PREDATION AND RISK FACTORS ASSOCIATED WITH PARASITIC INFESTATIONS OF FARMED FISH IN KIRINYAGA COUNTY, KENYA

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ABSTRACT

Predators affect aquaculture by feeding on fish, causing injuries and spreading diseases. Questionnaires were administered to 137 fish farmers in Kirinyaga County assessing farming practices, constraints, type of predators and extent of predation experienced by fish farmers. Prevalence of parasites was evaluated in 289 fish (203 tilapia, 86 catfish) and 50 piscivorous birds in the region. Tilapia, catfish and ornamental fish were the main species of fish farmed. Overgrown vegetation, low water levels and poor predator control methods were the main management constraints observed. Low quality and expensive feeds, water scarcity, predation, theft and lack of proper markets were major fish production constraints. Piscivorous birds (Herons, kingfisher, ibis, hamerkop), otters, monitor lizards and snakes were the main predators encountered. Predators were controlled by fencing (10%), pond netting (21%) and chasing them away (74%). Tilapia (39%) and catfish (45%) from earthen ponds were infested with at least one species of helminth parasite. Farms which had higher presence of birds also had more parasitic infestations. Prevalence of parasites isolated in tilapia were; *Acanthocephala* spp. (11%), *Clinostomum* spp. (5%), *Dactylogyrus* spp. (3%) and *Diplostomum* spp. (22%). In catfish, they were; *Acanthocephala* spp. (4%), *Contracaecum* spp. (24%), *Dactylogyrus* spp. (5%), *Diplostomum* spp. (11%), *Gyrodactyrus* spp. (6%) and *Paracamallanus* spp. (16%). Water birds including herons, cormorants, kingfishers, hamerkop, spoonbill and several stilts were infested with *Clinostomum* spp. (4%), *Contracaecum* spp. (2%), *Acanthocephala* spp. (16%), and cestodes (36%). Genera of parasites with documented zoonotic importance isolated from fish and predatory birds were; *Clinostomum* spp., *Contracaecum* spp. and *Acanthocephala* spp. Predation has a

significant role in aquaculture profitability. Most farmers don't practice effective predator control methods due to inadequate knowledge on losses impacted and ability of predators to spread diseases in aquaculture. Farmers should be trained and advised on handling and cooking of fish to avoid contracting zoonotic parasites.

DECLARATION

I, Joseph Wairia Murugami, do hereby declare to the Senate of Sokoine University of Agriculture, that this dissertation is my own original work and that it has neither been submitted nor concurrently being submitted in any other institution.

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Joseph Wairia Murugami Date

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Prof. P.G. Mbuthia Date

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DEDICATION

To my late father Mr. Nahashon Murugami Ndegwa who was a mentor from my young years.

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LIST OF ABREVIATIONS AND ACRONYMS

ESP –	Economic Stimulus Program
FFEPP –	Fish Farming Enterprise and Productivity Program
FZTs –	Fish Zoonotic Trematodes
MOFD –	Ministry of Fisheries Development
UoN –	University of Nairobi
SUA –	Sokoine University of Agriculture

CHAPTER ONE

1.0 INTRODUCTION

Kenya vision 2030 aims at a food secure country with fish farming forming one of the strategic pillars (Kenya, 2013). Aquaculture is a source of income and nutrition security to communities (Geheb and Binns, 1997). Tilapia and African catfish are the main species in freshwater aquaculture in Kenya. The demand for aquaculture products is high due to a rapidly growing population, declining natural fish stocks and active fish farming promotion by the government (Rothuis *et al.*, 2011). Farmer management practices influence growth of the aquaculture sector and fish health (Munguti *et al.*, 2014; Mavuti *et al.*, 2017a).

Fish are known to be hosts to various fish ecto- and endo- parasites. Fish infested with parasites can be unsightly and their market value greatly decreased (Roberts, 2012). There are also public health concerns as some fish parasites are zoonotic (Florio *et al.*, 2009; Hung *et al.*, 2015). Studies on fish parasites have been done in some regions in Kenya (Aloo, 2002; Migiro *et al.*, 2012; Khamis *et al.*, 2017; Mavuti *et al.*, 2017b). Information is lacking on the types of fish parasites, life cycles and those of public health concern in farmed fish in Kenya.

Fresh water aquaculture farms are frequently invaded by predatory birds in search for food. Competition between birds and man in fish farming can be high when fish ponds are constructed near bird migratory routes and known flyways (Ogoma, 2012). Construction of ponds in isolated areas where birds can easily access fish, presence of overgrown vegetation, trees and other structures for birds to perch, nest and hide increases the level of predation (AGRI-FACTS, 1999). Predators cause significant losses in farmed fish enterprises through fishing and eating of the fish, causing injuries and act as intermediate/final hosts and vectors for parasites (Shitote *et al.*, 2012). Piscivorous birds like cormorants, kingfishers, herons, egrets and pelicans, for example, can remove large numbers of fish from aquaculture facilities and as they move from one pond to another can spread bacterial and parasitic diseases (Barson and Marshall, 2004). Studies on predator diversity in Kenyan fish ponds and the type of losses caused are few (Ogoma, 2012). Their roles in the life cycle of fish parasites and spread of diseases and farming practices that enhance fish parasitism and predation have not been documented in Kenya aquaculture establishments.

1.1 Problem statement and justification

Predation impacts negatively in aquaculture. There is a need to know the types of predators affecting fish farms in Kirinyaga County, the farming practices that encourage their presence and their impacts to aquaculture. There is lack of efficient methods of predator control without causing conservation concerns as there is limited information on predator dynamics in fish ponds. Studies to assess the possible impact of fish predatory birds on aquaculture development are also few (Ogoma, 2012). Predatory birds have been documented to harbor adult stages of trematodes (Gustinelli *et al.*, 2010) and nematodes (Barson and Marshall, 2004) that can be transmitted to farmed fish and even to humans. Parasites in farmed fish and predatory birds in Kirinyaga County and Kenya at large need to be documented. Fish-borne parasitic zoonosis like *Opisthorchiosis*, intestinal *Trematodiosis*, *Anisakiosis* and *Diphyllobothriosis* are less recognized in many parts of the world (Chai *et al.*, 2005). Fish- borne zoonotic trematodes (FZTs) are important emerging infestations (Clausen *et al.*, 2012). This study was to contribute to the understanding of the types of predators and practices that enhance predation in local aquaculture farms in Kirinyaga County, Kenya. Also, parasites in piscivorous birds and farmed fish were studied to explain spread of parasites and document zoonotic ones.

1.2 Study objectives

1.2.1 Overall objective

To investigate predation and the risk factors associated with parasitic infestations in farmed fish in Kirinyaga County, Kenya.

1.2.2 Specific objectives

i. To investigate the type and extent of predation in aquaculture facilities as experienced by farmers in Kirinyaga County

ii. To investigate farming practices that predispose to parasitic infestations and predation in aquaculture facilities in Kirinyaga County

iii. To determine the prevalence of parasites of farmed tilapia, catfish and captured piscivorous birds in the study area.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Aquaculture in Kenya

The government of Kenya, through the Fish Farming Enterprise and Productivity Program (FFEPP), allocated more than three billion Kenya shillings for the aquaculture sector between 2008 – 2011 financial years for construction of fish ponds, provision of fingerlings, fish feed and extension services (MOFD, 2010). The FFEPP increased small scale aquaculture farming in many regions of Kenya. Although farmers have larger ponds with higher stocking numbers, the economic returns are still not realized due to low harvesting weights and various production challenges (Maina *et al.*, 2014). Tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*) farming in earthen and plastic liner ponds is commonly practiced. Ornamental fish, rainbow trout (*Oncorhynchus mykiss*) and common carp (*Cyprinus carpio*) are also farmed in some regions (Ngugi *et al.*, 2007). The increased trends in fish farming over recent years in Kenya has brought about the need to monitor the health of fish stock to produce fish that is safe for human consumption. Intensification in aquaculture alters the natural environment for fish hence new infections/infestations are cropping up due to increased stress levels and reduced immunity (Mennerat *et al.*, 2010).

2.2 Challenges of aquaculture in Kenya

Studies by Hyuha *et al.*, (2011) and Shitote *et al.*, (2012) reported that farmers were getting small profit margins from their fish farms. This was attributed to predation, lack of functional credit facilities, expensive feeds and poor quality of fingerlings among others. Low profitability has seen farmers abandon fish farming in many areas in Kenya with ponds becoming health hazards when not managed (Howard and Omlin, 2008).

2.3 Fish parasites

Fish parasites are diverse and affect both farmed and wild fish. Some parasites are host specific but many are harmless to their hosts. The number of parasites necessary to cause harm to fish varies considerably with fish species, size, and health status (Overstreet, 1993; Iwanowicz, 2011). Intensive fish farming encourages propagation of parasites and can result to serious outbreaks. Some documented phyla of fish parasites include Protozoa, Platyhelminthes, Nematoda, Acanthocephala, Arthropoda, and Annelida (Woo, 2006).

2.4 Helminth parasites of fish

2.4.1 Phylum Platyhelminthes

These are the flatworms that are dorso-ventrally flattened, bilaterally symmetrical and acoelomate. They lack an anus as well as specialized skeletal, circulatory and respiratory systems. Most of them are hermaphrodites (Hoffman, 1999; Woo, 2006).

2.4.1.1 Class Trematoda

2.4.1.1.1 Order Monogenea

Monogenea are small ectoparasitic flatworms mainly found on skin, fins and gills of fish. They lack respiratory, skeletal and circulatory systems and have weakly-developed oral suckers or none. Monogenea have well developed attachment structures like hooks and clamps. They are oviparous or viviparous and with a direct life cycle. The main genera affecting most tropical fish include *Gyrodactylus*, *Dactylogyrus* and *Cichlidogyrus*. Heavily infested fish have thickened cuticle, frayed fins, skin ulcers and damaged gills due to the feeding activities of the parasites and damage by attachment hooks (Buchmann and Lindenstrøm, 2002).

2.4.1.1.2 Order Digenea

Digenea are endoparasites of vertebrates with a life cycle involving at least one intermediate host. They have two suckers, one anteriorly and the other antero-ventral. Metacercarial stages are found in fish and adult stages in predators, mostly birds (Gustinelli *et al.*, 2010). All digeneans undergo part or all of their larval development in molluscs. The family Heterophyidae (*Heterophyes* spp. and *Haplorchis* spp.) are found in internal organs of tilapia as cysts while *Clinostomum* spp. are found in tilapia and other cichlid fish in skin and internal organs as cysts called ‘yellow grubs’ which can be unsightly and unacceptable to consumers. The family Diplostomatidae, (*Diplostomum* spp., *Tylodelphys* spp. *and Neascus* spp.) are found in various fish on the eyes, skin and gills causing eye fluke blindness or ‘blackspot’ on the skin (Palmieri *et al.*, 1977). The blind fish are prone to predation since they tend to feed for long hours and are not able to hide from predators (Brassard *et al.*, 1982; Seppala *et al.*, 2005).

2.4.1.2 Class Cestoda

These are endoparasites with at least one intermediate host in their life cycle. Their body (strobila) is divided into a number of segments (proglottids), each with a single set of reproductive organs, with exception of order Caryophyllaeidea that is not segmented (Molnár *et al.*, 2003). The scolex, used for attachment is found anteriorly and is useful for identification of the worms. Adult worms are elongated and white in color. They are parasitic in the intestines of the host fish, with the larval forms (plerocercoids) often found encysted in the viscera and musculature of host fish. Some species in this class include *Bothriocephalus* spp., *Diphyllobothrium* spp., *Ligula* spp., *Caryophayllaeus* spp., *Tetraphyllidea* spp., *Trypanorhynchidea* spp., *Protocephalidea* spp. and *Amphilinidae* spp. Effects of cestode parasite infestation include swollen abdomen, compression and distortion of the viscera and inhibition of gonadal maturation due to the large sizes of the worms and absorption of host nutrients when in body cavities (Woo, 2006; Roberts, 2012).

2.4.2 Phylum Nematoda

Nematodes are bilaterally symmetrical, coelomate elongate worms with cylindrical body tapering at both ends with a solid resistant cuticle. Their mouth is terminally anterior, with the gut clearly divided into esophagus and intestines. Sexes are separate. Those that parasitize fish require at least one intermediate host. *Contracaecum* spp., *Ampliceacum* spp., *Eustrongyles* spp. and camallanid nematodes (*Camallanus*, *Paracamallanus* and *Procamallanus* spp.) are some examples in this group (Anderson, 2000).

2.4.3 Phylum Acanthocephala

These are also referred to as spiny or thorny headed worms. They are elongated cylindrical worms armed with an anterior retractable proboscis carrying hooks. They have no gut and the sexes are separate, with males being smaller than the females. They are mostly gut worms with at least one intermediate host in their life cycle. *Acanthocentis* spp has been described affecting tilapia in East Africa (Florio *et al.*, 2009). Fibrotic nodules due to acanthocephalan infestations have been observed on the surface of the intestines (Woo, 2006).

2.5 Factors affecting fish parasitism

In ideal aquatic environments, parasites will exist at equilibrium with their hosts without adverse damaging effects (Iwanowicz, 2011). Increases in levels of stressors will lead to higher parasitic loads due to decreased immunity (Gilbert and Avenant-Oldewage, 2016). These stressors include poor water quality, overcrowding, introduction of new species, and habitat alteration leading to increased presence of vectors and intermediate hosts of parasites like snails and predatory birds.

2.6 Fish predation

Predators cause significant losses in farmed fish enterprises by fishing and eating the fish, causing injuries and acting as intermediate/final hosts for parasites (Shitote *et al.*, 2012). However, their erratic appearances from time to time, makes it is difficult to exactly quantify losses caused to aquaculture (Harris *et al.*, 2008). Piscivorous birds can deplete stock of fish from aquaculture facilities and are a threat to pond biosecurity as they move around freely from one pond to another (Barson and Marshall, 2004). A survey by Ogoma, (2012) in Lamu County in coastal Kenya reported egrets, herons, storks, cormorants, ibises and kingfisher to be the major groups of birds visiting small scale fish farms in the region. Non-lethal forms of predator control should be adopted in order for farmers to realize returns on investment without causing conservation concerns (Ogoma, 2012). Other predators reported include monitor lizards, otters, snakes and frogs (Ngugi *et al.*, 2007). Previous studies did not conduct parasitological studies in documented predatory birds in fish farms in Kirinyaga County and the Kenyan highlands as a whole. Due to the increasing interest in aquaculture in Kenya, studies on predation patterns and extent in other areas will be useful to potential farmers and extension officers.

Some of the predators found in fish farming areas in Kenya are described below. Most of these predators are documented to be present in the tropics. This study was to find out if fish farming areas in Kirinyaga County have experienced increased predator presence than other areas, and also if predator presence is related to higher parasitic disease occurrence in aquaculture.

2.6.1 African clawless otter

The African clawless otter (*Aonyx capensis*), is an aquatic mammal found near permanent bodies of water in savannah and lowland forest areas characterized by partly webbed and clawless feet. The diet of these otters includes aquatic animals like crabs, fish, frogs and worms. They dive for prey then swim to shore where they eat. Otters will often invade fish ponds near rivers bringing economic losses and wildlife conflict (Reed-smith, 2004).

2.6.2 Marabou stork

The marabou stork (*Leptoptilos crumenifer*) is a large wading bird in the stork family *Ciconiidae* found in Africa south of the Sahara, in both wet and arid habitats, often near human habitation. This bird is found around most urban settlements in Kenya. It is a scavenging bird observed to feed on a wide variety of food including fish (Zimmerman *et al.*, 2005). This bird has not been documented as a common fish predator in Kirinyaga County.

2.6.3 Order Suliformes

2.6.3.1 Reed cormorant

The reed cormorant/ long-tailed cormorant (*Microcarbo africanus*), of the family *Phalacrocoracidae* measures about 50–55 cm length and 85 cm wingspan. It has a long tail, a short head crest and a red or yellow face patch. This bird can dive to considerable depths, but usually feeds in shallow water, frequently bringing prey to the surface. It feeds on a variety of fish such as mormyrids, catfishes, and cichlids

(Zimmerman *et al.*, 2005). This study sought to investigate the role of bids in the family Suliformes as fish predators in Kirinyaga County.

2.6.3.2 African darter

The African darter (*Anhinga rufa*), resembles the cormorant but with a long neck. It also dives for fish and is often seen along watersides with cormorants (Zimmerman *et al.*, 2005).

2.6.4 Order Pelecaniformes

2.6.4.1 Pelicans

A good example is the pink-backed pelican (*Pelecanus rufescens*). They are usually found fishing in groups and usually eat fish and amphibians. Among the fish preyed upon are cichlids like haplochromis and tilapia (Zimmerman *et al.*, 2005). Presence of this fish predator in Kirinyaga County fish ponds needs to be documented.

2.6.4.2 The hamerkop

The hamerkop (Family *Scopidae; Scopus umbretta*), occurs in Africa south of the Sahara, Madagascar and Arabia in wetland habitats and irrigated land such as rice paddies. It is also found in savannahs and forests. They feed during the day alone or in pairs. They mainly feed on amphibians, fish, shrimp, insects and rodents (Zimmerman *et al.*, 2005). The role of hamerkops in fish predation has not been adequately documented in Kirinyaga County.

2.6.4.3 Family Ardeidae

This family includes the herons and egrets. The grey heron (*Ardea cinerea*) and Goliath heron (*Ardea goliath*) feed mostly on aquatic creatures which they catch after standing stationary beside or in the water or by stalking the prey through the shallows. The egrets like the great egret (*Ardea alba*) and the little egret (*Egretta garzetta*) feed mainly on fish, frogs, small mammals and are found stalking their prey in shallow water (Zimmerman *et al.*, 2005).

2.6.4.4 Family Threskiornithidae

This family includes the ibises and spoonbills. The African sacred ibis (*Threskiornis aethiopicus*) and African spoonbill (*Platalea alba*) will be found near water feeding on various fish, frogs and small mammals (Zimmerman *et al.*, 2005).

2.6.5 Kingfishers

These are in the order *Coraciiformes,* family *Alcedinidae.* They include giant kingfisher (*Megaceryle maxima*) and pied kingfisher (*Ceryle rudis*) among others. They mainly feed on fish and will often be found perched on vegetation near water (Zimmerman *et al.*, 2005).

2.7 Role of predators in fish parasitism

Predatory birds are definitive hosts of some parasites (Woo, 2006). Various species of birds have been documented to harbor adult stages of parasite of fish like *Clinostomum* spp. (Gustinelli *et al.*, 2010), *Contracaecum* spp. (Barson and

Marshall, 2004), *Gryporhynchidae* cestodes (Ortega-Olivares *et al.*, 2008) and Cyclophyllidean cestodes (Schmidt, 1972) among others. As they feed on fish, the metacercaria and plerocercoids of the parasites will develop to adult stages (Figure 1 a and b). Parasites have been documented to manipulate hosts in ways such as causing blindness or altering feeding behavior hence making fish more susceptible to predation. This enables completion of the parasites' life cycles (Brassard *et al.*, 1982; Lafferty and Morris, 1996). With exception of few studies (Florio *et al.*, 2009; Gustinelli *et al.*, 2010; Otachi *et al.*, 2011), there is no adequate documentation on the role of water birds in the life cycles of various fish parasites in aquaculture in Kirinyaga County and Kenya at large. This study attempted to bridge this knowledge gap by conducting parasitological studies on different species of water birds.

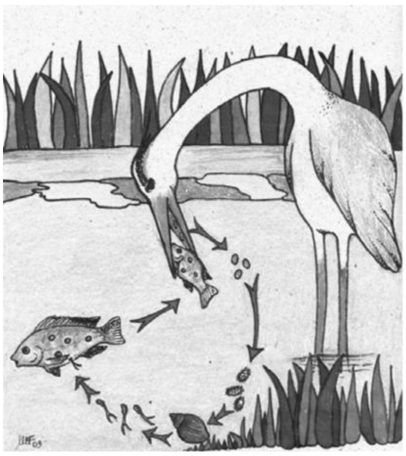
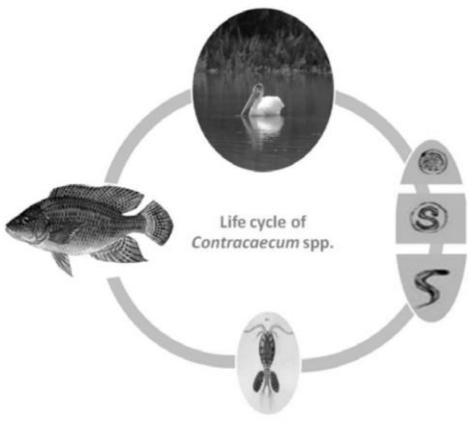
a.  b. 

Figure 1: Illustration of the life cycle of a. *Clinostomum* spp. and b. *Contracaecum* spp. depicting piscivorous birds as final hosts. (Florio *et al.*, 2009)

2.8 Factors predisposing to fish predation

Aquaculture in itself attracts water birds and other animals that feed in or near water reserves. Having overgrown vegetation and trees near ponds allows predators to nest, hide and easily access ponds to look for fish. When fish ponds are left open without cover nets, fish are easily preyed on by birds. Fish ponds should have a depth of at least one meter and the banks should be steep to make it difficult for birds to wade through water (Ngugi *et al.,* 2007).

2.9 Control of predators in fish farms

Construction of fish ponds in isolated areas where birds get easy access to fingerlings, presence of vegetation and other perching, nesting and hiding structures for birds increases the level of predation. Removal of these structures, clearing vegetation around ponds and increasing pond shore depth to a minimum of one meter with steep banks reduces success of predation (AGRI-FACTS, 1999). Pond netting and use of barbed wire over ponds are efficient ways to control bird predators. Fencing is also indicated to keep off thieves and other predators like otters and monitor lizards out (Ngugi *et al.,* 2007).

2.10 Fish parasites and public health

Some fish parasites are zoonotic and have been documented to be infective to humans. This has been further enhanced by increased international transport of fish and consumption of raw fish products like sushi and sashimi (Nawa *et al.,* 2005). However, most of these infestations can be prevented by proper cooking of fish and deep freezing at -20^{0}C to kill the encysted parasites (Adams *et al.*, 1997; Chai *et al.*, 2005). Cyprinid fishes are culprit to the spread of zoonotic digean parasites of the family Echinostomatidae (*Clonorchis sinensis* and *Opisthorchis viverrini*). Lung infestations have been reported due to *Paragonimus* flukes like *P. westermani* and *P. heterotremus.* Nematodes of *Gnathostoma* spp. cause skin infections in man due to migration of larvae while intestinal infestations have been reported due to *Capillaria* spp., and nervous disease due to the nematode *Angiostrongylus cantonensis* (Nawa *et al.*, 2005). Cestodes like *Diphyllobothrium latum* and nematodes like *Anisakis* spp. and *Contracaecum* spp. have been documented to be zoonotic (Roberts, 2012). Data on zoonotic fish parasites in East Africa is not readily available compared to other regions like Asia. This study compared information on parasites found in Kirinyaga County with other studies from other regions to understand public health aspects of fish parasites in East Africa. Factors of transmission process of zoonotic parasites and possible intervention measures are shown in Figure 2.

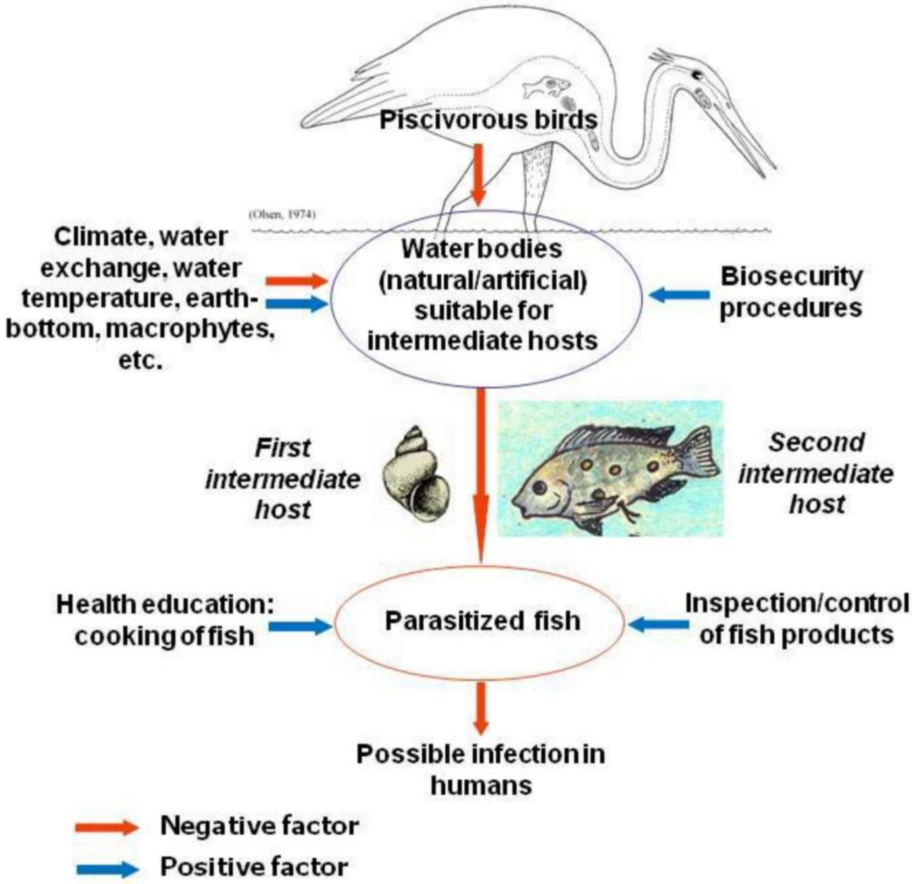


Figure 2: Factors influencing transmission of zoonotic fish parasites to humans and possible control strategies (Florio et al., 2009).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study area

This study was conducted in Kirinyaga County, Kenya, 100 km North East of Nairobi, with an altitude of 1230 m above sea level, latitude 0°12'S-$0^0$45'S and longitude 37°11'E-$37^0$30'E. Annual air temperatures range between 12 °C and 26 °C and annual precipitation of about 1250mm. This county has 1,376 fish farmers with 1,400 active fish ponds covering a total area of 342, 633 hectares (MOFD, 2010). Farmers who owned or managed at least one active fish pond were targeted. This county was chosen due to ease of access and the long history of involvement in aquaculture (Figure 3).

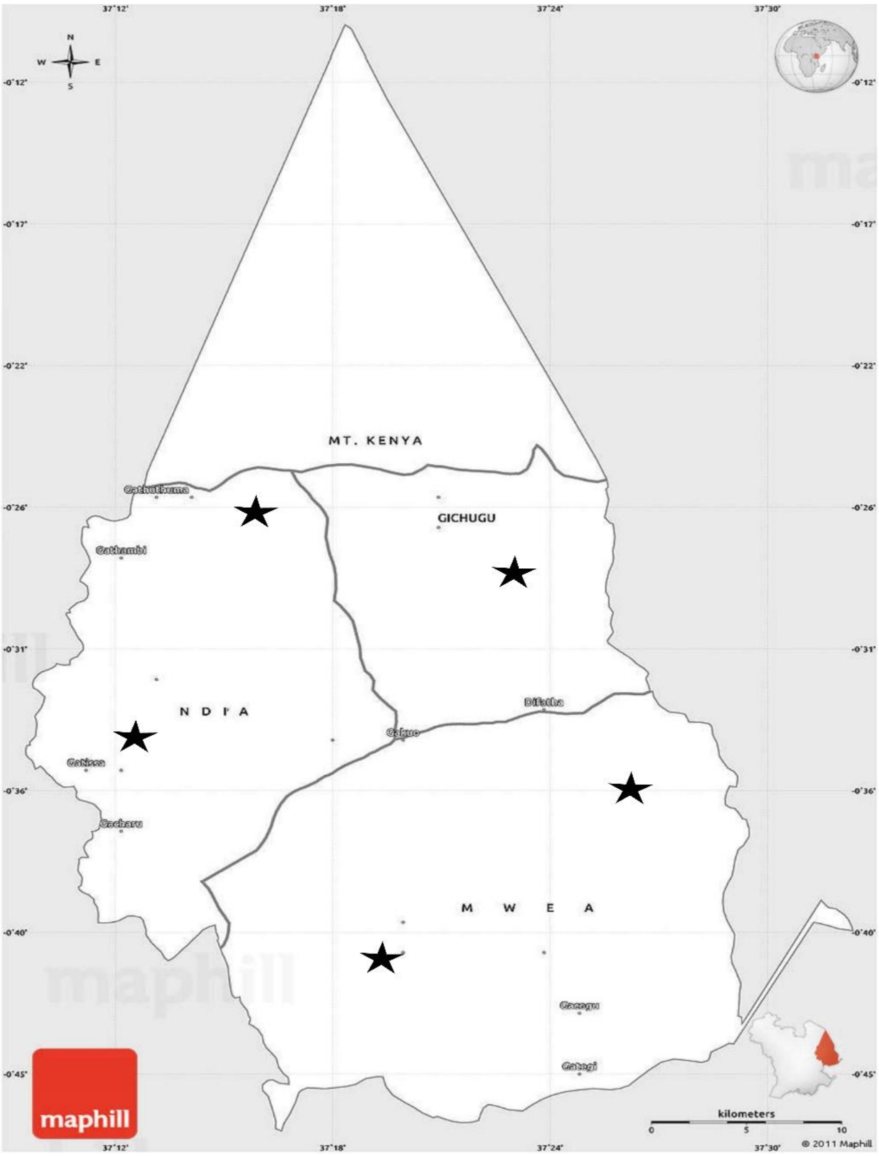


Figure 3: Kirinyaga county map showing the five sub counties (stars) visited during the study. Source: http:// www. maphill. com/ kenya/ central/ kirinyaga/ simple-maps/silver-style-map/

3.2 Sampling strategy and data collection

Participants of the study were drawn from fish farmers in all sub counties of Kirinyaga County. A list of fish farmers was obtained from the County Fisheries Department. Stratified random sampling was used. Those with active fish ponds were identified and chosen based on their availability for interviews and sampling. Sampling and data collection was done in three stages, first being questionnaire administration and observations, then fish sampling and finally capturing of water birds.

3.2.1 Questionnaire administration and observations

Permission to carry out the study was sought from the county fisheries office. A semi structured questionnaire (Appendix 1), with both closed and open-ended questions was used as the survey instrument. It was used to evaluate the fish farming, challenges experienced by farmers, types of fish predators encountered and periods they were in plenty. The questionnaire was supplemented with direct visual observations by the interviewers. Global positioning system (GPS) co-ordinates were taken for each fish farm included in the study to facilitate researchers to make a follow-up. Questionnaires were administered in October 2016 to 137 farmers in the five sub-counties of Kirinyaga County as follows; Kirinyaga East (35), Mwea East (34), Kirinyaga Central (29), Mwea West (22) and Kirinyaga West (17) (Figure 4). Observations on the status of the fish ponds and the types of piscivorous birds seen in each farm were made and recorded with the help of a binoculars and a digital camera. Identifications of the bird species were made with the help of bird keys from Zimmerman *et al.* (2005).

Figure 4: A). The investigator (with a clip board) administering questionnaires in Kirinyaga West sub-county, B). Sampling of fish using a seine net in Kirinyaga Central sub-county of Kirinyaga County

3.2.2 Fish sampling

Three sub-counties (Kirinyaga Central, Kirinyaga West and Mwea East) were purposively selected after the questionnaire survey based on the high number of active fish ponds and fish predatory birds. Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*) were the species of interest. The sample size (n) was determined using the formula according to Naing *et al.*, (2006): $n = \frac{z^2 p(1-p)}{d^2}$

Where, z is the value of the corresponding confidence level (1.96 for 95% confidence); d is the precision (5%) and p is the estimated proportion of a sample that have the condition of interest {15% parasitic prevalence (Otachi *et al.*, 2011)}. This gave a sample size of 200 fish. Verbal consent was sought from the owners of the fish farms before sampling. To get a representative sample, 10 fish were purchased per pond from the selected farmers (Figure 4).

3.2.3 Necropsy examination of fish

Fish were transported live to Kerugoya Veterinary Department Laboratory for examination (Figure 5). Post mortem examination done using standard procedures (Kane *et al.*, 1999; Roberts, 2012). The fish were stunned by a sharp blow to the head anterior to the eyes. The skin was examined grossly for ectoparasites. Skin scrapings, one eye, a section of the second gill arch and a portion of the intestine were taken and placed on a microscope slide for direct microscopic examination at X10 and X40 magnification for any parasites. The fish was laid on its side (tilapia) or back (catfish) on the prepared bench. A midline incision was made with a scalpel blade starting at the anterior end of the vent to the operculum. A lateral incision from the vent on the abdominal wall of the fish up to the upper corner of the operculum was made to expose the abdominal organs. The body wall was then lifted and the organs observed grossly in situ. A third incision connecting the two previous incisions at the operculum was made to remove skin and muscular flap. The gut was collected and preserved in 70 % ethanol for further parasitological analysis.

Figure 5: A). Catfish in a bucket before post mortem examination. B). Necropsy: Gross and microscopic examination for parasites in Kirinyaga Veterinary Laboratory

3.2.4 Sampling of water birds

Capture of water birds was done with permission from Kenya Wildlife Service. The research authorization and capture permit for the same are shown in appendices 2 and 3. Mist nets were set up in Sagana Aquaculture Center and Mwea Aqua Fish Farm to capture the water birds (Figure 6). Fifty water birds of different species were captured during the study period.

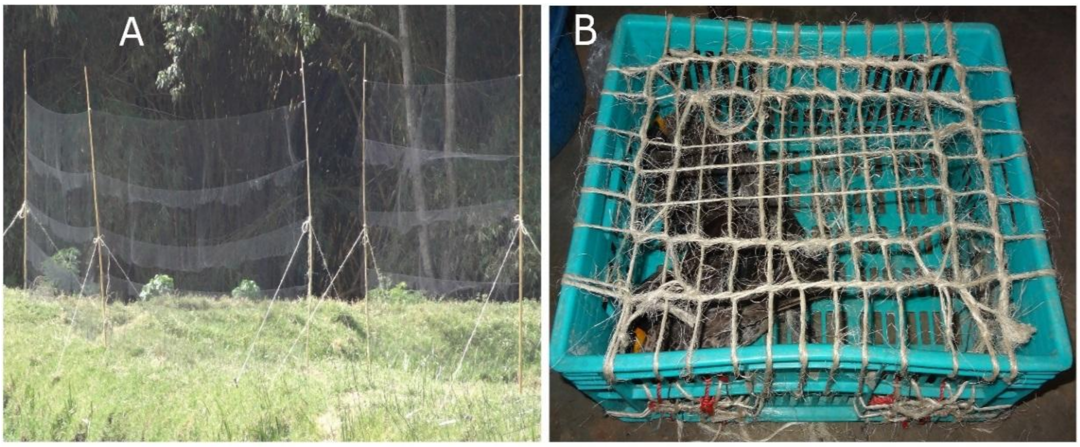


Figure 6: A). Mist nets set up for capturing birds in Sagana Aquaculture Center. B). Birds in a modified cage being transported to the laboratory

3.2.5 Necropsy of water birds

The captured birds were transported to the laboratory in Kerugoya Town in cages (Figure 6). The birds were euthanized by cervical dislocation and post mortem examination done as described by Brown (2012). The whole carcass was dipped into a bucket of water to thoroughly wet all the feathers. This was aimed at decreasing the dander that might aerosolize from the skin as a biosafety measure and keep the instruments free of small feathers during dissection. The carcass was placed on its back on the bench with its head facing the examiner. A cut was made through the commissure of the mouth to examine the oral cavity, larynx, trachea, esophagus and crop for presence of parasites. The carcass was then placed on its back with the feet facing the examiner and wings deflected back. A cut was made through the skin between the legs and the body fully abducting the legs to lie flat against the table. Skin from the ventral surface of the bird was removed by incising along the midline with a scalpel blade and deflecting it sideways. A cut was made into the body cavity using scissors behind the breast bone and extended caudally to expose abdominal viscera. The keel bone and breast muscles were then removed by incising the pectoral muscles on each side of the keel and cutting through the ribs. Breast muscles were incised and examined for parasites. The internal organs from oral cavity to the rectum were examined *in situ* for any abnormalities before removing them. The gastrointestinal tract from the birds was collected and preserved in 70% ethanol for parasitological analysis in the Department of Pathology, Microbiology and Parasitology, Kabete Campus, UoN.

3.2.6 Isolation and identification of parasites

Intestines from fish and birds were opened longitudinally using scissors and dissecting pins. The contents were expressed, washed with water and scanned for parasites using a dissecting microscope. Parasites isolated were counted and observed on a compound microscope at X10 and X40 magnification. Parasite identification guides by Chubb *et al.* (1987); Hoffman (1999); Woo (2006) and Roberts (2012) were used in the morphologic identification of isolated parasites. Morphological descriptions from journal publications (King and As, 1997; Scholz *et al.*, 2002; Barson and Marshall, 2004; De Chambrier *et al.*, 2007; Florio *et al.*, 2009; Gustinelli *et al.*, 2010; Khamis *et al.*, 2017) were also used for identification.

3.2.7 Quantifying parasite infestations

Prevalence and mean intensities were calculated to quantify the infestation levels of different parasites (Rózsa *et al.*, 2000). These were calculated as shown;

$$\text{Prevalence (P)} = \frac{\text{Number of fish infested with a specific parasite}}{\text{Total number of fish sampled}} \text{x } 100$$

$$\text{Mean intensity} = \frac{\text{Total count of a specific parasite}}{\text{Total number of fish infested with that parasite}}$$

3.3 Data analysis

All the data were entered into the computer, cleaned and sorted using Microsoft Excel 2016. Data were analyzed using the Statistical Package for Social Sciences (SPSS version 16.0) and Epi Info version 7. Descriptive statistics consisting of frequencies were computed for different data categories to facilitate comparisons of parasitic infestations between fish farms, fish species and water birds. Chi square test was used to compare proportions and prevalence of parasite infestations. Student's t-test and p values were used to determine statistical significance of the results.

CHAPTER FOUR

4.0 RESULTS

4.1 Survey on fish farming and predation in Kirinyaga County

4.1.1 Fish farms and owners' data

Majority of fish farmers in Kirinyaga County were male (82.3%; 102/124) over 50 years of age (77.4%; 96/124). Most of the fish farm owners (74.9%; 93/124) had attained secondary school education and above. Aquaculture was practiced as a business venture (sales) by (84%; 115/137) of the farmers and for subsistence (home consumption) by 15% (20/137) of the farmers. Daily farm management was done by owners and their immediate family members (76%; 104/137) and workers (22%; 30/137). Of those managing the fish farms, 58.4% (80/137) reported to have attended some training in fish farming mainly in form of seminars. Of the interviewed farmers, 15.3% (21/137) had been practicing aquaculture for less than two years, 39.4% (54/137) between 3-5 years, 38% (52/137) between 6-10 years and 7.3% (10/137) above 10 years. Most farmers (56.2%; 77/137) had earthen ponds while 40.9% (56/137) and 2.9% (4/137) had plastic liner and concrete ponds respectively. Water used for fish farming was sourced from rivers (65.7%; 90/137), untreated piped water (20.4%; 28/137), underground springs (7.3%; 10/137) and boreholes (6.6%; 9/137). Many fish ponds in the study area were poorly managed (70%; 96/137) with overgrown vegetation, poor fertilization for tilapia ponds and low water levels in some instances (Figure 7).

Figure 7: An earthen pond (A) with overgrown vegetation and a poorly managed liner pond (B) with collapsing walls and litter in it

4.1.2 Type of fish farmed and funding

Tilapia, catfish and ornamental fish were the main species of fish farmed in Kirinyaga County as shown in figure 8. The first stock of fingerings was sourced from government breeding farms by 66% and in private farms by 21% of farmers. Fingerlings for restocking were sourced from government farms by 17% of farmers, 27% from private farms while 40% left the fish to breed in their ponds.

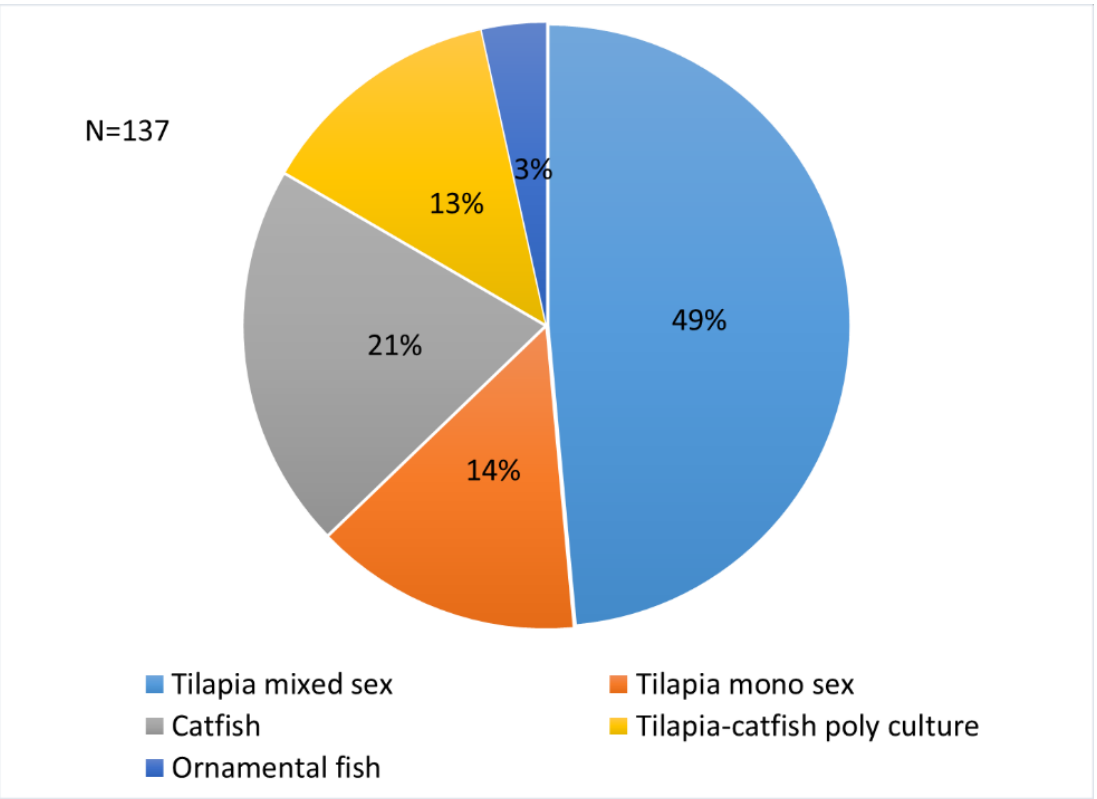


Figure 8: Type of fish species and farming systems in Kirinyaga County (N=137)

Of the interviewed farmers, 56.2% (77/137) got their start up capital from the Economic Stimulus Program (ESP), 42.3% were self-funded while 1.5% received funds from non-governmental organizations. It was noted that most of the farmers who reported fish farming to be unprofitable based on their experience were funded by the ESP (Figure 9). This was subjective based on the experience of the farmers.

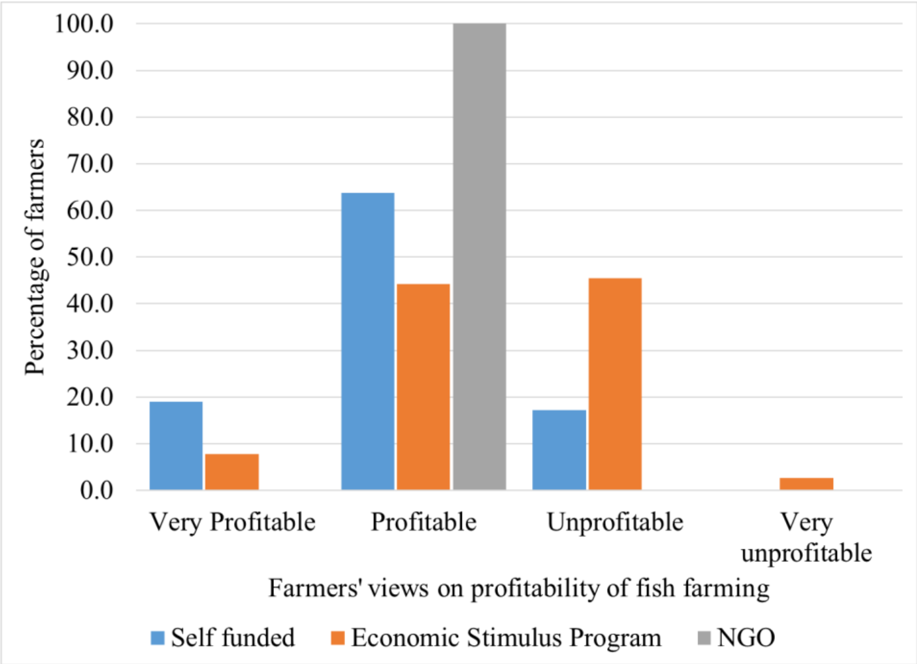


Figure 9: Farmers' views on profitability of fish farming based on source of startup capital

4.1.3 Challenges experienced by farmers

Farmers were asked to rate challenges experienced in fish farming as major, minor or no problem (Table 1) and it emerged that feed availability and predation were major constraints to fish production in all sub-counties. Theft was also a major concern among most fish farmers since most fish ponds were constructed far from the homesteads. Mwea West and Kirinyaga West had notably higher concerns of water availability for fish farming than other sub-counties. Availability of markets and low prices of fish were also considered as major problems. It was evident that not many farmers had encountered diseases in their fish ponds and some were not aware of fish diseases (Table 1).

Table 1: Some of the major challenges faced by fish farmers in Kirinyaga County

Challenges	**Sub-counties**				
	Mwea East	**Mwea West**	**Kirinyaga Central**	**Kirinyaga East**	**Kirinyaga West**
Feed availability	+++	+++	+++	+++	+++
Predators	++	+++	++	++	++
Low market prices	++	+	+	+	+
Theft	+	+	+	++	+
Water availability	+	++	+	+	++
Diseases	+	+	-	-	-

Key: +++ = Major challenge (61-100%); ++ = Challenge (31-60%); + = Minor challenge (1-30%); - = Not experienced; N = 137

Farmers were also asked their suggestions on how to counter the constraints that have hindered maximum productivity in fish farming. The response from 137 farmers was that they needed affordable quality feeds (57%), better organization of markets (30%), training on fish farming and management (29%), better breeds of fingerlings (17%), subsidies on fish farming inputs (13%), and provision of credit facilities (11%) among others (Appendix 4).

4.1.4 Type and extent of predation

Farmers in the study area reported piscivorous birds, otters, monitor lizards, and snakes as the common predators. Among these, birds were of major concern due to their numbers and frequency in the ponds (Table 2; Figure 10) Herons (43.8%) (60/137) and kingfisher (37.2%) (51/137) were the predatory birds of most concern to most farmers (Table 3). Ibis and hamerkop, both at 29.9% (41/137) were also reported to cause considerable loss to aquaculture followed by cormorants and egrets, both at 11.7% (16/137). Pelicans (8.8%) (12/137) and fish eagles (2.2%)

(3/137) were not very common in the study area. Farmers reported that most of these fish predatory birds frequented the farms throughout the year as opposed to specific periods in the year. Also, snails of the genus *Melanoides* were noted in many areas.

Table 2: Various major problematic types of predators in different sub-counties of Kirinyaga County

Types of Predators	Mwea East	Mwea West	Kirinyaga Central	Kirinyaga East	Kirinyaga West
Birds	+++	+++	++	++	+
Otters	+	+	+	+	+
Monitor lizards	+	+	-	+	+
Snakes	+	-	+	+	-

Key: +++ = Major challenge (61-100%); ++ = Challenge (31-60%); + = Minor challenge (1-30%); - = Not experienced N = 137 farmers

Table 3: Ranking of farmers on challenges posed by various fish-eating birds in Kirinyaga County (N=137)

Species of birds	Major problem (%)	Minor problem (%)	Not a problem (%)
Herons	43.8	8.8	47.5
Kingfisher	37.2	11.7	51.1
Ibis	29.9	17.5	52.6
Hamerkop	29.9	17.5	52.6
Egrets	11.7	5.8	82.5
Cormorants	11.7	5.8	82.5
Pelicans	8.8	1.5	89.8
Fish eagles	2.2	2.2	95.6

Avian fish predators that were identified as a threat to fish farming in Kirinyaga County were: grey heron (*Ardea cinerea*), pied kingfisher (*Ceryle rudis*), great egret (*Ardea alba egretta*), little egret (*Egretta garzetta*), reed cormorant (*Microcarbo africanus*), sacred ibis (*Threskiornis aethiopicus*), hamerkop (*Scopus umbretta*), and giant kingfisher (*Megaceryle maxima*) (Figure 10). Some farmers reported predation by riverine otters (*Lutrinae* spp.) to be very destructive. Otters attack ponds mainly at night by diving or burrowing into the ponds where they kill and eat large numbers of fish. Their presence such as fecal droppings and walking paths were evident in the vicinity of the ponds during farm visits.

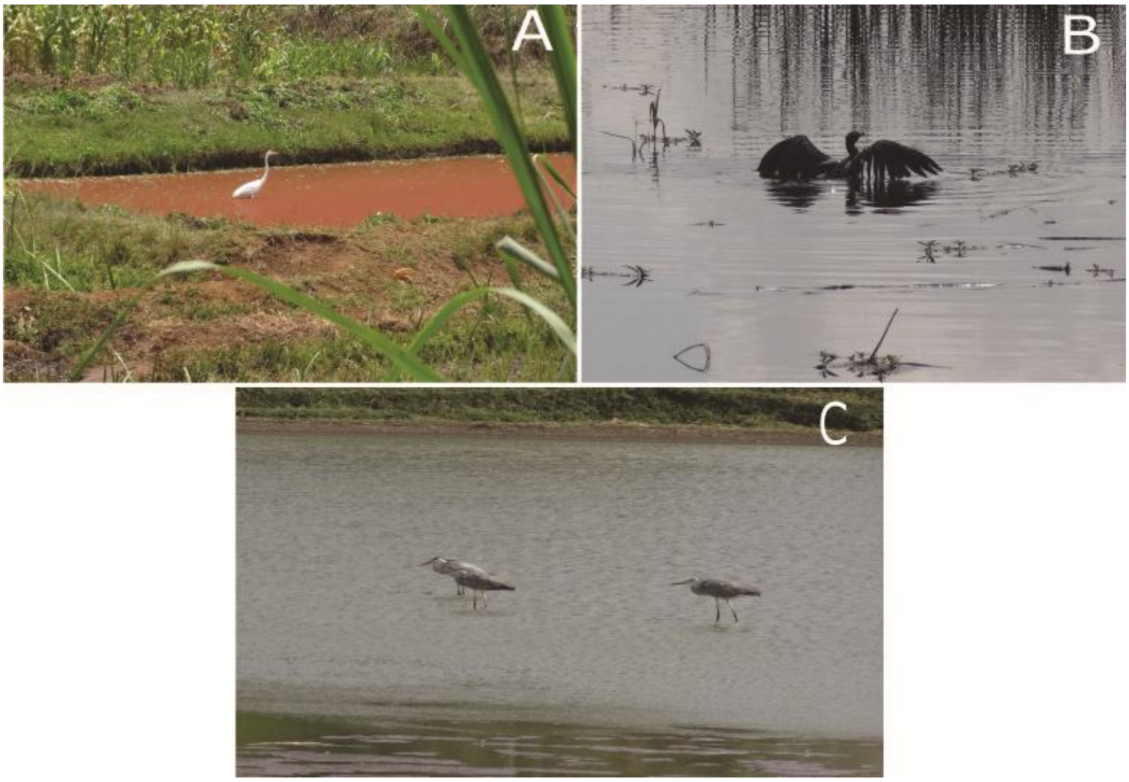


Figure 10: A great egret (A), reed cormorant (B) and grey herons (C) hunting for fish in different fishponds in Kirinyaga County.

Majority of the farmers (92.7%; 127/137) agreed that predation causes considerable loss to aquaculture facilities. A total of 43.8% (60/137) of the interviewed farmers agreed that predators can spread diseases and parasites to fish while 41.6% (57/137) did not know. On consuming raw fish, 51% (70/137) of the farmers felt it was not right, or could affect a person, 36.5% (50/137) did not know while 12.4% (17/137) said there was no problem in consuming raw fish. Most of the farmers (46.7%; 64/137) did not know if fish diseases can affect humans. Majority of the farmers 65.7% (90/137) said killing of the piscivorous birds is harmful to the ecosystem (Appendix 6). During the study period, injuries in fish caused by predatory birds were also observed while at times birds were seen taking fish from the fish ponds (Figure 11).

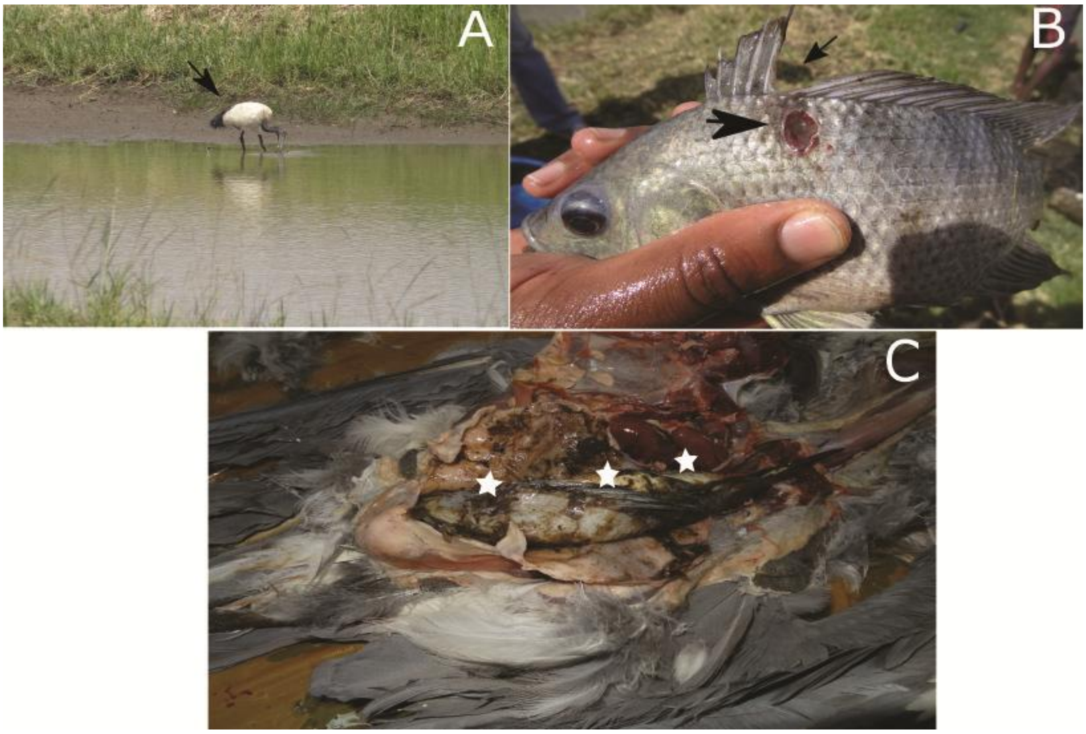


Figure 11: A. Sacred ibis (Threskiornis aethiopicus) feeding on fish in a fish pond (arrow). B. Tilapia fish with a bill wound (large arrow) and a tear on the dorsal fin (small arrow) inflicted by predatory birds. C. A grey heron (Ardea cinerea) with whole fish (white stars) in the stomach

4.1.5 Predator control methods

Majority of the farmers (74%) (89/137) reported to control predators by chasing them away when they visit the farms. However, this method was not rated as efficient as using pond netting and barbed wire over the ponds to control predators. Pond nettings were reported to be expensive hence only 21% (26/137) of farmers used them (Figure 12, Table 4). Some farmers attempted to make nets by passing strings over the ponds. Fish ponds with overgrown vegetation and low water levels were more likely to face higher predation challenge than those that were well managed. Farmers had erected fences around their fish ponds in an attempt to control theft by humans and predation by non-bird species like otters and monitor lizards (Figure 12). However, most of these fences were broken down hence ineffective.

Figure 12: Using pond netting (A, arrow) and fences (B) to control predators in fish ponds

Table 4: Methods used to control predators in fish farms and their efficiency as rated by farmers in Kirinyaga County

Control method	% usage	Rated efficiency
Chasing away	74	+
Pond netting	21	+++
Guarding of ponds	12	++
Barbed wire	10	+++
Scare crows	6	++
Traps	2	+

Key: **+++** = Very efficient; **++** = Moderate; **+** = Not efficient; N=137

4.2 Study of parasites of fish in Kirinyaga County

The study on parasites affecting farmed fish was conducted in March 2017 in three sub counties of Kirinyaga County. Fifteen private farms and one government farm were sampled based on availability of farmers and number of active fish ponds. The number of fish sampled per sub-county are shown in Table 5.

Table 5: Number of fish sampled per sub-county

Species	**Sub-county**			**Total**
	Kirinyaga Central	**Mwea East**	**Kirinyaga West**	
Tilapia	50	51	102	203
Cat fish	0	40	46	86
Total	50	91	148	**289**

During the study period, 50 tilapia from Kirinyaga Central, 51 tilapia and 40 catfish from Mwea East and 102 tilapia and 46 catfish from Kirinyaga West sub-counties were acquired. Out of the total 289 fish, 203 were tilapia with a mean weight of 130.5±79.5 g and mean total length of 18.95±3.69 cm while 86 were catfish with a mean weight of 392±2.88 g and mean total length of 39.54±7.6 cm. Of these, 20%

(10/50), 34% (31/90), and 52% (77/148) from Kirinyaga Central, Mwea East and Kirinyaga West sub-counties were infested with at least one species of parasites. Fish from earthen ponds (52%) (114/219) were found to be more infested with parasites than liner (7%) (4/60) and concrete ponds (1/60) (Table 6).

Table 6: Fish species and parasite presence in different ponds

Pond type	Tilapia	Cat fish	Total	Any Parasite*
Earthen	163	56	219	114
Liner	30	30	60	4
Concrete	10	0	10	0
Total	203	86	289	118

*includes all samples with at least one species of parasite

4.2.1 Prevalence of helminth parasites of fish

The prevalence of helminth parasites recovered from the sub-counties is shown in Figure 13. The highest prevalence of *Diplostomum* spp. was in Mwea East sub-county (26.4%). *Contracaecum* spp. (14.2%) and *Clinostomum* spp. (6.8%) were isolated from Kirinyaga West sub-county only. Parasitic infestations per subcounty were not statistically different ($p>0.05$).

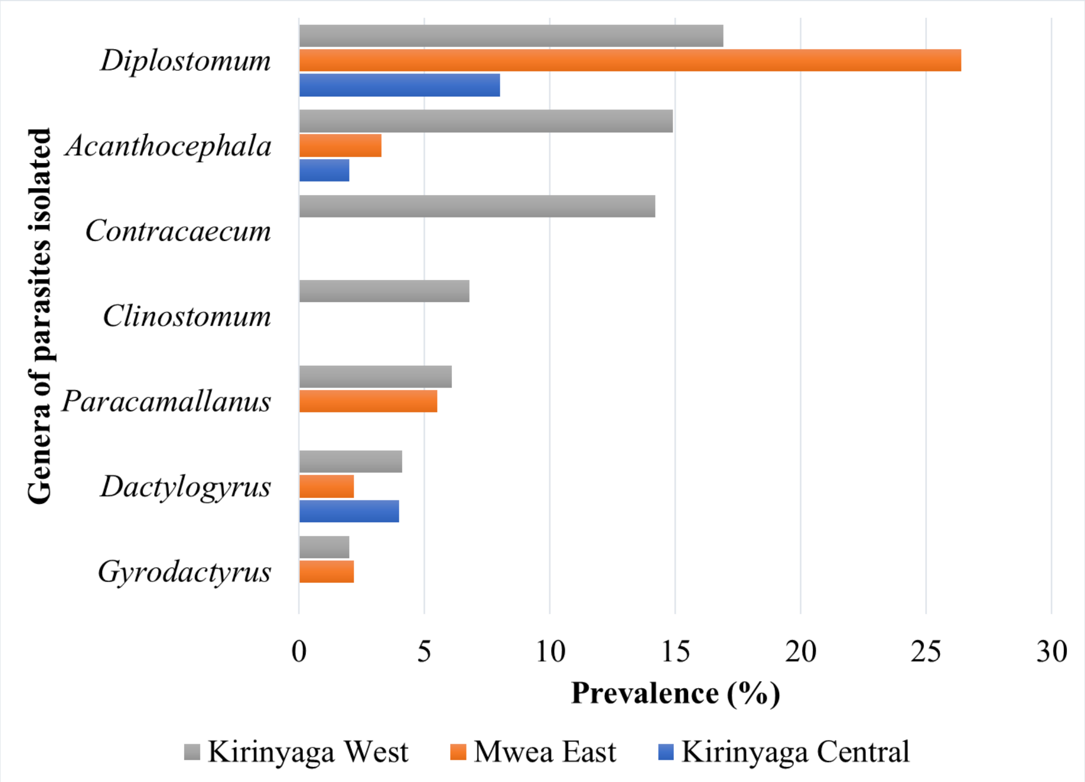


Figure 13: Prevalence of fish helminth parasites from the study area

Among the farms visited during the study period, two breeding farms namely Sagana Aquaculture Center in Kirinyaga West sub-county and Mwea Aqua Fish Farm in Mwea East sub-county had significantly higher parasitic infestations ($p<0.05$) than the rest of the farms with an infestation rate of 69% and 68% respectively while the rest were below 50% level of infestation. Mwea Aqua Fish Farm had higher infestation with *Diplostomum* spp. (59%) than Sagana Aquaculture Center (23%). *Contracaecum* spp., *Acanthocephala* spp. and *Clinostomum* spp. were isolated from Sagana Aquaculture Center and were absent in Mwea Aqua Fish Farm (Figure 14). However, there was no significant difference between overall parasitic infestation rates of the two farms ($p>0.05$).

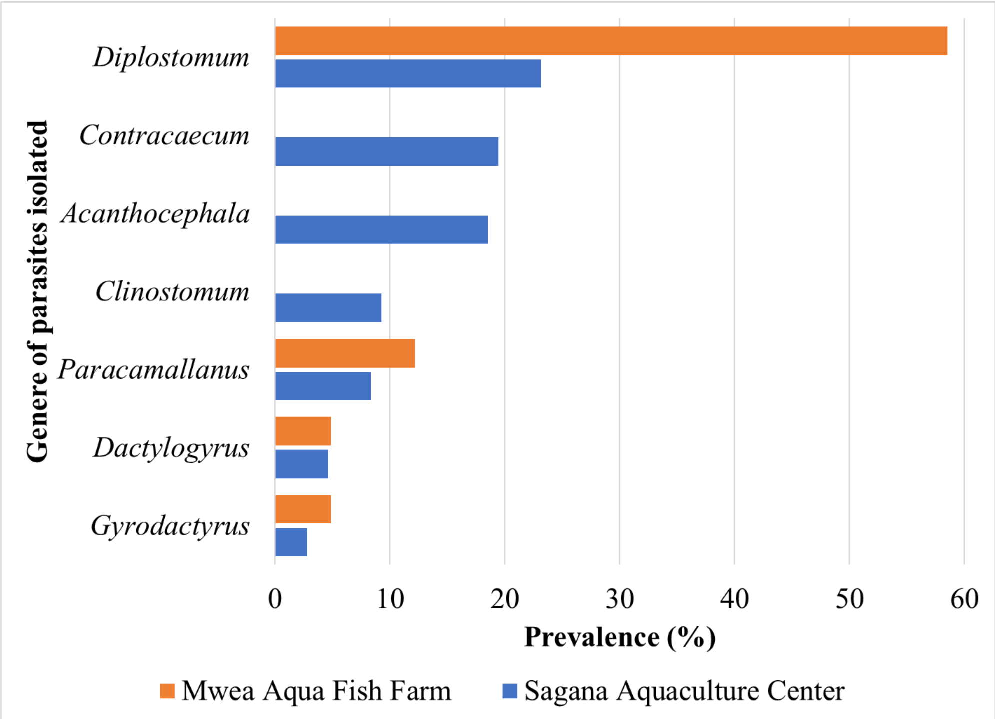


Figure 14: Prevalence of parasites from the major breeding farms

In all, 39% (79/203) of the tilapia and 45% (39/86) of the catfish examined were infested with at least one species of helminth parasite. There was no significant difference between the infestation rates of the two species (p=0.45, risk ratio=0.86). There was also no significant difference of infestation between the sexes as 39% (82/208) of male fish and 44% (36/81) of female fish had at least one species of parasite (p=0.57, risk ratio=0.89). However, fish recovered from earthen ponds (52%) (114/163) had significantly higher parasitic infestations relative to those from liner ponds (7%) (4/60) ($p<0.05$, risk ratio=7.43).

The overall prevalence of various helminth parasites recovered from the fish are shown in Table 7. *Contracaecum* spp., *Gyrodactyrus* spp., and *Paracamallanus* spp. were recovered from catfish only while *Clinostomum* spp. was recovered only from tilapia fish.

Table 7: Prevalence of parasites isolated in different organs of fish from Kirinyaga County

Parasite (Genus)	Organ found	Tilapia prevalence	Catfish prevalence
Acanthocephala	Intestines	11.3	3.5
Clinostomum	Muscles, skin	4.9	0.0
Contracaecum	Abdominal cavity	0.0	24.4
Dactylogyrus	Gills	3.0	4.7
Diplostomum	Eyes	21.7	10.5
Gyrodactyrus	Skin, gills	0.0	5.8
Paracamallanus	Intestines	0.0	16.3

4.2.2 Intensities of helminth parasites

4.2.2.1 Monogenean trematodes

The monogenean species isolated were *Dactylogyrus* and *Gyrodactyrus* (Figure 15). The mean intensity of *Dactylogyrus* spp. in tilapia was 1.2±0.4 while in catfish it was 1.3±0.5 with an abundance range of 0-2 parasites in both species. There were no statistical differences between the intensities in the two species (t=-0.29; df=8). The intensities in male and female fish were 1.0 and 1.3±0.5 parasite respectively which was not significantly different (t=-0.98; df=8) (Figure 15).

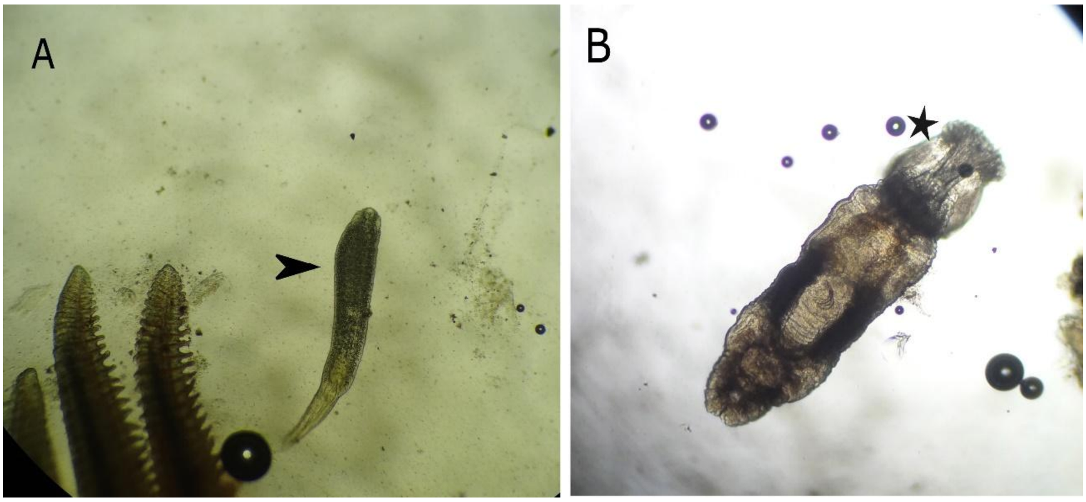


Figure 15: A). Dactylogyrus spp. from the gills of tilapia (arrow head) and B). Gyrodactylus spp. from the skin of catfish showing the haptor (star)

4.2.2.2 Digenean trematodes

The mean intensity of *Diplostomum* spp. (Figure 16) in tilapia was 2.5±2.2 with an abundance range of 0-10, while in catfish it was 1.9±1.4 worms per eye with an abundance range of 0-5 in the sampled fish. There was no significant difference in the intensities of *Diplostomum* spp. in the two species (t=0.783; df=51). The mean intensity in eyes of males was 2.6±2.3 while in females was 1.4±0.7 showing no statistical difference (t=1.675; df=51).

Clinostomum spp. was isolated from tilapia only with a mean intensity of 9.6±14.7 (std. error=4.7) with a range of 1-48 cysts per fish in the infested fish. The mean intensity of *Clinostomum* in the male fish was 5.2±7.1 while in female fish was 19.7±24.8 which was not statistically different (t=-1.507; df=8).

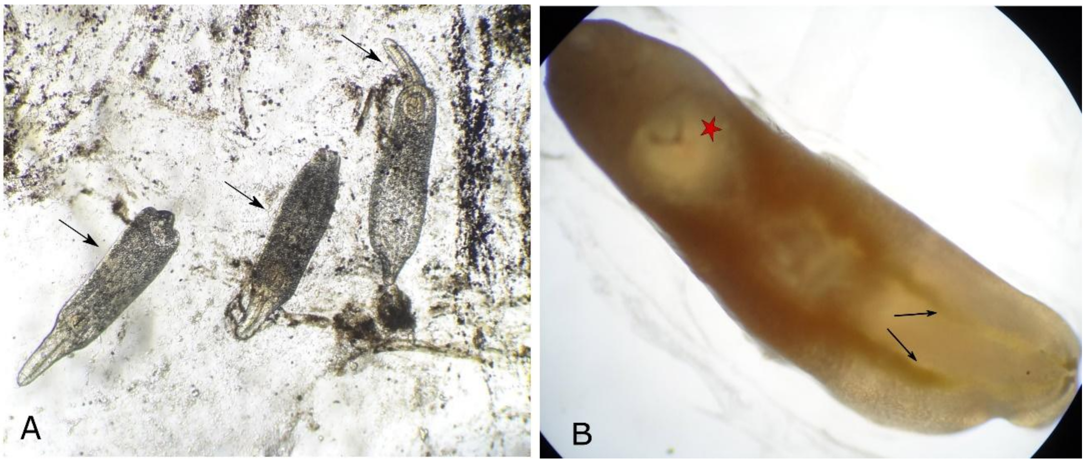


Figure 16: A. Diplostomum spp (arrows) recovered from the vitreous humor of catfish and tilapia B. Clinostomum spp from the skin of tilapia with the anterior sucker (red star) and intestinal caeca (arrows) shown

4.2.2.3 Cestodes

Two catfish from Sagana National Aquaculture Center were found to be infested with a Pseudophyllidean and a Protecephallid tapeworm each (Figure 17).

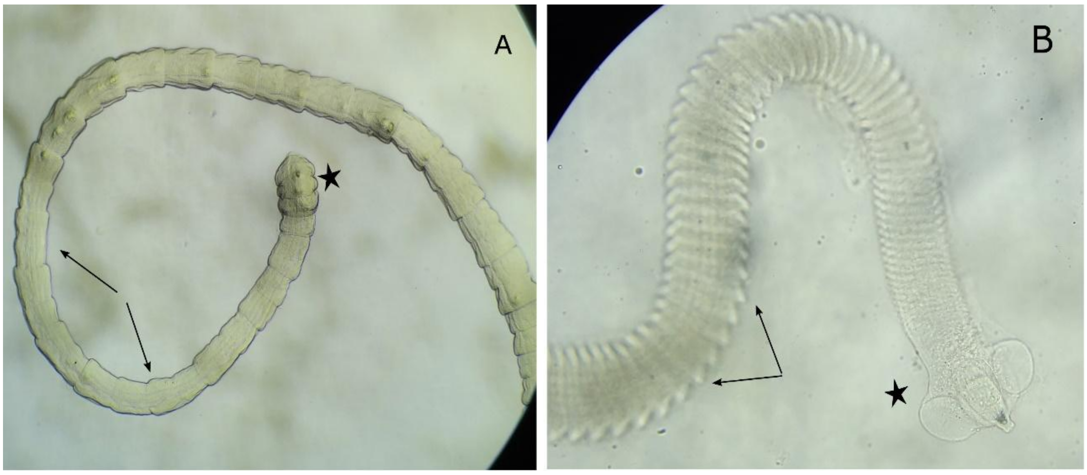


Figure 17: A). Pseudophyllidean and B). Proteocephallid cestodes from the intestines of catfish showing the scolex (star) and proglottids (arrows)

4.2.3 Intensity of nematode parasites

4.2.3.1 *Contracaecum* species

Contracaecum spp. (Family Anisakidae) was isolated in catfish from Sagana National Aquaculture Center with a range of 2-56 worms per fish in the peritoneal cavity of the 20 infested fish (Figure 18). The overall mean intensity was 15±13.3 (std. error=3) worms per fish. The mean intensity in the males was 15.1±9.5 while in females was 14.8±16.2 which was not significantly different (t=0.048; df=18).

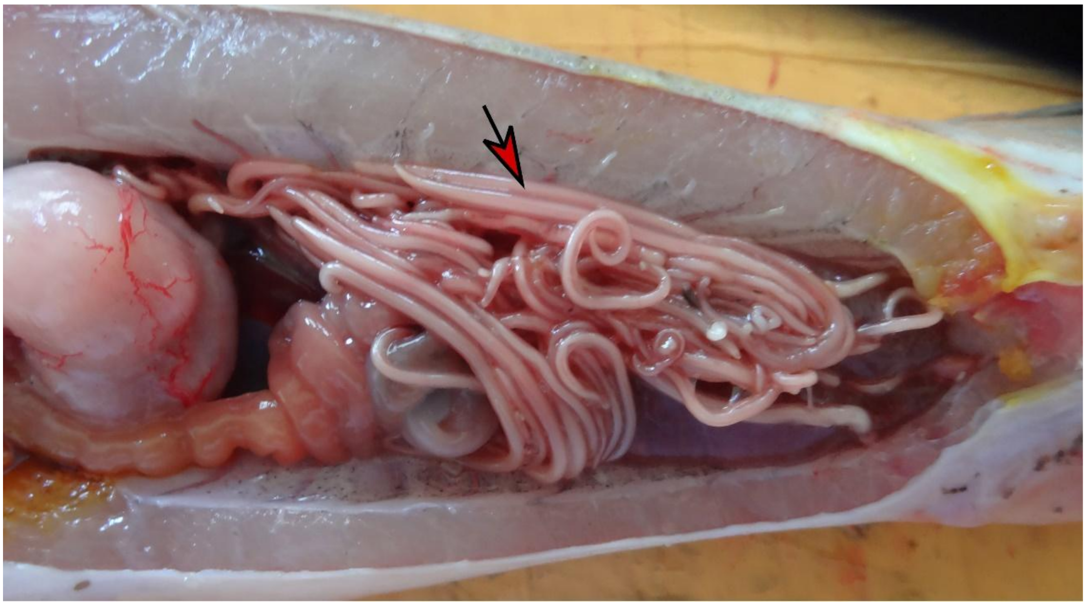


Figure 18: Contracaecum worms (arrow) in the peritoneal cavity of catfish from Sagana Aquaculture Center

4.2.3.2 *Paracamallanus* species

Paracamallanus spp. were isolated from catfish with an abundance range of 0-12 and a mean intensity of 3.8±3.1 worms in the infested fish (Figure 19). The mean intensity in the male fish was 3.7±2.1 while in female fish was 4±5.3 showing no statistical difference (t=0.033; df=12).

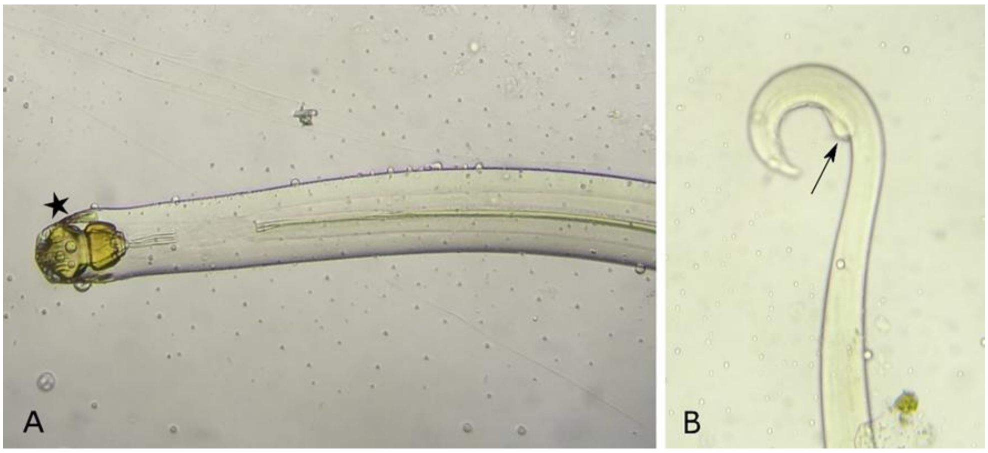


Figure 19: A. Anterior segment of Paracamallanus spp. from the intestines of catfish showing the buccal capsule (star) and B. Posterior segment with the genital flap (arrow)

4.2.4 Intensity of Acanthocephala species

Acanthocephalan worms were common in both catfish and tilapia (Figure 20). The mean intensity in tilapia was 1.5±0.8 with an abundance range of 0-4 and while in catfish it was 1. The mean intensity was not significantly different between tilapia and catfish (t=1.05; df=24). The mean intensity in the male fish was 1.5±0.8 while in female fish was 1.4±0.9 with no statistical difference (t=0.185; df=24).

Figure 20: A. Acanthocephala spp. showing proboscis with hooks (arrow) and with retracted proboscis (B)

4.3 Study of parasites of water birds in Kirinyaga County

Piscivorous birds of different species were captured from Sagana Aquaculture Center and Mwea Aqua Fish Farm as shown in Appendix 8. Of the 50 water birds of different species captured, 46% (23/50) were found to be infested with at least one species of parasite after necropsy examination. Among the birds, those whose diets mainly consists of fish include the herons, kingfisher, cormorant, spoonbill and hamerkop.

4.4 Prevalence of parasites in piscivorous birds

Of the captured birds, 34% (11/32) form Sagana Aquaculture Center and 67% (12/18) from Mwea Aqua Fish Farm were infested with at least one species of parasite. Prevalence of different parasites isolated from the two farms is shown in Table 8.

Table 8: Prevalence of parasites of water birds in two fish farms in Kirinyaga County

Parasite	Region			
	Sagana Aquaculture Center		**Mwea Aqua Fish Farm**	
	Number	Prevalence (%)	Number	Prevalence (%)
Any Parasite*	11	34	12	67
Acanthocephala	0	0	8	44
Tapeworms	11	34	7	39
Roundworms	1	3	0	0
Trematodes	1	3	1	6

*includes all samples with at least one species of parasite

4.4.1 Acanthocephalans

One pied kingfisher (*Ceryle rudis*), 2 giant kingfishers (*Megaceryle maxima*), 1 wood sandpiper (*Tringa glareola*), 1 great painted snipe (*Rostratula benghalensis*), 2 hamerkops (*Scopus umbretta*) and 1 Temminck’s stilt (*Calidris temminckii*) had acanthocephalan worms after necropsy examination. The overall prevalence of acanthocephalan worms in water birds during the study was 16%. Acanthocephalans were only recovered in birds from Mwea Aqua Fish Farm.

4.4.2 Cestodes

The overall prevalence of cestode infestation in water birds from the two farms was 36%. These were isolated from 1 black winged stilt (*Himantopus himantopus*), 1 striated heron (*Butorides striata*), 2 giant kingfishers, 2 great painted snipes, 3 three-banded plovers (*Charadrius tricollaris*), 2 temmink's stilts, 1 common snipe (*Gallinago gallinago*), 1 grey heron (*Ardea cinerea*), 1 long toed plover (*Calidris subminuta*), 1 reed cormorant (*Microcarbo africanus*), 1 African spoonbill (*Platalea alba*), 1 spur winged plover (*Vanellus miles*) 1 one yellow billed duck (*Anas undulata*). Dilepidid cestodes (Cyclophyllidea) were identified in the cormorant and Proteocephalid cestodes from the African spoonbill (Figure 21,Figure 22).

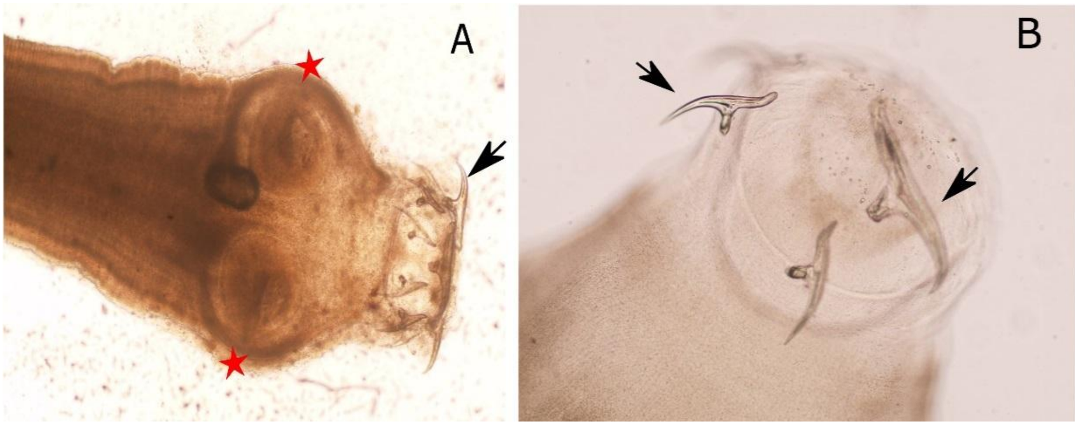


Figure 21: A). and B). Armed scolexes of Dilepidid cestodes from the reed cormorant with hooks (arrows)

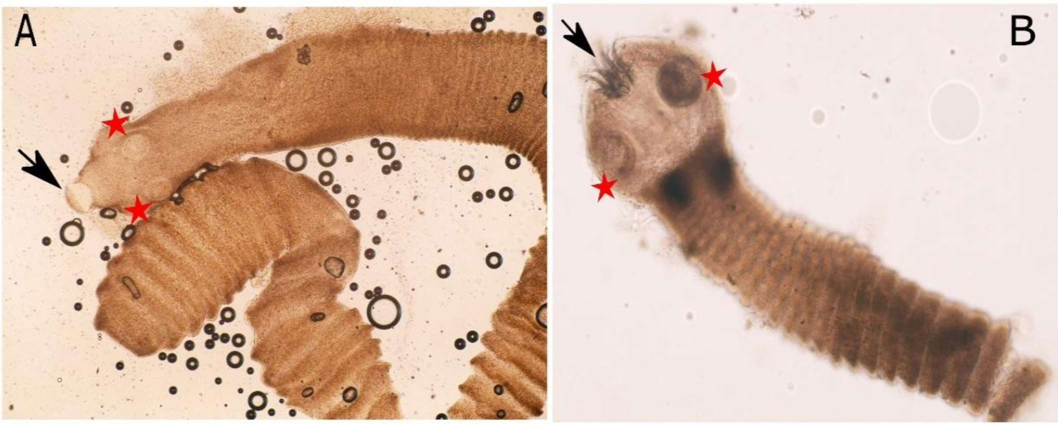


Figure 22: A). and B). Cestode scolexes isolated from the African spoonbill showing suckers (red stars) and hooks (arrows)

4.4.3 Nematodes

Contracaecum spp. (Family Anisakidae) was only isolated from one grey heron from Sagana Aquaculture Center (Figure 23) with a prevalence of 2%.

Figure 23: A. Contracaecum spp. (arrows) and B. Clinostomum spp. from the grey heron showing the anterior sucker (red star)

4.4.4 Trematodes

Trematodes were isolated from one grey heron from Sagana Aquaculture Center and one black winged stilt from Mwea Aqua Fish Farm with a prevalence of 4%. *Clinostomum* spp. was identified morphologically in the heron (Figure 23).

4.5 Comparison of parasites of fish and birds

From this study, parasites were common to both fish and water birds. The prevalence of *Acanthocephala* spp in fish was 11.3% in tilapia and 3.5% in catfish while in birds it was 16%. *Contracaecum* spp was present in catfish and grey heron while *Clinostomum* spp was present in tilapia and grey heron. Cestode parasites were recovered from catfish and birds including the reed cormorant and African spoonbill.

CHAPTER FIVE

5.0 DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 Discussion

As reported in previous studies (Maina *et al.*, 2014; Ngwili *et al.*, 2015), tilapia was the dominant species kept by the farmers under monoculture system. Fish in many areas were small (less than 200 grams). Smaller fish are usually preyed on more by predators than larger fish (AGRI-FACTS, 1999). Fish in some farms, especially those started with their own funding were doing well having tilapia of 200-400 grams and catfish over 700 grams.

Many fish ponds in Kirinyaga County were overgrown with vegetation which makes it easy for birds and other predators to hide and attack fish. It was also observed that the water level in many ponds was low (less than 0.5 meters) due to either siltation or lack of frequent topping up. The recommended water depth in fish ponds is 1 meter (AGRI-FACTS, 1999; Ngugi *et al.*, 2007) which makes it difficult for non-swimming birds to land in water. However, In Kirinyaga County, it was relatively easy for birds like herons, egrets and ibis to wade through the water hence the high incidences of predation. Scarcity of water in some areas especially in Mwea West Sub-county, also contributed to this problem.

Apart from directly feeding on fish, avian predators cause injuries to fish in case of unsuccessful predation (Reimchen, 1988). Fish may succumb to these injuries or heal with deformities. For food fish, such injuries reduce the value of the fish as they are less likely to be bought by consumers. Removal of fish from the ponds by avians and other predators reduces the profitability of fish farming enterprises. Presence of fish eating birds also completes life cycles of parasites like digenean trematodes and act as paratenic host of other parasites (Woo, 2006; Roberts, 2012). During the study period, larger fish farms had more water birds activity compared to smaller ones. Since it was a dry season, birds were migrating from other regions in search of water and food. The presence of the birds was reported to be a big challenge to aquaculture during this time of the year. Mostly, the water birds were in high numbers early in the morning and late evenings. It is therefore necessary to intensify control measures around this time of day especially for those without pond cover nets.

Knowledge of farmers about the existence and spread of fish diseases was low, with many asking whether fish actually get sick. It will be crucial for fish farmers to be made aware of fish diseases due to the current trends of intensification in fish farming and also importation of brood stocks from other countries. This in due course is likely to introduce new pathogens in Kenyan fish ponds which may lead to devastating losses. Predator control should also be encouraged since some predators including birds spread diseases and parasites to fish (Barson and Marshall, 2004; Ortega-Olivares *et al.*, 2008).

It was a concern that most farmers funded by the Economic Stimulus Program put very little additional investment to the fish ponds. This has led to very low production with most of them viewing fish farming as unprofitable as opposed to those who were self-funded. Many ESP funded farmers were still expecting hand-outs from the government in form of feeds, fingerlings and liners for their ponds. There has been shortage of high quality fish feeds for aquaculture in Kenya hence the dependence on expensive imported feeds and low quality feeds like maize bran. However, with local companies entering the market, this is expected to change. Training of farmers and farmers groups on homemade fish formulations would also be of great assistance. There was a lot of enthusiasm by the farmers that profitability of aquaculture will increase in the near future (Munguti *et al.*, 2014).

Kirinyaga West Sub-county had the highest parasite infestation levels due to presence of Sagana Aquaculture Center where more fish were sampled. This farm was frequented by many species of birds which can be attributed to the high parasitic incidences. The same scenario was replicated in Mwea Aqua Fish Farm in Mwea East Subcounty which had the highest *Diplostomum* spp. infestations. Migration of birds poses a risk of spreading parasites and other disease causing pathogens from one region to another. At times, it is difficult to completely keep birds off fish farms without incurring costs. This study established that parasites were equally common to fish (tilapia and catfish) as well as water birds. Of the water birds sampled, the fish-eating species were found to be infested with more than one species of parasites. Earthen ponds had the highest levels of parasitic infestations probably due to the interplay of vegetation growth, presence of snails and piscivorous birds in these ponds.

The monogeneans reported in this study were *Dactylogyrus* and *Gyrodactyrus* spp. Overcrowding in fish ponds with poor environmental and management factors promote heavy infestations with monogeneans and can result to fish losses (Hecht and Endemann, 1998). Though Monogeneans have a direct life cycle, it is also possible for other hosts like birds to be infested as accidental hosts and spread the parasites (Strona, 2015). Digenean parasites *Diplostomum* spp. and *Clinostomum cutaneum* were recovered. The metacercariae of Diplostomatid eye flukes are found in the vitreous humor of the eyes in fish without major pathological effects. Cases of cataract are seen with *Diplostomum spathecum* which is found non-encysted in the lens. This causes blindness and fish are more prone to predation (Seppala *et al.*, 2005). The adult forms of digenean parasites are found in piscivorous birds (Aohagi *et al.*, 1992; King and As, 1997). Snails of the genus *Bulinus*, *Lymnae* and *Melanoides* are intermediate hosts of digenean trematodes. *Clinostomum* species of the *'cutaneum'* group were isolated in both fish and piscivorous birds (grey heron) in agreement with a study by Gustinelli *et al.* (2010), that was done in Sagana Aquaculture Center. This study used genetic comparisons of parasites from fish and birds but it was not possible for the same in this study due to financial and time constraints. This parasite causes 'yellow grubs' that make fish unsightly when present in large numbers. This causes economic losses due to rejection by consumers (Florio *et al.*, 2009; Roberts, 2012). Human cases of *Clinostomum* spp. infestation have been reported in Korea (Chung *et al.*, 1995) and Japan (Hara *et al.*, 2014) hence a public health concern.

Cestode parasites (Dilepididae, Pseudophyllidae and Proteocephallidae) were more commonly recovered in birds than fish. Only two catfish had a tapeworm in the intestines. Water birds, mainly piscivorous species have been reported to harbor tapeworms which can spread to fishes and humans. Chubb *et al.* (1987) described scolexes of different genera of cestodes as a guide to identification. Cyclophyllidean cestodes of the family Dilepididae have been described in piscivorous birds in Mexico (Scholz *et al.*, 2002). These include *Cyclustera capito, C. ibisae* and *Neogryporhynchus* spp in heron, spoonbill and cormorants. Hill (1941), described *Gryporhynchus* spp in the great blue heron. Species identification of Caryophyllidean cestodes was described by Oros *et al.* (2010) in fish and birds. Proteocepalidae cestodes (Scholz *et al.*, 1998; De Chambrier *et al.*, 2007) also affect fish. *Diphyllobothrium latum*, *Proteocephalus* spp. and *Caryophyllaeidea* spp have been reported in Kenya by Khamis *et al.* (2017). *Diphyllobothrium* spp have been reported to be zoonotic (Chai *et al.*, 2005).

Fish nematodes recovered in the study were *Contracaecum* and *Paracamallanus* spp. the former being reported only in catfish. *Contracaecum* in catfish has been reported in several regions in Kenya (Mavuti *et al.*, 2017) and Zimbabwe (Barson, 2004). This parasite has been reported in tilapia and carp in other studies (Aloo, 2001; Szostakowska and Fagerholm, 2007; Florio *et al.*, 2009). Sagana Aquaculture Center had a 19% prevalence of *Contracaecum* spp. Although this farm kept both tilapia and catfish, some even in the same ponds, tilapia species were not infested with *Contracaecum* spp. and this could suggest a different species of the parasite affecting tilapia and catfish. This parasite was also recorded in piscivorous birds by

Barson and Marshall, (2004) in Zimbabwe by genetic and electric microscopy comparisons of the larvae from fish and adults from birds. Parasites of the Anisakidae family are reported to be zoonotic. Allergic reactions have been reported where sensitization occurs to ingesting live parasites in raw fish or those killed by cooking or pasteurization (McCarthy and Moore, 2000). Experimental infestation of *Contracaecum* spp. in the domestic cat resulted to successful development to adults causing hemorrhages in the intestine (Vidal-Martínez *et al.*, 1994). This shows that *Contracaecum* spp. can affect mammals including humans and thus of public health importance. Camallid nematodes were recovered in catfish. These are common parasite to this species of fish without major pathological effects (Barson *et al.*, 2008).

Acanthocephalans, also called ‘spiny’ or thorny-headed worms commonly parasitize fish, amphibians, birds and mammals. Low and moderate infestations result to localized changes but heavy infestations have been reported to cause granulomas and fibrosis in the intestines (Paperna, 1964). Florio *et al.* (2009) described infestations of tilapia fish with *Acanthosentis tilapia* in East Africa. Infestations of humans with acanthocephalans after eating raw or undercooked fish has been documented (Schmidt, 1971).

Piscivorous birds, mainly herons, cormorants and ibis were difficult to capture using mist nets in the fairly open landscape of Sagana Aquaculture Center and Mwea Aqua Fish Farm. During the study period, mists nets were the available capture method as the capture permit restricted use of shooting to catch specific birds (Appendix 2). Birds capture methods can be fairly expensive hence restricting our options due to financial and time constraints. This study however gives an excellent indication of the parasite species in various species of water birds. Accurate prevalence of infestation can only be obtained with larger sample sizes.

5.2 Conclusions

Piscivorous birds play a significant role in the profitability of fish farming but most farmers don't practice effective predator control methods. Knowledge of fish diseases and the role of fish predators in spreading disease and parasites is low among fish farmers in Kirinyaga County. Despite the increased interest in fish farming due to the ESP, there were still very little profit margins from many fish farming ventures. Earthen ponds were more predisposed to parasite infestations than liner and concrete ponds. Genera of parasites with documented zoonotic species like *Clinostomum* spp, *Contracaecum* spp and *Acanthocephala* spp. were identified in farmed fish in Kirinyaga County.

5.3 Recommendations

Extension workers should educate farmers that fish farming is a viable business venture viz side-projects in order to realize returns. This is especially so for those funded by ESP. Farmers should be made aware of risks of parasitic infestations and other diseases of fish and the need to consult qualified experts in such cases. Farmers, traders and consumers should be advised on handling and cooking fish to avoid infestation with zoonotic parasites. Proper predator control methods should be undertaken in fish farms in order to increase returns from aquaculture.

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APPENDICES

Appendix 1: Questionnaire on fish farming and predation in Kirinyaga County

UNIVERSITY OF NAIROBI
COLLEGE OF AGRICULTURE AND VETERINARY SCIENCES

Date of interview .... Telephone no. .... Code ....

QUESTIONNAIRE FOR FISH FARMERS ON ASSESSMENT OF THE TYPE AND EXTENT OF FISH PREDATION IN AQUACULTURE IN KIRINYAGA COUNTY

This questionnaire seeks your views on the challenge of predation in fish farming. The information obtained is for research purpose and will be kept confidential.

Section A: Background Information

1. Sub county_____________ Ward ______________ Village _____________
2. GPS readings:
   Eastings ___________ Northings/southings _________ Elevation ___________
3. Acreage of the farm ____________________

Section B: Biodata

4. Name of the owner _______________________________________
5. Age of the owner?
   [1] 21-30 years [2] 31-40 years [3] 41-50 years [4] > 50years
6. Gender of the owner? [1] Male [2] Female
7. Main occupation of the owner:
   [1] Farming [2] Business [3] Salaried employee [4] Other (Specify) ____
8. Education level of the owner ___________________
   [1] No Formal Education [2] Primary Level [3] Secondary Level [4] Tertiary Level
9. Name of the respondent: ____

10. Relationship of respondent to owner: (*Please tick appropriately*)
[1] Owner [2] manager [3] attendant [4] Family member [5] Other (Specify)__

11. Gender of respondent: [1] Male [2]Female

12. Education level of the respondent: (*Please tick appropriately*)
[1] No Formal Education [2] Primary Level [3] Secondary Level [4] Tertiary Level

Section C: Information on the fish farm

13. Who is responsible for the day to day management decisions of the farm? (*Please tick appropriately*)
[1] Owner [2] Spouse [3] Daughter/Son [4] Worker [5] Other (specify)………

14. Gender of the person responsible for day to day management decisions:
[1] Male [2] Female

15. What is the education level of the person responsible for day to day management decisions?
[1] No Formal Education [2] Primary Level [3] Secondary Level [4] Tertiary Level

16. Has the person responsible for day to day management decisions of the farm attended any formal training in fish farming? [1] Yes [2] No

17. How long has the fish farm enterprise been operational?
[1] Less than 1 year [2]1-2 years [3] 3-5 years [4] 5- 10 years [5]>10 years

18. Observe and note the type of ponds in the farm:
[1] Earthen [2] Liner ponds [3] Concrete [4] others (specify)

19. Which fish species are cultured in the farm farm? (*Please tick appropriately*)
[1] Tilapia mixed sex [2] Tilapia mono sex [3] Catfish [4] Tilapia-catfish poly culture [5] Others (specify)__________

20. What was the source of your startup capital for fish farming? (*Please tick appropriately*)
[1] Self-funded [2] Economic Stimulus Progra [3] NGO [4] Other (specify) ______

21. Where did you source the first stock of fingerlings?

Source of fingerlings (*Please tick appropriately*)	**Please specify**
[1] Government breeding farms	
[2] Private breeding farms	
[3] From own ponds	
[4] From other farmers	
[5] Others	

22. Where does the farm source the restocking fingerlings?

Source of fingerlings (*Please tick appropriately*)	**Please specify**
[1] Government breeding farms	
[2] Private breeding farms	
[3] From own ponds	
[4] From other farmers	
[5] Others	

23. Where do you source water for the fish farm? (*Please tick appropriately*)
[1] River [2] Borehole [3] Dam [4] Harvested rain water [5] Other (specify)______

Section D: Challenges and predation

24. What were the previous stocking and harvesting numbers for the last 3 seasons? (*Starting with the most recent*) (*Please fill in as appropriate*)

Season	**Production period**	**Stocking numbers**	**Harvesting numbers**
1			
2			
3			

25. What is the main reason of doing fish farming?
[1] Business [2] Subsistence [3] Hobby [4] Others (specify) ________

26. From your experience, rate the profitability of fish farming: (*Please tick appropriately*)
[1] Very profitable [2] Profitable [3] Unprofitable [4] Very unprofitable

27. Rate the challenges you face as a fish farmer? (*Please tick appropriately*)

Challenge	**[1] Major**	**[2] Minor**	**[3] Not a problem**
[1] Water availability			
[2] Feed availability			
[3] Predators			
[4] Theft			
[5] Low market prices			
[6] Diseases			
[7] Others specify...			

28. Rate the challenges posed by the following predators to the fish farm?(*Please tick appropriately*)

Predator	**[1] Major**	**[2] Minor**	**[3] Not a problem**
[1] Otters			
[2] Dogs			
[3] Monitor lizards			
[4] Birds			
[5] Cats			
[6] Others (specify)			

29. Rate the challenges posed by the following fish eating birds to your enterprise? (*Please tick appropriately*)

Birds	**[1] Major**	**[2] Minor**	**[3] Not a problem**
[1] Pelicans			
[2] Kingfisher			
[3] Herons			
[4] Egrets			
[5] Cormorants			
[6] Fish eagles			
[7] Others (specify)			

30. Which months do the birds pose greatest challenge to your fish farm? (*Please tick appropriately*)

	Period				
Birds	**Throughout the year**	**Jan-March**	**April-June**	**July-Sept**	**Oct-Dec**
[1] Pelicans					
[2] Kingfisher					
[3] Herons					
[4] Egrets					
[5] Cormorants					
[6] Fish eagles					
[7] Others (specify) ….…..					

31. What are your views on the following statements with regard to fish farming? (*Please tick appropriately)*

Statement	**Strongly disagree [1]**	**Disagree [2]**	**Agree [3]**	**Strongly agree [4]**	**Don't know [5]**
[1] Predation causes considerable loss in aquaculture					
[2] Predators can spread diseases and parasites to fish					
[3] It is relatively easy to control fish predators in aquaculture					
[4] Some predators have benefits to aquaculture					
[5] Extension services to control predators are readily available					
[6] There is no problem in consuming raw fish					
[7] Fish eating birds spread disease from one farm to another					
[8] Killing fish eating birds scares away other birds					
[9] Killing of birds is harmful for the ecosystem/ environment					
[10] Some diseases of fish can affect humans					
[11] Others (specify)					

32. Which method(s) do you use to control predators? (Tick appropriately)
[1] Traps [2] Scare crows [3] Barbed wire [4] Pond netting [5] Guarding of ponds [6] Others (specify) _____________

33. From your experience, rate the efficiency of these methods for predator control? (*Tick as appropriate*)

Method of control	**Efficiency**		
	[1] Very efficient	**[2] Moderate**	**[3] Not efficient**
[1] Traps			
[2] Scare crows			
[3] Barbed wire			
[4] Pond netting			
[5] Guarding of ponds			
[6] Others (specify) ________________			

..................Thank you for taking your time to fill this questionnaire......................

Appendix 2: Research authorization from Kenya Wildlife Service

KENYA WILDLIFE SERVICE

ISO 9001:2008 Certified

KWS/BRM/5001

10 October 2016

Mr. Joseph Wairia Murugami
Health of Aquatic Animal Resources
P.O.Box 3348-00100
NAIROBI
e-mail: wairiajm@gmail.com

Dear Mr. Wairia

PERMISSION TO CONDUCT RESEARCH ON WATER BIRDS IN KIRINYAGA COUNTY

We acknowledge receipt of your letter dated 21st September 2016 requesting for permission to conduct research on a project titled: '**Predation and Prevalence of Zoonotic Parasites in Piscivorous Birds and Farmed Fish in Kirinyaga County**'. The study will generate data and information that will assist in the surveillance and control of zoonotic diseases in piscivorous birds and humans.

You have been granted permission to conduct the study from **October 2016 – October 2017** upon payment to KWS academic research fees of **Ksh.6,000** (Masters Study). However, you will obtain a capture permit from KWS Licensing Office to capture the target bird species for sampling. You will also be required to work closely with our Head Veterinary Services and Senior Scientist in-charge of Mountain Conservation Area (MCA), whom you will give the progress report on the study.

You will submit a bound copy of your MSc thesis to the KWS Deputy Director, Biodiversity Research and Monitoring on completion of the study.

Yours Sincerely,

DR. THADEUS OBARI, PhD
FOR: DEPUTY DIRECTOR
BIODIVERSITY RESEARCH AND MONITORING

Copy to:

- Head Veterinary Services
- Senior Scientist, MCA

P.O Box 40241-00100, Nairobi, Kenya. Tel: +254-20-2609233, +254-20-2609234
Wireless: +254-020-2379407-15. Mobile: +254-735 663 421, +254-726 610 508/9. Fax: +254-020-2661923
Email: kws@kws.go.ke Website:www.kws.go.ke

Appendix 3: Capture permit from Kenya Wildlife service

KENYA WILDLIFE SERVICE

ISO 9001:2008 Certified

KWS/4004

10th October, 2016

Mr. Joseph W. Murugami
MSC, Healthy of Aquatic
Animal Resources,
P. O. Box 3348-00100
NAIROBI

RE: PERMISSION TO CAPTURE FISH PREDATORY BIRDS IN KIRINYANGA COUNTY AS AMSC THESIS A SOKOINE UNIVERSITY OF AGRICULTURE, TANZANIA

Your request on the above subject, that you intend to conduct research on Fish predatory birds in Kirinyaga County Kenya, as partial fulfillment in your Masters degree in **Health Aquatic Animal Resources**, is hereby acknowledged.

The authority to capture 50 fish predatory birds of different species for parasitological analysis is hereby granted. The authority is however subject to:

1) You will liaise with the **Warden Mwea/Embu Stations** and **Mwea Rice Farmers** for guidance an any other logistics.
2) You will capture the birds using appropriate gears, that shall have minimal injury to the birds, if any. **No shooting** will be allowed under any circumstances.
3) Where applicable, the birds captured shall be released in consultation with the Warden.
4) The 50 fish predatory birds of different species will be captured in Mwea Rice Scheme and the environ, and any other areas within Kirinyaga County as may be guided by the respective area Warden (Embu, Mwea)
5) The animals shall be kept in appropriate housing during the research project.
6) You shall file returns and status report to respective area Warden within seven (7) and fourteen (14) days to Director General Kenya Wildlife Service, upon completion of the capture exercise.

I. K. LUBIA
CHIEF LICENSING OFFICER
FOR: DIRECTOR GENERAL

Copy: Warden Embu Station
Warden Mwea Reserve

P.O Box 40241-00100, Nairobi, Kenya. Tel: +254-20-2609233, +254-20-2609234
Wireless: +254-020-2379407-15. Mobile: +254-735 663 421, +254-726 610 508/9. Fax: +254-020-2661923
Email: kws@kws.go.ke Website:www.kws.go.ke

Appendix 4: Challenges and suggestions of improvement by farmers (N=137)

Challenges experienced by farmers		Suggestions to improve production	
Unavailability and high cost of feeds	69.30%	Provision of affordable quality feeds	57.10%
Unavailability of markets	33.60%	Better organization of markets	30.10%
Fish predators	32.80%	Training on fish farming and management	28.60%
Poor breeds of fingerlings	24.10%	Improve breeds of fingerlings	17.30%
Insufficient water for fish farming	21.20%	Subsidies on fish farming inputs	13.50%
lack of capital	13.10%	Provision of credit facilities	10.50%
Poor knowledge in fish farming	13.10%	Increased aid from the government	9.80%
Theft and vandalism in fish ponds	12.40%	Improved extension services	9.80%
Lack of harvesting equipment	5.80%	Provision of harvesting equipment	8.30%
High cost of liners	5.10%	Formulating home-made feeds	8.30%
Poor extension services	2.90%	Sensitization to eat more fish	8.30%
Lack of storage facilities	2.90%	Have sufficient water for fish farming	6.80%
Lack of support from government	2.20%	Formation of cooperatives to help farmers	5.30%
Lack of follow up after ESP	1.50%	Provision of liners	4.50%
Poor security	1.50%	Provision with pond nets	4.50%
Inadequate labor in the fish farm	1.50%	Improved security	3.80%
Low acceptability of fish meat by communities	0.70%	Better support by the government	2.30%
Poor management	0.70%	Create awareness on benefits of aquaculture	1.50%
High mortality of fish	0.70%	Fencing of ponds to reduce predation	1.50%
Vets not practicing fish health	0.70%	Improved management of fish farms	1.50%

Appendix 5: Challenges experienced by farmers in percentages (N=137)

Challenge	Mwea East	Mwea West	Kirinyaga Central	Kirinyaga east	Kirinyaga West
Water availability	18	45	10	9	35
Feed availability	79	77	79	83	71
Predators	56	68	59	43	53
Theft	29	18	28	37	18
Low market prices	32	5	3	23	18
Diseases	3	5	0	0	0

Appendix 6: Likert items on opinions of farmers in issues of fish farming and predation in percentages (N= 137)

Question	Strongly disagree	Disagree	Agree	Strongly agree	Don't know
Predation causes considerable loss to aquaculture	2.2	5.1	47.4	45.3	0
Predators can spread diseases and parasites to fish	3.6	10.9	39.4	4.4	41.6
It is easy to control fish predators	19.7	31.4	38.7	6.6	3.6
some predators have benefits to aquaculture	38	38.7	14.6	2.2	6.6
Extension services to control predators are readily available	13.1	29.2	34.3	15.3	8
No problem in consuming raw fish	28.5	22.6	10.2	2.2	36.5
Fish eating birds spread disease from one farm to another	3.6	13.1	38	10.2	35
Killing fish eating birds scares away other birds	8.8	39.4	19	5.8	27
Killing birds is harmful for the environment/ecosystem	8	8.8	46.7	19	17.5
Some diseases of fish can affect humans	9.5	11.7	28.5	3.6	46.7

Appendix 7: Intensities of Parasites in different species and sexes of fish sampled

Mean intensities of parasites of tilapia and catfish										
Parasite	**Tilapia**				**Catfish**				**Students t test**	
	N	Mean Intensity	Std. Deviation	Std. Error Mean	N	Mean Intensity	Std. Deviation	Std. Error Mean	t statistic	deg. Freedom
Dactylogyrus	6	1.7	0.408	0.167	4	1.25	0.5	0.25	-0.29	8
Diplostomum	44	2.5	2.246	0.339	9	1.89	1.364	0.455	0.783	51
Acanthocephala	23	1.5	0.846	0.176	3	1	0	0	1.05	24
Clinostomum	10	9.6	14.774	4.672	0					
Contracaecum	0				20	14.95	13.316	2.978		
Paracamallanus	0				14	3.79	3.093	0.827		
Mean intensities of parasites between sexes of fish										
Parasite	**Male**				**Female**				**Students t test**	
	N	Mean Intensity	Std. Deviation	Std. Error Mean	N	Mean Intensity	Std. Deviation	Std. Error Mean	t statistic	deg. Freedom
Dactylogyrus	3	1	0	0	7	1.29	0.488	0.184	-0.98	8
Diplostomum	43	2.63	2.279	0.347	10	1.4	0.699	0.221	1.675	51
Acanthocephala	21	1.48	0.814	0.178	5	1.4	0.894	0.4	0.185	24
Clinostomum	7	5.29	7.088	2.679	3	19.67	24.786	14.31	-1.507	8
Contracaecum	9	15.11	9.48	3.16	11	14.82	16.278	4.908	0.048	18
Paracamallanus	10	3.7	2.058	0.651	4	4	5.354	2.677	0.033	12

Appendix 8: Parasites isolated from various water birds in Kirinyaga County

Species of Bird	Scientific name	Total number	Farm Captured		Parasites isolated				
			Sagana Aquculture Center	Mwea Fish Farm	Any Parasite	Acanthocephala	Tape worms	Round worms	Trematodes
African Jacana	*Actophilornis africanus*	10	9	1	0	0	0	0	0
Pied Kingfisher	*Ceryle rudis*	3	1	2	1	1	0	0	0
Black winged Stilt	*Himantopus himantopus*	1	0	1	1	1	1	0	1
Common sandpiper	*Actitis hypoleucos*	1	0	1	0	0	0	0	0
Striated Heron	*Butorides striata*	1	0	1	1	0	1	0	0
Giant Kingfisher	*Megaceryle maxima*	3	0	3	3	2	2	0	0
Great paited Snipe	*Rostratula benghalensis*	2	0	2	2	1	2	0	0
Hamerkop	*Scopus umbretta*	2	0	2	2	2	0	0	0
Malachite Kingfisher	*Corythornis cristatus*	2	1	1	0	0	0	0	0
Three band Plover	*Charadrius tricollaris*	5	3	2	3	0	3	0	0
Temmink's Stint	*Calidris temminckii*	5	3	2	3	1	2	0	0
Common Snipe	*Gallinago gallinago*	1	1	0	1	0	1	0	0
Grey Heron	*Ardea cinerea*	1	1	0	1	0	1	1	1
Grey headed Kingfisher	*Halcyon leucocephala*	1	1	0	0	0	0	0	0
long toed plover	*Calidris subminuta*	1	1	0	1	0	1	0	0
Red billed teal	*Anas erythrorhyncha*	1	1	0	0	0	0	0	0
Reed Cormorant	*Microcarbo africanus*	1	1	0	1	0	1	0	0
Spoon bill	*Platalea alba*	1	1	0	1	0	1	0	0
Spur winged plover	*Vanellus miles*	3	3	0	1	0	1	0	0
Wood sandpiper	*Tringa glareola*	1	1	0	0	0	0	0	0
Yellow billed duck	*Anas undulata*	4	4	0	1	0	1	0	0
Total		50	32	18	23	8	18	1	2