predatory bird for example, can far exceed the value of any fish consumed by this same predator. So, the total extent of damage to an aquaculture stock by predators can be highly varied and extremely costly depending on many other factors.

Some predatory animals have a high capacity for causing damage which may cause significant economic losses for the farmer. Impacts by birds for example, have been estimated to exceed several million dollars per year (Nora, 2013). Detailed knowledge of the negative effects of any given predator at aquaculture sites require an assessment of the predators' population biology, feeding behavior, aggressiveness, and the likelihood of effective control measures existing to control damages (Akoll & Mwanja, 2022).

Birds, fish and mammals are known predators of cultured fish with bird predation being a major source of fish loss at aquaculture facilities. African rock pythons stopping at the ponds to drink water sometimes attack the fish. Turtles, nocturnal birds and kingfishers also prey on fish, and can clean a whole pond of its stock, but the worst of all are water beetles, which sometimes swarm at the onset of the rains. The bugs feed on the insides of fingerlings, young fish 10-15 centimeters (4-6 inches) in length, leaving a floating mess of dead remains. Some bird species represent a unique hazard to aquaculture because of the potential for this predator to travel vast distances between farms. This may result in the spread of certain disease-causing organisms between farms that are otherwise geographically isolated from one another, or from wild animals to the farm stock (Musyoka & Mutia, 2016).

An additional concern to fish farmers is the potential for increases in bacterial (faecal) coliform contamination that may result from the presence of large numbers of waterfowl (both predatory and non-predatory) near fish beds. The end result is that the fish may become unsuitable for human consumption or sale. Predatory fish can also be a major concern to fish stocks, followed by mammal predation to a much lesser extent (Munguti *et al.,* 2019). The variety of predators means fish farmers need to fully understand the types and the damage prevention and control techniques available to them. The predators control measures may be used singly or in combination to alleviate the predation.

2.3 Predator Control Measures in Fish Farming

Although in many cases, farmers have a legal right to protect their livestock from predators, there are certain limitations to the type of methods employed to achieve this protection. According to Bevan, *et al*., (2022), in America, before any control method is considered, aquaculture producers have to first determine whether the predatory control is economically justified, and if federal or provincial laws protect the predatory species in any way. Most mammals and bird species are protected, to some extent, by either federal or provincial legislation, a situation that is not fully replicated in Kenya with only a blanketed regulation to avoid killing any of the wildlife. There are three main approaches to controlling predation at aquaculture sites which includes exclusion and barrier techniques, deterrents, and removal of predator by transfer or destruction.

2.3.1 Exclusion and Barrier Techniques

The separation of the cultured animal from its potential predators is the most effective solution for controlling the impacts of predation (Russell *et al.,* 2020). Several techniques exist for relatively secure containment of aquatic livestock in farming systems that use cages, raceways and tanks. These containment methods include the use of separate nets, covers, building enclosures and other types of ‘barriers’, which can range in cost from relatively inexpensive to prohibitive, depending on the size of the enclosure required (Kimberly *et al.,* 1996). Fish pond farmers on the other hand often utilize perimeter nets, guards installed at the pond bottom, and nets stretched over the tops of the pens to prevent access to water and aerial predators (Bevan, *et al*., 2022). These predator nets

provide both physical protection as well as a visible deterrent. These protection methods are rarely implemented in fish farms in Kenya due to the huge costs of implementing these control methods. It will be very important to understand which barrier techniques fish farms in Kitui Sub-Counties apply to control the prevalent predators.

2.3.2 Deterrents

A variety of the so-called 'deterrent' methods can be used to discourage predators from attacking their prey. These usually involve some form of auditory, visual or physical noxious stimuli, such as scare crows and models of other natural predators, or by the use of guard dogs, birds of prey (e.g. falcons), and noise emitting devices, laser lights and even systems to spray water to scare away undesirable species (Kimberly *et al.,* 1996). Generally, farmers can expect deterrents to reduce but not eliminate predation. For a deterrent program to be effective over the long-term, several methods need to be used in combination. Frequently, predators will habituate to most deterrents and eventually recognize them as non-threatening stimuli. For example, pre-cast models of owls, eagles, alligators and cannibal fish species have been used on farms to scare away certain bird and mammalian predators, but they quickly learn that these are not real and will ignore them, (Russell *et al.,* 2020).

In 2011, the United States Department of Agriculture in conjunction with the Animal and Plant Health Inspection Service and the Wildlife Services (USDA, APHIS and WS) undertook a joint predation assessment in the U.S.A where it was observed that in some situations of the pond system of fish culture , it is possible to reduce easy access and feeding opportunities of a predator by redesigning the culture system by introducing steeper banks and having deeper shoreline water which reduces the effectiveness of wading birds, or by limiting the availability of protective habitat for the predator to hide in. There are other methods that a farmer can apply to deter predators. Different methods used by farmers can help determine the most reliable control measure. Figure 2a represents an ultrasonic device that is triggered remotely to scare away predators in a pond. Figure 2b is a picture showing rods that swing around with the assistant of wind

and the shiny reflections scare away potential predators. These were explained by Nyaku, *et al*., (2017).

2.3.3 Removal of Predator by Transfer or Destruction

This is usually the method of the last resort when benign, non-lethal techniques fail. It involves the removal of the predator from the farm. Removal methods, when feasible, include live trapping and relocation of the predators to other suitable sites. In extreme circumstances, and usually only after other non-lethal methods of control have been exhausted, it is sometimes necessary to kill a nuisance predator, especially those which represent a high impact risk to the farmer. Wherever possible, this is accomplished using the quickest, safest and most humane method available. This is a control strategy of last resort, and not one encouraged within the aquaculture industry. Bevan, *et al*., (2022) observed that strict control measures ought to be put in place to ensure that other animals and people are not placed at risk, and also that the fish is protected as well.

Generally, farmers have a legal right to protect their livestock and other property from predation and while the legal right to destroy a predator may exist, most farmers adhere to established ethical standards, respecting the value of all animal life. Unites States Department of Agriculture, Animal and Plants Health Inspection Service & Wildlife Service (2011) observed that most fish farmers try to use preventative methods, such as net covers or other barriers, to reduce predation impacts. Predator control is a management precaution which is necessary to ensure the health and safety of captive livestock and to protect the economic interests of the farmer (Tamale *et al.*, 2020). Not unexpectedly, there are emerging ethical issues surrounding the appropriateness and effectiveness of some of the control methods being currently employed, and failure of majority of fish farmers to apply either of the methods.

Very few researchers have taken direct interest in studying issues related to Fish predators, predator control and management within the aquaculture sector hence very few studies are available for review on the same, with none being realized in Kenya. However, there are many studies which have reported the issues of predators, their

control and management, not as part of their basic objective, but as one of the outcomes within their study. Predators have been widely mentioned within the aquaculture studies as a key challenge and a key factor in the survival of the fish farms. However, a few researchers have looked at the problem of predators on fish farming.

Pemberton *et al*., (2019) undertook a study that looked at predators in marine fish farms in Tasmania. They found that physically excluding predators from the fish is ultimately the only way to prevent the loss of marine-farmed fish. They described a total of six predators that interact with the farms and proposed the necessary protection methods to be incorporated into the design of the farms before farm development to protect the farmers from losses incurred due to predation.

Another study was done by Littauer *et al.,* (2018) who looked at the control of bird predation at aquaculture facilities mainly dwelling on the strategies and cost estimates. They observed that bird predators have huge impact on productivity in fish farming and producers, but they can optimize the current control efforts by understanding and considering the logic, costs, and limitations of different techniques and by developing integrated strategies for their use. Another study by Barras (2017) assessed the avian predators at aquaculture facilities in the Southern United States where the researcher came up with a profile of each of the common bird predators within the Southern United States region, availing their management and control measures.

Nationally in Kenya, National Agricultural Farmer Information System (NAFIS) undertook a survey of disease parasites and predators dwelling mostly on their management and control in Kenya where they came up with the common parasites and the predators affecting fish farming in Kenya. They proposed the various methods through which these predators can be managed or controlled to minimize their impact on the farmer's ventures. Many other studies unintentionally came across the fish farming predator issue. One such study is that undertaken by Chen *et al*., (2020) who observed that predators attack is the key challenge fish farmers' face in developing countries and

major fish-producing countries, leading to their significant emphasis on the management and development of predator control methods in the aquaculture industry.

Akoll & Mwanja, (2022) observed that from their research carried out in Uganda, predators are the key transfer agents for infectious parasites and diseases that affect public and private fish farms. Bacterial pathogens (*Flavibacteruimsp*, *Pseudomonas sp., And Aeromonas sp*.), were observed to be transferred between fish farms by the bird predators visiting the farms with those farms protected from bird predators being less affected by the disease than those that are not protected (Akoll & Mwanja., 2022). Since a majority of the fish farms take little precaution against predators, farmed fish are susceptible to diseases, and under stress conditions emanating from predator attacks which result in low productivity. Halasi (2018) also made similar observations noting that the predator control methods practiced by fish farmers in Uganda are not very effective and not well understood due to insufficient information to guide policymakers, researchers, and farmers.

Mwangi (2018) on the other hand observed that inadequate technical skills by extension staff occasioned by low staff levels and limited practical aquaculture skills is the main constraint to commercial aquaculture in Kenya, raising specific claim on the extension workers lack of skills in integrating predators' control and management practices within the design of fish ponds in the region. Ngugi *et al.,* (2017) similarly observed the same challenges as a stumbling block towards commercial fish farming in Kenya. The two studies however did not expressly highlight how significant the factors were in influencing survival of commercial aquaculture. Similarly, one of the challenges observed by Mwamuye *et al*., (2021) is that of inappropriate pond construction techniques, which tend to be associated with higher levels of predator attacks.

Another study by Kariuki (2018) assessed the strategic practices for effective implementation of fish farming enterprise productivity programme in Kenya done in Molo County where it was found that predator management and control methods integration during pond design and maintenance is a very strategic practice that all fish

farmers ought to uphold. Patrick and Kagiri (2016) on the other hand undertook an assessment of factors affecting sustainability of fish farming projects in public secondary schools in Kiambu County, Kenya, where one of the factors affecting fish farming sustainability was observed to be diseases, parasites and predator attacks. They observed that farmers in Kiambu County loose a significant number of fish due to predator attacks prior to harvesting.

From these studies, it is clear that there is very minimal interest among researchers on the issues surrounding predator control and management at the global, regional and local levels. The study deciphers from the literature review that only a few studies, mainly done by government institutions, have been undertaken towards familiarizing with and finding solutions to the fish predators' problems. The predator management and control methods available in literature are mainly general and suitable for the common predators, but the predator problems fish farmers in Kitui County are faced with are unique and cannot be applied in most of the instances. This study therefore sought to provide answers to these existing gaps on fish predation.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Study Area

The study area was Kitui County, specifically in seven sub-counties comprising of Kitui Central, Kitui West, Kitui Rural, Kitui South, Mwingi North, Mwingi West, and Mwingi Central (***Figure 3***). The county has a population of 1,012,709 (2009 census) and an area of 24,385.1 Km².It is located in the central south of Kenya (**Figure 3 below**), between latitude 0º 3.7' and 3º 0' South and longitude 37º 45' and 39º 0' East. Kitui County shares its borders with seven counties: Tharaka and Meru to the north, Embu to the northwest, Machakos and Makueni to the west, Tana River to the east and southeast, and Taita Taveta to the south (. Located at an elevation of 1121.2 meters (3678.48 feet) above sea level, Kitui has a Tropical wet and dry or savanna climate. The county's yearly temperature is 20.51ºC (68.92ºF) which is -1.99% lower than Kenya's average annual temperature. Kitui typically receives about 96.67 millimeters (3.81 inches) of precipitation and has an average of 180.81 rainy days (49.54% of the time) annually (Everlyn Mutunga *et al.*,2022)

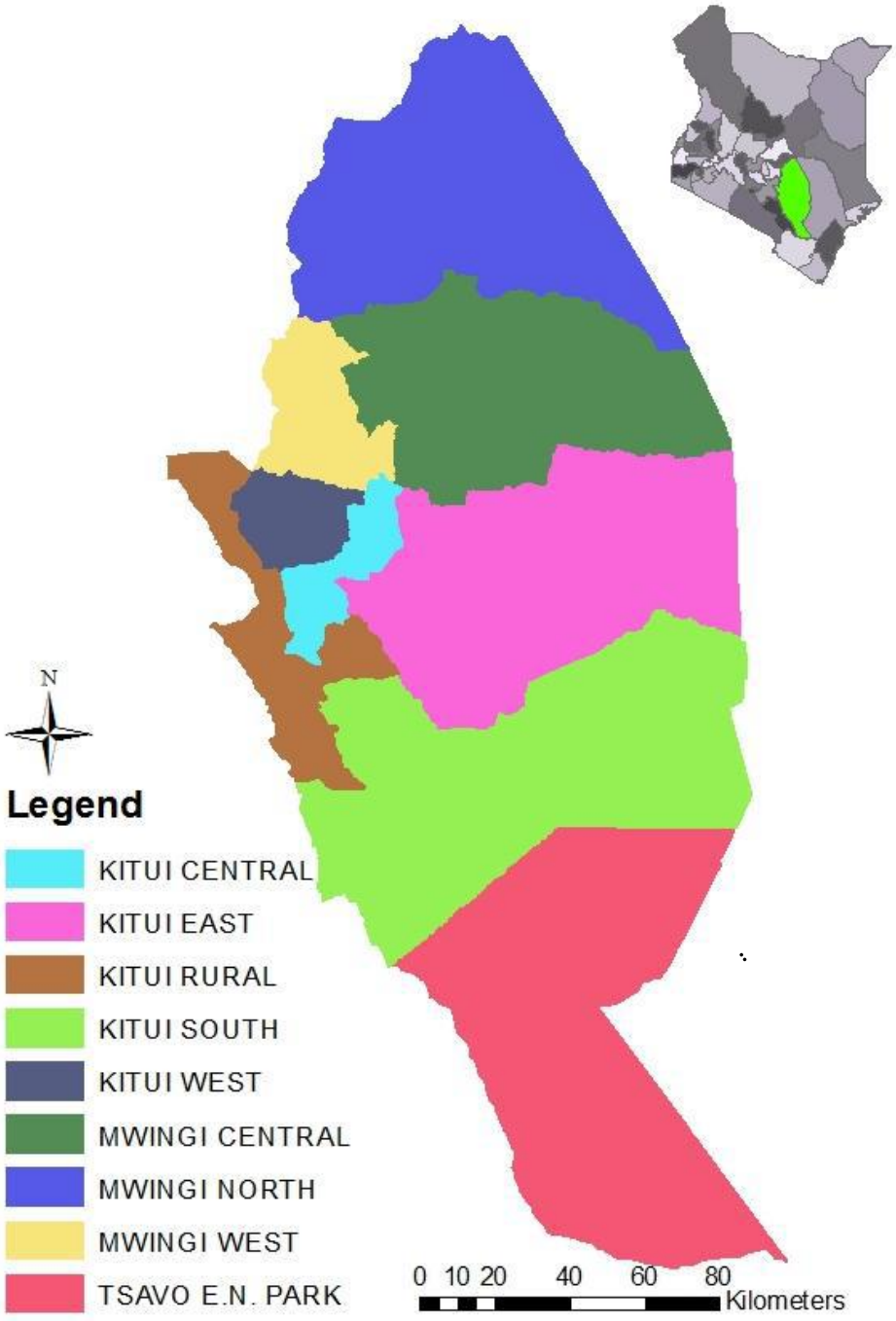

Figure 2: Kitui Map showing Sub Counties and study area (Source ASDSP Kitui 2018)

3.2 Research Design

The study adopted a mixed-method research design. This design allows the adoption of multiple ways of exploring a research problem which offers the researcher the advantage of overcoming the limitations of a single design. Through the mixed methods design, a researcher can explore, explain, describe, or experiment within the same study (Cooper & Schindler, 2018). According to Denscombe (2017), mixed methods research design emphasizes producing answers to the research problem based on data, based on real-world observation whether in the form of qualitative or quantitative formats, through a purposeful and structured approach. The study integrated both observational and quantitative methods. By adopting this design, the researcher was able to draw inferences about the status of predators' presence, and their management and control practices within the study region; hence the mixed methods research design was the most appropriate.

3.3 Target Population

A population is the total set of elements about which a researcher wishes to make some inferences; whereas population elements refer to the subject on whom the measurement is being taken (Cooper & Schindler, 2018). The population of this study comprised all the active fish ponds in Kitui County. However, the scope of this study targeted fish ponds in seven sub-counties of Kitui County. From this, inferences were made with the assumption that the data obtained was representative of the population. According to the Kitui Fisheries Department, it is estimated that Kitui County has 120 active ponds, all of which were considered as the target population in the study.

3.4 Sample Size and Sampling Procedure

The available literature on study samples indicated that a researcher applies population sampling to get a sample that is used in drawing inferences on all the units in the population, from the partial information obtained from the subset (Hart, 2005). Sampling is done using specified procedures with a view of identifying sufficient sources of data for both the study of the phenomena and the analysis of that data thereafter. This study sought fish farmers from Kitui -County who are involved in *O. niloticus* farming while

ensuring geographical distribution and socio-economic factors were put into consideration. The sample size of this study was confirmed to be the entire 120 active polyethylene-lined fish ponds under *O. Niloticus* in the study region. The study covered the entire 120 active ponds to have a representation of Kitui County.

The study adopted 2 data collection methods: observation and interview. The 120 sample size is targeted to interview fish farmers in the study region from where 110 responses were realized. Then a 40% sub-sample (40% of 120 is a sample of 48 ponds from which 26 ponds were reached). Therefore, the target sample for observation is 48 ponds, from which 26 ponds (54%) were reached for observation where the researcher visited the ponds and recorded observations of the predators in the vicinity of the ponds during the visit

3.5 Field Observations

On-field observation was integrated into the data collection plan to complement the questionnaire tool and offer further information that answered some of the research questions in the study. The field observations where each of the 48 sub-sampled ponds were visited and data picked on predators visiting the pond, their types, and the number of visits were also noted to complement the data collected by questionnaires from farmers. Predator observations were done 3 hours each in the morning, midday, and evening.

This method involved the collection of information by way of the investigator's observation, without interviewing the respondents. The information collected related to what is currently happening and was not complicated by either the past behavior or future intentions or attitudes of respondents. See the observation tool in Appendix III.

3.6 Data collection

3.6.1 Data Collection Instrument

According to Creswell (2003), the study instruments are tools used in the collection of data on the phenomenon of the study. The research instrument employed in the study as a

tool for data collection was a questionnaire which was administered to the fish farmers identified in the sample, accompanied by an on-field observations checklist. A questionnaire is a list of standard questions prepared to fit a certain inquiry (Mugenda and Mugenda, 2003). The use of a questionnaire ensured that respondents were faced with identical stimuli and facilitated reliability. Open-ended and close-ended questions were used on the target respondents. These types of questionnaires do not restrict the target population from providing their thoughts and views on the problem at hand. For this reason, the researcher gathered information and was able to compare the responses leading to an all-inclusive study.

3.6.2 Pilot Study

A pilot test of the research instruments was administered to 2 fish farmer respondents in the study region (in Kitui Central sub-County) before the actual study commenced. According to Mugenda and Mugenda (2019), a small number of respondents in a sample is enough to pilot the research instrument. A pilot test helps to establish the quality and effectiveness of research instruments in yielding required data for the study besides determining field experiences. The study thereafter made the necessary corrections and adjustments to the instruments after the pilot test to increase the reliability of the instruments.

3.6.3 Validity of the Research Instruments

The validity of the study instruments was maintained in the research. According to Kothari (2019), content validity is the extent to which a measuring instrument provides adequate coverage of the topic under investigation. Validity deals with the appropriateness, correctness, and meaningfulness of specific inferences on research results (Frankel and Wallen, 2008). Validity was assessed during the pre-testing period where the tools were given to specialists in the sector for their review from which the level of validity was realized. A Confirmatory Factor Analysis (CFA) was undertaken to assess the level of validity for constructs informing the study variables to be considered in the final variables model. Any variables loaded above 0.40 were considered for further

analysis and those below 0.40 were dropped from the model as they were determined to lack validity (Taherdoost, 2018).

Table 1: KMO and Bartlett's Validity Test

KMO and Bartlett's Test	Kaiser-Meyer-Olkin Measure of Sampling Adequacy.	Bartlett's Test of Sphericity		
		Approx. Chi-Square	df	Sig.
State of Fish Farming	.609	163.707	18	.000
Predator Incidence Levels	.684	194.508	15	.000
Frequency of Predator Attacks	.818	209.110	13	.000
Predator Control Measures	.713	152.911	21	.000

The results of the Kaiser-Meyer-Olkin (KMO) test were: 0.609 for the state of fish farming; 0.684 for predator incidence levels; 0.818 for frequency of predator attacks; and 0.713 for predator control measures. These KMO and Bartlet's test results revealed coefficients that were far higher than the acceptable index of 0.4 for each of the variables studied. Additionally, Bartlett's test of sphericity was confirmed to be statistically significant ($0.000 \leq 0.05$) for all the variables to reveal that the correlation matrix for each variable is not the identity matrix, and confirm that there is a substantial correlation between the variables and thus factors are suitable for analysis. Therefore the research instruments were valid.

3.6.4 Reliability of the Research Instruments

Reliability is the measure to which a research instrument yields consistent results from data after repeated trials (Mugenda & Mugenda, 2007). The reliability of instruments indicates the stability and consistency with which the data collection instruments measure the variables in the study to measure the reliability, Cronbach alpha coefficient (α) was used. The value of the coefficient alpha varies from zero, which denotes no internal consistency, to one representing perfect internal consistency. It indicates the extent to which a set of test items can be treated as measuring a single latent variable. A measure is

considered reliable if a person's scores on the same test given twice are similar. The collected data was coded and responses were input into the SPSS data analysis system to generate the reliability coefficient. The internal consistency and homogeneity of the items that make up the scale are measured where less than 0.5 is low reliability; 0.51 – 0.60 is slightly reliable; 0.61 - 0.70 is reliable; 0.71 – 0.80 is very reliable; 0.81 – 0.90 is Greatly reliable; and Above 0.90 is excellently reliable (Golafshani, 2003).

Table 2: Reliability assessment using Cronbach Alpha

Variables	Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items	Observation
Demographic Information	.504	.544	5	Slightly Reliable
State of Fish Farming	.718	.738	13	Reliable
Predator Incidence Levels	.764	.806	9	Reliable
Frequency of Predator Attacks	.851	.864	6	Greatly Reliable
Predator Control Measures	.743	.788	15	Reliable

The test of the reliability of the data collection tool was undertaken where the Cronbach Alpha coefficients were calculated from the constructs for all the study variables. Cronbach's Alpha (α) shows the internal consistency statistic on the degree to which a set of measurement items have an internal consistency variable. This is consistent with Brotherton's (2008) recommendation that the instrument be administered repeatedly and that the correlation between the two sets of results be assessed. The instrument revealed very high internal consistency as all the variables revealed they have internal consistency of more than 0.7; and is thus judged to show that the instrument is dependable. The Chronbach alpha for each of the main study variables is: State of Fish Farming (α = 0.718); Predator Incidence Levels (α = 0.764); Frequency of Predator Attacks (α = 0.851); and Predator Control Measures (α = 743), revealing presence of internal consistency in all the study constructs and thus a high level of reliability for the study variables. However, for demographic information, a low Cronbach alpha (α = 0.504) was

expected due to the fact that each of the five items in the demographics such as gender (male/female) has a unique scale when compared to other measures such as age, or education, which reduces internal consistency. This is not an issue since this is not information that is used in inferential analysis and if used, the constructs are considered individually, hence for information in this model, internal consistency is not a mandatory requirement.

3.6.5 Data Collection Methods

The study used questionnaires and key informant interviews (County Ministry staff) to collect primary data. The questionnaire (Appendix 1) was administered to fish farmers in the target farms by drop-and-pick method. Observation was done in the morning, midday, and in the evening, mostly curated to the feeding patterns of the predators being studied, hence the researcher maintained flexible visit time plans to cover all predators. Other predators (Terrestrial) were studied through physical examination of ponds and their surroundings. This was done for the sampled 48 ponds targeted for observation visits. It was done to track and confirm predator information collected from farmers and document through observation the nature, type, and methods of predation occurring within the industry.

3.7 Data Analysis Plan

The primary data collected was sorted to ensure its completeness. It was then coded and entered into statistical packages for social sciences (SPSS) version 21 for analysis. The quantitative data was analyzed through descriptive statistics such as frequencies and measures of central tendency such as mean and standard deviation. To assess the impact of fish predation on the socio-economic state of fish farmers, the study also applied inferential statistics such as regression analysis. The regression was used to determine the relationship between fish predation and the socio-economic status of the farmers. Regression is a way of describing a numerical relationship between the dependent variable (farmers' socio-economic status) and the independent variables (fish predation). The regression model applied was:

$$Y = a_0 + a_1 x_1 + e$$

Where Y is the extent of social-economic effects associated with fish predation while x is the level of fish predation within the farms. These two factors were measured using a Likert scale in the research and by observation outcomes. Data presentation was done by the use of pie charts, bar charts and graphs, percentages, and frequency tables. This ensured that the gathered information was clearly understood. Articulated and easy-to-understand explanations of findings were offered by the researcher as illustrated in each table and chart. Qualitative data on the other hand was analyzed through content analysis and presented in prose or simplified tables. The analysis assisted in drawing the study conclusions and making recommendations based on the findings. The study utilized SPSS in undertaking the analysis which was combined with MS Excel to present the frequencies, means, and standard deviation using tables and graphs. Further inferential analysis was undertaken through the same tools.

3.8 Ethical Considerations

For this study, permission to carry out the study was sought from officials of institutions mandated with oversight and within the study region and any other relevant authorities in the study industry. The researcher assured confidentiality to the study respondents and affirmed that the study was made to accomplish academic goals.

3.9 Response Rate

The study sought information from a sample of 120 fish farmers in Kitui County from whom primary data was to be collected but only managed to collect data from 110 respondents, though the accessed respondents were 114, 4 of the respondents gave back incomplete responses and hence couldn't be considered. These outcomes are presented in Table 3.

Table 3: Study Response Rate

Population Segment	Sample Size	Number of Respondents	Response Rate
Fish farmers in Kitui County	**120**	**110**	**91.67%**
Ponds visited for observation	48	26	54.17%

The researcher managed to interview 110 of the 120 respondents from the targeted sample. This gave a response rate of 91.67%, with only 8.33% of the target respondents failing to respond to the questionnaires. This is a sufficient response rate to inform the study objectives, meeting the sufficient threshold set by Mugenda and Mugenda (2019) of at least 70% response. The observation visits targeted 48 ponds in the study area and 26 ponds realizing a 54.17% response rate.

CHAPTER FOUR

4.0 RESULTS

4.1 Introduction

This chapter contains the data analysis results, discussing the study findings about the data collected from the respondents who comprised the active fish farmers with ponds in Kitui County. The first section presents the demographic information about the respondents. The other sections cover the fish farming practices in the county and the various predator control measures employed in the region.

4.2 Study Demographics

The gender representation among the respondents within this study has the outcomes as shown in Figure 3.

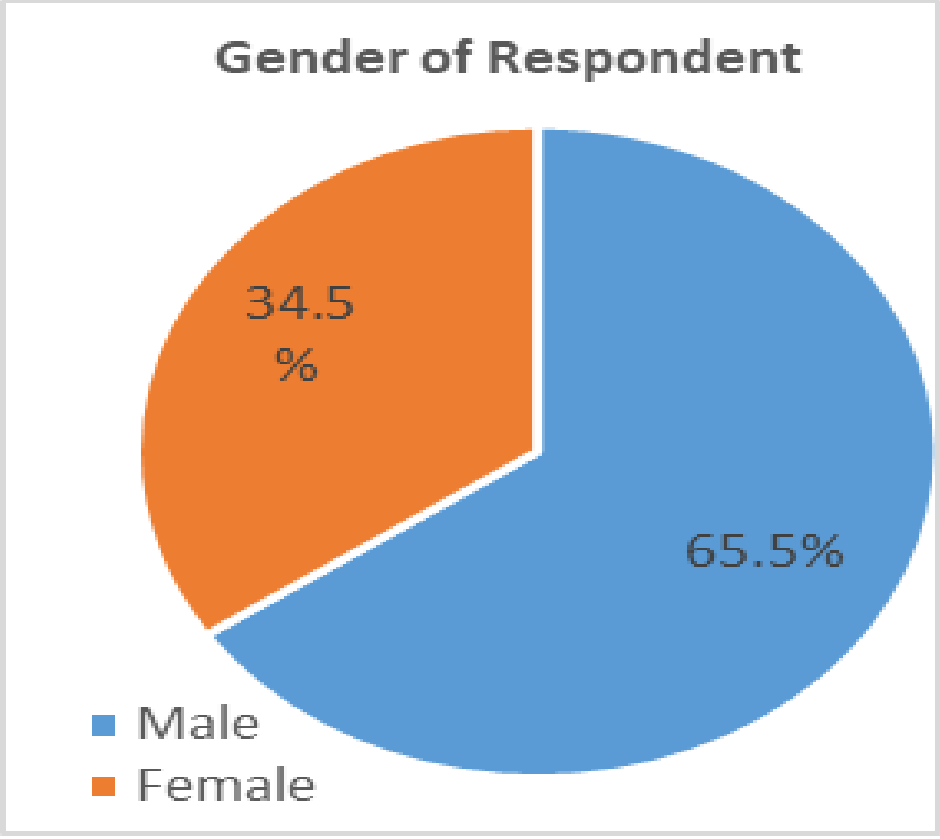

Figure 3: Gender of respondents

The results show that the majority of the respondents (who are the heads of households sampled) were male (65.5%) with the female respondents making up 34.5%. The male respondents were more as they are mainly considered the heads of the household but given that the data was collected during the day, a significant proportion of female household heads were available at the time of collecting the data, though some of these 5% households had 0.2 % women as the sole head of the household.

The marital status of fish farmers was looked at to understand the state of households undertaking aquaculture. The marital status distribution of the respondents is shown in Figure 5. Among the 110 respondents who participated in the study from Kitui County, a large majority were married (76.4%). A small proportion of the respondents were either divorced (1.8%) or single (7.3%), with a further significant proportion of the respondents (14.5%) indicating that they are widowed.

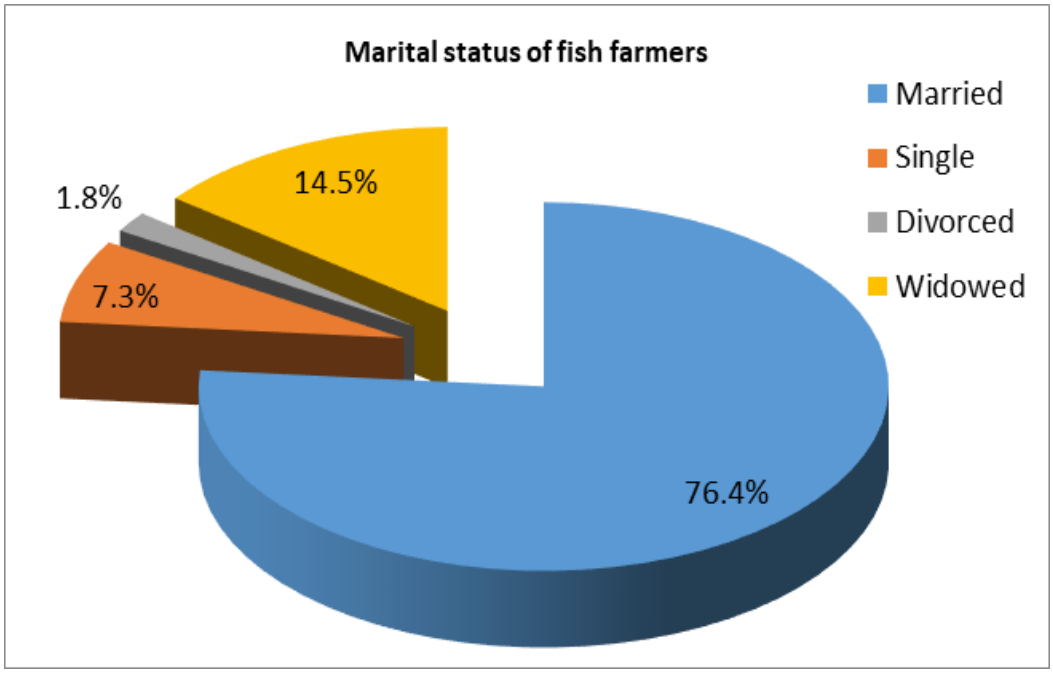

Figure 4: Marital Status of Fish Farmers

The age distribution of the respondents is shown in Figure 4. The views given in this study were mainly from respondents between 36-60 years (67.3%) followed by those

above 60 years (18.2%). Those within the age group 18-35 years were observed to be 14.5%.

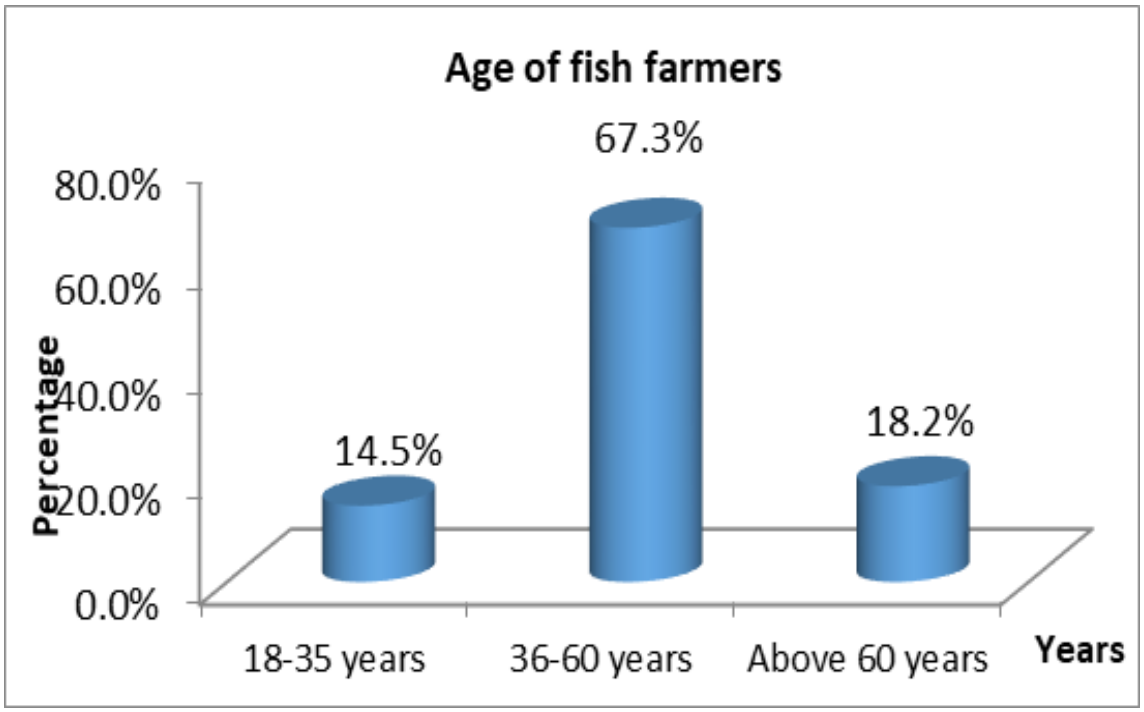

Figure 5: Age of Fish Farmers

The education level of the household heads interviewed is shown in Figure 6. The fish farmers who took part in this study had various education qualifications. Most of them had achieved a secondary level qualification (34.5%), followed by those with post-secondary non-agriculture education level (30.9%). Other qualifications include those who had post-secondary agriculture qualifications (19.1%). A small percentage had low levels of qualifications at primary (10.9%) and a small percentage (4.5%) had no formal education.

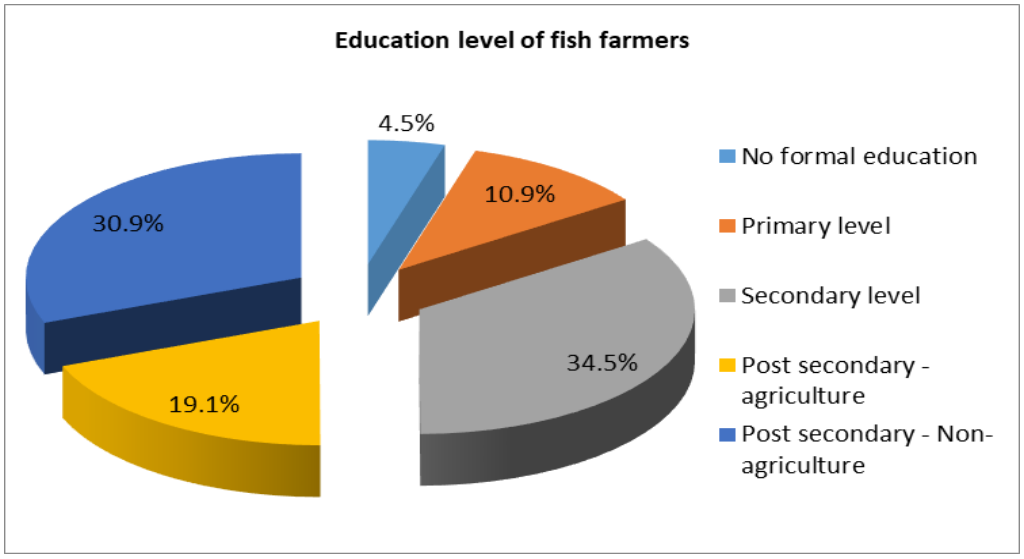

Figure 6: Education level of Fish Farmers

The location of the respondents was also put into consideration during the study whose outcomes are presented in Figure 7.

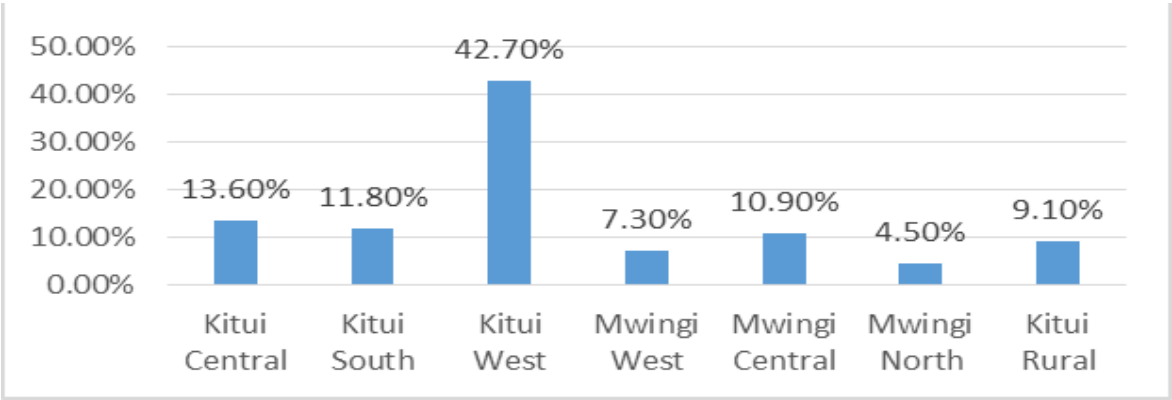

Figure 7: Sub-county distribution of Fish Farmers in Kitui County

The proportion of respondents who participated in the study from Kitui West out of a possible 110 respondents was 42.7%, followed by Kitui Central 13.6%. The proportion of respondents from Kitui South was 11.8%, Mwingi Central 10.9%, Kitui Rural 9.1%, Mwingi West 7.3%, and Mwingi North 4.5% the lowest proportion of respondents who participated in the study. Kitui West had more functioning ponds than other sub-counties because of farmers who were able to mitigate the challenges of water shortages and embrace good management practices.

The study also considered the duration these respondents have had in the fish farming industry and the results are as presented in Figure 9.

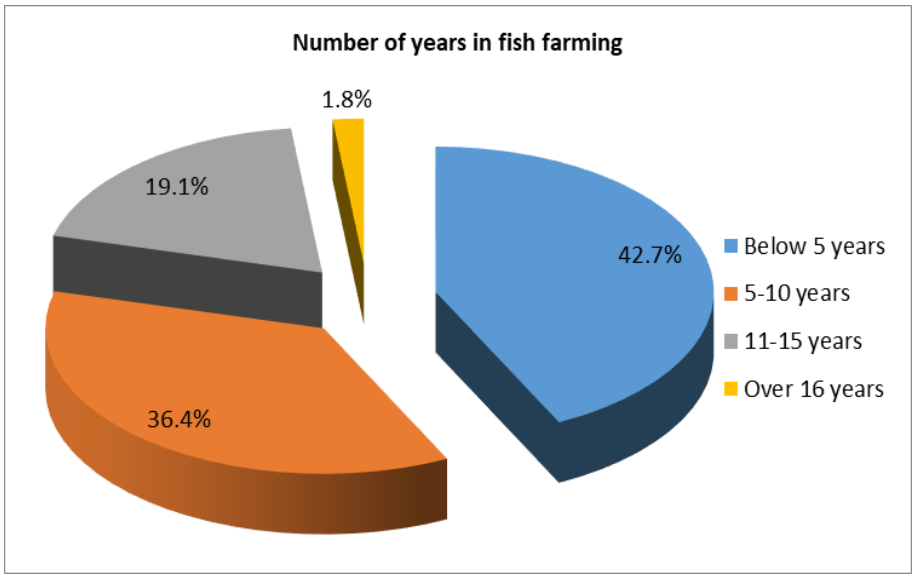

Figure 8: Level of experience in fish farming

The study found that most of the respondents (42.7%) had less than 5 years in fish farming, indicating that they had a very low level of experience in the art of fish farming. A further 36.4% of fish farmers had an experience of 5-10 years within the aquaculture industry while a further 19.1% have been in the field a bit longer for 11- 15 years, and only 1.8% had been in the industry for more than 15 years.

Most of the fish farmers in the study have 1-3 ponds (73.6%). A significant number of the fish farmers had 4-10 fishponds (23.6%) while a further 2.8% had more than 10 fish ponds.

The fish species cultured in Kitui County are presented in Table 4. It was observed that Tilapia is the most cultured fish, followed by Catfish. Ornamental fish are not cultured in the region.

Table 4: Species of fish reared in Kitui County

Fish Species Cultured in Kitui County	Yes
Tilapia Cultured	71.1
Catfish Cultured	28.9

4.3 Predator prevalence

The prevalence of predators within the fish farming community was assessed in this study. The incidences of predator attacks were observed in 93% of the fish farms in the county. These are presented in Figure 9.

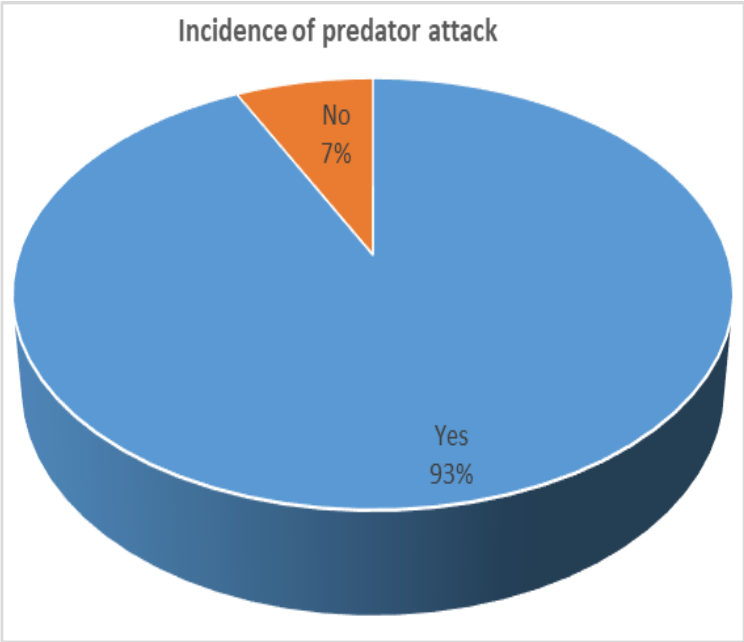

Figure 9: Incidence of predator attacks in Kitui County

Determining the level of attack by predators presented in Figure 11 revealed that the majority of the farmers (59%) have experienced 1-10% losses from attack, while a further 36% have had 11-50% losses from predator attack. A further 1.05% experienced 51-70% losses from predator attacks.

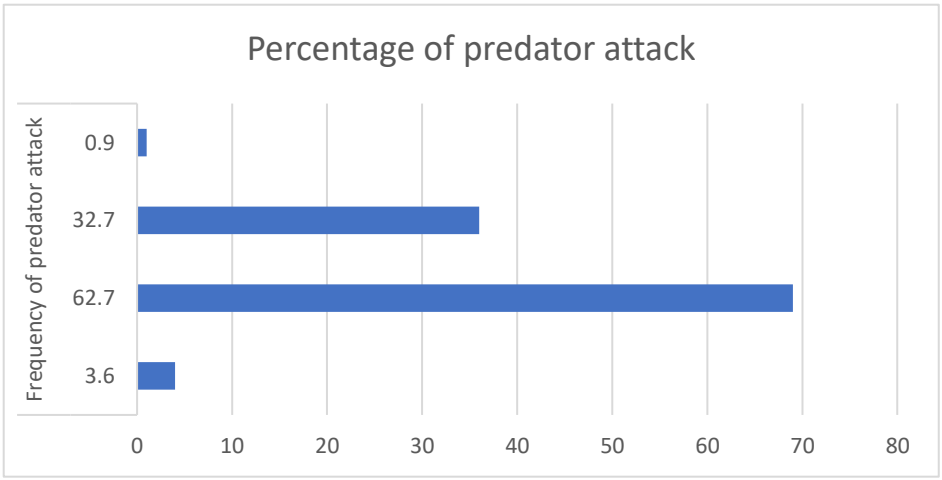

Figure 10: Level of attack of predators in fish farms

Investigating the types of predators affecting fish farmers in Kitui county are birds(87%), domesticated birds(60%), domestic animals(36%), humans (30%), wild animals(24.5%), and, ranked the level of incidence within the farms.

Comparing the frequency of predator attacks in fish farming revealed that the high levels of attack are realized from birds, while small proportions of other fish species, reptiles, and domestic animals represent high-level predator attacks in the county. These predators are also seen to have low levels of attack. These outcomes are presented in Table 5.

Table 5: Frequency of predator attacks

Frequency of Attack by Predators	**N**	**Never**	**Rarely**	**Once in a while**	**Often**	**Very often**	**High-Level Attacks**
Birds	95	2.11%	4.21%	18.95%	67.37%	7.37%	74.74%
Domestic Animals	95	31.58%	29.47%	35.79%	3.16%		3.16%
Wild Animals Attack	95	73.68%	18.95%	7.37%			0.00%
Other Predators	95	45.26%	20.00%	30.53%	4.21%		4.21%

According to the majority of the fish farmers (86.4%) birds are the worst predators, with only a small proportion of the farmers indicating domestic animals, wild animals, and reptiles as the worst predators affecting their fish farms. These outcomes are presented in Figure 11.

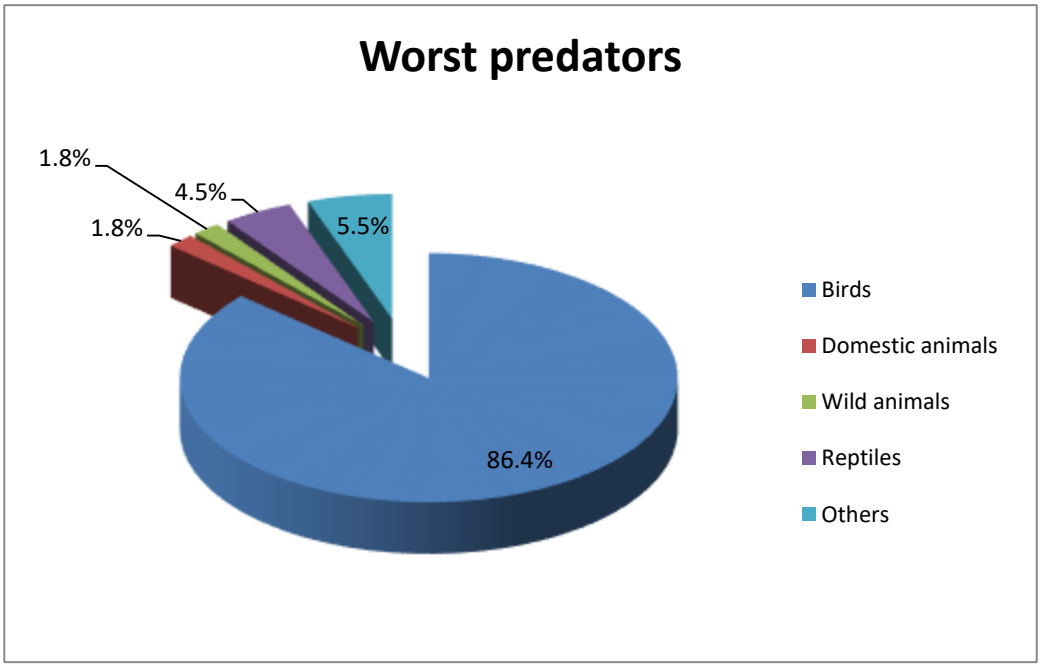

Figure 11: Worst predators affecting fish farmers

4.3.1 Fish Farm Predator Control Measures

According to a majority of the fish farmers (86%), they have put in place various predator control measures while only a small proportion of the farmers (14%) have not instituted predator control measures in their farms. These outcomes are presented in Figure 12.

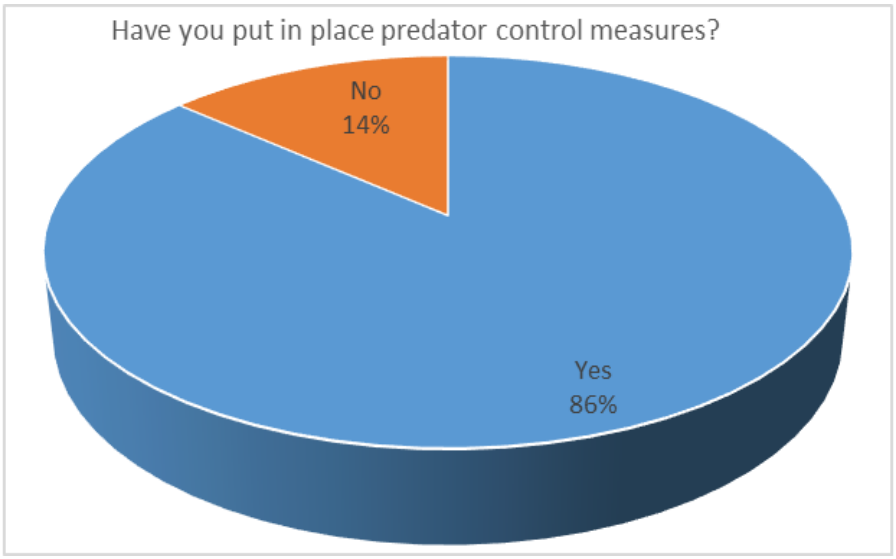

Figure 12: Presence of predator control measures

Comparing the labor allocation in the fish farms within the county reveals that the control of the predators is left to fathers in the majority of the fishponds (57%), with women, children, men workers, and women workers having the predator control role in the rest of the farms. A small proportion of the farmers have hired labor (15%) in their farms. A large proportion of the farms have males in predator control (57%), but a significant proportion is female-controlled (43%), with fathers making labor allocation in most of the farms (72.6%). These outcomes are presented in Figure 13.

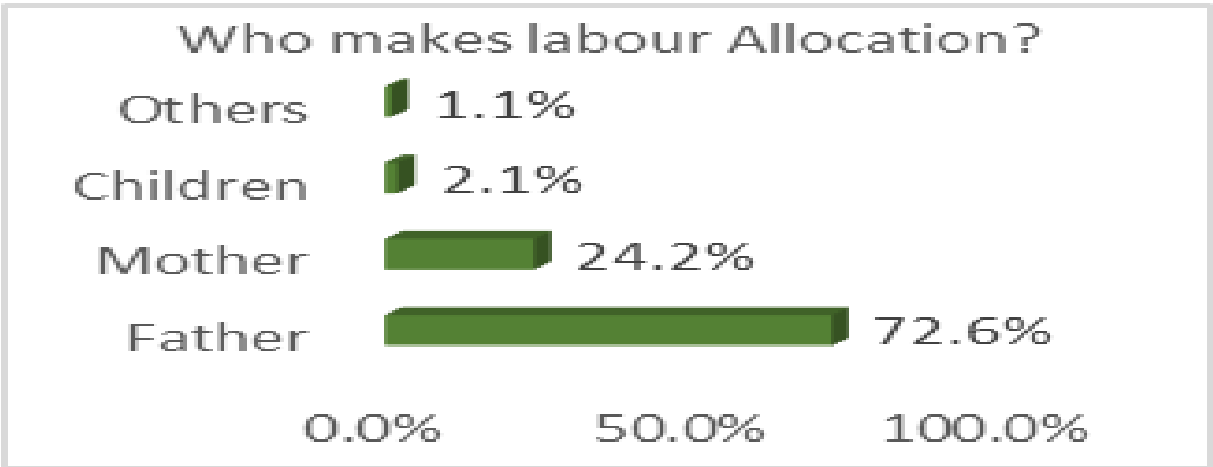

Figure 13: Fish farm predator control labor roles

The majority of the farmers have instituted predator control measures in their farms (86%). However, a significant proportion of the farmers lack any predator control measures instituted in their farms.

The majority of the farmers use a combination of predator control measures. Fencing/Overhead nets/Scarecrows (30.5%). A further 22% use fencing combined with overhead nets, while 18% use fencing and scarecrows with a further 12.6% fencing the pond area. Use of overhead nets (8%) and scarecrows (2%) are used by very few farmers. These outcomes are presented in Table 6.

Table 6: Predator control measures

Predator control measures used	**Frequency**	**Percent**
Fencing/Overhead nets/Scarecrows	29	30.5%
Fencing/overhead nets	21	22.1%
Fence/Scarecrows	17	17.9%
Fencing of pond area	12	12.6%
Use of overhead nets	8	8.4%
Scarecrows	2	2.1%
None	6	6.3%
Total	**95**	**100.0%**

Finding out the effectiveness of predator control measures used revealed that the majority of the predator control measures have very low levels of effectiveness, with a majority of the farmers indicating that they have a low extent of effectiveness (37.9%), and a further 36.8% indicated to have a moderate-extent level of effectiveness. A very low proportion of the farmers indicated that they have great (11.6%) and very great extent (1.1%) of effectiveness. The effectiveness rating in line with each of the predator control measures was assessed and the outcomes presented in Table 7 were realized.

Table 7: Impact of control and the predator control measures used

Impact of Control	Predator control measures used							Total
	Fencing of pond area	**Use of overhead nets**	**Scare crows**	**Fencing/ overhead nets**	**Fencing/ Overhead nets/ Scare crows**	**Fence/ Scare crows**	**None**	
No impact	8.3%	25.0%	50.0%	0.0%	13.8%	0.0%	66.7 %	12.6%
Low impact	58.3%	50.0%	0.0%	33.3%	20.7%	58.8%	33.3 %	37.9%
Moderate impact	16.7%	12.5%	50.0%	47.6%	55.2%	29.4%	0.0%	36.8%
Great impact	16.7%	12.5%	0.0%	14.3%	10.3%	11.8%	0.0%	11.6%
Very Great impact	0.0%	0.0%	0.0%	4.8%	0.0%	0.0%	0.0%	1.1%

4.3.2 Socio-economic Impacts of Fish Predation

Fish farmers revealed that their initial investment in predator control was about Kshs-15,000 to 30,000 (38.9%). Further, a significant proportion invested less than Kshs. 15,000 (31.6%), with small proportions of the farmers investing large amounts of money in predator control. These outcomes are presented in Table 8.

Table 8: Farmer's initial cost of predator control

Predator Initial Control Cost (Kshs)	Frequency	Percent
Less than Ksh. 15,000	30	31.6%
Ksh. 15,001-30,000	37	38.9%
Ksh. 30,001 - 45,000	20	21.1%
Ksh. 45,001-60,000	4	4.2%
Above Ksh. 60,000	4	4.2%
Total	**95**	**100.0%**

According to the survey, most fish farms (69.5%) reported annual losses of less than Kshs. 30,000. A further 30.5% of farmers indicated annual losses from predator attacks of more than Ksh 30,000.

These outcomes are presented in Table 9.

Table 9: Estimated annual losses among fish farmers

Estimated Annual Losses (KES)	Frequency	Percent
Less than Ksh. 30,000	66	69.5%
Ksh. 30,001 - 60,000	9	9.5%
Ksh. 60,001 - 90,000	12	12.6%
Ksh, 90,001 - 120,000	5	5.3%
Above Ksh. 120,000	3	3.2%
Total	**95**	**100.0%**

The predator control costs faced by fish farmers in Kitui County were observed to be less than Kshs. 20,000 farmers, but a significant proportion (27.4%) spend between Kshs. 20,000 to 45,000. The rest of the farmers (11.6%) have high costs of more than Kshs. 45,000 on predator control. Table 9 shows the outcomes of the study.

Table 10: Annual predator control costs to farmers

Annual Predator Control Cost (KES)	Frequency	Percent
Less than Ksh. 20,000	58	61.1%
Ksh. 20,000-45,000	26	27.4%
Ksh. 45,000 - 70,000	5	5.3%
Ksh. 70,000 - 95,000	2	2.1%
Above Ksh. 95,000	4	4.2%
Total	**95**	**100.0%**

The costs farmers incur per production cycle in hiring labor in their farms for predator control were also considered where it was observed that a large majority of the farmers spend less than Kshs. 5,000 (86.3%), with a significant proportion (7.4%) spending between Kshs. 50001 to 15,000, while the rest (6.3%) spend above 20,000 as labor for predator control. These outcomes are presented in Table 11.

Table 11: Cost of hired labor per cycle directed toward predator management

Cost of hired labor per cycle	Frequency	Percent
Less than Ksh. 5,000	82	86.3%
Ksh. 5,001 - 10,000	4	4.2%
Ksh. 10,001 - 15,000	3	3.2%
Above Ksh. 20,000	6	6.3%
Total	**95**	**100.0%**

The study found that those ponds that used fencing (50%), scarecrows (50%), and fence/scarecrows (47.1%) as a predator control measure have the highest number of farms experiencing great to very great extent of severe losses. Lower loss severity was experienced when the fish farmers used overhead nets and a combination of measures where overhead nets were applied. The use of combined control measures lowered the severity of losses that the farmers experience from predator attacks. These outcomes are presented in Table 12.

Table 12: Severity of losses and predator control measures used

Severity of Losses	Predator control measures used							Total
	Fencing of pond area	**Use of overhead nets**	**Scarecrows**	**Fencing/ overhead nets**	**Fencing/ Overhead nets/ Scarecrows**	**Fence/ Scarecrows**	**None**	
No extent	1	0	0	0	2	0	1	4
	8.3%	0.0%	0.0%	0.0%	6.9%	0.0%	16.7%	4.2%
Low Extent	6	2	0	5	7	3	4	27
	50.0%	25.0%	0.0%	23.8%	24.1%	17.6%	66.7%	28.4%
Moderate	0	5	1	12	20	8	0	46
extent	0.0%	62.5%	50.0%	57.1%	69.0%	47.1%	0.0%	48.4%
Great Extent	3	0	1	3	0	5	1	13
	25.0%	0.0%	50.0%	14.3%	0.0%	29.4%	16.7%	13.7%
Very Great	2	1	0	1	0	1	0	5
Extent	16.7%	12.5%	0.0%	4.8%	0.0%	5.9%	0.0%	5.3%
Total	**12**	**8**	**2**	**21**	**29**	**17**	**6**	**95**

Reviewing predator control measures and the various related cost elements revealed that the farmers with no form of predator control measures instituted faced the highest estimated annual losses for of Kshs. 26,666 and spent the highest costs annually while to control predators (Kshs. 24,274). Those farmers using only 1 form of predator control such as fencing the pond or scarecrows or using the overhead nets on their own indicates also high costs and losses for the farmers. On average, a farmer in Kitui County spends Kshs. 24,274 on initial predator control measures, a further Kshs. 23,520 annually on predator control. These outcomes are presented in Table 13.

Table 13: Predator Control Measures and Costs

Predator control measures used	**Predator Initial Control Cost (KES)**	**Annual Predator Control Cost (KES)**	**Estimated Annual Losses (KES)**
Fencing of pond area	23,750	24,750.00	49,333.33
Use of overhead nets	24,000	12,875.00	41,937.50
Scare crows	15,500	12,500.00	42,500.00
Fencing/overhead nets	30,740	27,904.76	23,388.10
Fencing/ Overhead nets/ Scare crows	29,052	21,634.48	22,093.10
Fence/Scare crows	18,235	833.33	7,416.67
None	.00	0	0
Average	**24,274.21**	**14,356**	**26,666,**

The study looked at the costs within the lenses of the level of attack by predators, where it was observed that the farmers with highest levels of attack (51-70%) realized the highest estimated annual losses (Kshs. 80,000), though they invested very little in predator control costs. However, a unique occurrence is where farmers experienced 0% level of attack where little was invested in predator control or annual control costs, as well as low estimated losses to predators hence the low attack (0%) is mostly due to the pond's location (Near homesteads) having low levels of predators, rather than the farmers taking defensive measures. These outcomes are presented in Table 14.

Table 14: Level of attack and predator control costs

Level of attack	Estimated Annual Losses (KES)	Predator Initial Control Cost (KES)	Annual Predator Control Cost (KES)
0%	6,875.00	2,500.00	2,500.00
1%-10%	19,550.89	27,491.96	19,292.86
11%-50%	64,161.76	22,220.59	33,647.06
51%-70%	80,000.00	1,000.00	.00
Average	**35,619.47**	**24,274.21**	**23,520.00**

It was observed that those farms that indicated that fish farming is profitable had higher initial investments directed towards predator control lower annual costs directed to predator control and lower estimated annual losses. Those who indicated that fish farming is not profitable had lower initial investments in predator control, higher annual costs on predator control and higher annual losses, hence their view about fish farming profitability has a direct linkage with fish predation and control activities. These outcomes are presented in Table 15.

Table 15: Fish farm profitability against losses and costs (KES)

Fish Farm Profitability	Estimated Annual Losses (KES)	Annual Predator Control Cost (KES)	Predator Initial Control Cost (KES)
Yes	35,377.59	23,429.89	24,632.76
No	38,250.00	24,500.00	20,375.00

4.4 Inferential Statistics

The study undertook an inferential analysis that involved computation of regression analysis using SPSS tool highlighting the relationship between farmers' socio-economic status and the level of fish predation. The outcomes of this analysis produced the outcomes presented in Tables 15, 16, and 17. Table 16 shows the regression model summary.

Table 16: Regression Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	-.638	.407	.356	.03239

a. Predictors: (Constant), Fish_predation_level

In the regression model summary, a negative correlation coefficient of - 0.63 was observed with a coefficient of determination of 0.407 revealing a relationship between the dependent and independent variables, where fish predation was observed to have the ability to explain 40.7% of the variability in farmers' socio-economic conditions like income, protein source and status.

An ANOVA of the study model was carried out to further investigate the variances in the regression and residual data for the farmer's socio-economic conditions and the fish predation levels presented in Table 17 related to the amount of money made within the apiculture enterprise. According to the outcomes presented, the p-value (sig.) was 0.000 ($P<0.05$) indicating that the influence is statistically significant at a 95% confidence level. The ANOVA model shows that the relationship between farmer socio-economic conditions and the level of fish predation is statistically significant and confirms the presence of a direct relationship between the study factors.

Table 17: Regression model ANOVA

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	4.514	3	1.505	8.374	.000[b]
	Residual	6.290	94	.180		
	Total	10.804	97			

a. Dependent Variable: Farmer_socio-economic_conditions

b. Predictors: (Constant), Fish_predation_level

A further analysis of the relationship gave the outcomes presented in Table 18 showing the regression model coefficients.

Table 18: Model Regression Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t.	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.108	.463		4.876	.000
	Farmer_socio-economic_condition	-.752	.144	.859	3.356	.002

a. Dependent Variable: Fish_predation_level

The information contained in Table 17 revealed the results of the regression analysis model. According to the findings, fish predation levels (-0.752, p=0.002) in fish farms have a statistically significant influence on the socio-economic conditions of farmers in Kitui County. The regression model indicates that the relationship between the independent variables (fish predation levels) and dependent variable (farmers' socio-economic conditions) have a significant negative regression coefficient and a constant of 3.108. Fish farmers' socioeconomic conditions are significantly reduced with an increase in predation. The regression model of this relationship is presented as:

$$\mathbf{Y = 3.108 + (-)\ 0.752\ } x + \mathbf{\varepsilon}$$

Y = Farmers' Socio-Economic Condition;

x = Fish Predation Level;

Ɛ = Error Term.

CHAPTER FIVE

5.0 DISCUSSION CONCLUSION AND RECOMMENDATION

5.1 Introduction

This chapter consists of the following sections: discussion of findings, conclusions, recommendations, and areas of further research. The first section provides a discussion of findings within each of the study areas, followed by the study conclusions. The chapter also provides the study recommendations and culminates with recommendations for further studies.

5.2 Discussion of Findings

This study sought to assess the effects of predation on aquaculture production in Kitui County. The study sample had adequate gender representation and was not gender biased, as it sought information from the targeted respondents. Most of the respondents were married. However, a few farms were headed by widowed, single, or divorced individuals. Most fish farmers accessed were above 35 years of age (85.5%). Fish farming in Kitui requires the availability of water, land, and expenses for maintenance which are sometimes difficult to come by for persons below 35 years of age due to land rights and financial ability. Fish farmers below 35 years were (14.5%), and this is the age they start investing in fish farming and they progressively improve the enterprise within the county. The majority of the fish farmers involved in fish farming were from Kitui West, which indicated that a large proportion of the fish farmers are located in the Kitui West sub-county of the number of active ponds. Kitui West Sub County was the first Sub-County to roll out the economic stimulus initiative from the national government. The farmers in Kitui West had adequate water supply from their boreholes.

The respondents had adequate experience in fish farming and were able to offer the information required in the study, while not leaving out the views of the new entrants in the industry. This is a clear indication that the farmers have high numbers of ponds for fish farming in Kitui County with a significant proportion of the farmers having more than 1 functional pond. In Kitui County, the majority of the farmers rear tilapia species,

followed by catfish. Tilapia and catfish are mostly preferred as they are easily marketed and widely used in restaurants and households. A large majority of the fish farmers in the county perceive fish farming as a profitable venture, which confirms the findings by FAO (2022) indicating the high profitability experienced by fish farmers in the region.

5.2.1 Predator prevalence among fish farms

There is a very high prevalence of predator attacks in fish farming within Kitui County, with 93% of the fish farmers indicating that they have experienced a predator attack, from which they experienced significant losses in their production. The predators observed in the area include birds, reptiles, domestic animals, and raccoons, ranked high in occurrences, with birds being the most prevalent fish predator in fish farms in Kitui County.

It was found that birds caused the highest attacks on fish farms in the region, with wild and domestic animals having a low scale of attacks. Birds are considered the worst predators in Kitui County. It was observed that ponds near trees and shrubs were prone to attacks from Kingfishers, while open ponds were susceptible to Stork and Pelicans. The highest losses were linked to bird predation according to Murugami *et al.* (2018) who observed that bird litter on dykes of the ponds have been confirmed to play a possible role in the transfer of pathogens into aquatic life with piscivorous bird attacks linked to the transmission of fish parasites, for example, digenean parasites, in Kirinyaga County. The regression model showed a significant difference between the socioeconomic status of fish farmers who had their fish preyed on by the predators and those who had experienced no such cases. This research finding agreed with the findings of Kimathi *et al*., (2013); Shitote *et al*., (2013), and Maina *et al*., (2017) who found that predation by birds and frogs was a major challenge in fish farming.

5.2.2 Predator control measures

The majority of fish farmers have adopted predator control measures in their fish farms, with fathers having the highest predator control responsibilities while some farmers rely on hired labor to control predators. Various predator control measures are available to the

farmers including the use of fencing, overhead nets, and scarecrows, though the most widely used is the combination of all three measures of fencing/overhead nets/scarecrows. A significant number of farmers use fencing and overhead nets to protect their ponds.

The effectiveness of these measures revealed that the use of the two measures together, fencing/overhead nets, has had the highest level of effectiveness, followed by combining all three measures of fencing/overhead nets/scarecrows. The use of overhead nets is less effective than fencing and adding nets within the pond area, and the use of scarecrows was observed to be the least effective control measure. According to David *et al.*, (2002), fish farming exclusion and barrier techniques involving the separation of the fish from their potential predators is the most effective solution for controlling the impacts of predation. Installing fishnets and fencing the pond area are two key exclusion techniques used by farmers in Kitui County. Usage of deterrents such as scarecrows was reported to be less effective as confirmed in this study.

5.2.3 Predator attacks and the farmers' socio-economic conditions

The study hypothesized that fish predation influences the socio-economic conditions of farmers in Kitui County. The study found that farmers have experienced significant losses due to predators' attacks in fish farms and is accompanied by costs in trying to control predators that attack their farms, both of which are activities that affect the actual productivity of the fish farmers. The study found that fish predation significantly correlates with the farmers' socio-economic conditions, with the survey realizing that fish predation correlates negatively with farmers' socio-economic conditions. Further, fish predation level was found to have the ability to predict 40.7% of the variability in farmers' socio-economic conditions, which could indicate that an increase in fish predation level leads to a significant decline in the farmers' socio-economic conditions.

According to the regression model, there is a statistically significant inverse link between the socioeconomic circumstances of Kitui County farmers and the amount of fish predation. Thus, in Kitui County, where a negative impact was observed, the study

demonstrates that the socioeconomic status of farmers is negatively impacted by the levels of fish predation. A positive shift in fish predation levels was found to have a detrimental impact on the socioeconomic status of the county's farmers.

There is therefore a direct linkage between fish predation levels and the socio-economic conditions of fish farmers. Similar observations were made by Omeje *et al*. (2021) who observed that fish predation can reduce a farmer's net profit margin by 25.93% and return on investment by 35%. Another study by Nzevu (2018) revealed that fish predation, especially by Kingfishers, significantly affects the fish farm income levels and hence affects the survival of the fish farming ventures.

Farmers are affected by predation through the physical loss of fish, which leads to socio-economic losses and a lowering of their status within the community. This also leads to the abandonment of ponds, which cannot be maintained by farmers because of renewed costs of destroyed liner replacement.

Apart from highlighting that birds are the worst predators affecting fish farmers in Kitui County, the study also confirmed that fish farmers face significant negative socio-economic effects from fish predation in the County, which might explain the large proportion of abandoned fish ponds in Kitui County.

5.3 Conclusion

This study sought to assess the state and effects of fish predation on fish farming in Kitui County, by investigating the level of prevalence of fish predators in the county, the control measures used in fish farming, and assessing the influence of predator attacks on farmer socio-economic conditions. The study found that there are varying types of fish predators that attack fish and that bird predators are the worst with far-reaching destruction of fish stock. The study therefore concludes that fish predation in fish farming within Kitui County is a major problem affecting farmers in Kitui County.

It was found that farmers have been employing various mechanisms to control fish predation in their farms, with the combination of exclusion, barrier, and deterrent methods (overhead nets, fencing, and use of scarecrows) being observed to have the best ability to control fish predators. A combination of predator control methods is more effective than using only one method. However, Nzevu (2018) observed that some predators such as Kingfisher attacks the control measures destroying the nets placed to control them before attacking the fish stock. The best control measures were also found to be linked to high initial investment and control costs, which eat into the profit margins for the farmers. Fish predation control was therefore found to be an expensive undertaking for the farmer, and similarly, failure to control predation was also found to lead to great losses in fish stocks for the farmers, thus similarly leading to major losses. Therefore, it is concluded that fish predator control activities adopted by fish farmers are costly but important activities among fish farmers in Kitui County.

The study found that fish predation directly leads to a decline in the profitability of fish farming ventures in Kitui County. Additionally, farmers were forced to invest time in controlling predation which could have been used in other activities. Hired labor is sometimes used to control predators. Predator control requires resources within the farm and this may cause a diversion of funds meant for other activities within the farmThe farmers are also forced to redirect their funds on various predator control measures in the farm, lack of which would lead to significant losses in the fish stock of the farmer. The study therefore confirms that fish predation significantly affects the socio-economic conditions of the farmers, and fish farmers in the county are significantly affected by the level of fish predation in the area. The study concludes that fish predation is a major problem for fish farmers in Kitui County.

5.4 Recommendation

The study recommends that the Kitui County government implement farmer training and extension programs aimed at sensitizing as well as creating awareness among fish farmers on the kind of predators they are likely to face. This awareness would ensure fish farmers integrate predator control measures and can optimize profits avoid catastrophic

losses in their farms, and reduce the negative socio-economic impacts on the farmers. The County government of Kitui can promote fish farming if capacity building and awareness measures are integrated with fish predation for fish farmers to realize greater economic returns from their fish farming ventures. The support to control bird attacks such as from King-fisher birds would require support from the county government like subsidized fish nets.

Another recommendation is that researchers in aquaculture enthusiastically support innovations in fish predator control technologies. The industry should ensure that innovations are introduced that lower the cost of controlling fish predators so that farmers can minimize the socio-economic impacts of fish predation. The sector could introduce technological innovations and strategies that prevent interactions between predators and farm stocks wherever possible, whether through exclusion, barrier, or deterrent methods. The use of budget-friendly drones can be effective in scaring predators like birds and the use of flashing LED lights has been shown to scare birds and wildlife affecting fish in ponds.

5.5 Areas for Further Research

Based on the scope of the study, and with the growing aquaculture farming in the region, further studies are recommended to address predation within the sector. The study was undertaken in Kitui County and therefore cannot be generalized into other regions of the country as predation patterns and situations in these counties may differ. Therefore, The study recommends further research on the prevalence of fish predators in other counties in Kenya to highlight the situation and the control measures being implemented in these regions. Further research in different counties can be undertaken to quantify the socio-economic impact of predation and further confirm the findings made in this study.

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APPENDICES

Appendix i: Introduction Letter

Eric Musya Kaindi
South Eastern Kenya University
P.O Box 170 – 90200,
Kitui, Kenya.

Date……..

Dear Sir/ Madam,

Re: Request for Participation in the Data Collection Process

My name is Eric Kaindi a master's student from South Eastern Kenya University. I am in the research stage of my postgraduate studies. I am conducting a study on the socio-economic impact of predation in aquaculture and the control measures within Kitui County. Your farm has been sampled to participate in this undertaking and I would like to request your participation in filling a short questionnaire for the study. Your feedback and views will help in compiling my research findings. The data collected is for academic research purposes only.

A questionnaire is attached which can take approximately 20 minutes of your time to complete. Your participation in this research will add value to a growing body of global empirical evidence on the issues related to fish predation and will help us understand the predation problem in our County and Kenya as well. All responses received are anonymous and information collected will not be distributed to any other party.

I am very grateful for your participation and for allowing us to undertake observations within your fish ponds. Thank you.

Yours Sincerely,
Eric M. Kaindi
Masters Candidate
South Eastern Kenya University

INTRODUCTION LETTER AND QUESTIONNAIRE

ERIC KAINDI

P.O.BOX 460, 90100,

MACHAKOS

Date……

Dear Sir/Madam

RE: REQUEST TO FILL QUESTIONNAIRE FOR ACADEMIC PURPOSES

I am a postgraduate student at South Eastern Kenya University (SEKU) Department of Range and Wildlife Sciences, School of Agriculture and Veterinary Sciences. I am carrying out a research on predator effects in aquaculture in Kitui Central Sub- County.

The information gathered will be treated as confidential and will be for the sole purpose of this study. Kindly respond to the items in the attached questionnaires to the best of your knowledge.

Kind regards,

Eric M.Kaindi

Appendix ii: Research Questionnaire

1. Village……..…Ward……..…; Sub-County: ……

2. Indicate the sex of the farm owner

☐ Male ☐ Female

3. Marital status

☐ Married

☐ Single

☐ Divorced

☐ Widowed

4. Indicate highest level of education

☐ No formal Education

☐ Primary Education

☐ Secondary Education

☐ Post-Secondary Education (In agricultural Field)

☐ Post-Secondary Education (In non-agricultural field)

5. Indicate the age of the farmer

☐ Below 18 years

☐ 18- 35 years

☐ 36 – 60 years

☐ Above 60 years

6. Indicate the number of years you have been involved in fish farming in this County:

☐ Below 5 years

☐ 5 to 10 years

☐ 11 to 15 years

☐ Over 16 Years

7. How many fish ponds does your farm have? …….

☐ 1 – 3 Ponds

☐ 4 – 10 Ponds

☐ Above 10 Ponds

8. Which kind of fish do you rear in your farm? ……..

……

9. What fish species of fish are reared ……..

10. In your view, do you perceive fish farming as a profitable enterprise in Kitui County?

……

……

Section 1: Prevalence of Fish Predators

11. Have you had an experience of predators attack in your farm?

……

……

12. To what extent do you consider predator attacks in your pond and location?

- ☐ No extent at all
- ☐ Low Extent
- ☐ Moderate Extent
- ☐ Great extent
- ☐ Very great extent

13. Which are the key fish predators that you have seen in your farm? (Please indicate their local names)

Birds: ……...…..…;

Domestic Animals (e.g. cat): …….;

Wild Animals: ……..……. ;

Reptiles (e.g snakes): …….……..;

Others: ……..……;

14. Which fish predators have you heard about within this area which are affecting other farmers, but are not yet observed in your farm?

Birds: ……...…..……;

Domestic Animals (e.g. cat): ……...;

Wild Animals: ……..……..…;

Reptiles (e.g snakes): …….……..;

Fish: ……..…..……..;

Racoons…….;

Others: ……..……;

15. How often do you get reports of attacks by these predators in your farm (Indicate 1 as never, 2 rarely; 3 once in a while; 4 often; 5 very often):

	1	2	3	4	5
Birds					
Domestic Animals (e.g. cat)					
Wild Animals					
Reptiles (e.g snakes)					
Fish					
Others					

16. Among the predators that have been attacking your farm which are the most prevalent?……..

……

……

17. Which predators do you think have the worst impact on your ponds in terms of production?.....

……

……

18.Which of the predators do you consider as the most destructive in your enterprise?.....

……

……

……

Section 2: Control Measures

17. Have you put in place control measures to stop predation within your fish ponds?

YES ( ); NO ( )

17. What general predator control measures have you put in place within your fish pond?

……

……

……

18. In specific terms, what control measures have you installed to prevent attacks by each of the following predators?

Birds: ……...…….…;

Domestic Animals (e.g. cat): ……...;

Wild Animals: ……..……..…;

Reptiles (e.g snakes): ……..……..;

Fish: ……..…...……..;

Others: ……..……;

19. To what extent are the control measures put in place effective in controlling predation within your farm?

- ☐ No extent at all
- ☐ Low Extent
- ☐ Moderate Extent
- ☐ Great extent
- ☐ Very great extent

20. Which predator(s) have you been fully able to control? How? ……...

……

……

……

21. Which predator(s) have you been fully unable to control? Why? ……..……

……

Section 3: Socio-economic Impacts of Fish Predation

22. To what extent would you rate the severity of losses incurred directly due to predator attacks within your farm?

- ☐ No extent at all
- ☐ Low Extent
- ☐ Moderate Extent
- ☐ Great extent
- ☐ Very great extent

23. How much more did you have to invest in a bid to install predators control installations such as overhead nets? …….

……..

24. How much in monetary value would you give as the estimated annual losses you incur due to predator attacks in Kenya shillings? Ksh. …….

25. How much do you spend annually in setting up/ maintaining predators control measures within your farm? Ksh. ……

26. In your estimation, how much do you save by adopting various predation control measures in your farm? ……

27. To what extent does each of the following predators affect the productivity of your fish ponds? Indicate in the table below where 1 means no extent, 2 low extent, 3 moderate extent, 4 great extent, and 5 very great extent.

	1	2	3	4	5
Birds					
Domestic Animals (e.g. cat)					
Wild Animals					
Reptiles (e.g snakes)					
Fish					
Others					

28. In which ways does predators attack affect your day to day activities at the farm?

……

……

……

29. Does predation have any social ramifications in your life? Which ones?

……

……

……

30. a. How have agricultural policy makers and governments assisted you in managing fish predation? ……..
……
30. b. How would you want policy makers and government to assist you in the control of fish predators? ……...
……
31. What other views or recommendations do you have? ……
……
……..
……..

32(a). Who is mostly involved in predator control in your pond(s)……
32(b). How much time do the above spend in the activity of predator control?.....
.....
33(a). Do you at any time hire labor to carry out predator control in the fish pond(s)

1) Yes
2) No

33(b) If yes what is the estimated cost for the activity for the entire crop?.....
33 What gender and age do you engage in controlling predators in fish ponds?.....
34. Who makes labor allocation decisions in your fish pond(s)

1) Man	( )
2) Woman	( )
3) Children	( )
4) Other please state	( )

35. What are the sources and distribution of labour in your farm?

Source of labour		**Tick**	**Time spent (hrs/day)**
Household members	Father		
	Mother		
	Children		
Hired labour			

That's all I had, I appreciate your participation

THANK YOU

Appendix iii: Observation form

Date		**Time**	**AM**	
Name of Farmer		**Ward**	**Village**	
Pond No			**PM**	
Pond surroundings 50 meter square	**Trees**	**Bushes**	**Grass**	
Pond water quality	**Turbid**		**Clear**	
Average production per pond (Kg)				
Loss per pond (Kg)				
Type of Predator observed	**Number observed**	**Frequency**		**Remarks**
Reptiles				
Snakes				
Lizards				
Frogs				
Other				
Birds				
Egrets				
King Fisher				
Marabou stock				

Eagles				
Ducks				
Pellicans				
Hammerkop				
Gulls				
Other				
Terrestrial animals				
Dogs				
Cats				
Humans				
Cray fish				
Turtles				
Otters				
Murkats				
Mink				
Other				

Appendix iv: Interview Guide for Extension Workers

1. What is the current state of fish farming in Kitui County, what are the key challenges and the advantages facing fish farmers in the area
2. How big is the problem of fish predation in the County and how much does it affect the ponds' productivity within the area?
3. Which are the key predators observed in Kitui County? How do they affect fish farming and at what extent?
4. What are the key control measures instituted by the farmers to manage predation; and how successful are they in the control?
5. Are the control measures effective in reducing predation in fish farming, and are they cost-effective for the farmers? Are the control measures affordable to all fish farmers?
6. What social effects have you observed being caused by predators' attacks in fish farming?
7. In your estimates, predation control in fish farming eats up what proportion of profits gained by farmers per season? What can farmers do to reduce this proportion to a more appropriate amount?
8. Have you came across a farmer who had to discontinue fish farming due to a predator attack in Kitui County? Which predators were disturbing the farmer and what control measures he had instituted?
9. In your views, how can fish farmers maximize income from fish farming despite the risks posed by predators?

Appendix v: Timeframe

Task Description	**February 2019**	**March 2019**	**April 2019**	**May 2019**	**June 2019**	**July 2019**	**August 2019**	**September 2019**
Proposal Development								
Pilot test and reviews								
Data Collection								
Data Entry and Analysis								
Preparation of the report								
Presentation of project report								

Appendix vi: Budget

The budget breakdown for the study is as follows:-

No.	Description of Item	Unit Cost (Kshs)	Total Cost (Kshs)
1.	Research permit	1,000	1,000
2.	Printing & binding costs: Proposal – 2,000/- Questionnaires – 3,000/- Research Project -5,000/-	10,000	10,000
3.	Research Assistants (3)	5,000	15,000
4.	Field Observations	10,000	10,000
5.	Airtime for co-ordination	5,000	5,000
6.	Contingency 10%		10,000
	Total		**51,000**