

**PREVALENCE OF ECHINOCOCCOSIS IN DOGS,  
CATTLE, SHEEP AND GOATS, LEVEL OF  
KNOWLEDGE AND ASSOCIATED ECONOMIC  
LOSSES IN LAIKIPIA WEST SUB-COUNTY, KENYA**

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**Prevalence of echinococcosis in dogs, cattle, sheep and goats, level of  
knowledge and associated economic losses in Laikipia west sub-  
county, Kenya**

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**Thesis submitted in partial fulfillment for the Degree of Master of  
Science in Public Health, in the Jomo Kenyatta University of  
Agriculture and Technology**

**2018**

## DECLARATION

This thesis is my original work and has not been presented for a degree in any other University

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## **DEDICATION**

I dedicate this work to my husband Dr. Gachengo M.M and our children: Grace, Daudi and Dorcas.

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## DEFINITION OF TERMS

**Coproantigens:** These are antigens found in faeces

**Definitive Host:** A host infected with the adult stages of a parasite

**Hydatid cyst:** Fluid containing bag found in the intermediate host due to infection  
with larvae of *Echinococcus*

**Intermediate host:** A host infected with the larval stages of a parasite

**Metacestode:** The second larval stage

**Onchosphere:** Tapeworm egg that contains the first larval stage

**Proglottid:** Segment of a tapeworm that forms the reproductive unit

**Protoscolices:** The immature heads of tapeworm found in hydatid cyst and each is  
capable of developing into an adult tapeworm

**Reproduction Ratio:** Refers to the number of adult parasites in the offspring  
generation divided by the number of adult parasites in the  
parent generation

**Scolex:** The head of an adult tapeworm

**Strobila:** The segmented body of a tapeworm

**Zoonosis:** Disease affecting both humans and other vertebrates.

## ACRONYMS AND ABBREVIATIONS

**ACUC** Animal Care and Use Committee

**AE:** Alveolar Echinococcosis

**AMREF:** Africa Medical Research Foundation

**ASAL:** Arid and Semi-Arid Lands

**BC:** Before Christ

**CE:** Cystic Echinococcosis

**CESSARi:** Cystic Echinococcosis in Sub Saharan Africa Institute

**CI:** Confidence Interval

**CMR:** Centre for Microbiology Research

**CT:** Computed Tomography

**DALYs:** Disability Adjusted Life Years

**DNA:** Deoxyribonucleic Acid

**dNTPs:** Deoxynucleoside Triphosphates

**EG95:** Vaccine against *Echinococcus* in dogs

**ELISA:** Enzyme Linked Immunosorbent Assay

**ERC:** Ethical Review Committee

**FAT:** Fluorescent Antibody Technique

**G1-G10:** Strains of *Echinococcus granulosus*

**GIS:** Geographical Information System

**GPS:** Global Positioning System

**IHAT:** Indirect Haemagglutination Test

**KAPs:** Knowledge, Attitude and Practices

**KEMRI:** Kenya Medical Research Institute

**KES:** Kenya Shilling

**KNBS:** Kenya National Bureau of Statistics

**L<sub>1</sub>:** Larval stage one

**L<sub>2</sub>:** Larval stage two

**LAT:** Latex Agglutination Test

**MgCl<sub>2</sub>:** Magnesium Chloride

**MRI:** Magnetic Resonance Imaging

**MS:** Microsoft

**NaOH:** Sodium Hydroxide

**NACOSTI:** National Commission for Science, Technology and Innovation

**NRF:** National Research Fund

**ODK:** Open Data collection Kit

**OIE:** Office International des Epizooties (World Organization for Animal Health)

**PAIR:** Puncture, Aspiration and Instillation and Reaspiration

**PBS:** Phosphate Buffered Saline

**PCR:** Polymerase Chain Reaction

**PE:** Polycystic Echinococcosis

**PZQ:** Praziquantel

**R<sub>0</sub>:** Reproduction Ratio

**RFLP:** Restriction Fragment Length Polymorphism

**SD:** Secure Digital

**SDG:** Sustainable Development goals

**SPSS:** Statistical Package for Social Scientists

**SSA:** Sub-Saharan Africa

**SERU:** Scientific and Ethics Review Unit

**TBE:** Tris-Borate-EDTA buffer

**URL:** Universal Resource Locator

**US \$:** United States Dollar

**US:** Ultrasonography (ultra sound)

**VHDCO:** Village Hydatid Disease Control Officers

**WHO:** World Health Organization

$\chi^2$ : Chi-square

## ABSTRACT

Cystic Echinococcosis (CE) is an emerging and re-emerging zoonotic infection caused by the larval stage of the dog tapeworm of the genus *Echinococcus*. It causes great public health and economic problems and remains neglected in Sub-Saharan Africa. The level of knowledge is poor in most developing countries. This study was carried out to determine the prevalence of echinococcosis and its trend, level of knowledge and associated economic losses in Laikipia West Sub-County. A total of 4969 animals (522 cattle, 3428 sheep and 1019 goats) slaughtered in abattoirs were inspected for hydatid cysts; a questionnaire was administered to one adult member from each of the 300 household using mobile data collection Kit. Faecal samples from 401 dogs were used to determine prevalence of echinococcosis in dogs. Data from Veterinary office meat inspection reports 2010-2014 were used to determine trends and associated economic losses due to CE. The prevalence of CE in slaughtered animals was 8.8% in cattle, 1.7% in sheep and 1.7% in goats. Prevalence of echinococcosis in dogs was 0.5% (2/401). The level of knowledge of echinococcosis was 25% (n=300). A total of 98,495 animals were inspected during the period 2010-2014 and results showed an increasing trend with time for both prevalence and economic loss. There was evidence of CE transmission and the level of knowledge of Echinococcosis was low. The public health implications and economic losses call for concerted control efforts. More elaborate studies on echinococcosis are recommended in dogs and man.

## CHAPTER ONE

### INTRODUCTION

#### 1.1 Background Information

Echinococcosis is a zoonotic parasitic disease due to infection with the dog tapeworm of the genus of *Echinococcus granulosus* (Dinkel *et al.*, 2004). The definitive hosts, particularly the dog and the foxes get infected when they feed on raw organs containing fertile cysts (Thompson, 1995; Njoroge *et al.*, 2002). The tapeworm eggs are passed in the faeces into the environment exposing both humans and other intermediate hosts to risk. The intermediate hosts, commonly the herbivores ingest the eggs, while grazing in contaminated environments. Man as an aberrant host gets infected when He accidentally ingests eggs from contaminated environments or directly from close contact with dogs. Hydatid cysts (fluid- filled bags) develop in vital organs such as the liver and lungs, although they can develop anywhere else in the body (Romig *et al.*, 1986). Infection with the larval stage (metacestode) is referred to as Cystic Echinococcosis (CE) which is an emerging and a re-emerging zoonosis with a worldwide distribution (Eckert *et al.*, 2000; Eckert and Deplazes, 2004). Approximately two to three million people are afflicted worldwide (Budke *et al.*, 2006). It is one of the oldest known parasitic diseases as reported in WHO/OIE manual of echinococcosis (2001).

Cystic Echinococcosis continues to be a neglected disease in Sub-Saharan Africa (SSA) despite its economic and public health importance (WHO/OIE, 2001). There

is limited information and knowledge about the magnitude of the problem and this creates a false impression that the burden and impact to society is low. Consequently, the health and livelihoods of those affected continue to be at risk (WHO, 2013). The disease causes public health and economic problems due to Disability-Adjusted Life Years (DALYs) lost and organ condemnation (WHO/OIE, 2001; Torgerson and Budke, 2003; Budke *et al.*, 2006; Ahmadi and Meshkehkar, 2011; Odero *et al.*, 2014). The global DALYs are estimated at US \$193,529,740 and the estimated annual livestock production loss is at least US \$141,605,195 (Budke *et al.*, 2006). In Kenya, the estimated average direct annual cost of treatment is US \$ 22,658 while the indirect annual economic losses were estimated to be US \$ 4,414 and US \$1,339 for a herdsman and housewife respectively (Odero *et al.*, 2014). Gathura *et al.*, (1991) reported losses due to hydatid cysts condemnation in Kenya as US\$ 97393.2 in cattle in 1984 and US\$ 5588.2 in sheep and goats in 1986.

The highest global human incidence of CE (220/100,000) has been reported from Kenya where the disease is endemic (French *et al.*, 1982; French and Nelson, 1982). Most of the work done on CE in the country has been in the Rift Valley region and focused more on two loci; Turkana and Maasai lands (Macpherson *et al.*, 1985; Wachira *et al.*, 1993a; Buishi *et al.*, 2006; Addy *et al.*, 2012). The prevalence of CE has not been documented in Laikipia County which is in Rift Valley region of Kenya and is sandwiched between two known CE hot spot areas. The county is an Arid and Semi-Arid Land (ASAL) bordering other pastoralist counties such as Samburu, Baringo and Isiolo. Laikipia is known for livestock production and has a number of ranches and conservancies; these factors favor occurrence of CE. Home slaughtering

occurs in many communities but meat inspection is rarely done and dogs can easily get access to infected offal; this perpetuates the cycle (Njoroge *et al.*, 2002). Knowledge, Attitude and Practices (KAPs) studies have shown that the level of knowledge is poor both in the general public and among health professionals (John *et al.*, 2008; Ernest *et al.*, 2009; Kagira and Kanyari, 2010). In humans, diagnosis, and treatment is expensive requiring radiological techniques and radical surgery among other approaches (WHO/OIE, 2001; Craig *et al.*, 2007). In livestock, diagnosis is often made at postmortem when nothing can be done except to condemn the affected organs thus leading to economic loss. The situation is further complicated by the definitive hosts that can carry high worm burdens and continue to shed eggs in the environment without reported clinical effects (WHO/OIE, 2001). They continue to be a source of infection for man and his livestock unnoticed.

In order to design and carry out an effective control program of CE, prevalence data is required. This study therefore set out to estimate the prevalence of echinococcosis in livestock (cattle, sheep and goats) slaughtered in abattoirs and dogs of Laikipia west Sub County; assess the level of knowledge and determine trends in prevalence and associated economic losses due to CE in Laikipia West Sub-County.

## **1.2 Statement of the Problem**

Cystic Echinococcosis is a neglected, emerging and re-emerging zoonotic disease with a worldwide distribution affecting 2-3 million people (Budke *et al.*, 2006). The greatest impact is felt in developing countries where it occurs in remote areas among disadvantaged communities who face a myriad of challenges. The diagnosis and

treatment procedures are expensive and often found far away from the affected areas. The global disease burden in terms of DALYs is reported to be close to that of African Trypanosomiasis and greater than that of Onchocerciasis, yet CE receives far less attention. In man, cysts in the liver and lungs may lead to mechanical dysfunction of affected or adjacent organs and can burst leading to anaphylactic shock. The long incubation period coupled with deficiency of proper diagnostic aids can easily result in misdiagnosis. Cysts in animals persist for life and diagnosis is only made at postmortem during meat inspection leading to condemnation of affected organs. The highest global human incidence (220/100,000) has been reported from Kenya where CE is endemic (French *et al.*, 1982; French and Nelson, 1982). High prevalence in livestock (3%- 30%) have been reported in the country (Ndirangu *et al.*, 2004, Addy *et al.*, 2012). Home slaughtering where meat inspection is rarely done increases chances of transmission to dogs, that contaminate the environment thus exposing man and other intermediate hosts to risk (Njoroge *et al.*, 2002). The level of knowledge is poor both in the general population and among health workers (Kagira and Kanyari, 2010). Despite of Laikipia West Sub-County having pastoralist communities, there are no documented studies on echinococcosis from the area. This study set out to determine the prevalence of echinococcosis in dogs and livestock, asses the level of knowledge of CE and to determine trends in prevalence and associated economic losses due to CE. Data on prevalence is necessary for planning an effective control strategy of any disease.

### **1.3 Justification of the Study**

No specific studies have been documented on prevalence and level of knowledge of CE in Laikipia West Sub-County which is sandwiched between two known CE hot spot areas and therefore liable to this infection. Base line data is important for any successful disease control program. This study is an important contribution to the achievement of Sustainable Development Goal (SDG-2030) number 3: Ensure healthy lives and promote well-being for all at all ages. Documentation of CE in the study site is an urgent requirement that will contribute to the people's improved health and livelihoods, hence reducing the burden of CE and DALYS on the communities.

### **1.4 Research Questions**

1. What is the prevalence of CE in animals (cattle, sheep and goats) slaughtered in abattoirs of Laikipia West Sub-County?
2. What is the prevalence of echinococcosis in dogs in Laikipia West Sub-County?
3. What is the level of knowledge of echinococcosis among the population of Laikipia West Sub-County
4. What are the trends in prevalence and economic losses due to CE in livestock slaughtered in abattoirs of Laikipia West Sub-County?

## **1.5 Objectives**

### **1.5.1 Broad Objective**

To determine the prevalence of echinococcosis in domestic animals, determine trends and associated economic losses due to Cystic echinococcosis in slaughtered livestock and to assess the level of knowledge of CE among the population of Laikipia West Sub-County.

### **1.5.2 Specific objectives**

1. To determine the prevalence of CE in animals (cattle, sheep and goats) slaughtered in abattoirs of Laikipia West Sub-County.
2. To determine the prevalence of echinococcosis in dogs in Laikipia West Sub-County.
3. To determine the level of knowledge of echinococcosis among the population of Laikipia West Sub-County.
4. To determine trends in prevalence and economic losses due to CE in livestock slaughtered in abattoirs of Laikipia West Sub-County.

## CHAPTER TWO

### LITERATURE REVIEW

#### 2.1 Aetiology of Cystic Echinococcosis

Cystic Echinococcosis is caused by larval stages (metacestodes) of the genus *Echinococcus* (Dinkel *et al.*, 2004). Four species were recognized for a long time (Thompson and McManus, 2002), but a new specie has been described by Xiao *et al.*, (2005). The species are:

-*Echinococcus granulosus*- Has a worldwide distribution and causes CE.

-*Echinococcus oligarthrus* and *Echinococcus vogeli* - occur in America and the Northern hemisphere where they cause Polycystic Echinococcosis (PE).

-*Echinococcus multilocularis* - occurs in the Northern hemisphere and causes Alveolar Echinococcosis (AE). This is a tumour-like invasive condition that is acute and often fatal.

-*Echinococcus shiquicus* has been isolated from small Tibetan mammals but its effects to humans is unknown (Xiao *et al.*, 2005).

Metacestodes of *E. granulosus* and *E. multilocularis* cause great socio-economic effects. In Africa, *E. granulosus* causes CE in man and the domestic animals. Ten genotypes/strains have been described: G1 (Sheep strain), G2 (Tasmanian sheep strain), G3 (Buffalo strain), G4 (Horse strain), G5 (Cattle strain), G6 (Camel strain), G7 (Pig strain), G8 (cervid strain), G9 (Lion strain) and G10 (Fennoscandian cervid strain). The sheep strain (G1) is predominant in Kenya and is known to be most

pathogenic for man (Bowles *et al.*, 1992; Bowles *et al.*, 1993; Bowles *et al.*, 1995; Thompson and McManus, 2002; Nakao *et al.*, 2007; Hüttner *et al.*, 2008; Maillard *et al.*, 2009).

Although many adult members of the Taenidae family are normally long and have many segments, adult *Echinococcus* usually has a maximum of six segments and rarely exceeds 7 millimeters. The adults are hermaphrodites and live in the small intestines of the definitive host. It consists of a scolex (head) which has four suckers and two rows of hooks for attachment. The body (strobila) is segmented and the terminal segment (proglottid) carries eggs that are released into the environment together with faeces. The eggs are sensitive to desiccation but are highly resistant in a moist environment (Veit *et al.*, 1995). They contain a hexacanth embryo (Oncosphere), and cannot be distinguished morphologically from eggs of other species in the same family (Eckert and Deplazes, 2004; Trachsel *et al.*, 2007).

## **2.2 Global Distribution of Cystic Echinococcosis**

Cystic Echinococcosis is an important zoonosis with a worldwide distribution. It was recognized by Hippocrates (460 BC) who referred to the lesions observed at postmortem in cattle and pigs as “water-filled tumors” (Grove, 1990). The true global picture of the distribution is incomplete due to lack of well-documented data. A recent review however, has shown that *E. granulosus* occurs on all continents and in more than 100 countries (Eckert and Deplazes, 2004). High prevalence occurs in parts of Europe and Asia (particularly Russia and China), the Mediterranean region, Africa (Northern and eastern regions), Australia, and South America (Moro and

Schantz, 2006; Moro and Schantz, 2009). In Asia, CE is considered as one of the major public health problems with at least 270 million people (58% of the population) at risk (Zhang *et al.*, 2015). Some islands such as Iceland and Greenland are considered to be free of *E. granulosus* (BurrIDGE and Schwabe, 1977). It is an emerging and re-emerging zoonosis especially in Eastern Europe, Asia, South America and Africa (Eckert *et al.* 2000).

### **2.3 Distribution of Cystic Echinococcosis in Sub-Saharan Africa**

Despite its economic and public health importance CE is considered a neglected disease in Sub-Saharan Africa (SSA) (WHO/OIE, 2001; Magambo *et al.*, 2006). In Sudan, CE has been reported in livestock from Central, Western and South Sudan (Omer *et al.*, 2010). Other areas that reported CE in slaughtered livestock include Northern Khartoum and the Blue Nile State (Mohamed 2013; Ibrahim *et al.*, 2011). The camel strain (G6) is the predominant pathogenic strain for humans in Sudan and has been isolated from patients in Khartoum and Juba. It occurs in Northern parts of Africa (Azlaf and Dakkak, 2006). Abattoir surveys from Ethiopia reported high prevalence in various parts of the country (Fromsa and Jobre, 2011; Haftu and Kebede, 2015; Jones *et al.*, 2012; Birhanu, 2014). There are also reports from Tanzania (Ernest *et al.*, 2009). In South Africa, Mogoye *et al.*, (2013) gave the first report of genotypes G5 and G7 from man in Africa. Huttner *et al.*, (2009), reported *E. felidis* (lion strain) in Queen Elizabeth National park in Uganda. High prevalence in Zebras, lions and jackals were reported by Wassermann *et al.*, (2015) from Etosha National Park in Namibia. The occurrence of CE in both domestic and wildlife

animals, coupled with many strains of *Echinococcus* species that infect different hosts in SSA only complicates the control efforts (Romig *et al.*, 2011).

#### **2.4 Distribution of Cystic Echinococcosis in Kenya**

Cystic Echinococcosis is endemic in Kenya. The public health importance of CE in Northern Kenya has been studied by many researchers (French *et al.*, 1982; Macpherson *et al.*, 1985; Wachira *et al.*, 1993a; Njoroge *et al.*, 2002; Buishi *et al.*, 2006; Kisenge, 2008). The highest incidence of CE in man (220/100,000) has been reported among the Turkana community in Kenya (French *et al.*, 1982 and French and Nelson, 1982).

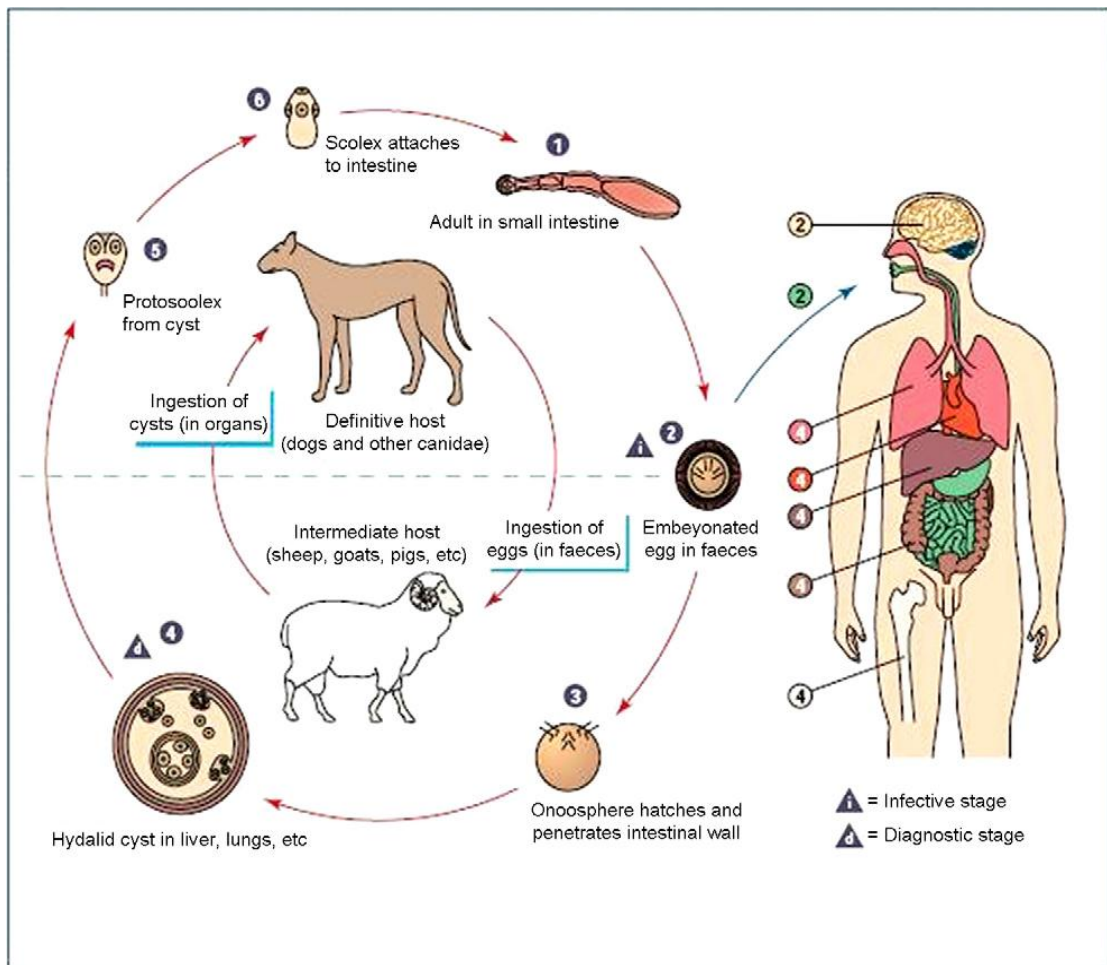
Rift Valley region has consistently reported high prevalence of CE (10.8%-25.8% in slaughtered animals in the country (Njoroge *et al.*, 2002; Ndirangu *et al.*, 2004, Addy *et al.*, 2012). Reports of CE in livestock from central Kenya have been documented (Mbaya *et al.*, 2014). Wachira *et al.*, 1993(b) reported the disease in dogs in Nairobi while Buishi *et al.*, (2006) reported it in Turkana dogs. A recent survey of *Echinococcus* species of wildlife carnivores in six conservation areas in Kenya using environmental faecal samples and RFLP-PCR showed that *E.granulosus* and *E.felidis* occur (Kagendo *et al.*, 2014).

#### **2.5 Transmission and Risk factors for Cystic Echinococcosis**

The eggs containing larval stage one (L<sub>1</sub>) in the environment (contaminated soil, water and vegetation) are picked by a wide range of intermediate hosts, usually the herbivores while grazing and man. Once in the small intestines, L<sub>1</sub> is released by the

action of enzymes and penetrates the intestinal wall to enter into blood circulation. Some larvae are retained in the liver while others move to the lungs and other organs such as the kidneys, spleen and the brain where they develop into larval stage two (L<sub>2</sub>- also known as metacestode or hydatid cyst). Man acts as a dead end host because He does not participate in the perpetuation of the life cycle. It may take several months before L<sub>2</sub> is fully developed. The adult stage develops when the definitive host ingests a fertile metacestode containing protoscolices. It takes four to six weeks for sexually mature adults to be seen. Adults then release eggs into the environment and the cycle continues (Thompson, 1995). Although there are many life cycles, the domestic cycle involving the dog and sheep is the most important in Kenya (figure 2.1). This cycle is maintained by the ignorance and irresponsibility of man regarding disposal of diseased organs after home slaughter (Watson-Jones and Macpherson, 1988; Thompson and McManus, 2001).

Risk factors for human Cystic Echinococcosis include a pastoral occupation, history of dog ownership, poor education, age, sex, and source of drinking water (McManus *et al.*, 2003). In Kenya, Buishi *et al.*, (2006) reported that dog owner's lack of knowledge about the transmission of echinococcosis significantly increased the risk level of positivity in dogs studied.



**Figure 2.1: Life cycles of *Echinococcus granulosus***

Source: <http://www.dpd.cdc.gov/dpdx>

## 2.6 The Hydatid Cyst

This is a fluid filled bag that develops in tissues of the intermediate host infected with *Echinococcus*. It consists of an outer granulation and fibrous tissue developed from the host's immune reaction which forms a rigid protective layer that makes the fluid within to be under pressure. There is a middle layer that permits passage of nutrients but is impervious to bacteria. Brood capsules (small spheres of disrupted

germinal layer) and protoscolices are produced from the inner germinal layer through asexual budding (McManus *et al.*, 2003). The brood capsules and protoscolices may break free from the germinal layer and float in the fluid as a white sediment known as hydatid sand. A fertile metacestode may contain one thousand protoscolices and each one is capable of developing into a sexually mature worm. Sterile metacestodes do not produce protoscolices and are therefore not infective to the definitive host. Most cysts from sheep and goats are fertile while those from cattle are 70% sterile (Ndirangu *et al.*, 2004; Macpherson *et al.*, 1985). In Iran, sheep is the most important intermediate host of *E. granulosus* as shown by high condemnations due to hydatid cysts (Daryani *et al.*, 2007).

## **2.7 Prevalence of Echinococcosis in livestock**

The highest prevalence of CE is found where sheep rearing is practiced and this explains the public health importance of the sheep strain (G1) of *E. granulosus* (Khuroo, 2002). Most prevalence studies in intermediate hosts have relied on looking for cysts in visceral organs of slaughtered animals (Baldock *et al.*, 1985). The lesions of CE usually remain for life in the animal and will be found at postmortem (Njoroge *et al.*, 2002). In Kenya, Nelson and Rausch (1963) found that over 30% of slaughtered cattle, sheep and goats had CE. Since then, similar studies carried out by other researchers. Gathura and Kamiya (1990), reported prevalence of 30%, 15% and 13% in cattle, sheep and goats respectively. A slaughter house survey of Turkana by Njoroge *et al.*, (2002), revealed prevalence of 19.4% in cattle, 3.6% in sheep and 4.5% goats. Kisenge (2008), using Ultrasonography in the same area reported that

4.3% sheep and 1.5% goats had CE. Addy *et al.*, (2012), reported prevalence of 25.8%, 16.5% and 10.8% in cattle, sheep and goats respectively from Maasailand. A similar study from central Kenya reported prevalence of 1.92%, 4.62% and 0.37% in cattle, sheep and goats respectively (Mbaya *et al.*, 2014). In all the surveys, the lung was the most affected organ. Although the prevalence has reduced, it is still high in some areas. The difference could be attributed to diversity of cultural practices among the communities.

In North Africa, a slaughter house survey in Algeria revealed prevalence of 13.9% in cattle. Although the sheep strain was present, the major intermediate hosts were cattle and camels (Bardonnnet *et al.* 2003). In Sudan, Omer *et al.*, (2010) found prevalence of 59%, 6%, 11% and 2% in camels, cattle, sheep and goats respectively from Central, Western and South Sudan. Mohamed, (2013), found prevalence of 1.05% and 3.45% in cattle and sheep respectively in Northern Khartoum. A similar survey in the Blue Nile State reported prevalence of 29.7% in camels, 2.7% in cattle, and 0.6% in sheep (Ibrahim *et al.*, 2011). The commonest strain was G6/7 (*E. Canadensis*). In Ethiopia, a cross-sectional study at Adama Municipal abattoir on 384 sheep reported that 60.2% were positive for CE (Birhanu, 2014). Most of the cysts were in the lungs (56.1%).

High parasite prevalence has been reported in parts of Europe, Asia, Middle East, Africa, Australia and South America. Derylo and Szilman (1998) reported that, 0.007% of cattle and 18.7% of sheep and goats in Poland had hydatid cysts. In the Middle East, high prevalence has been reported (Dar and Alkarmi 1997). In Asia and

particularly The People's Republic of China, the disease is endemic in 21 out of 31 provinces. High prevalence in animals and humans occur in the pastoral and semi-pastoral Western provinces where strains G1 and G6 are common (Wen and Yang, 1997).

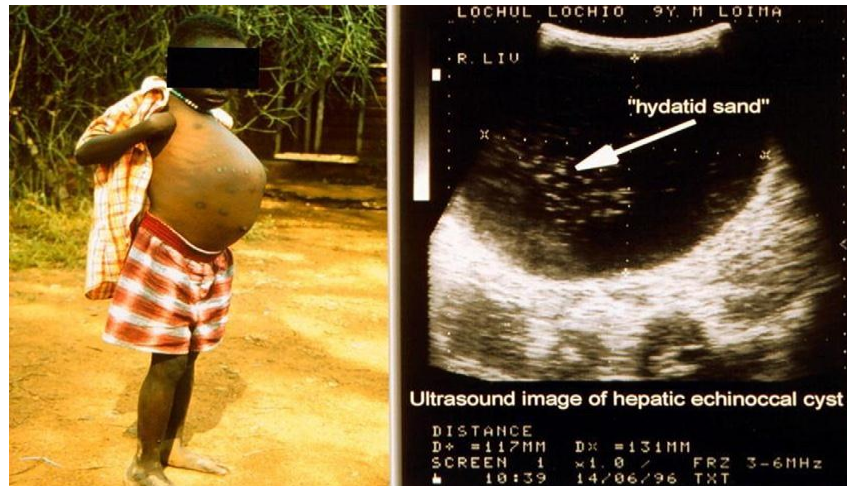
## **2.8 Prevalence of Echinococcosis in Dogs**

The prevalence of echinococcosis in dogs varies depending on location. Postmortem examination of the gastro-intestinal tract of dogs from Turkana reported a prevalence of 33%, while coproantigen ELISA test reported that 42 out of 161 (26%) faecal samples from the same area were positive for *Echinococcus* (Buishi *et al.*, 2006). Nelson and Rausch (1963) found 27 out of 43(62.8%) of dogs in Kenya with *Echinococcus*. Thirty percent (30%) of the domestic dogs in Turkana were reported to have *E. granulosus* (Macpherson and Wachira, 1997). Wachira *et al.*, (1993b), reported a prevalence of 10% in dogs in Nairobi and about 72% in dogs from around Dagoretti slaughter house (Wachira *et al.* 1994). From Tripoli in Libya, Buishi *et al.*, (2005) reported that sheep-dogs showed higher coproantigen prevalence (100%) when compared to guard or pet dogs (23.6%). Younger dogs (<5 years) had comparatively higher prevalence. From Southern Ethiopia, Jones *et al.*, (2012) reported that 30% of dogs had *E. granulosus*.

## **2.9 Effects of Cystic Echinococcosis in man and animals**

### **2.9.1 Pathological Effects**

Cystic Echinococcosis (CE) due to *E. granulosus* and Alveolar Echinococcosis (AE) due to *E. multilocularis* are of great medical importance. Alveolar Echinococcosis forms a tumour-like invasive condition which is acute and often fatal (CDC website; WHO/OIE 2001). Cystic Echinococcosis due to various strains of *E. granulosus* causes the disease in both man and animals in Kenya (Wachira *et al.*, 1993a). In humans, the hydatid cyst grows slowly as a space-occupying lesion leading to distension of cavities (figure 2.2). The cysts usually develop in the lungs and liver, although development in other tissues such as bone and muscle has been reported (Kassa *et al.*, 2014). Cysts do not usually cause trouble unless they lead to mechanical dysfunction of affected or adjacent organs or they burst leading to anaphylaxis (Thompson and Allsopp, 1988). Spillage of cyst fluid with viable protoscolices can result in daughter cysts. Large cysts containing over 20 litres of cyst fluid have been recorded (Ammann and Eckert, 1995).



**Figure 1.2: Abdominal distension due to Echinococcosis of the liver**

(Source: Moro and Schantz 2009)

### **2.9.2 Economic Effects**

The global burden (Disability-Adjusted Life Years [DALYs]) for human Cystic Echinococcosis was recently estimated to be more than for Onchocerciasis and almost the same as for African Trypanosomiasis (Budke *et al.*, 2006). The estimated global DALYs lost are US \$193,529,740 (95% CI, \$171,567,331–\$217,773,513). The amount is higher when underreporting is accounted for. At least US \$141,605,195 (95% CI, \$101,011,553–\$183,422,465) and possibly up to US \$2,190,132,464 (95% CI, \$1,572,373,055–\$2,951,409,989) of annual livestock production loss is estimated (Budke *et al.*, 2006). A study done by Odero *et al.*, (2014) in Kenya, estimated the average direct annual cost of treatment as US \$

22,658 while the indirect annual economic losses were estimated to be US \$ 4,414 and US \$1,339 for a herdsman and housewife respectively.

Although the disease is not apparent to farmers, it is of great economic and public health importance (Torgerson and Budke, 2003; Ahmadi and Meshkehkar, 2011). There is considerable economic loss due to condemnation of the affected organs and loss of production and/or life. Gathura *et al.*, (1991) reported losses due to hydatid cysts condemnation in Kenya as US\$ 97,393.2 in cattle in 1984 and US\$ 5,588.2 in sheep and goats in 1986. The definitive host can carry high worm burdens without reported clinical effects (WHO/OIE, 2001).

## **2.10 Diagnosis of Echinococcosis**

Diagnosis is important for surveillance, treatment and monitoring the impact of a control program. In humans, the diagnosis of CE is based on epidemiology and clinical signs. Confirmation is by imaging techniques such as X-rays, Ultrasonography (US), Computerized Tomography (CT) scan and Magnetic Resonance Imaging (MRI). Other useful methods include necropsy; Immunological tests such as Enzyme Linked Immunosorbent Assay (ELISA), Indirect Haemagglutination Test (IHAT), Latex Agglutination Test (LAT) and Fluorescent Antibody Technique (FAT); and molecular biological techniques like PCR (Craig, 1997; WHO/OIE, 2001). Both ELISA and Ultrasonography can be used in mass screening. Although the above methods can be applied in animals, their practicability is restrictive. Diagnosis in livestock is therefore often done during postmortem (Baldock *et al.*, 1985).

### **2.10.1 Copro-Antigen Enzyme-Linked Immunosorbent Assay**

This method involves detection of genus-specific *Echinococcus* antigens (coproantigens) in faeces of the definitive hosts using ELISA (Allan *et al.*, 1992; Deplazes *et al.*, 1992). This method has better specificity and sensitivity over serum antibody detection since it shows current status of infection (Jenkins *et al.*, 2000).

### **2.11 Treatment of Echinococcosis**

The treatment of CE is expensive, requiring approaches such as radical surgery, PAIR (Puncture, Aspiration of cystic fluid, Instillation of 70% ethanol and Reaspiration of the ethanol) and chemotherapy. Treatment options for CE in man as recommended by WHO are: surgery, PAIR, chemotherapy and “wait and observe” (WHO, 1996; Pawlowski, 1997b; Perdomo *et al.*, 1997). Surgery is still the treatment with the potential to successfully remove the cyst in most patients (90%) if the cyst is located in less risky places and it is discovered early. Chemotherapy in combination with PAIR is recommended when cysts are multiple and occurring in many organs. When cysts are calcified, it is advisable to wait and observe. A combination of surgery and chemotherapy is often used, either pre or post-operatively. Presently, there is no practical and effective treatment against metacestodes in animals but Benzimidazoles can be used alone or with praziquantel (Eckert *et al.*, 2001). Oxyfendazole is more effective in sheep and goats while Praziquantel is effective in dogs (Njoroge, 2001).

## 2.12 Control of Echinococcosis

Control refers to the implementation of a programme with the aim of limiting the prevalence of a disease. Baseline data on prevalence in animals and local epidemiology are required for successful planning, implementation and monitoring of any control programme (Ngatia, 1993). The domestic life cycle of *E. granulosus* is known to have low stability and to respond quickly to control (Gemmell *et al.*, 1986); Control programs however, are expensive to set up and maintain in poor countries (Craig *et al.*, 2007). An effective control program should aim at reducing the reproduction ratio ( $R_0$ ) – (the ratio of the number of adult parasites in the offspring generation to the number of adult parasites in the parent generation) to below one ( $R_0 < 1$ ). If a  $R_0 < 1$  is maintained for *E. granulosus*, it is possible to achieve eradication because its basic  $R_0$  is low (Gemmell *et al.*, 1986).

Iceland eradicated the disease after 26 years of educational campaign (BurrIDGE and Schwabe, 1977). In Tasmania, Cyprus, New Zealand and Argentina, successful control was due to educational campaign, administration of arecoline to dogs and surveillance (Gemmell *et al.*, 1986). Many pilot control programs were initiated in China but the most successful of the programs used a combination of strategies, (deworming of dogs, education, and destruction of stray dogs) and was carried out by Village Hydatid Disease Control Officers (VHDCO) also referred to as “bare foot doctors.” The prevalence of disease in dogs was reduced from 14.7-18.6% to zero in Hutubi and Wensu counties (Zhang *et al.*, 2009).

In Kenya, a pilot hydatid-control programme was initiated by the African Medical and Research Foundation (AMREF), in North–Western Turkana in 1983. The programme used supervised treatment of dogs with praziquantel (PZQ) and health education of the local people (Macpherson *et al.*, 1984; Macpherson *et al.*, 1986). An evaluation of the programme by Macpherson and Wachira (1997), showed a reduction in prevalence of human CE from 8% to 3% in the pilot area.

A vaccine, EG95 to be used in animals has been produced and it is promising (Heath *et al.*, 2003). A vaccine for dogs has also been developed Zhang *et al.* (2006). Dogs play an important role in transmission of CE to man and livestock; hence the successful use of a vaccine in dogs would prove to be highly cost effective given that dogs are usually less than livestock.

### **2.13 Level of knowledge of echinococcosis**

Low levels of knowledge have been reported from studies conducted in many countries. Dawit *et al.*, (2013) carried out a survey on KAPs among pastoralists and Health professionals in Northern Ethiopia. The results showed that 4.29% of pastoralists were aware of CE and that majority of the Human and Veterinary health professionals did not have their facts correct regarding the disease. Similar results were reported from Tanzania (John *et al.*, 2008) and Uganda (Nyakarahuka *et al.*, 2013). Reports from Kenya show that more veterinary personnel than medical health professionals have knowledge of CE (Kagira and Kanyari 2010). A telephone survey about knowledge of CE in Europe, revealed that majority of the populace in

Switzerland and Germany (> 60%) and only 14% from Czech republic were aware of CE ( Hegglin *et al.*, 2008).

#### **2.14 Trends in prevalence and economic losses due CE in livestock**

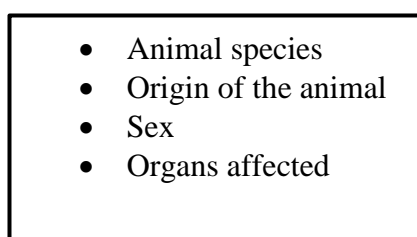
A retrospective study by Ndirangu *et al.*, (2004) using ten years'(1989-1998) data from post-mortem meat inspection records from the Director of Veterinary services, reported that Rift Valley region had the highest prevalence at 14.1% in cattle, 15.6% in sheep and 11.8% in goats. Only Coast region reported prevalence of 1% while other regions had between 4% and 10%. Among the thoracic and the abdominal cavity organs inspected, the lungs and liver were most frequently affected with the kidney and heart being least affected. Another survey carried out for the whole country from 1977-1988 by Gathura and Gathuma (1991) showed that the losses due to organ condemnation were highest in cattle followed by sheep and then goats.

Survey data of 15 years (1985-1999) from 21 abattoirs located in various parts of Ethiopia reported that, 8036/22,863 (35.15%) cattle, 768/6518 (11.78%) sheep, 36/1753 (4.9%) goats, and 70/417 (16.79%) camels had hydatid cysts (Fromsa and Jobre, 2011). In most of the reports stated above, cattle had the highest prevalence followed by sheep and then goats. Although there were no trend lines drawn, individual annual prevalences were reported.

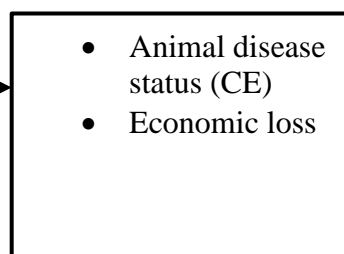
## 2.15 Conceptual framework

The conceptual framework (Figure 2.3) shows the relationship between the study variables. The independent variables were: animal species, origin of the animals, sex and the organs affected. Dependent variables were disease status (CE) and economic loss.

### Independent variables



### Dependent variables



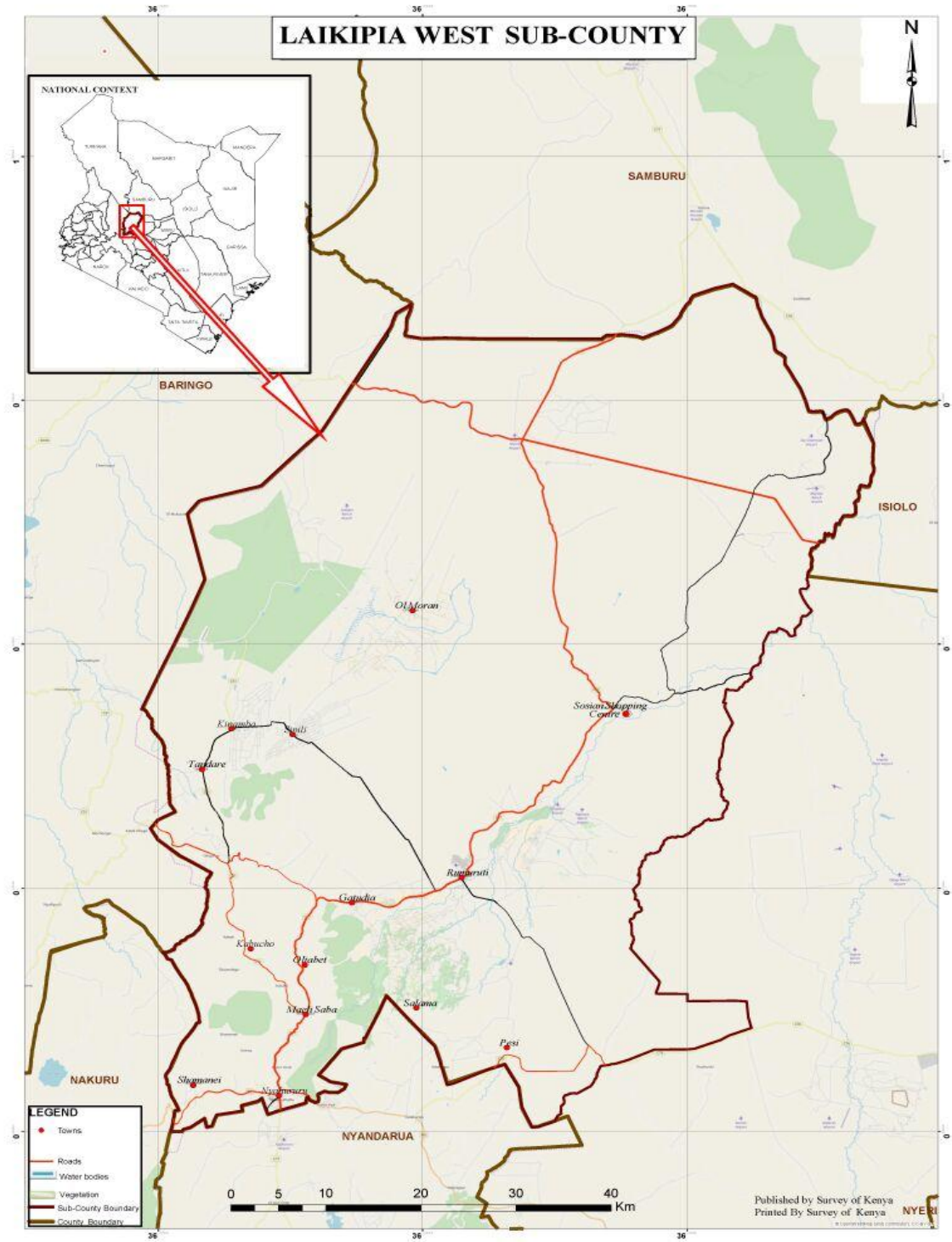
**Figure 2.3: Conceptual framework**

## **CHAPTER THREE**

### **MATERIALS AND METHODS**

#### **3.1 Study Site**

The study was conducted in Laikipia West Sub-County of the larger Laikipia County which is located in the Rift Valley region of Kenya (Figure 3.1). The study area has a population of 224,431 (KNBS, 2010) and covers an area of 3,891.4 km<sup>2</sup> comprising six wards; Marmanet, Igwamiti, Salama, Githiga, Rumuruti Township and Ol-Moran. It shares borders with Laikipia East Sub-County, Samburu, Baringo, Nakuru and Nyandarua North Sub-County. The County is an ASAL (Arid and Semi-Arid Lands) area with many ranches and conservancies. The main source of water for both domestic and animal use includes seasonal rivers, shallow wells and surface run off. Most residents practice agro-pastoralism. The Nyahururu - Mararal road traverses the study area.



**Figure 3.1: Location of Laikipia West Sub-County**

(Source: Survey of Kenya, 2018)

### **3.1.2 Environmental characteristics of the study area**

The annual rainfall ranges from 900mm on the foot of the Nyandarua ranges to 500mm in the Western parts of the Sub-County. There are two rainy seasons; long rains which fall in March- May while the short rains fall in October-November. Day temperatures range from 20-27<sup>0</sup> C while night temperature ranges from 15-18<sup>0</sup>C. January, February and March are the hottest months while June and July are the coldest months. Some areas are prone to frost when temperatures fall to about 10<sup>0</sup>C ([https://en.climate\\_data.org](https://en.climate_data.org)).

### **3.2 Study design**

This was an observational study encompassing both a cross-sectional and a retrospective documents review that was carried out between October and December 2015. The mixed study designed aimed at getting a better picture by comparing a snapshot view to a historical occurrence of the disease.

### **3.3 Study population**

The study targeted different populations from Laikipia West Sub-County that play a role in the epidemiology of CE in order to meet the stated objectives, the main one being occurrence of the disease and hence point out the public health risk to the human population:

- i) 4969 animals (522 Cattle, 3428 sheep and 1019 goats) slaughtered in abattoirs of Laikipia West Sub-County
- ii) 401 Dogs
- iii) 300 adult persons

### **3.4. Inclusion and exclusion criteria for livestock**

#### **3.4.1 Inclusion criteria**

A total of 4969 animals (522 cattle, 3428 sheep and 1019 goats) slaughtered in abattoirs (appendix1), under the supervision of the Directorate of Livestock and Fisheries in the study area were included in the study. These species are commonly slaughtered in the area with sheep and goats being commonly involved in home slaughter where meat inspection is rarely done and poor offal disposal that perpetuates the cycle is most likely to occur (Njoroge *et al.*, 2002).

#### **3.4.2 Exclusion criteria**

Other animals such as pigs and camels slaughtered in abattoirs

### **3.5 Inclusion and exclusion criteria for humans and dogs**

#### **3.5.1 Inclusion criteria for households and dogs**

Households with dogs

300 Households whose heads/adults consented to participate in the study

Dogs aged three months and above. The age was estimated using the history given by the owner regarding the birth or acquisition of the dog

Dogs that had lived in the study area for at least two months were more likely to have picked infection and could be shedding eggs considering that the life cycle of

*Echinococcus granulosus* takes about one and half months to be completed (Thompson and McManus, 2001).

### **3.5.2 Exclusion criteria for households and dogs**

Households that keep dogs but refused to consent to participate in the study

New dogs in the study area having stayed for less than two months prior to recruitment

### **3.6 Sample size determination**

The following formula according to Fischer *et al.*, (1998), which is used to calculate the minimum sample size involving proportions, was used:

$$n = \frac{Z^2 P (1-P)}{d^2}$$

Where, “n” is the required sample size, “Z” is standard value for the desired level of precision; “P” is expected prevalence and “d” the desired absolute precision. At 95% confidence interval, Z=1.96 and d = 0.05

#### **3.6.1 Sample size determination for livestock**

The reported prevalence of CE in Kenya in the areas studied recently range from 2-25% in cattle, 0.3-10% in goats and 4%-16% in sheep (Addy *et al.*, 2012 and Mbaya *et al.*, 2014). Taking expected prevalence of 25% for cattle, 16% for sheep and 10% for goats, the estimated minimum sample sizes were:

a) Cattle

$$n_{\text{cattle}} = \frac{1.96^2 (0.25(1-0.25))}{0.05^2}$$

= 288 cattle

b) Sheep

$$n_{\text{sheep}} = \frac{1.96^2(0.16(1-0.16))}{0.05^2}$$

= 207 sheep

c) Goats

$$n_{\text{goats}} = \frac{1.96^2(0.1(1-0.1))}{0.05^2}$$

= 138 goats

### **3.6.2 Sample size determination for dogs**

The prevalence of echinococcosis reported in dogs was 10% in Nairobi (Wachira *et al.*, 1993b) and 26% in Turkana (Buishi *et al.*, 2006). Using expected prevalence of 26% the estimated minimum sample size was:

$$n = \frac{1.96^2(0.74)(1-0.74)}{0.05^2}$$

=295 dogs

A minimum of 295 dogs was required but this was rounded up to 300 dogs

### **3.6.3 Sample size determination for Human population**

A study done by Dawit *et al.*, (2013) on Knowledge Attitude and Practices (KAPs) of pastoralist communities in Ethiopia in relation to CE and the Public Health risks showed that only 4.29% had some knowledge. Level of knowledge in Uganda was

3.9% according to Nyakarahuka *et al.*, (2013). Assuming a level of knowledge of 4% and substituting:

$$n_{\text{people}} = \frac{1.96^2 (0.4 \times 0.96)}{0.05^2}$$

=59 people

The estimated minimum sample size was 59 people. This was scaled up to 300 so as to correspond with the minimum number of dogs assuming one dog per household.

### **3.7 Sampling Techniques**

Different techniques were used:

#### **3.7.1 Census**

This was used for livestock, where every Cattle, sheep and goat slaughtered in abattoirs during the period of the study (five weeks) was included. The sampling was chosen in order to avoid bias of reporting by the research assistants and also to include animals from market days.

#### **3.7.2 Multi-stage random sampling**

This technique was applied to select the area location from where households were picked to provide both human and dog populations Thrusfield (1986). There are six administrative units (wards) whose names were written on separate pieces of paper for balloting. Three papers were picked randomly one at a time. Then all the names of locations in each ward that was picked were written on separate pieces of paper

and put in a basket. Only one location from each ward was picked randomly. The process was repeated for each ward until three locations in total were picked.

### **3.7.3 Systematic sampling**

The technique was employed to pick the study units. Every day, the first household that qualified for the study was randomly picked and there after every alternative household was enrolled.

## **3.8 Data collection and procedures**

### **3.8.1 Training of research assistants**

Accurate and meaningful data can only be collected when research assistants thoroughly understand all their field instructions. For this study, thirteen research assistants (trained meat inspectors) were trained for one day on recognition of hydatid cysts and were supervised only occasionally.

The research assistants who administered questionnaires were trained for two days with an emphasis on ethical approach to data collection: empathy, confidentiality and respect for every individual's autonomy. Simulations were carried out in order to enhance the assistants' confidence. The principal investigator worked with them for the first day and was available throughout data collection period to provide guidance.

### **3.8.2 Data from abattoirs**

Data was collected from thirteen abattoirs from the study area. The abattoirs are run by qualified meat inspectors who were recruited as research assistants after undergoing a brief refresher course organized by the PI on hydatid cyst recognition.

Data was collected daily from each abattoir for six days per week for 5 weeks and recorded in data collection sheets detailing the species, sex, origin, status of disease, and organs affected where applicable (Appendix 2).

Every cattle, sheep and goat slaughtered in the abattoirs during the period of the study was inspected visually and by palpation during postmortem examination for presence of hydatid cysts in both the thoracic and abdominal organs. The organs found with cysts were removed whole, put in polythene bags and labeled appropriately. The day's collection was then transferred to an airtight bucket for collection and transportation to the laboratory at AHITI–Nyahururu for further examination. Cysts with protoscolices and/or with a healthy white germinal layer were considered fertile, while those calcified and showing signs of degeneration were considered sterile. Contents of individual cysts were separately put in labeled specimen bottles, preserved with 70% ethanol and transported to KEMRI's Centre for Microbiology Research (CMR) laboratory where confirmation of cysts' viability was done with the assistance of Yvonne Omore. Details of cysts' data were recorded and these included the species, sex, origin of animal, organ affected, number of cysts recovered and their fertility.

### **3.8.3 Spatial data of abattoirs**

Abattoir names were coded and programmed in MS Excel 2010 and Open Data Kit collect (ODK collect) and used to get their coordinates as explained in section 3.9 below. Smart phones and a tablet were used as GPS (Global Positioning System) to collect vector data (x, y) - the latitude and longitude location for each abattoir. The

data was uploaded onto the server and later transferred to a geo-referenced map of the area in order to show the distribution of abattoirs in the study area.

#### **3.8.4 Collection of dog faecal samples**

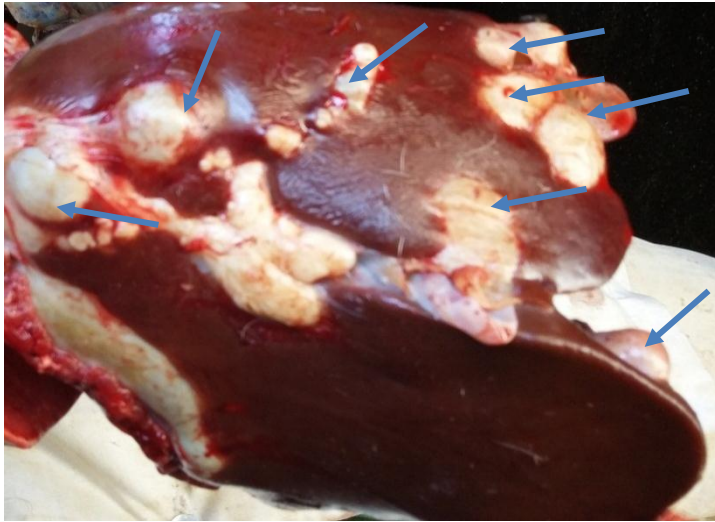
Dog faecal samples were collected from 401 dogs in households that own dog(s) and consented to be assessed for the level of CE knowledge. While one research assistant was administering the questionnaire, the other collected dog faecal material from the ground, put it in a labeled polypot and added 80% ethanol. The samples were transported for temporary storage at the laboratory of the Animal Health and Industry Training Institute (AHITI) –Nyahururu and later transported to the CMR parasitology laboratory at, KEMRI where they were stored at room temperature awaiting processing. The preserved samples were used for isolation of taeniid eggs for Polymerase Chain Reaction/Restriction Fragment Length Polymorphism (PCR/RFLP) using the procedure described by Huttner *et al.* 2008.

#### **3.8.5 Data on level of knowledge of echinococcosis**

A letter of introduction to the area local leaders was obtained from the Deputy County Commissioner, Nyahururu (Appendix 3). The area Chiefs of the selected Locations were visited and briefed about the exercise prior to the commencement of the data collection (this was necessary for purposes of publicity). The Chiefs then organized for a one day's seminar for the village managers and the PI's team where the village managers were sensitized about CE and their role in the project during data collection.

A questionnaire was prepared (Appendix 4) and used to assess the level of knowledge. The ODK 1.2 (2012) application which is a free source was used to collect data based on the prepared questionnaire. A Google server with a URL was created with a secure password using appspot. The coded questions in the questionnaire were programmed using MS Excel 2010 and uploaded onto the server. Smart phones used in data collection were fitted with Secure Digital (SD) cards and the ODK application downloaded onto them. Completing the form was done offline but network was required to download the form and also for uploading the completed questionnaires.

Systematic sampling procedure was used to pick 300 households that keep dogs. For every day of data collection, the assistance of the village elder or their representative was enlisted for guidance and introduction to participants. After introduction, the voluntary participation and a written consent of one adult member from the household was sought. Once consent was given, the mobile data collection based on the Questionnaire (appendix 4), was opened and administered by a research assistant using a smart phone. The participant was first shown a photograph of an organ with hydatid cysts (figure 3.2) and their response to the question whether they were aware of a disease that affects the organs as seen in the photograph was noted.



**Figure 3.2: Liver showing hydatid cysts**

Arrows point to positions of cysts

After going through the questionnaire with the participant, information regarding the life cycle and mode of transmission of *E. granulosus* to humans/livestock was provided to the participant ([www.dpd.cdc.gov](http://www.dpd.cdc.gov)). A coded identification number was assigned to each household and used only for the purpose of sample tracking in order to maintain confidentiality. Once the data was entered into the phone and verified, it was uploaded to the server from where it was later retrieved for analysis. The use of ODK was to reduce use of paper besides authenticating the data collected as it was easier to counter check records based on coordinates (GPS) points recorded.

### **3.8.6 Data on trends in prevalence and Economic losses due to CE**

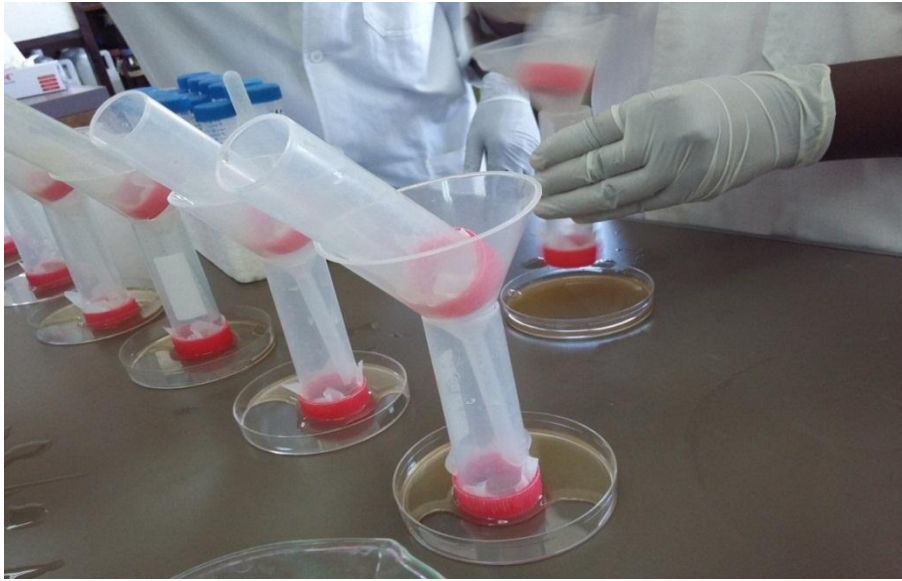
Secondary (retrospective) data for a period of five years (2010-2014) was acquired from the veterinary office records/reports at Rumuruti and Nyahururu offices using

data collection sheets detailing the year, month, sex, disease status and the organs condemned (Appendix 5). The average price of the given organs was obtained from the Butcher's association and veterinary office records/reports on livestock production and marketing. This was multiplied by total number of the individual organs to get the total cost.

### **3.9 Laboratory Procedures**

#### **3.9.1 Taeniid eggs isolation**

The isolation of taeniid eggs was done using Zinc Chloride floatation method (Mathis *et al.*, 1996). The faecal sample was diluted in PBS-Tween, centrifuged and the pellet suspended in zinc chloride for further centrifuging. The supernatant containing taeniid eggs was passed through a sieve mesh size 44 $\mu$ m and rinsed thoroughly with water. The flow through fraction containing the eggs was then passed through a sieve mesh size 22 $\mu$ m and rinsed thoroughly with water (Figure 3.3). The taeniid eggs were retained by the sieve which was put upside down in a funnel standing in a collection tube. The sieve was washed thoroughly with water and the collection centrifuged for 10 minutes at 400g. Excess supernatant was carefully removed using a pipette until about 1 ml was left which was transferred to a 1.5ml tube and stored at 4<sup>0</sup>C until screened for taeniid eggs microscopically. Each sample went through the same process. All apparatus used during the day's work were soaked overnight in 2% sodium hypochlorite solution for destruction of any eggs left on them (Appendix 6).



**Figure 3.3: An assembly of apparatus used in Taeniid eggs isolation**

Key: The tube in the funnel has a 44 $\mu$ m sieve while the tube in the petri dish has a 22 $\mu$ m sieve which traps the Taeniid eggs

### **3.9.2 Identification of Taeniid eggs by Microscopy**

A drop of the sample was put on a microscopy slide, drop iodine added and mixing done using an applicator stick. A microscopy slide cover was applied onto the mixture which was observed under a light microscope at  $\times 40$  objective power lens for taeniid eggs. This process was repeated for each sample. Samples with taeniid eggs were stored separately at 4<sup>0</sup>C awaiting egg picking process.

### **3.9.3 Egg picking**

A few drops of the sample were mixed with water in a petri dish and individual eggs were picked from each positive sample using a micropipette under a light microscope. Each egg was transferred into a separate nucleic acid free PCR tube

containing 10µl of 0.02M NaOH. A maximum of 20 eggs were picked from each sample and stored at 4<sup>0</sup>C.

### **3.9.4 DNA extraction**

The egg samples were lysed in 0.02M NaOH at 95 °C for 10 minutes in a Thermal cycler as described by Nakao *et al.* (2003).

### **3.9.5 Polymerase Chain Reaction (PCR) of individual eggs**

The nested PCR assay was conducted to amplify the nad-1 gene following the method described by Huttner *et al.* (2009). The reaction mixture included 2 µl lysate, 10 PCR buffer, 2mM MgCl<sub>2</sub>, 10 µl deoxynucleoside triphosphates (dNTPs), 6.25 pmol primer and 1.25 units of Taq polymerase. The mixture was put in a thermal cycler for 35 cycles for amplification: One cycle consists of denaturation at 94°C for 30s, annealing at 55°C for 30s, elongation at 72°C and post cycling final elongation at 72 °C for 5minutes. Agarose gel was prepared by adding 2.5g of agarose powder in 100ml of 1 Tris-Borate-EDTA buffer (TBE) buffer in a flask and heating for 1-2 minutes. The solution was cooled to about 55°C and poured into a plastic tray. A comb was carefully placed in the gel to make wells without touching the bottom. The comb was removed after the gel solidified. The amplified PCR material was put into the wells formed while maintaining the order of labeling. The first well on the left of the gel was put a DNA ladder (Appendix 7) and the last two wells on the right were put a positive and a negative control respectively. Electrophoresis was applied and results detected as banding patterns visualized on a 2.5% (w/v) agarose gel stained with ethidium bromide. The gels were photographed using the transilluminator.

### **3.9.6 Restriction digestion (RFLP) of individual PCR amplicons**

Since eggs of all *Taenia* cannot be distinguished morphologically, PCR-RFLP was carried out to differentiate *E. granulosus* from other *Taenia* spp (Trachsel *et al.*, 2007). The procedure described by Huttner *et al.* 2008 and 2009 was used. The nad-1 positive PCR amplicons were digested overnight in an incubator at 37 °C using Hph-1 restriction enzyme. The amount of secondary PCR product used in the reaction mixture depended on how well amplified the nad-1 gene was in the primary PCR: Reaction mixture for the well amplified gene consisted of 10 µl of the primary PCR product, 7.5 nuclease free water, 0.5 enzyme and 2.0 buffer while the less amplified gene consisted of 15 µl of the primary PCR product, 2.5 nuclease free water, 0.5 enzyme and 2.0 buffer.

Agarose gel was prepared as explained above and a drop of restricted product from each sample was put into the wells and electrophoresis run. The wells included a marker on the left side of the gel and the last four wells on the right hand side having G1, G5, G6 and undigested (uncut) PCR. The separated fragments were visualized as banding patterns and photographed using the transilluminator.

### **3.10 Data management**

#### **3.10.1 Data Entry**

Data from collection sheets were checked by the PI for eligibility and completeness before being entered into MS excel 2010. Double data entries were practiced and the PI conducted checks for their accuracy. The ODK data which was captured directly has an inbuilt validation system that verifies all entries.

### **3.10.2 Data Backup and Storage**

All software data entries were saved regularly and backed up after every working session. The completed data on internet was downloaded onto a hard disk and secured. Copies of each data type were saved in different locations including the computer, external hard disk, flash discs as well as on SD cards that were detached and stored separately. Internet backup in the PI's email folder was made. All software data were protected by password. All hard copies of the informed consent documents, and any files generated during data analysis were kept secure from unauthorized access, damage or loss.

### **3.11 Data analysis**

Data analysis was done using MS excel 2010 and SPSS version 20.0 and commenced after all data had been verified. Descriptive statistics, trend line and Chi-square test of association were carried out. The level of statistical significance was 5%.

#### **3.11.1 Data from abattoirs**

SPSS version 20.0 was used for analysis after importing data from MS excel 2010. Categorical variables were analysed using frequency distributions. Cross tabulation (Chi-Square) was used to compare the various variables. Estimates of the parameters were considered statistically significant at  $p < 0.05$ . The significant factors were further analyzed using the Poisson model. This model was picked because the events could be counted as whole numbers and their occurrences were independent.

The abattoirs coordinates' data was transferred to a geo referenced map. The information is presented using tables, charts and maps.

### **3.11.2 Data on dogs and level of knowledge**

Analysis was done after importing data from MS excel 2010 into SPSS version 20.0. Categorical variables were analysed using frequency distributions. Cross tabulation was carried out to check for association between factors and the level of knowledge. Parameters were considered statistically significant at  $p < 0.05$ . The information is presented using tables, charts and maps.

### **3.11.3 Data on trends in prevalence and economic**

Data analysis on trends in prevalence and economic loss due to CE was done using MS excel 2010 and the information is presented in tables, line graphs and trend line.

## **3.12 Ethical Considerations**

This research involved collection of data from animals and human subjects. Ethical considerations were therefore observed for both. Approval to carry out the study was sought and obtained from the KEMRI's Scientific and Ethics Review Unit (SERU) and the Animal Care and Use Committee (ACUC): reference SERU/CMR/P0020/3081 (Appendices 8 and 9).

### **3.12.1 Animal ethical considerations**

The PI obtained permission from The Director of Veterinary Services, State department of Livestock in the Ministry of Agriculture, Livestock and Fisheries

(Appendix 10), as well as from the County Director of Livestock and Fisheries, Laikipia County (Appendix11).

### **3.12.2 Human considerations**

The consenting process started after getting final approval from SERU. The PI obtained a letter of introduction to the area local leaders from the Deputy County Commissioner, Nyahururu (Appendix 4). The area Chiefs and the village elders from the target population were briefed about the research procedures. Documented consent was sought from the selected individual participants.

## CHAPTER FOUR

### RESULTS

#### 4.1 Cystic Echinococcosis in animals slaughtered in abattoirs of Laikipia West Sub County

##### 4.1.1 Characteristics of animals slaughtered

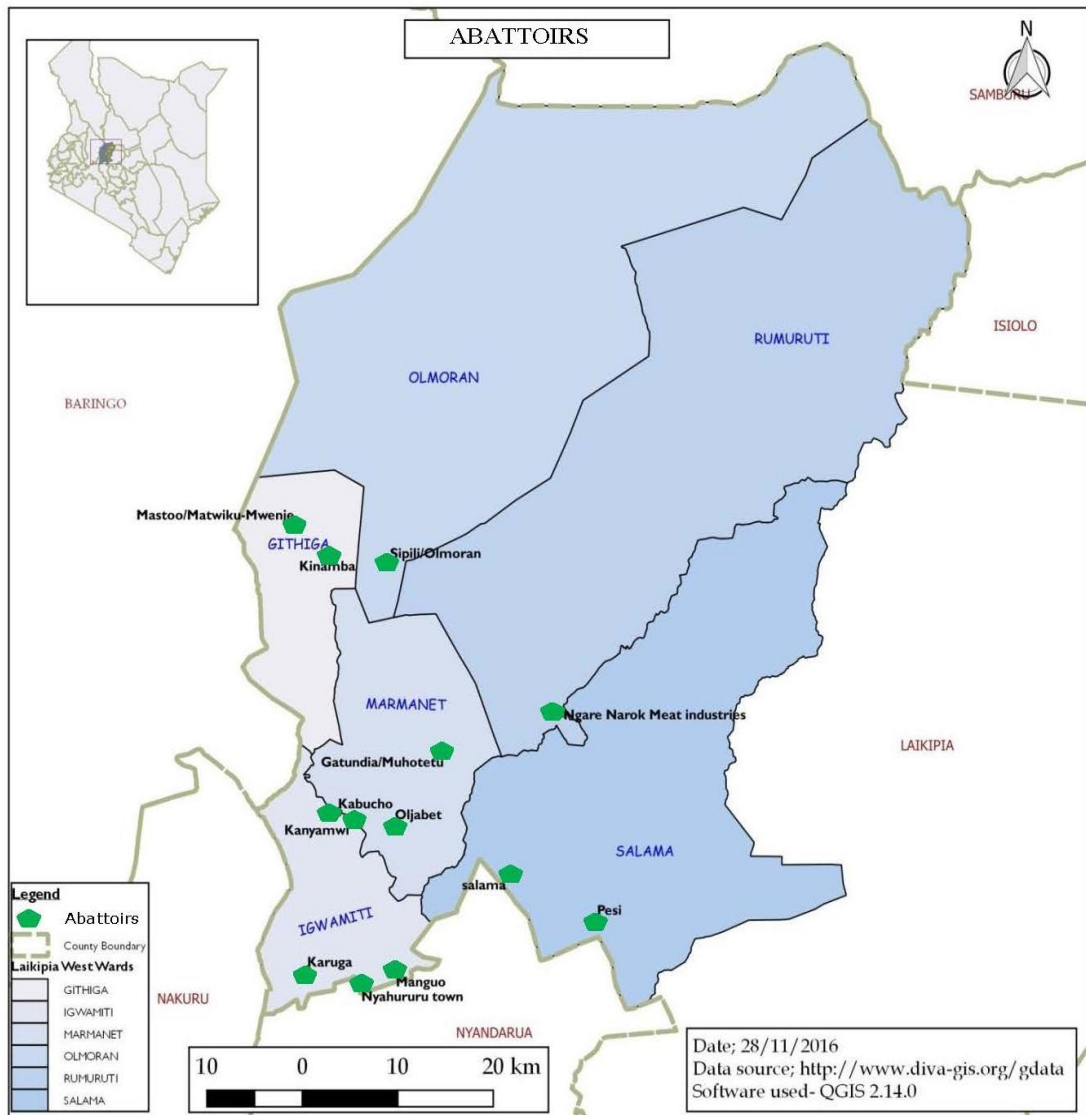
A total of four thousand, nine hundred and sixty-nine (4969) animals were inspected for hydatid cysts from thirteen abattoirs. There were 3428 (69%) sheep, 1019 (20.5%) goats and 522 (10.5%) cattle (Table 4.1). The proportion of males to females slaughtered was 50.3:49.7(1:1) and most (98.5%) of the animals slaughtered were from Laikipia west sub county. The animals positive for CE were 122 giving an overall prevalence of 2.5%.

**Table 4.1: Characteristics of animals slaughtered in abattoirs of Laikipia West Sub County**

| Variable       | Category              | Frequency | Percentage ( % ) |
|----------------|-----------------------|-----------|------------------|
| Species        | Cattle                | 522       | 10.5             |
|                | Sheep                 | 3428      | 69.0             |
|                | Goats                 | 1019      | 20.5             |
| Sex            | Male                  | 2500      | 50.3             |
|                | Female                | 2469      | 49.7             |
| Origin         | Within Laikipia west  | 4896      | 98.5             |
|                | Outside Laikipia west | 73        | 1.5              |
| Disease status | Positive              | 122       | 2.5              |
|                | Negative              | 4847      | 97.5             |

#### **4.1.2 Distribution of animals by abattoir and place of origin**

The distribution of abattoirs in Laikipia west Sub County is shown in figure 4.1. The animals slaughtered in each abattoir are shown in (Appendix 12). Manguo abattoir had the highest proportion of animals slaughtered (26.7%) followed by Nyahururu (19.5%), while Pesi had the least (0.7%) followed by Salama (1.2%). Ngare Narok meat industries abattoir contributed the highest proportion (30.3%, n=122) of the positive animals followed by Manguo (15.6 %) and Nyahururu (14.8%) while Salama, Karuga, and Matuiku abattoirs each contributed less than 2% and Oljabet reported zero positive cases. Kabucho abattoir which is located near the boundary between Baringo and Laikipia counties had the highest proportion (50.7%, n=73) of animals slaughtered from outside the county while over 60% (8/13) of the abattoirs slaughtered animals from within the study site locality.



**Figure 4.1: Distribution of abattoirs in Laikipia West Sub County**

Source: <http://www.diva-gis.org/gdata>

### 4.1.3 Prevalence and characteristics of CE positive animals

There was an overall prevalence of 2.5% (n=4969). Sheep contributed the highest proportion of the overall prevalence while goats contributed the least (Table 4.2).

The prevalence of individual species was 8.8% in cattle, 1.7% in sheep and 1.7% goats. About 62% of the CE positive animals were females while 38% were males. The lungs were the most frequently parasitized organ (68%) followed by both lungs and liver (23%), while the spleen was the least affected organ (2.5%).

**Table 4.2: Prevalence and characteristics of CE positive animals slaughtered in abattoirs of Laikipia West Sub County**

| Variable | Category         | Frequency (%) | Frequency of positive (%) |
|----------|------------------|---------------|---------------------------|
| Species  | Cattle           | 522 (10.5)    | 46 (8.8)                  |
|          | Sheep            | 3428 (69.0)   | 59 (1.7)                  |
|          | Goats            | 1019 (20.5)   | 17 (1.7)                  |
| Sex      | Male             | 2500          | 46(37.7)                  |
|          | Female           | 2469          | 76(49.7)                  |
| Organs   | None             | 4845 (97.5)   | 0 (0.0)                   |
|          | Lungs            | 84 (1.7)      | 83 (68.0)                 |
|          | Liver            | 8 (0.2)       | 8 (6.6)                   |
|          | Lungs and liver  | 29 (0.6)      | 28 (23.0)                 |
|          | Lungs and spleen | 3 (0.1)       | 3 (2.5)                   |

The occurrence of CE was significantly associated with species, sex and organs (Table 4.3).

**Table 4.3: Association of CE with species, sex and organs in animals slaughtered in abattoirs of Laikipia West Sub County**

| Variable | $\chi^2$ | Df | P- value |
|----------|----------|----|----------|
| Species  | 98.4     | 2  | 0.000    |
| Sex      | 8.0      | 1  | 0.005    |
| Organs   | 4969     | 4  | 0.000    |

#### 4.1.4 Poisson model of disease status and animal characteristics

Poisson model was applied to the factors in table 4.3. The coefficients were 1.7 in cattle and 0.03 in sheep. The log of expected counts of CE was expected to increase by 1.7 and 0.03 in cattle and sheep respectively when compared to goats (Table 4.4). The occurrence of CE in cattle was significantly more likely than in the other species ( $p \leq 0.05$ ) The coefficients for males was -0.515, meaning the log of expected counts was expected to be -0.5 units lower in males i.e. CE is more likely to be found in females ( $p=0.006$ ) relative to the males. The occurrence of cysts in lungs was statistically significant ( $p \leq 0.05$ ).

**Table 1.4: Analysis of CE disease status and animal characteristics using Poisson model**

| Factor  | Level        | Frequency of positive | Prevalence | Coefficients [95% C.I] | P-value |
|---------|--------------|-----------------------|------------|------------------------|---------|
| Species | Cattle       | 46                    | 8.8        | 1.7[1.1, 2.2]          | 0.000   |
|         | Sheep        | 59                    | 1.7        | 0.031[-0.5, 0.6]       | 0.910   |
|         | Goats        | 17                    | 1.7        | Ref                    |         |
| Sex     | Male         | 46                    | 37.7       | -0.5 [-0.9, -0.1]      | 0.006   |
|         | Female       | 76                    | 62.3       | Ref                    |         |
| Organs  | Lungs        | 84                    |            |                        | 0.001   |
|         | Liver        | 8                     |            |                        |         |
|         | Lungs/Liver  | 29                    |            |                        |         |
|         | Lungs/Spleen | 3                     |            |                        |         |

#### 4.1.5 Prevalence of Cystic Echnococosis in cattle

Five hundred and twenty two (522) cattle were examined for the presence of hydatid cysts and 46 (8.8%, [95% CI, 7.6% - 10.0%]) of the cattle slaughtered in abattoirs in the study area had hydatid cysts. Most cattle with CE (80.4%, n=46) originated from Laikipia west sub county as shown in (Appendix 13). Proportionally, Nyahururu,

Matuiku and Ngarenarok meat industries abattoirs contributed more towards the prevalence. About 35% (16/46) of the CE positive cattle had fertile cysts and most (81.3%, n=16) of them were from Laikipia west (Table 4.5).

#### **4.1.6 Prevalence of Cystic Echnococosis in Sheep**

Fifty nine of 3,428 sheep slaughtered in all abattoirs in the study area had hydatid cysts (1.7%, [95% CI, 1.5% - 1.9%]) and (78%, n=59) originated from Laikipia west sub county (Appendix 14). Pesi, Kanyamwi and Ngare Narok meat industries contributed most proportionally towards the prevalence. About 40% (23/59) of the positive sheep had fertile cysts and (95.7%) came from Laikipia west (Table 4.5).

#### **4.1.7 Prevalence of Cystic Echnococosis in goats**

Seventeen out of 1,019 goats slaughtered in all abattoirs in the study area had hydatid cysts (1.7%, [95% CI; 1.3% - 2.1%]) and over 90% (16/17) of the goats originated from Laikipia west Sub County (Appendix 15). Ngare Narok meat industries, Gatundia and Manguo abattoirs contributed more towards the prevalence. Three of the positive animals (17.6%, n=17) had fertile cysts and all of them originated from Rumuruti market in Laikipia west sub county (Table 4.5).

#### **4.1.8 Origin of animals with fertile cysts**

Thirty four percent (34.4%, n=122) of CE positive animals had fertile cysts. This consisted of 38.1% cattle, 54.8% sheep, and 7.1 %goats. Most, (90.5%) animals with fertile cysts originated from Laikipia west Sub County (Table 4.5).

**Table 4.5: Origin of animals with fertile cysts per ward**

| Species/<br>Origin | Igwamiti | Githiga | Olmoran | Marmanet | Rumuruti<br>Township | Salama | Total<br>Laikipia west (%) | from<br>west (%) | Total from other<br>county (%) | Total overall animals<br>with cysts (%) |
|--------------------|----------|---------|---------|----------|----------------------|--------|----------------------------|------------------|--------------------------------|---|
| Cattle             | 1        | 0       | 3       | 0        | 9                    | 0      | 13(81.3)                   |                  | 3(18.8)                        | 16(38.1)                                |
| Sheep              | 1        | 0       | 1       | 0        | 19                   | 1      | 22(95.7)                   |                  | 1(4.3)                         | 23(54.8)                                |
| Goats              | 0        | 0       | 0       | 0        | 3                    | 0      | 3(100.0)                   |                  | 0(0.0)                         | 3(7.1)                                  |
| Total              | 2        | 0       | 4       | 0        | 31                   | 1      | 38(90.5)                   |                  | 4(9.5)                         | 42(100)                                 |

#### 4.1.9 Cysts' fertility and distribution in organs

The total number of cysts recovered from all animals was 911, distributed as 506 (55.4%) in cattle, 348 (38.2%) in sheep and 57 (6.3%) in goats. About seventeen percent (16.6%) of the cysts recovered were fertile. Sheep had the highest proportion (32.2%) of the fertile cysts while cattle and goats had almost the same proportions, 6.9% and 7.0% respectively. Cattle had the highest proportion (20.6%) of calcified cysts while sheep had the least (7.0%). Most cysts (62.8%) occurred in lungs and very few (0.7%) in the spleen (Table 4.6).

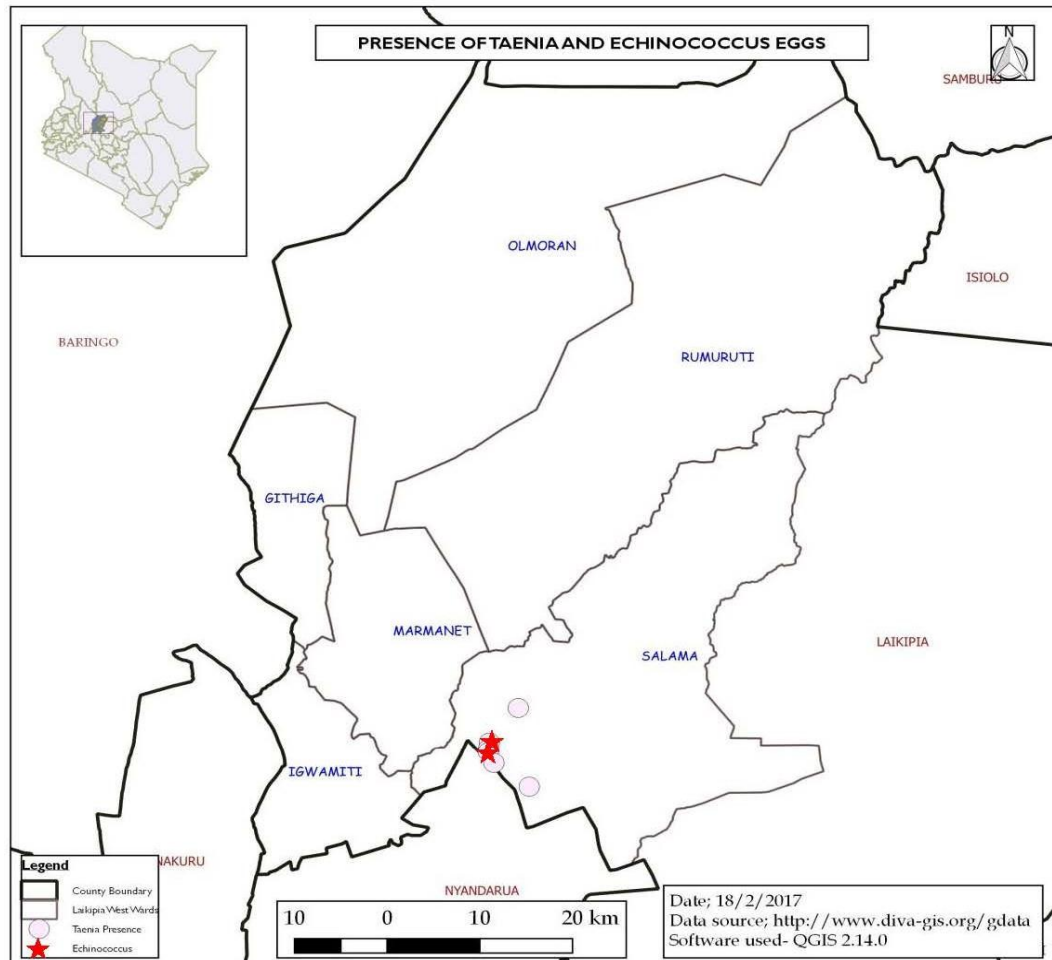
**Table 4.6: Cysts' fertility and distribution in organs**

| Variable                     | Category        | Frequency | Percent (%) |
|------------------------------|-----------------|-----------|-------------|
| Cattle                       | Fertile cysts   | 35        | 6.9         |
|                              | Sterile cysts   | 367       | 72.5        |
|                              | Calcified cysts | 104       | 20.6        |
| Sheep                        | Fertile cysts   | 112       | 32.2        |
|                              | Sterile cysts   | 231       | 66.4        |
|                              | Calcified cysts | 5         | 1.4         |
| Goats                        | Fertile cysts   | 4         | 7.0         |
|                              | Sterile cysts   | 49        | 86.0        |
|                              | Calcified cysts | 4         | 7.0         |
| Cysts distribution in Organs | Lungs           | 572       | 62.8        |
|                              | Liver           | 333       | 36.6        |
|                              | Spleen          | 6         | 0.7         |

#### 4.2 Prevalence of Echinococcosis in dogs

Faecal samples were collected from 401 dogs which comprised 170 from Salama location, 128 from Igwamiti Location and 103 from Sipili Location. Microscopy

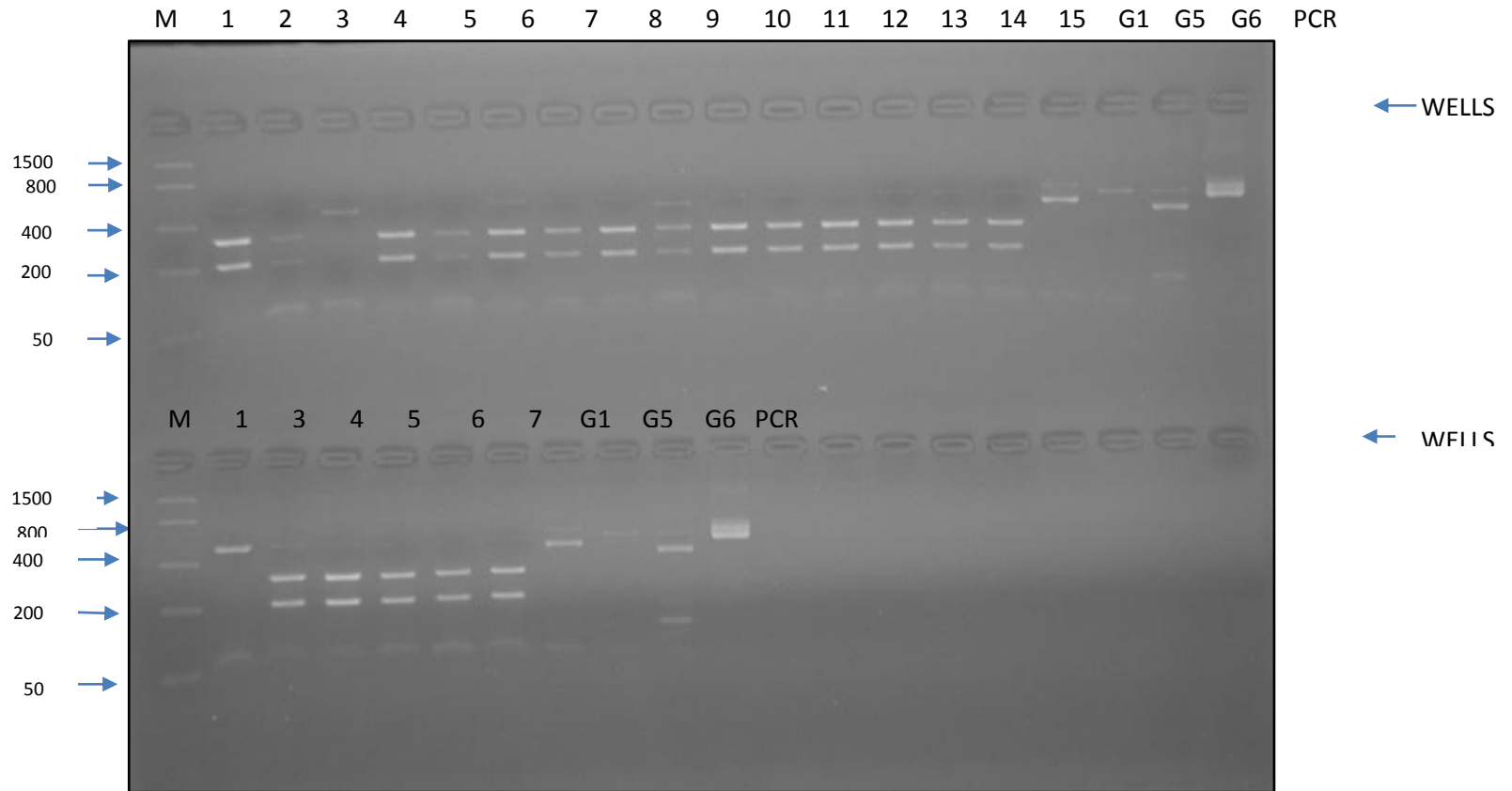
results showed that seven of the samples had *Taenia* eggs and all were from Salama location (figure 4.2); thus a locational prevalence of 1.2%.



**Figure 4.2: Distribution of dogs having Echinococcus eggs.**

Source: <http://www.diva-gis.org/gdata>

The RFLP results showed that two samples (well number 3 of top row and well number 1 of lower row) were positive for *Echinococcus granulosus* type G1 (Figure 4.3), giving prevalence of Echinococcosis in dogs as 0.5%.



Key: M=Marker; 1-15=Wells with digested nad-1 amplicons; G1, G5, and G6= wells containing *E.granulosus* genotypes; PCR=well with undigested nad-1 amplicon

**Figure 4.3: Agarose gel photo of PCR- RFLP of nad-1 gene using Hph-1.**

### 4.3 Level of knowledge of echinococcosis in Laikipia West Sub County

#### 4.3.1 Socio demographic characteristics of study participants

A total of 300 participants were interviewed. Most of them ranged from 26-46 years (47%) and 58.3% were females. About half (51%) had primary level of education, 13% had no formal education and only 6% had post – secondary level. Majority (89%) were of Kikuyu ethnicity and 38% of the households used borehole water while 8.7% and 6% used dam and river water respectively (Table 4.7).

**Table 4.7: Socio demographic characteristics of study participants**

| Variable        | Category             | Frequency | Percentage ( % ) |
|-----------------|----------------------|-----------|------------------|
| Gender          | Male                 | 125       | 41.7             |
|                 | Female               | 175       | 58.3             |
| Location        | Igwamiti             | 100       | 33.3             |
|                 | Salama               | 100       | 33.3             |
|                 | Sipili               | 100       | 33.3             |
| Age group       | 18-25                | 22        | 7.3              |
|                 | 26-46                | 141       | 47.0             |
|                 | 46+                  | 137       | 45.7             |
| Ethnicity       | Kikuyu               | 267       | 89.0             |
|                 | Embu                 | 1         | 0.3              |
|                 | Meru                 | 2         | 0.7              |
|                 | Kamba                | 1         | 0.3              |
|                 | Kalenjin             | 14        | 4.7              |
|                 | Turkana              | 12        | 4.0              |
|                 | Kisii/ Luhya         | 2         | 0.7              |
|                 | Samburu              | 1         | 0.3              |
| Education level | No formal education  | 38        | 12.7             |
|                 | Primary level        | 153       | 51.0             |
|                 | Secondary            | 91        | 30.3             |
|                 | Post-secondary level | 18        | 6.0              |
| Source of water | Borehole             | 114       | 38               |
|                 | Dam                  | 26        | 8.7              |
|                 | River                | 18        | 6.0              |
|                 | Springs              | 37        | 12.3             |
|                 | Tap water            | 48        | 16.0             |
|                 | Others               | 57        | 19.0             |

### 4.3.2 Level of knowledge of echinococcosis among study participants

Among the interviewed participants, 25 % (75/300) had knowledge of echinococcosis and 63% (n=75) knew that the disease affects domestic animals while only 2.7% knew that it affects people (Table 4.8).

**Table 4.8: Level of knowledge of echinococcosis among study participants**

| Factor                          | Response         | Frequency | Percentage ( % ) of those who were aware |
|---------------------------------|------------------|-----------|--|
| Those affected by CE            | People           | 2         | 2.7                                      |
|                                 | Domestic animals | 63        | 84.0                                     |
|                                 | Don't know       | 9         | 12.0                                     |
|                                 | Others           | 1         | 1.3                                      |
| Organs affected by CE           | Lungs            | 15        | 20.0                                     |
|                                 | Liver            | 23        | 30.7                                     |
|                                 | Don't know       | 37        | 49.3                                     |
| Recognition of CE at postmortem | Cysts in organs  | 61        | 81.3                                     |
|                                 | Don't know       | 8         | 10.7                                     |
|                                 | Others           | 6         | 8.0                                      |
| Transmission of CE to man       | Domestic animals | 19        | 25.3                                     |
|                                 | Wild animals     | 1         | 1.3                                      |
|                                 | Dogs             | 11        | 14.7                                     |
|                                 | Don't know       | 38        | 50.7                                     |
|                                 | Others           | 6         | 8.0                                      |

### 4.3.3 Chi-Square analyses of factors associated with level of knowledge

Chi-Square analyses show that the location area where respondents came from was the only significant factor showing association with the level of knowledge (p-value =0.001). Among the respondents, Salama had the highest proportion of respondents being aware of CE while Sipili had the least. Gender (p-value 0.068) is on the borderline which signifies a weak association (Table 4.9).

**Table 4.9: Factors associated with level of knowledge of echinococcosis among study participants**

| Factor          | Level               | Frequency (%) | $\chi^2$ | df | p-value |
|-----------------|---------------------|---------------|----------|----|---------|
| Location        | Igwamiti            | 24 (8.0)      | 14.187   | 2  | 0.001   |
|                 | Salama              | 37 (12.3)     |          |    |         |
|                 | Sipili              | 14 (4.7)      |          |    |         |
| Gender          | Male                | 125 (41.7)    | 3.333    | 1  | 0.068   |
|                 | Female              | 175 (58.3)    |          |    |         |
| Age group       | ≤46 years           | 163 (54.3)    | 1.617    | 1  | 0.204   |
|                 | 46+                 | 137 (45.7)    |          |    |         |
| Education level | No formal education | 38 (12.7)     | 5.696    | 3  | 0.127   |
|                 | Primary             | 153 (51.0)    |          |    |         |
|                 | Secondary           | 91 (30.3)     |          |    |         |
|                 | Post-secondary      | 18 (6.0)      |          |    |         |
| Ethnicity       | Kikuyu              | 267(89.0)     | 11.832   | 8  | 0.159   |
|                 | Embu                | 1(0.3)        |          |    |         |
|                 | Meru                | 2(0.7)        |          |    |         |
|                 | Kamba               | 1(0.3)        |          |    |         |
|                 | Kalenjin            | 14(4.7)       |          |    |         |
|                 | Turkana             | 12(4.0)       |          |    |         |
|                 | Kisii/ Luhya        | 2(0.7)        |          |    |         |
|                 | Samburu             | 1(0.3)        |          |    |         |

#### **4.3.4 Dog ownership, feeding, home slaughtering and animal deworming practices**

Many households (61.3%) own one dog with a mean of 1.6 dogs per household. Most respondents (98%) cooked food for their dogs while 28.3% never deworm their dogs. Majority of those interviewed slaughter at home (93.7%) and 35% give diseased organs to the dogs (table 4.10).

**Table 2.10: Dog ownership, feeding, home slaughtering and animal deworming practices**

| Variable                    | Category                           | Frequency | Percentage ( % ) |
|-----------------------------|------------------------------------|-----------|------------------|
| Number of dogs owned        | 1                                  | 184       | 61.3             |
|                             | 2                                  | 80        | 26.7             |
|                             | 3                                  | 25        | 8.3              |
|                             | 4+                                 | 11        | 3.7              |
| Dog feeding                 | Scavenging                         | 2         | 0.7              |
|                             | Cooked food                        | 294       | 98               |
|                             | Raw butchery/ slaughterhouse waste | 2         | 0.7              |
|                             | Others                             | 2         | 0.7              |
| Deworming dogs per year     | Never                              | 85        | 28.3             |
|                             | Once                               | 68        | 22.7             |
|                             | Twice                              | 32        | 10.7             |
|                             | Others                             | 115       | 38.3             |
| Home slaughtering           | Yes                                | 281       | 93.7             |
|                             | No                                 | 19        | 6.3              |
| Disposal of diseased organs | Give to dogs                       | 106       | 35.3             |
|                             | Burry                              | 15        | 5.0              |
|                             | Throw in the bush                  | 5         | 1.7              |
|                             | Others                             | 174       | 58.0             |

#### **4.4 Trends in prevalence and economic losses due to Cystic Echnococosis in livestock slaughtered 2010-2014**

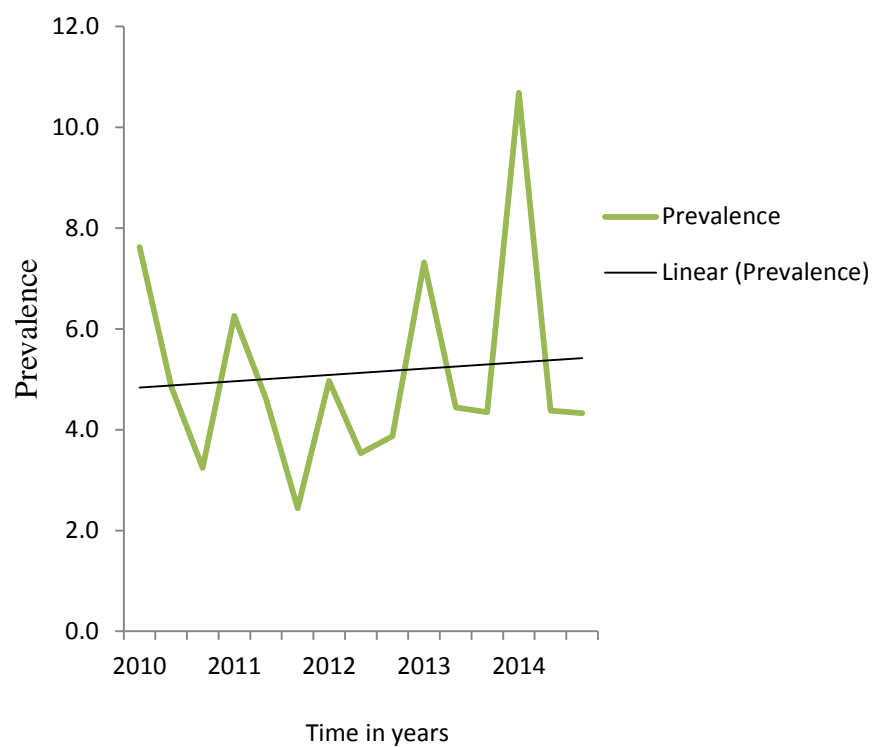
##### **4.4.1 General trends in prevalence and economic loss**

Data from the meat inspection reports show that a total of 98,495 animals comprising 18,358 (18.6%) cattle, 54,666 (55.5%) sheep and 25471(25.9%) goats were inspected during the period 2010-2014 and 4,785(4.9%) had hydatid cysts leading to organ condemnation. During the five year period, the average prevalence was 4.9%. The highest prevalence (10.7%) was recorded in cattle in 2014 which corresponded with

the highest economic loss, while the lowest prevalence (2.4%) was recorded in goats in 2011 (appendix 16). The general trend in prevalence is shown in figure 4.4.

Organs condemned were 4,106 lungs, 3,581 livers and 291 spleens leading to a gross total loss of KES 1,291,460.00 and an annual loss of KES 258,292.00 (Table 4.11).

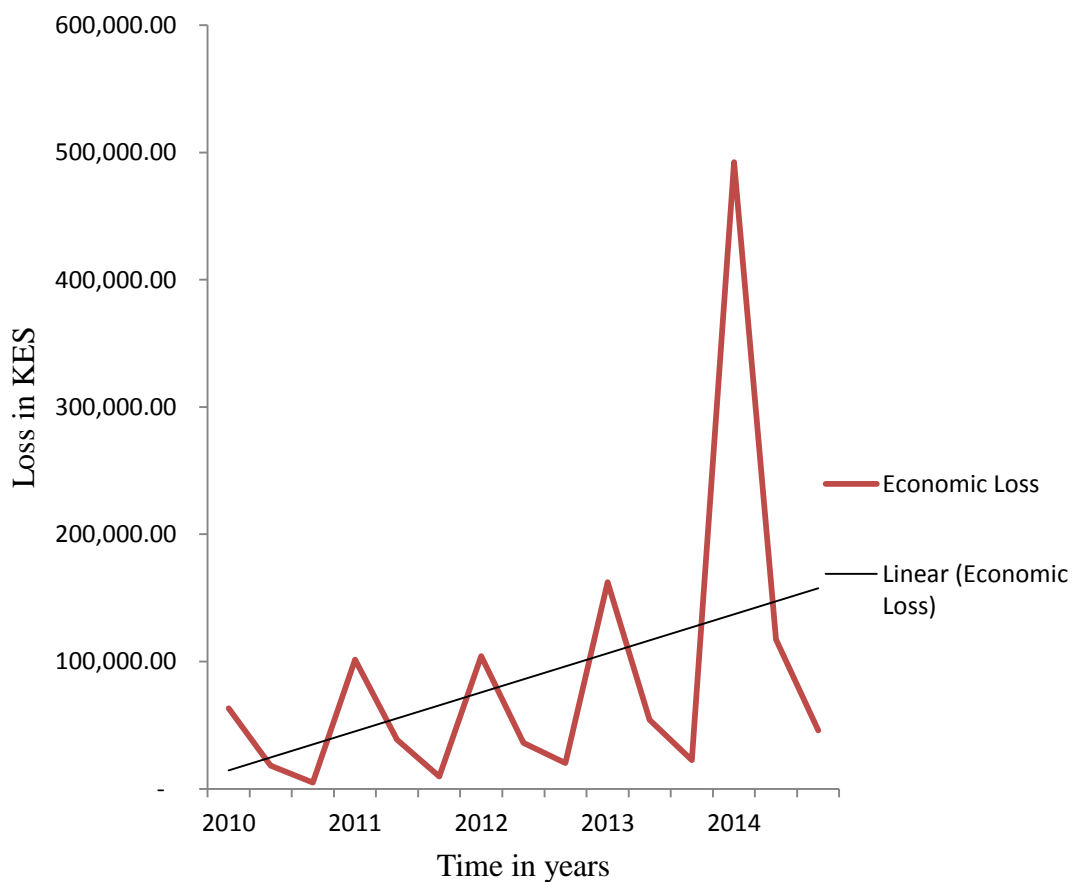
The general trend in economic loss is shown in figure 4.5.



**Figure 2.4: Trends in prevalence of CE in animals slaughtered in Laikipia west Sub County during 2010-2014**

**Table 4.11: Summarized data from meat inspection reports on cattle, sheep and goats slaughtered in Laikipia west Sub County during 2010-2014**

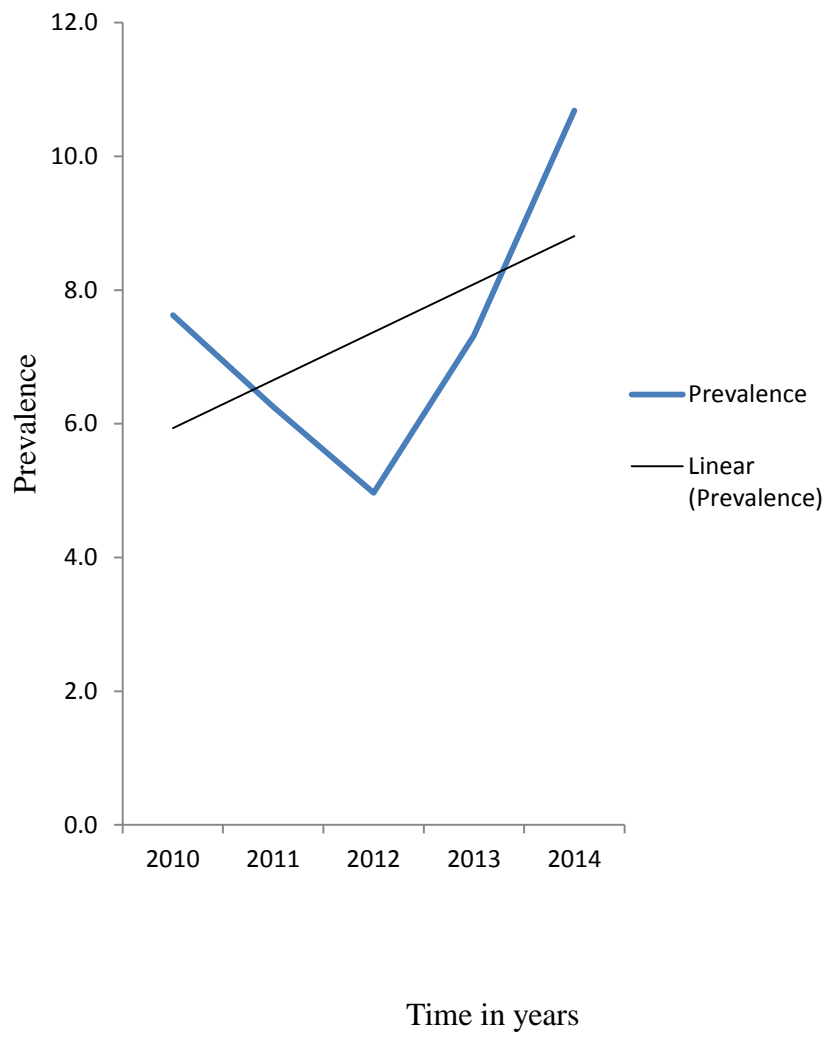
| Species | Total negative | Total positive | Total animals slaughtered | Prevalence | Total lungs condemned | Total livers condemned | Others (spleen) | Lungs Total cost (KES) | Livers Total cost (KES) | Others(Spleen) Total cost (KES) | Total cost of all organs (KES) | Annual cost/Loss (KES) |
|---------|----------------|----------------|---------------------------|------------|-----------------------|------------------------|-----------------|------------------------|-------------------------|---------------------------------|--------------------------------|------------------------|
| Cattle  | 16934          | 1424           | 18358                     | 7.8        | 1287                  | 1063                   | 134             | 303,700.00             | 610,300.00              | 9,950.00                        | 923,950.00                     | 184,790.00             |
| Sheep   | 52285          | 2381           | 54666                     | 4.4        | 2042                  | 1820                   | 132             | 90,850.00              | 171,450.00              | 1,990.00                        | 264,290.00                     | 52,858.00              |
| Goats   | 24491          | 980            | 25471                     | 3.9        | 777                   | 698                    | 25              | 35,820.00              | 67,000.00               | 400.00                          | 103,220.00                     | 20,644.00              |
| Total   | 93710          | 4785           | 98495                     | 4.9        | 4106                  | 3581                   | 291             | 430,370.00             | 848,750.00              | 12,340.00                       | 1,291,460.00                   | 258,292.00             |



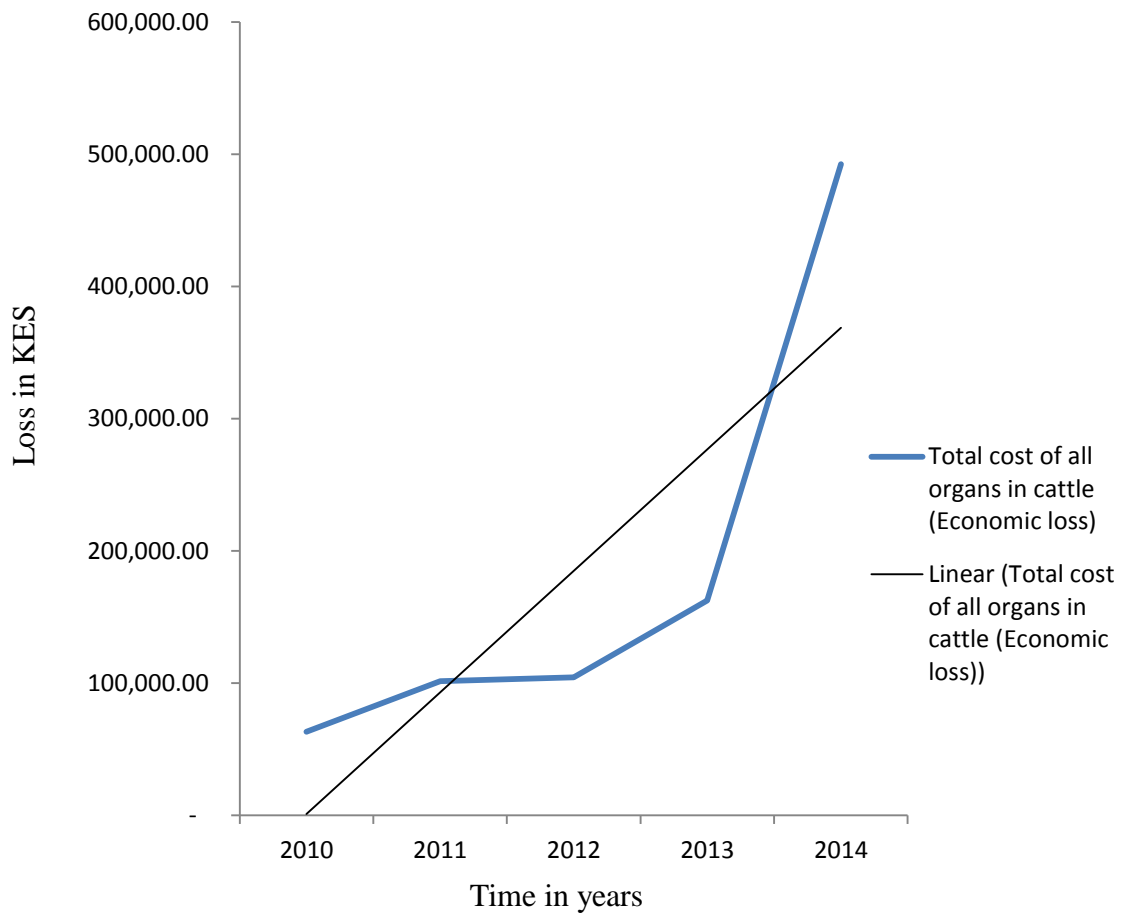
**Figure 4.5: Trends in Economic loss due to CE in Laikipia west Sub County during 2010-2014**

#### **4.4.2 Trends in prevalence and economic losses due to CE in cattle**

The prevalence of CE in cattle ranged between 5-11% (Appendix 16). The total economic loss due to CE in cattle was KES 923,950 (table 4.11). There was a general increase in both prevalence and economic loss from 2010-2014 (figures 4.6 and 4.7).



**Figure 4.6: Prevalence trend of CE in cattle slaughtered in Laikipia west sub county 2010-2014**

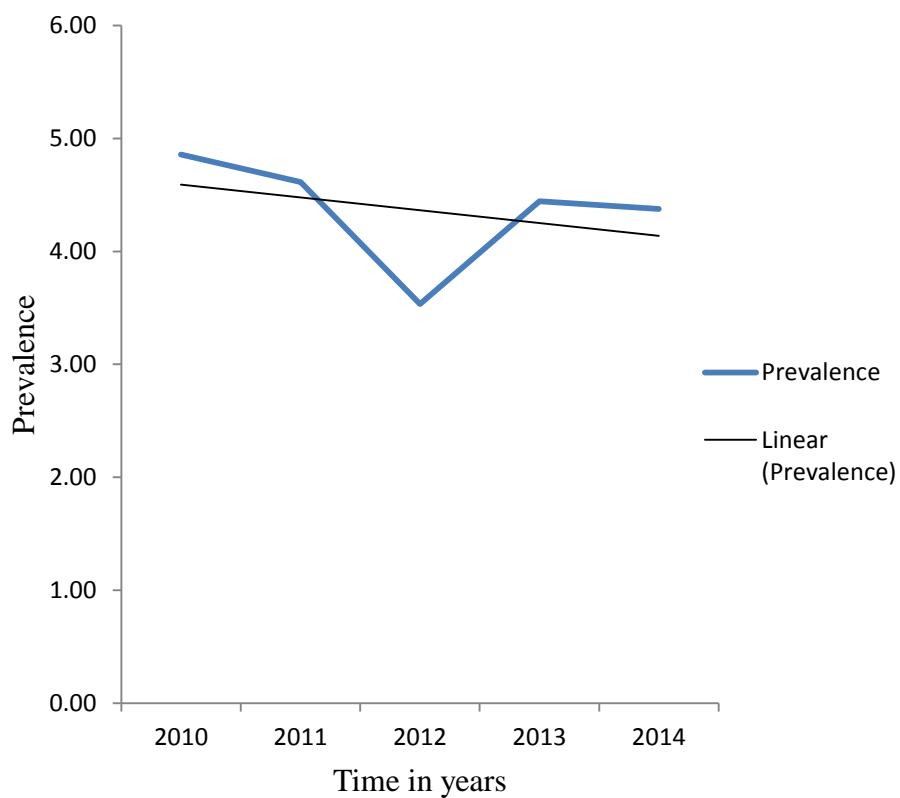


**Figure 4.7: Trend in total economic loss due to CE in cattle slaughtered in Laikipia west sub county 2010-2014**

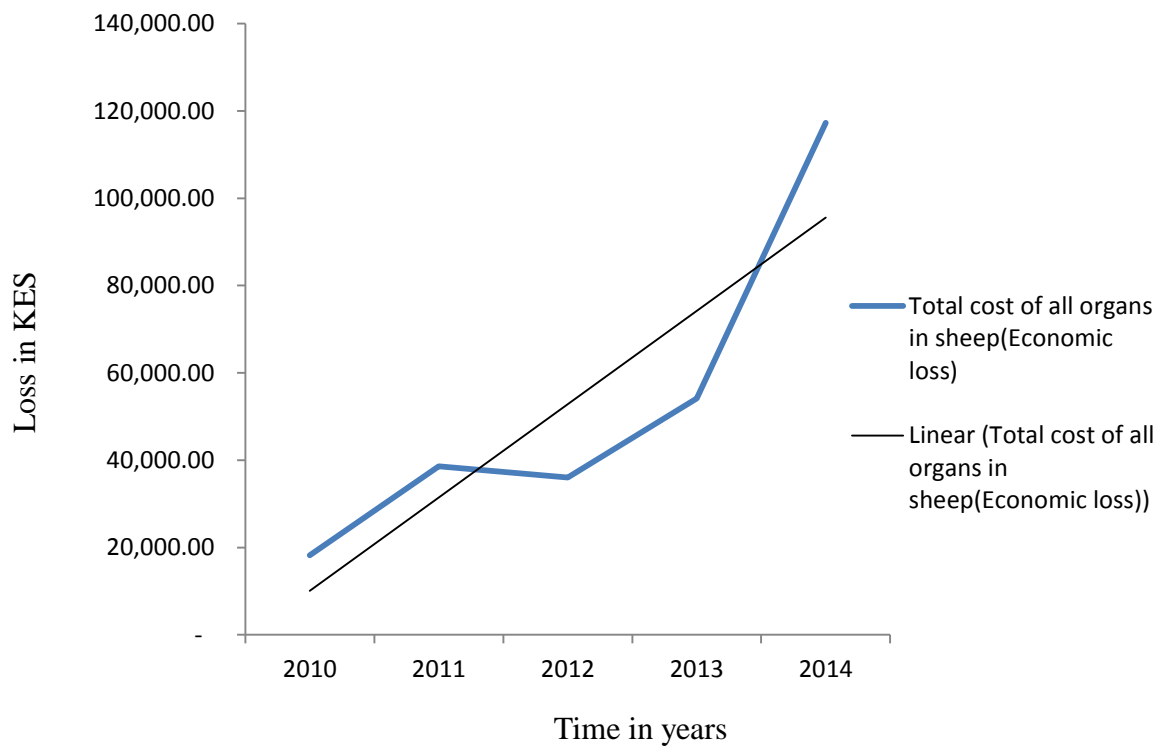
#### **4.4.3 Trends in prevalence and economic losses due to CE in sheep**

The prevalence in sheep ranged between 3-5% (Appendix 16). The trend line showed a slight declining prevalence (Figure 4.8). The total economic loss was KES 264,290

(table 4.11) and there was a general increasing trend in economic loss due to organ condemnation (figure 4.9).



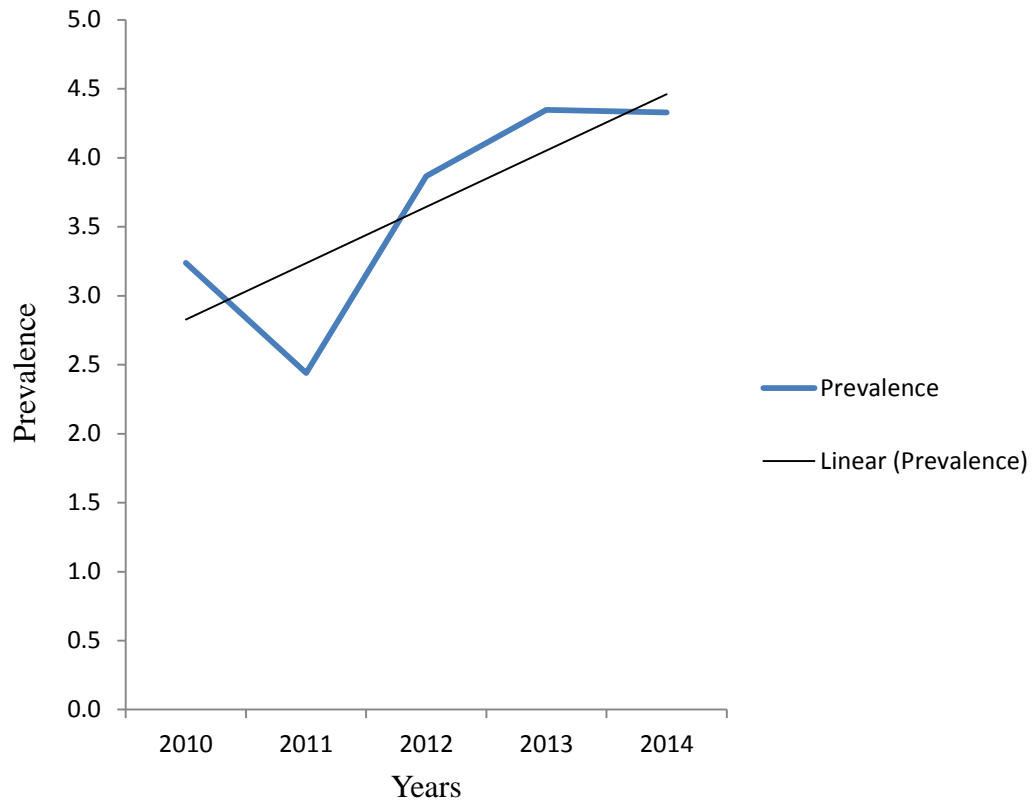
**Figure 4.8: Prevalence trend of CE in sheep slaughtered in Laikipia west sub county 2010-2014**



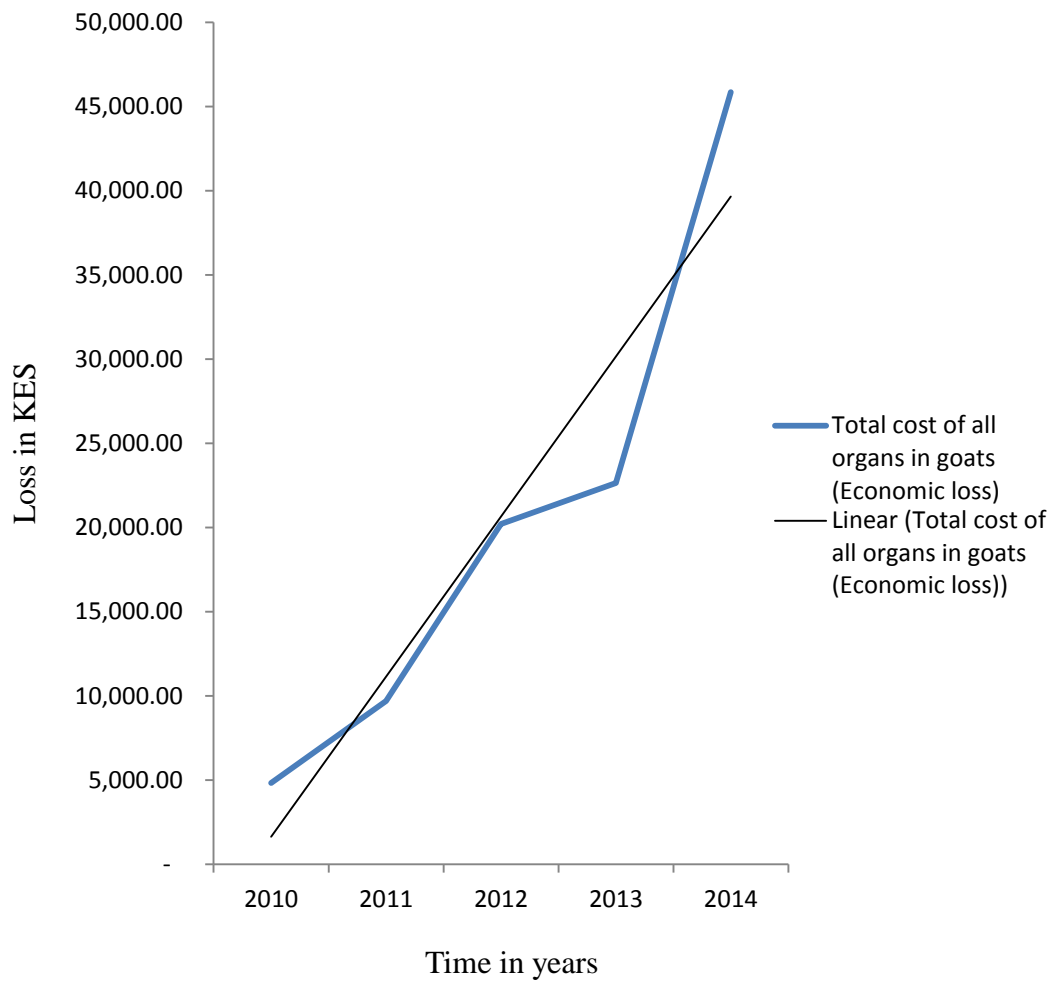
**Figure 4.9: Trend in total economic loss due to CE in sheep slaughtered in Laikipia west sub county 2010-2014**

#### **4.4.4 Trends in prevalence and economic loss due to CE in goats**

The total economic loss due CE in goats was KES 103,220 (Table 4.11). There was a general increasing trend both in prevalence and economic loss (Figures 4.10 and 4.11).



**Figure 4.10: Prevalence trend of CE in goats slaughtered in Laikipia west sub county 2010-2014**



**Figure 4.11: Trend in economic loss due to CE in goats slaughtered in Laikipia west sub county 2010-2014**

## CHAPTER FIVE

### DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

#### 5.1 Discussion

##### 5.1.1 Prevalence of Cystic Echinococcosis in cattle, sheep and goats

In this study, cattle had the highest prevalence of CE (8.8%) which corroborates reports from previous studies in Kenya, except that the proportions are different (Njoroge *et al.*, 2002, Addy *et al.* 2012, Mbaya *et al.*, 2014). When compared to the most recent survey in Kenya by Mbaya *et al.*, (2014) from a non CE hot spot area in central Kenya, the prevalences in this study were higher by a factor of four in cattle and goats and lower by about a half a factor in sheep. The prevalence in cattle was just about a half of that from the two known CE hot spot areas of Turkana and Maasailand (Njoroge *et al.*, 2002, Addy *et al.*, 2012) while that of sheep and goats was about a half of what was reported by Njoroge *et al.*, (2002) from Turkana. The differences in prevalence between studies could be attributed to the difference in sample sizes; with the smaller sizes being more likely to have a higher degree of bias (Njoroge *et al.*, 2002). Other factors that influence the difference in prevalence include origin of animals, individual variation in cysts detection during postmortem examination, frequency of home slaughter, feeding of dogs with raw offals and the dog population (Njoroge *et al.*, 2002, Buishi *et al.*, 2006, Kisenge 2008 and Addy *et al.*, 2012).

Except for the study by Mbaya *et al.*, (2014), the prevalence agrees with similar studies done elsewhere in Kenya whose results showed that cattle were leading in prevalence (Ndirangu *et al.*, 2004, Njoroge *et al.*, 2002, Addy *et al.*, 2012). Examples of other studies from outside Kenya with similar trends include North Africa (Bardonet *et al.*, 2003); Sudan (Ibrahim *et al.*, 2011) and Ethiopia (Fromsa and Jobre, 2011). In Sudan however, more studies show sheep as the leading species when compared to cattle (Omer *et al.*, 2010, and Mohamed, 2013). The results of this study show that sheep contributed the highest proportion to the overall prevalence while goats contributed the least. Among the animals slaughtered, cattle were more likely to have CE than sheep or goats. This could be explained by the fact that cattle take longer to mature for slaughter and since CE develops slowly, lesions are more likely to be seen in cattle than in sheep or goats (Gathura and Kamiya, 1990). The prevalence registered in sheep was the same with that in goats. However, goats being browsers are expected to have lower prevalences compared to sheep which are indiscriminate grazers. The similarity in prevalence could be explained by the difference in their sample sizes.

Despite the ratio of males to females sent for slaughter being equal, CE was more likely in females than males. Although the reasons for this are not clear, in most communities males are more likely to be sent to slaughter at an earlier age than females unless they are selected for breeding. Most females are kept for offspring production and hence they are only sent to slaughter when they become unproductive and this offers cysts time to grow in females unlike the case of younger males.

The lung was the most (68%) frequently parasitized organ and this agrees with results from other studies (Mbaya *et al.*, 2014, Ndirangu *et al.*, 2004, Njoroge *et al.*, 2002, and Gathura and Kamiya 1990) however, it differs from the results of Addy *et al.*, 2012, where the liver was the most affected organ. The consistently higher involvement of the lungs could be explained by the large capillary network and the loose connective tissue structure of the lung where Onchospheres can easily get trapped and develop into cysts (Ndirangu *et al.*, 2004). Even though cattle had the highest prevalence (8.8%) and proportion of cysts recovered (55.4%), sheep had 38.2% but with the highest proportion of fertile cysts 54.5% (cattle had 38.1%) and the results agree with the findings from other similar studies elsewhere (Njoroge *et al.*, 2002, Addy *et al.*, 2012). Given that sheep are more likely to be slaughtered at home during functions and ceremonies where meat inspection is rarely done and consequently improper disposal of organs found unfit for human consumption are more likely to occur; the public health importance of sheep in regards to CE cannot be ignored. The low levels of knowledge on CE reported among both the health professionals and the general public only increases the public health concerns (John *et al.*, 2008, Kagira *et al.*, 2010).

Most of the animals slaughtered (98.5%) were from Laikipia west and these contributed 80% of the positive cases (n=122) while only 1.5% from outside the county contributed 20% of the positive cases. Given that 34% (42/122) of the animals with CE had fertile cysts and that most, (90.5%) of these originated from Laikipia west, there is a high possibility of environmental contamination with

*Echinococcus* eggs in the study site posing danger of both human and livestock infection.

Although most CE positive animals (60%) originated from Rumuruti township ward, it is important to note that there is a big livestock market which receives animals from other counties. The study site is multiethnic with diverse cultural practices. The presence of a large livestock market at Rumuruti encourages both human and livestock movement. This movement, coupled with home slaughter and low levels of knowledge provides fertile ground for the spread and transmission of CE which is considered as an emerging and a re-emerging zoonosis (Eckert *et al.*, 2000): The disease is being reported in areas previously considered clean and it is reappearing in areas where it had been controlled. This is mainly caused by human behavior of exposing the dog to infected offals (Thompson and McManus, 2001).

Majority of the abattoirs (over 60%) slaughter animals from the surrounding areas and hence the features encountered were more likely to be a true reflection of the local area under study. Matuiku/Mwenje, Pesi, Karuga and salama are slaughter slabs and serve as a good example. They received almost 100% of their slaughter animals from the surrounding areas. Animals with fertile cysts were reported from salama abattoir in salama ward and karuga abattoir in Igwamiti ward and this suggests environmental contamination with *Echinococcus* eggs. Ngare Narok meat Industries consistently contributed the highest proportion to the positive animals in all the species and was followed by Pesi in the sheep category despite its low percentage of animals slaughtered. The source of animals for Ngare Narok meat industries is varied

since most animals are from the market. Pesi on the other hand is remote and all the positive animals reported were from mutaara area which borders a ranch.

### **5.1.2 Prevalence of echinococcosis in dogs**

The prevalence of echinococcosis in dogs was 0.5%. Although this is lower than what has been reported from other studies in Kenya, it is an indicator of transmission occurring within the study area and this is very important from a public health point of view. The prevalence was low compared to 33% from Turkana using necropsy method and 26% using coproantigen method (Buishi *et al.*, 2006). It is still lower than what was reported by Wachira *et al.*, (1993b) from Nairobi (10%) and 72% from dogs around dagoretti slaughter house (Wachira *et al.*, 1994). The prevalence is lower than what has been reported from other parts of Africa; Tripoli in Libya 23.6% (Buishi *et al.*, 2005) and Southern Ethiopia 30% (Jones *et al.*, 2012). A recent survey of *Echinococcus* species of carnivores in conservation areas of Kenya by Kagendo *et al.*, (2014), showed the existence of *Echinococcus* from areas surrounding Laikipia County which has conservancies and hence a potential sylvatic cycle source of CE.

Even though the prevalence of echinococcosis in dogs was low; the existence of risk factors such as 93.7% home slaughter, 35% feeding dogs on raw offals, less than 30% level of knowledge of CE and presence of a vibrant livestock economy should raise an alarm of possible transmission of CE to man in the area (Khuroo, 2002). The low levels of prevalence could be explained by the high levels of formal education (over 80%) and the majority of those interviewed cooking for their dogs. More

explanations could be based the periodic shedding of eggs after the worm reaches maturity and the sensitivity of tests used to detect eggs.

### **5.1.3 The level of knowledge of Cystic echinococcosis**

The level of knowledge of CE was 25% and this may be even lower, given that among those who claimed to know CE, some had no idea how the disease is transmitted and that it affects man. Studies by Buishi *et al.*, (2005) and Buishi *et al.*, (2006) reported that a low level of knowledge was a risk factor for transmission of CE in Turkana. In Ethiopia, Dawit *et al.*, (2013) reported that 4.29% of pastoralists were aware of CE and this is about a quarter of what was found in Laikipia west. The findings of similar studies in Uganda and Tanzania reported lower levels too (John *et al.*, 2008; Nyakarahuka *et al.*, 2013). However, the reported level of knowledge was higher than what was reported from Eastern Europe (14%) by Hegglin *et al.*, (2008). The relatively higher level of knowledge when compared to other similar studies from the region is not clear but may be explained by the fact that more than 80% of the participants have had some formal education, they cook food for their dogs and over 70% deworm dogs.

### **5.1.4 Trends in prevalence and economic losses associated with echinococcosis**

The trend in prevalence was increasing with time from 2010-2014 and this was similar to that reported by Ndirangu *et al.*, (2004), using ten years' (1989-1998) data from meat inspection reports from the DVS. Although the overall prevalence in this study was lower, it is comparable to that reported by Ndirangu *et al.*, (2004) from the

Rift Valley region where Laikipia West is located (14.1% in cattle, 15.6% in sheep and 11.8% in goats). Even though the increasing trend in prevalence may not be explained fully, the emerging and reemerging of the disease could be a factor (Eckert, 2000). Other contributing factors could be low levels of knowledge and the accompanying risk factors for CE.

In a similar study (1985-1999) from Ethiopia; Fromsa and Jobre (2011) reported prevalence of 35.15%, 11.78% and 4.9% in cattle sheep and goats respectively. In Iraq during the period 1990-1998, the prevalence was 15%, 6.2% and 10.9% in cattle sheep and goats respectively but with a decreasing trend (Saeed *et al.*, 2000). A similar survey in the same country (1999-2004) showed a further decline in trends (Ansari-Lari, 2005) and this was explained by the enforcement of a vigorous control programme which included prosecution of those found slaughtering at home.

Organ condemnation in this study was highest in cattle followed by sheep and then goats and this agrees with a survey carried out for the whole country from 1977-1988 by Gathura and Gathuma (1991). The annual economic loss due to CE condemnations was US\$1847.9 in cattle and US\$735.021984 in shoats and this was low when compared to what was reported by Gathura and Gathuma (1991). This could be explained by the relatively higher prevalences in earlier studies and hence more organs condemnation. The increasing trend in organ condemnation may be due to the relative increase in prevalence and the increasing unit price of the organs condemned.

Despite the prevalence reported in this study being lower than what has been reported from similar studies elsewhere as explained above, the relatively increasing trends in prevalence that corresponds to prevalence from abattoirs in this study is worrying. These facts point to the reality of the emerging and re-emerging phenomena of CE as explained by Eckert *et al.*, (2000).

## **5.2 Conclusions**

1. The prevalence of CE in slaughtered livestock (cattle, sheep and goats) in Laikipia West Sub County range from 1.7% to 8.8%.
2. The prevalence of Echinococcosis in dogs in Laikipia West Sub County is 0.5%.
3. The level of knowledge of CE among the population of Laikipia west Sub County is 25%.
4. Except for sheep which showed a slight decreasing trend in prevalence against time, there was a general upward trend in prevalence and economic loss in livestock slaughtered in Laikipia west Sub-county from 2010 to 2014.

## **5.3 Recommendations**

1. Enhanced Public health education is recommended in order to raise the level of knowledge of echinococcosis in the study area.

2. More elaborate epidemiological studies involving humans and dogs from the study site are recommended with a focus on prevalence in man and associated risk factors.

## REFERENCES

- Addy, F., Alakonya, A., Wamae, N., Magambo, J., Mbae, C., Mulinge, E., ... & Romig, T. (2012). Prevalence and diversity of cystic Echinococcosis in livestock in Maasailand, Kenya. *Parasitology Research*, *111*, 2289-2294.
- Ahmadi, N.A. and Meshkehkar, M. (2011). An abattoir-based study on the prevalence and economic losses due to cystic Echinococcosis in slaughtered herbivores in Ahwaz, south-Western Iran. *Journal of Helminthology*, *85*, 33–39.
- Allan, J. C., Craig, P. S., Garcia-Noval, J., Mencos, F., Liu, D., Wang, Y. & Zeyhle, E. (1992). Coproantigen detection for immunodiagnosis of Echinococcosis and taeniasis in dogs and humans. *Parasitology*, *104*, 347–355.
- Ammann, R.W. & Eckert J. (1995). *Clinical diagnosis and treatment of Echinococcosis in humans*. In *Echinococcus and hydatid disease* (R.C.A. Thompson and A.J. Lymbery, Eds). CAB International, Wallingford, Oxon, 411-463.
- Ansari-Lari, M. (2005). A retrospective survey of hydatidosis in livestock in Shiraz, Iran, based on abattoir data during 1999-2004. *Veterinary Parasitology*, *133*(1), 119-23.
- Azlaf, R. & Dakkak, A. (2006). Epidemiological study of the cystic Echinococcosis in Morocco. *Veterinary parasitology*, *137*(1), 83-93.
- Baldock, F.C., Arthur, R.J. & Lawrence, A.R. (1985). A meat works survey of bovine hydatidosis in Southern Queensland. *Australian*

*Veterinary Journal*, 62(7), 238-242.

- Bardonnet, K., Benchikh-Elfegoun, M.C., Bart, J.M., Harraga, S., Hannache, N., Haddad, S. ...& Piarroux, R. (2003). Cystic Echinococcosis in Algeria: cattle act as reservoirs of a sheep strain and may contribute to human contamination. *Veterinary Parasitology*, 116, 35–44.
- Birhanu, T. (2014). Prevalence, Financial Loss and Public Health Significance of Ovine Hydatidosis in Adama Municipal Abattoir, Ethiopia. *Natural Sciences*, 12(10), 176-182.
- Bowles, J. & McManus, D.P. (1993). Molecular variation in *Echinococcus*. *Acta Tropica*, 53, 291-305.
- Bowles, J., Blair, D. & McManus, D.P. (1995). A molecular phylogeny of the genus *Echinococcus*. *Parasitology*, 110, 317-328.
- Bowles, J., Blair, D. & McManus, D.P. (1992). Genetic variants within the genus *Echinococcus* identified by mitochondrial DNA sequencing. *Molecular and Biochemical Parasitology*, 54, 165–174.
- Budke, C.M., Deplazes, P. & Torgerson, P.R. (2006). Global socioeconomic impact of cystic echinococcosis. *Emerging Infectious Diseases*, 12, 296-303.
- Buishi, I. E., Njoroge, E. M., Bouamra, O. & Craig, P. S. (2005). Canine Echinococcosis in Northwest Libya: assessment of coproantigen ELISA, and a survey of infection with analysis of risk-factors. *Veterinary parasitology*, 130(3), 223-232.
- Buishi, I., Njoroge, E., Zeyhle, E., Rogan, M. T. & Craig, P. S. (2006). Canine

- Echinococcosis in Turkana (North–Western Kenya): a coproantigen survey in the previous hydatid-control area and an analysis of risk factors. *Annals of tropical medicine and parasitology*, 100(7), 601-610.
- Burridge, M.J. & Schwabe, C. W. (1977). Epidemiological analysis of factors influencing rate of progress in *E.granulosus* control in New Zealand. *Journal of hygiene Cambridge*, 78, 151.
- Centers for Disease Control and Prevention. Life cycles of *Echinococcus granulosus*. Retrieved from: <http://www.dpd.cdc.gov/dpdx/html/Echinococcosis.htm>.
- Craig, P.S. (1997). *Immunodiagnosis of Echinococcus granulosus and a comparison of techniques for diagnosis of canine Echinococcosis*. In: Andersen, F.L., Ouhelli, H., Kachani, M. (Eds.), *Compendium on Cystic Echinococcosis in Africa and in Middle Eastern Countries with Special Reference to Morocco*, Brigham Young University, Provo, UT, p. 85–118.
- Craig, P. S., McManus, D. P., Lightowers, M. W., Chabalgoity, J. A., Garcia, H. H., Gavidia, C. M., ... & Schantz, P. M. (2007). Prevention and control of cystic Echinococcosis. *The Lancet infectious diseases*, 7(6), 385-394.
- Dar, F.K. and Alkarmi, T. (1997). Public health aspects of cystic Echinococcosis in the Arab countries. *Acta Tropica*, 67, 125-132.
- Daryani, A., Alaei, R., Arab, R., Sharif, M., Dehghan, M. H. & Ziaei H (2007). Prevalence, intensity and viability of hydatid cysts in slaughtered animals in the Ardabil province of Northwest Iran. *Journal of Helminthology*, 81(1), 13–17.
- Dawit, G., Adem, A., Simenew, K. & Tilahun, Z. (2013). Prevalence, cyst

- characterization and economic importance of bovine Hydatidosis in Mekelle municipality abattoir, Northern Ethiopia. *Journal of Veterinary Medicine and Animal Health*, 5(3), 87-93.
- Dawit G., Aklilu, F., Gebregergs, T., Hasen, A. & Ykealo, T. (2013). Knowledge, Attitude and Practices of Hydatidosis in Pastoral Community with Relation to Public Health Risks in Ayssaita, Northeastern of Ethiopia. *Global Veterinaria*, 11(3), 272-279.
- Deplazes, P., Gottstein, B., Eckert, J., Jenkins, D.J., Ewald, D. & Jimenez-Palacios, S. (1992). Detection of *Echinococcus* coproantigens by enzyme-linked Immunosorbent assay in dogs, dingoes and foxes. *Parasitology Research*, 78, 303–308.
- Derylo, A. and Szilman, P. (1998). Prevalence of Echinococcosis in swine, beef-cattle, sheep and goats in Poland during 1995-1997. *Wiadom Parazytol*, 44, 413.
- Dinkel, A., Njoroge, E.M., Zimmermann, A., Walz, M., Zeyhle, E., Elmahdi, I. E., ... & Romig, T. (2004). A PCR system for detection of species and genotypes of *Echinococcus granulosus*-complex, with reference to the epidemiological situation in Eastern Africa. *International Journal for Parasitology*, 34(5), 645-653.
- Eckert, J., Conraths, F.J. & Tackmann, K. (2000). *Echinococcosis*: an emerging or re-emerging zoonosis? *International Journal for Parasitology*, 30, 1283-1294.
- Eckert, J. & Deplazes, P. (2004). Biological, epidemiological, and clinical aspects of

- Echinococcosis, a zoonosis of increasing concern. *Clinical microbiology reviews*, 17(1), 107-135.
- Ernest, E., Nonga, H.E., Kassuku, A.A. & Kazwala, R.R. (2009). Hydatidosis of slaughtered animals in Ngorongoro Sub-County of Arusha region, Tanzania. *Tropical Animal Health and Production*, 41, 1179-1185.
- Fischer, A. A., Laing, J. E. and Strocker, J.E. (1998). *Handbook for Family Planning, Operation Research Design in Sampling*. Population Council, 40-45.
- French, C.M. & Nelson, G.S. (1982). Hydatid disease in the Turkana Sub-County of Kenya II. A study in medical geography. *Annals of Tropical Medicine and Parasitology*, 76, 439-457.
- French, C.M., Nelson, G.S. & Wood, M. (1982). Hydatid disease in the Turkana district of Kenya. I. The background to the problem with hypotheses to account for the remarkably high prevalence of the disease in man. *Annals of Tropical Medicine and Parasitology*, 76, 425-437.
- Fromsa, A. & Jobre, Y. (2011). Infection prevalence of (*Echinococcus granulosus*, Batsch, 1786) in domestic animals in Ethiopia: A synthesis report of previous surveys. *Ethiopian veterinary journal*, 15(2).
- Gathura, P.B. & Kamiya, M. (1990). Echinococcosis in Kenya: Transmission characteristics, incidence and control measures. *Japanese Journal of Veterinary Research*, 38, 107-116.
- Gathura, P.B. & Gathuma, J. (1991). An evaluation of the economic losses resulting

- from condemnation of cattle and small stock livers due to the presence of hydatid cysts in Kenya. *Bulletin of animal Health and Production in Africa*. 39(2), 225 – 229.
- Gemmell, M.A., Lawson, J.R. & Roberts, M.G. (1986). Control of Echinococcosis. *Bulletin of the World Health Organization*, 64, 333-339.
- Grove, D.F. (1990). *A History of human helminthology*. CAB International, Wellingford, UK
- Haftu, B. & T. Kebede. (2015). Study on Prevalence Economic Significance of Bovine in Bako Municipal Abattoir, West Shoa zone, Oromiya Regional State, Ethiopia. *Global Journal of Animal Scientific Research*, 3(1), 109-118.
- Heath, D.D, Jensen, O. & Lightowlers, M.W. (2003). Progress in control of Echinococcosis using vaccination—a review of formulation and delivery of the vaccine and recommendations for practical use in control programs. *Acta Tropica*, 85, 133-43.
- Hegglin, D., Bontadina, F., Gloor, S., Romig, T., Deplazes, P. & Kern, P. (2008). Survey of public knowledge about *E. multilocularis* in four European countries. Need for proactive information. *BMC Public Health*, 8, (247), 1-11.
- Hüttner, M., Nakao, M., Wassermann, T., Siefert, L., Boomker, J.D., Dinkel, A., ... & Ito, A. (2008). Genetic characterization and phylogenetic position of *Echinococcus felidis* (Cestoda: Taeniidae) from the African lion. *International journal for parasitology*, 38(7), 861–868.
- Hüttner, M., Siefert, L., Mackenstedt, U. & Romig, T. (2009). A survey of

- Echinococcus* species in wild carnivores and livestock in East Africa. *International journal for parasitology*, 39(11), 1269-1276.
- Ibrahim, K., Thomas, R., Peter, K. & Omer, R. A. (2011). A molecular survey on cystic Echinococcosis in Sinnar area, Blue Nile state (Sudan). *Chinese medical journal*, 124(18), 2829-2833.
- Jenkins, D.J., Fraser, A., Bradshaw, H. & Craig, P.S. (2000). Detection of *Echinococcus granulosus* coproantigens in Australian canids with natural or experimental infection. *Journal of Parasitology*, 86, 140–145.
- John, K., Kazwala, R. & Mfinanga, G.S. (2008). Knowledge of causes, clinical features and diagnosis of common zoonoses among medical practitioners in Tanzania. *BMC Infectious Diseases*, 2, 162-169.
- Jones, O., Kebede, N., Kassa, T., Tilahun, G. & Macias, C. (2012). Occurrence of bovine Hydatidosis and evaluation of its risk to humans in traditional communities of Southern Region of Ethiopia. *Ethiopian Journal of Health and Development*, 26 (1), 43-48.
- Kagendo, D., Magambo, J., Agola, E. L., Njenga, S. M., Zeyhle, E., Mulinge, E., ... & Romig, T. (2014). A survey for *Echinococcus* spp. of carnivores in six wildlife conservation areas in Kenya. *Parasitology international*, 63(4), 604-611.
- Kagira, J.M. & Kanyari, W.N. (2010). The role of veterinary and medical personnel in the control of zoonoses in urban settlements on the shores of Lake Victoria, Kenya. *Science Parasitology*, 1, 61-66.
- Kassa, B.G., Yeshe, M.M., Abraha, A.H., & Gebremariam T.T. (2014). BMC

Resources notes; 11(7), 631.

Khuroo, M.S. (2002). Hydatid disease: current status and recent advances. *Annals of Saudi Medicine*, 122, 56-64.

Kisenge, K.E. (2008). *The prevalence and risk factors of Hydatidosis in man, sheep and goats in Northwestern District of Turkana, Kenya*. Unpublished MSc Thesis, Nairobi: University of Nairobi.

Kenya National Bureau of Statistics, (2010). The 2009 Kenya Population and Housing Census. Retrieved from: <http://www.knbs.or.ke/index/php/html>.

Macpherson, C. N. L., Wachira, T. M., Zehyle, E., Romig, T. & Macpherson, C. (1986). Hydatid disease: research and control in Turkana. IV. The pilot control programme. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 80, 196–200.

Macpherson, C.N., Zeyhle, E. & Romig, T. (1984). An *Echinococcus* pilot control programme for North-West Turkana, Kenya. *Annals of Tropical Medicine and Parasitology*, 78, 188 – 192.

Macpherson, C.N.L., French, C.M., Stevenson, P., Karstad, L. & Arundel, J.H. (1985). Hydatid disease in the Turkana District of Kenya IV. The prevalence of *Echinococcus granulosus* infections in dogs, and observations on the role of the dog in the lifestyle of the Turkana. *Annals of Tropical Medicine and Parasitology*, 79, 51–61.

Macpherson, C.N.L. & Wachira, T.M. (1997). *Cystic Echinococcosis in Africa south of the Sahara*, In: Andersen, F.L., Ouhelli, H., Kachani, M., (Eds.), *Compendium of Cystic Echinococcosis in Africa and in Middle Eastern*

- Countries with Special Reference to Morocco. Brigham Young University, Provo, p. 245–277.
- Magambo, J., Njoroge, E. & Zeyhle, E. (2006). Epidemiology and control of Echinococcosis in sub-Saharan Africa. *Parasitology International*, 55, 193–195.
- Maillard, S., Gottstein, B., Haag, K.L., Ma, S., Colovic, I., Benchikh-Elfegoun, M.C. & Piarroux, R. (2009). The EmsB tandemly repeated multilocus microsatellite: a new tool to investigate genetic diversity of *Echinococcus granulosus* sensu lato. *Journal of Clinical Microbiology*, 47, 3608–3616.
- Mathis, A., Deplazes, P. & Eckert, J. (1996). Improved test system for PCR based specific detection of *Echinococcus multilocularis* eggs. *Journal of Helminthology*, 70, 219–222.
- Mbaya, H., Magambo, J., Njenga, S., Zeyhle, E., Mbae, C., Mulinge, E., ... & Romig T. (2014). *Echinococcus* spp. in central Kenya: a different story. *Parasitology research*, 113(10), 3789-3794.
- McManus, D. P., Zhang, W., Li, J. & Bartley, P. B. (2003). Echinococcosis. *The Lancet*, 362(9392), 1295-1304.
- Mogoye, B. K., Menezes, C. N., Wong, M. L., Stacey, S., von Delft, D., Wahlers, K. & Freaan, J. (2013). First insights into species and genotypes of *Echinococcus* in South Africa. *Veterinary parasitology*, 196(3), 427-432.
- Mohamed, S. S. (2013). Prevalence, Health and Economical Impacts of Liver Diseases in Slaughtered Cattle and Sheep during 2009-2012 at Alkadroo Abattoir. *Sudan Journal of Applied and Industrial Sciences*, 1(3), 6-11.

- Moro, P. & Schantz, P.M. (2009). Echinococcosis: a review. *International Journal of Infectious Diseases*, 13, 125-133.
- Moro, P.L. & Schantz, P.M. (2006). Echinococcosis: historical landmarks and progress in research and control. *Annals of Tropical Medicine and Parasitology*, 100, 703-714. Review.
- Nakao, M., Sako, Y. & Ito A (2003). Isolation of polymorphic microsatellite loci from the tapeworm *Echinococcus multilocularis*. *Infection Genetics and Evolution* 3(3), 159-163.
- Nakao, M., McManus, D.P., Schantz, P.M., Craig, P.S. & Ito, A. (2007). A molecular phylogeny of the genus *Echinococcus* inferred from complete mitochondrial genomes. *Parasitology*, 134, 713–722.
- Ndirangu, P.N., Njeruh, F.M., Gathura, P.B. & Kyule, M.N. (2004). The prevalence of Hydatidosis in slaughtered livestock in Kenya. *The Kenya Veterinarian*, 27, 73-77
- Nelson, G.S. & Rausch, R.L. (1963). *Echinococcus* infections in man and animals in Kenya. *Annals of Tropical Medicine and Parasitology*, 57, 136-149.
- Ngatia, C.G. (1993). *An evaluation of the pilot hydatid control project in Northwestern Turkana District, Kenya*. Unpublished MSc Thesis Nairobi: University of Nairobi.
- Njoroge, E.M., Mbithi, P.M., Gathuma, J.M., Wachira, T.M., Gathura, P.B., Magambo, J.K. & Zeyhle, E. (2002). A study of cystic Echinococcosis in slaughter animals in three selected areas of Northern Turkana, Kenya. *Veterinary Parasitology*, 104: 85-91.

- Njoroge, E.M. (2001). *Evaluation of ultrasonographic diagnostic, treatment and epidemiology in sheep and goats*. Unpublished MSC dissertation, Nairobi: University of Nairobi.
- Nyakarahuka, L., Lalobo-Oryema, M., Kankya, C., Siefert, L., Ocaido, M. & Ejobi, F. (2013). Knowledge, attitudes and practices towards CE in Pastoral communities in Kasese district, Uganda. *Advance Tropical Medicine and Public Health International*, 3(1), 10 - 24.
- Odero, J., Magambo, J., Zeyhle, E., Kutima, H., Ndahi, L., Njoroge, F., ... & Romig, T. (2014). The monetary burden of cystic Echinococcosis and its distribution based on gender and age in Turkana North District, Kenya. *Asian Journal of Pharmaceutical and Health Sciences*, 4(4).
- Omer, R. A., Dinkel, A., Romig, T., Mackenstedt, U., Elnahas, A. A., Aradaib, I. E., ... & Adam, A. (2010). A molecular survey of cystic Echinococcosis in Sudan. *Veterinary parasitology*, 169(3), 340-346.
- Pawłowski, Z.S. (1997b). – *Critical points in the clinical management of cystic Echinococcosis: a revised review*. In Compendium on cystic Echinococcosis in Africa and in Middle Eastern Countries with special reference to Morocco (F.L. Andersen, H. Ouhelli and M. Kachani, Eds). Brigham Young University, Print Services, Provo, Utah, 119-135.
- Perdomo, R., Alvarez, C., Monti, J., Ferreira, C., Chiesa, A., Carbò, A. & Yazarbal, L. (1997). Principles of the surgical approach in human liver cystic Echinococcosis. *Acta Tropica*, 64, 109-122.
- Romig, T., Omer, R. A., Zeyhle, E., Hüttner, M., Dinkel, A., Siefert, L. & Kern, P.

- (2011). Echinococcosis in sub-Saharan Africa: emerging complexity. *Veterinary parasitology*, 181(1), 43-47.
- Romig, T., Zeyhle, E., Macpherson, C.N.L., Rees, P.H. & Were, J.B. (1986). Cyst growth and spontaneous cure in hydatid disease. *The Lancet*, 1 (8485), 861.
- Saeed, I., Kapel, C., Saida, L. A., Willingham, L. & Nansen, P. (2000). Epidemiology of *E.granulosus* in Arbil Province Northern Iraq. *Journal of Helminthology*, 74(1), 83-8.
- Thompson, R.C.A. (1995). *Biology and systematics of Echinococcus*. In *Echinococcus and hydatid disease* (R.C.A. Thompson and A.J. Lymbery, Eds). CAB International, Wallingford, UK 1-50.
- Thompson, R. A. & Allsopp, C. E. (1988). *Hydatidosis: veterinary perspectives and annotated bibliography*. CAB international Wallingford, UK.
- Thompson, R.C. & McManus, D.P. (2002). Towards a taxonomic revision of the genus *Echinococcus*. *Trends in Parasitology*, 18, 452-457. Review.
- Thompson, R.C. & McManus, D.P. (2001). *Aetiology: Parasites and Life cycles of Echinococcus* in WHO/OIE (Eds) Manual on Echinococcosis in humans and animals. World Health Organization and World Organization for Animal Health, Paris: France.
- Thrusfield, M. V. (1986). *Veterinary epidemiology*. London: Butterworth.
- Torgerson, P. R. & Budke, C. M. (2003). Echinococcosis—an international public health challenge. *Research in veterinary science*, 74(3), 191-202.
- Trachsel, D., Deplazes, P. & Mathis, A.(2007). Identification of eggs of canine taeniids by multiplex PCR. *Parasitology*, 134, 911–920.

- Veit P., Bilger B., Schad V., Schäfer J., Frank W. & Lucius R. (1995). – Influence of environmental factors on the infectivity of *Echinococcus multilocularis* eggs. *Parasitology*, 110, 79-86.
- Wachira, T. M., Bowles, J., Zeyhle, E. & McManus, D. P. (1993a). Molecular examination of the sympatry and distribution of sheep and camel strains of *Echinococcus granulosus* in Kenya. *The American journal of tropical medicine and hygiene*, 48(4), 473-479.
- Wachira, T.M., Sattran, M., Zeyhle, E. & Njenga, M. (1994). Abattoirs and Echinococcosis in Nairobi dogs. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 88, 166.
- Wachira, T.M., Sattran, M., Zeyhle, E. & Njenga, M.K. (1993b). Intestinal helminths of public health importance in dogs in Nairobi. *East African Medical Journal*, 70, 617-619.
- Wassermann, M., Aschenborn, O., Aschenborn, J., Mackenstedt, U. & Romig, T. (2015). A sylvatic lifecycle of *Echinococcus equinus* in the Etosha National Park, Namibia. *International Journal for Parasitology: Parasites and Wildlife*, 4(1), 97-103.
- Watson-Jones, D.L. & Macpherson, C.N.L. (1988). Hydatid disease in the Turkana District of Kenya, VI. Man: dog contact and its role in the transmission and control of Hydatidosis amongst the Turkana. *Annals of Tropical Medicine and Parasitology*, 82, 343–356.
- Wen, H. & Yang, W.G. (1997). Public health importance of cystic Echinococcosis in China. *Acta Tropica*, 67, 133-145.

- WHO, (2013). *Sustaining the drive to overcome the global impact of neglected tropical diseases: second WHO report on neglected diseases*. World Health Organization: Geneva
- WHO/OIE, (2001). *Manual on Echinococcosis in humans and animals*. World Health Organization and World Organization for Animal Health, Paris: France
- World Health Organization, (1996). Guidelines for treatment of cystic and alveolar Echinococcosis. WHO Informal Working Group on Echinococcosis. *Bulletin of the World Health Organization*, 74, 231-242.
- Xiao, N., Qiu, J., Nakao, M., Li, T., Yang, W., Chen, X. & Ito, A. (2005). *Echinococcus shiquicus* species, a taeniid cestode from Tibetan fox and plateau pika in China. *International Journal for Parasitology*, 35, 693-701.
- Zhang, W., Zhang, Z., Shi, B., Li, J., You, H. & Tulson, G. (2006). Vaccination of dogs against *Echinococcus granulosus*, the cause of cystic hydatid disease in humans. *Journal of Infectious Diseases*, 194, 966—74.
- Zhang, W., Zhang, Z., Wu, W., Shi, B., Li J., Zhou, X., ... & McManus, D.P. (2015). Epidemiology and control of Echinococcosis in central Asia, with particular reference to the People's Republic of China. *Acta Tropica*, 141, 235–243.
- Zhang, W., Zhang, Z., Yimit, T., Shi, B., Aili, H., Tulson, G., ... & Wang, J. (2009). A pilot study for control of hyper endemic cystic hydatid disease in China. *PloS Neglected Tropical Diseases*, 3, 534.

## APPENDICES

### Appendix 1: Laikipia West Abattoirs 2015

| Serial No. | Abattoir name                  | Ward     | Location(administrative) |
|------------|--------------------------------|----------|--------------------------|
| 1          | Laikipia County Government S/H | Igwamiti | Nyahururu town           |
| 2          | Manguo S/Slab                  | Igwamiti | Manguo                   |
| 3.         | Karuga S/Slab                  | Igwamiti | Karuga                   |
| 4.         | Kanyamwi S/Slab                | Igwamiti | Gatero                   |
| 5.         | Kabucho S/Slab                 | Igwamiti | Gatero                   |
| 6.         | Laikipia County Govt S/Slab    | Githiga  | kinamba                  |
| 7.         | Matuiku S/Slab                 | Githiga  | Matuiku -Mwenje          |
| 8.         | Mastoo S/Slab                  | Githiga  | Mastoo- Mwenje           |
| 9.         | Laikipia County Govt S/Slab    | Olmoran  | Sipili                   |
| 10.        | Olmoran S/Slab                 | Olmoran  | Olmoran                  |
| 11.        | Gatundia S/Slab                | Marmanet | Gatundia                 |
| 12.        | Muhotetu S/Slab                | Marmanet | Mutanga                  |
| 13.        | Oljabet S/Slab                 | Marmanet | Oljabet                  |
| 14.        | Ngare Narok meat industries    | Rumuruti | Rumuruti                 |
| 15.        | Kiamariga S/Slab               | Salama   | Kiamariga                |
| 16.        | Pesi S/Slab                    | Salama   | Pesi                     |
| 17.        | Salama S/Slab                  | Salama   | Salama                   |

**Appendix 2: Slaughter data collection sheet**

| Month         |        |     |   |       |                     |   |                                      |   |       |       |   |       |                 |                 |                     |          |                       |  |          |          |
|---------------|--------|-----|---|-------|---------------------|---|--------------------------------------|---|-------|-------|---|-------|-----------------|-----------------|---------------------|----------|-----------------------|--|----------|----------|
| Abattoir name |        |     |   |       |                     |   |                                      |   |       |       |   |       |                 |                 |                     |          |                       |  |          |          |
| Date          | Spp    | Sex |   | Total | Negative (no cysts) |   | Positive (organs with cysts)-Numbers |   |       |       |   |       |                 | Laikipia County |                     |          |                       | Extra County (Specify name and number) |          |          |
|               |        | M   | F |       | M                   | F | Lung                                 |   | Total | Liver |   | Total | other (specify) |                 | Sub County Location |          | Other County Location |  | Positive | Negative |
|               |        | M   | F |       | M                   | F | M                                    | F |       | M     | F |       | M               | F               | Positive            | Negative | Positive              | Negative                               | Positive | Negative |
|               | Cattle |     |   |       |                     |   |                                      |   |       |       |   |       |                 |                 |                     |          |                       |  |          |          |
|               | Sheep  |     |   |       |                     |   |                                      |   |       |       |   |       |                 |                 |                     |          |                       |  |          |          |
|               | Goats  |     |   |       |                     |   |                                      |   |       |       |   |       |                 |                 |                     |          |                       |  |          |          |
|               | Cattle |     |   |       |                     |   |                                      |   |       |       |   |       |                 |                 |                     |          |                       |  |          |          |
|               | Sheep  |     |   |       |                     |   |                                      |   |       |       |   |       |                 |                 |                     |          |                       |  |          |          |
|               | Goats  |     |   |       |                     |   |                                      |   |       |       |   |       |                 |                 |                     |          |                       |  |          |          |
| <b>TOTALS</b> |        |     |   |       |                     |   |                                      |   |       |       |   |       |                 |                 |                     |          |                       |  |          |          |

### Appendix 3: Letter of introduction from the Deputy County Commissioner Nyahururu



OFFICE OF THE PRESIDENT  
MINISTRY OF INTERIOR AND COORDINATION OF NATIONAL GOVERNMENT

Telegram: "DISTRICTER"  
Telephone: 065 2022100  
When replying please quote:

The Deputy County Commissioner  
Nyahururu Sub-County -**LAIKIPIA**  
P.O. Box 2003-20300  
**NYAHURURU**

Ref No **NHR/ED/12/8/VOL.I/(199)**  
and date  
Email -[dcnyahururu@yahoo.com](mailto:dcnyahururu@yahoo.com)  
Fax Line -0652022100

29<sup>th</sup> September, 2015

**TO WHOM IT MAY CONCERN**  
**NYAHURURU SUB-COUNTY**

**RE: APPROVAL TO CARRY OUT STUDY ON PREVALENCE EHINOCOCCOSIS IN DOGS, CATTLE, SHEEP AND GOAT; THE LEVEL OF AWARENES AND ASSOCIATED ECONOMIC LOSES IN NYAHURURU SUB-COUNTY**

This is to confirm that Mabel Inyangala Gachengo has been authorized to carry out research on the above mentioned topic within the Sub-county. Kindly give her any necessary assistance.

  
**LUCY NDEMO**  
**FOR: DEPUTY COUNTY COMMISSIONER**  
**NYAHURURU**

#### Appendix 4: Questionnaire

### PREVALENCE OF ECHINOCOCCOSIS IN DOGS, CATTLE, SHEEP AND GOATS, THE LEVEL OF AWARENESS AND ASSOCIATED ECONOMIC LOSSES IN LAIKIPIA WEST SUB-COUNTY, KENYA

Code of the Enumerator .....

Location name: .....

House Hold Questionnaire No: ..... Date: .....

Tick in the box only the most applicable response

1. Gender: Male  Female

2. Age:

18- 25 years

26- 46 years

Above 46 years

3. Ethnicity/Tribe .....

4. Area Location (GPS) .....

5. Education background

No formal education

Primary level

Secondary level

Post-secondary level

6. What is your main source of water? Borehole  Dam

River  Springs  Tap water

Others (specify).....

7. How many dogs do you have a dog in your home?

8. How does your dog mainly get fed? Scavenging  Cooked food Raw

Butchery/slaughterhouse waste

Others (specify).....

9. How often do you deworm the dog(s) per year? Never   
 Once  Twice    
 Others (specify).....
10. Do you know of a disease(s) that you can acquire from a dog? Yes   
 No
11. If yes, which ones are they? Rabies  Malaria   
 Brucellosis  Don't know  
 Others (specify).....
12. Do you know CE? (The participant is shown a photo of an organ with hydatid  
 cysts) Yes  No
13. Who does the disease affect? (Tick appropriately) People   
 Domestic animals  Wild animals  Don't know   
 Others (specify).....
14. Which organs does the disease mainly affect? Lungs  Liver   
 skin  Don't know   
 Others (specify).....
15. How do you recognize the disease at postmortem? Cysts in organs   
 Fluid in lungs  Fluid in abdomen  Don't know   
 Others (specify).....
16. What is the source of transmission of CE to man? Domestic animals   
 Wild animals  dogs  Don't know   
 Others (specify).....
17. Do you slaughter sheep, goat or cattle at home? Yes  No
18. What do you do to organs with hydatid cysts? Give to dogs   
 Burry  Throw in the bush  Eaten by people   
 Others (specify).....

#### KIAMBATISHO 4: KIDADISI/HOJAJI

KIWANGO CHA ECHINOCOCCOSIS KWENYE MBWA, NG'OMBE, KONDOO NA MBUZI, KIWANGO CHA UHAMASISHAJI WA CE NA PIA HASARA INAYO AMBATANA NA CE KATIKA JIMBO NDOGO LA LAIKIPIA MAGHARIBI, KENYA

Kata/Lokesheni: .....

Nambari ya usajili: ..... Tarehe: .....

Weka alama kwenye jibu sahihi

1. Jinsia: Mume  Mke
2. Umri:  
Miaka 18- 25   
Miaka 26- 46   
Zaidi ya miaka 46
3. Kabila: .....
4. Alama ya eneo kwenye Ramani (GPS) .....
5. Elimu: Hajahudhuria shule rasmi  Shule ya msingi   
Sekondari  Elimu ya juu kupita sekondari
6. Je, mara nyingi mnapata maji wapi? Kisima  Bwawa   
Mto  Chemichemi  Maji ya mfereji/Bomba la maji   
Nyingineyo (bainisha).....
7. Je, mna mbwa wangapi nyumbani kwenu?
8. Je, mbwa wenu mara nyingi hupata chakula vipi? Kurandaranda   
Kupikiwa chakula  Mabaki kutoka kwenye kichinjio au bucha bila kupikwa   
Nyingineyo (bainisha).....
9. Unawapatia mbwa wako dawa za minyoo mara ngapi kwa mwaka?  
Hapana/Kamwe  Mara moja  Mara mbili   
Nyingineyo (bainisha).....
10. Je wajua ugonjwa au magonjwa gani waweza kupata kutoka kwa mbwa?  
Ndio  La

11. Kama ni ndio, ni gani? Kichaa cha mbwa  Malaria   
 Brucella  Sijui   
 Nyingineyo (bainisha).....
12. Je, unafahamu ugonjwa wa CE? (Muhojiwa anaonyeshwa picha ya kiungo kilicho na hydatid cysts ) Ndio  La
13. Ugonjwa wa CE (hydatid disease) unadhuru nani? (Tia alama kwa ile inafaa)  
 Watu  Wanyama wa kufugwa  Wanyama Pori  Sijui   
 Nyingineyo (bainisha).....
14. Je, ugonjwa huu huathiri/hudhuru viungo vipi sana? Mapafu   
 Ngozi  Maini  Sijui   
 Nyingineyo (bainisha).....
15. Je, waweza kuutambua aje ugonjwa huu kwa mnyama aliye chinjwa? Kuona vibofu vyenye maji (cysts) kwenye viungo  Kuona maji tumboni   
 Kuona maji kwenye mapafu  Sijui   
 Nyingineyo (bainisha).....
16. Je, ugonjwa huu huenezwa/huambukiza binadamu vipi/Kupitia kwa?   
 wanyama wa kufugwa  Wanyama Pori  Mbwa  Sijui   
 Nyingineyo (bainisha).....
17. Je, huchinja kondoo, mbuzi au ng'ombe nyumbani kwenu?  
 Ndio  La
18. Je, hufanyia nini viungo vilivyo adhiriwa na CE (hydatid disease) Huwapa  
 mbwa  Huzikwa  Hutupwa msituni  Huliwa na watu   
 Nyingineyo (bainisha).....

**Appendix 5: Trends data collection sheet**

| Year           |        |          |   |          |     |   |       |       |        |                    |     |          |       |   |   |       |       | Comments/<br>Origin of<br>animals |        |
|----------------|--------|----------|---|----------|-----|---|-------|-------|--------|--------------------|-----|----------|-------|---|---|-------|-------|-----------------------------------|--------|
| Disease status |        | Negative |   | Positive |     |   |       |       |        | Negative           |     | Positive |       |   |   |       |       |                                   |        |
|                |        | Sex      |   | Total    | Sex |   | Total | Lungs | Livers | Other<br>(specify) | Sex |          | Total |   |   | Total | Lungs |                                   | Livers |
| Date/mo.       | Spp    | M        | F |          | M   | F |       |       |        |                    | M   | F        |       | M | F |       |       |                                   |        |
| January        | Cattle |          |   |          |     |   |       |       |        |                    |     |          |       |   |   |       |       |                                   |        |
|                | Sheep  |          |   |          |     |   |       |       |        |                    |     |          |       |   |   |       |       |                                   |        |
|                | Goats  |          |   |          |     |   |       |       |        |                    |     |          |       |   |   |       |       |                                   |        |
| February       | Cattle |          |   |          |     |   |       |       |        |                    |     |          |       |   |   |       |       |                                   |        |
|                | Sheep  |          |   |          |     |   |       |       |        |                    |     |          |       |   |   |       |       |                                   |        |
|                | Goats  |          |   |          |     |   |       |       |        |                    |     |          |       |   |   |       |       |                                   |        |
| <b>Totals</b>  |        |          |   |          |     |   |       |       |        |                    |     |          |       |   |   |       |       |                                   |        |

## Appendix 6: Parasite egg isolation by sieving procedure

### Materials

PBS containing 0.3 % Tween 20

Zinc chloride solution (density 1.45 g/cm<sup>3</sup>)

Sodium hypochlorite solution 2 %

House made sieves

### Method

- Dilute untreated faecal samples 1:4 in PBS-Tween
- Centrifuge for 10 min at 1600 g
- Discard supernatant
- Re-suspend pellet (about 2 ml) in 8 ml zinc chloride solution
- Centrifuge for 30 min at 400 g – the supernatant solution contains the taeniid eggs
- Pass the supernatant through the sieve with mesh size 45-50 µm, rinse thoroughly with water – taeniid eggs will be in the flow-through fraction
- Pass flow-through fraction through the sieve with mesh size 20-25 µm, rinse thoroughly with water – taeniid eggs will be retained by the sieve
- Put the sieve upside down in a funnel standing in a collection tube
- Collect the taeniid eggs by washing the sieve thoroughly with water
- Centrifuge for 10 min at 400 g
- Remove the supernatant carefully by using a pipette until approximately 1 ml is left
- Transfer the pellet/taeniid eggs with the remaining water to a 1,5 ml tube

Put the funnels and house made sieve tubes overnight into sodium hypochlorite solution 2 %, eggs which possibly remained in the funnels or tubes will be destroyed.

## Appendix 7: DNA ladder

**thermo  
scientific**

### PRODUCT INFORMATION

## Thermo Scientific FastRuler Low Range DNA Ladder, ready-to-use

Pub. No. MAN0013027

Rev. Date 5 December 2016 (Rev. B.00)

Lot: \_      Expiry Date: \_

| Components                                    | #SM1103    |
|---|------------|
| FastRuler™ Low Range DNA Ladder, ready-to-use | 2 × 500 µL |
| 6X MassRuler™ DNA Loading Dye                 | 1 mL       |

Store: at room temperature or at 4°C for periods up to 6 months. For longer periods store at -20°C.

[www.thermofisher.com](http://www.thermofisher.com)

For Research Use Only. Not for use in diagnostic procedures.

### Description

Thermo Scientific™ FastRuler™ Low Range DNA Ladder is specially designed for fast sizing and quantification of double-stranded DNA in 48-well (or 96-well) gels as well as in conventional agarose gels. The Ladder consists of five blunt-end chromatography purified individual DNA fragments (in base pairs): 1500, 850, 400, 200 and 50, mixed in equal quantities. The ladder bands are easily resolved after an 8-14 min run on appropriate agarose gels in a short 10-20 mm linear separation distance and visualized by ethidium bromide or SYBR™ Green I staining. The Ladder is premixed with a loading buffer and can be applied directly onto an agarose gel.

### Storage and Loading Buffer

10 mM Tris-HCl (pH 7.6), 10 mM EDTA, 0.005% bromophenol blue and 10% glycerol.

### 6X Thermo Scientific™ MassRuler™ DNA Loading Dye

10 mM Tris-HCl (pH 7.6), 0.03% bromophenol blue, 60% glycerol and 60 mM EDTA.

### CERTIFICATE OF ANALYSIS

Well-defined bands are formed during 8-14 min agarose gel electrophoresis.

The absence of nucleases is confirmed by a direct nuclease activity assay.

Quality authorized by:

 Jurgita Zilinskiene

Rev.7



53

### Protocol for Loading

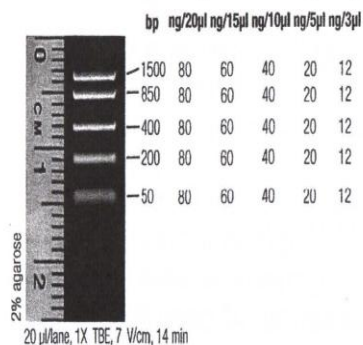
**Step 1:** Mix gently

**Step 2:** Load 1  $\mu$ L per 1 mm gel lane

### Recommendations

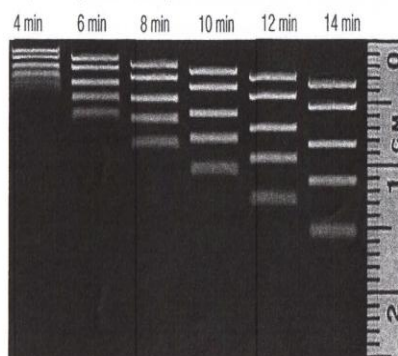
- Do not heat before loading.
- For sizing:
  - dilute your DNA sample with the MassRuler DNA Loading Dye (#R0621, supplied with the Ladder): mix 1 volume of the dye with 5 volumes of the DNA sample;
  - load equal volumes of the Ladder and an experimental sample;
- For quantification:
  - adjust the concentration of your sample such that the expected amount of material loaded is approximately equal to that of a DNA Ladder band of a nearest size.
- For DNA band visualization with SYBR<sup>TM</sup> Green and other intercalating dyes, do not add the dyes into the sample, use gel staining after electrophoresis or include dyes into agarose gel to avoid aberrant DNA migration.
- **Important note:** For DNA bands visualization with GelRed<sup>TM</sup> use gel staining after electrophoresis to avoid aberrant DNA migration.

### Amount of DNA (ng) in each band of FastRuler<sup>TM</sup> Low Range DNA Ladder, ready-to-use



#### Note

The apparent intensity of bands containing equal ng quantities of DNA may differ in different horizontal sections of gel (diminishes from top to bottom). This effect derives from higher diffusion rates of the shorter fragments, resulting in the lower compactness and lower peak intensity of the corresponding bands. Among factors effecting the severity of this effect are: temperature (the lower the better), overall duration of an electrophoretic and staining procedure (shorter), gel percentage (higher). The time course of DNA fragments separation is presented in the Fig.1.



**Fig 1.** Time course of band separation.

Electrophoresis conditions: 2% agarose, 1X TBE, 7 V/cm.

## Appendix 8: Ethical (SERU) Approval Letter



# KENYA MEDICAL RESEARCH INSTITUTE

P.O. Box 54840-00200 NAIROBI - Kenya  
Tel: (254) (020) 2722541, 254 (020) 2713349, 0722-205901, 0733-400003 Fax (254) (020) 2720030  
Email: director@kemri.org info@kemri.org Website: www.kemri.org

**KEMRI/RES/7/3/1**

**August 27, 2015**

**TO: MABEL INYANGALA GACHENGO,  
PRINCIPAL INVESTIGATOR**

**THROUGH: THE DIRECTOR, CMR, NAIROBI** *Forwarded 4/9/15*

**RE: KEMRI/SERU/CMR/P0020/3081 (RESUBMISSION OF INITIAL SUBMISSION):  
PREVALENCE OF ECHINOCOCCOSIS IN DOGS, CATTLE, SHEEP AND GOATS,  
THE LEVEL OF AWARENESS AND ASSOCIATED ECONOMIC LOSSES IN  
LAIKIPIA WEST SUB-COUNTY, KENYA-(VERSION 2.0 DATED 25<sup>TH</sup> MAY, 2015)**

Reference is made to your letter dated 4<sup>th</sup> August, 2015. KEMRI/Scientific and Ethics Review Unit (SERU) acknowledges receipt of the revised study documents on 17<sup>th</sup> August, 2015.

This is to inform you that the Committee notes that the issues raised during the 240<sup>th</sup> C meeting of the KEMRI/Scientific and Ethics Review Unit held on 25<sup>th</sup> June, 2015 have been adequately addressed.

Consequently, the study is granted approval for implementation effective this day, **27<sup>th</sup> August, 2015** for a period of one year. Please note that authorization to conduct this study will automatically expire on **August 26, 2016**. If you plan to continue data collection or analysis beyond this date, please submit an application for continuation approval to SERU by **July 15, 2016**.

You are required to submit any proposed changes to this study to SERU for review and the changes should not be initiated until written approval from SERU is received. Please note that any unanticipated problems resulting from the implementation of this study should be brought to the attention of SERU and you should advise SERU when the study is completed or discontinued.

You may embark on the study.

Yours faithfully,

*Prof. Elizabeth Bukusi*  
**PROF. ELIZABETH BUKUSI,  
ACTING HEAD,  
KEMRI/SCIENTIFIC AND ETHICS REVIEW UNIT**

In Search of Better Health



## KENYA MEDICAL RESEARCH INSTITUTE

P.O. Box 54840 - 00200 NAIROBI - Kenya  
Tel: (254) (020) 2722541, 254 (020) 2713349, 0722-205901, 0733-400003 Fax (254) (020) 2720030  
Email: director@kemri.org info@kemri.org Website:www.kemri.org

**KEMRI/RES/7/3/1**

**February 02, 2016**

**TO: MABEL INYANGALA GACHENGO,  
PRINCIPAL INVESTIGATOR**

**THROUGH: THE DIRECTOR, CMR,  
NAIROBI**

*Forwarded  
11/2/16*

Dear Madam,

**RE: PROTOCOL NO. KEMRI/SERU/CMR/P0020/3081 (RESUBMITTED-1<sup>ST</sup>  
AMENDMENT): PREVALENCE OF ECHINOCOCCOSIS IN DOGS, CATTLE,  
SHEEP AND CATTLE, THE LEVEL OF AWARENESS AND ASSOCIATED  
ECONOMIC LOSSES IN LAIKIPIA WEST SUB COUNTY, KENYA-(VERSION  
2.2 DATED 20<sup>TH</sup> JANUARY, 2016)**

Reference is made to your letter dated 20<sup>th</sup> January, 2016. KEMRI/Scientific and Ethics Review Unit (SERU) acknowledges receipt of the revised documents on 25<sup>th</sup> January, 2016.

This is to inform you that the Committee determines that the issues raised at the 245<sup>th</sup> committee B meeting of the KEMRI/SERU held on 18<sup>th</sup> November, 2015 are adequately addressed. You are therefore **authorized** to implement the following Amendment accordingly:

1. A change in the study procedures from using copro-antigens to determine the prevalence of Ethinococcus in dogs to using taeniid egg isolation and PCR

Please note that you are responsible for submitting any further changes to the approved version of the study protocol to SERU for review and the changes should not be initiated until written approval from the SERU is received.

Yours faithfully,

*EAB*

**PROF. ELIZABETH BUKUSI,  
ACTING HEAD,  
KEMRI/SCIENTIFIC AND ETHICS REVIEW UNIT**

In Search of Better Health

## Appendix 9: Animal Care and Use Committee (ACUC) approval letter



### KENYA MEDICAL RESEARCH INSTITUTE

Centre for Virus Research, P.O. Box 54628 - 00200 NAIROBI - Kenya  
Tel: (254) (020) 2722541, 254 02 2713349, 0722-205901, 0733-400003 Fax (254) (020) 2726115, Email: cvr@kemri.org

KEMRI/ACUC/ 01.09.15

9<sup>th</sup> September 2015,

Mabel Gachengo,  
ITROMID,  
CMR, KEMRI.

Gachengo,

**RE: Animal use approval for CMR P0020 3081- " Prevalence of Echinococcosis in dogs, cattle, sheep and goats, the level of awareness and associated economic losses in Laikipia west sub-county, Kenya " protocol**


The KEMRI animal care and use committee acknowledges the resubmission of the above mentioned protocol for review. The committee has established that faecal collection and post mortem sampling of the listed animal species in the protocol is necessary in attaining the study objectives.

It has also been confirmed that access to the sampling sites has been granted by the Department of Veterinary Services who are mandated to handle livestock animals as stated in the letter **REF MEAT.VOL.XV/59** dated 22<sup>nd</sup> July 2015.

Approval is granted for a period of one year starting from when the final SERU approval will be obtained. If you still intend to collect animal samples after expiry of this initial approval, you are required to submit an application for continuing approval to the ACUC 1 month prior to the expiry of this initial approval.

The committee expects you to adhere to all the animal handling procedures as described in the protocol. The committee wishes you all the best in your work.

Yours sincerely,

  
Dr. Konongoi Limbaso  
Chairperson KEMRI ACUC



## Appendix 10: Letter from The Director of Veterinary Services



REPUBLIC OF KENYA

MINISTRY OF AGRICULTURE, LIVESTOCK & FISHERIES  
STATE DEPARTMENT OF LIVESTOCK  
Office of the Director of Veterinary Services

Telephone: 020 – 8043441  
E-mail: [veterinarydep@gmail.com](mailto:veterinarydep@gmail.com)

VETERINARY RESEARCH LABORATORIES  
PRIVATE BAG, 00625 KANGEMI  
NAIROBI

When replying, please quote:  
**REF: MEAT. VOL.XV/59**  
All correspondences should be addressed to:  
The Director of Veterinary Services

22<sup>nd</sup> JULY 2015

Mabel Inyangala Gachengo  
C/O AHITI Nyahururu  
P.O. BOX 1-20300  
Nyahururu

**RE: APPROVAL TO CARRY OUT STUDY ON PREVALENCE OF EHINOCOCCOSIS IN DOGS, CATTLE, SHEEPS AND GOAT; THE LEVEL OF AWARENESS AND ASSOCIATED ECONOMIC LOSSES IN LAIKIPIA WEST SUB COUNTY**

Your letter dated 2<sup>nd</sup> June 2015 refers.

There is no objection to you carrying out the said study on condition that the findings of your study are communicated with this office

However it is important for you to seek the approval of the County office responsible for veterinary Services

  
**DR. JOYCE THAIYA**  
**FOR: DIRECTOR OF VETERINARY SERVICES**

FOR:  
DIRECTOR OF VETERINARY SERVICES

## Appendix 11: Letter from The County Director Livestock and Fisheries, Laikipia County

REPUBLIC OF KENYA



COUNTY GOVERNMENT OF LAIKIPIA  
Department of Agric, Livestock & fisheries Development

LKP LF/Research/ vol1/003

Mabel Inyangala Gachengo,  
C/O AHITI – Nyahururu,  
P. O. BOX 1-20300,  
Nyahururu

Directorate of Livestock and Fisheries  
Development;  
Laikipia County  
P.O. Box31- 10400, Nanyuki  
23<sup>rd</sup> July 2015

**Ref: PERMISSION TO CARRY OUT RESEARCH IN LAIKIPIA WEST SUB  
COUNTY.**

**(Dr. MABEL INYANGALA GACHENGO)**

Permission to use of any of the slaughter houses and slabs in Laikipia West Sub County for checking the presence of hydatid cysts and Collection of faecal material from the dogs across the sub county is hereby granted as requested.

This is on condition that you will agree to share with the county insights gotten from your study after graduation.

Otherwise, I wish you success with your studies.

**DR. D.N THUO  
DIRECTOR OF LIVESTOCK AND FISHERIES DEVELOPMENT;  
LAIKIPIA COUNTY**

**Appendix 12: Distribution by abattoir and origin of the of animals slaughtered in Laikipia west sub county**

| Abattoir name               | Frequency (%) | Frequency of positive (Prevalence) | Origin of animals within Laikipia west (%) | Origin of animals Outside Laikipia west (%) |
|-----------------------------|---------------|------------------------------------|--|---|
| Ngare Narok Meat Industries | 435(8.8)      | 37 (8.5)                           | 435(100)                                   | 0   |
| Karuga                      | 165(3.3)      | 2 (1.2)                            | 165(100)                                   | 0   |
| Gatundia                    | 811(16.3)     | 17 (2.1)                           | 811(100)                                   | 0   |
| Oljabet                     | 275(5.5)      | 0 (0.0)                            | 275(100)                                   | 0   |
| Kanyamwi                    | 119(2.4)      | 9 (7.6)                            | 112(94.1)                                  | 7(5.9)                                      |
| Kabucho                     | 180(3.6)      | 8 (4.4)                            | 143(79.4)                                  | 37(20.6)                                    |
| Nyahururu                   | 967(19.5)     | 18 (1.8)                           | 947(97.9)                                  | 20(2.1)                                     |
| Sipili                      | 316(6.4)      | 3 (0.9)                            | 316(100)                                   | 0   |
| Salama                      | 57(1.1)       | 1 (1.8)                            | 57(100)                                    | 0   |
| Manguo                      | 1328(26.7)    | 19 (1.4)                           | 1328(100)                                  | 0   |
| Kinamba                     | 169(3.4)      | 3 (1.8)                            | 161(95.3)                                  | 8(4.7)                                      |
| Matuiku                     | 111(2.2)      | 2 (1.8)                            | 110(99.1)                                  | 1(0.9)                                      |
| Pesi                        | 36(0.7)       | 3 (8.3)                            | 36(100)                                    | 0   |
| <b>Total</b>                | <b>4969</b>   | <b>122 (2.5)</b>                   | <b>4896(98.5)</b>                          | <b>73(1.5)</b>                              |

**Appendix 13: Distribution of CE in cattle slaughtered in abattoirs in Laikipia west Sub County**

| Abattoir                   | Total animals slaughtered (observed) | Animals with hydatid cysts (Prevalence) | Origin of animals with hydatid cysts from west(No.) | Origin of animals with hydatid cysts from Laikipia west(No.) | Origin of animals with hydatid cysts from outside Laikipia west(No.) |
|----------------------------|--------------------------------------|---|---|--|--|
| NgareNarok meat Industries | 201                                  | 24 (11.9)                               | Ol Moran  | (3)  | (0)  |
| Karuga                     | 21                                   | 1 (4.8)                                 | Rumuruti mkt  | (21)   | (0)  |
| Gatundia                   | 24                                   | 2 (8.3)                                 | Igwamiti  | (1)  | (0)  |
| Oljabet                    | 25                                   | 0 (0.0)                                 | Thome   | (1)  | (0)  |
| Kanyamwi                   | 12                                   | 0 (0.0)                                 | Rumuruti mkt  | (1)  | (0)  |
| Kabucho                    | 43                                   | 1 (2.3)                                 | -   | (0)  | (0)  |
| Nyahururu                  | 114                                  | 14 (12.3)                               | Marmamet  | (1)  | (0)  |
| Sipili/Ol Moran            | 14                                   | 1 (7.1)                                 | Rumuruti mkt  | (5)  | Samburu county (7)   |
| Salama                     | 0                                    | 0 (0.0)                                 | -   | (0)  | Nyandarua county (2)   |
| Manguo                     | 13                                   | 0 (0.0)                                 | Sipili  | (1)  | (0)  |
| Kinamba                    | 48                                   | 2 (4.2)                                 | -   | (0)  | (0)  |
| Matuiku/Mwenje             | 7                                    | 1 (14.3)                                | Sipili  | (1)  | (0)  |
| Pesi/Kiamariga             | 0                                    | 0 (0.0)                                 | Kinamba   | (1)  | (0)  |
| Total                      | 522                                  | 46 (8.8)                                | Matuiku   | (1)  | (0)  |
|                            |                                      |   |   | (0)  | (0)  |
|                            |                                      |   |   | (37)   | (9)  |

**Appendix 14: Distribution of CE in sheep slaughtered in abattoirs in Laikipia west Sub County**

| Abattoir                   | Total animals slaughtered (observed) | Animals with hydatid cysts (Prevalence) | Origin of animals with hydatid cysts from Laikipia west (No.)  | Origin of animals with hydatid cysts from outside Laikipia west (No.) |
|----------------------------|--------------------------------------|---|--|---|
| NgareNarok meat Industries | 69                                   | 8 (11.6)                                | Salama (1)<br>Rumuruti mkt (7)                                 | (0)<br>(0)  |
| Karuga                     | 131                                  | 1 (0.8)                                 | Igwamiti/Losogwa (1)   | (0)   |
| Gatundia/Muhotetu          | 629                                  | 10 (1.6)                                | Rumuruti mkt (10)  | (0)   |
| Oljabet                    | 200                                  | 0 (0.0)                                 |  | (0)   |
| Kanyamwi                   | 67                                   | 9 (13.4)                                | Siron (1)<br>Muthengera (1)<br>Rumuruti mkt (1)<br>Olmoran (2) | Baringo county (4)  |
| Kabucho                    | 100                                  | 7 (7.0)                                 | Muthengera (1)   | Baringo county (6)  |
| Nyahururu                  | 698                                  | 3 (0.4)                                 | Rumuruti mkt (2)   | Samburu county (1)  |
| Sipili/Olmoran             | 224                                  | 1 (0.4)                                 | Olmoran (1)  | (0)   |
| Salama                     | 33                                   | 1 (3.0)                                 | Salama (1)   | (0)   |
| Manguo                     | 1084                                 | 14 (1.3)                                | Rumuruti mkt (12)<br>Olmoran (2)                               | (0)<br>(0)  |
| Kinamba                    | 90                                   | 1 (1.1)                                 |  | (0) Baringo county (1)  |
| Matuiku/Mwenje             | 82                                   | 1 (1.2)                                 |  | (0) Baringo county (1)  |
| Pesi/Kiamariga             | 21                                   | 3 (14.3)                                | Mutara (3)   | (0)   |
| <b>Total</b>               | <b>3428</b>                          | <b>59 (1.7)</b>                         |  | <b>(46) (13)</b>  |

**Appendix 15: Distribution of CE in goats slaughtered in abattoirs in Laikipia west Sub County**

| Abattoir                   | Total animals slaughtered (observed) | Animals with hydatid cysts (Prevalence) | Origin of animals with hydatid cysts from west(No.) | Origin of animals with hydatid cysts from Laikipia west(No.) | Origin of animals with hydatid cysts from outside Laikipia west(No.) |
|----------------------------|--------------------------------------|---|---|--|--|
| NgareNarok meat Industries | 165                                  | 5 (3.0)                                 | Rumuruti mkt  | (5)  | (0)  |
| Karuga                     | 13                                   | 0 (0.0)                                 |   | (0)  | (0)  |
| Gatundia                   | 158                                  | 5 (3.2)                                 | Rumuruti mkt  | (3)  | (0)  |
|                            |                                      |   | Gatundia  | (2)  | (0)  |
| Oljabet                    | 50                                   | 0 (0.0)                                 |   | (0)  | (0)  |
| Kanyamwi                   | 40                                   | 0 (0.0)                                 |   | (0)  | (0)  |
| Kabucho                    | 37                                   | 0 (0.0)                                 |   | (0)  | (0)  |
| Nyahururu                  | 155                                  | 1 (0.6)                                 |   | (0)  | Samburu county (1)   |
| Sipili/Olmoran             | 78                                   | 1 (1.3)                                 | Sipili  | (1)  | (0)  |
| Salama                     | 24                                   | 0 (0.0)                                 |   | (0)  | (0)  |
| Manguo                     | 231                                  | 5 (2.2)                                 | Rumuruti mkt  | (5)  | (0)  |
| Kinamba                    | 31                                   | 0 (0.0)                                 |   | (0)  | (0)  |
| Matuiku/Mwenje             | 22                                   | 0 (0.0)                                 |   | (0)  | (0)  |
| Pesi/Kiamariga             | 15                                   | 0 (0.0)                                 |   | (0)  | (0)  |
| <b>Total</b>               | <b>1019</b>                          | <b>17 (1.7)</b>                         |   | <b>(16)</b>  | <b>(1)</b>   |

**Appendix 16: Data from meat inspection reports on cattle, sheep and goats slaughtered in Laikipia west Sub County during 2010-2014**

| Year         | Species | Total kill   | Total negative | Total positive | Prevalence | Total lungs | Lung unit cost | Total livers | Liver unit cost | Others (specify ) spleen | Others (spleen) Unit cost | Lungs Total cost (KES) | Livers Total cost | Others (spleen) Total cost | Total cost of all organs |
|--------------|---------|--------------|----------------|----------------|------------|-------------|----------------|--------------|-----------------|--------------------------|---------------------------|------------------------|-------------------|----------------------------|--------------------------|
| 2010         | Cattle  | 3685         | 3404           | 281            | 7.6        | 277         | 100            | 170          | 200             | 32                       | 50                        | 27,700                 | 34,000            | 1,600                      | 63,300                   |
| 2011         | Cattle  | 3005         | 2817           | 188            | 6.3        | 188         | 200            | 124          | 500             | 37                       | 50                        | 37,600                 | 62,000            | 1,850                      | 101,450                  |
| 2012         | Cattle  | 3341         | 3175           | 166            | 5.0        | 164         | 250            | 120          | 500             | 33                       | 100                       | 41,000                 | 60,000            | 3,300                      | 104,300                  |
| 2013         | Cattle  | 2992         | 2773           | 219            | 7.3        | 196         | 300            | 145          | 700             | 21                       | 100                       | 58,800                 | 101,500           | 2,100                      | 162,400                  |
| 2014         | Cattle  | 5335         | 4765           | 570            | 10.7       | 462         | 300            | 504          | 700             | 11                       | 100                       | 138,600                | 352,800           | 1,100                      | 492,500                  |
| 2010         | Goat    | 3396         | 3286           | 110            | 3.2        | 101         | 20             | 56           | 50              | 0                        | 10                        | 2,020                  | 2,800             | -                          | 4,820                    |
| 2011         | Goat    | 3564         | 3477           | 87             | 2.4        | 69          | 50             | 62           | 100             | 4                        | 10                        | 3450                   | 6,200             | 40                         | 9,690                    |
| 2012         | Goat    | 4137         | 3977           | 160            | 3.9        | 121         | 50             | 141          | 100             | 6                        | 10                        | 6,050                  | 14,100            | 60                         | 20,210                   |
| 2013         | Goat    | 4370         | 4180           | 190            | 4.4        | 168         | 50             | 140          | 100             | 12                       | 20                        | 8400                   | 14,000            | 240                        | 22,640                   |
| 2014         | Goat    | 10004        | 9571           | 433            | 4.3        | 318         | 50             | 299          | 100             | 3                        | 20                        | 15,900                 | 29,900            | 60                         | 45,860                   |
| 2010         | Sheep   | 7781         | 7403           | 378            | 4.9        | 375         | 20             | 211          | 50              | 15                       | 10                        | 7,500                  | 10,550            | 150                        | 18,200                   |
| 2011         | Sheep   | 7065         | 6739           | 326            | 4.6        | 297         | 50             | 235          | 100             | 24                       | 10                        | 14,850                 | 23,500            | 240                        | 38,590                   |
| 2012         | Sheep   | 8548         | 8246           | 302            | 3.5        | 292         | 50             | 212          | 100             | 26                       | 10                        | 14,600                 | 21,200            | 260                        | 36,060                   |
| 2013         | Sheep   | 9656         | 9227           | 429            | 4.4        | 423         | 50             | 322          | 100             | 39                       | 20                        | 21,150                 | 32,200            | 780                        | 54,130                   |
| 2014         | Sheep   | 21616        | 20670          | 946            | 4.4        | 655         | 50             | 840          | 100             | 28                       | 20                        | 32,750                 | 84,000            | 560                        | 117,310                  |
| <b>Total</b> |         | <b>98495</b> | <b>93710</b>   | <b>4785</b>    | <b>4.9</b> | <b>4106</b> | <b>1590</b>    | <b>3581</b>  |                 | <b>291</b>               | <b>540</b>                | <b>430370</b>          | <b>848750</b>     | <b>12340</b>               | <b>1,291,460</b>         |

## Appendix 17: Part of results published in the *East African Medical Journal*

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### PREVALENCE OF CYSTIC ECHINOCOCCOSIS IN LIVESTOCK SLAUGHTERED IN SELECTED ABATTOIRS OF LAIKIPIA WEST SUB-COUNTY, KENYA

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### PREVALENCE OF CYSTIC ECHINOCOCCOSIS IN LIVESTOCK SLAUGHTERED IN SELECTED ABATTOIRS OF LAIKIPIA WEST SUB-COUNTY, KENYA

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#### ABSTRACT

**Background:** Cystic echinococcosis (CE) is a neglected, emerging and reemerging zoonotic disease caused by the larval stage of the dog tapeworm of the genus *Echinococcus*. It causes great public health and economic concerns wherever it occurs. CE is endemic in Kenya and most studies done in the country focused on two loci; Turkana and Maasai communities. The prevalence of CE has not been documented in Laikipia County which is located between two CE hot spot areas in Kenya.

**Objectives:** To estimate the prevalence of CE in livestock slaughtered in abattoirs of Laikipia west Sub County

**Design:** A cross-sectional study

**Setting:** Three selected abattoirs in Laikipia west Sub County

**Subjects:** All cattle, sheep and goats slaughtered in the selected abattoirs between October and December, 2015.

**Main outcome measures:** Species, sex, CE status, and origin

**Results:** A total of 339 cattle, 1396 sheep and 478 goats were examined for presence of hydatid cysts in both the thoracic and abdominal cavities during postmortem meat inspection. Overall prevalence was 3.3% and individual species' prevalence was 11.8%, 1.5% and 2.3% in cattle, sheep and goats respectively. Most (99.1 %) slaughter animals originated from the study area. Forty-three percent (31/72) of the CE positive animals had fertile cysts and 87.1% of them originated from the study area.

**Conclusion:** The results show a significantly higher prevalence of CE in cattle with most slaughter animals and those with fertile cysts originating from the study area. Possible implications for public health and the livestock economy require immediate control measures.

#### INTRODUCTION

Cystic echinococcosis (CE) is a zoonotic parasitic disease caused by larval stage of the dog tapeworm of the genus *Echinococcus* (1). The

definitive hosts, particularly the dog and foxes get infected while feeding on raw organs containing fertile cysts. The tapeworm eggs are passed in faeces into the environment exposing

humans, domestic livestock and other intermediate hosts to risk. The intermediate hosts, commonly the herbivores ingest the eggs, while grazing in contaminated environments. However, humans as aberrant hosts get infected when they accidentally ingest the eggs either from contaminated environments or directly from close contact with the dog (1, 2).

Hydatid cysts (fluid-filled bags) develop in vital organs primarily the liver and lungs, although they can develop anywhere else in the body (3). It is an emerging complexity; an emerging and a re-emerging zoonosis with a worldwide distribution (4). Approximately two to three million people are afflicted worldwide (5). It is among the oldest known zoonotic parasitic diseases as reported in WHO/OIE manual of echinococcosis (6). Despite its economic and public health importance, CE remains a neglected disease in Sub-Saharan Africa (6). There is little information and awareness about the extent of the problem which gives a false perception that the burden and impact to society is low and yet people's health and livelihoods continue to be at risk (7).

The disease causes considerable public health and economic problems due to Disability-Adjusted Life Years (DALYs) and organ condemnation (6, 5). Globally, the estimated DALYs and annual livestock production losses are US \$193,529,740 and \$141,605,195 respectively (5). In Kenya, the estimated average direct annual cost of treatment is US \$ 22,658 while the indirect annual economic losses were estimated to be US \$ 4,414 and US \$1,339 for a herdsman and housewife respectively (8).

Reported losses due to hydatid cysts condemnation in Kenya were US\$ 97393.2 in cattle in 1984 and US\$ 5588.2 in sheep and goats in 1986 (9). CE is endemic in Kenya from where the highest global human incidence (220/100,000) has been reported (10). Most of the work done on CE in the country has been in the Rift Valley region and focused more on two loci; Turkana and Maasai

communities (11, 2, and 12). The prevalence of CE has not been documented in Laikipia County which is in the Rift Valley region of Kenya and is sandwiched between the two known CE hot spot loci.

The county is an Arid and Semi-Arid Land (ASAL) bordering other pastoralist counties such as Samburu, Baringo and Isiolo. Laikipia is known for livestock production and has a number of ranches and conservancies; these factors favor the occurrence of CE. Home slaughtering occurs in many communities but meat inspection is rarely done and dogs can easily get access to infected offal thereby perpetuating the cycle (2). Studies have shown a low level of awareness even among health professionals (14, 13).

In livestock, diagnosis is often made at postmortem when nothing can be done except to condemn the affected organs. In humans, diagnosis requires radiological techniques while treatment employs radical surgery which makes the management of CE to be very expensive and out of reach for the affected persons who are usually from the marginalized poor communities (6). This study set out to estimate the prevalence of CE in cattle, sheep and goats slaughtered in abattoirs in Laikipia West Sub-County and to contribute to the body of knowledge on CE.

#### MATERIALS AND METHODS

The study was conducted in Laikipia West Sub-County (Figure 1) which has a population of 224,431 (15) and covers an area of 3,891.4 km<sup>2</sup> comprising of six wards; Marmanet, Igwamiti, Salama, Githiga, Rumuruti Township and Ol-Moran. It shares borders with Samburu, Baringo, Isiolo, Nakuru and Nyandarua counties.

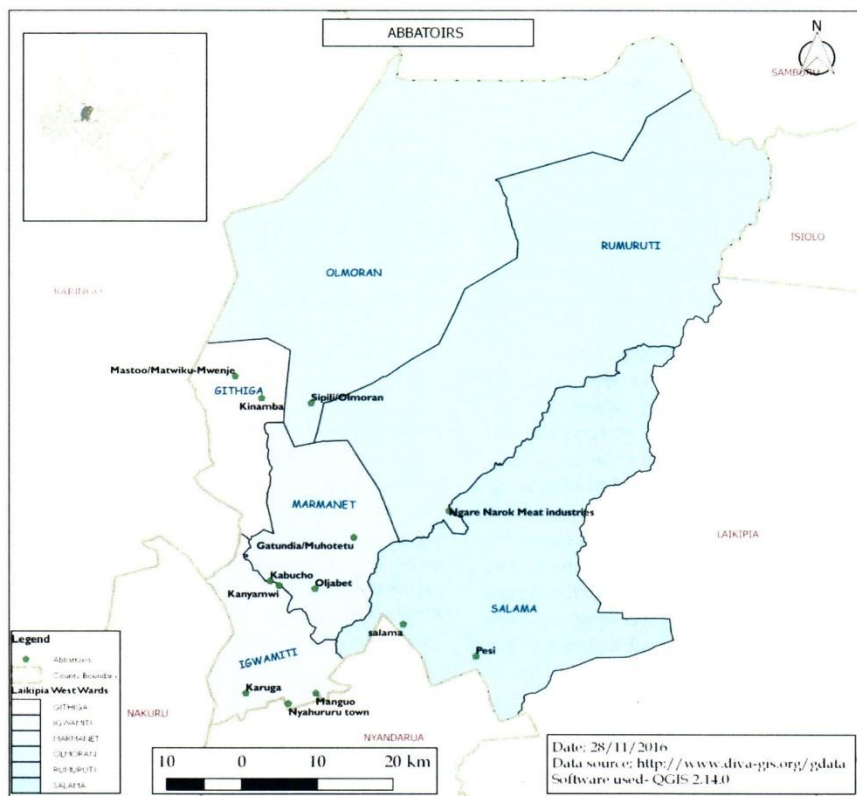
The County is an ASAL area with many ranches and conservancies. The main source of water for both domestic and animal use includes seasonal rivers, shallow wells and surface run off.

Most residents practice agro-pastoralism. Although Kikuyu is the major ethnic community, other ethnicities such as Kalenjin, Turkana and Samburu who are pastoralists are present. The

annual rainfall ranges from 900mm on the foot of the Nyandarua ranges to 500mm in the Western parts of the Sub-County.

Figure 1

Map showing the location of Laikipia west Sub County and distribution of abattoirs



Approval to carry out the study was sought and obtained from the KEMRI's Scientific and Ethics Review Unit (SERU) and the Animal Care and Use Committee (ACUC) reference: SERU/CMR/P0020/3-081. Permission to carry out the study was obtained from The Director of Veterinary Services, State department of Livestock in the Ministry of Agriculture, Livestock and Fisheries as well as from the County Director of Livestock and Fisheries, Laikipia County.

A cross-sectional study design was conducted between October and December, 2015. The study population included all cattle, sheep and goats slaughtered in three selected abattoirs (Ngare Narok meat Industries, Gatundia and Nyahururu) in Laikipia west Sub County (figure 1). The abattoirs are run by qualified meat inspectors who were recruited as research assistants after undergoing a brief refresher course organized by the Principal Investigator (PI) on hydatid cyst recognition.

Data was collected daily from each abattoir for six days per week for 5 weeks and details of animals recorded in data collection sheets detailing the species, sex, origin, status of disease, and the organs affected where applicable. Every cattle, sheep and goat slaughtered in the abattoirs during the period of the study was inspected visually and by palpation during postmortem examination for presence of hydatid cysts in both the thoracic and abdominal organs. Any swelling within the organs that felt firm like a tennis ball was considered to be a hydatid cyst. The organs found with cysts were removed whole, put in polythene bags and labeled appropriately. The day's collection was then transferred into an airtight bucket and transported to the laboratory at the Animal Health and Industry Training Institute (AHITI) – Nyahururu for further examination. Cysts with protoscolices and or with a healthy white germinal layer on incision were considered fertile, those calcified and showing signs of degeneration were considered sterile.

Contents of individual cysts were separately put in labeled specimen bottles and preserved with ethanol. The samples were transported to Kemri's Centre for Microbiology Research (CMR) laboratory where confirmation of cysts' viability and genotyping was done by another researcher. Details of cysts' data were recorded and these included the species, sex, origin of animal, organ affected, and fertility. All data received were entered into Microsoft office (MS) Excel, 2010 and counterchecked.

Data analysis was done using SPSS version 20.0 and this commenced once all data had been verified and imported into SPSS. Daily backup and storage was done to ensure data safety. Categorical variables were analysed using frequency distribution. Statistical analysis of the species characteristics was carried out. Estimates of the parameters were considered statistically significant at  $p < 0.05$  and 95% confidence interval.

## RESULTS

A total of two thousand, two hundred and thirteen (2,213) animals were inspected for hydatid cysts in three abattoirs (Ngare Narok meat Industries, Gatundia/Muhotetu and Nyahururu). These consisted of 63.1% (n=1396) sheep, 21.6% (n=478) goats and 15.3% (n=339) cattle. The overall proportion of males to females slaughtered was 41:59 (1:1.5) while in individual species the proportions were: 38:62 (1:1.6), 42:58 (1:1.4) and 38:62 (1:1.6) in cattle, sheep and goats respectively. Most (99.1%) of the animals slaughtered originated from Laikipia west sub county (Table 1). Details of the animals slaughtered in each abattoir are shown in table 1. Nyahururu abattoir had the highest proportion (43.7%) of animals slaughtered while Ngare Narok meat industries abattoir had the least proportion (19.7%).

**Table 1***Prevalence of CE and distribution of animals slaughtered by abattoir and origin*

| Abattoir name         | All cattle, sheep and goats slaughtered (%) | Prevalence of CE in cattle (n) | Prevalence of CE in sheep (n) | Prevalence of CE in goats (n) | Origin of animals (%) |              |          |
|-----------------------|---|--------------------------------|-------------------------------|-------------------------------|-----------------------|--------------|----------|
|                       |   |                                |                               |                               | Within Laikipia west  | Outside west | Laikipia |
| Ngare                 |   |                                |                               |                               |                       |              |          |
| Narok Meat Industries | 435(19.7)                                   | 11.9(201)                      | 11.6 (69)                     | 3.0 (165)                     | 435(100)              | 0(0.0)       |          |
| Gatundia/Muhotetu     | 811(36.6)                                   | 8.3(24)                        | 1.6 (629)                     | 3.2 (158)                     | 811(100)              | 0(0.0)       |          |
| Nyahururu             | 967(43.7)                                   | 12.3 (114)                     | 0.4 (698)                     | 0.6 (155)                     | 947(97.9)             | 20(2.1)      |          |
| Total                 | 2213  | 11.8 (339)                     | 1.5 (1396)                    | 2.3 (478)                     | 2193(99.1)            | 20(0.9)      |          |

The overall prevalence of CE was 3.3% (72/2213). Ngare Narok meat industries abattoir contributed the highest proportion (51.4%) to the positive animals despite having just about half of the number of animals from Gatundia/Muhotetu abattoir which contributed the least proportion (table 2). Cattle contributed the highest proportion (40/72) to the overall prevalence while goats contributed the least 11/72 as shown in table 2. Ngarenarok meat industries abattoir contributed most proportionally, towards the prevalence of cattle and sheep while Gatundia/Muhotetu contributed most proportionally towards the prevalence of goats. The individual species prevalence was 11.8% in cattle, 1.5% in sheep and 2.3% in goats. Table 3 shows comparison of

prevalence to those from recent studies in the country. The prevalence of CE in cattle was significantly higher than in both sheep and goats ( $p=0.000$ ). A significantly higher number of females had the disease ( $p=0.012$ ). The association between CE and organs affected was significant ( $p=0.000$ ). The lung was the most (62.5%) frequently parasitized organ. The prevalence of CE in Ngare narok meat industries abattoir was significantly higher than in the other abattoirs ( $p=0.000$ ). Most (76.4%,  $n=72$ ) of the positive animals originated from Rumuruti township ward and about 15% came from outside the sub county (table 2).

**Table 2***Prevalence of CE and characteristics of animals slaughtered in three abattoirs in Laikipia west Sub County*

| Variable               | Category                    | Frequency (%) | Frequency of positive (Prevalence) | $\chi^2$ p-value |
|------------------------|-----------------------------|---------------|------------------------------------|------------------|
| Species                | Cattle                      | 339 (15.3)    | 40 (11.8)                          | 0.000            |
|                        | Sheep                       | 1396 (63.1)   | 21 (1.5)                           |                  |
|                        | Goats                       | 478 (21.6)    | 11 (2.3)                           |                  |
| Sex                    | Male                        | 901 (40.7)    | 18 (25.0)                          | 0.012            |
|                        | Female                      | 1312 (59.3)   | 54 (75.0)                          |                  |
| Organs                 | None                        | 2141(96.7)    | 0 (0.0)                            | 0.000            |
|                        | Lungs                       | 45 (2.0)      | 45 (62.5)                          |                  |
|                        | Liver                       | 8 (0.4)       | 8 (11.1)                           |                  |
|                        | Lungs/liver                 | 18 (0.8)      | 18 (25.0)                          |                  |
|                        | Lungs/spleen                | 1 (0.0)       | 1 (1.4)                            |                  |
| Origin (specific ward) | Other county                | 20 (0.9)      | 11 (15.3)                          | 0.000            |
|                        | Igwamiti                    | 1 (0.0)       | 0(0.0)                             |                  |
|                        | Githiga                     | 0 (5.0)       | 0 (0.0)                            |                  |
|                        | Ol Moran                    | 64 (2.9)      | 3 (4.2)                            |                  |
|                        | Marmanet                    | 10 (0.5)      | 2 (2.8)                            |                  |
|                        | Rumuruti township           | 2117 (95.7)   | 55 (76.4)                          |                  |
|                        | Salama                      | 1 (0.0)       | 1 (1.4)                            |                  |
| Abattoir name          | Ngare narok meat industries | 435( 19.7)    | 37(51.4)                           | 0.000            |
|                        | Gatundia/Muhotetu           | 805(36.4)     | 15(20.8)                           |                  |
|                        | Nyahururu                   | 973(44.0)     | 20(27.8)                           |                  |

**Table 3***Comparison of CE prevalence's in livestock in Kenya from recent studies*

| Livestock species | Laikipia west (this study) | Confidence Interval (this study) % | Turkana (Njoroge et al. 2002) | Maasailand (Addy et al. 2012) | Central Kenya (Mbaya et al. 2014) |
|-------------------|----------------------------|------------------------------------|-------------------------------|-------------------------------|-----------------------------------|
| Cattle            | 11.8 (n=339)               | [10.1– 13.6]                       | 19.4 (n=381)                  | 25.8 (n=587)                  | 1.9 (n=4,595)                     |
| Sheep             | 1.5 (n=1396)               | [1.2 -1.8]                         | 3.6 (n=588)                   | 16.5 (n=430)                  | 4.6 (n=65)                        |
| Goats             | 2.3 (n=478)                | [1.6 - 3.0]                        | 4.5 (n=5,752)                 | 10.8 (n=194)                  | 0.4 (n=2,955)                     |

Thirty one (43%, n=72) of the CE positive animals had fertile cysts (Table 4). These consisted of 42.0% cattle, 51.6% sheep and 6.5% goats. Most, (87.1%) of the animals with fertile cysts originated from

Laikipia west Sub County. About 33% (n=40), 76% (n=21) and 18% (n=11) of the positive cattle, sheep and goats respectively had fertile cysts.

**Table 4**

*Origin of animals with fertile cysts*

| Species/<br>Origin | Igwamiti | Githiga | Olmoran | Marmanet | Rumuruti<br>township | Salama | Total<br>Laikipia<br>west<br>(%) | Total<br>from<br>other<br>county<br>(%) | Overall<br>Total (%) |
|--------------------|----------|---------|---------|----------|----------------------|--------|----------------------------------|---|----------------------|
| Cattle             | 0        | 0       | 1       | 0        | 8                    | 0      | 9 (69.2)                         | 4 (30.8)                                | 13(42.0)             |
| Sheep              | 0        | 0       | 0       | 0        | 16                   | 0      | 16 (100.0)                       | 0 (0.0)                                 | 16(51.6)             |
| Goats              | 0        | 0       | 0       | 0        | 2                    | 0      | 2 (100.0)                        | 0 (0.0)                                 | 2(6.5)               |
| Total              | 0        | 0       | 1       | 0        | 26                   | 0      | 27 (87.1)                        | 4 (12.9)                                | 31                   |

## DISCUSSION

Most studies on prevalence of CE have been based on data from abattoir surveys (16). Slaughter surveys are considered economical and since the lesions of CE remain for life, it is possible to tell at postmortem whether the animal was infected or not.

This study provided information on CE infection status and the origin of the animals slaughtered in abattoirs in Laikipia west Sub County during the study period. However, there was the limitation of establishing the true origin of some animals since only the immediate history on arrival at the abattoir could be ascertained. The significant difference in prevalence between the abattoirs could not be fully explained, but most probably it depends on the source of animals for slaughter.

The individual species prevalence in cattle, sheep and goats depict a familiar trend when compared to previous studies in Kenya, where cattle generally had the highest prevalence (2, 12, and 17). When compared to the most recent survey

from a non hot spot area in central Kenya (17), the prevalence in this study were higher by a factor of six in cattle and goats (11.8:1.9) and about a third that of sheep (1.5:4.6).

The prevalence in cattle was just about a half (11.8:19.4&25.8) of that from the two known hot spot areas of Turkana and Maasai land (2,12) while that of sheep and goats was about a half (1.5:3.6 &2.3:4.5) of what was reported from Turkana (2). Although Laikipia west has not been documented as a CE hot spot area, these results are reasonably comparable to those from Turkana and Maasai land which are known all over the world for CE.

The differences in prevalence between the studies could be attributed to the differences in sample sizes; with the smaller sizes being more likely to have a higher degree of bias. Except for the study from central Kenya (17) where sheep had the highest prevalence, the prevalence agrees with similar studies done elsewhere in Kenya whose results showed that cattle were leading in prevalence (2, 12, 18). Examples of other studies from outside Kenya with similar trends include North Africa (19) Sudan (20) and Ethiopia (21).

The results of this study show that cattle contributed the highest proportion to the overall prevalence while goats contributed the least. Among the animals slaughtered, cattle were more likely to have CE than sheep or goats. This could be explained by the fact that cattle take longer to mature for slaughter and since CE develops slowly, lesions are more likely to be seen in cattle than in sheep or goats.

Females were three times more likely to have CE than males, in spite of the ratio of males to females sent for slaughter being 1:1.5. Although the reasons for this are not clear, in most communities males are more likely to be sent to slaughter at an earlier age than females unless they are selected for breeding. Most females are kept for offspring production and hence they are only sent to slaughter when they become unproductive; if there is any infection, cysts will have enough time to grow in females unlike in case of most males. The lung was the most (68%) frequently parasitized organ and this agrees with the results from other studies (2, 11, 16, and 18).

The consistently higher involvement of the lungs could be explained by the large capillary network and the loose connective tissue structure of the lung where Onchospheres can easily get trapped and develop into cysts (18). Even though cattle had the highest prevalence (11.8%); sheep had the highest proportion (76%) of animals with fertile cysts and the results agree with the findings from other similar studies elsewhere (2, 12). Given that sheep are more likely to be slaughtered at home during functions and ceremonies where meat inspection is rarely done and consequently improper disposal of organs found unfit for human consumption are more likely to occur; the public health importance of sheep in regards to CE cannot be ignored!

The reported low levels of knowledge of CE among even the health professionals (14, 13) only increases the public health concerns. Most (99.1%) of the animals slaughtered originated from Laikipia west sub county and these contributed 85% of the positive cases (n=72) while only 0.9% from outside the sub county contributed 15% of the

positive cases. Given that 43% (31/72) of the animals with CE had fertile cysts and that most, (87.1 %) of these originated from Laikipia west Sub County; there is a high possibility of environmental contamination with *Echinococcus* eggs in the study site.

Even though most positive animals (76.4%, n=72) originated from Rumuruti township ward, it is important to note that there a big livestock market which receives animals from other counties. The study site is multiethnic and the presence of a large livestock market at Rumuruti encourages both livestock and human movement. This movement, coupled with home slaughter and low levels of awareness (14, 13) provides fertile ground for the spread and transmission of CE which is considered as an emerging and a re-emerging zoonosis (4); the disease is being reported in areas previously considered clean and it is also reappearing in areas where it had been controlled.

#### CONCLUSION

The results show a significantly higher prevalence of CE in cattle compared to sheep and goats. Although the study area is not among the known CE hot spot areas of Kenya, the prevalence in this study are just about half of what has been reported from these areas. Most slaughter animals and those with fertile cysts originate from the study area. This suggests environmental contamination and possible transmission of CE in the study area. Possible implications for public health and the livestock economy require immediate control measures.

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#### REFERENCES

1. Thompson R.C.A. Biology and systematics of Echinococcus. In Echinococcus and hydatid disease (R.C.A. Thompson & A.J. Lymbery, Eds). CAB Int Wallingford 1995; 1-50.
2. Njoroge, E.M., Mbithi, P.M., Gathuma, J.M., Wachira, T.M., Gathura, P.B., Magambo, J.K., et al. A study of cystic Echinococcosis in slaughter animals in three selected areas of Northern Turkana, Kenya. *Vet. Parasitol.* 2002; 104: 85-91.
3. Romig, T., Zeyhle, E., Macpherson, C.N.L., Rees, P.H. & Were, J.B. Cyst growth and spontaneous cure in hydatid disease. *The Lancet* 1986; 1(8485): 861.
4. Eckert, J., Conraths, F.J., Tackmann, K. Echinococcosis: an emerging or re-emerging zoonosis? *Int. J. Parasitol* 2000; 30:1283-1294
5. Budke, C.M., Deplazes, P. and Torgerson, P.R. Global socioeconomic impact of cystic echinococcosis. *Emerg Infect Dis* 2006; 12: 296-303.
6. WHO/OIE. Manual on Echinococcosis in humans and animals World Health Organization and World Organization for Animal Health, Paris: France 2001
7. WHO. Sustaining the drive to overcome the global impact of neglected tropical diseases: second WHO report on neglected diseases. World Health Organization, Geneva: Switzerland 2013
8. Odero, J., Magambo, J., Zeyhle, E., Kutima, H., Ndahi, L., Njoroge, et al. The monetary burden of cystic Echinococcosis and its distribution based on gender and age in Turkana North District, Kenya. *Asian J Pharm Health Sci* 2014; 4 Issue -4
9. Gathura, P. and Gathuma, J. An evaluation of the economic losses resulting from condemnation of cattle and small stock livers due to the presence of hydatid cysts in Kenya. *Bull Anim Health Prod Afr* 1991; 39(2): 225 – 229.
10. French, C.M., Nelson, G.S., Wood, M. Hydatid disease in the Turkana district of Kenya. I. The background to the problem with hypotheses to account for the remarkably high prevalence of the disease in man. *Ann Trop Med Parasitol* 1982; 76: 425–437.
11. Macpherson, C.N.L., French, C.M., Stevenson, P., Karstad, L., Arundel, J.H. Hydatid disease in the Turkana District of Kenya. IV. The prevalence of Echinococcus granulosus infections in dogs, and observations on the role of the dog in the lifestyle of the Turkana. *Ann Trop Med Parasitol* 1985; 79: 51–61.
12. Addy, F., Alakonya, A., Wamae, N., Magambo, J., Mbae, C., Mulinge, et al. Prevalence and diversity of cystic Echinococcosis in livestock in Maasailand, Kenya. *Parasitol Res* 2012; 111: 2289-2294.
13. Kagira, J.M., Kanyari, W.N. The role of veterinary and medical personnel in the control of zoonoses in urban settlements on the shores of Lake Victoria, Kenya. *Sci Parasitol* 2010; 1:61-66.
14. John, K., Kazwala, R., Mfinanga, G.S. Knowledge of causes, clinical features and diagnosis of common zoonoses among medical practitioners in Tanzania. *BMC Infect Dis* 2008; 2: 162-169.
15. Kenya National Bureau of Statistics, (2010). The 2009 Kenya Population and Housing Census [web page] <http://www.knbs.or.ke/index/php/html>, date accessed: 20 March, 2015.
16. Baldock, F.C., Arthur, R.J., Lawrence, A.R. A meat works survey of bovine hydatidosis in Southern Queensland. *Aust. Vet. J.* 1985; 62(7): 238-242
17. Mbaya H., Magambo J., Njenga S., Zeyhle E., Mbae C., Mulinge E., et al. Echinococcus spp. in central Kenya: a different story *Parasitol Res* 2014; 113(10): 3789-3794.

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18. Ndirangu, P.N., Njeruh, F.M., Gathura, P.B., Kyule, M.N. The prevalence of Hydatidosis in slaughtered livestock in Kenya. *The Kenya Veterinarian* 2004; 27: 73-77.
  19. Bardonnet, K., Benchikh-Elfegoun M.C., Bart J.M., Harraga S., Hannache N., Haddad S., et al. Cystic Echinococcosis in Algeria: cattle act as reservoirs of a sheep strain and may contribute to human contamination. *Vet Parasitol* 2003; 116: 35-44
  20. Ibrahim, K., Thomas, R., Peter, K., & Omer, R. A. A molecular survey on cystic Echinococcosis in Sinnar area, Blue Nile state (Sudan). *Chin Med J* 2011; 124(18): 2829-2833.
  21. Fromsa, A., & Jobre, Y. Infection prevalence of (*Echinococcus granulosus*, Batsch, 1786) in domestic animals in Ethiopia: A synthesis report of previous surveys. *Ethiop Vet J* 2011; 15(2).