The burden of Cystic Echinococcosis in selected regions in Kenya

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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 wish to dedicate this thesis to my late grandfather, Mr. Manas Odero Aluko for introducing me to the art of caring and working with livestock at an early age. This later became part and parcel of my daily routine to date when I joined Animal Health and Industry Training Institute-NDOMBA in 1990 to train as an Animal Health Assistant. In 1993 I joined Egerton University for a diploma course in Animal Health and became a Veterinary Technologist in 1996.

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The Ministry of Agriculture, Livestock and fisheries staffs were of great help by allowing me access their annual meat inspection data bases at the district level. The District Veterinary Officers of Kisumu, Kajiado North, Kajiado Central and Isiolo Central districts and the Meat inspectors of the various slaughter houses/slabs visited during the slaughter house surveys contributed immensely towards the realization of this study.

Mr. Eberhard Zeyhle of AMREF- Kenya was of great help in terms of financial support to collect retrospective data, conduct slaughter house surveys and also accompanied me in actual data and sample collection in slaughter houses in various study sites. Mr. Zeyhle also assisted me to access the Cystic Echinococcosis patient’s data at AMREF-Kenya office.

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LIST OF ABBREVIATIONS AND ACRONYMS

AMREF	African Medical Research Foundation
CDC	Centre's for Disease Control and prevention
CE	Cystic Echinococcosis
CESSARi	Cystic Echinococcosis Sub Saharan Africa Research initiative
CBHWs	Community Based Health Workers
DALYs	Disability Adjusted Life Years
DNA	Deoxyribose Nucleic Acid
ELISA	Enzyme-linked immunosorbent assays
G1- G10	Granulossus 1- Granulossus 10
GBD	Global Burden of Disease
GDP	Gross Domestic Product
KMH	Kakuma Mission Hospital
Km^2	Square Kilometers
Kshs	Kenya shillings
PAIR	Puncture-Aspiration-Injection-Re-aspiration
PCR	Polymerase Chain Reaction
SH	Slaughter house
US$	United States Dollar (currency)
WHO	World Health Organization
YLD	Years of Life lot due to Disability
YLL	Years of Life Lost due to premature death

ABSTRACT

Cystic Echinococcosis (CE) is caused by the larval stage of the tapeworm *Echinococcus granulosus.* The disease occurs worldwide, and is highly endemic in parts of Kenya, especially Turkana and Maasai areas. The life cycle involves dogs and other canids as definitive hosts and livestock as intermediate hosts. Humans are aberrant intermediate hosts. It's a chronic debilitating disease resulting in morbidity, mortality and economic losses in human and animal populations. The outcome of the infection in livestock and human is cyst development in the liver, abdomen, lungs and other organ systems. In resource poor countries like Kenya surgical intervention is the main mode of treatment in CE infected individuals. In livestock the infection is typically asymptomatic and the most reliable diagnostic method is cyst detection during meat inspection and postmortem. Condemnation of animal organs (liver, lungs) at meat inspection results in CE-associated direct monetary loss. This study involved a retrospective review of CE patients' medical records obtained from AMREF-Kenya (1991-2011), with patients originating from Turkana North district of Kenya. Retrogressive annual meat inspection record review (5 years) and slaughter house surveys from selected regions (Kisumu East and West, Isiolo and Kajiado North districts) were conducted to assess the livestock CE-associated direct monetary loss. Data obtained were used to calculate CE-associated direct losses in human and livestock populations. A total of 586 surgical cases treated at Kakuma Mission Hospital, Turkana, Kenya were evaluated. The ratio of male: female infection was 1:2, individuals in the 31-40 age groups being most prevalent. The average direct cost of a CE surgical treatment was Kshs 60,000.00. The total direct cost for 586 surgical patients, including an additional factor of 10% for unreported and non-healthcare seeking patients, over the 20 year study period was Kshs 38,649,000.00 with an average of Kshs 1,932,450.00 per year. Annual indirect CE-associated monetary losses were calculated based on the lost economic opportunities by a herdsman or housewife in the Turkana community due to CE morbidity or mortality; this amounted to Kshs 411,250.00 for a herdsman and Kshs 117,716.00 for a house wife. The total direct

revenue loss attributed to condemned CE infected organs in the livestock species slaughtered in Kisumu East and West districts during the 5 years under review was Kshs 2,238,975.00, average Kshs 447,795.00 per year, Isiolo district was Kshs 1,824,450.00, average of Kshs 364,890.00 per year. Direct economic loss in Kajiado North during a 10 day slaughter house survey (meat inspection survey) was Kshs 234,025.00, average Kshs 23,403.00 per day. The indirect livestock production based losses were difficult to quantify in monetary values as they could also be associated with the harsh environmental conditions the livestock are found during certain seasons of the year. The results show a significant economic burden on individuals and livestock in these regions, this require proper CE surveillance and implementation of concerted effective and efficient CE control mechanisms at the definitive host (dog), intermediate hosts and community levels to prevent future incidences, spread of the infection outside its known endemic areas and also reduce the economic burden of the zoonosis.

CHAPTER ONE

1.0 INTRODUCTION AND LITERATURE REVIEW

1.1 Echinococcosis

Cystic Echinococcosis (CE) is a zoonotic disease caused by the hydatid cyst form of *Echinococcus granulosus.* Dogs and other canids are the primary definitive hosts for this parasite, with livestock acting as intermediate hosts and humans as aberrant intermediate hosts. The outcome of the infection in livestock and the human host is cyst development in the liver, lungs, or other organ systems. Intermediate hosts become infected when they ingest eggs passed from the adult tapeworm in dogs. The resulting oncosphere larvae penetrate the intestinal wall and enter the blood stream to develop, mainly in the liver and lungs, into slow-growing hydatid cysts that can reach up to 20 cm in diameter. As the cysts enlarge, they exert pressure on surrounding organs and can cause several pathological changes (Pawloski, *et al*., 2001).

The range of intermediate host species depends on the infecting strain of *E. granulosus*, regional or local differences in the availability of the various intermediate host species (Eckert *et al.*, 2001a). Since the life cycle relies on carnivores eating infected herbivores, the human host are usually a “dead-end” host for the parasite. However this is not always the case, many trans-human groups in hyper endemic regions of eastern Africa, such as the Turkana region of northwest Kenya, do not bury their dead. Dogs and wild carnivores are able to scavenge from the human remains; if the cadaver harbors’ cysts, then under these unique circumstances, human beings can act as intermediate hosts (Macpherson, 1983).

The initial phase of the infection is always asymptomatic. Small, well encapsulated, non-progressive or calcified cysts typically do not induce major pathology, and patients may remain asymptomatic for years or permanently (Ammann & Eckert, 1996; Pawloski *et al*., 2001). The induction of morbidity depends on the number, size, and developmental status of the cysts (active or inactive), the involved organ, the localization of the cysts within the organ, the pressure of cysts on surrounding tissues and structures, and the defense mechanisms of the infected individual (Larrieu & Frider, 2001).

The cysts can either be viable or non-viable. Viable cysts are usually filled with clear fluid with few calcifications; whereas non- viable cysts are mainly calcified. Viable cysts can either be fertile, containing protoscoleces, or sterile, containing only highly antigenic fluid (Kern, 2003) which causes the disease.

The disease is generally characterized by symptoms such as jaundice, fever and abdominal pain. Associated complications include hepatomegally, portal hypertension and cholangitis (Pawloski *et al*., 2001). Fatal complications may arise secondary to rupture of the cyst which can result in anaphylactic reactions due to the release of hydatid fluid. The rupture can result in secondary infection due to the release of protoscoleces, which have the potential to differentiate into new hydatid cysts (Filice & Brunetti, 1997; Sinan *et al.,* 2002).

It's of major public health importance in sheep rearing areas worldwide (Eckert & Deplazes, 2004) due to its morbidity that causes economic impact and animal production associated losses; the affected viscera are condemned at the slaughterhouses/slabs. The parasite is cosmopolitan and possess the second rank after Schistosomiasis in consideration of helminthic diseases significance (Muller, 2002; Torgerson & Budke, 2003; Sadjjadi, 2006) with a wide global distribution (Fig 1.1).

It is endemic in several areas, particularly the Mediterranean, central Asia including the Tibetan plateau, Northern and Eastern Africa, Australia, and southern South America (Macpherson, 2005; Magambo *et al*., 2006; Jenkins *et al*., 2005).

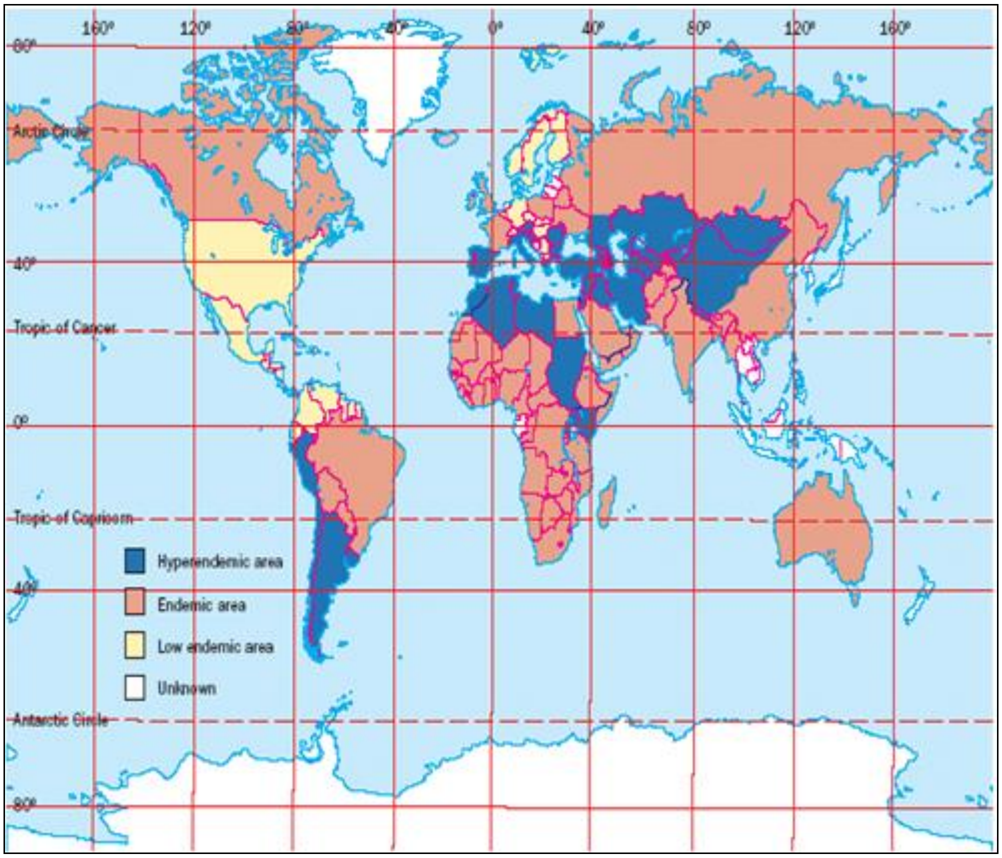

Figure 1.1: Global distribution of Cystic (Eckert & Deplazes, 2004)

Generally, the highest prevalence's of the disorder are in nomadic populations. Nomadic people keep dogs for various reasons, such as herding and guarding, as food, as bed-warmers, and as sanitation animals. The combination of people and dogs living in close proximity, scarce water resources, and conditions with poor hygiene provide the ideal environment for *Echinococcus* species (Pawloski, *et al*., 2001).

Cystic Echinococcosis is highly endemic in sub-Saharan Africa (Magambo *et al.,* 1996). It has been reported in West and East African countries where it is prevalent among the nomadic pastoralists. Cystic Echinococcosis is rare in Central and Southern African countries (Magambo *et al.,* 1996). Due to the lack of well-documented data from many countries in Africa, the sub-Saharan picture of the CE situation is not complete (Magambo *et al*., 1996).

Five out of ten *Echinococcus granulosus* strains designated G1 to G10 are infective to human in sub-Saharan Africa. Most human cases of CE are caused by the sheep strain (G1) and camel strain (G6). Other strains occurring in the area are horse strain (G4 or *Echinococcus equinus*), and cattle strain (G5 or *Echinococcus ortleppi*) and a lion (G7) strain (Macpherson & Wachira, 1997; Dinkel *et al*., 2004). Sheep and goats are the most common domestic intermediate hosts; camels are equally important hosts in Sudan and Turkana (Dinkel *et al*., 2004; Omer *et al*., 2004).

In Kenya, CE occurs in most parts of the country but available data are mostly from Turkana communities in the northwest and from Maasai communities in the south (Fig 1.2). Both communities are nomadic pastoralists rearing huge herds of livestock including sheep, goats, cattle, donkeys and camels (Wachira *et al*., 1993; Wahlers *et al*., 2012) (Fig 1.2). The CE prevalence in cattle, sheep and goats is estimated at 25.8 %, 16.5% and 10.8% respectively in Maasai area with majority of cysts occurring in the liver (Addy *et al*., 2012).

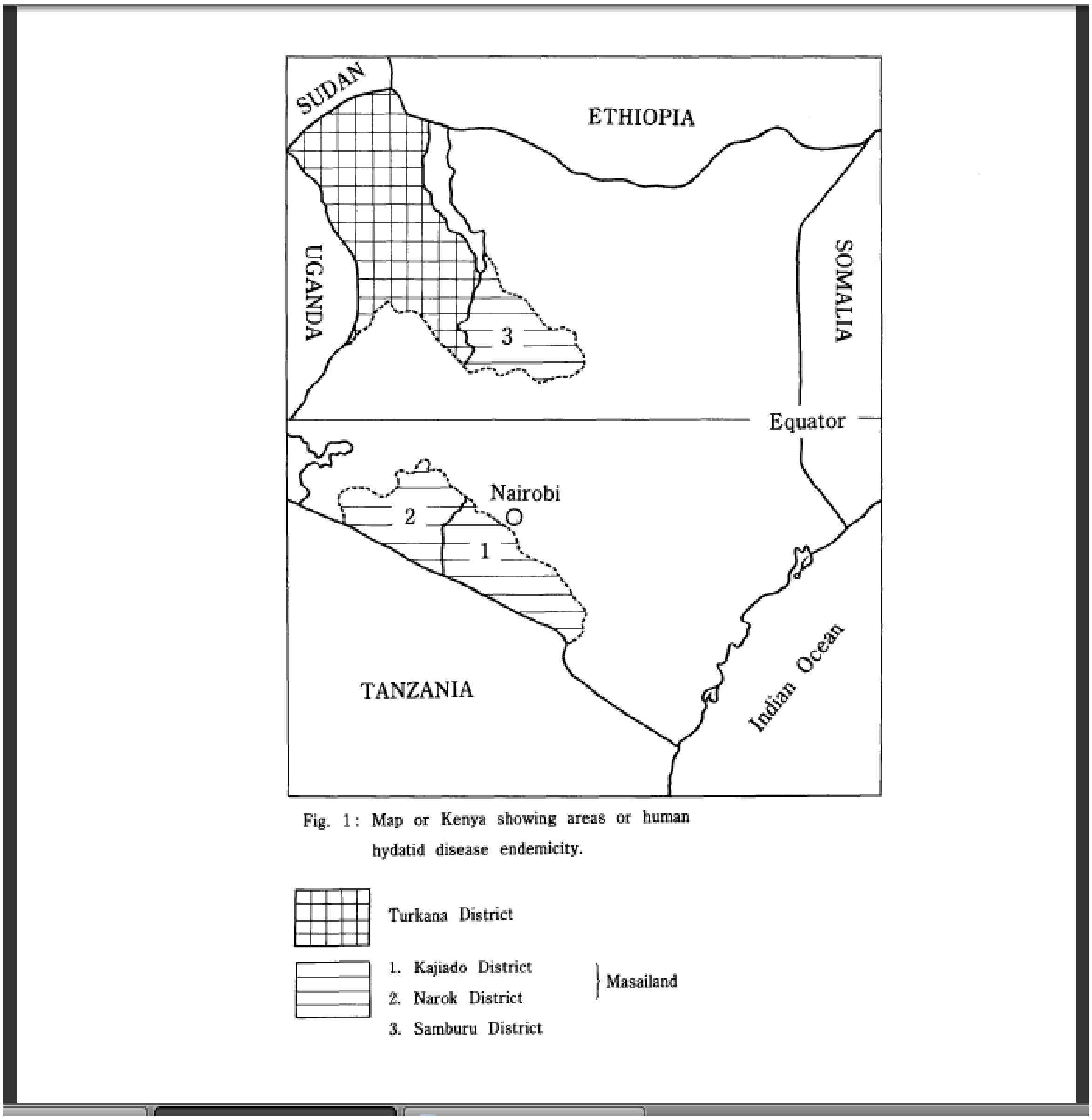

Figure 1.2: Map of Kenya showing Cystic Echinococcosis endemic (Gathura & Kamiya, 1990)

Cystic Echinococcosis affects both humans and livestock and has important economic consequences (Togerson, 2003). Human associated economic losses arise from diagnosis procedures including ultrasound and various laboratory tests, surgical or chemotherapeutic treatment, hospitalization and convalescence, life impairment and fatalities (Budke *et al.,* 2006). The main hydatid induced production losses in ruminants are productivity losses (reduction in carcass weight, milk production, and fleece value), losses of offal (liver, lung, etc.), and fertility losses (Yildiz & Gurcan 2003; Sariozkan & Yalcin, 2009).Estimation of economic burden in human and livestock is important and should be part of any cost-benefit program for the control of parasitic zoonoses (Budke *et al.,* 2006).

Two methods previously used to assess disease burden are disability adjusted life years (DALYs) and the calculation of monetary losses. Cystic Echinococcosis results in mortality, morbidity and economic losses in human and animal populations. Because the total societal impact is often unknown, DALYs is used to assess the burden of this disease in non-monetary terms (Carabin *et al*., 2005).

A DALY has the same value in poor and rich countries (Carabin *et al*., 2005). The DALY is used as a single measure to quantify the burden of diseases, injuries and risk factors (Murray, 1996). A DALY is an indicator of burden of disease in a population. It takes into account not only premature mortality, but also disability caused by disease or injury (WHO Report, 2009). Important risk factors for human CE include socio-economic and cultural factors, such as unrestrained dogs living closely with people, uncontrolled slaughter of livestock, and unsanitary living conditions (Tiaoying *et al*., 2005; Schantz, 2006).

The DALY is a time-based measure that combines years of life lost due to premature mortality and years of life lost due to time lived in health states less than ideal health. One DALY can be thought of as one lost year of “healthy” life, and the burden of disease can be thought of as a measurement of the gap between current health status and an ideal situation where everyone lives into old age, free of disease and disability

(Tulchinsky & Varavikova, 2000; Murray and Lopez, 2004; WHO Report, 2004; WHO Report, 2009).

The global burden of CE is estimated at less than one million Disability Adjusted Life Years (DALYs) lost, which gives CE a greater impact than Onchocercosis. Indeed CE approaches the burden caused by African Trypanosomosis and Schistosomiasis combined, less than one and a half million DALYs (Budke *et al*., 2006).

In Kenya no CE burden estimates in humans or livestock has been documented before. Such an estimate is imperative since it can be used as a tool to prioritize control measures for CE, which is essentially a preventable disease. In this study, the calculation of the CE-associated monetary losses in humans and livestock in selected regions of Kenya has been used to estimate the CE burden. The direct CE-associated monetary losses in livestock were based on the lost revenue from condemnation of Hydatid infected organs at meat inspection. Indirect CE-associated monetary losses in humans in this study were estimated based on the lost economic opportunities by a healthy herdsman or housewife due to CE morbidity or mortality in the Turkana community of Kenya. The disease affect children even below 1 year old, however their economic contribution to the family or community was assumed to be negligible as they depend on the parents for their basic needs and the boys do not own livestock which is the measure of wealth in the community.

1.2 Cystic Echinococcosis in the human host

Cystic Echinococcosis is caused by the metacestode stage of various strains of *E. granulosus*, which is a cystic structure typically filled with a clear fluid (hydatid fluid). About 5 days after ingestion of eggs, the metacestode is a small vesicle (60 to 70 µm in diameter) consisting of an internal cellular layer (germinal layer) and an outer acellular, laminated layer (Eckert & Deplazes, 2004). This cyst (endocyst) gradually expands and induces a granulomatous host reaction, followed by a fibrous tissue reaction and the formation of a connective tissue layer (pericyst). The size of cysts in the human body is highly variable and usually ranges between 1 and 15 cm, but much larger cysts (less than 20 cm in diameter) may also occur (Ammann & Eckert, 1996; Pawlowski, 1997; Shambesh, 1997).

The exact time required for the development of Protoscoleces within cysts in the human host is not known, but it is thought to be more than 10 months post infection (Eckert & Deplazes, 2004). Protoscoleces can already be formed in cysts of 5 to 20 mm in diameter (Pawlowski *et al.,* 2001); on the other hand, a proportion of cysts does not produce protoscoleces and remain "sterile." Most of the cysts are univesicular i.e. unilocular, but in some, smaller daughter cysts are formed within larger mother cysts.

Cystic Echinococcosis occurs in various age groups but from as younger less than 1 year to over 75 years. In some areas of endemic infection, most hospital cases are recorded in the age groups between 21 and 40 years, but the highest morbidity may also occur in younger individuals aged between 6 and 20 years (Ammann & Eckert, 1996; Pawlowski *et al.,* 2001).

The primary phase of the infection is always asymptomatic, small cysts not inducing major disease may remain asymptomatic for many years, if not permanently. The incubation period of CE is unclear but probably lasts for many months to years (Chai *et al.,* 1993). The infection may become symptomatic if the cysts either rupture or exert a mass-effect on various body organs. Recurrence may arise following surgery on primary cysts (Utrilla *et al.,* 1991).

Cysts can reach very huge size producing discomforting pressure at affected sites. For example the biggest cyst isolated in human in Turkana, Kakuma Mission Hospital (KMH), Kenya contained 26 litres of fluid (Zeyhle & Magambo, 2007).

More than 90% of cysts occur in the liver (Fig 1.3), lungs, or both. Symptomatic cysts have been reported occasionally in the kidney, spleen, peritoneal cavity, and the skin (2-3% each) and muscles; and rarely in the heart, brain, vertebral column, and ovaries (1% or less in each organ) (Chai *et al.*, 1993).

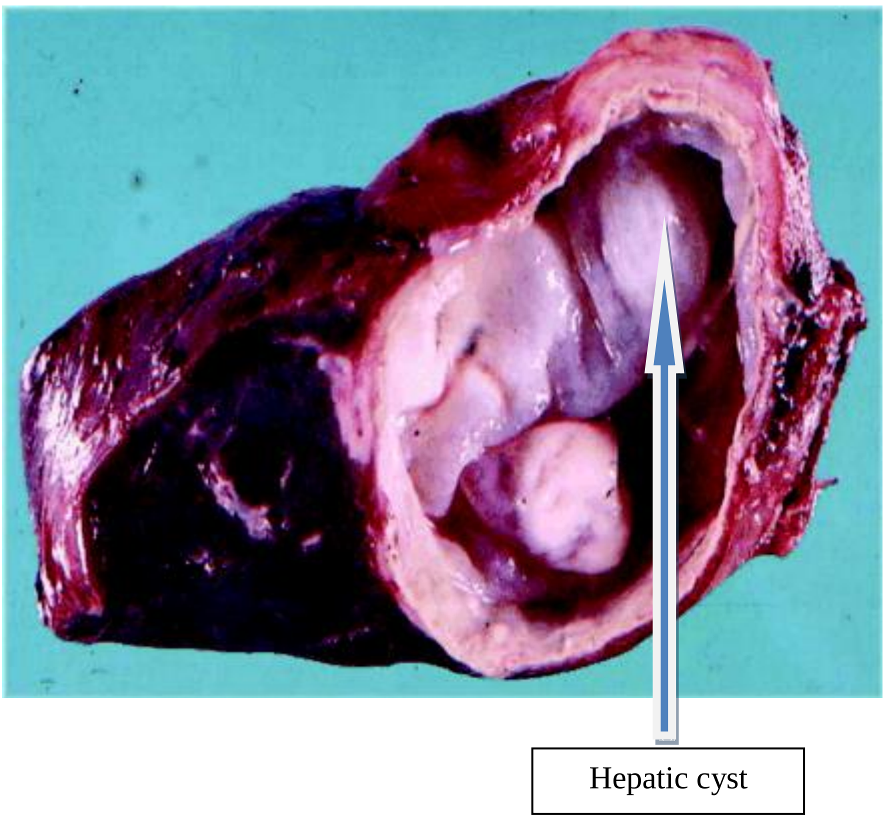

Figure 1.3: Diagram showing hepatic Cystic Echinococcosis in a patient [endocyst removed; lesion size approximately 3 by 3.5 cm] (Eckert & Deplazes**,** 2004).

Cystic Echinococcosis symptoms are highly variable and depend on the organ involved, size of the cysts and their position within the organ, the mass effect within the organ and upon surrounding structures, and complications relating to cyst rupture and secondary infection (al-Karawi *et al.*, 1990; Pawlowski *et al.*, 2001). Manifestations of systemic immunological responses may be evident in response to cyst leakage or rupture.

Common complications include rupture into the biliary tree with secondary cholangitis and biliary obstruction by daughter cysts, sub phrenic abscess formation, intra-peritoneal rupture, rupture into the bronchial tree, and development of a bronchobiliary fistula (Pawlowski *et al.*, 2001).

1.3 Description of *Echinococcus granulosus* parasite

Echinococcus granulosus, the causative agent of CE, is a cosmopolitan parasite of man and animals, both domestic and wild herbivores and carnivores. The parasite has at least nine host adapted strains occurring worldwide (Thompson, 1995). Dogs and other canids are the definitive hosts where-as mammals (herbivores and camels) and humans are the intermediate hosts. The parasite has three developmental stages; larva, egg and adult. The mature adult measures 3-9 mm long and consists of 3 proglottids (the immature, mature and gravid), a scolex with 4 suckers and a double crown of 28-50 hooks on the rostellum at the tip of the scolex (Wardle *et al*., 1974; Kearn, 1998). Eggs are spherical to ellipsoidal in shape with an oncosphere. The adult parasites are found in the small intestines of the definitive hosts, while the larval stages occur as cysts in the visceral organs (liver and lungs) of the intermediate host, causing CE (Thompson, 1995).

1.4 Life cycle of *Echinococcus granulosus*

The life cycle of this parasite involve two mammalian hosts. The adult cestode inhabits the small intestine of a carnivore (definitive host) and produces eggs containing infective oncosphere. Either cestode segments (proglottids) containing eggs or free eggs are released from the intestinal tract of the carnivore into the environment (Eckert & Deplazes, 2004).

After oral uptake of eggs by an intermediate host animal, a larval stage, the metacestode, develops in internal organs. Typically, mature metacestodes produces numerous protoscoleces, each having the potential to develop into an adult cestode after being ingested by a suitable definitive host (Eckert & Deplazes, 2004). Accidentally, eggs are also ingested by humans and other "aberrant" hosts that do not play a role in the natural cycle. On rare occasions, the spectrum of aberrant hosts may even include definitive hosts (dogs). Whereas the infection of carnivores with immature or mature intestinal stages of *E. granulosus* does not cause morbidity, the invasion of various organs (mainly liver and lungs) of intermediate or aberrant hosts by metacestodes can cause severe and even fatal disease, Echinococcosis (Eckert & Deplazes, 2004).

The adult parasite resides in the small intestines of the definitive hosts, dogs or other canids where the gravid proglottids release eggs that are passed in the feces. After ingestion by a suitable intermediate host, the egg hatches into an oncosphere that penetrates the intestinal wall and migrates through the circulatory system into various organs and develops into a fluid filled cyst. The definitive host becomes infected by ingesting the cyst-containing organs of the infected intermediate host, the protoscoleces evaginate, attach to the intestinal mucosa, and develop into adult stages. The lifecycle of *E. granulosus* is shown in the schematic diagram in Fig 1.4.

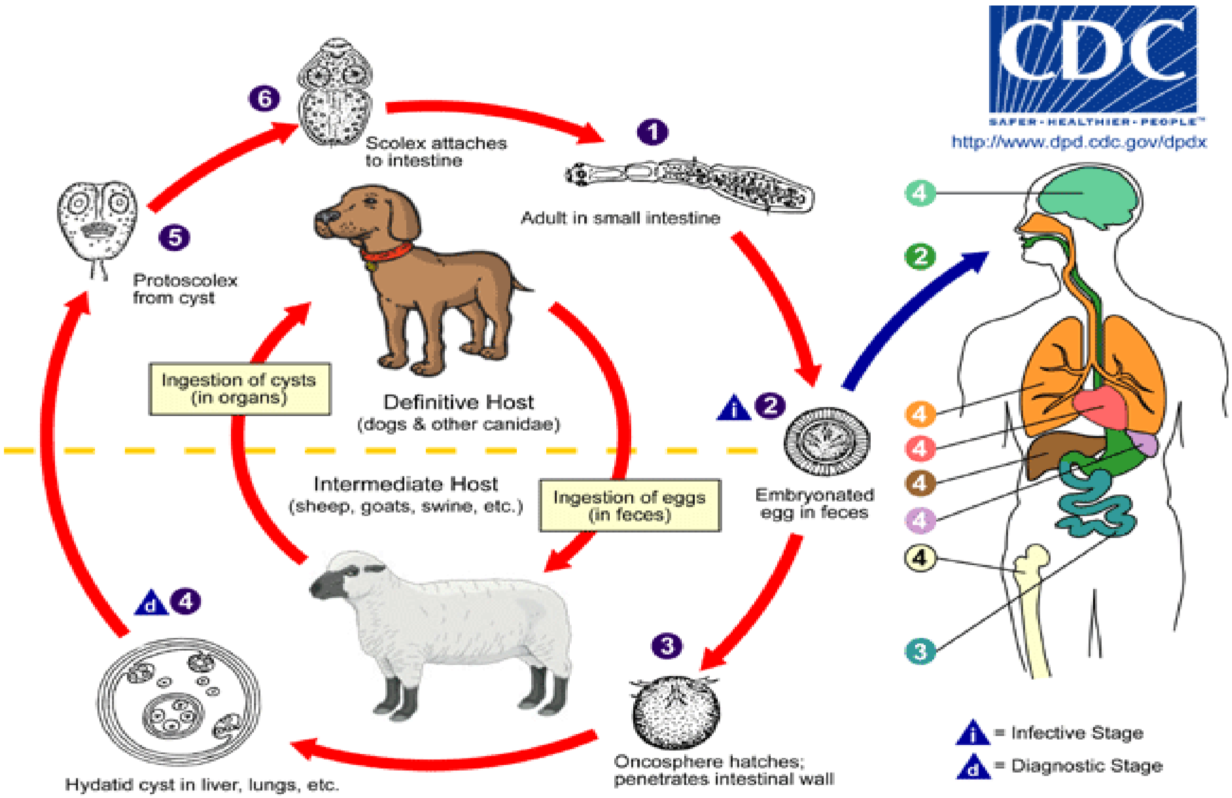

Figure 1.4: Life cycle of *Echinococcus granulosus* (http//www.dpd.cdc.gov/dpdx)

1.5 Social reasons favoring the life cycle of Cystic Echinococcosis

Many social reasons favor the life cycle of *E granulossus* and the persistence of CE in many parts of the world. Many families have small plots of land and live in close proximity with their flocks and dogs. The gathering and grazing together groups of animals belonging to different owners lead to circulation of infections, including CE. Home slaughter and feeding of dogs on offal favor the parasite's life cycle. Numerous small insufficiently equipped abattoirs built in the vicinity of human settlements, public health education are other factors that favor the life cycle of *E granulosus*.

Stray dogs and other canids especially wolves may feed on dead animals and garbage, and hunt intermediate hosts. Dogs and livestock living in close proximity with man leading to circulation of zoonotic infection. Moreover, the high cost and difficulties of slaughtering single animals consequent to legislative rules may create situations of uncontrolled slaughtering (Battelli, 2009).

1.6 Description of hydatid cyst

The completely developed hydatid cyst is spherical in shape and is characteristically unilocular (Schantz, 1982) which is fluid filled. However, the cysts occurring in the lungs of the sheep are usually multilocular (Soulsby, 1982). This fluid filled cavity is surrounded by a germinal layer internally and a tough elastic acellular laminated layer externally (Fig 1.5). The latter is supported by fibrous capsule of host origin. Increase in size of this single chambered cyst occurs by concentric enlargement (Thompson, 1995). Capsule is produced by the asexual multiplication of the cyst germinal layer. These brood capsules in turn produce multiple protoscolices by polyembryony (Schantz, 1982).

Several cysts may come closer to each other and fuse to form a cluster of small cysts of different sizes (Thompson, 1995). Formation of daughter cysts is common in human, where the size of the cyst is usually large (Soulsby, 1982), containing large volume of fluid and protoscoleces (Schantz, 1982). Secondary hydatid cyst may be produced from the protoscoleces if the cyst within the intermediate host bursts (Thompson, 1995). Not all hydatid cysts are fertile enough to produce brood capsules and protoscoleces, and this depends upon host species and site of development (Soulsby, 1982).

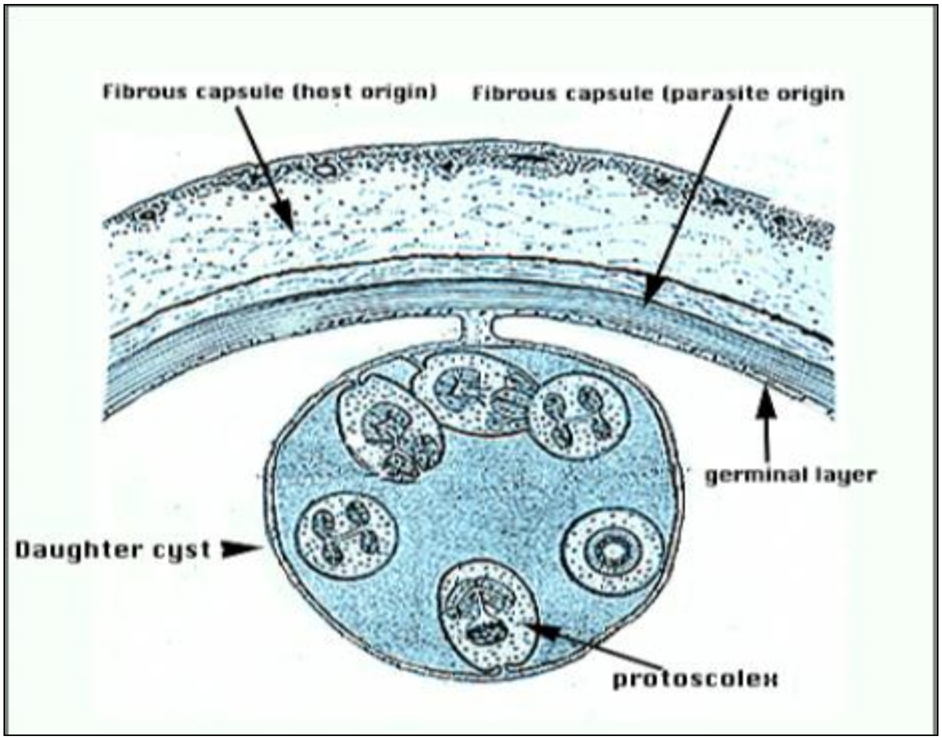

Figure 1.5: Schematic illustration of a hydatid cyst

(http://www.soton.ac.uk/~ceb/Diagnosis/Vol8.htm)

1.7 Epidemiology of Cystic Echinococcosis

Echinococcus granuloss has worldwide distribution with the highest prevalence in parts of Europe, Asia, North and East Africa, Australia and S. America (Eckert *et al.,* 2001a). The life cycles of *E. granulosus* strains can be classified as domestic, involving the domestic dog as the principal definitive host and various species of domestic ungulates as intermediate hosts, or as sylvatic, involving wild carnivores and ungulates as hosts, the wildlife cycle. Within the cycles, the specific role of various host species may differ considerably between regions of endemic infection. In many areas of endemic infection, domestic and sylvatic life cycles coexist or overlap (Rausch, 1995).

The dog-sheep strain is globally the most widespread and important strain of *E. granulossus* and exists in its domestic form involving dogs and domestic animals such as sheep and goat in many regions. Complex situations of overlapping domestic and sylvatic cycles also exist in other regions such as Africa and Eurasia and represent special problems in Echinococcosis control (Rausch, 1995; Macpherson & Wachira, 1997; Macpherson, 2001; Jenkins, 2002). In the countries like Nepal and Poland, the parasite cycles between pigs and dogs (Pawlowski *et al*., 2001).

Wild animals are involved in sylvatic cycles in different parts of the world with small zoonotic importance compared to the domestic cycles. There is also overlapping of both domestic and sylvatic cycles which represent special problems in Echinococcosis control (Jenkins, 2002).

Environmental temperature and humidity influence egg survival and infectivity; but do not regulate the parasite population (Eckert *et al.*, 2001b). *Echinococcus granulosus* eggs can survive under humid conditions for several weeks or months in areas of warm and cold climates, but they are sensitive to desiccation (Eckert *et al*., 2001b; Gemmell *et al*., 2001). Humans acquire primary CE by ingestion of *E. granulossus* eggs from plants, soil or dog fur contaminated by infected dog feces (Eckert *et al*., 2001b).

Key factors associated with persistence, emergence, or reemergence of CE include the presence of stray dogs infected with *E. granulosus*, insufficient facilities for slaughter and destruction of infected viscera and illegal or un-inspected home slaughter of livestock. A close association with dogs, uncontrolled animal trade and movements of livestock within and between countries are other important epidemiological factors (Todorov & Boeva, 1999; Battelli *et al*., 2002).

1.8 Diagnosis of Cystic Echinococcosis

The diagnosis of CE in individual patients is based on identification of cyst structures by imaging techniques, predominantly ultrasonography, computed tomography, X-ray examinations, and confirmation by detection of specific serum antibodies by immunodiagnostic tests (Craig, 1997; Grimm, 1998; Gottstein, 2000; Kern, 2001; Pawlowski *et al.*, 2001; Teggi *et al.*, 2002). For more than 30 years, ultrasound scanning has been used in the detection of abdominal CE (Gharbi *et al*., 1981; Macpherson *et al*., 2003).

The combination of ultrasound and confirmatory serology is now a standard approach for epidemiological surveys that provide information on the prevalence of the disease, both overall and by age, and identifying high-risk and low-risk groups (Macpherson *et al*., 2003; Moro *et al*., 2005; Wang *et al*., 2005). The value of ultrasound is extended to follow up after chemotherapeutic or surgical intervention and provides a visual guidance for needle aspiration of cyst contents for diagnosing clinically doubtful cases of CE (Stefaniak *et al*., 1997) and in treatment by Puncture-Aspiration-Injection-Re-aspiration (PAIR) (Filice & Brunetti, 1997).

The diagnosis of intestinal *E. granulosus* infection in living dogs is difficult because the small proglottids spontaneously discharged with feces are usually overlooked and eggs detected by routine coproscopic techniques cannot be differentiated by light microscopy from the eggs of other *Echinococcus* species or of *Taenia* species. Enzyme Linked Immunosorbent Assay (ELISA) for detecting parasite antigens in fecal samples, coproantigens has been used in specialized laboratories for the last few years (Deplazes, 1994; Craig, 1995).

Infections with *E. granulosus* cysts in the livestock intermediate hosts are typically asymptomatic, except a few cases of long-standing and heavy infections, for example in horses (Figure 1.6) (Eckert & Deplazes 2004). There are no reliable methods for the routine diagnosis of the infection in living animals, but in rare cases cysts have been identified by ultrasonography and serum antibody detection (Eckert *et al*., 2001a). A new ELISA with a specificity and sensitivity of 50% to 60% is useful for detecting *E. granulosus* cysts in sheep on a flock basis but cannot be used for reliable diagnosis of infected individual animals (Kittelberger *et al.*, 2002). The most reliable diagnostic method is cyst detection during meat inspection or at postmortem examination.

1.8.1 Horse liver with multiple cysts of *Echinococcus granulosus*

A horse liver infected with multiple cysts of *E. granulosus* as shown in Fig 1.6. The cyst diameters were approximately 1 to 10 cm. The horse exhibited clinical signs of the disease (Eckert & Deplazes, 2004).

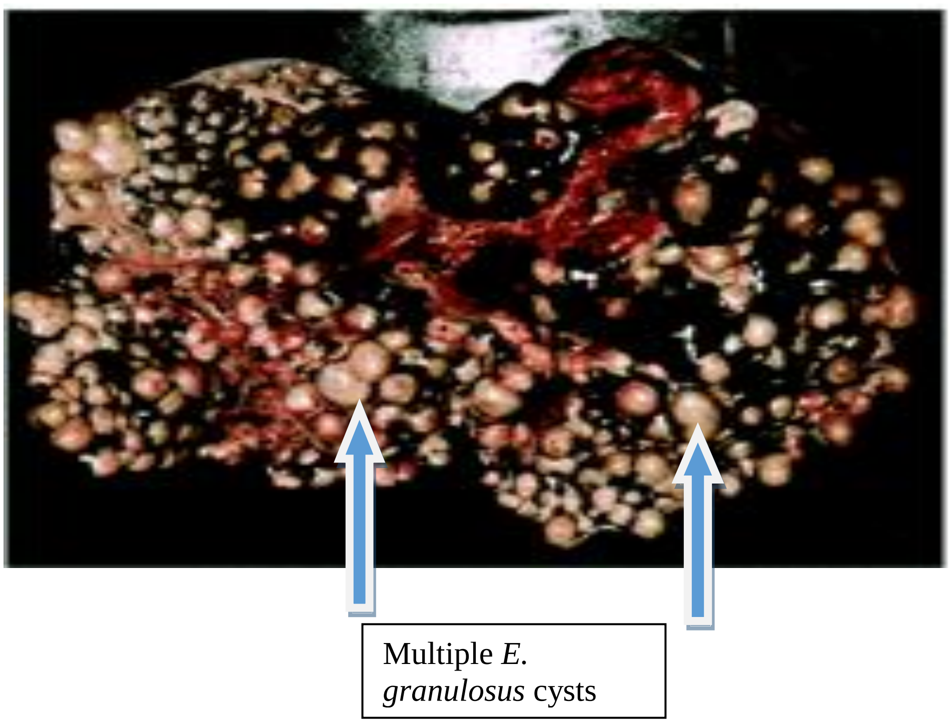

Figure 1.6: Horse liver with multiple cysts of *Echinococcus granulosus* (Eckert & Deplazes, 2004).

1.9 Treatment of Cystic Echinococcosis

Medical treatment does not definitively cure hydatid cysts, and surgical management aims to eliminate the parasite, favoring rapid disappearance of the residual cavity, preventing complications and recurrence, and shortening the hospital stay (Cinerei & Bertoldi, 2001). Treatment of the disease in human host involves surgical removal of either the entire cyst (Laparotomy) or its contents by Puncture, Aspiration, Injection and Re-aspiration (PAIR) (Filice *et al*., 1997; Sinan *et al*., 2002) or the use of benzimidazole chemotherapy. Albendazole is the drug of choice; beneficial results have been obtained in 75% of cases treated with it (Eckert *et al*., 2004). All forms of treatment carry the risk of recurrent disease if a viable parasite material remains after treatment or surgery.

The PAIR is a minimally invasive technique and includes the following steps, percutaneous puncture of the cyst under ultrasonographic guidance, aspiration of a substantial portion of about 10 to 15 ml of the cyst fluid, injection of a parasitocidal solution which is 95% ethanol; approximately an equivalent of one-third of the amount aspirated, and re-aspiration of the fluid content after 5 minutes (WHO, 2001). Hypertonic, 15% NaCl solution in the cyst fluid can be used as a parasitocidal solution, but its action is slower, so that re-aspiration is performed after 15 to 20 minutes (Khuroo *et al.,* 1997; WHO, 2001).

Surgery, using various technical approaches (Morris & Richards, 1992; Ammann & Eckert 1996; Pawlowski, 2001), has the potential to remove the cysts and lead to complete cure. It can be successfully performed in a high proportion of patients with simple forms of CE. This refers to limited cyst number and organ involvement, cysts not in risky locations and disease not too far advanced. However, surgery may be impractical in other cases, predominantly in patients with multiple cysts in several organs, in patients with a high surgical risk, and if facilities for advanced surgery are inadequate. In such situations, PAIR or chemotherapy can be considered as alternative options of treatment.

The PAIR technique was introduced in the mid-1980s (Amor *et al.*, 1986; Gargouri *et al.*, 1990; Filice *et al*., 1990; Filice & Brunetti., 1997). Only skilled practitioners should undertake this technique, with intensive-care support in the event of anaphylaxis (MacManus *et al.*, 2003). Cyst aspirates should be assessed for the presence of protoscolices and bilirubin. The PAIR should only be used in patients with chemotherapeutic cover to minimize the risk of secondary CE. There is no experience of this technique in children and pregnant women. Puncture-Aspiration-Injection-Re-aspiration is best used for liver cysts of 5 cm or greater diameter that are anechoic, multiseptate, or multiple.

The PAIR has been used in patients who have relapsed after surgery. It is contraindicated for superficial or inaccessible cysts, and for cysts that are calcified, solid, or have communication with bile ducts (Anonymous, 1996). Complication rates for PAIR range from 28% in the absence of albendazole (Men *et al.*, 1999) to 5-10% with concomitant chemotherapy (Pelaez, 2000; Aygun *et al.*, 2001).

The benzimidazole compounds such as albendazole and mebendazole have been the cornerstone of chemotherapy for CE. Treatment with albendazole, 10 mg/kg in divided doses of 400 mg twice daily results in the disappearance of up to 48% of cysts and a substantial reduction in size of a further 24% (Horton, 1997). Cyst non-viability increases with duration of treatment from 72% of cysts non-viable after 1 month to 94% of cysts non-viable after 3 months of treatment (Gil-Grande *et al.*, 1993).

Praziquantel is the drug of choice for treating *E. granulosus* infested dogs (Eckert *et al.*, 2001a). The pre-patent period of *E. granulosus* is approximately 6 weeks; the treatment interval of *E. granulosus* infested dogs with praziquantel is 6 weeks (Torgerson & Budke, 2003). Oral praziquantel has been used since 1970s; recently sub cutaneous implants of praziquantel have been developed in China to overcome the inconvenience of frequent dosing after every 6 weeks (Ito *et al.*, 2003).

1.10 Control and prevention of Cystic Echinococcosis

The control program consist of three main components namely, at the human intermediate host level, mass screening and treatment through surgery, PAIR and chemotherapy can be applied. At the definitive host level, dog population control through killing of stray dogs, sterilization of female dogs before their first breeding age and regular de-worming of all owned dogs are important control measures. Community public health education to create awareness on the transmission mode and dangers of the infection is a key control and prevention measure (Magambo *et al*., 2006).

Data on control of CE is lacking in most parts of sub-Saharan Africa. This may be explained by low priority given by respective governments to arid pastoral areas where the disease is most prevalent (Magambo *et al*., 2006). Sub-Saharan Africa is the world poorest region where more than 46% of the population, approximately 316m people survives on less than US$1 a day. The contribution of pastoral communities to the Gross Domestic Product (GDP) of their respective countries is low and hence low priority focus of these governments to these areas (Magambo *et al*., 2006).

Long-term CE control measures include public health education with primary health care (Parodi *et al.*, 2001) and veterinary public health activities, such as the improvement of slaughter hygiene and meat inspection, dog registration and sanitation measures (Gemmell *et al.*, 2001). These aim at creating CE awareness and controlling the infection at the intermediate host, livestock and the definitive host, dog.

Base-line data required before the implementation of any successful control program to serve as references for measuring control progress include the prevalence of *E. granulosus* in dog populations and the age-dependent prevalence of cysts in the intermediate hosts. Modern techniques can be used for surveys; the coproantigen ELISA to detect *E. granulosus* in dog populations and ultrasonography in combination with serology for mass diagnosis of CE in humans (Craig, 1997; Schantz, 1997; WHO 2001; Christofi *et al.*, 2002; Fraser *et al.*, 2002; Rogan & Craig, 2002).

The main constraints for CE control in Turkana, a known CE endemic area in Kenya include the nomadic nature of the Turkana community and their neighbors and lack of long term funding and government support to mount CE research and control program. Failure of the community to adopt control measures due to presence of other myriad problems related to poverty also affect CE control in Turkana community (Magambo *et al.*, 2006).

1.11 Factors hindering the control of Echinococcosis

The control of CE is directly linked to social, political and economic situations, and sometimes to religious practices, in the affected areas. A situation of social and political instability and poverty favors the spread of the disease owing to uncontrolled animal slaughtering and viscera disposal, uncontrolled animal trade, presence of roaming dogs and above all absence or scarcity of veterinary services. Inadequate knowledge and health education and information of the people are barriers facing the effectiveness of control programs and interventions (Battelli, 2009). For instance, control of CE is less effective without the support of dog-owners, and this support can only be obtained if the people have a clear understanding of the life cycle of *E. granulosus* and of risk factors for human infections (Heath *et al.*, 2006). Other important factors facilitating the spread of CE may be occurrence of emergencies such as earthquakes, floods, famine, wars and institutional upsets.

1.12 Socio-Economic impact of Cystic Echinococcosis

Socio- Economic consequences of CE are related to both human and livestock infections and the costs of control programs. In humans, CE has various consequences, including direct monetary costs such as diagnosis, hospitalization, surgical or percutaneous treatments. Therapy, post-treatment care and travel for both patient and family members and other indirect costs which may be mortality, suffering and social consequences of disability, loss of working days or " production " and abandonment of farming or agricultural activities by affected or at-risk persons.

It is pertinent to note that some of the above-mentioned consequences are difficult to evaluate from an economic point of view and others can be mainly or exclusively evaluated in social terms because the disease may negatively affect the quality of life. Some studies conducted in the United Kingdom (Torgerson & Dowling, 2001) and Jordan (Torgerson *et al.*, 2001) suggested that patients surgically treated for CE had a significant decrease in their quality of life, and that patients presenting for treatment of CE had twice the unemployment rate of the general population in Kyrgyzstan (Torgerson *et al.,* 2003). Logistical costs which include payments to Surgeons and other staff involved during the operation, traveling costs, fuel costs, follow up costs and public health education costs add up to the economic loss.

In livestock, the following consequences of CE must be considered, reduced yield and quality of meat, milk and wool; decreased hide and skin value; reduced birth rate and fecundity. Moreover others such as delayed performance and growth; condemnation of organs, especially liver and lungs; costs for destruction of infected viscera and dead animals also counts. There are also other possible indirect detrimental consequences, such as bans on export of animals and their products if these are required to be free of CE. For the case of livestock, the importance of the above-mentioned economic consequences will depend, to a large extent, on the typology and general health status of the animals and on the characteristics of the farming or livestock industry (Battelli, 2003).

Quantification, standardized evaluation of such losses and exclusion of biasing factors in animal production are very difficult and therefore the available data should be interpreted with caution (Battelli, 2003). An annual worldwide livestock associated production loss for CE was estimated at US$ 142 million and possibly increase up to US$ 2.2 billion

(Budke *et al.,* 2006).

1.13 Disability Adjusted Life Years (DALYs) as a measure CE burden

The DALYs were first constructed for the Global Burden of Disease Study, which was developed to attempt to quantify the worldwide burden of disease attributed to 107 causes by sex and age. This technique considers the impact of both premature mortality and morbidity caused by a disease state and can then be used to evaluate the economic impact of the disease on the community as well as the potential cost-effectiveness of intervention strategies (Murray, 1994; Murray & Lopez, 1996). However CE was not among the diseases evaluated in the Global Burden of Disease Study of 1996. Expenses, loss of health and vitality associated with CE can become a significant burden not only for the affected individual and his or her family, but also for the community as a whole. Two previous studies suggested that patients surgically treated for CE had a significant decrease in the quality of life (Torgerson & Dowling, 2001; Torgerson *et al.,* 2001).

Subjects presenting for treatment have also been reported as having a substantially higher rate of unemployment (Torgerson *et al.*, 2003). However, to evaluate the societal burden of the disease it is important to understand the effect that CE has on previously undiagnosed individuals. Potential impact of the disease on afflicted individuals must be taken into consideration when constructing a DALY estimate. A health survey is a useful tool with which to evaluate the physical and mental health state of a person with CE compared with a control population. (Budke, *et al* 2004).

The burden of a disease is the impact of a health problem in an area measured by financial cost incurred, mortality and morbidity due to the disease. It is often quantified in terms of DALYs, which combine the CE burden due to death and morbidity into one index. It also makes it possible to predict the possible impact of health interventions as defined by WHO, 2004. The DALY is a health gap measure that extends the idea of potential years of life lost due to premature death, to include equivalent years of healthy life lost to poor health or disability (Murray *et al*., 2000). Information on both mortality and morbidity outcomes are thus combined into a single measure of population health.

A DALY is equivalent to the loss of one year of healthy life and it allows the burden of disease in a population to be measured as the gap between current health and an ideal situation where everyone lives to old age, free of disease and disability. To calculate DALYs for a disease in a population, the years of life lost due to premature mortality (YLL) from the cause are added to the years lost due to disability (YLD) from incident cases of the disease: DALY = YLL+ YLD (Mathers *et al*., 2001).

1.13.1 Years of Life Lost Due To Premature Mortality (YLL)

The YLLs are the mortality component of DALYs. The burden of disease due to premature death, the mortality burden is described in terms of Years of Life Lost (YLL) and is calculated according to the formula:

YLL = N x L [i] (Murray, 1996).

Where: **N**= the number of deaths, **L**= the average life expectancy at age of death

There is evidence for an intrinsic biological difference in life expectancy for males and females, but that it is much less than the approximately 5–7 years observed in 16 developed countries. Much of this excess is due to higher male exposure to various risks such as occupational exposures (Murray, 1996).

1.13.2 Years of life Lost due to Disability (YLD)

The burden for people living with a condition, morbidity burden is described in terms of YLDs. Disability in this context refers to any departure from a state of perfect health. As a year with less than perfect health is considered to contribute less to the disease burden than a year lost to premature mortality, YLDs are weighted according to the severity of the condition. Each condition has a severity weighting in the range 0 to 1 with 1 being the most severe (Mathers *et al.*, 1999).

The loss of healthy life due to non-fatal health conditions (YLD) requires estimation of the incidence of the health condition, disease or injury in the specified time period. Years of life Lost due to Disability is calculated by the formula:

$$\mathbf{YLD = I'D' \, [1 - \exp(-r\,L)] / r} \quad \text{[ii] (Murray \& Lopez, 1996a).}$$

Where **I** is the number of incident cases in the reference period, **D** is the disability weight (in the range 0–1), **L** is the average duration of disability (years) and **r** is the discounting rate (Murray *et al*., 1996).

1.14 Construction of DALYs

The basic formula for DALYs lost by an individual is as follows:

$$-\left[\frac{DCe^{-\beta a}}{(\beta + r)^2}\left[e^{-(\beta+r)(L)}1 + (\beta + r)\big((L + a)\big) - (1 + (\beta + r)a)\right]\right] \quad \text{[iii]}$$

Where, ***r*** is a discount rate, **β** is an age-weighting parameter, ***C*** is an age-weighting correction constant, ***D*** is a disability weight, ***a*** is the age of the individual at diagnosis, and ***L*** is the time lost to disability or premature mortality (Murray, 1994).

Parameter values used were ***r*** = 3%, **β** = 0.04, and ***C*** = 0.16243 (Murray, 1994; Murray & Lopez, 1996). Disability weights (*D*), derived for CE, was based on values for liver cancer obtained from the original Global Burden of Disease Study as well as from the Dutch Disability Weight Group, which produced a set of disability weights for use in a western European context (Stouthard, 2000).

Liver cancer was chosen for this purpose because like Echinococcosis, it causes a space-occupying mass and often results in similar clinical symptoms (Wilson & Rausch, 1980; Schaefer & Khan, 1991; Vuitton *et al.,* 1996; Sithinamsuwan *et al.,* 2000). Life expectancy was based on the Japanese estimated life span, which is one of the longest known, and was used to standardize DALYs lost in accordance with the Global Burden of Disease Study (Murray, 1994).

A standard expectation of life and gender gap is usually applied to calculate DALYs from morbidity and premature mortality, a standard expectation of life at birth of 82.50 years for women and 80 years for men. This gap is considerably smaller than the observed gender gap in life expectancy in low mortality populations like Japan which has a gender gap of 6 years. The gender gap of 2.5 years is argued to correspond purely to the "biological difference in survival potential between males and females" (Murray, 1994), factoring the effects of life expectancy of males' greater exposure to social and other risk factors e.g. occupation such as herding and protecting the community from external aggression and cattle rustling. In the calculation of DALYs lost, Monte Carlo sampling techniques and Stochasticity are introduced to cater for uncertainty of assigning disability weights and the uncertainty in the point prevalence estimate of the infection (Carabin *et al*., 2005).

1.14.1 Disability weights

A disability weight is a weight factor that reflects the severity of the disease on a scale from 0, perfect health to 1, equivalent to death. Years Lost due to Disability are calculated by multiplying the incident cases by duration and disability weight for the condition. The disability weights used in DALY calculations quantify societal preferences for different health states as shown in Table 2.1.

1.14.2 Examples of disability weights used to calculate DALYs

The disability weights shown in Table 2.1 are weight factors used in the computation of DALYs of CE. The weights ranging between 0 and 1 reflect the severity of the disease with a healthy individual given a weight factor of zero. As the state of health decreases due to the morbidity of the disease the weight factor increases up to one when the infected individual dies due to CE.

Table 1.1: Examples of disability weights used to calculate Disability Adjusted Life Years (DALYs) (Murray, 1994)

Healthy	0
Limited ability to perform at least one activity in one of the following areas recreation, education, procreation or occupation.	0.096
Limited ability to perform most activities in one of the following areas recreation, education, procreation or occupation.	0.220
Limited ability to perform most activities in two or more of the following areas: recreation, education, procreation or occupation.	0.400
Limited ability to perform most activities in all of the following areas: recreation, education, procreation or occupation.	0.600
Requires assistance with instrumental activities of daily living such as meal preparation, shopping or housework	0.810
Requires assistance with activities of daily living such as eating, personal hygiene or toilet use	0.920
Dead	1

1.14.3 Discounting rate

The DALY measures the future stream of healthy years of life lost due to each incident case of disease or injury. It is thus an incidence-based measure rather than a prevalence-based measure. The global burden of disease (GBD) applied a 3% time discount rate to years of life lost in the future to estimate the net present value of years of life lost. With this discount rate, a year of healthy life gained in 10 years' time is worth 24% less than one gained now. Discounting of future benefits is standard practice in economic analysis and there are some specific arguments for applying discounting to the DALY in measuring population health (Murray & Acharya., 1997). This is to be consistent with measurement of health outcomes in cost-effectiveness analyses and to prevent giving excessive weight to deaths at younger ages, without discounting, death at age zero results in 50% more YLL than a death at 25 years and 100% more than a death at 40 years.

1.14.4 Age weighting

The Global Burden of Disease (GBD) Study weighted a year of healthy life lived at young ages and older ages lower than for other ages. This choice was based on a number of studies that have indicated there is a broad social preference to value a year lived by a young adult more highly than a year lived by a young child or at older ages (Murray, 1996). A 3% discounting and non-uniform age weighting was used in the original GBD 1990 study. These adjustments result in less weight given two years lived at young and older ages.

1.15 Statement of the problem

Cystic Echinococcosis not only causes severe disease and possible death in humans, but also results in significant economic losses, direct costs such as cost of diagnosis, hospitalization, surgical or percutaneous treatments, therapy, post-treatment care, travel for both patient as well as family members, lost wages due to mortality or disability and indirect costs being mortality, suffering and social consequences of disability, loss of working days or abandonment of farming or agricultural activities by affected or at-risk persons.

Livestock production associated losses include reduced yield and quality of meat, milk and wool; decreased hide value; reduced birth rate and fecundity; delayed performance and growth; condemnation of edible organs, especially liver and lungs; costs for destruction of infected viscera and dead animals. Another possible indirect detrimental consequence is a ban on export of animals and their products infected with CE.

To date, no estimates exist for CE burden in humans or livestock in Kenya. Such an estimate is imperative since it can be used as a tool to prioritize control measures for CE, which is essentially a preventable disease.

1.16 Justification of the study

Cystic Echinococcosis is a zoonotic helminthiasis of major public health importance in rural and nomadic/pastoral communities worldwide due to its resultant morbidity that causes direct and indirect economic losses as a result of disability and possible mortality in humans. The disease in livestock results in direct economic losses from condemnation of hydatid cyst infected organs such as the liver and lungs; these are the lost revenue to the livestock traders. Indirect livestock production-associated economic losses such as reductions in live weight-gain, fecundity, milk yield, fertility rates and value of wool also occur. The bans on the export of meat products of hydatid infected livestock will increase significantly the livestock production associated economic losses indirectly. This is indirectly lost foreign exchange to the government and employment opportunities to the people of Kenya in the animal products processing industries.

The high global burden of CE which is estimated at approximately one million DALYs gives CE a greater impact globally, the CE global burden is almost equal to the burden of African Trypanosomosis and Schistosomiasis combined, 1.5 million DALYs (Budke *et al*., 2006). At the national and regional levels, the burden of CE has not been estimated in both humans and livestock and therefore the study seeks to provide key information required for the control and prevention of the disease.

The high monetary values attributed to diagnosis and treatment of CE in a low-income country or community such as Turkana that would be lost with a reduction in productivity is virtually always uncertain. Individuals surgically treated for CE has a significant decrease in their quality of life and decreased chances of employment placement.

High prevalence regions of CE are focally distributed in Kenya, with a prevalence level of 6 % in nomadic pastoralist communities such as Turkana (Magambo *et al*., 2006). The study suggested ways of reducing the incidence and prevalence level of the infection by providing relevant information that can direct and prioritize cost effective control methods based on the established CE burden. The burden indicators, mortality and human/livestock associated economic losses of CE gave the magnitude of the disease in the study sites and the findings can also be used to direct the limited financial resources to sites where they can be most effective in the control program of CE.

1.17 Research questions

i. What is the socio-economic burden of CE in the human host and livestock in Turkana North, Kisumu East and West, Isiolo and Kajiado districts?
ii. What is the prevalence of CE in the human host and livestock in Turkana North, Kisumu East and West, Isiolo and Kajiado districts?
iii. What is the distribution by age and gender of CE in human in Turkana North districts?

1.18 Hypothesis

Cystic Echinococcosis does not have significant impact on humans and livestock in Northern Turkana and other selected regions in Kenya.

1.19 Objectives

1.19.1 General objective

To determine the burden of Cystic Echinococcosis in the human host and livestock in selected regions in Kenya.

1.19.2 Specific objectives

1. To determine the prevalence of Cystic Echinococcosis in the human host in Turkana North district between 1991 and 2011.
2. To evaluate economic losses due to Cystic Echinococcosis in the human host in Turkana North (1991-2011) and livestock in Kisumu East and West (2005-2009), Kajiado North (slaughter house survey) and Isiolo districts in Kenya (2006-2010).
3. To establish the distribution pattern of human Cystic Echinococcosis in different age groups and sexes in Turkana North district between 1991 and 2011.
4. To determine the prevalence of Cystic Echinococcosis in slaughtered livestock in Kisumu East and West (2005-2009) and Isiolo districts in Kenya (2006-2010).

1.20 Scope of the study

The scope of this study was to determine and evaluate the economic burden of CE in humans and livestock in Turkana North, Kisumu East and West, Isiolo and Kajiado districts. This involved a retrospective review of CE patients' medical records of patients from Turkana North district obtained from AMREF-Kenya (1991-2011) to determine the direct CE-associated economic burden. Indirect CE-associated human economic burden. Indirect CE associated was determined based on the lost economic opportunities by a herdsman or housewife in the Turkana district due to CE morbidity or mortality. The CE prevalence and distribution by age and gender were also determined in the district.

A retrogressive annual meat inspection record review (5 years) and slaughter house surveys were conducted to evaluate the CE-associated direct economic burden due to condemnation of hydatid cyst infected organs in livestock (cattle, camels, sheep and goats) slaughtered in Kisumu East and West, Isiolo and Kajiado North districts were in those districts.

1.21 Limitations of the study

Lack of good meat inspection records from the district veterinary offices and accessing the slaughter houses during the slaughter house surveys were some of the challenges noted in the course of the study. There were gaps in recording of the meat inspection reports. These gaps can be addressed by designing monthly meat inspection forms at the district veterinary offices which can be entered in a computer data base store for future references and analyses to follow the trend of certain zoonotic parasites of public health importance in a region.

The other limitation was lack of the expertise to apply the Disability Adjusted Life years (DALYs) to compute the impact of both the premature mortality and morbidity caused by CE and evaluate its economic burden using the DALYs. Bio statisticians as part of capacity building in research, control and prevention of CE should be trained with a view of applying DALYs to measure the burden of CE as a single measure of population health combining both morbidity and mortality outcomes of the disease.

The indirect CE-associated losses in human in Turkana North district was difficult to estimate due to lack of uniform conversions of various services and commodities into monetary values in the rural areas of Turkana community. Therefore certain assumptions were made based on the cost of those services and commodities in Lodwar town in Turkana County. Indirect livestock production CE-associated production losses, decreased weight, milk production, weight of fleece, fecundity in livestock were not possible to estimate due to the harsh environmental conditions the animals are found during certain seasons of the year. The indirect livestock production associated losses were therefore not included in the calculation of the monetary losses in livestock.

Another limitation to the study was noted during sourcing of data from AMREF-Kenya office where some key data for the study were lacking in the institution's medical data base. The total number of the people of Turkana that were screened during the mass ultra sound diagnostic screening before surgical operation at KMH during the period under review. This made the calculation of the disease prevalence over time difficult.

CHAPTER TWO

2.0 MATERIALS AND METHODS

2.1 Study sites

Turkana North district (Turkana County), Kisumu East and Kisumu West districts (Kisumu County), Isiolo district (Isiolo) and Kajiado North district (Kajiado County) (Fig 2.1). (www.geocurrents.info.com)

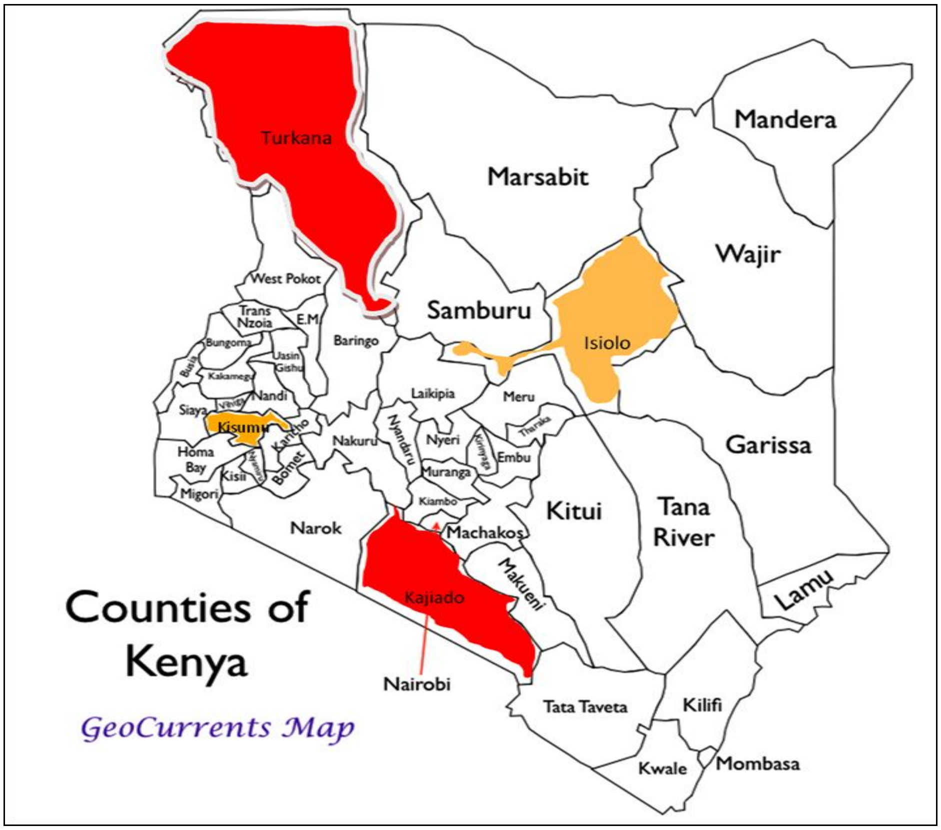

Figure 2.1: Map of Kenya showing the research study sites.

KEY

Known Cystic Echinococcosis endemic areas

Non Cystic Echinococcosis endemic areas

2.1.1 Turkana North District

Turkana County occupies the area of North Western Kenya to the west of Lake Turkana in the rift valley province. Turkana is the largest county within Kenya and covers an area of 77,000 square km. It borders Marsabit and Samburu County in the east, Baringo and West Pokot counties in the South and in the North shares international boundaries with Ethiopia and Sudan and Uganda to the west. The population of Turkana County is 855,399 people according to the 2009 Kenya national population census report (Kenya National Bureau of Statistics, 2012).

The study site, Turkana North district is situated in Turkana County of Kenya. The CE diagnostic ultrasound mass screening conducted by AMREF-KENYA medical team each year covers various parts of the county and all the CE patients requiring surgical intervention are assembled at Kakuma Mission Hospital (KMH) for the surgery by the AMREF-Kenya medical team. The health facility is situated in Kakuma division, Turkana West District. The human CE data analyzed during the study originated from the hospital, kept at the AMREF- Kenya office data base in Nairobi.

The AMREF- Kenya maintains CE patients' data in Kenya. The organization has constructed a slaughter house for hygienic slaughter of animals, meat inspection, and disposal of condemned organs and maintenance of CE data in the livestock intermediate host in Lokichogio. The slaughter house provides a ready market for the livestock farmers in the region.

The County is hot and dry for most part of the year. Average rainfall in the plains is about 150-550 mm falling to less than 150mm in the arid central parts (Hijmans *et al*., 2004). Rainfall is erratic and unreliable and famine is a constant threat. Turkana County has a very low agricultural potential and is only suitable for extensive rearing of indigenous livestock, nomadic pastoralist. The urban population has limited economic alternatives for survival. There is lack of employment opportunities and unavailability of adequate development funds, thus most of the people in urban centers and settlements have to be provided with famine relief food.

Due to low productivity of the rangelands and the high variation of rainfall, pastoralists are forced to move frequently to exploit the available resources between the seasons. Their movement depends on the security situation and pasture/water availability. Relatively safe areas in the central parts of the district have high concentration of pastoralists as compared to Northern, North-Western and Southern areas, which are prone to armed cattle rustling. The major economic activity in the county is nomadic pastoralist and the livestock species kept include indigenous cattle, sheep, goats, donkeys and camels.

2.1.2 Kajiado North district

The climate in Kajiado County is of a semi-arid nature with rainfall ranging between 500-1250mm (Bekure *et al*., 1991) and a lot of wildlife thrives in that area. The total area of the County is 21,292.7 Km^2 with a population of 687,312 according to the 2009 Kenya National population census (Kenya National Bureau of Statistics, 2012). The main ethnic community of Kajiado County is the Masaai. There is an increased influx of other people from various regions of the country who have also settled in the area. The Masaai people are pastoralists and therefore rear large herds of cattle, sheep and goats that have contributed to the semi-arid nature of the land due to consumption of vegetation cover.

Part of the livestock data were obtained from Suswa and Kitengela slaughter houses in Kajiado North district, Kajiado County during slaughter house surveys. The slaughter house surveys involved participation during the meat inspection procedures in the two slaughter houses. Livestock species slaughtered in the two slaughter houses included cattle, sheep and goats.

2.1.3 Isiolo County

Isiolo County is located in the upper eastern region of Kenya. It borders seven counties with Garissa to the east, Wajir to the north east, Meru to the south west, Samburu to the east and Marsabit to the north west, with Kitui and Tana River counties to the south west and south east respectively. The total area of the County is 25,336.1 Km^2 with a population of 143,294 according to 2009 Kenya National population census (Kenya National Bureau of Statistics, 2012). The climate of the county include an average temperature range from minimum of between 12^0 C to a maximum of 28^0 C. Rainfall ranges from 150mm to 650 mm per annum typical of arid and semi-arid lands (ASALs) in Kenya. The main economic activities are nomadic pastoralist, subsistence agriculture and small-scale livestock trade.

Part of the livestock retrospective and slaughter house survey data were obtained from Isiolo district veterinary office and Isiolo Central division slaughter house respectively. The livestock species slaughtered in the slaughter house were cattle, sheep, goats and camels.

2.1.4 Kisumu East and West districts

Kisumu County borders Vihiga County to the North, Nandi County to the North East, Kericho County to the East, Nyamira to the South, Homa Bay to the South West and Siaya to the West. The County has a total population of 968,909 (Kenya National Bureau of Statistics, 2012) and covers an area of 2,009.5 Km^2. Kisumu East and West districts has an area of 135.9 Km^2 and 212.9 Km^2 respectively and a population of 150,124 and 131,246 (Kenya National Bureau of Statistics, 2012) respectively. The County experiences an annual relief rainfall between 1200 mm and 1300 mm with a mean annual temperature of 23^0C and ranges between 20^0C and 35^0C. The Main economic activities/industries are subsistence farming, livestock keeping, fishing, Rice farming, sugar cane farming, and small scale trading.

Part of the retrospective livestock data used in this study was obtained from Kisumu East and West districts in Kisumu County. A slaughter house survey was conducted in Mamboleo slaughter house in Kisumu East district, Kisumu County.

The retrospective data was generated from Mambo-leo, Rabuor, Otonglo, Kiboswa and Dago slaughter points, Kisumu East district and Daraja Mbili/Lela, Holo/Reru and Maseno/Opasi slaughter points, Kisumu West district. The major slaughter point is Mambo-leo situated in Kiumu city. Livestock species slaughtered include cattle, sheep, goats and pigs slaughtered in the Municipal slaughter slab.

2.2 Study Design

A retrospective data review was used to carry out the research. The human data that was used during the study was obtained from AMREF- Kenya office data base in Nairobi. The CE patient's data were from KMH in Turkana County. A twenty year retrospective survey of the CE patient's records, between 1991 and 2011 were considered to generate the human data.

A 5 year retrospective review of the annual meat inspection data was carried in Kisumu East and West districts, 2005-2009 and Isiolo district, 2006-2010. Slaughter House (SH) survey was conducted in Kajiado North district, Suswa and Kitengela slaughter houses. The slaughter house survey in Kajiado North district was done to compare the prevalence of CE in a known endemic area and unknown areas such as Kisumu East & West and Isiolo districts.

2.3 Methodology

A total of 586 CE patients operated between 1991 and 2011 were considered for the estimation of the direct human CE associated losses in this study. African Medical Research Foundation-Kenya CE medical team operated a total of 12 patients either by Laparotomy or PAIR per trip at KMH. Each operation period took 5days. The ultrasound mass screening was conducted in 7 health facilities in Turkana County; all surgical operations were conducted at a central place, KMH for ease of the surgical exercise and management of the patients before and after the surgery procedure.

The data collected indicated the year and date of diagnosis, type of treatment, patient's name, age and sex. The location of cyst in the various body organs, type of surgery; Laparotomy or PAIR and cost of each type of surgical intervention were recorded. The data was entered in spreadsheet and analyzed to determine the economic loss of the infection in monetary terms per year. The CE cases that were not reported and asymptomatic CE cases, not treated in the health facility were given a factor of 10% of the total economic loss per year to capture the asymptomatic CE cases and non-healthcare seeking cases.

A visit to KMH during the surgery operation was done to get the real picture and burden of CE from the patients that were to be operated by the AMREF-Kenya medical team. The patients had been diagnosed following an ultra sound mass screening before they were transported and admitted at KMH. The exercise took two days.

The livestock retrospective data was obtained from the Ministry of Agriculture, Livestock and Fisheries, department of livestock annual meat inspection data base at the district veterinary office headquarters of the study sites. The data included the species of animals slaughtered, number of Hydatid cysts noted in various body organs e.g. liver, lungs, kidneys, spleen, the disposal method of infected organs, total number of each animal species slaughtered, prices of the products per kilogram (beef, mutton, chevron, stripes/offal, liver, lungs, kidneys, spleen) and origin of the animals slaughtered. The movement permit which is issued by the veterinary department to livestock traders transporting livestock from one region to another confirmed the origin of the livestock.

Slaughter house surveys involved actual meat inspection in the slaughter houses/slabs within the study areas and involved ante mortem examination, age approximation, sex determination, source of the animals either locally or another district and recording the various identification marks on the skin put by the traders for ease of following the slaughtered animal/carcass from flaying to the time of the actual meat inspection. The second level involved the real meat inspection checking all the carcasses and concentrating on the liver and lungs. The organs were palpated for any hard round swelling, hydatid cyst suspect or abscess, incised for any other types of parasite present such as liver flukes in the liver and visualized for any calcification, discoloration or enlargement. When hydatid cysts were noted on any organ, the cysts were carefully removed, counted per organ recorded either as single or multiple cysts. The cystic organ were then condemned and disposed of in secured condemnation pits located within the slaughter house area.

Meat inspection is a public health routine tool conducted on all slaughtered livestock in designated slaughter points either slaughter slabs or abattoirs to ascertain that the carcasses are fit for human consumption. The slaughter is conducted humanely in a clean slaughter house or slab to ensure the safety of the carcass and animal products; this is the core function of the Ministry of Agriculture, Livestock Development and Fisheries, veterinary public health department. The animals are examined before slaughter, ante mortem examination to confirm their health and the carcasses inspected after slaughter. Each organ and body system is inspected and any organ or the whole carcass found to be unfit for human consumption due to any infection is condemned and the organ or carcass disposed of either through burning, burying or discarded in a condemnation pit. The whole process of meat inspection is conducted by trained meat inspectors or graders.

2.3.1 Economic evaluation of human-associated loss in monetary terms

The human parameters used in the analysis were the diagnosed and surgically treated CE patients in males and females. The number of reported and treated CE cases by age and gender were obtained from AMREF-Kenya CE patients' data base. This data was used to estimate the CE associated economic loss in human in monetary terms and CE distribution based on gender and age in Turkana North district. The unreported and asymptomatic CE cases were assumed to constitute a factor of 10% of the total cost per year.

The costs incurred due to CE in human were divided into direct and indirect costs. The direct costs included diagnosis (ultrasound), surgical operation (Laparotomy or PAIR), hospitalization costs (maximum 10 days), personnel pay (Surgeon, Anesthetist, Nurses), logistical costs, flight from Nairobi to Lokichogio and back using AMREF flying doctor's aircraft, diesel for local running, food and follow up costs. Indirect costs included all the opportunities that were lost as a result of the death of a family bread winner, disability due to CE, reduced quality of life due to CE and reduced chances of employment.

The lost opportunity costs corresponded to the productive time lost due to an infected person working less efficiently than uninfected (healthy) person. It was assumed that the same level of lost opportunity applied to the unreported and asymptomatic CE cases. The indirect costs or lost opportunities were difficult to quantify in monetary values and were not used to evaluate the economic impact of CE in this study.

During the AMREF outreach program in Turkana North district, ultrasound screening is done in seven different locations. The positive cases recorded, chemotherapy using albendazole prescribed and administered to positive cases that do not require surgical operation and all surgical procedures were conducted at KMH. A group of twelve patients are operated in one operation session taking 5 days. The CE patients are hospitalized at KMH for an average of 10 days. The total estimated cost of operating a single CE patient at KMH was estimated at Kshs 59,637.00 (US$ 702).

2.3.2 Estimated cost/CE patient operated at KMH

The estimated cost of diagnosis and treatment of a CE patient through surgical procedure at KMH, Turkana was based on the laboratory costs, bed and food charges (in patients), diesel for local running, diagnosis and surgical costs, surgeon, anesthetist and nurses salary, cost of flying AMREF's flying doctor's aircraft from Nairobi to Lokichogio and back, follow- up costs and logistical expenditures. The direct CE associated parameters considered in this study and their estimated costs at KMH (Table 2.1), a healthcare facility in Turkana North district. The bed charges for in-patients were estimated for a maximum of 10 days for uncomplicated surgical procedures however complicated surgical procedures could take more days.

Table 2.1: Estimated costs /Cystic Echinococcosis patient operated at Kakuma Mission Hospital, Turkana West district.

S/N	**ITEM**	**COST (Ksh)**
1	Laboratory costs (chemicals, equipments and personnel)	2,000.00
2	Bed charges (Ksh 200/day) for 10 days	2,000.00
3	Food (Ksh 300/day) for 10 days	3,000.00
4	Diesel (Ksh 10,000/5days,12 patients	830.00
5	Logistical costs/patients	2,500.00
6	Laparotomy or Puncture, Aspiration, Injection and Re-aspiration (PAIR) (drugs and equipments)	20,000.00
7	Ultra Sound screening/patient	200.00
8	Follow up visits after operation/patient	2,000.00
9	Surgeon's salary (Ksh 595,000/22 days, 5 days operation,12 patients)	11,300.00
10	Anesthetist salary (2) (Ksh 130,000/22 days, 5 days operation,12 patients)	5,000.00
11	Nurses salary (3) (Ksh 30,000/22 days, 5 days operation,12 patients)	1,700
12	Flight- Nairobi to Lokichogio and back (Ksh 765,000/ trip,7 health centres,12 patients)	9,107.00
TOTAL		**59,637.00**

2.3.3 Economic Evaluation of livestock-associated Loss in monetary terms

The animals considered in the analysis of the livestock associated economic loss were sheep, goats, cattle and camels. The number of CE infected organs for each animal species was obtained from the Ministry of Agriculture, Livestock and Fisheries, district veterinary annual meat inspection reports, retrospective data review and the slaughter house surveys in the slaughter houses within the study area.

Direct costs mainly the loss of revenue through organ condemnation such as liver and lungs. The indirect loss due to reductions in the growth rate, fecundity and milk production of infected animals were not included in the estimate of the total costs associated with CE in livestock. It was difficult to consider these indirect factors as they could also be associated with the harsh environment that these animals are found. The estimated weights of various livestock organs and their average market prices in the study sites. (Table: 2.2).

In Kenya identification of hydatid cysts at meat inspection leads to condemnation of the whole infected organ and hence loss of revenue. Calcified cysts which appear as white spots on affected organs are normally trimmed off and the organ passed to be fit for human consumption. To estimate the total cost of condemned organs in all the species, the lost revenue for all CE-infected organs were calculated based on the average weight and market value. Each organ from each animal species was assigned an average weight and market value per kilogram for the calculation of the revenue lost due to condemnation of CE infected organs.

The estimated average weights of various livestock organs and their market prices in the study sites (Table 2.2). Detection of a single cyst or suspect cyst calcification on an organ during meat inspection leads to direct condemnation of the whole organ. The direct revenue lost due to condemnation of a hydatid cyst infected organ represents the direct economic loss due to CE in livestock. The loss is equivalent to the total cost of the organ which is based on the average weight of the organ multiplied by its market price per kilogram. This is the direct economic loss to the livestock traders.

Table 2.2: Estimated average weight of organs of slaughtered animals and their market prices (Kisumu East & West and Isiolo districts veterinary office annual meat inspection report)

ANIMAL	**ORGAN**	**AVERAGE WEIGHT (KG)**	**PRICE PER KG (Kshs)**	**TOTAL PRICE/ ORGAN(Kshs)**
CATTLE	LIVER	5.0	360.00	1,800.00
	LUNGS	2.0	200.00	400.00
	SPLEEN	1.5	360.00	540.00
	HEART	1.5	360.00	540.00
SHEEP/GOATS	LIVER	1.0	200.00	200.00
	LUNGS	0.25	100.00	25.00
	HEART	0.25	200.00	50.00
CAMELS	LIVER	7.0	400.00	2,800.00
	LUNGS	3.0	200.00	600.00
	HEART	2.5	400.00	1,000.00
	SPLEEN	2.5	400.00	1,000.00

The origin of livestock for slaughter was very important during the retrospective data review and slaughter house survey in the study sites. The origin showed whether the animals originated from known CE endemic areas. This was confirmed from the No objection forms issued to the livestock traders by the district veterinary officer of the district the animals are to be moved to either for slaughter or breeding. The No objection form confirms that the recipient district is free from any notifiable disease. The movement permit form is issued by the district veterinary officer the animals are originating from upon confirmation from the No objection form issued to the livestock trader by the district veterinary officer of the district the animals are to be moved to.

Before an animal is slaughtered in any slaughter house or abattoir, its origin is confirmed through the two forms issued by the veterinary department.

Northern Turkana and Masaai land (Kajiado North) study sites were chosen because they are known CE endemic areas and both communities are nomadic pastoralists and are very close to their livestock and dogs which is the definitive host of *E. granulosus*. African Medical Research Foundation Kenya has been involved in the diagnosis of CE through ultrasound mass screening of the Turkana community and treatment annually for over two decades hence the availability of CE patient's data.

The study areas outside the CE endemic areas, Isiolo and Kisumu West/East districts were chosen to determine the prevalence of the infection in non-endemic areas and the predisposing factors leading to the emergence of the infection in none endemic areas. The study in the non CE endemic areas targeted the livestock intermediate hosts slaughtered in the study sites with a view of determining the direct economic loss associated with CE.

This study has quantified the economic losses of human and livestock CE into monetary terms. Cystic Echinococcosis in farm animals caused considerable economic problems due to loss of the edible liver, lungs and other organs resulting from condemnation during meat inspection. Significant loss of meat and milk production and value of the wool from infected sheep also occur. These losses are critical in countries of low economic output where sheep production is of particular importance (Torgerson *et al*., 2001).

CHAPTER THREE

3.0 RESULTS

3.1 The prevalence of Cystic Echinococcosis in human in Turkana North district, 1991-2011

The number of CE positive cases that were operated at KMH during the years (1991-2011) under review grouped in different age groups (Table 3.1). A total of 586 CE patients were surgically operated. The percentage infection per age group calculated to determine the most and least affected age groups.

Table 3.1 Prevalence of CE in humans in Turkana North district in different age groups

Year	**Different age group of Cystic Echinococcosis patients in years**							**Total**
	<1-10	**11-20**	**21-30**	**31-40**	**41-50**	**51-60**	**61-70**	
1991	-	3	1	3	-	-	-	7
1992	1	2	3	8	-	3	-	17
1993	13	8	14	7	4	6	1	53
1994	15	15	17	15	12	4	-	78
1995	6	4	14	4	7	-	1	36
1996	2	3	4	7	3	2	-	21
1997	-	3	2	1	-	-	-	6
1998	5	5	4	4	4	5	-	27
1999	7	4	2	10	2	2	1	28
2000	9	9	9	12	13	3	-	55
2001	8	15	15	12	18	8	-	76
2002	7	9	4	8	13	3	-	44
2003	4	13	9	8	3	1	-	38
2004	3	1	4	9	7	3	-	27
2005	6	9	7	5	8	1	-	36
2006	1	-	-	1	3	1	-	6
2007	1	1	1	2	2	3	1	11
2009	-	-	1	-	4	-	1	6
2010	2	-	-	-	2	1	-	5
2011	3	2	-	1	3	-	-	9
TOTALS	93	106	111	117	108	46	5	**586**
Percent infection/age group	16	18	19	20	18	8	1	

3.2 Economic loss due to Cystic Echinococcosis in humans in Turkana North district, 1991-2011

The direct economic loss per year based on the number of patients surgically treated at KMH between 1991 and 2011 (Fig 3.1). The cost of treating a single CE patient at KMH as estimated by AMREF- Kenya is Ksh 60,000 (US $ 706). The total direct CE-associated economic loss in Turkana North district was calculated at Kshs 35,160,000 in monetary terms, translating to Kshs 1,758,000 per year in KMH, Turkana. This total monetary loss did not include the CE asymptomatic and non-healthcare seeking cases, an additional factor of 10% of the total cost was used to calculate the overall CE burden within the study site. The overall burden was KSh 38,676,000.00.

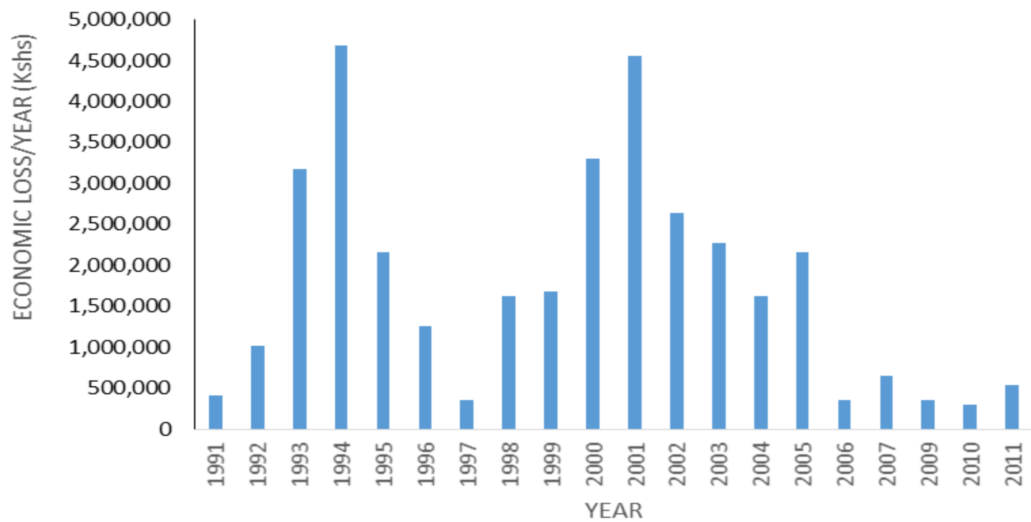

Figure 3.1: Economic loss due to Cystic Echinococcosis in humans in Turkana North district in monetary terms

3.3 Indirect economic loss due to CE infection in human in Turkana

The indirect CE associated economic losses in Turkana community refer to the lost opportunities by a herdsman or a house wife who cannot perform his/her daily activities due to the severity or death as a result of CE infection. The literacy level in Turkana County stands 18% according Kenya National Bureau of Statistics reports, the adult members of the community do not have formal employment and contribute to the family or community economy through herding of livestock (men) while the rural Turkana women are home managers. As a pastoralist community, livestock owned by the male gender is normally used as a measure of wealth, herding is an important activity in the community.

3.4 Economic value of a herdsman in Turkana

The estimated herd/flock size, average calving, lambing, kidding/year, value of calves, lambs and kids and sold mature animals/year as opportunity cost lost by an individual herdsman in Turkana community due to CE (Table 3.2). The livestock values used in Table 3.2 were assumptions based on the existing environmental conditions prevailing in Turkana county, indigenous livestock breeds reared and the average market prices of the various livestock species sold in good body condition.

The total monetary loss by an individual herdsman per year due to CE in Turkana will be the equivalent of the total value of the calves, lambs, kids and number of animals sold per year per household. A healthy herdsman will contribute the value of the total young animals born and adult animals sold in a particular year in monetary terms to the economy of the family and community. The estimated total value of a healthy herdsman in Turkana community was KShs 411,250, the total value of young animals and animals sold.

Table 3.2: Estimated herd/flock size and livestock values in monetary terms in Turkana community.

Type of animals	Individual average herd or flock size	Average No. of calving, lambing kidding per year	Value of calves, lambs, kids (Kshs)	Total value of young animals (Kshs)	No. of animals sold/ year	Value of animals sold (Kshs)	Total Value Sold animals (Kshs)
Cattle	50	15	800	12,000	10	15,000	150,000
Camels	20	7	2,000	14,000	4	30,000	120,000
Sheep	80	20	200	4,000	15	3,000	45,000
Goats	80	25	250.00	6,250	15	4,000	60,000
				36,250			**375,000**

3. 4.1 Economic value of a rural house wife in Turkana community

Rural Turkana women are house managers without any form of formal employment due to low literacy levels, 7% according to the latest Kenya National Bureau of Statistics report. Their main economic contribution to the family and community include giving birth, caring of children, drawing water from the river for domestic use, fetching firewood and building of traditional huts (manyatta) using local materials (Alex, *et al*., 2012). The provision of these services to the family will be negatively affected due to CE morbidity and/or mortality.

The economic value of a housewife in Turkana community was estimated by converting these services performed by a healthy housewife in Turkana community into monetary values by making assumptions based on existing costs of these services in an urban settlement within Turkana county of Kenya. Lodwar town the capital of the county was chosen. Currently there are no uniformly acceptable costs of such services in the rural parts of Kenya. The estimated total value of a healthy housewife in Turkana community was KShs 117,716.00.

3. 4.2 Caring of children

This service was equated with the cost of hiring a house help in Lodwar town in Turkana County. The cost of hiring Cleaners, Gardeners, General Workers, House servants, Children's ayah, Sweepers, Day watchmen, Messengers in all other areas (neither cities nor municipalities nor town councils) in Kenya is KShs 5,217.95/month according to Minimum Consolidated Wages by Region and Occupation in Kenya with effect from 1st May, 2013 (Africapay.org/Kenya, 2013). [KShs 5,218/month for 12 months= KShs 62,616.00/year].

3. 4.3 Drawing of water from rivers

This service was equated with the value of a 20 litre container of water in Lodwar town in Turkana County. Assuming that one woman can manage 4, 20 litre container using a donkey daily from a river {[4 @ KShs 20.00= KShs 80.00 daily]. Therefore KShs 80.00 x 30 days x 12 months= KShs 28,800.00/year}.

3. 4.4 Fetching firewood

This service was equated with the value of a bundle of firewood in Lodwar town in Turkana County. Firewood is the source of energy used by low income residents living in low class estates within Lodwar town. {[1 bundle @ KShs. 50.00 used daily to prepare meals.] Therefore KShs 50.00 x 30 days x 12 months= KShs 18,000.00/year}.

3. 4.5 Building of traditional homesteads ("Manyatta")

This service was equated with the value of building materials of houses within a manyatta divided by the approximate number of women in one "manyatta" in Turkana County. Assumptions: Each manyatta has an average of 15 houses built of locally available materials with approximately 9 married women. {[Average cost of 1 house=

KShs 5,000.00] Therefore 15 houses @ KShs 5,000.00 divide by 9 women= KShs 8,300.00/woman}.

The total economic loss due to CE morbidity and/or mortality in an infected housewife was estimated at KShs. 117,716.00 per year per woman. The monetary value of the process of giving birth as an activity of the women in Turkana community was difficult to estimate due lack of a uniform conversion measure and a similar activity that could be related to the process of giving birth which can be converted to monetary terms and used as an assumption.

3.5 Cystic Echinococcosis patients from Kakuma Mission Hospital, Turkana North district

Cystic Echinococcosis patient's pictures from Kakuma Mission Hospital with extremely swollen abdomen, and emaciation (Fig 3.2) that were diagnosed and operated at the health facility. The patients cannot perform their daily activities without assistance and hence have a low quality of life due to CE morbidity. Such patients with advanced CE cannot contribute to the economic development of their families and the community. The total overall cost of diagnosing and treatment of the patient is the direct CE associated economic loss in monetary terms. The lost economic opportunity because of CE morbidity and/or mortality is the indirect CE associated economic loss in monetary terms.

Figure 3.2: Cystic Echinococcosis patients in Kakuma Mission Hospital, Turkana North district, Kenya (Courtesy of African Medical Research Foundation, Kenya office Cystic Echinococcosis patient's medical database)

3.6 Percentage organ cyst location in the human intermediate host

The location of the *E. granulosus* larvae (cyst) in a CE patient in percentages (Fig 3.3). During the development of the larval stage of the parasite in the human intermediate host, the larvae can develop in various organs in the human body. The liver, abdomen, kidneys, spleen and ovary in that order were the organs where cysts were usually located. Multiple infections of an organ or different organs were also noted in a single patient. The 2.6% representing other organs include thigh, lungs, lumber region, urinary system, pelvis, mandibles, shoulder, cervix, muscles, parotids and gall bladder. The location and number of the cysts in the body of a CE patient will determine the type of surgical treatment that would be used, Laparotomy/PAIR or chemotherapy.

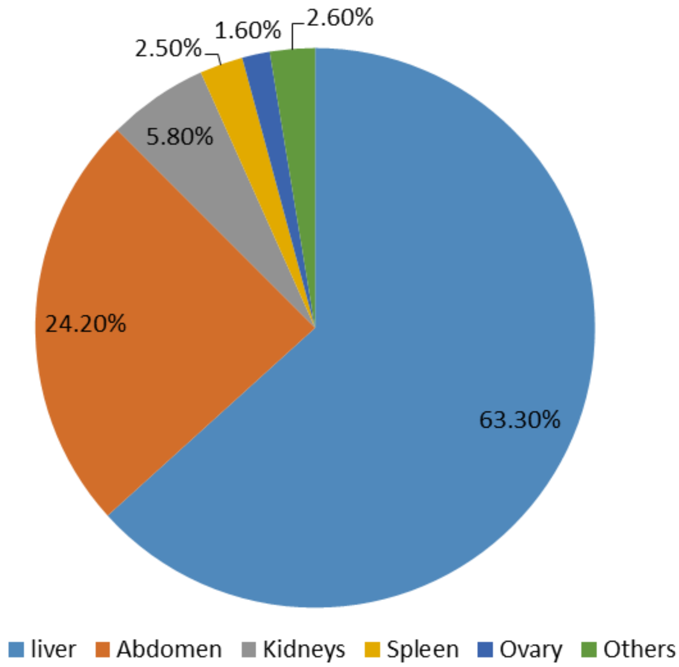

Figure 3.3: Organ cyst location in the human intermediate host.

Hydatid cysts removed from the abdominal cavity, intra-peritoneal cysts and the numerous cyst vesicles and cystic fluid removed from a single cyst in a patient (Fig 3.4 and Fig 3.5) at KMH during the 2013 AMREF-Kenya medical Outreach CE ultrasound mass screening and surgical treatment. The same patient had a total of 8 cysts in the abdominal cavity with a total of 4 liters cystic fluid.

Figure 3.4: Hydatid cyst removed from a Cystic Echinococcosis patient in Kakuma Mission Hospital-Turkana on 9th October, 2013

Figure 3.5: Numerous daughter cysts and cystic fluid removed from a Cystic Echinococcosis patient in Kakuma Mission Hospital, Turkana on 9th October, 2013

3.7 Economic loss due to CE in monetary terms in livestock in Kisumu East and West districts

The direct livestock associated economic loss due to CE in Kisumu East and West districts between 2005 and 2009. The livestock considered were cattle, sheep and goats. The organs used to compute the direct economic loss were the liver and lungs where the cysts were commonly found (Tables 3.3 and 3.4).

Table 3.3: Economic loss from condemned cystic liver in monetary terms in livestock slaughtered in Kisumu East and West districts.

Year	**Animals slaughtered**	**No. of cystic liver**	**Wt. of cystic liver (kg)**	**Revenue lost from liver (Kshs)**
2005	Cattle	197	985	354,600
	Goats	73	73	14,600
	Sheep	92	92	18,400
	Pigs	1	2	0
2006	Cattle	182	910	327,600
	Goats	60	60	12,000
	Sheep	77	77	15,400
	Pigs	0	0	0
2007	Cattle	151	755	271,800
	Goats	50	50	10,000
	Sheep	52	52	2,250
	Pigs	0	0	0
2008	Cattle	163	815	293,400
	Goats	63	63	12,600
	Sheep	43	43	8,600
	Pigs	0	0	0
2009	Cattle	237	1185	426,600
	Goat	81	81	16,200
	Sheep	38	38	7,600
	Pigs	0	0	0
				1,791,650

Table 3.4: Economic loss from condemned cystic lungs in monetary terms in livestock slaughtered in Kisumu East and West districts

(Kisumu East and West districts annual meat inspection report)

Year	**Animals slaughtered**	**No. of cystic lungs**	**Wt. of cystic lungs (kg)**	**Revenue lost from lungs (Kshs)**
2005	Cattle	259	518	103,600
	Goats	92	23	2,300
	Sheep	100	25	2,500
	Pigs	0	0	0
2006	Cattle	357	714	142,800
	Goats	120	40	4,000
	Sheep	135	33.75	3375
	Pigs	0	0	0
2007	Cattle	213	426	85,200
	Goats	90	22.5	2,250
	Sheep	105	26.25	2625
	Pigs	0	0	0
2008	Cattle	209	418	83,600
	Goats	58	14.5	1450
	Sheep	60	15	1,500
	Pigs	0	0	0
2009	Cattle	326	81.5	8,150
	Goat	79	19.75	1,975
	Sheep	80	20	2,000
	Pigs	0	0	0
				447,325

To estimate the total cost of the condemned edible organs (liver and lungs) in the livestock species slaughtered in Kisumu East and West districts, the lost revenue was calculated based on the average weight and market value of condemned liver and lungs. During the retrospective review, the numbers of infected organs were assumed to represent the total number of infected animals by species in the study site. The economic loss per organ was calculated by multiplying the average weight of infected organ by the number of cystic organs and the market price per kilogram of the infected organ.

The formula below was used to calculate the direct CE livestock associated economic loss. Refer Table 2.2 (Methodology) for the estimated average weight of organs of various livestock species and their average market prices in the study sites.

[Direct economic loss per organ = Average weight of the organ x the number of the cystic organs x market price of the non-infected organ].

The total direct revenue loss attributed to condemned liver and lungs due to hydatid cyst infection in the three livestock species considered in Kisumu during the five years (2005-2009) was Kshs 2,238,975.00 with an average of Kshs 447,795.00 per year.

3.8 Slaughter house survey in Kisumu East and West districts

Hydatid cyst found in cattle lungs during the slaughter house meat inspection survey in Mambo-leo slaughter house, Kisumu East district on 21st June, 2010. The organ was condemned and disposed in a condemnation pit. This indicated an economic loss in terms of lost revenue to the livestock trader. The lost revenue is equivalent to the average weight of the condemned organ multiplied by the marker price of the organ. The method used in the disposal of the condemned organ affects the perpetuation of the *E. granulosus* parasite cycle in the environment.

The use of the condemnation pit in the disposal of cystic infected livestock organs stop the parasite cycle at the slaughter house level during meat inspection (herbivore intermediate host level). In Figure 3.6 the suspected organ is palpated to feel the hard round swelling, hydatid cyst suspect and in Figure 3.7 the swelling is incised to expose the cyst in the lungs. Presence of a cyst in any organ led to direct condemnation of the organ.

However the condemned lungs was disposed in the condemnation pit, handling of the condemned organs in general was not done in the correct manner by the meat inspectors, the flayers and livestock traders were ignorant about the hydatid cysts and its dangers. Marauding dogs within the Mambo-leo slaughter house area was also a common feature.

Location of hydatid cyst in lungs of cattle on palpation during meat inspection at Mamboleo slaughter house.

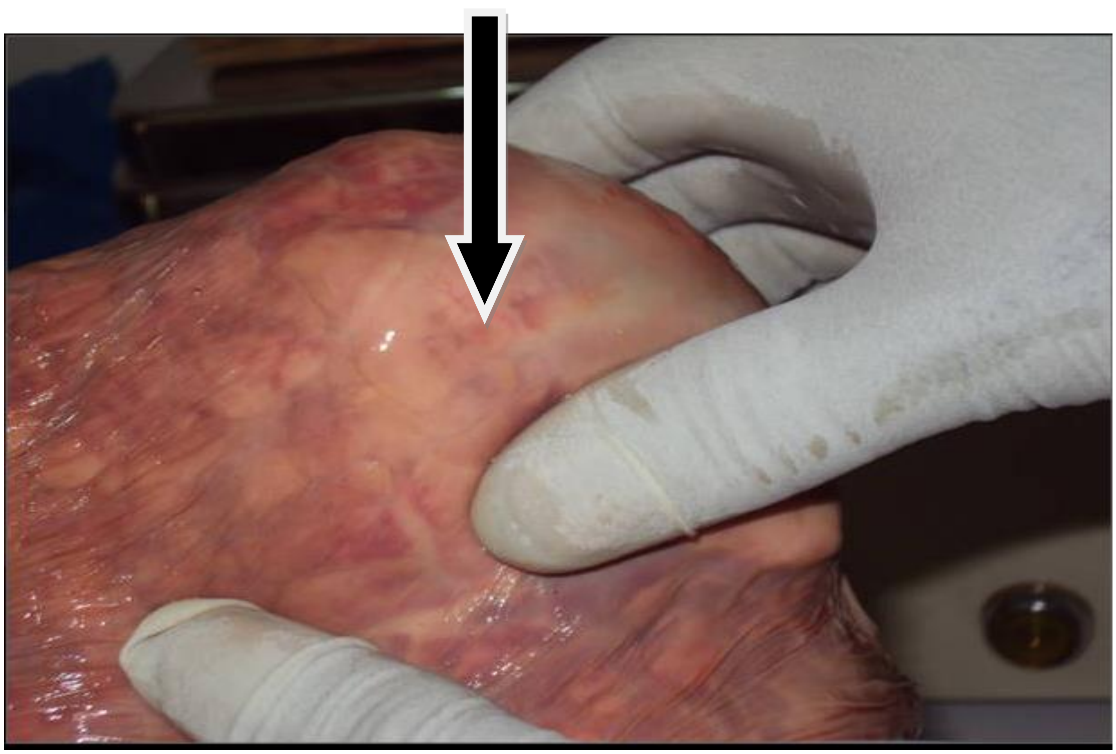

Figure 3.6: Hydatid cysts in cattle lungs, Mamboleo Slaughter House in Kisumu East district

Figure 3.7: Hydatid cysts in cattle lungs, Mamboleo Slaughter House in Kisumu East district

3.9 Economic loss due to CE in monetary terms in livestock Isiolo district

Direct livestock associated economic loss due to CE in Isiolo district, Isiolo central slaughter house between 2006 and 2010 (Tables 3.5 and 3.6). The livestock considered were camels, cattle, sheep and goats. The organs used to compute the direct economic loss were the liver and lungs where the cysts were commonly found.

3.10 Economic loss from condemned cystic liver in animals slaughtered in Isiolo district

Table 3.5: Economic loss due to condemned Cystic liver in monetary terms in livestock: Isiolo district (Isiolo district annual meat inspection report)

Year	Animals slaughtered	No. of cystic liver	Wt. of cystic liver (kg)	Revenue lost from liver (Kshs)
2005	Cattle	9	45	16,200
	Goats	2	2	400
	Sheep	0	0	0
	Camels	53	371	148,400
2006	Cattle	2	10	3,600
	Goats	6	6	1,200
	Sheep	4	4	800
	Camels	58	406	162,400
2007	Cattle	46	230	82,800
	Goats	3	3	600
	Sheep	5	5	1000
	Camels	184	1288	515,200
2008	Cattle	63	315	113,400
	Goats	12	12	2,400
	Sheep	14	14	2,800
	Camels	114	798	319,400
2009	Cattle	8	40	16,000
	Goat	0	0	0
	Sheep	0	0	0
	Camels	35	245	98,000
				1,484,600

Table 3.6: Economic loss due to condemned Cystic lungs in monetary terms in livestock: Isiolo district (Isiolo district annual meat inspection report)

Year	Animals slaughtered	No. of cystic lungs	Wt. of cystic lungs (kg)	Revenue lost from lungs (Kshs)
2005	Cattle	39	78	15,600
	Goats	2	0.5	50
	Sheep	0	0	0
	Camels	53	159	31,800
2006	Cattle	35	70	14,000
	Goats	10	2.5	250
	Sheep	3	0.75	75
	Camels	58	174	34,400
2007	Cattle	66	132	26,400
	Goats	14	3.5	350
	Sheep	2	0.5	50
	Camels	75	225	45,000
2008	Cattle	117	234	46,800
	Goats	71	17.75	1775
	Sheep	24	6	600
	Camels	142	426	85,200
2009	Cattle	25	50	10,000
	Goat	8	2	400
	Sheep	6	1.5	300
	Camels	44	132	26,400
				339,450

In Isiolo district a 5 year (2006-2010) retrospective study was conducted in Isiolo central slaughter house to assess the economic loss attributed to hydatid infection. Four types of livestock (cattle, sheep, goats and camels) were considered. Hydatid cyst infection was highest in the camels and cattle as compared to sheep and goats and in all the animals, the lungs and liver were the main organs infested. Condemnation of the two organs at meat inspection level resulted to the revenue lost due to CE. The total direct economic loss attributed to CE in Isiolo district was Kshs 1,824,450.00 with an average of Kshs 364,890.00 per year.

The estimated weight of various livestock organs and their market prices as shown in Table 3.2, the direct economic loss per organ = Average weight of the organ x the number of the cystic organs x market price of the infected organ.

3.11 Slaughter house survey in Isiolo district

Hydatid cyst found in a camel lung during a slaughter house survey in Isiolo central slaughter house, Isiolo district in June 2011 (Fig 3.8). The organ was condemned and disposed in a condemnation pit. This indicated a direct economic loss in terms of lost revenue to the livestock trader.

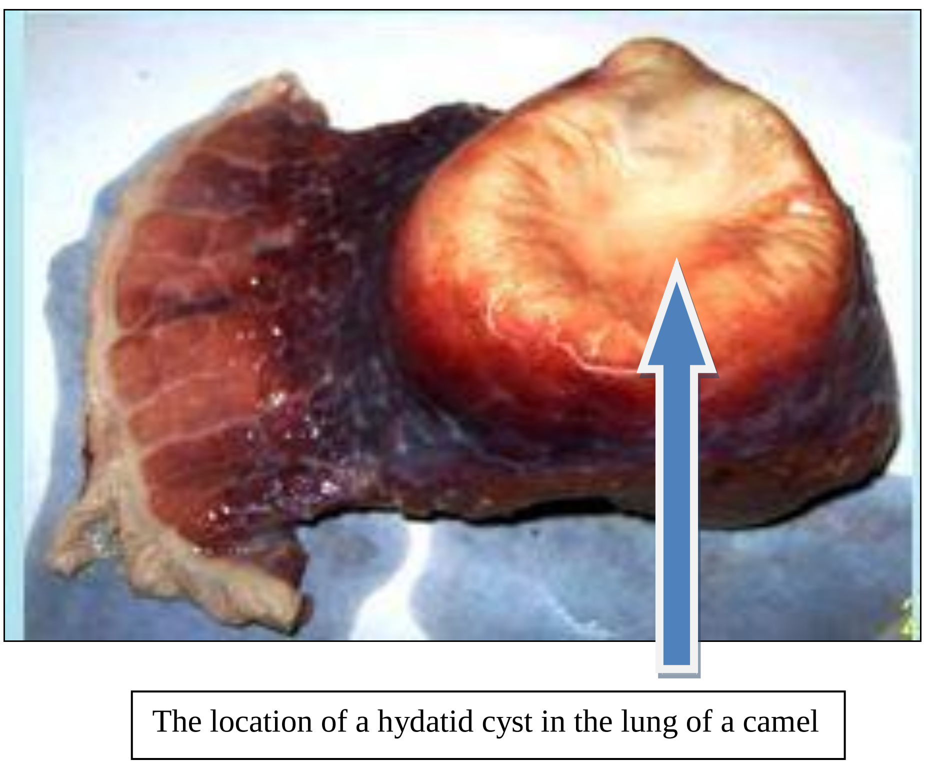

Figure 3.8: Hydatid cyst from camel lungs in Isiolo central Slaughter house, Isiolo district

3.12 Economic loss due to Cystic echinococcosis in livestock in monetary terms: Kajiado North District, Masaailand (Slaughter house Survey)

The direct livestock associated economic loss due to CE in Kajiado North district, Kitengela and Suswa slaughter houses (Table 3.7 and 3.8). The livestock slaughtered were, cattle (253), sheep (429) and goats (194) in Kitengela slaughter house and cattle (325) in Suswa slaughter house.

Table 3.7: Economic loss due to cystic liver in livestock in monetary terms: Kajiado North district, Maasailand (Slaughter house Survey)

Slaughter house	Animal slaughtered	No. of infected liver	Wt. of infected liver (kg)	Revenue lost from liver (Kshs)
Kitengela	Cattle	38	190	68,400
	Sheep	52	52	10,400
	Goats	12	12	2,400
Suswa	Cattle	65	325	117,000
				198,200

Table 3.8: Economic loss due to cystic lungs in livestock in monetary terms: Kajiado North district, Maasailand (Slaughter house Survey)

Slaughter house	Animal slaughtered	No. of infected lungs	Wt. of infected Lungs (kg)	Revenue lost from lungs (Kshs)
Kitengela	Cattle	19	38	7,600
	Sheep	28	7	700
	Goats	13	3.25	325
Suswa	Cattle	68	136	27,200
				35,825

[Direct economic loss per organ = Average weight of the organ x the number of the cystic organs x Average market price of the non-infected organ].

In Kajiado North district, Kajiado County, a slaughter house survey was done for a few days in 2 slaughter houses, Kitengela (6 days) and Suswa (4 days). In Kitengela slaughter house, the animals slaughtered include cattle, sheep and goats with a prevalence of 23% in cattle, 19% in sheep and 13% in goats. In Suswa slaughter house, the survey captured cattle only; prevalence in cattle (41%). The total livestock associated direct economic loss in Kitengela and Suswa was Kshs 89,825 and Kshs 144,200 respectively. These figures shows that there is a high hydatid infection rate in slaughtred livestock in Kajiado North district.

3.13 Slaughter house survey in Kajiado North district

Multiple conspicuous hydatid cysts found in the cattle liver and lungs during meat inspection in Suswa slaughter house, Kajiado North district (Fig 3.9).

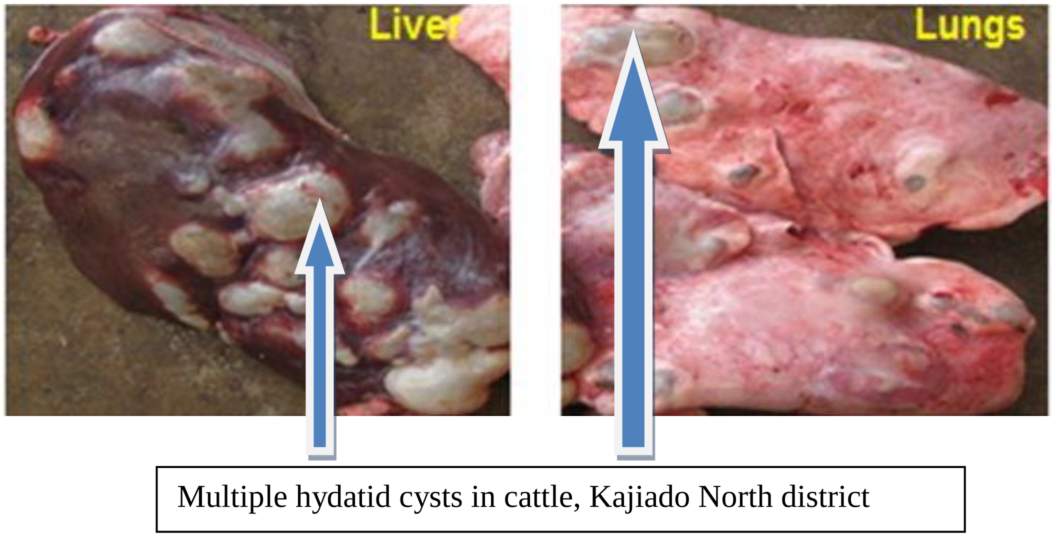

Figure 3.9: Hydatid cysts in the liver and lungs from cattle, Suswa slaughter house in Kajiado North district (conspicuous cysts)

3.14 Calcifications noted on the cattle liver in Suswa slaughter house in Kajiado North district during meat inspection

Multiple calcifications (small, white and round spots) on the surface of the liver (Fig 3.10). During meat inspection, the spots can be trimmed off the organ and the organ passed as fit for human consumption if they are few depending on the decision of the meat inspector, however this organ was condemned and disposed in a condemnation pit. This indicated an economic loss in terms of lost revenue to the livestock trader. The calcifications do not confirm that the organ is cystic at the slaughter house level during meat inspection however further sensitive tests at the laboratory, PCR can confirm whether the organ is cystic or not. The white spots are usually ignored during meat inspection, the organ passed as fit for human consumption after trimming off the spots but the organ is cystic. The calcifications are indicated by the white spots on the liver pointed by the arrows.

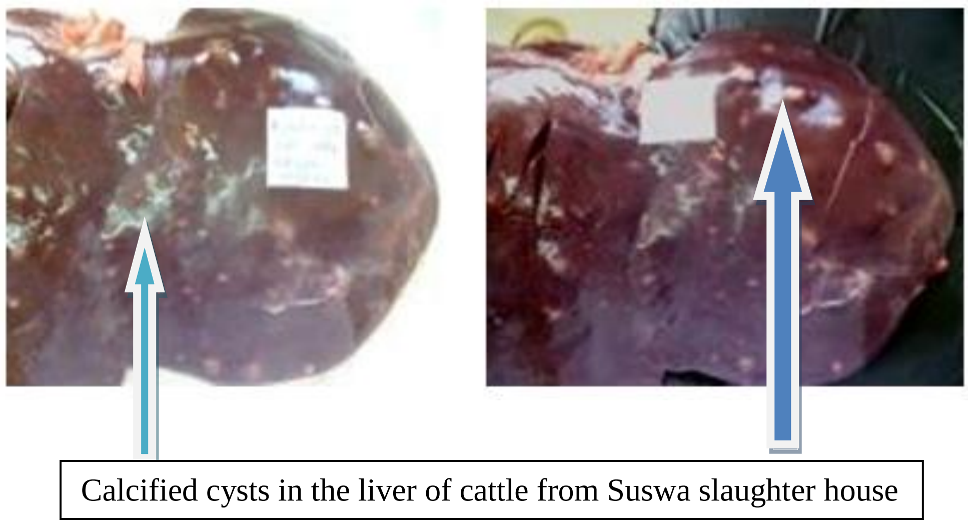

Figure 3.10: Calcified cysts in the liver of cattle from Suswa slaughter house in Kajiado North district

3.15 Distribution of Cystic Echinococcosis by age in Turkana North district

The distribution of CE by age in Turkana North district. A total of 586 CE patients that were surgically treated at KMH between 1991 and 2011 were grouped in various age groups (>1-10, 11-20, 21-30, 31-40, 41-50, 51-60, 61-70) (Fig 3.11). Cystic Echinococcosis affected both the old and young, the youngest CE patient was a 9 month old baby boy and the oldest patient was 62 years old. The middle age groups falling in the age brackets of 21-30, 31-40 and 41-50 were highly infected, 19%, 20% and 18% respectively. The old age groups, 51-60 and 61-70 had low infection rates, 8% and 1% respectively. The young age group, <1-10 had 16% infection rate.

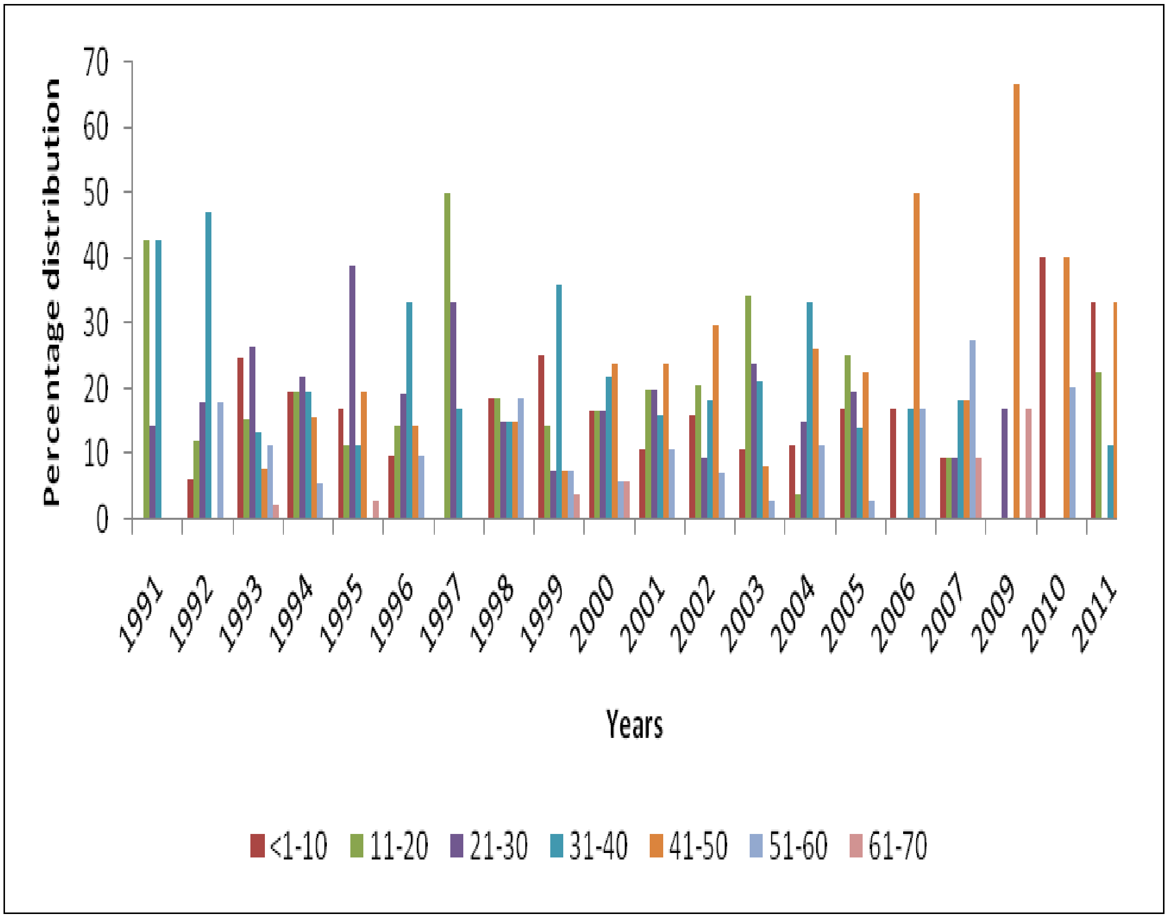

Figure 3.11: Distribution of Cystic Echinococcosis by age in Turkana North district

3.16 Distribution of Cystic Echinococcosis by gender in Turkana North district

A total of 586 CE patients were diagnosed and surgically treated at KMH between 1991 and 2011. A total of 172 males and 414 females were surgically operated. The data was used to determine the distribution of CE by sex. The patients were grouped based on gender, male or female. This was to determine which of the gender is at a higher risk of infection and how this aspect can be used in the prevention and control of CE in Turkana North district, a known CE endemic area.

Both the male and female gender was infected with the parasite, *E. granulosus*; females had the highest infection rate of 71%, 414 patients and 29% were males, 172 patients. The male: female sex ratio was 1:2; for every 1 male infected, 2 females were infected.

The distribution of CE by gender in Turkana North district was plotted on a graph, the total number of CE operated patients of both the gender on the Y-axis and the years under review on the X-axis. A total of 586 CE patients were operated during the review period, 172 males against 414 females were operated at KMH and the females had the highest CE infection rates, Male: Female ratio of 1:2 as shown in Fig 3.12.

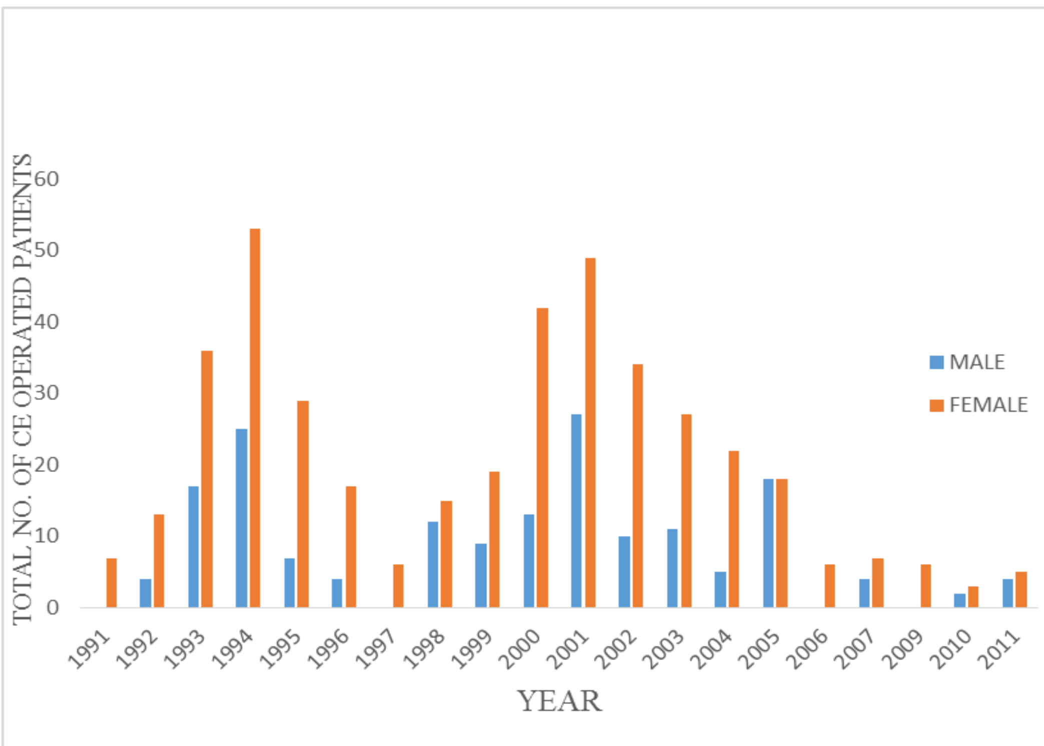

Figure 3.12: Distribution of CE by gender in Turkana North district

3.17 Prevalence of Cystic Echinococcosis in livestock slaughtered in Kisumu East and West districts, 2005- 2009

The prevalence of CE in livestock (cattle, goats, sheep and pigs) in Kisumu East and West districts. The total number of slaughtered animals per year was indicated against the cystic organs (Table 3.9). Each cystic organ was assumed to represent an infected animal; the total number of infected animals per species was based on the total number of infected livers and lungs per species. The CE prevalence in livestock slaughtered in Kisumu East and West districts based on the annual meat inspection report is 4% in cattle, 2% in goats, 4.5% in sheep and 0.05% in pigs.

Table 3.9: Prevalence of CE in slaughtered livestock in Kisumu East and West districts

Year	Animal slaughtered	Total slaughter numbers	Total No. of infected animals	% infection	Total No. of liver infected	Total No. of lungs infected
2005	Cattle	9822	456	5	197	259
	Goats	7231	165	2	73	92
	Sheep	3326	192	6	92	100
	Pigs	662	1	0	1	0
2006	Cattle	11037	539	5	182	357
	Goats	8801	180	2	60	120
	Sheep	5233	212	4	77	135
	Pigs	630	0	0	0	0
2007	Cattle	11377	364	3	151	
	Goats	8604	149	2	50	99
	Sheep	3631	157	4	52	105
	Pigs	151	0	0	0	0
2008	Cattle	10555	372	4	163	209
	Goats	6899	121	2	63	58
	Sheep	2473	103	4	43	60
	Pigs	154	0	0	0	0
2009	Cattle	11586	573	5	237	336
	Goats	6675	160	2	81	79
	Sheep	2632	118	4	38	80
	Pigs	602	0	0	0	0

3.18 Prevalence of Cystic Echinococcosis in slaughtered livestock in Isiolo district, 2006-2010

The prevalence of CE in livestock (camels, cattle, goats and sheep) in Isiolo district. The total number of slaughtered animals per year is indicated against the cystic organs (Table 3.10). Each cystic organ was assumed to represent an infected animal; the total number of infected animals per species was based on the total number of infected livers and lungs per species. The CE prevalence in livestock slaughtered in Isiolo central division slaughter house in Isiolo County was 6.0% in cattle, 25.3% in camels, 1.0% in sheep and goats.

Table 3.10: Prevalence of Cystic Echinococcosis in livestock in Isiolo district

Year	Animals slaughtered	Total slaughter numbers	Total No. infected	% infection	Total No. of liver infected	Total No. of lungs infected
2006	Cattle	1194	48	4	9	39
	Goats	2915	4	0	2	2
	Sheep	1048	0	0	0	0
	camels	447	106	24	53	53
2007	Cattle	1725	38	2	2	36
	Goats	3471	17	1	6	11
	Sheep	966	12	1	9	3
	camels	644	115	18	57	58
2008	Cattle	1637	112	7	46	66
	Goats	3772	17	1	3	14
	Sheep	730	5	1	3	2
	camels	650	184	28	109	75
2009	Cattle	1607	89	6	24	65
	Goats	4011	20	1	2	18
	Sheep	562	0	0	0	0
	camels	650	165	25	92	73
2010	Cattle	1341	160	12	58	102
	Goats	4340	83	2	12	71
	Sheep	839	38	5	14	24
	camels	813	240	30	111	129

CHAPTER FOUR

4.0 DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

4.1 DISCUSSION

This is the first documentation on the determination of the socio-economic impact of CE in humans and livestock in Kenya. The information from studies that estimate the socio-economic impact of an infection in an area, region or the entire country are very important in the implementation of a concerted and effective control program to reduce its future incidences and prevalence. The policy makers in the line ministries (Ministries of The National treasury, Health and Agriculture, Livestock & Fisheries) will use the information to identify specific areas in the CE control and prevention program that require urgent action and allocate the limited resources available to reduce the incidence and prevalence of CE in CE endemic and emerging areas.

The preferred way to capture both the human and agricultural effect of a zoonosis is to estimate its economic impact (Carabin *et al.*, 2005). This has been undertaken for CE in a number of European countries, including Wales (Torgerson & Dowling 2001), Jordan (Torgerson *et al.*, 2001) and Tunisia (Majorowski *et al.*, 2004).

The high monetary values attributed to the screening, diagnosis and treatment of each CE case and the daily salary of a farmer or homemaker in a low-income country that would be lost with a reduction in productivity is virtually always uncertain due to the morbidity and/or mortality associated with CE in human intermediate host. Individuals surgically treated for CE has a significant decrease in their quality of life. The disease negatively affects the quality of life; the CE patients from KMH, Turkana County, (Figure 3.2) with abnormally swollen abdomen may not be able to perform their daily routine duties without assistance due to the increasingly enlarging cyst within the abdominal cavity.

Studies conducted in the United Kingdom (Torgerson & Dowling, 2001) and Jordan (Torgerson *et al.,* 2001) suggested that patients surgically treated for CE had a significant decrease in their quality of life, and that patients presenting for treatment of CE had twice the unemployment rate of the general population in Kyrgyzstan (Torgerson *et al.*, 2003).

The reduced quality of life associated with CE patients that had been surgically treated or with advanced CE conditions will lead to an increase in the indirect CE-associated economic losses in the human host. The affected individuals will not be able to contribute positively towards the family and the community economy as a herdsman (infected males) or house wife (infected females). Cysts can reach very huge size producing discomforting pressure at the affected predilection sites. For example the biggest cyst ever isolated from a patient in KMH, Turkana had cystic fluid measuring 26 litres (Zeyhle & Magambo, 2007).

Cystic Echinococcosis causes considerable economic losses in livestock as a result of its morbidity. In the livestock intermediate hosts considered in this study, cattle, sheep, goats, pigs and camels the cyst occurrence in the body organs such as the liver and lung leads to outright condemnation of the edible organs at the slaughter houses during meat inspection and therefore the economic loss to the livestock traders. However detection of the cysts in live animals, ante mortem examination is not practically possible. Calcifications on the liver or lungs which are cyst suspects can also lead to condemnation of the whole organ or affected part trimmed off leading to loss of revenue to the livestock traders. Other studies by Kittelberger *et al*., 2002 also noted that cysts in the livestock intermediate host can only be detected at meat inspection and postmortem.

However ultrasonography and serum antibody detection have been used in rare cases to identify cysts in live animals (Eckert *et al*., 2001a).

4.1.1 Prevalence of Cystic Echinococcosis in human in Turkana North district, 1991-2011

The high proportions of Cystic Echinococcosis in the middle age group among the treated individuals at the health facility is an important finding in this study as the members of the Turkana community falling in this age bracket are the most economically active members to the family and community. The 586 CE patients that were surgically treated at KMH during the period under review, 57.3% were between 21 and 50 years old.

The prevalence of CE in these economic potential individuals will have a direct impact on the ultimate total burden of the infection to individual families and the Turkana community as a whole. The high prevalence of CE in the middle age group treated at KMH was proven by studies in other areas of endemic infection where most hospital cases were recorded in the age groups between 21 and 40 years, but the highest morbidity may also occur in younger individuals aged between 6 and 20 years (Ammann & Eckert, 1996; Pawlowski *et al.*, 2001).

The infection is also prevalent in female gender than male gender with a male: female infection ratio of 1:2; for every male surgically operated, 2 females are operated. The high prevalence in the female gender had also been noted in women of child-bearing age by other researchers in their studies in Turkana and East Africa (Rottcher, 1973; French, 1980; Okelo, 1986; Cooney *et al.*, 2004).

The affected individuals are not able to perform their daily routine duties such housework, personal hygiene, education, procreation, eating without any form of assistance. In advance abdominal CE cases the abdomen is extremely swollen and the patients are usually weak with difficulty in movement. In most cases such patients remain indoors and as such are not productive to the family and community. The same patients therefore require constant care which ends up increasing the economic burden of the infection to the families and community as a whole as the care providers are rendered unproductive. This confirms a high economic burden as proven in other studies such as Craig *et al.,* 2003 and McManus *et al.*, 2003.

The larval stage of *E. granulosus* can occur in various organs within the human body however the cyst is commonly found in the liver, abdomen and kidneys with 63%, 24% and 6% occurrence rates respectively. Other studies on the clinical surveys of CE have also confirmed that hydatid cysts of the liver are common, followed by abdominal cysts, kidneys, spleen, lung and soft tissue (Wahlers *et al.,* 2012). Because most rural hospitals do not have radiograph facilities, lung disease is likely to be under diagnosed in these populations (Rottcher, 1973; Irvin, 1974; Cooney *et al.,* 2004). The location of the cyst in the patient is an important parameter that determines the choice of treatment or surgical intervention such as Laparotomy, PAIR or chemotherapy to be applied and hence determines the cost of the treatment and the economic burden in monetary terms of the infection.

4.1.2 Estimation of human Cystic Echinicoccosis associated economic loss

4.1.2.1 Direct economic loss due to Cystic Echinicoccosis infection in human in Turkana North district

The direct human associated economic losses due to CE in this study were based on various parameters during the mass screening for CE positive cases and surgical treatment at KMH in Turkana County by AMREF medical personnel team. The parameters used to evaluate the human direct economic loss in this study were the costs of diagnosis mainly by ultrasound technique, treatment cost; surgery achieved either through laparotomy or PAIR, hospitalization costs (a maximum of 10 days for in-patients), surgeon's and anesthetic's salary, cost of drugs and equipment, follow up and logistical costs (preparation meetings, telephone costs and stationery). Other costs included flight cost using AMREF-Kenya Flying Doctor Aircraft from Nairobi to KMH and fuel used for local running during the outreach program. These parameters were the same with those of similar studies in Ningxia Hui Autonomous Region, China (Yang *et al*., 2006).

The total human CE-associated direct economic loss during the 20 years under review was Kshs 38,649,000.00 with an average of Kshs 2,034,158.00 loss per year. This figure included non-healthcare seeking individuals, the asymptomatic and unreported CE cases which were assumed to comprise 10% of the overall direct CE-associated economic loss per year.

The high monetary value attributed to the direct costs of treating the CE patients surgically in KMH, Turkana County a known CE endemic area in Kenya is an important finding in this study; this is because of the fact that the Turkana community is a nomadic pastoralist community and the region is dry in most periods of the year. Not all the CE infected individuals will be screened in the health facilities during the AMREF-Kenya outreach program conducted four times per year due to the community's nomadic way of life.

The male gender, middle age group are usually out of the homesteads most of time of the year moving with their livestock in search of pasture and water. Some of the CE infected individuals; advanced CE cases may also stay hidden at home making the direct economic loss attributed to CE even higher than reported in Turkana. Asymptomatic individuals may not present themselves for ultrasound screening due ignorance of CE and its risk factors.

The average annual direct economic loss of Kshs 2.0 million per year in a single health facility such as KMH in Turkana clearly show that CE is a zoonotic parasitic infection with a high economic burden in Turkana County. The economic loss attributed to CE infection in Kenya could be higher considering the various health facilities and referral health institutions that could be diagnosing and conducting surgery on patients with the disease in the whole country. This is mainly because of the mobility of CE infected individuals from Turkana who are diagnosed and treated in other health facilities.

Livestock slaughtered in the major abattoirs and slaughterhouses situated in cities and major towns are sometimes sourced from CE endemic areas (Turkana and Masaailand) and due to poor disposal/handling of condemned organs, definitive hosts (dogs) may come into contact with these CE infected organs hence the perpetuation of the parasite cycle, emergence and spread of the infection in new areas such as Kisumu East district where the movement permits in the district veterinary office confirm that livestock (goats and cattle) are sourced from Turkana and Narok districts which are known CE endemic areas.

The disease mainly affects the poor pastoralist communities and therefore constitutes a serious impediment to socio-economic development and a standard quality life to these communities. The disease has enormous socio-economic impact on individuals, families and communities in terms of the disease burden due to its morbidity. Loss of productivity and aggravation of poverty due to high cost of long term care of the infected individuals is also another impact. In advanced CE cases, social problems are experienced where wives desert their husbands as affected male individuals don't participate socially and instead stay hidden at home.

The affected individuals also have limited ability to perform daily life activities such as recreation, education, procreation or occupation. Due to low quality of life as a result of

CE, affected individuals require assistance to perform daily life activities such as eating, personal hygiene.

The Turkana people are a nomadic pastoralist community whose main occupation being herding. The community's wealth is measured in terms of the herd population owned by an individual and they have a special attachment to their livestock. Those male individuals who are CE infected may not be able to own any livestock or protect the community against cattle rustling by other neighboring communities because they can no longer herd animals due to their poor state of health and depend on other members of their community for survival.

Non healthcare seeking CE patients also end up dying due to CE complications, poor nutrition or hunger. The mortality as a result of CE therefore leads to the loss of a bread winner in a poverty stricken community thus making the economic burden even worse. The poverty index of Turkana county stands at 94.3% according to integrated survey (World Bank report, 2011). The poor quality of life amongst the CE affected individuals in Turkana leading to the high CE associated monetary losses is similar to other studies by Toggerson and Dowling, 2001; Toggerson et al., 2001; Toggerson et al., 2003 in the United Kingdom, Jordan and Kyrgyzstan respectively.

4.1.2.2 Indirect economic loss due to Cystic Echinococcosis infection in human in Turkana North district

Two parameters were considered to compute the indirect economic loss due to CE infection in human in Turkana North district. The economic loss that would be incurred when a herdsman and a housewife infected with CE cannot be able to carry out his or her daily activities without any assistance. A CE patient after a surgical treatment, Laparotomy will have a reduced quality of life leading to a reduced production output or participation in normal daily activities.

Livestock rearing is the main economic activity amongst the Turkana community in Kenya. Therefore a herdsman in the community contributes significantly to the economic development of the community in general. As nomadic pastoral community the main activity for men above 18 years old is to move from place to place with the livestock in search of good pastures and water. The animals are usually herded communally.

When the livestock are sold the livestock owners get income in monetary terms. The monetary value of the young ones and culled adult animals through sales constitute the lost opportunity or economic loss as a result of CE affecting the male gender above 18 years in the Turkana community. The same herdsmen also guard against theft of their livestock by the neighboring communities. Cattle rustling are a common phenomenon in Turkana County and the neighboring counties.

The community also depend on their livestock for food for example meat, milk and blood. The livestock are also important during traditional marriage as a means of paying dowry. When the male gender in the community is infected with CE they will not be able to carry out their herding activity and guarding of livestock against cattle rustling. Herding is the main activity of the Turkana men and it forms a major indirect economic loss when a man in Turkana community is infected with CE.

The total indirect economic loss due to advanced CE infection, reduced quality of life after surgical treatment or death as a result of CE of a herdsman in Turkana can be estimated. This can be computed by calculating the economic contribution of the herdsman in terms of the opportunity costs lost as a result of death of an individual herdsman or a reduced quality of life of a herdsman due to CE morbidity leading to incapacitation.

The Turkana community is a nomadic pastoralist community and rear cattle, camels, sheep and goats. An individual's wealth is measured in terms of the herd or flock size. The parameters used to calculate the economic contribution of a herdsman include the herd size of an individual, number of calving, lambing and kidding per year, number of cattle, camels, sheep and goats sold per year per household and the estimated value in monetary terms of the calves, lambs, kids at birth per year per household.

The total value of the young stock at birth and the livestock sold at market weight per year in monetary terms is the opportunities that will be lost when the herdsman is not productive due to reduced quality of life or death as a result of CE. The value of lost opportunities by the herdsman forms the indirect economic burden of CE. The KShs. 411,250.00 lost by a single herdsman per year due to CE is important in a pastoralist community whose main economic activity depends entirely on livestock.

The female gender in Turkana community are involved in taking care of children, drawing of water from the river, fetching firewood, cooking for the family and building of the traditional huts, "manyatta". The main daily activities carried out by women in Turkana community were computed in economic terms by equating each of the activities to the monetary values of same services or goods in Lodwar town in Turkana County. Lodwar town is the major urban settlement in the county.

When the female gender is infected with CE in the Turkana community, her contribution to the community through caring of children, drawing water from the river for domestic use, fetching firewood and building of homesteads will be reduced. This is mainly due to the severity of the disease in long standing cases or post-surgical treatment effects which lead to a reduced quality of life. These daily services to the family when converted in monetary terms constitute the indirect economic burden of CE in the female gender in Turkana community. The total of KShs 117,716.00 per year lost by one woman infected with CE in a poverty stricken community living below a dollar a day is significant.

4.1.3 Estimation of livestock costs

There are no reliable methods for routine diagnosis of the infection in living animals, but in rare cases cysts have been identified by ultrasonography alone or in conjunction with serum antibody detection (Eckert, *et al.*, 2001a). A new ELISA with a high specificity and a sensitivity of 50 to 60% might be useful for detecting *E. granulosus* cysts in sheep on a flock basis but cannot be used for reliable diagnosis of infected individual animals (Kittelberger, *et al.*, 2002). The most reliable diagnostic method is cyst detection during meat inspection or at postmortem examination. Hydatid cyst infected organs from a slaughtered animal will be out rightly condemned meaning lost revenue to the livestock traders.

In Kenya, meat inspection of slaughtered livestock is done by the Livestock department in the Ministry of Agriculture, Livestock and Fisheries. Any organ found to be infested with a single hydatid cyst or a suspect hydatid cyst calcification during meat inspection is directly condemned and disposed of in the recommended manner, condemnation pit to avoid contact with the dogs and other canids. The right disposal mechanism of the cystic condemned organs is a CE control strategy to stop the cycle of *E. granulosus* parasite at the intermediate host stage.

During slaughter house meat inspection survey, multiple organ infestation in a single animal were noted, a situation where both the liver and lungs from one animal was infected with hydatid cysts. A single organ from one animal, liver or lungs had multiple infestations and the cyst size ranged from tiny cysts, less than 1cm to large cysts with an average diameter of 5cm full of clear fluid, Fig 3.8. On the liver there were also calcifications which could also be hydatid cyst suspects, however these calcifications were only trimmed off and the organ passed as fit for human consumption during meat inspection, Fig 3.10. Multiple organ hydatid cyst infestation from a single slaughtered animal increased the level of the total revenue lost by the livestock traders; all the cystic organs were condemned at meat inspection.

However small calcified hydatid cysts in some organs such as the liver usually go undetected and such organs were declared fit for human consumption and sold to unsuspecting customers, putting the people at high risk of CE infection. The presence and confirmation of such calcified hydatid cysts can only be detected in the laboratory by subjecting the samples to sensitive molecular procedures like PCR, which cannot be conducted at the slaughter house level during meat inspection routines to confirm the presence of hydatid cysts. Any organ with suspect hydatid cyst calcification should be condemned during meat inspection.

The lost revenue due to condemnation of cystic organs is an economic loss incurred by the livestock traders some of which were only trading on an average of 1 animal slaughtered per species per day.

In the pigs there was one important isolated case of hydatid cyst in the liver however according to the records available at the Ministry of Agriculture, livestock and fisheries, Livestock department in Kisumu East district, the number of pigs slaughtered during the five years under review were very low. It's also important to note that pigs are mainly reared indoors therefore the possibility of coming into contact with the parasite eggs is very limited unless they are left to scavenge in a free range rearing system.

The total revenue lost as a result of condemnation of edible organs such as the liver and lungs in cattle, sheep and goats was Kshs 2,238,975.00 with an average of Kshs 447,795.00 per year in Kisumu East and West districts. Considering the direct revenue lost at an individual livestock trader level or per animal, the economic loss is important, I would urgent control measures to reduce such losses in future.

The livestock (cattle, sheep and goats) slaughtered in the study site according to the movement permits at the veterinary office originated from different areas outside the two districts. Most animals came from various livestock markets in the Rift Valley province (Kericho, Bomet, Nandi, Buret, Transzoia, and Turkana); others also came from Kuria, Migori, Suba, Kakamega, Butere districts. A smaller percentage of the livestock slaughtered originated from within the study site. The relationship of the CE prevalence and the origin of the slaughtered animals, cattle, sheep and goats in Kisumu East and Kisumu West districts confirm the spread of the infection in the areas the animals originated other than Turkana which is a known CE endemic area.

Livestock originating from Turkana County explains the emergence of hydatid disease in the study site and therefore more emphasis should be put in place to diagnose and control the infection in the definitive host, dogs which harbor the adult parasite.

In Isiolo district, Isiolo central division slaughter house was considered for the study, the animals slaughtered in the slaughter house include camels, cattle, sheep and goats. The affected organs were the liver and lungs which were condemned leading to loss of revenue. The total revenue loss from condemned cystic organs was Kshs 1,824,450.00 with an average of Kshs 364, 890.00 per year.

Direct livestock associated economic loss due to condemnation at meat inspection were estimated based on the total number and weight of the entire CE infected organs mainly liver and lungs per animal species. Other indirect costs, reduced milk production, fecundity, growth rate and hide value were not considered in computing the economic loss attributed to CE in the livestock species considered in this study. This is because these indirect livestock production associated economic loss parameters could also be attributed to the harsh environmental conditions that these animals are found.

The direct economic loss attributed to CE in the livestock intermediate hosts in the study sites considered during the retrospective data review concur with studies in other countries where economic loss due to condemnation of animal organs such as the liver and lungs during meat inspection have been conducted. A prior study in Ethiopia estimated the loss of at least 20 US$ per every hydatid infected subject (Yilma *et al*., 1996).

Other studies in Ethiopia on direct and indirect economic loss from organ condemnation and reduced carcass weight by (Getaw *et al*., 2010; Zewdu *et al*., 2010; Kebede *et al*., 2011) confirm a high direct monetary loss associated with CE in livestock due to condemnation of organs at meat inspection. Estimated global annual overall losses from the burden of human CE and livestock-associated losses were reported to be US$ 1,918,318,955 and US$ 2,190,132,464, respectively (Budke *et al*., 2006).

Differences between the quantities of losses amongst the countries could be due to different livestock population, prevalence rates, methodologies employed, input parameters measured for the analyses, differences in productivity of animals and retail prices (Abebe & Yilma, 2012).

4.1.4 Distribution of CE by gender in N. Turkana North district

From the results, both the males and females are at risk of contracting the infection with females at a higher risk than males. The male to female infection ratio is at 1:2; a total of 568 CE patients were operated at KMH and 172 were males (29%) and 414 were females (71%). French (1980) studied the age-sex distribution of 355 Turkana hydatid patients and obtained similar results of male: female ratio of approximately 1:2. He related the trends to the close contact of women and dogs during the child rearing age when the dogs are used as nurse maids to clean babies on defecation or vomiting.

The male: female ratio distribution of CE of 1:2 among the gender in Turkana North district can also be due to the fact that the female members of the community are normally within the homesteads (Manyatta) taking care of the children and are likely to be available during the AMREF-Kenya CE outreach programmes. Most females will therefore attend the CE screening sessions and the positive cases booked for treatment at KMH through surgical operation. The youths and middle aged men are always out of the homesteads grazing livestock and will not be captured fully during CE mobile screening using Ultrasound. The reason being that the Turkana community are nomadic pastoralists and the prevailing harsh environmental conditions in Turkana County force the male members of the community to move long distances in such of water and pastures for their livestock throughout the year.

The poor living conditions especially lack of clean water for both drinking and domestic use; lack of adequate public health education and the close contact with host dogs are key epidemiological factors that can be associated with the CE infections in Northern Turkana. Turkana being an arid region, water shortage is the main problem and therefore dogs are used as nurse maids to clean babies on defecation or vomiting. The closeness with the main definitive host, dogs either during herding of livestock and within the homesteads is an epidemiological risk factor that is responsible for the infection in both gender especially in the females in the community.

4.1.5 Distribution of CE by age in Turkana North district

The trend of CE distribution by age in Turkana North district shows that the middle age groups, 21-30 and 31- 40 had the highest infection rate and this could be associated with the close contact with the definitive host, dogs in the study site. The Turkana men are known to herd their livestock with dogs and the women get close contact with dogs during baby nursing stage. French (1980) observed in his study, the age-sex distribution of Turkana hydatid disease patients that the majority of patients were females of ages between 20 and 35 years old.

The age distribution trend of CE could also be associated with the presence of the wildlife cycle in Turkana (Macpherson *et al.*, 1983), eating of infected carnivores (dogs, jackals, hyenas, foxes). The young and energetic men are capable of hunting these carnivores and are at a high risk of CE infection through consumption of wild meat and handling of infected carnivores.

The old members of the community who are weak and malnourished would remain at home without seeking medical attention during the AMREF-Kenya outreach program in the various health facilities and could not be captured during the AMREF-Kenya CE screening and treatment period. Some of the old CE infected individuals would also remain hidden at homes without seeking medical attention due to stigmatization.

The middle age groups between the ages of 21 and 50 are the most affected with this debilitating infection. These are the most economically active individuals either through formal or informal engagement within the community. Their limited contribution to the economic development of the community due CE morbidity leads to the increased burden of the infection to the pastoralist community. The care and assistance given to the CE patients with advanced cases and after surgical operations also add to the burden of the infection in Turkana North district.

4.1.6 Prevalence of CE in livestock in the study sites

The prevalence of CE in livestock slaughtered in Kisumu East and West districts was 4.5% in sheep, 4.2% in cattle, 2.0% in goats and 0.05% in pigs. The high prevalence rates could be associated with the origin of the livestock slaughtered in the study site which originated as far as Turkana County a known CE endemic area. This was confirmed from the Movement permits and No objection form file seen in Kisumu East district veterinary office. The high infection rates and the origin of the slaughtered livestock in the study site show the spread and emerging trend of CE in new areas in Kenya. The low prevalence rate of CE infection in the pigs slaughtered in the study site of 0.05% could be explained by the low number of pigs slaughtered in the area and the fact that pigs are reared indoors therefore have least contact with *E. granulosus* eggs released by the definitive host (dogs).

The prevalence of CE in livestock slaughtered in Kisumu East and West districts and the origin of these animals show the extent at which the infection has spread over time from its known endemic areas. A trend that is very important to the public health stakeholders in the country and region.

In Isiolo district the animals slaughtered included camel, cattle, sheep and goats and these animals originate from the district a clear indication that the infection is prevalent in this county. Hydatid cyst infection was high in camels and cattle compared to sheep and goats. The prevalence of CE in livestock slaughtered in Isiolo central division slaughter house, Isiolo district was 6.0% in cattle, 25.3% in camels, 1.0% in sheep and goats.

The figures show that camels and cattle have a high infection rate than the small stock. These figures are also indicative that the infection is spreading outside its known endemic areas in Kenya. The close association of the communities in Isiolo County with their dogs and camels explain the high CE prevalence rates in camels in the study site. There is also the possibility of the infection in human beings in this study site.

A 10 year retrospective abattoir survey of slaughtered ruminants in Adama municipal abattoir, central Oromia, Ethiopia by (Getaw *et al*., 2010) showed a high CE prevalence of 46.8% (cattle), 29.3% (sheep) and 6.7% (goats), a similar prevalence trend in the livestock slaughtered in the two study sites, Kisumu East & West and Isiolo districts over a five year period.

4.2 CONCLUSION

Cystic Echinococcosis has a major significant impact on human and livestock in Turkana North and other selected regions in Kenya due to the enormous direct and indirect economic loss associated with its morbidity and mortality in the intermediate hosts. The social impact attributed to CE in endemic areas such as Turkana County is also important. Cystic Echinococcosis is therefore a parasitic zoonotic disease of public health importance in Kenya which requires urgent implementation of efficient and effective control measures to reduce its incidence and prevalence in endemic and emerging areas.

The CE direct economic impact in Turkana County is high considering the fact that the surgical operations were done in a single health facility in a remote area in Kenya. An average of Kshs. 2.0 million direct CE-associated monetary losses per year is significant in a poverty stricken pastoralist community in Kenya. The indirect CE-associated monetary losses for an infected herdsman and house wife in Turkana community were Kshs 411,250.00 and Kshs 117,716.00 respectively per year, the indirect monetary losses increased the overall burden of the infection.

4.3 RECOMMENDATIONS

From the results of this study, more considerations needs to be given to CE by public health experts in both the Ministries of Health and Agriculture, Livestock and Fisheries and Regional public health policy makers. This is mainly to prevent new incidences in the human host in endemic/high risk areas and reduce its economic burden. The high risk areas include urban areas and cities which receive their supplies of livestock for slaughter from all over the country, for example Mamboleo slaughter house in Kisumu city.

A sustainable CE control program should be put in place at the levels of the definitive host (dog), intermediate hosts (livestock and humans) and the community level. Both the central and county governments also to be involved for the successful implementation of the control program. All the stakeholders including dog owners should be involved for the success of the CE control program.

Definitive host (dog)

- Control of stray dog numbers through regular baiting by the Veterinary department.
- Registration and regular deworming of all owned dogs.
- Control of dog populations through spaying of female dogs before reaching their first breeding age.
- Proper handling of dog faeces.

Livestock intermediate host

- Proper meat inspection procedures by well-trained veterinary public health personnel.
- Construction of standard slaughter houses and slaughter slabs with the recommended disposal mechanisms of condemned organs at meat inspection.
- Reduction of home slaughter of livestock which are usually not inspected.
- Training and recruitment of veterinary public health personnel by the central and county governments.

Human intermediate host

- Regular mass screening of human in CE endemic areas (Turkana) and treatment through surgery or chemotherapy to reduce the suffering of the affected individuals.

Community level

- Public health training to create awareness on the mode of transmission of the disease, its dangers, risk factors and CE-associated direct and indirect burden.
- Training of community public health based workers on general public health hygiene.

Central and county governments

- Provision of funds in the national and county governments' annual budgets directed towards the implementation of CE control program and research on the disease to accumulate the required scientific information needed for the control of the disease.

REFERENCES

Abebe, F. and Yilma, J., (2012). Estimated annual economic loss from organ condemnation, decreased carcass weight and milk yield due to bovine hydatidosis (*Echinococcus granulosus*, Batsch, 1786) in Ethiopia. *Ethiopia Veterinary Journal.* **16** (2), 1-14

Addy, A., Alakonya, A., Wamae, N., Magambo, J., Mbae, C., Mulinge, E., … and Romig, T., (2012). Prevalence and diversity of cystic echinococcosis in livestock in Maasailand, Kenya. *Parasitolology Research*. **111,** 2289–2294

Africapay.org/Kenya., (2013). Minimum Consolidated Wages by Region and Occupation in Kenya.

Alex, o., Kipruto, C., Jane, M., Maimbo, M., Anne, k., Douglas, N., … and K., Duncan, O., (2012). Food security master plan for Turkana County, Diocese of Lodwar.Nairobi: *Colourprint Ltd,* 42.

al-Karawi, M., Mohamed, Ae-S., Yasawy, M., (1990). Advances in diagnosis and management of hydatid disease. *Hepatogastroenterology*; **37,** 327-331.

Ammann, R. W., and Eckert, J., (1996). Cestodes: *Echinococcus. Gastroenterology Clinics of North America,* **25,** 655-689.

Amor, B. N., Gargouri, M., Gharbi, H. A., Golvan, Y. J., Ayachi, K., Kchouk, H., (1986). Trial therapy of inoperable hydatid cysts by puncture. *Annales de Parasitologie Humaine et Comparée* **61,** 689-692.

Anonymous, (1996). Guidelines for treatment of cystic and alveolar echinococcosis in humans. *WHO Informal Working Group on Echinococcosis*. Geneva:WHO, **74**, 231-242.

Aygun, E., Sahin, M., Odev, K., Vatansev, C., Aksoy, F., Paksoy, Y., … and Karahan, O., (2001). The management of liver hydatid cysts by percutaneous drainage. *Canada Journal Surgery***. 44,** 203-209.

Batteli, G., (2009). Echinococcosis: costs, losses and social consequences of neglected zoonoses. *Veterinary Research Communications.* 47-52

Battelli, G., (2003). Overview of the epidemiological situation on echinococcosis in Mediterranean region. *Acta tropica*. 85, 191-195

Battelli, G., Mantovani, A. and Seimenis, A. (2002). Cystic echinococcosis and the Mediterranean Region: a long-lasting association. *Parasitologia* **44,** 43-57.

Bekure, S., de Leeuw, P. N., Grandin, G.E., Neate, P. J.H., (1991). Maasai herding: An analysis of the livestock production system ofMaasai pastoralists in eastern Kajiado District, Kenya. ILCA Systems Study 4. ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia.172 pp.

Budke, C.M., Deplazes, P., Torgerson, P.R., (2006). Global socioeconomic impact of cystic echinococcosis. *Emerging Infectious Diseases*. **12**, 296– 303.

Budke, C.M., Qiu, J., Wang, Q., Zinsstag, J., Torgerson, P.R., (2004). Utilization of DALYs in the estimation of disease burden for a high endemic region of the Tibetan plateau. *American Journal Tropical Medical Hygiene* **71,** 56–64.

Carabin, H., Budke, C.M., Cowan, L.D., Willingham III, A.L. and Torgerson, P.R., (2005). Methods for assessing the burden of parasitic zoonoses: cysticercosis and echinococcosis. *Trends in Parasitolology*. **21,** 327–33.

Chai, J.J., (1993). Sero-epidemiological surveys for cystic echinococcosis in the Xinjiang Uygur Autonomous Region, PRC. In :Andersen FL, Chai JJ, Liu FJ, eds. Compendium on cystic echinocococcosis with special reference to the Xinjiang Uygur Autono-mous Region, the People's Republic of China. Provo: Brigham Young University Print Services, 153-161

Christofi, G., P. Deplazes, N. Christofi, I. Tanner, P. Economides, and J. Eckert. (2002). Screening of dogs for Echinococcus granulosus coproantigen in a low endemic situation in Cyprus. *Veterinary Parasitology*. **104,** 299-306.

Cirenei, A., and Bertoldi, I., (2001).Evolution of surgery for liver hydatidosis from 1950 to today: analysis of a personal experience. *World Journal of Surgery.* **25,** 87–92.

Cooney, R.M., Flanagan, K.P., Zeyhle, E., (2004). Review of surgical management of cystic hydatid disease in a resource limited setting:Turkana, Kenya. *European Journal of Gastroenterology and Hepatology,* **16,** 1233-36.

Craig, P. S., (1997). Immunodiagnosis of Echinococcus granulosus and a comparison of techniques for diagnosis of canine echinococcosis, p. 85-118. In F. L. Andersen, H. Ouhelli, and M. Kachani (ed.), Compendium on cystic echinococcosis in Africa and Middle Eastern Countries with Special Reference to Morocco. Provo: Brigham Young University Print Services.

Craig, P. S., Gasser, R. B., Parada, L., Cabrera, P., Parietti, S., Borgues, C., … and Paolillo, E., (1995). Diagnosis of canine echinococcosis: comparison of coproantigen and serum antibody tests with arecoline purgation in Uruguay. *Veterinary Parasitology*. **56,** 293-301.

Craig, P.S., Rogan, M., and Campos-Ponce, M., (2003). Echinococcosis: disease, detection and transmission. *Parasitology* **127,** S5–S20

Deplazes, P., Jimenez-Palacios, S., Gottstein, B., Skaggs, J., and Eckert, J., (1994). Detection of *Echinococcus granulosus* coproantigens in stray dogs of northern Spain. *Applied Parasitology*. **35,** 297-301.

Dinkel, A., Njoroge, E. M., Zimmermann, A., Wa¨lz, M., Zeyhle, E., and Elmahdi, I. E., (2004). A PCR system for detection of species and genotypes of the Echinococcusus granulosus—complex with reference to the epidemiological situation in eastern Africa. *International Journal of Parasitolology*. **34**, 634–653.

Eckert, J., and Deplazes, P., (2004). Biological, epidemiological and clinical aspects of echinococcosis, a zoonosis of clinical concern. *Clinical microbiology Revised*, **17**, 107-135.

Eckert, J., Deplazes, P., Craig, P. S., Gemmell, M. A., Gottstein, B., Heath, D., … and Lightowlers, M., (2001a). Echinococcosis in animals: clinical aspects, diagnosis and treatment, p. 72-99. *In* J. Eckert, M. A. Gemmell, F.X. Meslin, and Z. S. Pawlowski (ed.), WHO/OIE Manual on echinococcosis in humans and animals: a public health problem of global concern. *World Organisation for Animal Health*, Paris: WHO.

Eckert, J., Gottstein, B., Heath D., and Liu, F.J., (2001b). Prevention of echinococcosis in humans and safety precautions, p. 238-247. *In* J. Eckert, M. A. Gemmell, F.-X. Meslin, and Z. S. Pawlowski (ed.), WHO/OIE manual on echinococcosis in humans and animals: a public health problem of global concern. *World Organisation for Animal Health*, Paris: WHO/OIE.

Filice, C., and Brunetti, E., (1997). Use of PAIR in human cystic echinococcosis. *Acta Tropic*a; **64**, 95-107.

Filice, C., Brunetti, E., D'Andrea, F., and Filice, G., (1997). Minimal invasive treatment for hydatid abdominal cysts: PAIR (Puncture, Aspiration, Injection, Reaspiration)—state of the art. Geneva: World Health Organization. *New England journal of medicine*. **338,** 391-393

Filice, C., Pirola, F., Brunetti, E., Dughetti, S., Strosselli, M. and Foglieni, C. S., (1990). A new therapeutic approach for hydatid liver cysts. Aspiration and alcohol injection under sonographic guidance. *Gastroenterology* **98,** 1366-1368.

Fraser, A.L., Elayoubi, F., Craig, P.S., (2002). Detection of cestodes in definitive hosts: present status and future advances, p. 157-175. In P.S Craig and Z. Pawlowski (ed.) Cestode zoonoses: Echinococcosis and Cysticercosis, an emergent and global problem. Amsterdam:IOS Press.

French, C. M. (1980): The age-sex distribution of hydatid disease in Turkana. *East African Medical Journal*. **57,** 791-794.

Gargouri, N., Amor B., Chehida, F. B., Hammou, A., Gharbi, H. A., Cheikh, M. B. … and Golvan, Y. J., (1990). Percutaneous treatment of hydatid cysts (*Echinococcus granulosus*). *Cardiovascular Interventional Radiololgy* **13,** 169-173.

Gathura, P. B., and Kamiya, M., (1990). Echinococcosis in Kenya: Transmission, Characteristics, Incidence and Control measures. *Japanese Journal of veterinary research*, **38,** 107-116.

Gemmell, M. A., Roberts, M. G., Beard, T. C., Campano, S., Diaz, J. R., Lawson, and Nonnemaker, J. M., (2001). Control of echinococcosis: control of *Echinococcus granulosus*, p. 195-204. *In* J. Eckert, M. A. Gemmell, F.-X. Meslin, and Z. S. Pawlowski (ed.), WHO/OIE manual on echinococcosis in humans and animals: a public health problem of global concern. *World Organisation for Animal Health*, Paris: WHO/OIE.

Getaw, A,. Beyene, D., Ayana D., Megersa B., and Abunna, F., (2010). Hydatidosis: Prevalence and its economic importance in ruminants slaughtered at Adama municipal abattoir, Central Oromia, Ethiopia. *Acta Tropica.* **113,** 221–225.

Gharbi, H.A., Hassine, W., Brauner, M. W., and Dupuch, K., (1981). Ultrasound examination of the hydatic liver. *Radiology* **139**, 459–463.

Gil-Grande, L.A., Sánchez-Ruano, J.J., García-Hoz, F., Bárcena, R., Rodriguez-Caabeiro, F., … and Dal-Ré, R., (1993). Randomised controlled trial of efficacy of albendazole in intra-abdominal hydatid disease. *Lancet* **342,** 1269-1272.

Gottstein, B., (2000). Immunodiagnosis of infections with cestodes. P 347-373. In Y. H. Hui, S.A Satter, K.D Murrel, W.K Nip and P.S Stanfield (ed.). Food borne disease handbook. New York, N.Y.: Marcel Dekker, Inc

Grimm, F., Maly, F. E., Lü, J. A., and Ilano, R., (1998). Analysis of specific immunoglobulin G subclass antibodies for serological diagnosis of echinococcosis by a standard enzyme-linked immunosorbent assay. *Clinical and Diagnostic Laboratory Immunology* **5,** 613-616.

Heath, D., Wen, Y., Tiaoying, L., Yogfu, X., Xingwang, C., Yan, H., ... and W., Jiamin, Q., (2006). Control of hydatidosis. Parasitology International, **55**, 247–252.

Hijmans, R.J., Cameron, S. and Parra, J. (2004). WorldClim climate surfaces. Retrieved from http:/www.worldclim.org

Horton, R., (1997). Albendazole in treatment of human cystic echinococcosis: 12 years of experience. *Acta Tropica*; **64**, 79-93.

Irvin, A.D., (1974). Hydatidosis in human patients from Turkana. *Tropical and geographical medicine*, **26**, 157-59.

Ito, A., Urbani, C., Jiamin, Q., Vuitton, D.A., Donguchun, Q., Heath, D.D., … and Schantz, P.M., (2003). Control of Echinococcosis and Cysticercosis, a public health challenge to International Cooperation of China. *Acta Tropica* **86,** 3-7

Jenkins, D. J., (2002). *Echinococcus* in Australia: the role of wildlife in transmission, with particular reference to South Eastern Australia, p. 327-332. *In* P. Craig and Z. Pawlowski (ed.), Cestode zoononoses: echinococcosis and cysticercosis, an emergent and global problem. Amsterdam: IOS Press.

Jenkins, D.J, Romig, T., and Thompson, R.C.A., (2005). Emergence/reemergence of *Echinococcus* spp—a global update. *International Journal of Parasitology*. **35,** 1205–19.

Kearn, G. C., (1998). Parasites and platyhelminthes. London: *Chapman and Hall*. 544.

Kebede, N., Gebre-Egziabher, Z., Tilahun, G., and Wossene, A., (2011). Prevalence and Financial Effects of Hydatidosis in Cattle Slaughtered in Birre-Sheleko and Dangila Abattoirs, Northwestern Ethiopia. *Zoonoses Public Health.* **58,** 41–46.

Kenya National Bureau of Statistics (KNBS), (2012). Kenyan Population and Housing Census Report by the Kenyan National Bureau of Statistics. Nairobi: KNBS.

Kern, p., (2003). Echinococcus granulossus infection: clinical presentation, medical treatment and outcome. *Langenbeck's Archives of Surgery*; **388**, 314-320

Kern, P., Reuter, S., Buttenschoen, K., and Kratzer, W., (2001). Diagnostik der zystischen Echinokokkose. *Deutsche Medizinische Wochenschrift*. **126,** 20-23.

Khuroo, M. S., Wani, N. A., Javid, G., Khan, B. A., Yattoo, G. N., Shah, A. H., and Jeelani, S. G., (1997). Percutaneous drainage compared with surgery for hepatic hydatid cysts. *New England Journal of Medicine.* **337,** 881-887.

Kittelberger, R., Reichel, M. P., Jenner, J., Heath, D., Lightowlers, M. W., Moro, P., and O'Keefe, J. S., (2002). Evaluation of three enzyme-linked immunosorbent assays (ELISAs) for the detection of serum antibodies in sheep infected with *Echinococcus granulosus. Veterinary Parasitolology*. **110,** 57-76.

Larrieu, E. J., and Frider, B., (2001). Human cystic echinococcosis: contributions to the natural history of the disease. *Annual Tropical Medical Parasitolology*. **95,** 679-687.

Macpherson C. N. L., (2005). Human behaviour and the epidemiology of parasitic zoonoses. *International Journal for Parasitology*. **35,** 1319–1331

Macpherson, C. N. L., (2001). Epidemiology of *Echinococcus granulosus* in transhumant situations, p. 156-163. *In* J. Eckert, M. A. Gemmell, F.-X. Meslin, and Z. S. Pawlowski (ed.), WHO/OIE manual on echinococcosis in humans and animals: a public health problem of global concern. *World Organisation for Animal Health*, Paris: WHO

Macpherson, C. N. L., and Wachira, T. W. M., (1997). Cystic echinococcosis in Africa south of the Sahara, p. 245-277. *In* F. L. Andersen, H. Ouhelli, and M. Kachani (ed.), Compendium on cystic echinococcosis in Africa and Middle Eastern Countries with special reference to Morocco. Provo: Brigham Young University Print Services.

Macpherson, C.N.L., (1983). An active intermediate host role for man in the life cycle of *Echinococcus granulosus* in Turkana, Kenya. *American Journal of Tropical Medicine and Parasitology*. **32**, 397-404.

Macpherson, C.N.L., Bartholomot, B., and Frider, B., (2003). Application of ultrasound in diagnosis, treatment, epidemiology, public health and control of Echinococcus granulosus and E. multilocularis. *Parasitology* **127,** S21

Macpherson, C.N.L., Bartholomot, B., and Frider, B., (2003). Application of ultrasound in diagnosis, treatment, epidemiology, public health and control of *Echinococcus granulosus* and *E multilocularis. Parasitology* **127**, 21–35.

Magambo, J., Njoroge, E., and Zeyhle, E., (2006). Epidemiology and control of echinococcosis in sub-Saharan Africa. *Parasitology International.* **55,** S193–95.

Magambo, J.K., Wachira, T.M., Zeyhle, E., and Mwaura, J., (1996). Prevalence of human hydatid disease in southern Sudan. *African Journal of Health Sciences*. **3**, 154–156.

Majorowski, M.M., Carabin, H., Kilani, M., and Bensalah, A., (2005). Echinococcosis in Tunisia: a cost analysis. *Transactions of Royal Society of Tropical Medicine and Hygiene*; **99**, 268-78

Mathers, C., Vos, E.T., and Stevenson, C.E., (1999). The burden of disease and injury in Australia. *Australian Institute of Health and Welfare* (AIHW) cat. No. PHE 17. Canberra: AIHW. 21

Mathers, C.D., Vos, E.T., Stevenson, C.E., and Begg, S.J., (2001). The burden of disease and injury in Australia Bulletin of the World Health Organization, **79**, 1076–1084.

Mcmanas, D.P., Zhang, W., Li, J., and Bartley, P.B., (2003). Echinococcosis. *The Lancet*. **362,** 1295-304.

Men, S., Hekimoglu, B., Yucesoy, C., Arda, I., and Baran, I., (1999). Percutaneous treatment of hepatic hydatid cysts: an alternative to surgery. *American Journal of Roentgenology*. **172**, 83-89.

Moro, P.L., Garcia, H.H., Gonzales, A. E., Bonilla, J.J., Verastegui, M., and Gilman, R.H., (2005). Screening for cystic echinococcosis in an endemic region of Peru using portable ultrasonography and the enzyme-linked immunoelectrotransfer blot (EITB) assay. *Parasitology Research* **96**, 242–246

Morris, D. L., Richards, K. S., (1992). Hydatid disease. Current medical and surgical management. *Butterworth-Heinemann Limited*, Oxford, United Kingdom.

Muller, R., (2002). Worms and human diseases, *CABI International*, Wallinggord: Oxon.

Murray C. J. L., and Lopez A. D., (1996a). Evidence-Based Health Policy: Lessons from the Global Burden of Disease Study. *Science*. **274** (5288), 740–43.

Murray, C.J and Acharya, A.K., (1997). Understanding DALYs. *Journal of Health Economics.* **16**, 703–730.

Murray, C.J., (1996). Rethinking DALYs, In: Murray CJ, Lopez AD (ed.). The Global Burden of Disease: a comprehensive assessment of mortality and disability from diseases, injuries and risk factors in 1990 and projected to 2020. Harvard*: Harvard School of Public Health.*

Murray, C.J., Salomon, J., and Mathers, C.D., (2000). A critical examination of summary measures of population health. Bulletin of the *World Health Oganization*, **78**, 427–438.

Murray, C.J.L., (1994) Quantifying the burden of disease: the technical basis for disability-adjusted life years. *World Health Organization*. **72**, 429–445

Murray, C.J.L., and Lopez A.D., (1996). The Global Burden of Disease: A Comprehensive Assessment of Mortality and Disability from Disease, Injuries, and Risk Factors in 1990 and Projected to 2020. *Cambridge, MA: Harvard University Press.*

Murray, C.J.L., and Lopez, A.D., (2004). Assessing health needs: the Global Burden of Disease Study. In: Detels R, McEwen J, Beaglehole R, Tanaka H, editors. Oxford Textbook of Public Health - Fourth edition. *New York: Oxford University Press Inc*. .243-54.

Okelo, G.B.A., (1986). Hydatid disease: research and control in Turkana, III. Albendazole in the treatment of inoperable hydatid disease in Kenya-a report on 12 cases. *Transactions of the Royal Society of Tropical Medicine* & *Hygiene,* **80,** 193-195.

Omer, R.A., Dinkel, A., Romig, T., Mackenstedt. U., Elamin, M., and Elnahas, A., (2004). Strain Characterization of Human Hydatidosis in Sudan. *International Archive of Hydatidosis* **35**, 41.

Parodi, P., Mantovani, A. and Seimenis. A., (2001). Public health education and training in control programmes, p. 219-225. *In* J. Eckert, M. A. Gemmell, F.-X. Meslin, and Z. S. Pawlowski (ed.), WHO/OIE manual on echinococcosis in humans and animals: a public health problem of global concern. World Organisation for Animal Health, Paris: WHO.

Pawlowski, Z. S., (1997). Critical points in the clinical management of cystic echinococcosis: a revised review, p. 119-135. *In* F. L. Andersen, H. Ouhelli, and M. Kachani (ed.), Compendium on cystic echinococcosis in Africa and Middle Eastern Countries with special reference to Morocco. Provo: Brigham Young University Print Services.

Pawlowski, Z. S., Eckert, J., Vuitton, D. A., Ammann, R. W., Kern, P., Craig, P. S., Dar, F. K., … and Wen, H., (2001). Echinococcosis in humans: clinical aspects, diagnosis and treatment, p. 20-66. *In* J. Eckert, M. A. Gemmell, F.-X. Meslin, and Z. S. Pawlowski (ed.), WHO/OIE manual on echinococcosis in humans and animals: a public health problem of global concern. *World Organisation for Animal Health,* Paris: WHO.

Pelaez, V., Kugler, C., Correa, D., Del Carpio, M., Guangiroli, M., Molina, J., Marcos, B., and Lopez, E., (2000). PAIR as percutaneous treatment of hydatid liver cysts. *Acta Tropica*; **75**, 197-202.

Rausch, R. L., (1995). Life cycle patterns and geographic distribution of *Echinococcus* species, p. 88-134. *In* R. C. A. Thompson and A. J. Lymbery (ed.), *Echinococcus* and hydatid disease. *CAB International*, Wallingford: Oxon.

Rogan, M. T., and Craig, P. S., (2002). Immunological approaches for transmission and epidemiological studies in cestode zoonoses—the role of serology in human infection, p. 135-145. *In* P. Craig and Z. Pawlowski (ed.), Cestode zoononoses:

echinococcosis and cysticercosis, an emergent and global problem. Amsterdam: IOS Press.

Rottcher, K.H., (1973). Hydatid cysts in East Africa. *East Africa medical journal*, **50,** 466-68.

Sadjjadi, S.M., (2006). Present situation of echinococcosis in the Middle East and Arabic North Africa. *Parasitology International Supply*. 197-202.

Sariozkan, S. and Yalcin, C., (2009). Estimating the production losses due to cystic echinococcosis in ruminants in Turkey. *Veterinary Parasitology*. **163,** 330–334.

Schaefer, J.W., and Khan, M.Y., (1991). Echinococcosis (hydatid disease): lessons from experience with 59 patients. *Review of Infectious Diseases* **13**, 243–247.

Schantz, P. M., (1997). Sources and uses of surveillance data for cystic echinococcosis, p. 72-84. *In* F. L. Andersen, H. Ouhelli, and M. Kachani (ed.), Compendium on cystic echinococcosis in Africa and Middle Eastern Countries with special reference to Morocco. Provo: Brigham Young University Print Services.

Schantz, P.M., (1982). Echinococcosis. In: Steele JH, Armbulo P (eds). *Handbook of Zoonoses. Volume III. Parasitic Zoonoses.* Pp 213-77. Florida: CRC Press.

Schantz, P.M., (2006). Progress in diagnosis, treatment and elimination of echinococcosis and cysticercosis. *Parasitology International* **55**,–13.

Shambesh, M. K. A., (1997). Human cystic echinococcosis in North Africa (excluding Morocco), p. 223-244. *In* F. L. Andersen, H. Ouhelli, and M. Kachani (ed.), Compendium on cystic echinococcosis in Africa and Middle Eastern Countries with special reference to Morocco. Provo: Brigham Young University Print Services.

Sinan, T., Mehraj, S., Fayaz, A.C., Osama, A.S., Zafar, S., Hira, P.R., and Abdullah B., (2002). Diagnosis of abdominal hydatid cyst disease: the role of ultrasound and ultrasound-guided fine needle aspiration cytology. *Medical Principles and Practice* **11**, 190–195

Sithinamsuwan, P., Piratvisuth, T., Tanomkiat, W., Apakupakul, N., and Tongyoo, S., (2000). Review of 336 patients with hepatocellular carcinoma at Songklanagarind hospital. *World Journal of Gastroenterology* **6**, 339–343.

Soulsby, E.J.L., (1982). Helminths, Arthropods and Protozoa of Domestic Animals, Seventh edition. London: Bailliere Tindall.

Stefaniak, J., (1997). Fine needle aspiration biopsy in the differential diagnosis of the liver cystic echinococcosis. *Acta Tropica*. **67**, 107–111

Stouthard, M.E.A., Essink-Bot, M.L., and Bonsel, G.J., (2000). Disability weights for diseases: a modified protocol and results for a Western European region. *European Journal of Public Health.* **10**, 24–30.

Teggi, A., and Divico, B., (2002). The natural history of human cystic echinococcosis (CE) by imaging methods, p. 125-134. *In* P. Craig and Z. Pawlowski (ed.), Cestode zoononoses: echinococcosis and cysticercosis, an emergent and global problem. Amsterdam: IOS Press.

Thompson, R.C.A., (1995). Biology and systematics of Echinococcosis. In: Thompson RCA, Lymbery AJ (eds). Echinococcus and Hydatid disease. Pp 1-37. *CAB International*, Wallingford: Oxon.

Tiaoying, L., Jiamin, Q., Wen, Y., Craig, P.S., Xingwang, C., and Ning, X., (2005). Echinococcosis in Tibetan populations, Western Sichuan Province, China. *Emerging Infectious Diseases.* **11**, 1866–73.

Todorov, T., and Boeva, V., (1999). Human echinococcosis in Bulgaria: a comparative epidemiological analysis. *Bull World Health Organisation*. **77**, 110-118.

Torgerson, P. R., and Dowling, P. M., (2001). Estimating the economic effects of cystic echinococcosis. Part 2: An endemic region in the United Kingdom, a wealthy, industrialized economy. *Annual Tropical Medical Parasitology*; **95,** 177-85

Torgerson, P. R., Dowling, P. M., and Abo-Shehada, M. N., (2001). Estimating the economic effects of cystic echinococcosis. Part 3: Jordan, a developing country with lower-middle income. *Annual Tropical Medical and Hygiene*. **95,** 595-603.

Torgerson, P.R., (2003). Economic effects of echinococcosis. *Acta Tropica* **85**,113-8

Torgerson, P.R., and Budke, C.M., (2003). Echinicoccosis- an international public health challenge. *Research in Veterinary Science*, **74**, 191-202

Torgerson, P.R., Karae, R.R., Corkeri, N., Abdyjaparo, T.A., Kuttubae, O.T., and Shaikeno, B.S., (2003). Human cystic echinococcosis in Kyrgystan: An epidemiological study. *Acta Tropica*, **85**, 51-61.

Tulchinsky, T.H. and Varavikova, E.A., (2000). Measuring and evaluating the health of a population. In: Tulchinsky TH, Varavikova EA. The New Public Health. An Introduction for the 21st century. San Diego: *Academic Press*.113-68.

Utrilla, J., Eyre, F., Muguerza, R., Alami, H., and Bueno, J., (1991). Hidatidosis en la infancia. *Archives of Hydatidology*; **30,** 721-731.

Vuitton, D.A., Bresson-Hadni, S., Bartholomot, B., Mantion, G., and Miguet, J.P., (1996). The natural history of alveolar echinococcosis before and during the era of benzimidazoles. Uchino J, Sato N, eds. Alveolar Echinococcosis. Strategy for Eradication of Alveolar Echinococcosis of the Liver. *Sapporo: Fuji Shoin*, 243–251.

Wachira, T.M., Bowles, J., Zeyhle, E., and McManus, D.P., (1993). Molecular examination of the sympatric existence and distribution of sheep and camel strains of *Echinococcus granulosus* in Kenya. *American Journal of Tropical Medicine and Hygiene.* **48**, 473–479

Wahlers, K., Menezes, C.N., Wong, M.L., Zeyhle, E., Ahmed, M. E., Ocaido, … and Grobusch M.P., (2012). Cystic echinococcosis in sub-Saharan Africa. *Lancet Infectious Diseases*. **12,** 871–80.

Wang, Y., Hea, T., Wena, X., Lia, T., . Wailia, T.T., Zhanga, W., … and Craig, P.S., (2005). Human cystic echinococcosis in two Mongolian communities in

Hobukesar (China) and Bulgan (Mongolia). *Transactions of the Royal Society of Tropical Medicine and Hygiene* 99, 692–698

Wardle, R., Mcleod, J., and Radinovsky, S., (1974). Advances in Zoology of tapeworms, 1950-1970. London: Oxford university press.

Wilson, J.F., and Rausch, R.L., (1980). Alveolar hydatid disease. A review of clinical features of 33 indigenous cases of Echinococcus multilocularis infection in Alaskan Eskimos. *American Journal of Tropical Medicine and Hygiene.* **29**, 1340–1355.

World Bank report, (2011). World Bank report on drought situation in Kenya. Nairobi: WB.

World Health Organization report, (2004). World Health Organization**.** *Global Burden of Disease*. Geneva: WHO.

World Health Organization report, (2009). World Health Organization. *About the Global Burden of Disease (GBD) project*. Geneva: WHO.

World Health Organization, (2001). Office International des Epizooties. WHO/OIE manual on echinococcosis in humans and animals: a public health problem of global concern. World Organization for Animal Health, Paris: WHO.

World Health Organization, (2001). Informal Working Group of Echinococcosis. Puncture, aspiration, injection, and re-aspiration. An option for the treatment of cystic echinococcosis, p. 1-40. Document WHO/CDS/CSR/APH/2001.6. Geneva: WHO.

Yang, Y.R., Williams, G.M., Craig, P.S., Sun, T., Yang, S.K., Cheng, L., … and McManus, D. P., (2006). Hospital and community surveys reveal the severe public health problem and socio-economic impact of human Echinococcosis in Ningxia Hui Autonomous Region, China. *Tropical Medicine and International Health*. **6,** 880–888.

Yildiz, K. and Gurcan, S., (2003). Prevalence of hydatidosis and fertility of hydatid cysts in sheep in Kirikkale, Turkey. *Acta Veterinaria Hungarica*. **51**, 181–187.

Yilmaz, U., Sahin, B., Hilmioglu, F., Tezel, A., Boyacioglu, S., and Cumhur, T., (1996). Endoscopic treatment of bronchobiliary fistula: report on 11 cases. *Hepatogastroenterology* **43,** 293-300.

Zewdu, E., Teshome, Y., and Wakwoya, A., (2010). Bovine hydatidosis in Ambo Municipality abattoir, West Shoa, Ethiopia. *Ethiopia Veterinary Journal.* **14(1),** 1-14.

Zeyhle, E., and Magambo, J.K., (2007). Common zoonotic diseases affecting pastoral communities. Turkana: AMREF, 1-10.