PREVALENCE OF PARASITIC INFECTION IN FARMED NILE TILAPIA AND FACTORS ASSOCIATED WITH TRANSMISSION IN KIAMBU COUNTY, KENYA

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A DISSERTATION SUBMITTED IN PARTIAL FULLFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN HEALTH OF AQUATIC ANIMAL RESOURCES OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

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ABSTRACT

The current study was undertaken between October 2016 and March 2017 to determine the prevalence of fish parasites infesting farmed Tilapia and the associated risk factors in Kiambu County, Kenya. A total of 148 questionnaires supplemented with direct observations were administered to fish farmers to assess the status of fish farming and management practices that could influence the occurrence of fish parasites in the farms. A total of 260 fish were purchased from farmers and examined for ecto-and endo-parasites. Most of the farmers were males, over 50 years of age, had been in fish farming for more than five years and were involved in farming of fish, crops and livestock as their main occupation. In majority (60.8%) of the farms, Tilapia (*Oreochromis niloticus)* was the main species farmed under semi intensive farming system in earthen ponds. Farm owners (66.7%) were responsible for day to day management of the farms and most had attained secondary school education. The management practices identified as possible risk factors for occurrence of fish parasites included: use of rivers as sources of fish pond water, earthen ponds with overgrown vegetation in and around them, stocking with fingerlings from non-certified sources, failure to change water within a production cycle, lack of pond draining, cleaning and treatment after harvesting and lack of or infrequent fertilization of ponds. Others were: use of poor quality feeds and lack of feeding or improper feeding, sharing of fishing nets among farmers and between ponds in the same farm, failure to clean and disinfect fishing nets, lack of knowledge on signs of fish diseases in general and parasitism in particular and presence of predators especially, predatory birds. The mean weight, total length and standard length of the fish collected were 110.2g (±83.7), 17.6 cm (±4.1) and 14.3 cm (±3.5), respectively while, the mean condition factor was 1.8 (± 0.4). Of the fish sampled, 68 (26.2%) were found to be infested by one or more species of parasites. Fish from earthen ponds (31%) were more parasitized relative to those from liner ponds (3.3%). More fish from ponds with overgrown vegetation (30.3%) were parasitized as opposed to those ponds whose vegetation around the pond was well trimmed (9.7%). Fish parasites recovered and their prevalence were: digenean trematodes, *Diplostomum* spp. (8.5%), and *Clinostomum* spp. (3.5%), monogenean trematodes, *Dactylogyrus* spp. (3.5%), *Gyrodactylus* spp. (0.4%) and the thorny headed worm, *Acanthocephalus* spp. (10.4%). Among the parasites recovered *Clinostomum* spp. and *Diplostomum* spp. have been reported to be zoonotic and therefore, more research is required to characterize them and determine their zoonotic importance. The prevalence and intensities of the parasites recovered were low and majority of infested fish were in good body condition. For profitable fish farming in Kiambu County, awareness in fish health and farm management practices among farmers, fisheries and veterinary extension workers, researchers and all other relevant stakeholders is indicated.

DECLARATION

I, Keziah Wanjiru Maina, 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 currently being submitted for a degree award in any other institution.

Keziah Wanjiru Maina   Date

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DEDICATION

This work is dedicated to my husband, Daniel M. Nyoro and our two sons James Nyoro and Kevin Maina.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

CAN	Calcium ammonium nitrate
DAP	Di-ammonium phosphate
DCP	Di-calcium phosphate
ESP	Economic stimulus programme
FZT	Fish-borne zoonotic trematodes
K	Condition factor

CHAPTER ONE

1.0 INTRODUCTION

Aquaculture in developing countries is a means of improving food security and supplementing income for families at subsistence level and the little surplus produced is sold in the local markets (Musyoki, 2014). The rapid increase in human population, increasing need for inexpensive sources of protein and the stagnating or declining catches of fish from inland natural lakes have justified the need to develop aquaculture rapidly and urgently (Musyoki, 2014; FAO, 2016). Therefore, fish farming has recently received increasing attention among governments and development agents.

Following national aquaculture suitability mapping and assessment 2009, 96% of Kenyan land was shown to be suitable for aquaculture development with varied potentials (Macharia *et al*., 2010). Aquaculture in Kenya benefited from the government funded Economic Stimulus Program (ESP) in 2010 in order to contribute to economic recovery for the attainment of Vision 2030. The government facilitated construction of 200 fish ponds per constituency, provided fingerlings and feeds, improved hatcheries and revamped aquaculture extension services (Munguti *et al*., 2014).

In Kenya, Nile tilapia (*Oreochromis niloticus)* accounts for 75% of production, followed by African catfish (*Clarias gariepinus)*, which contributes 21% while other species like common carp (*Cyprinus carpio)*, rainbow trout (*Oncorhynchus mykiss)*, koi carp (*Cyprinus carpio carpio)* and goldfish (*Carassius auratus)* are harvested in small amounts (Munguti *et al*., 2014). Tilapia species are reared as monoculture or polyculture with African catfish under extensive, semi-intensive or intensive farming systems. Semi-intensive system is the major contributor of more than 70% of the total production (Musyoki, 2014). Fish farmers in Kiambu County benefited from ESP program where 666 ponds were constructed and stocked with fish. There are also many farmers farming fish privately in the county (Musyoki, 2014). The Kiambu county government has recognized aquaculture as one of the development strategies and has funded construction of 48 new fish ponds in the county to boost fish production (Director of Fisheries, Kiambu County, personal communication). In this county, tilapia is the main species farmed while tilapia/catfish polyculture is practiced by few farmers (Musyoki, 2014). Ninety eight percent of fish farming is under semi-intensive system and few (1.6%) farmers practice extensive system (Musyoki, 2014). Eighty percent of the fish are sold to local consumers in the county and the rest sold to the neighboring Nairobi County (Musyoki, 2014). This shows that there is a high demand for fish in Kiambu County by the local population. Fish farming in the county has challenges in form of predators, lack of feeds, high mortality of fingerlings, pond leakage, scarcity of water, lack of management information and delay in delivery of fingerlings (Musyoki, 2014). Increased interest in fish farming stimulated by government support has resulted in new challenges such as environmental pollution, biosecurity and spread of fish diseases (Munguti, 2014) some of which could be zoonotic.

Epizootics and mass mortality brought about by parasitic infestations are very frequent in fishes (Otachi, 2009). The fish deaths may go unnoticed, particularly when the few dead fishes are immediately consumed by piscivorous birds (Otachi, 2009). The occurrences of parasites and losses due to parasitic infestations have not been investigated in Kiambu County only in few counties in Kenya such as Nyeri (Mavuti, 2017b).

Some of the fish parasites are zoonotic especially helminthes such as anisakid nematodes *Anisakis simplex*; *Pseudoterranova decipiens*, cestodes of the genus *Diphyllobothrium* spps. and digenetic trematodes of the families Heterophyidae, Opisthorchiidae and Nanophyetidae (Adams *et al.*, 1997; Noga, 2010; Robert, 2012). Factors associated with zoonotic helminthes include feeding animal resevoir hosts (dogs, cats, pigs, chicken, ducks) with live infested fish, humans feeding on undercooked or raw fish and by handling infested fish (Noga, 2010). Presence of snails and addition of green vegetation from othe farms have also been listed as risk fators (Phan *et al*., 2010). The snails (families Thiaridae and Bithynidae) act as intermediate hosts for fishborne zoonotic trematodes (FZT) while the vegetation could contaminate the ponds with FZT eggs from other farms (Clausen *et al.*, 2012) . These factors have not been investigated in Kiambu County in fish in aquaculture setup.

Various factors including: host age and size, parasites size, host specificity, host diet and host sex, environmental factors, such as season of the year, size and type of water body, altitude, temperature, salinity, oxygen content and pH have been shown to influence parasitism in fish (State and State, 2009; Lagrue *et al*., 2011; Ali *et al*., 2014). These need to be investigated to document factors that contribute to parasite infestivity in fish and their zoonotic importance in Kiambu County.

1.1 Problem statement and justification

Despite the great potential in fish farming, Kenyan aquaculture has been characterized by low production (Munguti *et al*., 2014). Fish parasites are a key constraint to production, sustainability and economic viability in aquaculture but little has been documented on fish parasites and their associated risk factors in small scale fish farms in Kiambu. Previous studies in Kenya done by Florio *et al*. (2009), Otachi (2009) and Mathenge (2010) were based on same tilapia breeding farm, a dam, caged and riverine fish while Mavuti, *et al*. (2017b) studied parasitism in small scale fish farms in Nyeri County. Kiambu County has being ranked among areas with high potential for aquaculture in the country and with the increased government support; farmers have embraced aquaculture as a source of income. This study therefore aimed at investigating parasites infesting farmed tilapia and associated risk factors in Kiambu County. The information obtained from this study will assist in designing cost effective control strategies for fish parasitism in central Kenya.

1.2 Objectives

1.2.1 General objective

To determine the prevalence and risk factors associated with parasitic infestation of farmed Nile tilapia in Kiambu County, Kenya

1.2.2 Specific objectives

i. To determine risk factors associated with occurrence of fish parasites in Kiambu County

ii. To determine the prevalence and mean intensity of fish parasites infesting farmed tilapia in Kiambu County

iii. To determine the effect of parasitism on fish body condition in Kiambu County

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Fish parasites

Parasites are usually at equilibrium with their host aquatic organisms thus their role in fish health are often overlooked (Iwanowicz, 2011). However, destabilization of this equilibrium by factors like intensification of aquaculture, deficient management practices and lack of biosecurity plans leads to establishment of parasitic diseases (Paredes-trujillo *et al*., 2016).

In general, the parasites reported to be problematic in African aquaculture include ectoparasites like protozoans (*Ichthyophthirius multifiliis*, *Chilodonella* spp. and *Trichodina* spp.), monogeneans (Dactylogyrids and Gyrodactylids), leeches, crustaceans and larval bivalve mollusks. Others are endoparasites such as protozoans (haemoflagellates, apicomplexans and microsporeans), myxosporeans, larval trematodes (*Bolbophorus* spp., Diplostomatids and Clinostomatids), cestodes, acanthocephalans and nematodes (Otachi, 2009). Economic effects of parasites on fish production include mass mortality, aesthetic rejection of infected fish by consumers when parasites and/or lesions are visible; and more importantly, reduced fertility rates, retarded growth and weight loss in infested fish (Otachi, 2009; Lagrue *et al*., 2011; Paredes-trujillo *et al*., 2016). Therefore they represent a key constraint to production, sustainability and economic viability (Shinn *et al.*, 2015).

2.1.1 Monogeneans

Monogeneans are flatworms (Platyhelminthes) found in freshwater, brackish and marine habitats. Majority are on external surfaces of fish (skin, fins, gills, mouth cavity, nostrils) but a few species have adopted an endoparasitic life (i.e., *Acolpenteron ureteroecetes* in the bladder and urinary ducts of labrids, *Enterogyrus* spp. in foregut and stomach of *Pomacanthus paru*) (Woo, 2006). Their anterior end contains apical sensory structures, a mouth with or without accessory suckers and special glands or clamps for attachment while posteriorly they attach by special positioned attachment organs (haptor or opisthaptor) to their host's skin or gills (Paperna, 1996; Abowei *et al*., 2011) and are hermaphrodites. Monogeneans have a direct life cycle and are host- and site-specific (Woo, 2006; Iyaji *et al*., 2009). They are common in aquaculture systems where fish are in high stocking densities and in confined environments. They are important pathogens as they propagate rapidly and are readily transmitted among fish. If left uncontrolled high morbidity and mortality can occur in farmed fish leading to serious economic loss to farmers (Reed *et al*., 2003).

Gyrodactylus and *Dactylogyrus* are the two most common genera of monogeneans that infest freshwater fish. They differ in their reproductive strategies and their method of attachment to the host fish. *Gyrodactylus* have no eyespots, have two pairs of anchor hooks and are generally found on the skin and fins of fish (Iyaji *et al*., 2009). They are viviparous (produce live young) in which the adult parasite can be seen with a fully developed embryo inside the adult’s reproductive tract. *Dactylogyrus* prefers to attach to gills. They have two to four eyespots, one pair of large anchor hooks and are egg layers (Klinger and Floyd, 2013). Cultured tilapia are more likely to be infested with monogeneans compared to wild ones as shown in a study by Lim *et al.* (2016) in Malaysia. This is due to the enclosed environment and high stocking densities. Paredes-trujillo *et al.* (2016) reported pathogenic monogenean *Gyrodactylus cichlidarum* in 26 of 29 farms visited, with an overall prevalence of 31% in Mexico. Penprapai and Chumchareon (2014) in southern Thailand reported 3 genera of monogeneans; *Cichlidogyrus* spp., *Gyrodactylus* spp. and *Dactylogyrus* spp. where *Cichlidogyrus* spp. was the most prevalent. The same study also described the morphology of the monogeneans as follows:- *Dactylogyrus* spp. had two pairs of lobe and two pairs of eye spot at the head. At the posterior end, it had opishaptor, one pair of anchor, transverse bar, and fourteen pieces of marginal hooks. *Gyrodactylus* spp. had two pairs of lobe at the head and lacked eyespots. At the posterior end, it had opishaptor as oval shape, anchor and one pair of central hook and sixteen pieces of hooklet around hook. For *Cichlidogyrus* spp. the head had three lobes and one pair of eye spot at the head while the posterior end had two pairs of large opishaptor, two pieces of transverse bar and fourteen pieces of small marginal hooks. In Brazil, 393 diagnosed cases reported by fish farmers at the Aquaculture center between 1993 to 1998 showed monogeneans were responsible for 36.6% mortality rate and changes in fish behavior with tilapia being among the infested fish (Martins *et al*., 2000). In Kenya Mavuti (2017b) reported *Dactylogyrus* spp in farmed tilapia in Nyeri County at a prevalence of 48.1%.

2.1.2 Digenean trematodes

Digenean trematodes have an indirect life cycle that involves a number of hosts. Fish can be the primary or intermediate host depending on the digenean species. They are found externally or internally in any organ. Metacercariae is the life stage most commonly observed in fish and encysts in fish tissues while piscivorous birds are the definitive hosts. The family Heterophyidae cause mortalities in pond-raised fish, genera *Posthodiplostonum* (white grub) cause reduction in growth rate while *Clinostonum* spp. (yellow grub) make fish unmarketable for aesthetic reasons

(Klinger and Floyd, 2013). *Diplostomum* metacercariae are the major fish parasites with complex three host lifecycle that involve piscivorous birds, snails and fish as definitive host, first intermediate host and second intermediate host respectively (Ndeda *et a*l., 2013). In the fish, the metacercariae moves to the lens, retina and aqueous humour of fish eyes as well as the brain, spinal cord and nasal spaces causing substantial losses. They cause diplostomosis (eye fluke disease) that is characterized by, a severe ocular involvement, lens opacity and blindness (Ibrahim *et al*., 2016). Since some fish physiological activities like swimming, feeding and mating depend on vision, the presence of this parasite affects its ability to perform and compete well with others. Poor feeding affects fish growth, and consequently the fish farming business. It could also expose the fish to predation increasing mortality. *Diplostomum* spp. metacercariae have been recovered from eyes at various prevalences. In a study by Ibrahim *et al.* (2016) in Oyo State Nigeria, 33.18% of the cat fish samples had *Diplostomum* parasites in the eye lens with higher occurrence in males (23.5%) than the females (9.7%).

In Kenya *Clinostomum* and *Diplostomum* spp have been reported in farmed tilapia in Tana River by Mathenge (2010) at a prevalence of 22.4% and 54.3 % respectively while, Mavuti (2017b) reported prevalence of 8.2% and 1.9% respectively in Nyeri County.

2.1.3 Acanthocephala

The acanthocephalans are commonly called “spiny or thorny headed worm.” Morphologically, they are elongate cylindrical worms readily recognized by their evaginable proboscis crowned with several rows of recurved hooks. In the encased larval stage, in tissues, the spiny proboscis is retracted. The worms are sac-like, containing lemnisci connected to the proboscis and genital organs opening posteriorly and they lack gastrointestinal truct. Moreover the worms have separate sexes and the male opening is within a membranous bursa. Males are smaller than the females. They have no gut. The number and arrangement of the hooks on the proboscis are the main criteria for differentiation of species (Paperna, 1996; Iyaji *et al*., 2009). They are mostly gut worms with at least one intermediate host in their life cycle. Eggs are laid into the intestinal lumen and excreted with faeces. First intermediate hosts are either amphipods, isopods, copepods or ostracods. The first larvae (acanthor) hatch from eggs after being swallowed by a suitable invertebrate host. Some species will develop to the adult stage when their larvae in the invertebrate host are ingested by the definitive vertebrate host (Paperna, 1996). Fish can serve as intermediate hosts, harboring a second larval stage (cystacanth). Definitive hosts are either predatory fish or piscivorous birds. In a study by Chacha and Lamtane (2014) in lakes Uba and Ruwe in Tanzania acanthocephalans and strigeid trematodes were the majority (47.9%) of all the parasites recovered in *Oreochromis urolepis*.

2.2 Factors influencing fish parasitism

2.2.1 Farm management practices

Intensification of crop densities in tilapia aquaculture, deficient management practices and lack of biosecurity plans have led to the spread and establishment of non-native parasitic diseases. Poor management conditions such as high stocking density, fish source, and high concentrations of nitrates and low frequency of water exchange in cultured tilapia have been identified as factors associated with reports of parasitic and bacterial diseases (Paredes-trujillo *et al.*, 2016). The study by Paredes-trujillo *et a*l. (2016) suggested that the high and low technology Nile tilapia farms in Yucatán Mexico have specific suites of ectoparasites, depending on their management and environmental variables. In Brazil, 393 diagnosed cases brought by fish farmers at the Aquaculture center between 1993 to 1998, comprised various parasites whose occurrence was attributed to high organic matter content, high stocking densities and farmers' failure to clean the fish nets (Martins *et al*., 2000).

Trade of fishes, their gametes and embryos as a result of fish farming and restocking of wild populations and ornamental fish exert a high risk for transmission of gonadal Myxosporeans (Sitja, 2009).Therefore, good management measures of the brood stock in hatcheries can prevent transmission of these parasites.

The source of water for fish farming is also an important factor in parasite transmission. Akoll *et al.* (2012) did a study to compare helminth infestations in a reservoir, therein operated cages as well as earthen fish ponds and the feeding stream to assess the significance of life cycle style and water sources in parasite transmission. The results showed domination of the two culture systems (cages and ponds) by trophically transmitted helminth species. Their occurrence in caged-fish was positively related to their prevalence in reservoir-dwelling hosts indicating the importance of water supply in spread of helminths. The prevalence in pond-raised fish was higher than in stream-dwelling ones suggesting the presence of local sources of infective stages within ponds.

Shitote *et al*. (2012) recorded that fish farmers faced several pond management problems including; high cost of feeds (33.6%), drying up of ponds during drought (18.5%), lack of fingerlings (13.8%), flooding (10.9%) and siltation of ponds (8.9%), pond maintenance (8.6%) and poor security (5.7%). Sheheli *et al*. (2013), while studying fish farming practices in Bangladesh reported various pre-stocking management practices practiced by farmers including dike repairing, removing excessive mud from pond bottom; eradicating predatory and undesired fish, lime and fertilizer application. The farmers used fertilizers mainly in form of cow dung, urea and triple super phosphate (TSP) at various rates. They also took various disease prevention measures including pond drying, lime application, controlling weed, removing undesirable fish and changing dirty water.

High stocking densities cause stress and facilitate parasitic transmission. It is much easier for the parasite to find a host in high density populations and this also allows the parasite to reproduce more rapidly and effectively (Komar and Wendover, 2007). In a study by Wanderson *et al.* (2012) the high prevalence of *Trichodina* spp. was shown to be correlated with the high stocking density of fish and with the physicochemical parameters of the water.

2.2.2 Host age, size and weight

Fish age and size have been found to be positively associated with the prevalence and/or intensity of parasitic infestation. Older fish have longer time to accumulate parasites than younger ones and may provide more internal and external space for parasite establishment (State and State, 2009). The occurrence of negative correlations has also been reported. This was attributed to changes in the feeding habit (the fish may give up feeding on a certain item which functions as an intermediate host in the adult phase) or to the development of the immunity reaction that occurs in older fish or premature mortality of infested older individuals (State and State, 2009). In a study by Mohamed (2010) on parasite infracommunities of *Tilapia Zillii* there was positive significant correlation of prevalence and mean parasite intensity with total host length indicating that larger hosts harbored more parasite species and more parasite burden than smaller ones. This was attributed to the fact that larger (older) fish had more time to accumulate parasites than the smaller (younger) ones.

Relationships between body weight and Lernaeid ectoparasites showed negative correlation. *Lernaea* spp. had the highest prevalence (25.9%) in weight group of <500g while, in weight groups 501 -1000g and >1000g its prevalence was 20.6% and 13.4%, respectively (Ali *et al.*, 2014). A Study by Khidr *et al*. (2012) showed positive correlation of the mean intensity of the monogenean *Microcotyloides* spp. found on the gills of the small scaled terapon fish (*Terapon putta*) and fish body weight. Wanderson *et al*. (2012) found that intensity of protozoan *Ichthyophthirius multifilis* was positively correlated with both weight and length of the Nile tilapia (*Oreochromis niloticus*). This indicates an increase of parasitism according to the growth of fish. Chacha and Lamtane (2014), reported fish in lower size classes and upper classes had few parasites while fish in middle class (160 - 189 mm) had higher prevalence of infestation. All fish in higher size classes or older fish had low intensity of infestation. This was attributed to ontogenetic change that is considered as the main factor determining parasite abundance in the alimentary canal due to changes in feeding behavior as a fish grow.

2.2.3 Host diet

In parasites acquired by ingestion, host diet is the main factor determining the number of parasite species and individuals to which a host is exposed. Ingestion of larval helminth parasites by fishes is a frequent event due to the abundance and diversity of these trophically transmitted parasites in aquatic ecosystems. Differences in trematodes (*Coitocaecum parvum)* infestation levels observed among fish species in the Lake Waihola community by Lagrue *et al.* (2011) in Newzealand were attributed to interspecific differences in host diets. However, prevalence and abundance of *Acanthocephalus galaxii* and nematode *Hedruris spinigera* were not, or only weakly correlated with fish host diets. Cirtwill *et al*. (2016), found no obvious link between individual fish host diet and helminth infestation levels. This was attributed to relatively low richness of freshwater helminth parasites in New Zealand and high host–parasite specificity.

2.2.4 Host sex

Sex-biased parasitism can result from differences in immunocompetence. Males are predicted to bear a greater cost of sexual selection and immunosuppressive effects of testosterone production thus becoming more susceptible to parasitic infestation than females. Differences in parasitic infestation between genders might also arise ecologically. For example, niche partitioning involving habitat or diet can result in differential exposure to parasites with either males or females exhibiting excess parasitism dependent on their probability of encountering the parasite (State and State, 2009). Studies on helminth parasites in largemouth bass, *Micropterus salmoides*, from Lake Naivasha showed female fish were heavily infested than males (Aloo, 1999). Chacha and Lamtane (2014) in lakes Uba and Ruwe in Tanzania reported overall prevalence (88.5%) and mean intensity (21.6%) of parasites was higher in males compared to females though the differences were not statistically significant (P>0.05). This was attributed to the inactivity of females since most had ripe gonads indicating a spawning period. Mohamed (2010) reported that the prevalence and intensity of most parasite species were higher in females than in male fish. The sex difference in infestation was attributed to immune response of the host due to the difference in endocrine glands activities between the host male and female fishes.

2.2.5 Seasonality of parasite transmission

Temperature and rainfall are important factors controlling the seasonal prevalence of parasites. As warm temperature would hasten the generation time, the absence of seasonal fluctuation in temperature would suggest a dynamic equilibrium of the parasite population with constant infestation and maturation (State and State, 2009). Ali *et al.* (2014) attributed the high prevalence of *Lernaea cyprinacea* and *L. polymorpha* in some fish species cultured in some nurseries and hatcheries in Pakistan to the hot climate in the area. In a study on helminth parasites in fish from Niger delta creek in Nigeria by Ogbeibu *et al*. (2014), parasites had the highest densities in the dry season, corresponding with the influence of season, change in physicochemical conditions, particularly salinity and improved availability of food prey. Report by Vagianou *et al.* (2007) showed sea bass reared in cages to be more likely to develop monogenean parasitism in autumn. This was due to the lower overall temperatures, specific wild fish fauna and climatic conditions present. Lower temperatures may affect the immune system rendering fish more susceptible to infection (Gupta *et al*., 2012). Studies on helminth parasites in largemouth bass

(*Micropterus salmoides)* from Lake Naivasha by Aloo (1999) showed no trends in seasonal variation. Khidr *et al*. (2012) showed that the mean intensity of the *Microcotyloides* spp. was positively correlated with water temperature where their mean intensity appeared to increase with the increase in water temperature resulting in a seasonal cycle of the parasite.

Rainfall affects water quality by diluting nutrients, food remains and other materials and increasing turbidity due to excess particles from sediments in the water (Taraves-Sipauba *et al*., 2007). Fish reared in cages in Greece showed increase in the prevalence and intensity of the monogenean *Diplectanum aequans* in sea bass after a heavy rainfall, a common phenomenon during autumn (Vagianou *et al*., 2007). Increased load of suspended solids and turbidity in the water was also present. This was attributed to the mixing of the water during the storms which facilitates the transfer of the parasites to the hosts or the sudden decrease of salinity resulting in immunosuppression due to stress. Parasites development and growth requires high temperature, low humidity and less rainfall (Dhole *et al*., 2010). These conditions enhance hatching of parasite eggs and also causes increase in density of intermediate hosts (Fartade *et al*., 2017).

2.2.6 Water quality

Poor water quality parameters such as high organic matter, high ammonia, low dissolved oxygen and high bacterial load can create a suboptimal environment that is stressful for the fish leading to a higher incidence of parasitic outbreaks (Komar and Wendover, 2007). As some parasites only survive in brackish water and others only tolerate freshwater, salinity is an important factor influencing infestation with a specific parasite. For instance, dinoflagellates such as *Amyloodinium* spp. can only survive in brackish and marine water; therefore it does not occur in freshwater. In contrast, some species of *Trichodina* can only tolerate freshwater and die with as little as 5ppt of salt in the water (Komar and Wendover, 2007). Khidr *et al*. (2012) reported the mean intensity of the monogenean *Microcotyloides* spp. found on the gills of the small scaled terapon fish (*Terapon putta)* and the fish water salinity were negatively correlated as the parasite is less tolerant to salinity changes.

2.2.7 Culture system

Each culture system has its own characteristics. For instance, tanks or cages, which hold high densities of fish, are a good environment for the transmission of ectoparasites with a direct life cycle such as monogenean trematodes. Earthen ponds are a more complex environment with vegetation where parasites such as crustacean copepods or leeches can lay eggs. The mud can be a reservoir for cysts of dinoflagellates such as *Amyloodinium* or invertebrates acting as intermediate hosts such as snails for digenean trematodes. Recirculation systems also favor the growth and concentration of parasites due to the build-up of sediment and slow turnover of water (Komar and Wendover, 2007). In a limited parasitological survey on wild and farmed tilapias in Kenya, Florio *et al.* (2009) reported that parasitic prevalence in different aquatic systems showed no remarkable differences with percentage of positivity slightly higher in farmed fish (caged 85.9% and pond 86.5%) unlike the wild ones (82.1%). Otachi (2009) reported occurrence of protozoan and helminth parasites in Nile tilapia from Sagana and Machakos County in Kenya, and had no significant difference in parasitic infection between caged and open pond fish. These authors however did not study the risk factors associated with the parasitism in the study area. Further they just studied tilapia in a breeding farm and a dam but not those in a small scale farms.

2.2.8 Fresh water snails

Pulmonate and prosobranch snails are intermediate hosts for trematodes of fishes (Cribb *et al*., 2001). Tigga *et al.*, (2014) reported highest prevalence of infection of snails with trematodes during the rainy season. This was because snails were infected by cercarial during mid-rainy season when eggs containing miracidium are carried to low-lying snail breeeding areas. The prosobranch *melanoides tuberculatus* occurs worlwide and occurs mainly in shady areas with fine sediment. Miranda-Rocha and Silva-Martins, (2006) recorded highest density of *M. tuberculatus* in Cana Brava River, Brazil. This was because the river was most impacted and had farming activities. This species is associated with spread of trematodes like *Centrocestus formosanus* to fish and ducks (Miranda-Rocha and Silva-Martins, 2006). Also, it is able to spread fast and colonize new habitats whether natural or man-made. Azugo, (2007) reported two pulmonates (*Lymnaea natalensis* and *Gyraulus costulantus*) and nine prosobranchs (*Lanistes lybicus, Lanistes ovum. Pila wernei, Pila ovata, Potadoma freethii, Bythinia sp. Orthalicus sp, Dvymaeus nurltilineatus* and *Bulimulus sp)* in lake Obutu in Nigeria. These snails had a close association with macrovegetation, macrophytes and microphytes found in the lake. Among the snails, 27.2% were infected with trematode cercariae. Lydig, (2009) reported fresh water pulmonates *Biomphalaria* spp, *Bulinus* spp, and *Lymnea* spp in Bahati District,Tanzania. Their presence was determined by food availability, localization, quantity and quality of food sources. The high temperatures in warm seasons help to maintain vector numbers. This is by favouring reproduction, ensuring food availability and availability of aquatic weeds used by snails for shelter both for themselves and their eggs (Lydig, 2009). In dry season infection of snails by trematodes is low but can be increased in permanent ponds due to visitation by final hosts such as wading and migratory birds (Brown *et al*., 2016).

2.3 Zoonotic fish parasites and associated risk factors

Numerous marine and fresh water fishes serve as a source of important zoonotic parasites with some causing severe clinical manifestation and death (Noga, 2010). The fish-borne intestinal flukes are much less well characterized clinically than the liver flukes, but are reported to cause significant pathology in the heart, brain, and spinal cord of humans (Chi *et al.*, 2008). Previously zoonotic infections were only prevalent in few countries that eat raw fish or fish products. Presently they have become more widespread with advent of international transport system, mass tourism and expansion in consumption of raw fish in both regional cuisine and international products such as sushi. Agents responsible are usually larval stages of parasites with low specificity at the adult stage thus are able to infect humans (Roberts, 2012). Fish can be an intermediate host involving humans as definitive hosts or paratenic hosts of the parasite that invade humans without undergoing further development. Natural definitive hosts are usually marine mammals or birds but few larval stages can mature in humans and animals like dogs, cats or pigs (Noga, 2010). The most important of the helminths acquired by humans from fish are the anisakid nematodes (particularly *Anisakis simplex* and *Pseudoterranova decipiens),* cestodes of the genus

Diphyllobothrium and digenetic trematodes of the families Heterophyidae, Opisthorchiidae, Nanophyetidae, Echinostomatidae, Troglotrematidae and Clinostomatidae (Adams *et al*., 1997; Roberts, 2012). Chi *et al*. (2008) documented an overall prevalence of 44.7% for fish borne zoonotic trematodes (FZTs) in fish from both nurseries and grow out ponds owned by a Vietnamese fish farming community. All species of metacercariae recovered were potentially zoonotic intestinal flukes belonging to either the Heterophyidae or the Echinostomatidae family. Although the prevalence of the intestinal flukes were high in fish, the prevalence in the human residents was low suggesting reservoir hosts, such as dogs, cats, and pigs may be important in sustaining the life cycles of these flukes in fish farms. This shows the importance of managing domestic animals in FZT control. The study also showed that distribution of infested fingerlings negatively affected control of FZT in grow out ponds. Phan *et al*. (2010) in Nan Dinh province in Vietnam investigated development and risk factors of fish borne zoonotic trematodes infestations in fresh water cultured fish. Liver fluke *Clonorchis sinensis* and different zoonotic intestinal flukes including *Haplochis pumilio, H. taichui, H. yokogawai, Centrocestus formosanus* and *Procerovum varium* were found in sampled fish.

2.4 Condition factor

Condition factor (K) is calculated from the relationship between the weight of a fish and its length in order to describe the “condition” of that individual fish (Mir *et al*., 2012; Sarkar *et al*., 2013). The Condition factor (K) allows quantitative comparison of the condition of individual fish within a population, individual fish from different populations and two or more populations from different localities (Barnham and

Baxter, 1998). It is influenced by age of fish, sex, season, stage of maturation, fullness of gut, type of food consumed, amount of fat reserve and degree of muscular development (Barnham and Baxter, 1998; Jain *et al*., 2016). Therefore, different values in K indicate the state of sexual maturity, food availability, age and sex of some species and also provide important clues on climate and environmental changes and change in human subsistence practices (Mir *et al*., 2012; Sarkar *et al.*, 2013; Jain *et al*., 2016). In females, the K value decrease when the eggs are shed. Condition of fish and effect of parasitism on fish body condition have not been documented in Kiambu County.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study area

The study was conducted in Kiambu County which is located in Central Kenya with geographical coordinates: 1° 10' 0" South, 36° 50' 0" East. The county has an area of 2,449.2km^2 and a human population of 1,623,282 (wikipedia.org/wiki/Kiambu County). It is divided into 12 sub-counties (Fig. 1) which are classified into four topographical zones; Upper Highland, Lower Highland, Upper Midland and Lower Midland. The Upper Highland Zone is found in Lari Sub-county and lies at an altitude of 1,800-2,550 metres above sea level. The lower highland zone is mostly found in Limuru and some parts of Gatundu North, Gatundu South, Githunguri and Kabete sub-counties. This zone lies between 1,500-1,800 metres above sea level. The upper midland zone lies between 1,300-1,500 metres above sea level and it covers parts of Juja and other sub-counties with the exception of Lari. The lower midland zone partly covers Thika Town (Gatuanyaga), Limuru (Ndeiya) and Kikuyu sub-counties. The area lies between 1,200-1,360 metres above sea level.

The county experiences bi-modal rainfall with long rains between Mid-March to May and the short rains between Mid-October to November. Rainfall ranges between 600 to 2000 mm depending on altitude, with an average of 1,200 mm annually. The mean temperature is 26^{o}C with temperatures ranging from 7^{o}C in the upper highland to 34^{0}C in the lower midland. The county‘s average relative humidity ranges from 54% in the dry months and 300% in the wet months.

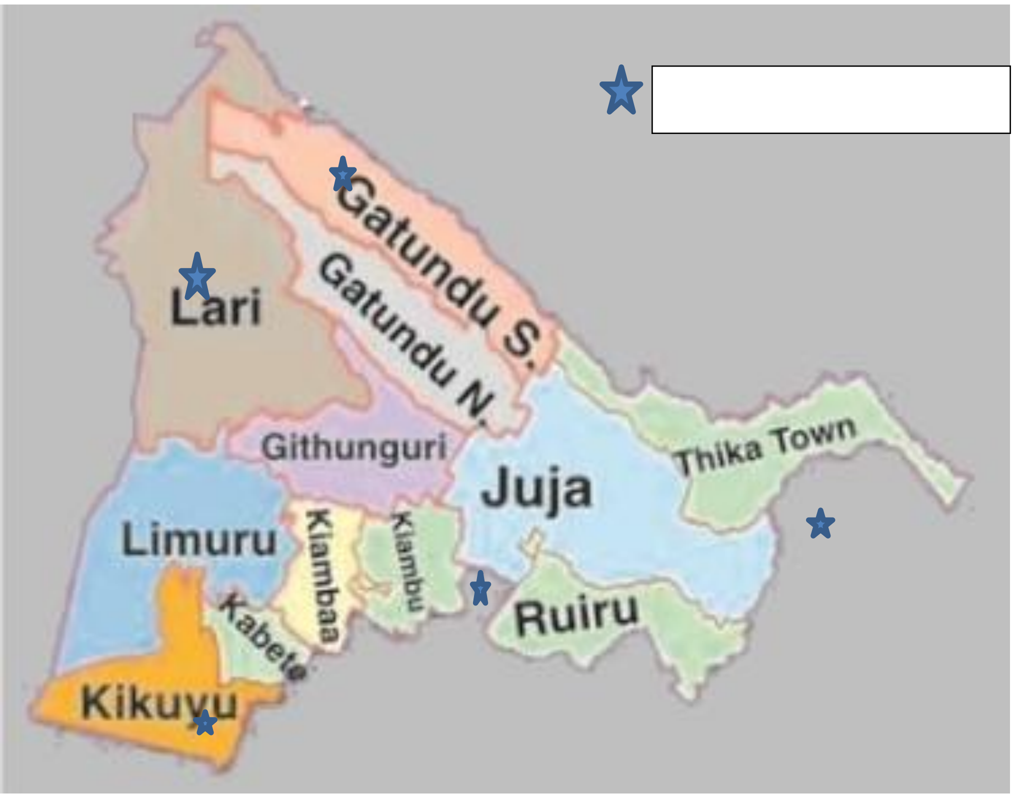

Figure 1: Map showing sampled sub-counties among the 12 sub-counties of Kiambu County

Source: Kiambu Agriculture, Livestock & Fisheries 2013-2017 Strategic Plan

3.2 Study design and sample size estimation

A cross sectional design involving farm visits in the study area was undertaken. The sample size was calculated using the following formula of Naing *et al*., (2006).

$n = z^2 P (1-P)/L^2$, Where n is defined as sample size, Z is confidence interval = 1.96 for 95% confidence, P is prevalence of disease = 86.5% (Florio *et al*., 2009), L is expected error = 0.05. Sample size $=1.96^2 \times 0.86 (1-0.14)/0.05^2$ = 185 fish.

3.3 Questionnaire preparation and administration

A semi-structured questionnaire (Appendix 1) was prepared, reviewed, pretested and a final version incorporating the pre-test results was produced. The questionnaires were administered through face-to-face interviews by the researcher with the help of six enumerators and complimented with direct observations. The farmers were purposively selected with the assistance of the sub-county fisheries officers depending on their availability and willingness to participate in the study.

Questionnaires were assessing brief history of the farm (duration of fish farming, fish species kept, culture system practiced, type of farming system practiced, types of ponds, sources of fingerlings, source of pond water), management practices (frequency of changing pond water, pond drainage after harvesting, pond treatment after harvesting, pond fertilization, type of feed used, sharing of fishing nets, cleaning of fishing nets, animals found in and around the pond, deworming of cats and dogs in the farm and management of vegetation around the ponds), disease history in the farm (fish abnormalities seen in the farm, fish losses due to fish diseases, frequency of fish deaths), disease control measures and knowledge on fish parasites. Other factors assessed were feeding fish to other animals, consumption of fish by the household members, fish preparation method and cooking duration, symptoms experienced after consuming fish and challenges encountered in fish farming. Basic information about the farm, the owner and the respondents were also recorded.

A total of 148 questionnaires were administered in all the twelve sub-counties depending on the number of farmers in each sub-county (Table 1).

Table 1: Number of questionnaires administered per sub-county in Kiambu County

Sub-county	Number of farmers	Percentage of farmers (%)
Lari	33	22.3
Kiambaa	15	10.1
Kiambu	15	10.1
Gatundu South	13	8.8
Thika	13	8.8
Githunguri	12	8.1
Gatundu North	10	6.8
Limuru	9	6.1
Kikuyu	8	5.4
Kabete	8	5.4
Ruiru	7	4.7
Juja	5	3.4
Total	**148**	**100**

3.4 Fish sample collection

One sub-county with the highest number of farmers with active ponds was purposively selected from each of the four zones. These included Gatundu South (Lower highland zone), Thika (lower midland zone), Lari (upper highland zone), Kiambu and Kikuyu (both in upper midland zone) sub-counties (Fig.1). Five farms from each of the sub-counties were purposively selected depending on availability of fish since sampling was done during the dry season. Fish were harvested by use of seine nets (Fig. 2) where ten fish were randomly selected from each farm. A total of 260 tilapia fish were purchased from farmers of which 200 were from earthen ponds and 60 from liner ponds. The fish were carried in plastic containers with pond water and transported to a central point in Thika sub-county for gross and parasite examination *in-situ*, post mortem and collection of parasitological samples for further analysis in the laboratory.

Figure 2: Fish sampling using a seine net (blue arrow) in Thika Sub-county

3.5 Parasitological examination

Live fish were stunned with a single blow to the back of the head and pithed to separate the central nervous system from the spinal cord. Macroscopic examination of the skin was done for ectoparasites. Fresh mounts of the skin scrapings and gill filaments were collected on slides with saline and examined under the microscope for ectoparasites. Total body weight, full and standard lengths were taken and recorded after which post mortem of the fish was performed as described by Noga (2010). The sex of the fish was determined at postmortem. The eyes were removed and contents expressed on a slide and examined for eye flukes. Each fish was laid on its side on the dissecting table. A transverse incision was made anterior to the vent from which a longitudinal incision along the ventral midline was made up to the operculum. Another incision from the transverse one in an arc was made on the abdominal wall of the fish up to the upper corner of the operculum. The muscular flap was then removed by connecting the two incisions at the operculum. The peritoneal cavity and the organs were examined grossly for parasites and then separated. Intestinal contents were put on a slide with 0.64% saline and examined for parasites.

Stomach and intestines were collected in containers with 70% ethanol and transported to the laboratory at the Department of Microbiology, Pathology and Parasitology, University of Nairobi for processing and examination for parasites. At the laboratory, stomach and intestines were put in a petri dish with saline, the contents expressed and examined under the dissecting microscope for parasites.

3.6 Parasites identification

All the parasites recovered were manually counted and recorded. Identification of parasites was achieved using morphological features as described by Woo, (2006).

3.7 Determination of fish condition factor

The fish condition factor was calculated after measuring the total length and weight of each fish. The length was measured from the tip of the mouth to the end of the tail fin in centimeters (cm) using a ruler while, the weight was measured in grams (g) using a table top digital weighing balance. The formula used for calculating the condition factor is as described by Froese, (2006) as follows:

$K=100\ W/L^3$ where:-

K= Fulton's condition factor, W = whole body wet weight in g and L = Total body length in cm; the factor 100 is used to bring K close to unity

The condition factor results obtained were compared with the standard values reported by Barnham and Baxter, (1998) (Table 2).

Table 2: The scale of fish condition factor and health status

K value	Condition of fish
1.6	Excellent
1.4	Good
1.2	Fair
1.0	Poor
0.8	Extremely poor

Source: Barnham and Baxter, (1998)

3.8 Data analysis

All the data collected from questionnaire administration and fish sampling exercises were entered and cleaned in the computer using Microsoft Excel. Analysis was done using SPSS version 16.0 and Epi info statistical software version 7.0. Prevalence was determined as the number of fish infested with one or more individuals of a particular parasite species divided by the number of fish examined for that parasite species. Mean intensity was determined as the average intensity of parasites among the infested fish (total number of specific parasite found in a sample divided by the number of infested fish) (Margolis *et al*., 1982). Chi square (X^2) and students 'T' test statistics were used to determine significance of results obtained. Where the counts in the cell were less than five, the Fishers' Exact Test probability was reported instead of Chi-square. $P \leq 0.05$ was considered significant and level of significance used was 95%.

CHAPTER FOUR

4.0 RESULTS

4.1 Questionnaire survey

4.1.1 Information about the farm owners, respondents and farm management

Majority of the farmers were males (79.8%), over 50 years of age (74.5%) and comprised majority (56.9%) of the respondents. Most farms were managed by the owners (66.7%) while some were managed by farm workers (28.5%), spouses (4.2%) and children (0.7%) to the fish farm owners who were also respondents in some farms.

Of the fish farms visited, 22.9% were owned by institutions which included: primary and secondary schools, polytechnics and children's homes. Most individual fish farmers (56.3%) were involved in farming as their main occupation while others were involved in business (15.3%) and some were salaried employees (5.6%). Almost all (95.4%) of the farmers went through formal education where most (35.2%) attained secondary level of education (Fig. 3).

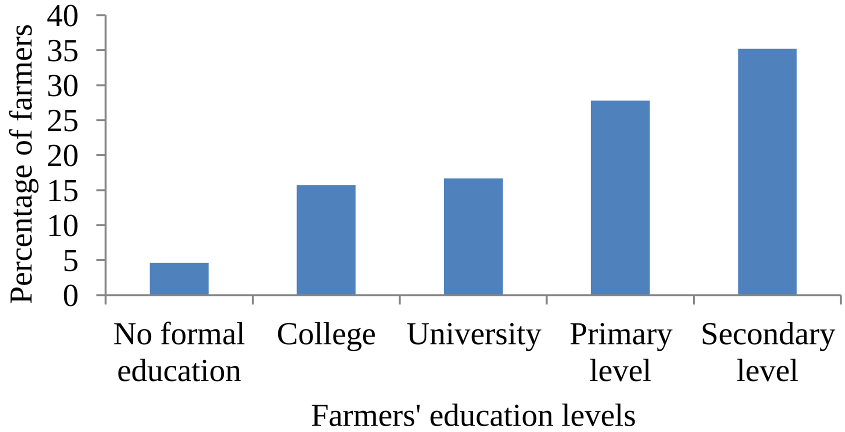

Figure 3: Fish farmers' education levels in Kiambu County

4.1.2 Farmers' experience in fish farming, fish species farmed and culture system practiced

Most farmers (52%) had been in fish farming for more than five years with tilapia being the main fish species farmed by 66.5% of farmers under mixed sex monoculture system (74.8%). Other fish species farmed in Kiambu County include catfish (31%), ornamental fish (2%) and rainbow trout (0.5%). Other culture systems practiced were monoculture one sex (17.7%) of either catfish or tilapia and catfish/tilapia polyculture (7.5%).

4.1.3 Type of farming system and pond types

Semi intensive farming system was practiced by majority (60.8%) of the farmers mainly in earthen ponds (53.9%). Other farming systems practiced included: extensive system and intensive system practiced by 23% and 16.2% of the farmers, respectively. Other pond types were liner (42.8%) and concrete (3.3%) ponds.

4.1.4 Sources of fingerlings

Majority of farmers sourced their first stock of fingerlings from government hatchery (78.8%) at Sagana while only a few sourced from private hatcheries. The number of farmers who restocked from private and government hatcheries was equal (25.6%) while, a considerable number of farmers (46.4%) left the fish to inbreed in the ponds without sourcing fingerlings from outside for restocking (Table 3). Five private hatcheries were serving the farmers in the county which include Samaki tu, Jasa fish farm, Athi fish farm, Jambo fish and Mwea aqua fish farm.

Table 3: Sources of fingerlings for fish farming in Kiambu County

Source of fingerlings	Number of farmers			
	Initial stock		Restocking	
	Frequency	Percentage	Frequency	Percentage
Government hatchery	115	78.8	32	25.6
Private hatchery	26	17.8	32	25.6
The wild fish capture	2	1.4	1	0.8
Other farmers	3	2.1	2	1.6
Own pond (In breeding)	0	0	58	46.4
Import fish or eggs	0	0	0	0
Total	**146**		**125**	**-**

4.1.5 Pond water sources and frequency of changing/refilling pond water

Rivers (33.1%) were the major sources of water for the ponds followed by wetlands (27%) and boreholes (25.7%). Other water sources were piped water (8.1%), dams (4.1%) and harvested rain water (2%). Majority of farmers (55.7%) did not change or refill water in the fish ponds during a production cycle. Others changed or refilled at various intervals including once per month (20.5%), twice per month (17%) and once every two months (6.8%).

4.1.6 Pond draining and treatment

Only 30.3% of farmers were draining their ponds during harvesting. Of these, 44.4% treated their ponds after draining. Sun drying was the major pond treatment method used by majority (64%) of farmers followed by liming (32%).

4.1.7 Ponds fertilization

Most farmers (83%) fertilized the ponds before fish stocking. Animal manure was used by majority of farmers (91.9%). Manure from cattle was mainly used (62.8%) followed by chicken manure (25.6%). Others used goat (5.4%), sheep (4.7%) and pigs (1.6%) manure. Chemical fertilizers were used alone or in combination with animal manure equally (4.05%). The chemical fertilizers used were urea, di-ammonium phosphate (DAP), di-calcium phosphate (DCP) and calcium ammonium nitrate (CAN). However the frequency of adding manure varied with 31.5% of farmers never adding manure within a production cycle, while 26.6% added when the green colour of pond water became less. Others added manure at various intervals including once every three months (19.4%), once per month (12.9%), once every two months (8.1%) while 1.6% added twice per month.

4.1.8 Types of fish feeds used

Commercial fish feeds were used by majority (42.2%) of farmers followed by other animal concentrates (maize bran, dairy meal, maize germ, pollard and pig growers mash) used by 21.7% of farmers and homemade formulations used by 15.5% of farmers. Other feeds used include vegetables (6.8%) and kitchen leftovers (2.5%). However, 11.2% of the farmers were not feeding the fish. Despite the farmers occupation they all used different types of feeds for the fish as shown in table 4 below. Many of the farmers using commercial fish feeds and other animal concentrates had attained tertially college education (88% and 41.7% respectively).

Table 4: Type of fish feeds used in Kiambu County

Farmers' occupation	**Type of fish feed used (percentage of farmers)**					
	Commercial fish feeds	Home made formulations	Kitchen leftovers	Vegeta bles	Other concentrates	No feeding
Farming	35.8	17.3	1.2	8.6	29.6	17.3
Business	50	22.7	0	4.5	13.6	9.1
Salaried employee	12.5	12.5	125	0	62.5	12.5
Institutions	72	13.8	6.5	9.1	9.1	3

4.1.9 Fishing nets usage and cleaning methods

Majority of the farmers (74.6%) shared fishing nets with other farmers while 90.1% of those with multiple ponds used the same net between ponds. After using the nets, most farmers (75.4%) washed them with water only while, 10.7% dried the nets on the sun without cleaning but 4.1% cleaned them using water with a disinfectant. However, 9.8% of the farmers did not clean the fishing nets at all.

4.1.10 Animals seen in and around the fish ponds

Predatory birds (58.8%) were the major animals seen in ponds (Table 4) followed by otters (22.6%). Other animals seen included: dogs (8%), cats (4.7%), snakes (4.1%), snails (1.4%) and monitor lizard (0.9%). Predatory birds and otters were reported to occur frequently. Dogs, snakes, monitor lizard and cats occurred less frequently while; snails were reported to be rare (Table 5). Kingfishers were the major (22.3%) predatory birds followed by Ibis (18.5%), herons (13.6%) and egrets (10.3%). Other predatory birds seen include: marabou stork (8.2%), cormorants (7.6%), hamerkop (7.1%), fish eagles (6%), wild ducks (2.7%), pelicans (2.2%) and crows (1.6%).

Table 5: Animals seen in and around fish ponds in Kiambu County

Animals seen	**Number of responses**	**Percentage of responses**	**Frequency (Percentage of farmers)**		
			Frequently	Less frequently	Rarely
Predatory birds	130	58.8	73.5	22.0	4.5
Otters	50	22.6	58.5	32.1	9.4
Monitor lizard	2	0.9	33.3	66.7	0.0
Cats	10	4.5	18.2	63.6	18.2
Dogs	17	7.7	15.8	68.4	15.8
Snakes	9	4.1	11.1	33.3	20.8
Snails	3	1.4	0.7	2.7	96.6

4.1.11 Deworming of cats and dogs

Among the farmers who owned cats and dogs, 61.3% dewormed them regularly.

4.1.12 Management of vegetation around the ponds

Among the 148 fish farms visited 53.5% of them had overgrown vegetation around the ponds (Fig.4). Majority were also observed to be highly silted. Majority of farmers who trimmed vegetation were salaried employees (50%) while 48.5% were institutions. Forty one percent (41.9%) were mainly involved in farming while 36.4% were involved in business. Majority of farmers (58.8%) whose ponds were well trimmed had attained tertially college education.

Figure 4: An earthen pond with overgrown vegetation (red arrows) around it in Githunguri Sub-county

4.1.13 Length of production cycle and weight at harvesting

Majority of the farmers harvested fish at the age of 7-9 months for both Catfish (44.4%) and tilapia (35.8%), respectively. Other farmers harvested at varying ages including; 6 months, 10-12 months and over 12 months while, a similar proportion (6.7%) of farmers harvested randomly for both catfish and tilapia. The weight of harvested fish could not be established as farmers were not weighing the fish during harvesting. The fish were sold according to the size.

4.1.14 Presence of fish abnormalities in the farm

Only 41.2% of farmers had seen fish abnormalities in their farms. Among the abnormalities observed include; skin lesions (spots, necrotic areas, nodules, discolouration and dry skin), bent tail, sluggish swimming, rubbing on pond sides, flashing when swimming, wounds, retardation, floating and death.

4.1.15 Losses due to fish diseases and frequency of fish deaths

Few farmers (29.7%) had experienced losses due to fish diseases with fish death being the major (68.4%) loss followed by poor growth rate (19.3%) as shown in Table 6. Majority of farms (51%) experienced fish deaths occasionally while others experienced fish deaths monthly (16.7%), after harvesting (13.7%), weekly (12.7%) or daily (5.9%).

Table 6: Losses experienced by fish farmers due to fish diseases in Kiambu County

Type of loss	Number of farmers	Percentage of farmers
Death	39	68.4
Poor growth rate	11	19.3
Reduced size/weight at harvesting	4	7.0
High cost of treatment	3	5.3
Total	**57**	**100**

4.1.16 Fish infestation by parasites and knowledge on signs of parasitism in fish

Only 7.4% of farmers reported that their fish had been infested by parasites. Of the farmers interviewed, 21.6% did not know any sign of fish parasitism while the others mentioned various signs which included: skin discolouration, poor or lack of feeding and reduced pond activity (27.1%) and fish deaths (21.1%) as the main signs (Table 7).

Table 7: Farmers knowledge on signs of fish parasitism

Clinical signs	Number of responses	Percentage of responses
Others (Discolouration, poor or no feeding, reduced activity in the pond)	54	27.1
Don't know	43	21.6
Death	42	21.1
Difficult breathing/gasping for air	14	7.0
Skin or gill lesions like white spots	13	6.5
Loss of weight	8	4.0
Fish appear bloated	1	0.5
Clamped or droopy fins	1	0.5
Total	**199**	**100**

4.1.17 Disease control activities practiced in the farm

Clearing of vegetation was the major disease control activity practiced by 54.3% of farmers followed by control of predatory birds (39.8%) (Table 8). Majority of the ponds where clearing of vegetation (84%) and control of predatory birds (66.7%)

were practiced belonged to institutions. Among individual farmers, majority (80%) who practiced vegetation clearing had no formal education while majority (66.7%) who did predatory birds control had attained university education.

Table 8: Disease control activities practiced in fish farms, Kiambu County

Activity	**Number of farms**	**Percentage of farms**
Clearing of vegetation	101	54.3
Control of predatory birds	74	39.8
Others (fencing, water changing)	5	2.7
Liming	3	1.6
Water treatment	2	1.1
Controlling snails	1	0.5
Deworming of fish	0	0.0

4.1.18 Feeding fish to other domestic animals

Majority of farmers (46.2%) fed fish to cats and dogs (43.6%) while pigs (7.7%) and chicken (2.6%) were rarely fed with fish meat (Table 9).

Table 9: Animals fed with fish in Kiambu County

Animal species	No. of farmers	Percentage of farmers
Cats	18	46.2
Dogs	17	43.6
Pigs	3	7.7
Chicken	1	2.6
Total	39	100

4.1.19 Preparation and consumption of fish

Majority of the farmers (94.5%) did consume fish. Of these, 91.3% consumed the fish when fresh and cooked by deep frying. Time spent while cooking fish varied with majority (36.2%) cooking for 5 to 10 minutes (Table 10). Only 2.1% of 142 household members had experienced uncomfortable symptoms within the past 6 months after consumption of a fish meal. The symptoms reported were stomach ache (1.4%) and allergic reaction (0.7%).

Table 10: Fish cooking duration in Kiambu County

Time spent in cooking fish	Percentage of farmers
5-10 minutes	36.2
11-15minutes	31.5
>15minutes	16.9
Don’t know	8.5
<5min.	6.9

4.1.20 Challenges faced by fish farmers

Feeds cost, poor quality and unavailability (23.7%) and fish predation (23.1%) were the major challenges faced by fish farmers. Other challenges reported were water shortage (9.8%), market unavailability (7.7%), theft (6.2%), slow growth of fish (5.6%) and lack of expertise in fish management and health (5.3%) (Table 11).

Table 11: Challenges faced by fish farmers in Kiambu County

Type of challenge	**Number of farmers**	**Percentage of farmers**
Feeds cost, quality and availability	80	23.7
Predation	78	23.1
Water shortage	33	9.8
Market unavailability	26	7.7
Theft	21	6.2
Slow growth of fish	19	5.6
Lack of expertise on fish health and management	18	5.3
High input and maintenance cost	14	4.1
Poor quality of fingerlings	12	3.6
Limited extension and delayed assistance	11	3.3
Financial shortage	11	3.3
Poor quality liners and high cost	8	2.4
Ponds too far and too large	7	2.1

4.2 Fish sampling

A total of 260 fish were collected from different farms. Of these, 200 (76.9%) were from earthen ponds and 60 (23.1%) from liner ponds. In all, 198 (76.2%) were male and 62 (23.8%) were female fish. One hundred and eighty eight (188) fish were from ponds that had overgrown vegetation while 72 were from ponds that had well-trimmed vegetation in and around them. The mean weight, total length and standard length of the fish collected were 110.2 g (±83.7), 17.6 cm (±4.1) and 14.3 cm (±3.5), respectively (Appendix 2). The mean condition factor of sampled fish was 1.8 (± 0.41) with majority (83.1%) of them having excellent body condition. Other fish had good (14.2%), fair (2.3%) and poor (0.4%) body conditions.

4.3 Occurrence and prevalence of fish parasites

Out of all fish sampled 68 (26.2%) were found to be infested by one or more species of parasites. More male (25.3%) fish were infested compared to females (22.6%) while fish from earthen ponds (31%) were more parasitized compared to those from liner ponds (3.3%) as shown in Appendix 3. Fish from ponds with overgrown vegetation (30.3%) were more parasitized compared to those where the vegetation around the pond was well trimmed (9.7%). The differences between the sexes were not statistically significant ($p>0.05$), while differences between the types of ponds and status of vegetation in and around the ponds were statistically significant ($p< 0.05$). Fish parasites recovered were digenean trematodes (*Diplostomum* spp. and *Clinostomum* spp.), monogenean trematodes (*Gyrodactylus* spp. and *Dactylogyrus* spp.) and *Acanthocephalus* spp. at various prevalence rates. *Acanthocephalus* spp. were recovered at 10.4% (27/260), *Diplostomum* spp. 8.5% (22/260), *Clinostomum* spp. 3.5% (9/260), *Dactylogyrus* spp. 3.5% (9/260), mixed infestation 1.5% (4/260) and *Gyrodactylus* spp. at 0.4% (1/260) (Appendix 4). For the mixed infestation, two fish (0.8%) were infested by *Clinostomum* and *Acanthocephalus* spp, one fish (0.4%) was infested by *Diplostomum* and *Acanthocephalus* spp and one (0.4%) by *Dactylogyrus* and *Acanthocephalus* spp.

4.4 Occurrence of parasites as per the fish body condition

Majority (32.4%) of parasitized fish were in good body condition while other infested fish had excellent (23.6%) and fair (16.6%) body conditions. None of the infested fish had poor body condition. Results from Chi square for trend showed that the differences of body conditions among the infested fish were not statistically significant (P>0.05). Most fish (16.7%) infested with *Acanthocephalus* spp. were in fair body condition while, majority of fish infested by *Diplostomum* spp. (10.8%), *Clinostomum* spp. (8.1%), *Dactylogyrus* spp (5.4%) and mixed infestation (2.7%) were in good body condition (Appendix 5). *Gyrodactylus* spp. (0.5%) was only found in fish with excellent body condition.

4.5 Parasites observed in various sub-counties

Among the sub-counties sampled Kikuyu was most infested (42.4%) followed by Gatundu South (32%), Kiambu (22%), Lari (18%) and Thika (11.5%) (Appendix 3). *Acanthocephalus* spp, *Clinostomum* spp and mixed infestations were mainly found in Kikuyu Sub-county. *Diplostomum* was mainly recovered from Gatundu South sub -county and *Dactylogyrus* from Kiambu sub-county. *Gyrodactylus* was only found in Thika sub -county.

4.6 Prevalence of digenean trematodes

4.6.1 *Diplostomum* spp.

Diplostomum spp. (eye flukes) metacercariae were found free in the vitreous humour of the eyes. They had a cup-shaped fore body with the suckers, and a cylindrical hind body containing the immature gonads (Fig.5). Out of the 22 infested fish, 18 (82%) were from Gatundu South sub-county while four (18%) were from Kiambu Sub-county. In all the ponds where the parasitized fish were collected, snail (*Melanoides tuberculata* spp.) shells were observed. All the infested fish were from earthen ponds that had overgrown vegetation while, the proportion of infested males (8.6%) and females (8.7%) were equal. The differences in pond types and vegetation status were significant ($p<0.05$) while the difference between the sexes were not significant ($p> 0.05$) as shown in Appendix 6.

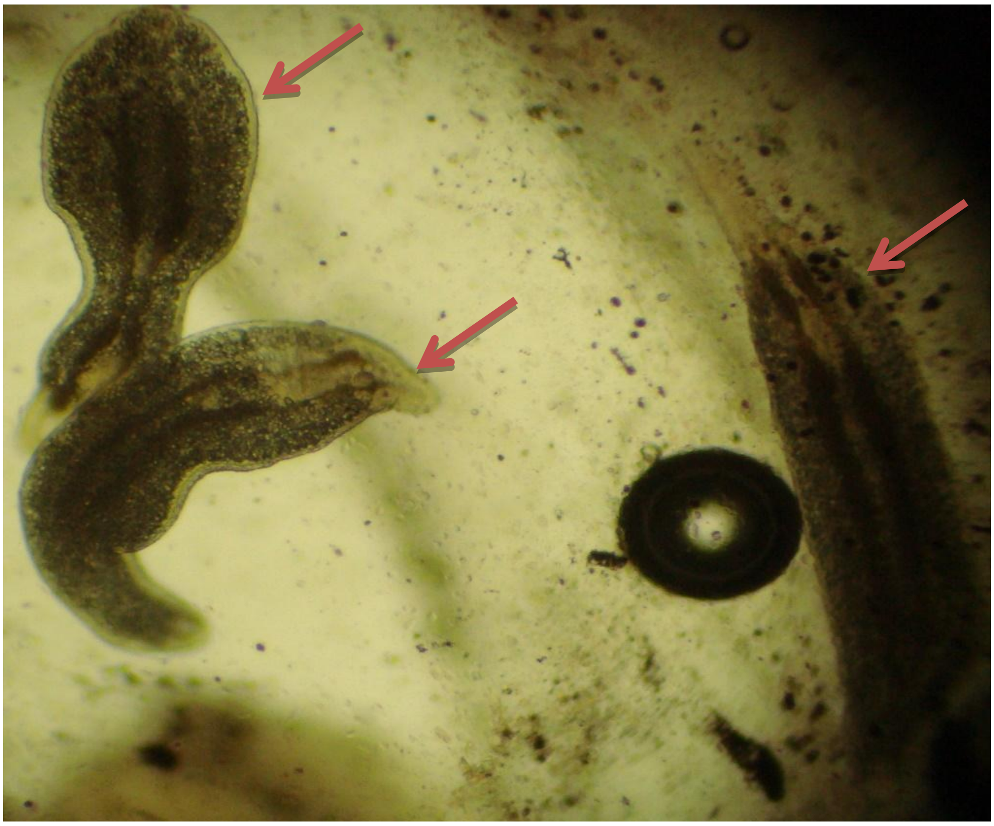

Figure 5: *Diplostomum* spp. (red arrows) recovered from the eyes of fish in Gatundu South sub-county, Kiambu County

4.6.2 *Clinostomum* species

The *Clinostomum* species metacercariae was isolated from the skin between or on the scales and in the muscles where it appeared as yellowish cysts (Fig.6). Morphologically, they were dorsoventrally flattened, oval, with a smooth body with a sucker around the anteroventral mouth and an acetabulum. They had a digestive system consisting of a pharynx connected to the mouth opening and a short esophagus and two blind intestinal caeca.

More male fish (4%) were infested than females (1.6%) but the differences were not statistically significant (P>0.05). All fish infested with *Clinostomum* spp were from earthen ponds with overgrown vegetation (Appendix 7). The infested fish were from Kikuyu (18.2%) and Thika (5.8%) sub-counties.

Figure 6: *Clinostomum* spp (left) from the fish muscles and cysts on the skin (red arrows) of tilapia from Kikuyu sub-county, Kiambu County

4.7 Prevalence of monogenean trematodes

4.7.1 Gyrodactylus species

The infested fish was from an earthen pond without vegetation in Gatuanyaga ward, Thika sub-county. This parasite was recovered from the skin, had a V-shaped head, lacked eye spots and had an opisthohaptor at the posterior end (Fig. 7).

Figure 7: *Gyrodactylus* spp. (red arrow) recovered from the skin of tilapia from Thika sub-county, Kiambu County

4.7.2 Dactylogyrus species

The parasite was recovered from the gills. It had a scalloped head with eye spots anteriorly (Fig.8). More male fish (4.9%) were infested than females (3%). The infested fish were from all sub-counties except Kikuyu and were mainly from earthen ponds (4%) with well-trimmed vegetation. The differences between sexes, pond types and vegetation cover were not statistically significant (P>0.05) (Appendix 8).

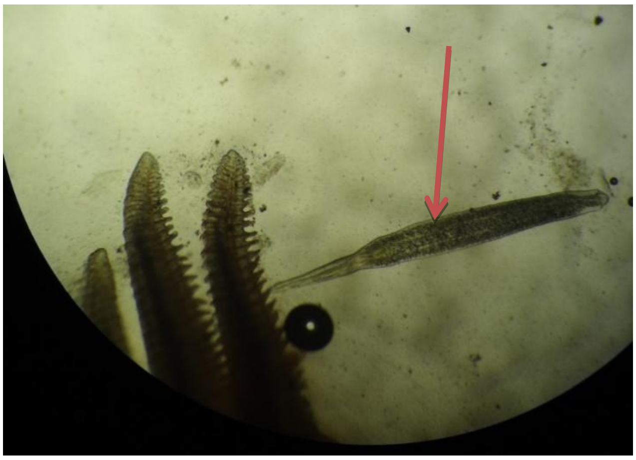

Figure 8: *Dactylogyrus* spp (red arrow) recovered from the gills of tilapia from Thika sub-county, Kiambu County

4.8 Prevalence of Acanthocephalus spp.

These worms were tiny, bilaterally symmetrical, pseudo coelomate and lacked an alimentary canal. They possessed a spined retractable proboscis that was sometimes invaginated in a saccular receptacle (Fig.9) and used for attachment to the intestinal mucosa.

Of all fish infested by *Acanthocephalus* spp. most were males (11.6%) from earthen ponds that had overgrown vegetation (13%). The differences between pond types were statistically significant ($p<0.05$) while, the differences between sexes and pond vegetation status were not statistically significant ($p>0.05$) (Appendix 9). The infested fish were from all five sub- counties except Thika. Kikuyu sub-county had the highest prevalence (30.3%) followed by Lari (16%), Kiambu (8%) and Gatundu South (6.7%) sub-counties.

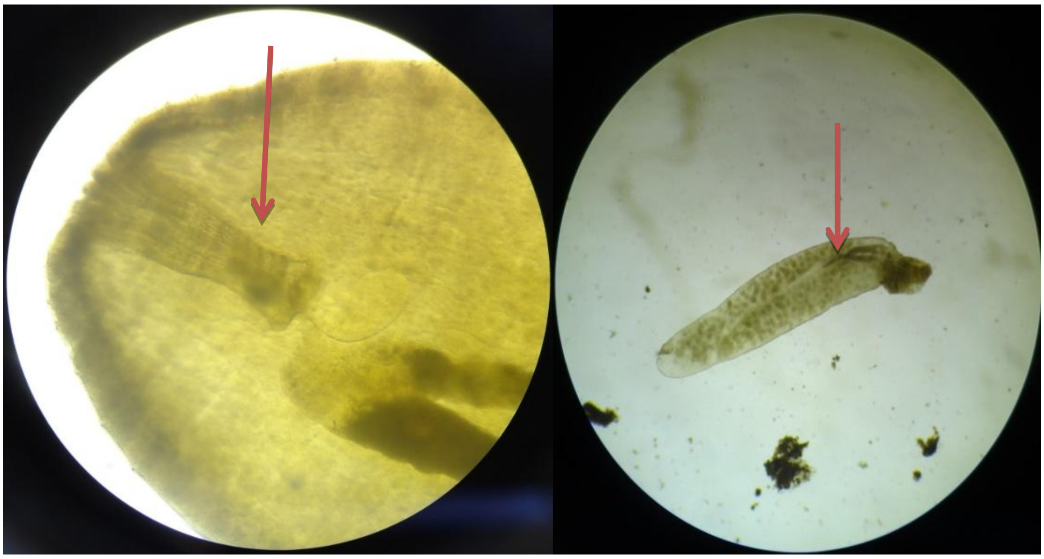

Figure 9: ***Acanthocephalus*** **spp. with invaginated proboscis (right red arrow) and with protruding proboscis (left red arrow) recovered from intestines of tilapia from Kikuyu sub-county, Kiambu County**

4.9 Mean intensity of parasites

Dactylogyrus spp. and *Gyrodactylu*s spp. had mean intensities of 1.1 (±0.3) and 1.0, respectively. The mean intensity of *Dactylogyrus* spp in male fish was 1.2 (±0.4) and 1.0 in females. The mean differences between the sexes were significant. *Gyrodactylus* spp. was only found in female fish. The mean intensity of *Dactylogyrus* spp. in earthen pond was 1.1 (±0.4) and 1.0 in liner ponds, respectively. The mean intensities for the two pond types were significantly different (Appendix 10). *Gyrodactylus* spp. was recovered from fish reared in earthen pond only.

Clinostomum spp. and *Diplostomum* spp. had mean intensities of 5.9 (±7.1) and 1.8 (±1.6), respectively. The mean intensity of *Diplostomum* spp. in males was 2.0 (±1.8) and 1.2 (±0.5) in females while, that of *Clinostomum* spp. was 6.5 (±7.3) in males and 1.0 in females (Appendix 11). The differences between the sexes were significant.

Acanthocephalus spp. had a mean intensity of 1.6 (±1.1). The mean intensity in males was 1.6 (±1.1) and 1.5 (±0.6) in females. Mean intensity in earthen ponds was 1.6 (±1.1) and 1.0 in liner ponds. The differences between the sexes and pond types were significant (Appendix 12).

CHAPTER FIVE

5.0 DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 Discussion

5.1.1 Status of fish farming and parasites occurrence

This study has shown that majority of the farmers were males, over 50 years of age, had been in fish farming for more than five years and were involved in farming as their main occupation. This is in agreement with a study by Garcia-Rodríguez and De La Cruz-Aguero (2011) in Nigeria, who reported majority of fish farmers were males who were mainly full time farmers who had been in fish farming for 6 - 10 years but majority were between 41 - 50years. In most of the farms, owners were responsible for day to day management decisions of the fish and had undergone formal training with majority attaining secondary school level. This indicated that the farmers were educated and could easily adopt innovations. Most farmers reared mixed sex tilapia as monoculture under semi intensive system in earthen ponds as previously reported by Ngwili *et al*. (2015) in Kiambu and Mavuti *et al*. (2017a) in Nyeri Counties, Kenya. It is different from the report by Garcia-Rodríguez and De La Cruz-Aguero (2011) in Nigeria who reported that most farmers reared Tilapia species in concrete ponds.

Fish in this County were infested with parasites of the genera *Diplostomum, Clinostomum, Gyrodactylus, Dactylogyrus* and *Acanthocephalus*. These parasites have been observed elsewhere in Kenya and other countries in both farmed and capture fish (Aloo, 1999; Florio *et al*., 2009; Otachi 2009; Mathenge, 2010; Mavuti *et al*., 2017b). However, these previous studies did not show difference in distribution of these parasites within different ecological zone within a county in the dry season as observed in this study. Eye flukes were present in lower highlands (Gatundu South) and upper midland (Kiambu) zones only unlike *Clinostomum* spp which were observed in upper midland (Kikuyu) and lower midland (Thika) zones. *Acanthocephalus* spp were widespread than other parasites in all zones except in lower midland zone (Thika).

Twenty four point five percent (24.5%) of fish had one or more species of parasites. This prevalence was low compared to other studies done in farmed fish in Kenya by Florio *et al*. (2009), Mathenge (2010) and Mavuti, *et al*. (2017b) who reported prevalence of 86.5%, 65.8% and 31.4% respectively. Florio *et al*. (2009) and Mathenge (2010) reports are based on same tilapia breeding farm, a dam and riverine fish where fish may have been in the culture farm or wild for a longer time than those in small scale farms in Kiambu. More males than female fish were infected with parasites as reported by Chacha and Lamtane (2014) in lakes Uba and Lubwe in Tanzania. This was attributed to inactivity of females as they were in spawning period. Other studies have recorded high prevalence in females than male fish (Aloo, 1999; Mohamed, 2010). Results in this study could be because most fish examined were males. Most earthen ponds were silted and had overgrown vegetation though majority of farmers reported trimming of vegetation around the ponds as one of the disease control strategies practiced in the farms. Fish from earthen ponds (31%) were generally more parasitized compared to those from liner ponds (3.3%). This is in agreement with Mdegela *et al*. (2011) who reported excessive siltation and higher parasite infestation rates in earthen ponds (20.9%) than in fish reared in concrete ponds (4.7%) in Morogoro, Tanzania. However, Mavuti *et al*. (2017b) reported no significant difference in overall fish parasite infestation rates between earthen and liner ponds in Nyeri County, Kenya. More fish from ponds with overgrown vegetation (30.3%) were parasitized as opposed to those ponds whose vegetation around the pond was well trimmed (9.7%). The vegetation offer good ecology for intermediate hosts. All fish infested by digenean trematodes *Diplostomum* spp. and *Clinostomum* spp. were from earthen ponds with overgrown vegetation and snails were collected from ponds with *Diplostomum* spp. infested fish. This agrees with the study by Mathenge (2010) who reported the presence of weeds in the ponds at Sagana fish breeding farm whose presence contributed to the high prevalence of digenean helminths found in the fish from that farm. Overgrown vegetation provides a good environment for parasites such as crustacean copepods or leeches and snails that are vectors/intermediate hosts for various parasites. The mud can be a reservoir for cysts of dinoflagellates and invertebrates intermediate hosts for digenean trematodes such as snails (Komar and Wendover, 2007).

Acanthocephalus spp. had the highest prevalence among all parasites. This is in agreement with a study by Chacha and Lamtane (2014) in lakes Uba and Ruwe in Tanzania who reported them to occur in high numbers (47.9%) among the parasites observed. They were recovered from fish collected from earthen ponds with overgrown vegetation. This is because the vegetation encourages presence of intermediate host (amphipods, isopods, copepods or ostracods) and the final definitive hosts (piscivorous birds) that helps in continuity of the life cycle (Paperna, 1996). Farmers obtained their first fingerling stock mainly from a government hatchery while few sourced from private hatcheries as they were provided by the government during the ESP (Ngwili *et al.,* 2015). Garcia-Rodríguez and De La Cruz-Aguero (2011) also reported that majority of farmers sourced fingerlings from government hatchery in Nigeria. Many private hatcheries were established after ESP to supply fingerlings to farmers. They however lacked suitably enhanced standards and Best Aquaculture Management Practices (BAMPs) (Orina *et al*., 2014). If such hatcheries had parasites or disease, these could spread to many farms. Trade of fishes, their gametes and embryos as a result of fish farming and restocking of wild populations and ornamental fish exert a high risk for transmission of gonadal myxosporeans (Sitja, 2009). Orina *et al.* (2014) recorded that parasites including leeches, gastropods, nematodes and trematodes were among the main fish health challenges experienced in hatcheries. It was also noted that a large number of farmers left the fish to continue inbreeding in the ponds as they practiced partial harvesting. This could lead to transmission of parasites from one generation to the other thus ensuring the propagation of the parasites like monogeneans that have a direct life cycle and depend on host availability for propagation. Orina *et al*. (2014) also attributed the occurrence of diseases, parasites and deformities to inbreeding among other reasons. Other farmers sourced fingerlings from fellow farmers whose quality cannot be certified while, others sourced from the wild especially rivers. This could lead to transmission of parasites and other pathogens from one farm to the other or from the wild to the ponds.

Most farmers sourced pond water from rivers and the wetlands along which the ponds were constructed. This is in agreement with studies by Mdegela *et al.* (2011) in Tanzania, Ngwili *et al.* (2015) and Mavuti *et al.* (2017a) in Kenya. However, it's unlike reports by Shitote *et al*. (2012) in Siaya County, Kenya and Garcia-Rodríguez and De La Cruz-Aguero (2011) in Nigeria where farmers sourced pond water mainly from springs and boreholes, respectively. Pond water source can be a source of infection/infestation as water is usually a vehicle of microorganisms which are potential pathogens for fish (Blanco *et al*., 2000). Akoll *et al*. (2012) reported the occurrence of trophically transmitted helminth species in caged fish that were positively related to the prevalence in reservoir dwelling hosts. Voutilainen *et al*. (2010) observed that fish in the rearing tanks were infected with *Diplostomum* spp. cercariae via the incoming water, hence the importance of water supply in spread of helminths. Mdegela *et al*. (2011) in Tanzania reported that earthen ponds which used river water had the highest infection rate with intestinal parasites. As observed by Ngwili *et al*. (2015) in Kiambu and Machakos and Mavuti *et al*. (2017a) in Nyeri farmers did not clean or drain ponds after fish harvesting in many farms in the study area leading to accumulation of mud and organic material. The majority of farmers who drained the ponds did not treat the ponds in any way before restocking. Some infectious diseases (particularly external fungal and bacterial diseases) and parasitic infestations are often attributed to accumulation of organic material in the culture unit (Blanco *et al.*, 2000). Lack of pond drainage and treatment after harvesting ensures reinfestation of fish by parasites since the cycle is not broken. Ponds can be sanitized between groups of fish by draining, drying and use of a chemical sterilant such as hydrated lime (Blanco *et al.*, 2000). This help to break the life cycle of the parasites.

Use of organic manure mainly from animals was popular among most farmers while few used chemical fertilizer or a combination of chemical fertilizer and organic manure. These findings are consistent with those of Mdegela *et al*. (2011), Ngwili *et al*. (2015) and Mavuti *et al*. (2017a) in Morogoro Tanzania, Kiambu and Machakos, and Nyeri counties in Kenya. Pond fertilization stimulates growth of plankton for the fish to feed on. The frequency of adding manure in the ponds varied among the farmers as reported previously (Ngwili *et al.*, 2015; Mavuti *et al.*, (2017a). However, a large proportion (31.5%) of farmers never added manure throughout the production cycle. This can lead to depletion of natural fish feeds that could compromise their nutritional state and immunity leading to attack by pathogens including parasites. Green water colour can be used to regulate fertilizer application in the ponds as it indicates good plankton production. To ensure good production of plankton, fertilization of the pond should be done once every two weeks (NSPFS-FAO, 2005). Fish growth and yields are usually higher with fertilization and supplementary feeding and besides supporting high stocking density, feeding enables the farmer to observe the behavior, health status, feeding level and change in size of the fish (NSPFS-FAO, 2005). However, excessive nutrient loading can result to overpopulation of phytoplankton, especially cyanobacteria and green algae which may lead to excessive oxygen production resulting in gas bubble disease (Mdegela *et al*., 2011). Farmers fed their fish mostly with commercial, and other supplemental feeds namely, dairy meal, bran, pollard, vegetables and kitchen left overs while others (11.2%) did not feed the fish at all as observed by Ngwili *et al.* (2015) and Mavuti *et al.* (2017a). Except for the commercial fish feeds the rest of the feeds used may not have all the nutrients required by the fish. Healthy fish are dependent on nutrition as the nutritional status is one of the important factors that determine the ability of fish immune defenses to resist diseases (Blanco *et al*., 2000). Outbreaks of fish diseases including parasites commonly occur when fish are stressed due to a variety of factors including poor nutrition. In the most severe cases, diets that are inadequate with respect to essential nutrients (proteins, amino acid, essential fatty acids, vitamins and minerals) lead to gross malnutrition and high disease susceptibility (Lall, 2000). Dörücü *et al.* (2002), reported positive correlation between the body condition of fish and the parasite burden.

Majority of the farmers were sharing one fishing net provided by sub-county fisheries officers and farmers with more than one pond used the same net between ponds. Only a small percentage of farmers washed the net, and disinfected it after use. Others sun dried the net without washing. However, some farmers did not clean nor treat the net in any way. Net sharing and lack of or improper cleaning and disinfection can lead to transmission of pathogens between farms and between ponds. Any equipment used in a fish pond should be thoroughly dried or chemically disinfected before being used in another pond or between groups of fish (Blanco *et al*., 2000). Martin *et al.* (2000) in Brazil reported fish mortality and behavior change, due to occurrence of parasites as a result of high organic matter content, high stocking densities and farmers' failure to clean the fish nets.

Piscivorous birds and otters were the main predators frequently found in and around the ponds. Among the predatory birds, Kingfishers were reported to be the most common. These results agree with those of Shitote *et al*. (2012) who reported kingfishers and other birds to be the common fish predators in Siaya County. The predators feed on the fish leading to economic losses. Despite eating fish, the predatory birds act as final hosts of fish parasites like digenean trematodes (Robert, 2012). Otachi (2009) and Mathenge (2010) reported that the helminth community in Sagana fish breeding farm in Kenya correlated well with high abundance and diversity of birds found at the farm. In this study, the presence of the piscivorous birds can explain the presence of major parasites recovered such as the digenean trematodes (*Diplostomum* and *Clinostomum* spp) and *Acanthocephalus* spp. Piscivorous birds control was reported to be among the main disease control strategies practiced in the farms in Kiambu County.

Most fish abnormalities reported including skin lesions (spots, necrotic areas, nodules, discolouration and dry skin), sluggish swimming, rubbing on pond sides, flashing while swimming, retardation, floating and death have been reported to be signs of parasitism in fish (Komar and Wendover, 2007). Fish deaths were reported to occur occasionally. Parasites cause gradual fish deaths that may go unnoticed especially when the dead fish are consumed by piscivorous birds (Otachi, 2009). This shows that lesions and deaths reported by the farmers could have been due to parasitism.

Some farmers mentioned various signs of fish parasitism. Others did not know signs of parasitism in fish and most of them lacked expertise on fish management and health. This shows there’s need for capacity building of fish health experts and farmers. This could enhance extension services so that farmers can recognize and report any signs of parasitism and other fish health issues. Dickson *et al.* (2016) reported improvement in profitability of fish farming in Egypt following training on best management practices. This could also, contribute to improved production, as extension services have been shown to have a great impact on agricultural productivity (Oduro-ofori *et al*., 2014; Dickson *et al.*, 2016).

Clearing of vegetation was the major disease control activity practiced by farmers followed by control of predatory birds. Clearing of vegetation destroys the habitats for intermediate hosts like snails and the piscivorous birds. Sheheli *et al.* (2013) reported pond drying, lime application, controlling of weed, removing of undesirable fish and changing of dirty water as some of the disease control strategies practiced by fish farmers in Bangladesh.

5.1.2 Risk of zoonosis

Among the animals kept by farmers, cats and dogs were the major animals that were fed on fish, accessed the ponds less frequently and majority of the farmers dewormed them regularly. Feeding animal reservoir hosts (dogs, cats, pigs, chicken, and ducks) with live infested fish have been documented as a risk factor for occurrence of zoonotic helminths (Phan *et al*., 2010). Cats have been shown as important final hosts for sustaining the life cycle of FZT, but their importance in FZT transmission may be questioned as cats tend to deposit faeces away from the pond (Phan *et al*., 2010). Chi *et al*. (2008) reported FZT metacercariae in grow-out fish and fingerlings with overall prevalence of 44.6% and 43.6% respectively though the prevalence in humans in the same area was low (<1%). This suggested that reservoir hosts such as dogs, cats, and pigs are more important in sustaining the life cycles of these flukes in fish farms than human hosts. Control of the flukes should therefore be focused more on these animals.

In humans, *Clinostomum* spp. metacercariae are released into the stomach and migrate through the esophagus before lodging in the throat. *C. complanatum* has been isolated in a 64 year old Japanese man who complained of an irritable sensation in the throat (Hara *et al.*, 2014). This occurred two days after eating raw freshwater fish (carp sashimi).

Majority of the farmers in the county do consume fish that is well cooked. This ensure zoonotic parasites are not acquired by humans if found in the fish. Feeding on undercooked or raw fish have been shown to be a risk factor for transmission of zoonotic parasites (Phan *et al*., 2010). It could also be the reason why only a small proportion of farmers reported to have experienced any symptoms within the last six months after consuming fish. The farmers attributed the symptoms to consumption of fish that were not well frozen after harvesting and were spoiled and/or infected by bacteria among others.

A study by Yanong (1976), cercariae of *Diplostomum spathaceum* parasites applied to cold-stored enucleated eyes of man entered the cornea but did not penetrate the anterior chamber. However, exposure to infestation may result in temporary conjunctival inflammation and persistent stromal nebulae**.**

5.1.3 Parasites of economic importance

Parasite infestations in fish causes production and economic losses through direct fish mortality; reduction in fish growth; reproduction and energy loss; increase in the susceptibility of fish to disease and predation; and through the high cost of treatment (Shinn *et al* 2015).

In the present study, most infested fish were in good, excellent and fair body conditions. This shows the infestation was low and had minimal effect on the fish body condition. This could be because of the low parasites intensity recorded. It is interesting that fish with *Acanthocephalus* spp were in fair body condition unlike others which had good to excellent body conditions. This may imply that these parasites may be more harmful to the fish than others observed in the study.

Diplostomum spp. (eye fluke) cause diplostomosis in fish that is associated with a severe ocular disease and lens opacity leading to eye fluke blindness (Ibrahim *et al*., 2016). Nassiri *et al*. (2012) reported fish blindness due to infestation by *D. spathaceum* whose metacercariae induce cataracts due to mechanical destruction of the lens and metabolic products excreted by the parasites. Since some fish physiological activities like feeding, depend on vision, the presence of this parasite affects its ability to feed and compete well with others. Poor feeding affects fish growth, and consequently the fish farming business.

Diplostomum spathaceum infestation in fish is also associated with changes in host behavior such as increased activity, migration towards the surface of the water and lack of responsiveness to visual stimuli (Lagrue and Poulin 2010). This alters fundamental fish antipredator mechanisms, such as crypsis and shoaling behavior, increasing the vulnerability of the fish to predation by piscivorous birds. This contributes to low production and consequently economic loss to the farmers. In experimentally infected rainbow trout with *D. pseudospathaceum*, Gopko *et al.* (2017) reported that fish harboring mature metacercariae increased their activity, preferred staying close to the water surface and spent less time immobile after the simulated avian predator attack compared to control fish. The change in behavior did not correlate with infestation intensity. This showed that the metacercariae changed the fish behavior exposing them to predation and consequent economic loss.

Clinostomum spp. are highly visible to the unaided eye as yellow grubs/cysts in the muscle or under the skin of infested fish. Though they are not harmful to humans if fish is well cooked; consumers do not readily accept infested fish due to their unsightly appearance (Lane and Morris, 2010).

Monogenean pathogenicity is due to their attachment organs, gland secretion and feeding strategy (Mhaisen *et al*., 2015). *Gyrodactylus* and *Dactylogyrus* spp. disturb the respiratory function of the skin and gills causing the fish to become dull, feeble, frequently swimming to water surface with erratic movement and may die of exhaustion (Adeyemo and Agbede, 2008). Large numbers of monogeneans (>10 organisms per low power field) on the skin or gills result in significant damage, secondary infection by bacteria and fungus and mortality (Klinger and Floyd, 2013). Gyrodactylids are pathogenic to their fish hosts, usually to younger fish raised in intense culture conditions. *Dactylogyrus* spp. induces severe hyperplasia of the gill filament epithelium, which interferes with respiratory function at extreme proliferation causing death to both young and fully-grown fish (Iyaji *et al*., 2009).

Pathogenic effects of acanthocephalans are due to attachment of the adult parasite in the digestive tract and also to the encapsulation of larval stages in the tissues. The extent of damage is proportional to the depth of penetration of the proboscis (Iyaji *et al*., 2009). Damages become extreme with extensive granuloma and subsequent fibrosis when the worms proboscis is anchored in the muscle layer or entirely perforates the intestinal wall.

Other effects of parasites on fish hosts include muscles degeneration, liver dysfunction, and interference with nutrition and respiratory functions, cardiac disruption, nervous system impairment, castration or mechanical interference with spawning, weight loss and gross distortion of the body (Iyaji *et al*., 2009).

5.1.4 Challenges in fish farming

Feeds availability, cost and quality was the major challenge reported by farmers in the county followed by predation. This is in agreement with Shitote *et al*. (2012) who reported lack of fish feed and their high cost to be the main problem facing fish farmers in Siaya County, Kenya but contrary to studies by Garcia-Rodríguez and De La Cruz-Aguero (2011) and Ngwili *et al.* (2015) which reported that irregular electricity supply and predation were the main challenges faced by farmers in Nigeria and Kiambu county, Kenya, respectively. In the present study, feeds were no longer being provided by the government and only few companies were making commercial fish feeds locally and those imported were expensive for the farmers.

5.2 Conclusions and recommendations

From this study *Acanthocephalus* spp and digenean trematodes (*Diplostomum* and *Clinostomum* spp) were the major parasites in farmed tilapia in Kiambu County. Their occurrence was influenced by many factors including; Use of rivers and wetlands as sources of water for use in the ponds, use of earthen ponds with overgrown vegetation in and around them, sourcing of fingerlings from non-certified sources, failure to change water within a production cycle, lack of pond draining and treatment after harvesting and lack of or infrequent manure addition in the ponds. Others were; use of poor quality feeds and lack of feeding, sharing of fishing nets among farmers and between ponds, failure to clean and disinfect fishing nets, lack of knowledge on signs of fish parasitism and presence of predators especially predatory birds. The prevalence and intensities of the parasites recovered were low and most of the fish infested were in good body condition. However, these parasites may proliferate in large numbers if pond conditions deteriorate, causing immunosuppression and predisposing fish to other infections that may reduce the productivity of the farms. They could also be more harmful to fingerlings and frys introduced into the ponds. There is therefore likelihood of disease outbreak if proper management practices are not enhanced. There is need to create awareness on farm management practices and fish health among farmers, fisheries and veterinary extension workers, researchers and all other relevant stakeholders.

Among the parasites recovered, *Clinostomum* and *Diplostomum* spp have been reported to be zoonotic. More research is therefore required to characterize them and determine their zoonotic importance.

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APPENDICES

Appendix 1: Questionnaire

UNIVERSITY OF NAIROBI

COLLEGE OF AGRICULTURE AND VETERINARY SCIENCE

Date of interview ....………Tel. no. of farmer..................................
Code............

QUESTIONNAIRE FOR FISH FARMERS ON ASSESSMENT OF RISK FACTORS ASSOCIATED WITH OCCURRENCE OF FISH PARASITES OF ECONOMIC AND ZOONOTIC IMPORTANCE IN KIAMBU COUNTY

Please tick or fill the appropriate areas. The information you give will be used for research purposes only and will be kept confidential.

Background information

1. Sub-County ....Ward ---------------------- Village........................
2. GPS reading:

Eastings………………. Northings/Southings ………………. Elevations --------------
-

3. Acreage of the farm ………………………..

Biodata

1. Name of the owner ………………………………………………
2. Age of the owner

[1] 20-30 years [2] 31-40 years [3] 41-50 years [4] > 50years

3. Gender of the owner? [1] Male [2] Female
4. Main occupation of the owner?

[1] Farming [2] Business [3] Salaried employee [4] Other ……… (Specify)

5. Education level of owner ……......................

[1] No Formal Education [2] Primary Level [3] Secondary Level [4] College

[5] University

6. Name of respondent: …………………………………………………………………

7. Education level of respondent?

[1] No Formal Education [2] Primary Level [3] Secondary Level [4] College

[5] University

8. Relationship of respondent to owner of the fish farm?

[1] Owner [2] Spouse [3] Child [4] Worker [5] Other Specify

9. Who is responsible for the day to day management decisions of the farm?

[1] Owner [2] Spouse [3] Child [4] Worker [5] Other Specify…

10. 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] College

[5] University

C. Information on management

11. How long have you been a fish farmer?

[1] <6 months [2] 6 month-2yrs [3] >2yrs- 5yrs [4] > 5yrs

12. What species of fish do you keep?

[1] Tilapia [2] Catfish [3] Trout [4] Others (Specify)

13. What type of culture system do you practice?

[1]Monoculture one sex [2] Monoculture mixed sex [3] Polyculture [4] other specify

14. What type of farming system do you practice?

[1] Extensive [2] Semi intensive [3] Intensive [4] Others specify

15. Observe and note the type of pond(s) in the farm?

[1] Earthen [2] Concrete [3] Liner [4] Others specify

16. Where did you source the first stock of your fingerlings?

Source (*tick as appropriate*)	Please specify the name
[1]Government hatchery	
[2] Private hatchery	
[3] The wild	
[4] Import	
[5] Own pond	
[6] Others (specify)	

17. Where do you source your restocking fingerlings? *Tick appropriately*

Source	Please specify the name
[1]Government hatchery	
[2] Private hatchery	
[3] The wild	
[4] Import	
[5] Own pond	
[6] Others (specify)	

18. What is the main source of water used in the pond(s)?

[1] River [2] Borehole [3] Rain [4] Dam [5] Tap [6] Others specify

19. How frequently do you change/top up water in the pond?

[1] Twice per month [2] Once per month [3] Once every two months [4] Never [5] other specify

20. Is the pond drained after harvesting fish?

[1] Yes [2] No

21. Is the pond treated after draining?

[1] Yes [2] No

22. How is the pond treated?

[1] Liming [2] Sun drying [3] Both [4] Others specify

23. Is the pond fertilized before stocking fingerlings?

[1]Yes [2] No

24. If yes, name the types of fertilizers used?

Type of fertilizer	*Please specify*
[1] Animal manure	
[2] Chemical fertilizer	
[3] Combination of animal manure and chemical fertilizer	
[4] Others (specify)	

25. How frequently do you fertilize the pond?

[1] Once per production cycle [2] Once a month [3] Twice per month

[4] Once every two months [5] Once every three months [6] Others specify

26. Which feed do you give the fish?

[1] Commercial fish feeds [2] Homemade fish feed [3] Kitchen leftovers [4] vegetables [5] others (specify)

27. Do you share fishing nets with other farmers?

[1]Yes [2] No

28. Do you use the same fishing net between ponds?

[1]Yes [2] No

29. How do you clean the net(s) after harvesting fish?

[1]Washing with water only [2] Washing and disinfecting [3] Drying in the sun [4] Never [5] others specify

30. Have you seen the following animals in your pond?

Type of animal	*Tick as appropriate*
[1] Birds *(please specify)*	
[2] Snails	
[3] Dogs	
[4] Cats	
[5] Monitor lizard	
[6] Snakes	
[7] Otters	
[8] Others specify	

31. How frequently are the animals in (24) above seen?

Type of animal	Frequency			
	Frequently	Less frequently	Rarely	Never
[1] Birds				
[2] Snails				
[3] Dogs				
[4] Cats				
[5] Monitor lizard				
[6] Snakes				
[7] Otters				
[8] Others specify				

32. Do you deworm cats and dogs in your farm?

[1] Yes [2] No

33. Observe vegetation around the pond and note how it is managed?

[1] Trimmed [2] not trimmed

34. After how long do you harvest the fish?

[1] 6 months [2] 7-9months [3] 10-12 months [4] >12 months [5] others specify

35. What is the average weight of fish during harvesting?

Age at harvesting	Weight at harvesting (grams)
[1] 6 months	
[2] 7-9 months	
[3] 10-12 months	
[4] >12 months	
[5] others specify	

36. Have you seen any fish abnormalities in your farm?

[1] Yes [2] No

37. If yes, please specify the abnormalities you have seen?

____
____
____

38. Have you experienced losses due to fish diseases?

[1]Yes [2] No

39. If yes, what type of losses? (*tick all that apply*)

Type of loss	Tick *appropriately*
[1] Poor growth rate	
[2] Death	
[3] Reduced size/weight at harvest	
[4] High cost of treatment	
[5] Others specify	

40. How often are fish deaths experienced in the farm?

Frequency	No. dead
[1] Daily	
[2] Weekly	
[3] Monthly	
[4] After harvesting	
[5] Other specify	

41. Have your fish been infected by parasites?

[1]Yes [2] No

42. How would you know when fish are infected by parasites?

Clinical signs	Tick appropriately
[1] Rubbing against pond sides and other objects	
[2] Flashing while swimming	
[3] Overproduction of gill and/or skin mucus	
[4] Skin or gill lesions(white spots)	
[5] Difficult breathing(gills move more rapidly)	
[6] Fish appear bloated.	
[7] Clamped or droopy fins	
[8] Loss of weight	
[9] Death	
[10] Others (specify).....	

43. Do you practice the following disease control activities in your fish farm?

Activity	Tick appropriately
[1] Controlling snails	
[2] Deworming of fish	
[3] Control of birds	
[4] Clearing of vegetation	
[5] Water treatment	
[6] Liming	
[7] Others specify	

44. Estimate the cost you incur in the disease control activities in your fish farm?

Activity	Estimated cost (Ksh.) per season
[1] Controlling snails	
[2] Deworming of fish	
[3] Control of birds	
[4] Clearing of vegetation	
[5] Water treatment	
[6] Liming	
[7] Others specify	

45. Do the household members consume fish?

[1]Yes [2] No

46. How is the fish prepared for consumption?

[1] Eaten raw [2] Cooked fresh [3] Dried then cooked [4] Others specify

47. If cooked, for how long is the fish cooked?

[1] <5minutes [2] 5-10 minutes [3] 11-15 minutes [4] > 15 minutes

[5] Others specify

48. Have you experienced the following symptoms within the last 6 months after consuming fish?

Symptom	Tick as *appropriate*
[1] Stomach ache	
[2] Diarrhoea	
[3] Vomiting	
[4] Allergic reaction like itching	
[5] Others specify	

49. What challenges are you facing as a fish farmer?

____

____

____

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

Appendix 2: Weight, lengths and condition factor of sampled fish

Variable	Total number of fish	Minimum	Maximum	Mean	Standard deviation
Weight (g)	260	15	620	110.2	83.7
Total length (cm)	260	6.0	35.0	17.6	4.2
Standard length (cm)	260	4.0	28.5	14.3	3.5
Condition factor	260	1.1	6.9	1.8	0.4

Appendix 3: Prevalence of fish parasites as per fish sex, pond types, vegetation status and sub-counties in Kiambu County

Variables		Number of parasitized fish (* %)	Number of non-parasitized fish (%)	Total Number of fish	P value
Sex	Male	50 (25.3)	148	198	0.797
	Female	14 (22.6)	48	62	
Pond types	Earthen	62(31%)	138	200	0.0000002
	Liner	1(3.3)	59	60	
Vegetation status	Overgrown	57 (30.3)	131	188	0.0004
	Trimmed	7 (9.7%)	65	72	
Sub-counties	Thika	6 (14.3)	46	52	
	Gatundu South	24 (32)	51	75	
	Lari	9 (18)	41	50	
	Kiambu	11(22)	39	50	
	Kikuyu	14 (42)	19	33	

*Percentage of parasitized fish

Appendix 4: Prevalence of different fish parasites recovered from tilapia in Kiambu County

Parasite recovered	**Organ affected**	**No. of fish examined**	**No. of infested fish**	**Prevalence (%)**
Acanthocephalus spp.	Intestines	260	27	10.4
Diplostomum spp.	Eyes	260	22	8.5
Dactylogyrus spp.	Gills	260	9	3.5
Clinostomum spp.	Muscles	260	9	3.5
Mixed infections	Intestines and muscles, Eyes and intestines or Gills and intestines	260	4	1.5
Gyrodactylus spp.	Skin	260	1	0.4

Appendix 5: Fish infestation as per their body condition

Parasite genera	**Number of infested fish (* %)**			
	Excellent	**Good**	**Fair**	**Poor**
Dactylogyrus	7(3.2)	2(5.4)	0	0
Diplostomum	18(8.3)	4(10.8)	0	0
Clinostomum	6(2.8)	3(8.1)	0	0
Gyrodactylus	1(0.5)	0	0	0
Acanthocephalus	22(10.2)	4(10.8)	1(16.7)	0
Total number of infested fish	51 (23.6)	12(32.4)	1(16.6)	0
Mixed infestation	3 (1.4)	1(2.7)	0	0

*Percentage of infested fish per fish body condition

Appendix 6: Prevalence of *Diplostomum* spp as per fish sex, pond types vegetation status and sub-counties in Kiambu County

Variables		**No. of fish with *Diplostomum* spp. (*%)**	**No. of fish without *Diplostomum* spp.**	**Total**	**P value**
Sex	Male	17 (8.6)	181	198	1.0
	Female	5 (8.1)	57	62	
Pond types	Earthen	22(11)	178	200	0.003
	Liner	0	60	60	
Vegetation status	Overgrown	22 (11.7)	178	188	0.003
	Trimmed	0	60	72	
Sub-counties	Thika	0	52	52	
	Gatundu South	18 (24)	57	75	
	Lari	0	50	50	
	Kiambu	4(8)	46	50	
	Kikuyu	0	33	33	

*Percentage of infested fish

Appendix 7: Prevalence of *Clinostomum* spp as per fish sex, pond types, pond vegetation status and sub-counties in Kiambu County

Variables		**No. of fish with *Clinostomum* spp. (* %)**	**No. of fish without *Clinostomum* spp.**	**Total**	**P value**
Sex	Male	8 (4)	190	198	0.620
	Female	1(1.6)	60	61	
Pond types	Earthen	9	191	200	0.204
	Liner	0	60	60	
Vegetation status	Overgrown	9	179	188	0.13
	Trimmed	0	72	72	
Sub-counties	Thika	3 (5.8%)	49	52	
	Gatundu South	0	75	75	
	Lari	0	50	50	
	Kiambu	0	50	50	
	Kikuyu	6 (18.2%)	27	33	

*Percentage of infested fish

Appendix 8: Prevalence of *Dactylogyrus* spp. as per fish sex, pond types, pond vegetation status and sub-counties in Kiambu County

Variables		**No. of fish with *Dactylogyrus* spp. (* %)**	**No. of fish without *Dactylogyrus* spp.**	**Total**	**P value**
Sex	Male	6 (3)	192	198	0.76
	Female	3 (4.9)	58	61	
Pond types	Earthen	8 (4)	192	200	0.64
	Liner	1(1.6)	59	60	
Vegetation status	Overgrown	6 (3.2)	182	188	0.99
	Trimmed	3 (4.2)	69	72	
Sub-counties	Thika	2	50	52	
	Gatundu South	2	73	75	
	Lari	2	48	50	
	Kiambu	3	47	50	
	Kikuyu	0	33	33	

*Percentage of infested fish

Appendix 9: Prevalence of *Acanthocephalus* spp as per fish sex, pond types, vegetation status and sub-counties in Kiambu County

Variables		**No. of fish with *Acanthocephalus* spp. (*%)**	**No. of fish without *Acanthocephalus* spp.**	**Total**	**P value**
Sex	Male	23 (11.6)	175	198	0.37
	Female	4 (6.6)	57	61	
Pond types	Earthen	26 (13)	174	200	0.02
	Liner	1 (1.7)	59	60	
Vegetation status	Overgrown	24 (12.8)	164	188	0.07
	Trimmed	3 (4.2)	69	72	
Sub-counties	Thika	0	52	52	
	Gatundu South	5 (6.7)	70	75	
	Lari	8 (16)	42	50	
	Kiambu	4 (8)	46	50	
	Kikuyu	10 (30.3)	23	33	

*Percentage of infested fish

Appendix 10: Mean intensity of *Dactylogyrus* spp.as per fish sex and pond types in Kiambu County

Variable		***Dactylogyrus* spp. mean intensity**	**Calculated t value**	**T distribution critical value**	**Remarks**
Sex	Male	1.2 ±0.4	0.683	2.365	The two means are different
	Female	1.0 ±0.0			
Pond Type	Earthen	1.1±0.4	0.333	2.365	The two means are different
	Liner	1			

Appendix 11: Mean intensity of *Diplostomum* spp. as per fish sex in Kiambu County

Variable		***Diplostomum* spp. mean intensity**	**Calculated t value**	**T distribution critical value**	**Remarks**
Sex	Male	2.0 ±1.8	0.968	2.08	The two means are different
	Female	1.2 ±0.4			

Appendix 12: Mean intensity of *Acanthocephalus* spp as per fish sex and pond types in Kiambu County

Variable		***Acanthocephalus* spp. mean intensity**	**Calculated t value**	**T distribution critical value**	**Remarks**
Sex	Male	1.57 ±1.12	0.112	2.06	The two means are different
	Female	1.5 ±0.58			
Pond types	Earthen	1.58±1.07	0.532	2.06	The two means are different
	Liner	1.0			