EVALUATION OF THE RE-EMERGENCE OF *LEPTOSPIROSIS* AND ITS IMPACT ON PUBLIC HEALTH STRATEGIES IN BUNGOMA COUNTY, KENYA

David Wanyonyi Nanyende

A thesis submitted in partial fulfilment of the requirements for the award of degree of Doctor of Philosophy in Disaster Management and Humanitarian Assistance of Masinde Muliro University of Science and Technology

November, 2024

DECLARATION

This thesis is my original work prepared with no other than the indicated sources and support and has not been presented elsewhere for a degree or any other award.

Signed:_____________________________________ Date:______________

David Wanyonyi Nanyende

CDM/H/01/12

CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance of Masinde Muliro University of Science and Technology, a thesis entitled **"Evaluation of the re-emergence of *Leptospirosis* and its impact on public Health strategies in Bungoma County, Kenya".**

Signed:_____________________________________ Date:______________

Prof. Jacob W. Wakhungu,
School of Agriculture and Veterinary Sciences and Technology
Masinde Muliro University of Science and Technology

Signed:_____________________________________ Date:______________

Prof. Donald Siamba
Department of Agriculture and Veterinary Science
Faculty of Sciences
Kibabii University

Signed:_____________________________________ Date:______________

Dr. Ferdinand Nabiswa, (PhD)
Department of Emergency Management Studies.
Masinde Muliro University of Science and Technology

COPYRIGHT

DEDICATION

To our lovely children Consolata N. Keng'ole, Mary-Noel Nasambu and Deusdeitte Wafula who, through their commitment and passion for learning are a source of inspiration.

ACKNOWLEDGEMENT

I thank the Almighty God for the good health and for taking me through the course successfully. I am greatly indebted to my supervisors Prof. Jacob W. Wakhungu, Prof. Donald W. Siamba and Dr. Ferdinand Nabiswa (PhD) for their guidance during the research topic identification, data collection and thesis writing. Their selfless dedication to enhancing the quality of this work is most appreciated.

Special thanks to the research assistants under the leadership of Dr Joseph Ganda who was very instrumental during serum collection. The laboratory testing of samples was done at the Veterinary Research Laboratories-Kabete through the support of Dr. Peter Wekhuyi. The support given by staff at the Veterinary Investigations Laboratory-Eldoret is appreciated.

I appreciate the support accorded to this study by the County Commissioner, County Director of Veterinary Services, County Director of Medical Services, County Director of Meteorological Services and the County Director of Education all from Bungoma County. The support accorded to this study by medical staff at Kimilili, Lugulu, Webuye, Wabukhonyi, and Bungoma health facilities is acknowledged. God bless you all. I also appreciate the support of my family for their patience and moral support. I also acknowledge the support of Agricultural Sector Development Support Programme staff under the leadership of Vincent Wanyonyi Wechabe for logistical support during data collection, analysis and thesis writing.

Finally, I acknowledge the cooperation I received from all farmers and other members of the public who voluntarily provided critical information for this study. I appreciate their sacrifice and provision of sampling animals thereby contributing to the success of this study.

ABSTRACT

Leptospirosis is an important re-emerging but neglected zoonosis with a worldwide distribution and it has socio-economic and public health implications. *Leptospirosis* is caused by the bacteria of the genus *Leptospira.* Humans get infected through direct or indirect contact with the urine of infected animals or the environment. It accounts for more than 300,000 severe cases annually worldwide with case fatality rates of over 30%. Lack of pathognomonic signs of the disease in both livestock and humans coupled with lack of laboratory confirmation makes diagnosis a challenge. The most notable outbreak of *Leptospirosis* in Kenya occurred in Bungoma County in 2004 and is listed as one of the major public health disasters in Kenya. The study was carried out between January and June 2017 with the overall objective being to evaluate the impact of the re-emergence of *Leptospirosis* on Public Health strategies in Bungoma County, Kenya. A cross-sectional design was employed in the study. The four specific objectives of the study were to determine the seroprevalence of *Leptospirosis* in cattle, determine the risk factors for re-emergence of *Leptospirosis,* examine the knowledge, attitude and practices (KAP) associated with *Leptospirosis* amongst the local community and to evaluate the impact of *Leptospirosis* outbreak on public health strategies in Bungoma County. In the study, a total of 400 households were identified using systematic random sampling in Kimilili and Mt Elgon sub-counties, Bungoma County. Two hundred (200) blood serum samples from cattle were collected in the five wards and one slaughterhouse and tested for *Leptospirosis* using Enzyme Linked Immunosorbent Assay (ELISA). The risk factors considered were; rainfall patterns, livestock management practices (grazing and watering system), home slaughter of livestock, consumption of un-inspected meat, rodent infestation in homes, and frequency of contact of livestock keepers with veterinary extension staff. In the third specific objective, a validated questionnaire was administered to the head of household to assess the knowledge, attitude and practices in the study area. In the fourth specific objective, the public health strategies for the management of *Leptospirosis* were evaluated. The study established the *Leptospirosis* seroprevalence in cattle in Kimilili and Mt Elgon sub-counties, Bungoma County is 16%. The seroprevalence of *Leptospirosis* in the study area by wards is as follows; 10.7% in Kibingei, 12.5% in Kimilili, 17.6 in Maeni, 16.7% in Kamukuywa and 15.6% in Kaptama. The study demonstrated that there are circulating antibodies of *Leptospirosis* in cattle in Bungoma County with the highest seroprevalence reported at Kimilili slaughterhouse (21.0%). The study showed that the risk factors for *Leptospirosis* in Kimilili and Mt Elgon include the close association of the community and their livestock, rodent infestation, slaughter of livestock in non-designated areas, low contact of the population with veterinary staff and poor knowledge about *Leptospirosis*. This study identified the knowledge gaps, cultural beliefs and practices that exacerbate disease or pose barriers to *Leptospirosis* control strategies. This information is critical in designing targeted awareness campaigns among the communities and providing baseline information for planning and implementing *Leptospirosis* control strategies in Bungoma County. The findings of this study are important in informing the implementation of appropriate and timely preparedness strategies for addressing public health emergencies such as *Leptospirosis*.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

DEFINITION OF OPERATIONAL TERMS

Attitude: It is a learned predisposition to think, feel and act in a particular way towards a given object. This influences susceptibility, seriousness and threat of *Leptospirosis*.

Awareness: Having any information about *Leptospirosis* outbreak in Chesamisi area.

Belief: Peoples' reported knowledge about *Leptospirosis* which deviates from known biomedical concepts.

Climate change: This represents a lasting alteration in the conventional patterns of space and time concerning climate, such as a transition from one climatic mode to another, which exists beyond the typical spectrum of natural climate variability, irrespective of the underlying cause.

Community: Refers to a group of people living in a particular area and having shared values, cultural patterns, and social problems.

Disaster: This represents a significant disturbance to the operations of a community or society, resulting in extensive human, material, economic, or environmental losses that surpass the capacity of the impacted community or society to manage with its available resources.

Emerging disease: A condition that has manifested in a human or animal population for the first time, or has been previously documented but is now experiencing a rise in incidence or spreading into regions where it has not been observed, typically over the past two decades.

Epidemiology: A field of medicine that examines the patterns and factors influencing health-related conditions, including disease prevalence within populations, and applies this knowledge to the management and prevention of health issues.

Infectious disease: A disease caused by a specific infectious agent or its toxic products that arises through transmission of that agent or its products from an infected person, animal, or reservoir to a susceptible host.

Knowledge: The ability of a person to have the correct understanding of *Leptospirosis* the causative agent, transmission, the risk factors, signs, treatment and prevention.

***Leptospirosis*:** An infectious bacterial disease which affects humans and animals, and occurred as an outbreak in Bungoma County in 2004.

Medical emergency: It is an acute injury or illness that poses an immediate risk to a person's life or long-term health.

Morbidity: The number of sick individuals divided by the total population.

Mortality: The number of dead individuals divided by the total population.

Outbreak: An increase in the number of cases above the number normally occurring in a particular locality over a defined period of time.

Pandemic: Is a disease outbreak of global proportions spreading across a wide geographical area affecting many people beyond national borders and possibly worldwide.

Practice: Routine activities and actions of individuals or groups which can expose them to the risks of *Leptospirosis* and also influence the prevention of the disease.

Public health: The systematic approach to averting illness, extending lifespan, and enhancing human well-being through coordinated initiatives and enlightened decisions made by society, organizations, both public and private entities, communities, and individuals.

Re-emerging disease: A disease whose incidence is increasing as a result of long-term changes in their underlying epidemiology.

Risk factor: Any factor, be it social, economic, climatic or human which has the potential of contributing to disease occurrence and spread. Some examples of risk factors for disease occurrence include underweight, unsafe sex, alcohol consumption, unsafe water, sanitation and hygiene.

Surveillance: The systematic ongoing collection, collation and analysis of data with timely dissemination of information to those who require it in order to take action.

Transmission: The passage of infectious agents from one host to another through various routes which can be direct or indirect.

Zoonosis (plural: zoonoses): An infectious disease which is transmissible between animals and humans.

LIST OF ABBREVIATIONS

CDC	Centre for Disease Control and Prevention
CDLP	County Director of Livestock Production
CDMS	County Director of Meteorological Services
CDVS	County Director of Veterinary Services
CGB	County Government of Bungoma
CRED	Centre for Research on the Epidemiology of Disasters
DVS	Directorate of Veterinary Services.
ELISA	Enzyme-Linked Immuno-Sorbent Assay
GoK	Government of Kenya
GPS	Geographic Positioning System
KAP	Knowledge Attitude and Practice
KIPPRA	Kenya Institute for Public Policy and Analysis.
KNBS	Kenya National Bureau of Statistics
Mand**H**	Medicine and Health
NCCRSK	National Climate Change Response Strategy for Kenya
WOAH	Office Internationale Epizootics (World Organization for Animal Health)
SF-DRR	Sendai Framework for Disaster Risk Reduction
SPSS	Statistical Package for Social Sciences
UNISDR	United Nations International Strategy for Disaster Reduction
VIL	Veterinary Investigations Laboratory
WHO	World Health Organization

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Disasters occur in all parts of the world; Kenya included and range from being highly localized to global phenomena (Huho *et al*., 2016). Global re-emergence of *Leptospirosis* has been associated with environmental and socio-economic factors including high rainfall, flooding, poverty, urbanization, and ecotourism (Munoz and Jarquin, 1995; Ricaldi, 2006; Lau *et al*., 2010). *Leptospirosis* is a disease of increasing global concern and is most prevalent in tropical climates where people and animals live in close contact (WHO, 2007; Allan, 2015). It is considered the most common zoonosis in the world (Plank and Dean, 2000). *Leptospirosis*, also known as Weil disease, icterohaemorrhagic fever, rice-field fever, mud fever, swineherd fever, Stuttgart disease, seven-day fever, rat catcher's fever, black jaundice, cane field fever, swamp fever or dairy farm fever shows a significant increase in incidence following heavy rainfall and flooding (Munoz and Jarquin,1995). It is considered an emerging disease whose incidence is increasing, as a consequence of global climate change (Lau *et al*., 2010).

Leptospirosis is underestimated and underdiagnosed in many countries because of difficult clinical diagnosis and lack of diagnostic laboratory services (Plank and Dean, 2000; Esteves *et al*., 2018). Surveillance therefore provides the basis for any intervention strategies in human and veterinary public health.

Global warming is a worldwide problem which leads to changing climate patterns, which results in prolonged droughts interspersed with flooding which results in increased waterborne diseases and the emergence of diseases such as *Leptospirosis* (Vijayachari *et* *al.*, 2008). *Leptospirosis* is an important but neglected bacterial zoonosis of global concern and is most prevalent in tropical climates (WHO, 2007).

In Africa, *Leptospirosis* is largely overlooked (Allan *et al*, 2015). It causes a wide range of symptoms such as high fever, headache, chills, muscle ache, jaundice, red eyes, abdominal pains, diarrhoea and rashes (Nakeel *et al*., 2016). These symptoms can be mistaken for other flu-like diseases such as malaria, dengue fever, hepatitis, brucellosis, typhoid, streptococcal infections and rheumatism (Esteves *et al*., 2018). In some cases, infected persons may have no clear symptoms at all. The lack of pathognomonic signs of *Leptospirosis* means that diagnosis is tentatively based on the evaluation of fever and myalgia in patients presenting at the hospital (Nanyende, 2010; Esteves *et al*., 2018). The disease is however rarely confirmed in most parts of the world due to a lack of affordable diagnostic assays (Esteves *et al*., 2018). In livestock, the disease has a major impact on reproductive efficiency which is associated with abortion, stillbirth and the birth of weak neonates with a high death rate (Adugna, 2016).

Kenya has experienced a variety of disasters ranging from hydro-meteorological such as droughts, floods, and landslides being common and man-made disasters such as fires, road traffic crashes, human conflicts and terrorism also being recorded and all of them have health ramifications (Government of Kenya [GoK], 2020). Disease outbreaks have been recorded as disasters in Kenya and are in many cases associated with extreme climatic conditions of heavy rainfall (Huho *et al*., 2016).

In Kenya, there have been disease outbreaks which have been recorded as disasters over the years. In 2015, there was an outbreak of cholera in 21 counties resulting in 6,529 cases and 131 deaths (GoK, 2017a). There were more outbreaks of cholera in 2008 and

2007 (GoK, 2017a). Other disease outbreaks recorded as disasters in Kenya were recorded in 2007 involving measles, in 2006 involving meningitis, food poisoning in 2005 and *Leptospirosis* in 2004 among others.

The disease in Kenya has been reported in both livestock and humans since the 1950s (Burdin and Froyd, 1957), 1960s (Forrester *et al*., 1969) and in 2004 (Lamprey and Reid, 2004). There was also a serious outbreak of *Leptospirosis* in humans in Bungoma County in 2004 at Chesamisi and the surrounding areas in Kimilili and Kaptama wards. The outbreak is recorded as one of the disasters in Kenya whereby 859 cases were confirmed and twelve fatalities, six of which were from Chesamisi High School and another two in the nearby Chesamisi Primary School (GoK, 2017a). There was also a confirmed case of cattle in Ziwa, Uasin Gishu in 2007 (DVS, 2007). Previous studies on *Leptospirosis* in Bungoma County have emphasized humans leaving out livestock which are considered to be the source of the infection. Data on the current status of bovine *Leptospirosis* in Bungoma County is scanty and therefore this study attempts to fill the gap.

1.2 Statement of the problem

Hydrometeorological disasters such as floods and droughts are known to occur in a cyclical manner and they are often associated with health risks (GoK, 2020a). In Kenya, the frequency and intensity of floods and droughts are increasing and have adverse effects on health and in the country is often caught unprepared leading to health emergencies. In 2004, there was a *Leptospirosis* outbreak in Kimilili and Mt. Elgon Sub Counties of Bungoma County, Kenya in 2004 and is recorded as one of the disasters in Kenya (GoK, 2017a). The disease caused deaths, especially in learning institutions such as Chesamisi High School and Chesamisi Primary School. Due to the non-specific clinical signs of the disease coupled with lack of laboratory confirmation, it took a protracted period of time to arrive at the diagnosis of the disease thereby resulting in the twelve fatalities during the outbreak (GoK, 2017a). Since then, limited research has been reported on the disease. In this study, *Leptospirosis* is considered as one health risk associated with hydrometeorological hazards and necessary preparedness measures must be set up to avert health emergencies in future.

Since the threat of hydrometeorological hazards remains present and similar health crises can recur, this study considered it necessary to evaluate the prevalence of leptospira in cattle in the region to determine the risk level for people. Furthermore, there was a gap in the research literature in regard to resident knowledge, attitude and practices toward the disease that could guide public health interventions and the application of known prevention and control measures. Therefore, this study sought to fill these gaps to improve preparedness and reduce future adverse health effects due to hydrometeorological hazards.

1.3 Research objectives

The overall objective of the study was to evaluate the impact of the re-emergence of *Leptospirosis* on Public Health strategies in Bungoma County, Kenya.

The specific objectives of the study were to:-

i. Determine the seroprevalence of *Leptospirosis* in cattle in Bungoma County, Kenya.
ii. Determine the risk factors for re-emergence of *Leptospirosis* in Bungoma County, Kenya.

iii. Examine the knowledge, attitude and practices (KAP) associated with *Leptospirosis* amongst the local community of Bungoma County, Kenya.

iv. Evaluate the impact and challenges of *Leptospirosis* outbreak on public health strategies in Bungoma County as perceived by relevant stakeholders.

1.4 Research Questions

To achieve the objectives of this study, the following research questions will be addressed;

i. What is the seroprevalence of *Leptospirosis* in cattle in Bungoma County?

ii. What are the risk factors that contribute towards the re-emergence of *Leptospirosis* in Bungoma County?

iii. What are the traditional knowledge, attitudes and social and cultural practices associated with handling health-related disasters among the local communities in Bungoma County?

iv. What were the impact and challenges posed by the *Leptospirosis* outbreak on public health strategies as perceived by the local community, local development partners, the Ministry of Livestock Development and the Ministry of Health and Sanitation?

1.5 Significance of the study

There was an outbreak of *Leptospirosis* in Bungoma County in 2004. *Leptospirosis*, which affects both humans and animals (both domestic and wild animals) is associated with enormous economic losses (Tilahun *et al*., 2013). In livestock, the losses include loss of calves and lamps through abortion and loss of milk following mastitis. In humans, the disease occurs as outbreaks with substantial loss of productive working time, negative economic impact on tourism and trade and significant political and social disruption (Agampodi *et al*, 2023; Faine, 1994). Because of the difficulties of arriving at a confirmatory diagnosis of the condition in both livestock and humans, it takes a protracted period to manage *Leptospirosis* outbreak. The study documented the bovine seroprevalence of *Leptospirosis* in Kimilili and Mt Elgon Sub-Counties, Bungoma County, Kenya. This is important in understanding the level of risk for the disease in the study area.

This study documented the knowledge, attitude and practices in relation to *Leptospirosis* thus providing a strong baseline for implementing control strategies that take into account the participation of the affected community. This study provided information about behavioural risks in the community which make them susceptible to *Leptospirosis*. This will help in developing targeted awareness campaigns to provide appropriate messages leading to a change in attitude and practices and thus save lives.

Whereas other studies have documented the risk factors for *Leptospirosis* in humans, this study uncovered the risk factors in livestock and thus attempted to unravel the linkage between the disease in humans and livestock. This study also documented strategies that should be adopted to manage emerging public health disasters in an efficient, all-inclusive and participatory manner. This reinforces the need for adopting a ‘one health’ approach where medical practitioners, veterinarians, and environmentalists work jointly while incorporating the local community in addressing public health challenges. This study therefore attempted to reveal the risk for *Leptospirosis* in Kimilili and Mt Elgon Sub-Counties and suggested possible approaches to responding to similar public health disasters.

1.6 Scope of the study

The study focused on the four wards of Kimilili Sub-County (Kimilili, Maeni, Kamukuywa and Kibingei) and Kaptama Ward of Mt. Elgon Sub-County in Bungoma County. The two areas constituted the epicentre of the 2004 *Leptospirosis* outbreak in humans. This study was conducted between 2014 and 2017 to determine the seroprevalence of *Leptospirosis* in cattle using ELISA test in the study area. This study was confined to cattle only despite the fact that the disease affects other livestock species such as sheep, goats, pigs and dogs among others. Cattle were considered in this study because the majority of the households in the study area keep cattle which are the most common source of meat. The other aspects considered in the study were the risk factors of *Leptospirosis* in cattle, the knowledge, attitude and practices of the people in relation to *Leptospirosis*. Also under consideration were public health programmes implemented to control and prevent *Leptospirosis* in Bungoma County.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents an overview of *Leptospirosis* in humans, livestock and wildlife. It emphasizes the causal agent, risk factors, treatment and prevention of *Leptospirosis* infection. The history of *Leptospirosis*, pathogenesis and clinical manifestations are presented before describing diagnostics. The section reviews the epidemiology and transmission of *Leptospirosis*, together with the prevention and control of human and animal *Leptospirosis*. In addition, the chapter presents the occurrence of public health disasters in Kenya with emphasis on the humanitarian aspects of the management of public health disasters and related public health programmes.

2.2 Seroprevalence of *Leptospirosis* in cattle

2.2.1 Epidemiology of *Leptospirosis*

Leptospirosis is a bacterial infection that impacts both domestic animals, including cattle, sheep, goats, pigs, and horses, as well as wild species such as rodents, buffaloes, raccoons, and opossums (Munoz and Jarquin, 1995). This disease is widely recognized as the most prevalent zoonotic illness globally; however, it remains significantly neglected and overlooked in the African context (Tesfaye et al., 2013, Allan et al., 2015). The occurrence of this disease has been documented across all continents, with the notable exception of the polar regions, where it has yet to be reported (Goris, 2016).

The initial documented instances of *Leptospirosis* in humans were characterized as a serious condition featuring jaundice and renal complications, as reported by Landouzy in 1883, Weil in 1886, and Vasiliev in 1888, as referenced by Maleki, Sookhtehzari, and

Abdollahpour (2015). These conditions were clinically distinct from other icteric and nephritic illnesses; however, the underlying cause remained undetermined (Maleki, Sookhtehzari, and Abdollahpour, 2015). The initial occurrence of bovine *Leptospirosis* was documented in the former USSR in 1935 (Amatredjo, 1975). The initial isolation of *L. hardjo* from cattle was conducted by Roth and Galton in America in 1960, followed by Robertson et al. in Canada in 1964, and subsequently by Sullivan and Stallman in Australia in 1969. Subsequently, additional serovars have been identified globally, leading to the classification of all pathogenic leptospires into a single species, *Leptospira interrogans*, which encompasses 223 serovars organized into 23 serogroups (Maleki, Sookhtehzari, and Abdollahpour, 2015).

Figure 2.1 illustrates the worldwide estimated annual incidence of *Leptospirosis* categorized by country. The annual incidence of disease is depicted through an exponential color gradient, transitioning from white (0-3), to yellow (7-10), then orange (20-25), and culminating in red (over 100), measured in cases per 100,000 individuals.

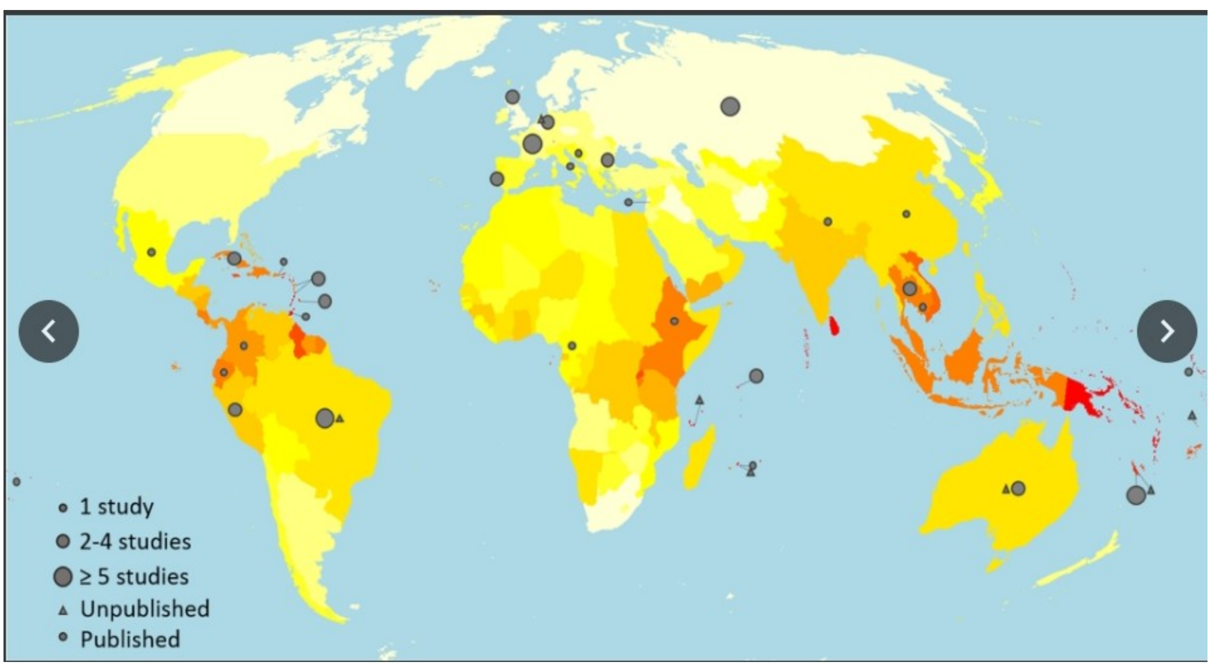


Figure 2.1: Estimated annual morbidity of *Leptospirosis* by country. The annual disease incidence is represented as an exponential colour gradient from white (0-3), yellow (7-10)

` Source: Costa *et al*., (2015)

Costa et al. (2015) demonstrated in their research that the most significant estimates of *Leptospirosis* morbidity and mortality were recorded in regions such as South and Southeast Asia, Oceania, the Caribbean, the Andean region, Central and Tropical Latin America, as well as East Sub-Saharan Africa.

Mammals possess the potential to be infected by any serovar of *Leptospira interrogans* (Goris, 2016). However, only a limited number of serovars are consistently present in any specific region. The most favorable conditions for survival include a warm and humid environment, water that is neutral or slightly alkaline, and the ability to endure cold water (Thiermann, 1984). Water serves as a significant vector for the dissemination of infection, leading to an increased likelihood of new cases during wet seasons and in low-lying regions, where both contamination and susceptibility are elevated (Fajriyah, Udiyono and Saraswati, 2017). Figure 2.1 illustrates the current state of acute human and confirmed animal *Leptospirosis* across the African continent.

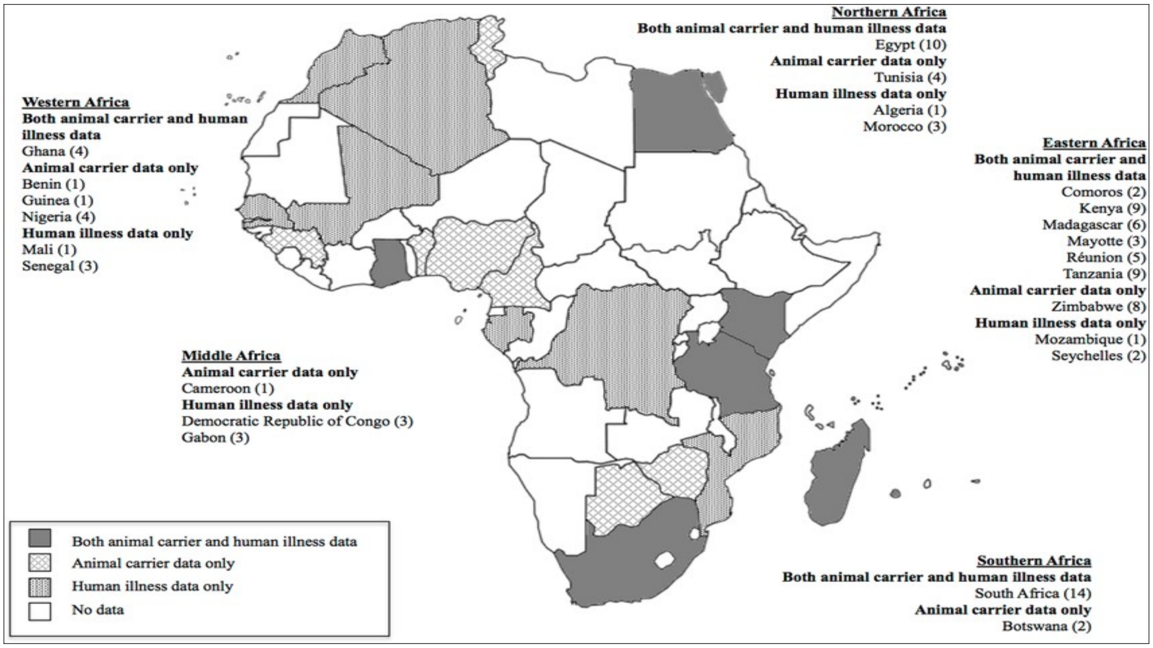


Figure 2.2: The status of acute human infection and confirmed animal *Leptospirosis* in Africa

Source: Allan *et al*., (2015)

Research has shown that while the conventional belief posits *Leptospirosis* as a disease predominantly found in regions with significant rainfall, it is also notably present in semi-arid areas. In these contexts, the incidence of the disease appears to correlate more closely with regional temperature rather than the volume of precipitation (Slack, Symonds, Dohnt, and Smythe, 2006; Miller et al. 1991). The disease is prevalent in Kenya, exhibiting a seroprevalence of 21.8% (54/248) among cattle in Kajiado County (Nakeel et al., 2016). This statistic underscores a significant risk of transmission to humans via direct contact and the consumption of livestock products.

Rodents are regarded as the primary carrier hosts for the majority of *Leptospira serovars;* however, *serovars pomona* and *hardjo* have adapted to agricultural animals as their carrier hosts, which has significant epidemiological implications (Chappel et al., 1989; Fajriyah et al., 2017).

Both domestic and wild animals that come into contact with reservoir rodents or the urine of infected animals may contract the infection, which can subsequently persist as an enzootic disease within the herd or flock (Fajriyah et al., 2017). The transmission rate among mammals, particularly through indirect contact, is significantly influenced by environmental conditions that promote the survival of *leptospires*. The disease tends to be prevalent in regions or during times characterized by warm and humid climates, alkaline soils, and a significant presence of surface water (Faine, 1994; Goris, 2016).

2.2.1.1 Sources of Infection

The primary source of infection arises from the urine of infected animals or healthy carriers, which has the potential to contaminate soil, pasture, drinking water, and feed (Fajriyah, 2017). In instances of leptospiral abortion, the transmission of the infection may occur through the aborted fetus and uterine discharges (Pritchard et al., 1989; Faine, 1994). A foetus that has been infected may retain the infection for a duration of up to 7 weeks post-birth (Giles et al., 1983). The semen of an infected bull has the potential to harbor leptospires, and instances of transmission to heifers through both natural mating and artificial insemination have been documented (Thiermann, 1984). Outbreaks of *L. hardjo* infection within herds have often identified a bull as the originating source of the infection (Ellis et al., 1985). Cattle that are infected have the capacity to excrete leptospires in their urine for a duration extending to 542 days (Thiermann, 1982), whereas cows that experience abortion can excrete *L. hardjo* from the genital tract for a period of up to 8 days following the event of abortion or calving. *L. hardjo* can be identified in the oviducts and uterus for a duration of up to 90 days following experimental infection, as well as in cows that have been naturally infected (Ellis et al., 1985). Ellis et al. (1985) determined that the genital tract was a site of *L. hardjo* localization that was equally significant as the urinary tract. The mammary gland may also serve as a site for persistent infection (Thiermann, 1982). Leptospiral infection has been documented to endure for as long as 142 days within the pregnant bovine uterus and for 96 days in the non-pregnant uterus (Thiermann, 1984). Evidence has shown that sheep serve as a maintenance host for *L. hardjo* (Cousins et al., 1989).

2.2.1.2 Modes of transmission

Leptospiral organisms predominantly infiltrate the body via cutaneous or mucosal abrasions. Oral transmission can take place when animals consume contaminated pasture or feed, or when they drink from or stand in polluted water (Fajriyah et al., 2017). Experimental transmission is achieved via injection and instillation into the nasal cavities, conjunctival sac, and vagina, with oral dosing proving to be less effective. Venereal transmission may additionally contribute to the epidemiology of bovine *Leptospirosis* (Ellis et al., 1985). While transplacental transmission is relatively rare, instances of neonatal infection, likely acquired in utero, have been documented (Ellis et al., 1985). The presence of this organism is frequently observed in the genital tract of bulls, with the transmission of the infection through venereal means believed to take place among cattle (Ellis et al., 1985). Transmission of human cases has occurred through sexual intercourse, breastfeeding, rodent bites, and as a result of laboratory accidents (Ellis et al., 1985). Leptospira spp. are incapable of reproducing outside of their host (World Organisation for Animal Health [WOAH], 2004). They have the capacity to persist for a duration ranging from several weeks to months in contaminated soil, as well as for multiple weeks in cattle slurry (WOAH, 2004). Under laboratory conditions, they can persist in water for several months; however, their survival rate diminishes in river water within natural environments (WOAH, 2004).

2.2.2 Disaster Management and humanitarian interventions to health-related disasters

The predominant individual natural disaster threat in Africa arises from epidemic disasters, constituting 32% of the total cumulative disaster events recorded between 1975 and 2002 (Achoka and Maiyo, 2008).

Epidemics may also arise as a result of various other disasters, including tropical storms, floods, earthquakes, and droughts (Achoka and Maiyo, 2008; Government of Kenya, 2020). Epidemics frequently emerge with alarming speed, leading to significant human and economic repercussions; thus, it is crucial to implement a prompt response (Achoka and Maiyo, 2008).

An epidemic manifests within a susceptible population when a pathogenic agent is present, coupled with conditions that promote extensive transmission, including contaminated water sources, vector populations, and the existence of at-risk human and animal groups (Hui, 2016). An epidemic is deemed an emergency when certain characteristics are evident, though it is not necessary for all to be present.

i. There exists a significant likelihood of the disease being introduced and disseminated within the population;

ii. A considerable incidence of cases is anticipated;

iii. The disease possesses a level of severity that may result in substantial disability or mortality;

iv. The presence of the disease poses a threat of social or economic upheaval;

v. Authorities are ill-equipped to manage the situation effectively due to a lack of adequate technical or professional personnel, organizational expertise, and essential supplies or equipment (WHO, 2015).

The categorization of "emergency" differs from country to country, depending on two local factors: whether the disease is endemic and means of transmitting the agent exists. Figure 2.2 shows the emergency management cycle for epidemics (WHO, 2009).

Emergencies are described in the form of a life cycle which has interrelated phases, namely Preparedness, Prevention, Response, Recovery and Mitigation (WHO, 2015). Figure 2.2 illustrates the fact that the phases of emergency management are circular and interrelated. Prior to undertaking an effective response towards an epidemic, all efforts should be directed towards early and accurate detection of disease and stop it from spreading. This is achieved through a risk-based surveillance system accompanied by a systematic and rigorous laboratory diagnosis (WHO, 2015). Any delay between an incursion and its detection is one of the most important factors in determining the severity of an outbreak and therefore determines the level of humanitarian interventions initiated. Emerging and re-emerging diseases include new ones for which there is scanty scientific knowledge if any (Zumla *et al*, 2015). This therefore presents a challenge at the detection stage. When therefore early detection cannot be done at the country level, the affected countries should seek the support of more sophisticated regional and global laboratories (De Souza *et al*., 2014).

Figure 2.3: Disaster Management Cycle

Source: WHO (2015)

The activities undertaken during the different stages of disaster management are presented in Table 2.1. The overall goal of the activities is to realize early detection of the disease and immediate implementation of response measures WHO (2015). Successful implementation of disaster management activities during the disaster management cycle depends on having a highly coordinated process amongst all the stakeholders with strong community engagement (Hui, 2016).

Table 2.1: Disaster Cycle Management Activities

Stage of Disaster Cycle	**Activities**
Preparedness	• Recognize the various stakeholders and resources present within the community, engage in the formulation of local plans, and implement practical exercises for functional application. •
Prevention	• Awareness and education, vaccination campaigns and biosecurity measures

	• Undertake risk-based surveillance and a robust laboratory diagnosis for early detection. Training of health service providers on recognition of important syndromes
Response	• After detection, activities are geared towards eliminating the infection quickly and stopping further spread. This is achieved through quarantine, isolation, stop movements, biosecurity, safe disposal, vaccination, cleaning and disinfection.
Recovery	• The affected community is supported to resume their normal livelihood activities after verifying that the disease has been eliminated.

Source: WHO, (2015)

In Kenya, the Early Warning System is well developed and the likelihood of occurrence of floods and droughts with possible adverse effects on health, however, the country is often caught unprepared leading to health emergencies (GoK, 2020a). There is a critical need for relooking at the health risks and coming up with comprehensive emergency health management systems which cover all stages of the Disaster Risk Management cycle.

2.3 Risk factors for re-emergence of *Leptospirosis*

Occupational exposure: Farmers (crop, dairy and pig), slaughterhouse workers, ranchers, trappers, veterinarians, loggers, sewer workers, rice field workers, military personnel, pet shop owners, field agricultural workers, plumbers, fishermen and milkers are reported to be at a higher risk of contracting the *Leptospirosis* (Hayes and Hayes, 2015; Tilahun *et al*., 2013). Farming is associated with higher exposure to contaminated soils and water especially in crops such as paddy, sugarcane, and bananas among others which require substantial water irrigation (Saha *et al*., 2023).

Recreational activities: Humans acquire the infection when they come into contact with water contaminated with urine from an infected animal. Recreational activities such as freshwater swimming, canoeing, fishing, and travelling to tropical areas have the potential to introduce an infection (Tilahun *et al*., 2013).

Household exposure: This has been observed among those handling pet dogs, domesticated livestock, households using rainwater catchment systems and households with infected rodents (Tilahun *et al.*, 2013). Exposure to wastewater and garbage is a risk, especially for the slum dwellers who occupy the urban and peri-urban settings of developing countries (Rono, 2021).

The number of *Leptospirosis* cases has been observed to increase after rainfall-related flooding. During flooding, there is contamination of surface water with animal urine putting a large population living especially in the low-lying areas, at a higher risk of susceptibility (Nguyen, Pu and Watanabe, 2019). The risk factors for *Leptospirosis* can be summarised in Figure 2.3.

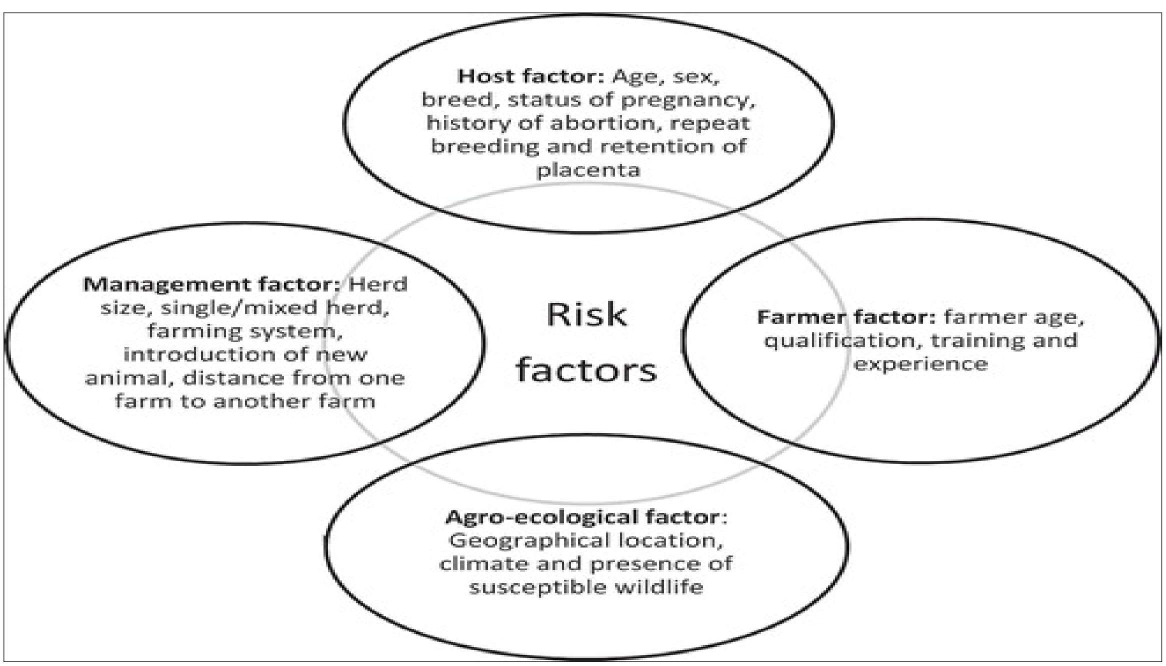


Figure 2.4: Risk Factors for *Leptospirosis* summarised

Source: Deka *et al*., (2018)

2.3.1 *Leptospirosis* in Animals

All mammals are susceptible to at least one species of *Leptospira*. The disease is rare in cats, and less common in sheep than cattle (Mgode *et al.*, 2014). The different serovars are associated with disease in different animal species as indicated in Table 2.2.

Table 2.2: Serovars associated with different animal species

S/No	Animal Species	Leptospira SEROVARS
1.	Cattle	hardjo, grippotyphosa, canicola, icterohaemorrhagiae.
2.	Sheep and goats	hardjo, Pomona, grippotyphosa and ballum.
3.	Pigs	pomona, grippotyphosa, Bratislava, canicola, icterohaemorrhagiae, tarassovi and muenchen.
4.	Horses	hardjo, Pomona, canicola, icterohaemorrhagiiae and sejroe.
5.	Dogs	pomona, grippotyphosa, canicola, icterohaemorrhagiae, pyrogenes, paidjan, tarassovi, ballum and bratislava.

Source: WOAH, (2014)

The principal reservoirs for the majority of *Leptospira serovars* are wild mammals, especially rodents (WOAH, 2014). Among domestic animals, the reservoir hosts comprise cattle, pigs, sheep, and dogs. The particular reservoirs present are contingent upon the serovar and the geographic locale (Fajriyah, 2017). Mgode et al. (2014) have demonstrated that bats may serve as potential reservoirs and transmitters of *Leptospira serovar Sokoine*. In reservoir hosts, the manifestation of disease tends to be asymptomatic, mild, or chronic in nature (Goris, 2016).

The duration of the incubation period in canines ranges from 4 to 12 days. In cattle, abortions typically transpire between 3 to 10 weeks following infection, whereas in pigs, this occurs approximately 15 to 30 days post-infection (Goris, 2016). Infections caused by *Leptospira* can present in a spectrum of manifestations, ranging from asymptomatic and mild cases to more severe forms, and may be classified as either acute or chronic in nature. The clinical manifestations frequently correlate with renal pathology, hepatic disorders, or reproductive anomalies. Animals with chronic infections frequently exhibit no symptoms (Goris, 2016).

2.3.1.1 Cattle

Acute *Leptospirosis* predominantly manifests in calves. The manifestations may encompass fever, anorexia, conjunctivitis, and diarrhoea. Animals that are significantly impacted may exhibit symptoms such as jaundice, haemoglobinuria, anaemia, pneumonia, or indications of meningitis, which include incoordination, salivation, and muscle rigidity (WOAH, 2014). Certain calves may succumb within a span of 3 to 5 days, while those that survive may exhibit unthrifty conditions post-recovery.

The clinical manifestations differ according to the serovar; for instance, infections caused by *serovar hardjo* typically do not correlate with haemolytic anaemia (Goris, 2016). In mature cattle, initial manifestations like fever and lethargy tend to be ephemeral and less severe. The most notable indicators of infection include miscarriages, reduced fertility, or diminished milk production. Certain serovars are associated with late-term abortions, stillbirths, and a heightened risk of neonatal mortality. In cases of abortion, the placenta may be retained in as many as 20% of cows, potentially leading to subsequent infertility (Fajriyah, 2017). Certain serovars may lead to abrupt agalactia or a reduction in milk yield. The milk may exhibit a thick, yellow appearance with blood-tinged hues; however, there is generally scant evidence of mammary inflammation (WOAH, 2014). The visual quality of the milk typically enhances within a span of 4 to 5 days, while the restoration of milk production to its baseline levels generally occurs after a period of 10 to 21 days. Jaundice can manifest in animals that are significantly impacted (WOAH, 2014).

2.3.1.2 Sheep and goats

The manifestation of *Leptospirosis* in ovine and caprine species bears resemblance to its presentation in bovine populations. This condition is marked by the presence of fever, loss of appetite, and, in certain animals, symptoms such as jaundice, *hemoglobinuria*, or anemia. Instances of abortions, stillbirths, underdeveloped lambs or kids, and infertility may manifest, accompanied or unaccompanied by additional clinical indicators. Clinical disease occurs infrequently in sheep (WOAH, 2014).

2.3.1.3 Swine

In swine, clinical *Leptospirosis* is predominantly marked by reproductive manifestations such as late-term abortions, infertility, stillbirths, mummified or macerated fetuses, and heightened neonatal mortality. Additionally, fever, diminished milk production, and jaundice may also be observed. In certain infected herds, the sole indication of infection might manifest as a temporary elevation in body temperature. Subclinical infections are prevalent (Bolin and Cassells, 1992).

In piglets, one may observe symptoms such as fever, anorexia, depression, diarrhoea, jaundice, haemoglobinuria, and gastrointestinal disorders, alongside indications of meningitis. Piglets that are affected may exhibit slower growth rates compared to their healthy counterparts, and elevated mortality rates can be observed particularly among the younger or weaker individuals.

2.3.1.4 Horses

A considerable number of infections in equines remain subclinical. Ocular disease represents the most prevalent syndrome. In the acute phase, one may observe ocular manifestations such as fever, photophobia, conjunctivitis, miosis, and iritis. Corneal opacity and periodic ophthalmia can emerge as consequences of acute infections. During the chronic phase, one may observe anterior and posterior adhesions of the eye, a turbid vitreous body, cataracts, uveitis, and various other ocular abnormalities (Murray et al., 2013). While systemic disease is rare, there have been documented instances of severe *Leptospirosis* associated with liver, kidney, or cardiovascular complications. Recent studies indicate a correlation between *Leptospirosis* and several instances of abortion (Jung et al., 2010).

2.3.1.5 Dogs

The manifestations and intensity of the disease exhibit considerable variability in canines. Certain infections may present without symptoms or exhibit mild manifestations, whereas others can be severe or even result in fatal outcomes (Prescott et al., 2002). The early manifestations are often vague and can encompass fever, depression, loss of appetite, rigidity, muscle pain, chills, and general weakness. The mucous membranes frequently exhibit signs of injection. The manifestation of these symptoms may subsequently be accompanied by indicators of renal pathology, such as anuria, haematuria, or heightened urinary frequency, alongside vomiting, dehydration, and oral ulceration (Klaasen et al., 2003). Abortions, diarrhoea, grey stools, coughing, dyspnoea, conjunctivitis, weight loss, and jaundice may also be observed (Prescott, 2002).

Haemorrhagic syndromes manifest in certain canine populations: the mucous membranes may exhibit extensive petechial and ecchymotic haemorrhages, and in the advanced stages of the condition, one may observe haemorrhagic gastro-enteritis and epistaxis. Certain dogs may experience sudden mortality without any preceding clinical manifestations. Chronic kidney disease may manifest as a consequence (Haake et al., 2002).

Chronic infections can present without symptoms, or may be linked to fever of unknown origin and conjunctivitis (Klaasen et al., 2003). Certain serovars exhibit a higher propensity to induce specific syndromes. Fever, haemorrhage, anaemia, and jaundice are commonly linked to the *serovar icterohaemorrhagiae* (Andre-Fontaine et al., 2003). *Serovar grippotyphosa* is known to induce significant acute kidney failure and/or chronic active hepatitis. Dogs infected with *serovar pomona* frequently exhibit no symptoms and can become chronic carriers. *Serovar canicola* frequently leads to chronic interstitial nephritis (Andre-Fontaine et al., 2003).

2.3.1.6 Wild animals

Leptospirosis serovars have been isolated from various wild animals, including hedgehogs, hamsters, moles, bats, squirrels, hares, raccoons, deer, rabbits, and certain marine mammals (Shearer et al., 2014). Infections in wild animals, including rodents, frequently present without symptoms. Wildlife serve as reservoir hosts for *leptospires* and frequently do not display clinical manifestations of the disease (Levett, 2001). It is posited that wild animals serve as reservoir hosts for leptospires, thereby acting as a source of infection for both humans and domestic animals (Tan et al., 2014).

2.3.1.7 Communicability

Leptospira spp. are excreted in the urine of animals experiencing acute infection (Shearer et al., 2014). Individuals who are chronic carriers may continue to excrete them for extended periods, potentially spanning months or even years. Furthermore, organisms may be identified in aborted or stillborn fetuses, as well as in healthy fetuses or vaginal discharges following calving (Levett, 2001).

2.3.1.8 Diagnosis

Leptospirosis is identified through methods such as culture, antigen or nucleic acid detection, or serological analysis (Bakhshandeh et al, 2021). The distribution of the organisms is contingent upon the manifestation of the disease. In cases of acute infections, *Leptospira* can be detected in various bodily fluids, including blood, milk, and cerebrospinal, thoracic, or peritoneal fluids (Haake and Levett, 2015). In the context of chronic infections, their presence in the urine has been documented (Levett, 2003). In acute cases, the liver, lung, brain, and kidney are gathered during necropsy, while in chronic cases, the kidney and genital tract undergo examination (Bakhshandeh et al, 2021). Organisms may also be present in the bodily fluids or tissues of aborted fetuses (Levett, 2001).

Leptospira species exhibit the capacity to be cultured on diverse media; however, they are notably fastidious and demonstrate slow growth during primary isolation (Raja and Natarajaseenivasan, 2015). Depending on the specific serovar, the culture process may extend over a duration of 13 to 26 weeks. The determination of species, serogroup, and serovar levels is conducted by reference laboratories employing genetic and immunological methodologies (Esteves et al., 2018). *Leptospira* may also be detected in clinical samples through the application of immunofluorescence and immunohistochemical staining, in addition to the utilization of DNA probes and polymerase chain reaction (PCR) methodologies. Darkfield microscopy is employed as well, though it lacks specificity. These organisms exhibit a lack of affinity for the Gram stain. Techniques for antigen detection, such as ELISAs and radioimmunoassay, are employed as well (Esteves et al., 2018). Serology serves as a method for diagnosis as well. While paired acute and convalescent samples are generally favored from the majority of animals, a solitary positive sample obtained from an aborted fetus serves as a definitive diagnostic indicator. Herd assessments are frequently employed in ruminant populations. The prevalent serological assessments include the microscopic agglutination test (MAT) and enzyme-linked immunosorbent assays (ELISAs) (Raja and Natarajaseenivasan, 2015). In the realm of veterinary medicine, serovar-specific ELISAs are accessible, and the occurrence of cross-reactions in animals is notably less frequent compared to humans.

Additional serologic assessments encompass radioimmunoassay, the microcapsule agglutination test, immunofluorescence, counter-immune electrophoresis, and thin-layer immunoassay. An ELISA for milk is capable of identifying antibodies in samples obtained from individual cows or in bulk milk (Radostits et al., 2000).

2.3.1.9 Treatment

Leptospirosis is managed through the administration of antibiotics, including tetracyclines, penicillin/ampicillin, dihydrostreptomycin, streptomycin, and fluoroquinolones (Sessions, 2004). The effectiveness of the treatment may be contingent upon the specific serovar involved. Fluid therapy, blood transfusions, and additional supportive care may also be requisite (Andre-Fontane et al., 2003).

2.3.1.10 Prevention

Vaccines for *Leptospirosis* are accessible for swine, bovines, and canines (Andre-Fontane et al., 2003). While vaccines are effective in preventing disease, they do not entirely eliminate the possibility of infection or the transmission of the organisms (Haake et al., 2002).

Immunity exhibits a significant degree of serovar specificity, which implies that vaccines provide protection solely against the serovars included in their formulation or those that are closely related. The administration of antibiotics as a preventive measure for exposed animals can effectively avert the onset of disease. The implementation of sanitation measures and the avoidance of interactions with contaminated environments or infected wildlife, especially rodents, can significantly reduce the likelihood of infection. It is imperative that animals are prohibited from accessing or consuming water from polluted sources. Effective sanitation practices can significantly diminish the likelihood of infection in kennels, as well as in regions designated for the breeding or birthing of livestock (Andre-Fontane et al., 2003).

In cattle, infections are typically introduced via an infected animal, through environmental factors, or through contact with infected sheep or pigs (Radostits et al., 2000). Replacement stock ought to be chosen from herds that are negative for *Leptospirosis*. Animals that are not confirmed to be free of *Leptospira* should undergo a quarantine period of four weeks and be subjected to testing prior to their integration into the herd (Radostits et al., 2000). Additional control measures encompass vaccination, the isolation and treatment of infected animals, management of rodent populations, minimizing contact with wildlife, sheep, and pigs, as well as restricting access to contaminated water sources (Jaykaran et al., 2013). The implementation of vaccination protocols and the strategic management practices, such as the segregation of younger cattle from their older counterparts, can lead to the gradual eradication of *Leptospirosis* within a herd over time. The successful eradication has been achieved in closed herds through a rigorous regimen of vaccination and testing conducted over a span of five years. Comparable strategies may assist in the prevention or management of *Leptospirosis* in porcine and ovine populations (Pappas et al., 2008).

2.3.2 *Leptospirosis* in Humans

The typical incubation period in humans spans from 7 to 12 days, although it can vary between 2 and 29 days (Jaykaran et al., 2013). Human infections can range from asymptomatic cases to those of a severe nature (Pappas et al., 2008). A considerable number of instances present with mild manifestations or remain asymptomatic, often eluding detection. Certain serovars exhibit a notable correlation with specific syndromes; for instance, serovar *icterohaemorrhagiae* is frequently linked to severe disease (Levett, 2001). Nonetheless, any serovar has the potential to induce any syndrome (WOAH, 2004).

In humans, *Leptospirosis* typically presents as a biphasic illness. The initial phase, referred to as the acute or septicaemic phase, typically commences suddenly and endures for about a week. This stage is marked by a range of nonspecific symptoms such as fever, chills, headache, and conjunctival suffusion. Myalgia, commonly impacting the back, thighs, or calves, frequently presents with significant severity (ILS, 2003).

At times, one may observe the emergence of a fleeting skin rash. Additional manifestations may encompass weakness, sensitivity to light, lymph node enlargement, abdominal discomfort, nausea, emesis, pharyngitis, cough, thoracic pain, and the expectoration of blood. During this phase, manifestations such as mental confusion, neck stiffness, and additional indicators of aseptic meningitis have been documented. Jaundice may manifest in cases of more severe infections. The duration of these symptoms ranges from approximately 4 to 9 days, subsequently giving way to a 1 to 3-day interval characterized by a decrease in temperature and the cessation of symptoms (WOAH, 2004).

The subsequent phase of *Leptospirosis*, referred to as the immune phase, is marked by the formation of anti-Leptospira antibodies and the elimination of the organisms through urine (WOAH, 2004). This phase may extend for a duration of 30 days or longer; however, it does not manifest in every patient. In the immune phase, the patient experiences a recurrence of illness (WOAH, 2004).

The initial stage presents with nonspecific symptoms, including fever and myalgia, which may reappear, albeit potentially with reduced severity compared to the first stage of the disease (WOAH, 2004). Two distinct manifestations of disease, namely icteric and anicteric, are observed (WOAH, 2004). The majority of infections manifest in the anicteric form (Pappas et al., 2008). The primary symptoms observed in this particular manifestation are linked to aseptic meningitis (Pappas et al., 2008). A significant headache, accompanied by a rigid neck and additional meningeal manifestations, presents in roughly fifty percent of patients and typically endures for several days. At times, these indicators may persist for a duration of up to two weeks. Among the less frequently observed manifestations are cranial nerve palsies, encephalitis, confusion, and alterations in consciousness (Levett, 2001). In the conventional anicteric presentation, fatalities are uncommon; nonetheless, a recently documented syndrome characterized by lethal pulmonary hemorrhage, absent of jaundice, has emerged (Anand and Garg, 2015). The icteric form presents with greater severity. This phenomenon manifests in 5-10% of the patient population, frequently exhibiting a rapid progression, and may correlate with multi-organ failure.

The organ systems most frequently implicated are the liver, kidneys, and central nervous system (CNS). In the icteric form, a period of improvement may be absent between the septicaemic and immune phases (Pappas et al., 2008).

Jaundice can manifest in a pronounced manner, imparting an orange hue to the skin; however, it is typically not correlated with significant hepatic necrosis (WOAH, 2004). Acute renal failure manifests in 16-40% of instances (WOAH, 2004). Certain patients exhibit pulmonary manifestations, with clinical indicators that may include cough, dyspnoea, chest pain, and varying degrees of haemoptysis, extending to adult respiratory distress syndrome (WOAH, 2004). Cardiac involvement may lead to congestive heart failure, myocarditis, and pericarditis (WOAH, 2004). Haemorrhages can manifest in various forms; *epistaxis*, *petechiae*, *purpura*, and *ecchymoses* are among the most prevalent indicators. However, one must also consider the potential for more severe occurrences, such as gastrointestinal bleeding, adrenal or subarachnoid haemorrhage, and pulmonary haemorrhages (Pappas et al., 2008). Uncommon complications encompass stroke, rhabdomyolysis, thrombotic thrombocytopenic purpura, acute acalculous cholecystitis, erythema nodosum, aortic stenosis, Kawasaki syndrome, reactive arthritis, epididymitis, nerve palsy, male hypogonadism, Guillain-Barre syndrome, and cerebral arteritis (Anand and Garg, 2015). Mortality may arise from renal failure, cardiac complications, pulmonary hemorrhage, or other significant organ dysfunction (Anand and Garg, 2015).

The recovery period from the icteric form may extend over a duration of 1 to 2 months (Anand and Garg, 2015). While jaundice may endure for several weeks, liver function typically normalizes following recovery, and hepatic disease seldom serves as the primary cause of mortality. A significant number of patients likewise regain kidney function (Anand and Garg, 2015). In 2-10% of instances, anterior uveitis may manifest as much as a year following recovery. A significant proportion of these patients achieve complete restoration of their vision. *Iridocyclitis* and *chorioretinitis* may arise as complications and can endure for extended periods (Pappas et al., 2008).

Instances of abortions, fetal demise, and infrequent congenital infections in neonates have been documented (Anand and Garg, 2015). Abortions may take place at any point, even during the recovery phase (Anand and Garg, 2015). The occurrence of infection exhibits a seasonal pattern, predominantly manifesting during the summer and autumn months in temperate areas (Fisman, 2012). In tropical regions, the highest occurrence is observed during the rainy season. Significant outbreaks have been observed following flood events (Pappas et al., 2008). It is believed that occupational exposure accounts for 30-50% of cases (Pappas et al., 2008). Occupations characterized by a significant risk of infection encompass sewer workers, coal miners, plumbers, agricultural laborers, veterinarians, pet shop proprietors, abattoir employees, meat handlers, slaughterhouse personnel, individuals in the fishing sector, and members of the military (Pappas et al., 2008). Between 8% and 29% of individuals engaged in livestock work possess antibodies to Leptospira (Balamurugan et al., 2017).

Engaging in recreational pursuits that elevate the likelihood of contracting *Leptospirosis* encompasses activities such as gardening and various water sports, including canoeing, swimming, and white-water rafting (Pappas et al., 2008). Individuals residing in certain metropolitan regions encounter exposure through the urine of rats (Prescott, 2002).

2.3.2.1 Communicability

While direct transmission between individuals is infrequent, it remains a possibility. *Leptospira* organisms are present in the urine during the second phase of the disease, known as the immune phase (Evangelista and Coburn, 2010). The majority of individuals expel these bacteria within a span of 60 days or fewer; however, instances of prolonged shedding extending over months or even years have been recorded. Alternative pathways of transmission may also exist: one instance involved an infant contracting the infection through breastfeeding, while another case documented transmission occurring during sexual intercourse (Higgins and Green, 2008).

2.3.2.2 Diagnosis

The differential diagnoses for *Leptospirosis* encompass dengue fever, meningitis, influenza, pneumonia, typhoid, and malaria (Lau C.L et al, 2010). Diagnostic challenges have been demonstrated, highlighting the necessity for enhanced laboratory capacity (Lau C.L et al, 2010). *Leptospirosis* may be identified through various methods, including culture, antigen or nucleic acid detection, or serological analysis (Pappas et al., 2008). *Leptospira* can be extracted from human specimens such as blood, cerebrospinal fluid, or urine (Pappas et al., 2008). The process of cultural adaptation can be complex and may necessitate a timeframe of approximately 13 to 26 weeks. The determination of species, serogroup, and serovar levels is conducted by reference laboratories employing genetic and immunological methodologies (Pappas et al., 2008). *Leptospira spp*. may be discerned in clinical samples through the application of immunofluorescence and immunohistochemical staining, in addition to the utilization of DNA probes and polymerase chain reaction (PCR) methodologies. Darkfield microscopy is applicable; however, it lacks specificity (Pappas et al., 2008).

The majority of human cases of *Leptospirosis* are identified through serological methods. The predominant serologic assays employed include the microscopic agglutination test (MAT) and enzyme-linked immunosorbent assays (ELISAs). The MAT test is characterized by its focus on serogroups rather than serovars, and it may present complexities due to potential cross-reactions. The ELISA method for detecting *immunoglobulin M antibodie*s, as outlined by *Serion Immunodiagnostica* GmbH in Wurzburg, Germany, demonstrates a sensitivity of 96%, specificity of 97%, a positive predictive value of 90%, and a negative predictive value of 99% (Chandhry et al., 2002). The assessment of IgM antibodies targeting *Leptospira* organisms through ELISA has developed into a dependable diagnostic method, demonstrating commendable specificity and sensitivity (Winslow et al., 1997). Tests that are utilized less frequently encompass complement fixation (CFT), radioimmunoassay, immuno-fluorescence, and thin layer immunoassay.

A high titer accompanied by consistent symptoms indicates an acute case; however, a rising titer is essential for a conclusive diagnosis. There exists a limited number of serovar-specific assays within the realm of human medicine (Winslow et al., 1997).

2.3.2.3 ELISA Test: Principles of the technique

This is a serological assay frequently employed in diverse formats, contingent upon the specific antigen and the reagents utilized throughout the testing process (Postic et al., 2000). The assay is designed solely to identify genus-specific antibodies and is not appropriate for the identification of serogroups or serovars (Esteves et al., 2018). The test sera antibodies are introduced to an antigen that is immobilized on a solid substrate, specifically a microtitre plate. Subsequent to an incubation phase and multiple washes aimed at removing surplus antibody, an enzyme-conjugated anti-species antibody, corresponding to the test serum, is introduced. The determination of enzyme activity is subsequently achieved through the addition of a particular chromogenic substrate.

The intensity of the color reaction, which correlates with the quantity of degraded substrate, is directly proportional to the amount of antibody present in the test serum, adhering to a specific concentration range as dictated by the Beer-Lambert laws (Esteves et al., 2018).

2.3.2.4 Treatment in humans

Antibiotics are employed in the treatment of severe *Leptospirosis* (Jaykaran et al., 2013). The application of antibiotics for the mild variant of the disease remains a subject of debate, with existing research yielding inconclusive results (Evangelista and Cobum, 2010). The antibiotics utilized in human medicine encompass doxycycline, ampicillin, amoxicillin, penicillin, and erythromycin. It may also be essential to provide supportive treatment and manage complications, including renal failure, hepatic issues, hemorrhages, and central nervous system diseases (Jaykaran et al., 2013).

2.3.2.5 Prevention and control

Various measures can be implemented to mitigate the risk of contracting *Leptospirosis* (Radostits et al., 2000). This involves engaging the expertise of a veterinarian to administer vaccinations to your pets, thereby safeguarding them against this disease (Radostits et al., 2000). The management of infections in livestock and companion animals mitigates the potential for human disease; however, the presence of wildlife reservoirs introduces complexities to prevention efforts (Radostits et al., 2000). Furthermore, it is imperative to refrain from contact with animal urine or bodily fluids, particularly in the presence of any cuts or abrasions on the skin (Radostits et al., 2000). Minimizing exposure to animal urine, bodily fluids, and water bodies that may be contaminated can significantly reduce the likelihood of infection (Radostits et al., 2000). It is imperative that domestic animals refrain from urinating in water sources that are utilized by humans. Alleviating the saturation of wet areas may likewise reduce the prevalence of disease (Radostits et al., 2000). It is imperative that food be safeguarded against potential sources of infection. It is advisable to refrain from swimming, walking in, or ingesting water that could potentially be contaminated with animal urine (Radostits et al., 2000).

Maintaining personal hygiene and utilizing protective clothing are essential strategies for prevention in occupations characterized by high risk. Utilizing gloves and face shields serves as a crucial measure in mitigating the risk of infections during interactions with infected animals or tissues. Rubber boots serve to mitigate the risk of infection among sewer and agricultural workers who may find themselves wading through water contaminated with urine (Radostits et al., 2000). The management of rodent populations is crucial in mitigating the risk of human infections, especially within urban environments (Levett, 2001).

Table 2.3: ***Leptospirosis*** **in Kenya: Humans**

S/No	Year	Where	Remarks	Reference
1.	April, 2004	Bungoma County	Occurred in Chesamisi area affecting students	Draft National Disaster Policy (2017)
2.	June, 2004	Trans Nzoia	An outbreak on an Agricultural Development Corporation (ADC) Farm	County Director of Veterinary Services, Trans Nzoia County, Reports (2004)

Source: Researcher, (2017)

Table 2.4: ***Leptospirosis*** **in Kenya: Animals**

S/No	Year	Species	Where	Remarks	Reference
1.	1948	Dog	No record	None	D' zousa, (1983)
2.	1956	Sheep, cattle and goats	Nanyuki	None	D' zousa, (1983)
3.	1957-1968	Cattle	Various parts of the country	None	D' zousa, (1983)
4.	1976-1982	Cattle	Several outbreaks	Involved hundreds of cattle in various parts of the	D' zousa, (1983)

			occur yearly	country including Nakuru, Baringo, Nyandarua, Laikipia and Kiambu	
5.	Nov 2007	Cattle	Ziwa, Uasin Gishu	-	VIL Report, (2007)

Source: Researcher, (2017)

2.4 Knowledge, attitude and practices (KAP) associated with *Leptospirosis* amongst the local community

2.4.1 Livestock and Human Health Concerns in Bungoma County

The specifics regarding the primary factors contributing to morbidity and mortality in cattle within Bungoma County are presented in Table 2.5. Several diseases contribute to mortality in cattle within the country, including East Coast fever, *Anaplasmosis*, and Heartwater. Additionally, Foot and Mouth Disease, along with various tick-borne illnesses, represent significant health challenges for affected cattle. The subsequent information elucidates the diverse health risks impacting the livestock within the region and underscores the necessity for implementing solutions aimed at reducing mortality and morbidity rates.

Table 2.5: Major causes of morbidity and mortality in cattle in Bungoma County

Cause of death in cattle in Bungoma County	Cause of morbidity in livestock in Bungoma County
1. East Coast Fever	1. Foot and Mouth Disease
2. Anaplasmosis	2. East Coast Fever
3. Heartwater	3. Other tickborne diseases (Anaplasmosis, heart-water, Red-Water)
4. Redwater	4. Pneumonia
5. Blackquarter	5. Helminthosis
6. Pneumonia	6. Ectoparasites
7. Calf scours	7. Blackquarter
8. Helminthosis	8. Lumpy Skin Disease

9.	Lumpy Skin Disease	9.	Mastitis
10.	Hardware disease	10.	Abortions

Source: County Director of Veterinary Services, (2016).

The provision of health services for the populace in Bungoma County is primarily managed by the County Government, operating under the auspices of the Ministry of Health. The county is home to a total of 136 health facilities, which include 11 hospitals, 4 nursing homes, 16 health centres, 78 dispensaries, 27 clinics, and 134 community units (County Government of Bungoma [CGB], 2013). As per the KDHS of 2011, 8.6% of the communities are located within a distance of 0-1 km from a health facility, 49.1% are situated within 1.1-4.9 km, and 48.4% are found at a distance of 5 km or more (CGB, 2013).

Table 2.6 delineates the principal factors contributing to human morbidity and mortality within Bungoma County. Malaria stands as the predominant contributor to both mortality and morbidity within the county. The table indicates that *Leptospirosis* is not identified as a significant contributor to mortality or morbidity in Bungoma County. Nevertheless, there exists a compilation of diseases or conditions that may be erroneously identified as *Leptospirosis*. Diseases and conditions such as malaria, anaemia, typhoid, and meningitis can be differentiated through the administration of confirmatory tests.

Table 2.6: Major causes of morbidity and mortality in humans in Bungoma County, Kenya

Cause of death in Bungoma County		Cause of ill-health in Bungoma County	
1.	Malaria	1.	Malaria (40%)
2.	Pneumonia	2.	Respiratory Tract Infections (19%)
3.	Anaemia	3.	Diseases of the skin (7%)
4.	Tuberculosis	4.	Diarrhoea (4%)

5.	HIV/AIDS	5.	Typhoid (3%)
6.	Cardiovascular diseases	6.	Pneumonia (3%)
7.	Meningitis	7.	Road traffic accidents (3%)
8.	Malnutrition	8.	Urinary Tract Infections (2%)
9.	Diabetes mellitus	9.	Eye infections (1%)
10.		10.	Dental (1%)

Source: CGB (2013)

The subsequent Table 2.7 delineates the prominent risk factors that pose threats to human mortality and morbidity within Bungoma County, Kenya. Factors influencing mortality risks include a lack of awareness regarding preventive measures, the impact of cultural beliefs, the presence of co-morbidities, and the causes of morbidity associated with environmental conditions, hygiene, and water quality.

Table 2.7: Major risk factors causing mortality in humans in Bungoma County, Kenya

Risk factors causing mortality		Risk factors causing morbidity	
1.	Inadequate knowledge of preventive measures, Cultural Beliefs and Attitudes.	1.	Environment
2.	Inadequate knowledge	2.	Weather
3.	Iron deficiency, co-morbidity	3.	Poor hygiene, allergies
4.	Poor ventilation, contacts, co-morbidity	4.	Poor hygiene

5.	Opportunity infections	5.	Unsafe water, hygiene
6.	Lifestyle	6.	weather
7.	Lifestyle	7.	Failed to observe traffic rules,
8.	Co-morbidity of HIV	8.	Poor hygiene, infections
9.	Poverty, cultural beliefs, Poor nutritional knowledge	9.	Trauma, infections
10.	Lifestyle	10.	Lifestyle

Source: CGB, (2013)

2.5 Impact and challenges of *Leptospirosis* outbreak on public health strategies as perceived by relevant stakeholders

2.5.1 Impact of *Leptospirosis*

Zoonoses exert a multitude of effects on both human and animal populations (Rahman, 2020). While quantifying the impact of zoonotic diseases like *Leptospirosis* presents challenges, it can be evaluated through various parameters, including disease prevalence, incidence, morbidity, mortality, and the economic repercussions (Meslin, 2006) stemming from disruptions in the trade of livestock and livestock products. The economic ramifications of zoonoses are assessed through their influence on livelihoods and overall well-being, the implications of isolation, the emergence of mental health challenges, the rise of antibiotic resistance, mortality rates, and the decline in productivity related to dairy and meat, among other commodities. (Rahman, 2020).

At present, there exists a lack of definitive information concerning the economic ramifications of *Leptospirosis* (Costa, 2015). The Global *Leptospirosis* Environmental Action Network (GLEAN) estimates that there are approximately 1.03 million clinical cases and 58,900 fatalities attributed to *Leptospirosis* globally each year, culminating in a loss of 2.90 million Disability-Adjusted Life Years (DALYs), predominantly affecting low and middle-income tropical nations (Torgerson et al., 2015). In comparison to other neglected tropical diseases, the burden of *Leptospirosis* seems to align closely with that of schistosomiasis, leishmaniasis, and lymphatic filariasis, as illustrated in Table 2.8 (Torgerson et al., 2015). Moreover, the 2.90 million DALYs signify the total loss of one year of healthy life for a population comparable to that of a city the size of Nairobi (Torgerson et al., 2015). *Leptospirosis* primarily impacts males, accounting for 80% of the overall burden, with a significant portion, 52%, affecting young adults aged 20 to 49 (Torgerson et al., 2015). *Leptospirosis* represents a significant economic challenge, particularly in lower- and middle-income nations, where young adult males constitute the most critical demographic for economic output (Costa et al., 2015).

Table 2.8: The burden of *Leptospirosis* per 100,000 compared to GBD estimates for the burden of various tropical and neglected diseases

	Disease	DALYs per 100,000
1.	Malaria	1200 (921-1594)
2.	Cholera	65(49-84)
3.	Leishmaniasis	48 (32-71)
4.	Schistomiasis	48 (25-91)
5.	*Leptospirosis*	42 (18.1-66)
6.	Lymphatic filariasis	40 (26-58)
7.	Rabies	21 (12-39)

Source: Torgerson *et al*., (2015)

2.5.2 Other Public Health Emergencies

Public health emergencies result in significant repercussions that impact both human health and socio-economic advancement; thus, it is imperative for communities to be directed towards self-protection (Han et al., 2021). A public health emergency is not limited to infectious diseases; it encompasses any crisis arising from exposure to chemical agents or radioactive materials (Halabi, Gostin and Crowley, 2017). Since 2005, the World Health Organization has issued eight declarations regarding public health emergencies of international concern, as illustrated in Table 2.9.

Table 2.9: Other Public Health Emergencies

S/No	Year	Disease	WHERE
1.	2009-2010	Swine flu (H1N1)	Pandemic
2.	2014	Polio	Declaration made under the Polio Global Eradication Initiative
3.	2013-2016	Ebola	Western Africa
4.	2015-2016	Zika virus epidemic	Brazil
5.	2018-2020	Kivu Ebola virus epidemic	Democratic Republic of Congo
	2012-2022	MERS-CoV (Middle East Respiratory Syndrome coronavirus)	Middle East, Africa and South Asia
	2022	Ebola	Uganda
6.	2020-2023	COVID-19	Pandemic
7.	2022-2023-2024	Mpox outbreaks	Burundi, Rwanda, Cameroon, Gabon, Morocco, Uganda, Guinea, Democratic Republic of Congo, Central African Republic

Source: WHO, (2024).

Kenya has experienced various disease outbreaks that are regarded as disasters (G0K, 2017). The outbreaks encompassed the following diseases: cholera, measles, meningitis, aflatoxicosis, *Leptospirosis*, and HIV/AIDS (GoK, 2017a). Table 2.10 presents a comprehensive overview of the diverse disease outbreaks affecting humans that transpired from 2000 to 2015. The frequency and impact of epidemics have escalated, largely attributable to the ramifications of climatic changes (Owuor, 2015). The outbreaks manifest in regions linked to conflict, drought, flooding, chronic marginalization, and inadequate life-coping skills, among other contributing factors (Owuor, 2015).

Table 2.10: Health-related disasters in Kenya between 2000 and 2015

S/No	Year	Where	Disease	Casualties
1.	2015	21 counties in Kenya	Cholera outbreak	- 131 dead, 6,529 cases
2.	2008	The former Nyanza, Western and North-Eastern Provinces, Wajir, Migori, Homa Bay, Siaya, Kisii, and Nakuru Counties.	Cholera outbreak	- 122 dead
3.	2008	Sirisia in Bungoma County.	Waterborne diseases	- 11 dead
4.	2007	Siaya/Suba	Cholera outbreak	10 dead
5.	2007	Countrywide	Measles outbreak	- 41 dead
6.	2006	Kacheliba and Alale Wards in West Pokot County.	Meningitis outbreak	-20 dead, 70 cases reported
7.	2005	Kitui, Makueni and Machakos	Food poisoning	- 13 dead, 66 cases
8.	2004	Makueni,Machakos, Kitui, Embu, Mbeere and Thika Sub-Counties.	Food Poisoning Aflatoxin	- 123 dead, 333 affected
9.	2004	Bungoma County	*Leptospirosis*	- 12 dead, 859 affected

Source: National Disaster Risk Management Policy, (2017)

2.5.3 Economic importance of *Leptospirosis*

Leptospirosis incurs economic losses that encompass diminished production, reproductive challenges, and the financial burden of treatment, among other factors (Tilahun et al., 2013).

A limited number of studies have sought to accurately measure the economic losses linked to both productive and reproductive declines in domestic animals naturally infected with *Leptospira spp*. (Bradley and Lockaby, 2023). In cattle, the disease manifests acutely with symptoms such as fever, haematuria, meningitis, and mortality, whereas the chronic manifestation is characterized by abortion, stillbirths, mummified foetuses, the birth of weak calves, reduced growth rate, prolonged calving intervals, irregular oestrus cycles, retained placenta, and infertility (Sanhueza et al., 2013; Martins and Lilenbaum, 2017). The insidious and persistent nature of this infection results in infertility and significant economic repercussions within the dairy industry (Bradley and Lockaby, 2023). Instances of abortions have also been documented in various domestic animal species (Tilahun et al., 2013).

Leptospirosis is linked to reductions in milk yield and may lead to both clinical and sub-clinical mastitis in domestic animals, consequently affecting the organoleptic properties (Sanhueza et al., 2013).

Additional losses related to *Leptospirosis* pertain to the expenses incurred for the treatment of the disease in both livestock and humans (Tilahun et al., 2013). The successful management of *Leptospirosis* requires the identification and treatment of urinary carriers, the quarantine of affected animals, and the treatment of those that are infected. Costs are also incurred related to vaccination and surveillance, which encompass the testing of serum samples prior to international transport (Pereira et al., 2013; Tilahun et al., 2013).

Human infection results in a significant reduction in productive working time and capacity (Faine, 1994, Broughton et al., 1984).

The economic ramifications linked to an outbreak of infectious disease, such as *Leptospirosis*, encompass a considerable adverse effect on tourism, travel, and trade, in addition to instigating notable political and social upheaval (Tilahun et al., 2013).

2.6 Theories, Models and Frameworks relevant to the study

This study was based on two social theories of global health (Kleinmann, 2010).

2.6.1 Social Theory of Global Health

The initial social theory pertaining to global health revolves around the unforeseen outcomes of intentional (or social) actions. This concept was put forth by the sociologist Robert Merton (Kleinmann, 2010). The theory posits that every social intervention is accompanied by unintended consequences, some of which may be anticipated and mitigated, while others remain unpredictable.

Consequently, it is imperative that all social actions undergo regular assessment to identify any unintended consequences (Kleinmann, 2010). The second theory pertains to the social construction of reality, a concept introduced by Peter Berger and Thomas Luckmann in the 1960s, which has since established itself as a cornerstone in the social sciences (Berger and Luckmann, 2016).

This theory posits that, in the tangible world, regardless of its material foundation, there exists a significant influence from social, cultural, and practical factors (Kleinmann, 2010). The dissemination of novel diseases is significantly shaped by the societal and cultural convictions and practices of the community (Kleinmann, 2010).

This study was firmly grounded in established frameworks, policies, plans, strategies, and legislations. In recent years, there has been a notable rise in the prevalence of health risks affecting both humans and animals (Mendoza et al., 2012). The exact influence remains uncertain owing to the intricate and multifaceted connections established by globalization (Mendoza et al., 2012). The proficient administration of these ailments necessitates that pertinent authorities direct their efforts towards strategies for disaster risk reduction and management (Mendoza et al., 2012). The Sendai Framework for

Disaster Risk Reduction (SF-DRR) 2015-2030, adopted in 2015, delineates a comprehensive roadmap aimed at enhancing the safety and resilience of communities in the face of disasters (SF-DRR, 2015). The framework advocates for UN member states to extend their focus beyond mere preparedness and response, aiming to disrupt the persistent cycle of poverty and disaster that afflicts communities.

Furthermore, the World Organization for Animal Health (WOAH) promotes the augmentation of the Veterinary Authorities' capabilities to bolster and refine nations' readiness and ability to avert and address calamities impacting the animal population, the economy, and veterinary public health (WOAH, 2019). In 2016, the Kenyan Government ratified the WOAH guidelines, aiming to incorporate disaster risk reduction within development policies, programs, and plans to promote sustainable development in the livestock sector.

This research has additionally drawn upon the established contingency plans for Rift Valley Fever, Highly Pathogenic Avian Influenza, and the National Strategy for the control and eradication of Peste Des Petits Ruminants (PPR) (2017-2027) (Benfield et al., 2023). The Livestock Policy of 2019 acknowledges the susceptibility of the livestock sector to the influences of Climate Change and variability, in addition to extreme weather occurrences (Mbae et al, 2020).

The policy delineates the emergence and re-emergence of both traditional and novel livestock diseases as significant consequences of climate change within the livestock sector. The Health Policy (2012-2030) acknowledges the necessity for collaboration with various sectors whose functions influence human health, to be realized through the implementation of a “Health in all Policies” approach (WHO, 2014). The Veterinary policy (2015), conversely, promotes a systematic inter-disciplinary cooperation and collaboration via the “one health” approach (GoK, 2020b). The Veterinary Policy acknowledges the significant influence of disasters on the livestock sector and aims to foster the creation of strategies for early warning, preparedness, and swift response to mitigate their effects. The Animal Disease Act (CAP 364) establishes measures for the prevention and control of animal diseases and pests/parasites, aiming to avert the escalation to epidemic proportions. The Public Health Act (CAP 242) establishes provisions for the assurance and preservation of health. It facilitates the protection of food safety concerning animal-related incidents, particularly in regions where meat inspection falls under the jurisdiction of the Ministry of Health.

The National Disaster Risk Management Policy of 2017 outlines the establishment and enhancement of disaster management institutions, fostering partnerships, networking, and the integration of disaster risk reduction within the development process (GoK, 2017b). The policy further advocates for the development of a cohesive multi-hazard disaster risk management strategy. This research employs the Disaster Logic Model (DLM) as a framework for assessing disaster programs. The model offers a framework essential for examining interventions related to disasters, all the while integrating the existing functional condition of a community or societal system. This model further aids in assessing the worth of the interventions.

2.7 Conceptual Framework for the study in Bungoma County, Kenya

This conceptual framework elucidates public health disasters, emphasizing the independent variables, dependent variables, and intervening variables (Adom et al., 2018). Health is a multifaceted notion that varies in definition according to the context and the individuals who engage with it (Kleinman, 2010). This study articulates a definition of health through the lens of public health methodology. The public health approach encompasses all systematic efforts aimed at safeguarding the health of populations, as well as preventing disease, enhancing well-being, and extending life expectancy for the community at large (Birnbaum et al., 2015). The public health approach underscores the intricate connections that exist between the populace and the surrounding environment. This is alternatively referred to as the Ecological public health approach (Kleinman, 2010).

Independent Variable

Re-emergence of Leptospirosis

Rainfall

Livestock management

Livestock movement

Socio-cultural practices

Level of awareness

Contact with extension staff

Intervening Variable

Leptospirosis outbreak

Level of education

Personal hygiene

Dependent Variable

Public health programmes:

Strength of the healthcare system: access to acute care services and intensive care units

Surveillance system (medical and veterinary).

Diagnostic capacity (medical and veterinary)

Livestock disease control programmes (vaccinations, livestock movement control)

Veterinary public health programmes-Meat Hygiene practices

Veterinary-medical and environmentalists working jointly through "one health approach"

Figure 2.5: Conceptual model of the study in Bungoma County, Kenya

Source: Researcher, (2017)

2.8 Gaps in Knowledge

Leptospirosis seroprevalence in cattle was evident in some areas of Kenya, but few serological studies were reported in Bungoma County. In a serological survey that was conducted on cattle in Kajiado County, Kenya, Nakeel *et al*., (2016) established a seroprevalence of 21.8 per cent and deemed that *Leptospirosis* was a potential threat to cattle and humans in Kenya. But recognizing how extensive *Leptospirosis* was particularly in Bungoma County still left a crevice. In order to address these concerns, more studies to determine the serovars closely associated with cattle in Bungoma needed to be done; and how the circulating strains were transmitted to humans. This piece of information could have helped in the early identification of preventive measures and control mechanisms compounds that are specific to the region.

Although previous studies identified various risk factors that predispose individuals to the disease such as occupational exposure, recreational activities and household conditions (Tilahun *et al*., 2013), literature with regard to how these past risk factors led to the re-emergence of the disease in Bungoma County was wanting. The previous literature review revealed that aspects like floods and intensive farming had evidently raised the risk (Karande *et al*., 2002; Deka *et al*., 2018); however, there is a dearth of knowledge about the current environmental and socio-economic context in Bungoma that paved the way to this re-emergence. In particular, the study should have been done in the area as to whether the local culture of interacting with farms and flooding through agricultural activities contributed to increasing risks of *Leptospirosis* among cattle and humans.

A literature review revealed that there was a shortage of knowledge on the KAP of the local communities in Kenya on *Leptospirosis*; particularly in the rural setting such as that of Bungoma County. The overwhelming majority of studies had been conducted on pathogens that affected larger groups, for instance, malaria or typhoid fever (CGB, 2013). A KAP study in Bungoma could also have shown low levels of awareness and knowledge concerning *Leptospirosis* out there that may have resulted in late presentation and diagnosis.

Despite some zoonoses such as *Leptospirosis* being a potential threat to human health, literature about the role that *Leptospirosis* outbreaks had on the formation of public health policy among such regions, including Kenya was conspicuous by its absence. The global economic and health effects of zoonotic diseases were also described by Costa *et al*. (2015) and Rahman (2020). However, more often than not, *Leptospirosis* was neglected in Kenya for diseases which were considered to be more conspicuous including malaria and HIV/AIDS. Research should have assessed the perception of and management of the challenges caused by *Leptospirosis* from the view of the local public health department and other stakeholders in Bungoma County. Lack of recognizing deficiencies in outbreak preparedness and response could have improved future approaches for controlling the disease.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

This chapter explains the methods used to achieve the objectives of the research. The chapter discusses the research design of the study. In this chapter, the study site, the study population, the target population and the data collection instruments for the study are described. An outline of how the primary and secondary data was collected, analysed and presented is given. In addition, the reliability and validity of the data is discussed. Also considered in this section are the assumptions, limitations and ethical issues taken into consideration during data collection.

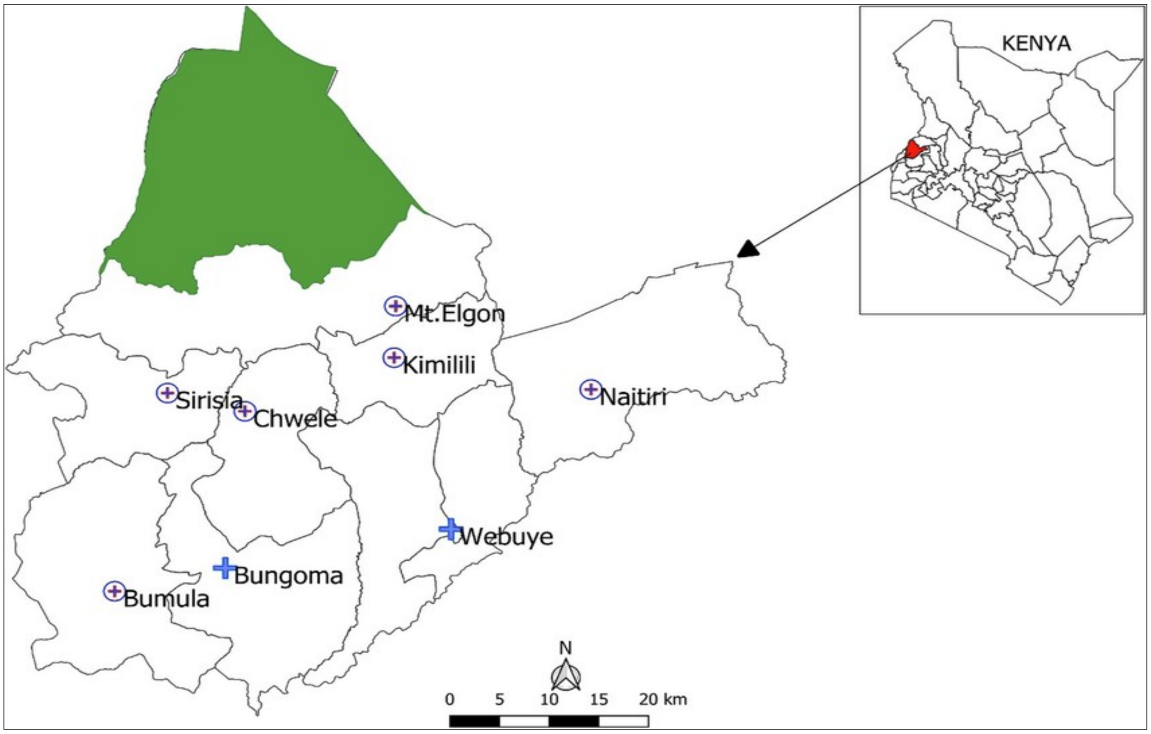
3.2 Study sites

The study was undertaken in four wards of Kimilili Sub-County and Kaptama Ward of Mt. Elgon Sub County, Bungoma County in Kenya, these being sampled purposively as they were considered to be the epicentre of the 2004 *Leptospirosis* outbreak. The study site is located in four wards of Kimilili Sub County namely; Kimilili, Kibingei, Maeni and Kamukuywa wards. In Mt Elgon Sub County one ward was considered for the study (Figure 3.1). Bungoma County is located on the southern slopes of Mt. Elgon and borders Uganda to the northwest, Trans-Nzoia County to the northeast, Kakamega County to the east and southeast, and Busia County to the west and southwest. The county lies between latitude $0^0 28^0$ and $1^0 30^0$ North and longitude $34^0 20^0$ and $35^0 15^0$ East (CGB, 2013). The study area was chosen based on the outbreak of human *Leptospirosis* in 2004 around Chesamisi area of Bungoma County. A scrutiny of hospital records at Kimilili, Webuye and Kaptama health facilities reveals that the cases were majorly reported in all the wards of Kimilili Sub-County and parts of Kaptama Ward in Mt Elgon Sub-County.

Kaptama is also the source of water used for drinking around Chesamisi village which was the epicentre of the outbreak (Nyongesa, 2016). The study area is occupied by two main ethnic communities: - the Sabaot who occupy the eastern slopes of Mt. Elgon and the Bukusu, a Luhya sub-tribe who occupy the lower region in Kimilili Sub-County. The County has an area of 2,403.2km2 of which 1,922.56 km2 is arable (CGB, 2013). The county enjoys good weather conditions and high amounts of rainfall (Chemarum, 2016). Rain-fed agriculture is the mainstay of the communities in Bungoma County (Chemarum, 2016). The main crops in the county include maize, beans, millet, potatoes and assorted vegetables. Sugarcane is the main cash crop (CGB, 2013). The main livestock kept in the county include cattle, sheep, goats, donkeys, pigs, poultry, and bees. Other domestic animals include dogs and cats (Omondi, Ngere and Ndeda, 2016). The County is divided into nine sub-counties (CGB, 2013).

The human population in Bungoma County is estimated at 1,759,499 according to the 2017 estimates with Kimilili and Mt Elgon having 239,343 and 220,064 respectively (CGB, 2013). The livestock population in Bungoma County is estimated at 367,496 heads of cattle, 118,058 sheep, 113,592 goats, 16,088 pigs and 3,811 donkeys. Of these populations, 73,951 heads of cattle, 23,003 sheep, 23,742 goats, 1,102 pigs and 2,456 donkeys are found in Kimilili and Mt Elgon Sub-Counties (CDLP, 2016). The Department of Agriculture, Livestock, Fisheries and Irrigation of the County Government of Bungoma is the main provider of animal health services (CDVS, 2016). The services include clinical work, meat inspection and surveillance (CDVS, 2017).

The area is also supported by the Regional Veterinary Investigations Laboratory based at Eldoret for surveillance and diagnostic services. The study area is served by two sub-county veterinary officers and four animal health assistants who also double up as meat inspectors (CDVS, 2017).



[Position of Bungoma county in Kenya is shaded in red]

Figure 3.1: Position of Bungoma County in Kenya

Source: GoK (2013)

3.3 Study population

The study focused mainly on the area that was severely affected by the 2004 *Leptospirosis* outbreak in the four wards of Kimilili Sub-County (Kibingei, Kamukuywa, Kimilili and Maeni) and one ward of Kaptama in Mt.Elgon Sub-County. The learning institutions- both primary and secondary schools in the region were included in the study to determine the impact of the disease on the population in the institutions. Additional data was obtained from the following institutions-the County Department of Livestock Production, County Director of Veterinary Services, County Director of Meteorological Services and the County Director of Education in Bungoma County.

In addition, the veterinary officers for Kimilili and Mt Elgon sub-counties, and the officers in charge of relevant health facilities and schools within the study area were also contacted. More information regarding the status of *Leptospirosis* in livestock in the study area was collected from the Regional Veterinary Investigations Laboratory-Eldoret, Kenya. The study team visited the major livestock markets in the study area which comprised Kamukuywa and Kimilili. More data was collected from the active slaughter facilities in Bungoma County which comprised Kimilili and Bungoma slaughterhouses.

3.4 Research Designs

This study employed an experimental and cross-sectional design for the first specific objective. The experimental design was used for the Laboratory test on collected blood serum samples was conducted to establish the seroprevalence for *Leptospirosis* in cattle using ELISA test.

To address the second and third specific objectives, a cross-sectional design was utilized. The fourth specific objective was achieved using a summative evaluation research design.

Table 3.1: Specific objectives, measurable variables/indicators and research design

S/No	Specific objective	Measurable variables/indicators	Research design
i.	To determine the seroprevalence of *Leptospirosis* in cattle in Bungoma County, Kenya.	• Number of blood sera samples collected from cattle in Kimilili and Kaptama Sub-Counties, Bungoma County. • Number of blood sera samples testing positive on ELISA Test in Kimilili and Kaptama Sub-Counties, Bungoma County.	Experimental and Cross-sectional survey
ii.	To determine the risk factors for the re-emergence of *Leptospirosis* in Bungoma County, Kenya.	• Rainfall patterns, • Livestock species kept. • Livestock grazing and watering system. • Livestock slaughtering and inspection, • Contact with veterinary staff, • Livestock movement patterns, • Level of awareness about *Leptospirosis* and the role of bats.	Cross-Sectional Survey
iii.	To examine the knowledge, attitude and practices (KAP) associated with *Leptospirosis* in Bungoma County, Kenya.	• Knowledge about *Leptospirosis*, • Risk practices • Demographic characteristics of the respondents.	Cross-Sectional Survey
iv.	To evaluate the impact of *Leptospirosis* on public health programmes in Bungoma County, Kenya.	• Public health programmes and strategies.	Summative Evaluation

Source: Researcher, (2017)

3.5 Sampling strategy

Kimilili and Mt Elgon sub-counties were sampled purposively based on the foci of the *Leptospirosis* outbreak of 2004. The two sub-counties were then stratified into the five wards of Kibingei, Kamukuywa, Maeni, Kimilili and Kaptama and further into the various locations and sub-locations. The sub-locations were selected purposively based on reports of any cases of *Leptospirosis* during the 2004 outbreak. The study team then visited the selected areas with the assistance of community leaders. In each location, the most affected sub-locations were further selected purposively and the number of households was established with the help of chiefs. Households were selected randomly for interviews and questionnaires administered to the head of the household. The minimum sample size of 178 heads of cattle was determined using the formula of estimating disease prevalence according to Thursfield (2005)

$$n=Z\alpha^2pq/L^2 \text{………………….Equation 3.1}$$

where:

n the required sample size,

$Z\alpha=1.96$, the normal deviate at a 5% level of significance

$p=0.5$ at a 50% seroprevalence,

$q=1-p(0.5)$

L is the precision of the estimate, 5%.

$n=1.96^2xo.5x0.5/(0.05)^2$

=384 households.

The number of cattle from which serum was collected in each of the five wards was proportional to the estimated cattle population.

A sample size of 200 blood sera was collected, based on the formula of Thursfield (2005) using an estimated seroprevalence of 13.4% in humans worked out at a 95% Confidence Interval:

$$n = Z\alpha^2 pq/L^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{Equation 3.2}$$

Where:

n = the number of bovine sera collected,

$Z\alpha$=1.96, the normal deviate at a 5% level of significance,

p= the estimated prevalence of *Leptospirosis* of 13.4% in humans as established by Cook *et al*., (2017).

q=1-p (0.134)

and L is the precision of the estimate, 5%.

$n=(1.96^2 xo.134x0.866)/(0.05)^2$

=178 serum samples.

3.6 Data Collection

The study utilized both secondary and primary data. Primary data were collected from the field and secondary data from archival sources.

3.6.1 Primary Data

Collection of primary data utilized participatory epidemiological techniques described by Catley and Mariner (2002) and Catley (2004) to identify livestock diseases and rank them according to prevalence and impact. The key participatory methods utilized were focused group discussions, semi-structured questionnaires, simple ranking and seasonal calendar. Transect walk and direct observation methods were also utilized in the study.

Questionnaires were administered to heads of households (Appendix II). Key informants who included heads of learning institutions (Appendix III), Sub County Veterinary Officers (Appendix IV), and Sub-County Medical Officers of Health (Appendix V) in the study area were interviewed. The total number of households and blood samples collected by location, ward and sub-county is shown in Appendix VII.

3.6.1.1 Serum Collection and laboratory testing

Blood was collected by bleeding cattle from the jugular vein following restraint. Plain vacutainers and 1.5-inch needles, gauge 18 were used to collect 10-15ml of blood. The samples were labelled immediately and stored on ice in a cool box. The blood sample was left to stand overnight in the cool box packed with ice to allow serum separation. Serum was then harvested by decanting into 2ml sterile vials and labelled appropriately and stored in a freezer at -20^{o}C. The samples were then transported to the Regional Veterinary Investigations Laboratory, Eldoret for temporary storage in a deep freezer.

Plate 3.1: Researcher taking the Blood Sample from a Cow in a household in Kimilili Sub County, Bungoma County, Kenya

Source: Researcher (2017)

After collecting all the samples, they were packed with ice in a cool-box and transported to the Central Veterinary Laboratory in Kabete, Nairobi where they were tested using ELISA test as described in Appendix X. The optical densities (OD) were measured at 450 nm in a micro plate photometer (Hum reader, model 18500/1, Awareness Technology inc. Germany). Sera and controls were run in duplicate to compare the two OD readings for every sample. The appearance of a blue solution indicates the presence of *Leptospira* antibodies (positive) which then turn yellow upon the addition of a stop solution. The absence of antibodies (negative results) was denoted by a lack of colouration. The seroprevalence for *Leptospirosis* in cattle was calculated by getting the number of positive samples for ELISA test divided by the total number of samples collected and multiplied by 100%.

3.6.1.2 GPS Mapping of the study sites

Using a Global Positioning System (GPS) handheld receiver, an accurate location for each of the sites visited was recorded capturing the various learning institutions that were affected by the disease in 2004, livestock markets, slaughter facilities, water bodies, health facilities that were used for the management of cases and veterinary offices. The geo-reference data included the latitude, longitude and the altitude. The GPS was positioned to have a clear view of the sky and away from any obstructions. The readings were obtained within 3-4minutes. Figure 3.2 shows the location of households visited during data collection. It also shows the health facilities where the majority of patients suspected to have *Leptospirosis* infection were treated during the *Leptospirosis* outbreak of 2004.

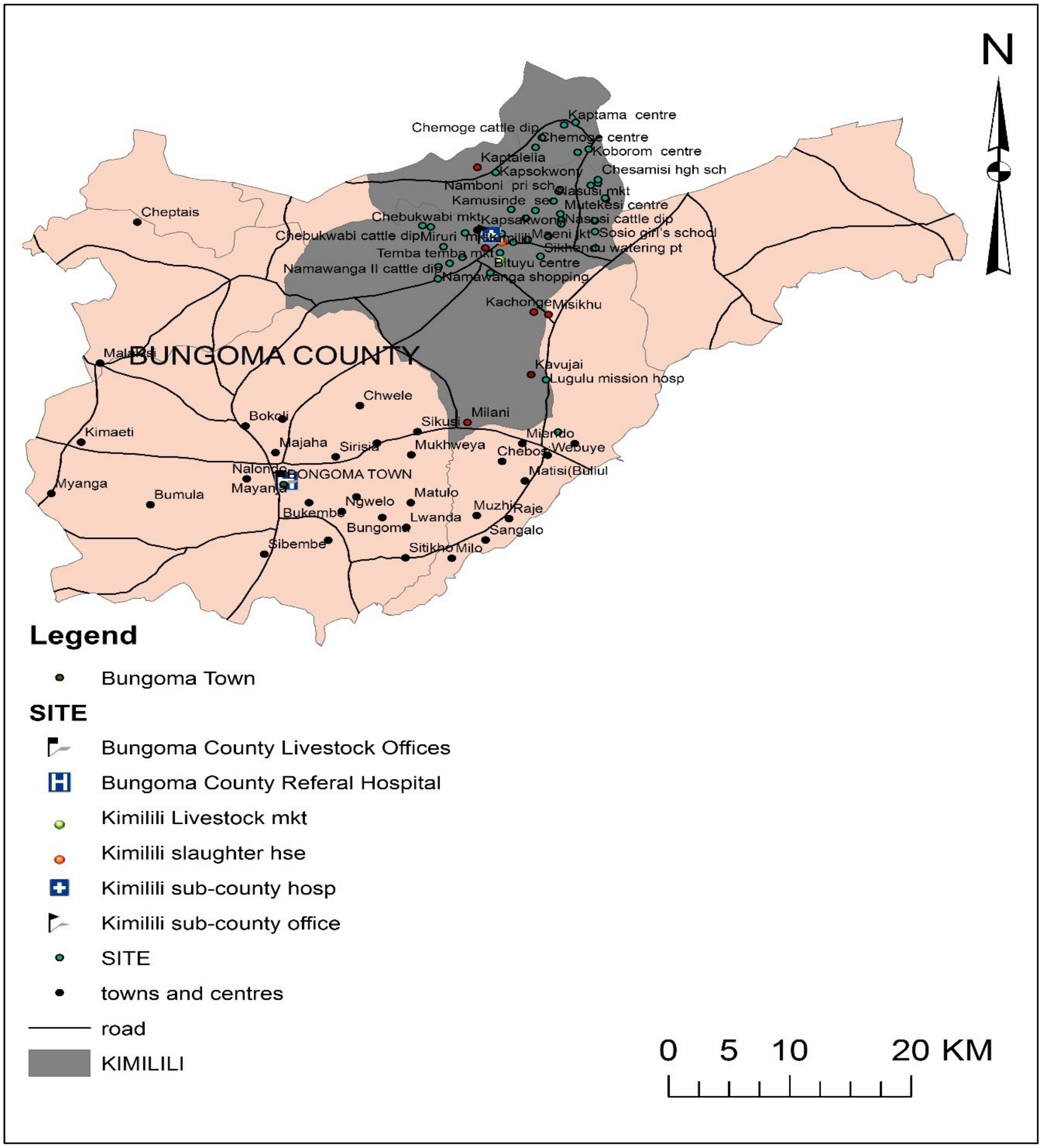


Figure 3.2: Map of the study area where livestock samples were collected, Key veterinary and medical facilities in Bungoma County, Kenya

Source: Researcher (2017)

3.6.2 Secondary data

Secondary data was sourced from journals and reports from relevant offices. The literature search was carried out in relation to recent *Leptospirosis* outbreaks in the world and recent seroprevalence studies in livestock, humans and other animals. Other searches involved the risk factors for *Leptospirosis* in both livestock and humans and the knowledge and attitude of affected communities. More searches were conducted in relation to the public health programmes and strategies implemented to control emerging zoonoses. The required information was obtained through the website search engines, publication databases and online libraries. Internet-accessible journals and other relevant electronic publications were used. Other relevant documented materials which could not be accessed through the Internet were collected from relevant offices and libraries using criteria as set out in Appendix VI.

The other reports used in the study included the following; - hospital records, research theses, newspapers in the relevant areas, monthly and annual reports from the Veterinary Department and the Ministry of Health. Laboratory reports from the Regional Veterinary Investigation Laboratory-Eldoret were also reviewed. Medical records from 2000 to 2010 were obtained from Kimilili and Webuye health facilities in Bungoma County. There were no records at Bungoma County Referral Hospital and Makhonge Health Centre. Records at Lugulu Hospital were unreliable due to inconsistencies in the reports. The data collected included the number of suspected *Leptospirosis* cases, and the age and gender of the patient. Laboratory records at the Regional Veterinary Investigations Laboratory at Eldoret were also obtained to show disease incidence.

Meteorological data for the period 2000 to 2010 were obtained from the County Director of Meteorological Services to assess the possible association of the disease incidence with rainfall patterns. Monthly rainfall records for the year 2004 were also obtained.

3.7 Limitations of the study

The following limitations in the field were expected during data collection:

i. Respondents gave inaccurate or non-truthful information during the interview. The researcher clearly explained the objective of the study to the respondents beforehand while emphasizing the importance of the information given to avert the recurrence of similar disasters.

ii. Availability of accurate, consistent and concrete information at the household level due to the non-availability of records. The researcher depended on estimates and approximations as narrated by the household's heads and this was triangulated with secondary information.

iii. Some stakeholders were not willing to release information for fear of being investigated. Prior to the interview, a signed Informed Consent Form was obtained from each participant. The form emphasized the fact that one participates in the study voluntarily and is allowed to withdraw at any stage. The researcher emphasized the fact that participation in the study was strictly based on willingness and an assurance of total confidentiality of the information released was given.

3.8 Validity and reliability of data collection instruments

Primary data was collected using reliable and validated instruments. Four (4) research assistants as technical staff from the field were recruited, competently trained and oriented for two days on data collection techniques. Also, research supervisors were involved in the content and construct validity of data collection instruments.

A pilot study was conducted at Maliki Ward of Tongaren Sub County of Bungoma County using 20% of the 200 (40) for pre-testing. The data collection instruments were administered to the respondents and then repeated after two weeks. Necessary revisions were made to data collection instruments based on feedback to make the questions complete and easily understood. A comparison of answers was made and analysed where a correlation of 0.8 was considered reliable for the study. Quality checks were carried out randomly by the researcher and his supervisors to ensure completeness and consistency of the data collection instruments.

3.9 Ethical consideration

At the location and sub-location level, the chiefs and assistant chiefs were asked for permission prior to the initiation of the research. At the individual level, verbal consent was received from each participant before data collection. A copy of the Informed Consent Form (Appendix I) was filled by each respondent. Respondents received a detailed description and objectives of the research. Confidentiality provisions and the fact that their participation in the study was voluntary allowing for withdrawal at any point if they so deemed was emphasized. The principles of privacy and confidentiality were upheld throughout the study.

A research permit was also obtained from the National Commission for Science, Technology and Innovation (Appendix XI).

The clearance of the County Director of Veterinary Services was also sought during the collection of livestock blood samples (Appendix XII). This study involved the collection of health records which required the authority of the County Director of Medical Services (Appendix XIII). In addition, all the information collected was treated with utmost confidentiality.

The researcher was given clearance by the County Director of Education to collect data from schools (XIV). During the exercise, the researcher strived to be objective and avoid any form of bias. Ethical approval and clearance for the study were granted by the Masinde Muliro University of Science and Technology Directorate of Research (Appendix XV).

3.10 Assumptions

The following assumptions were made during the study: -

i. Respondents were available and ready to provide accurate information.
ii. The key informants were willing to provide the required information.
iii. Variables not captured in the study remained constant.
iv. Intervening variables remained constant.

3.11 Data analysis and presentation

The primary data was entered, cleaned and stored in Microsoft Excel Programme (Microsoft Corp). The data was thereafter imported into the Statistical Package for Social Sciences (SPSS) version 20 (SPSS Inc., Chicago, IL, USA, 2002). Data analysis methods used include descriptive statistics, chi-square and regression analysis as shown in Table 3.2. The results were presented in the form of tables and graphs.

The seroprevalence was worked out by determining the number of positive samples on ELISA divided by the total number of samples tested. The Global Positioning System points were analysed using ArcView to generate maps to indicate areas where blood samples were collected, health facilities used during the *Leptospirosis* outbreak and livestock facilities in the study area.

Table 3.2: Specific objectives, measurable variables/indicators, research design and method of analysis

No	Specific objective	Research design	Methods of Analysis
i.	To determine the seroprevalence of *Leptospirosis* in cattle in Bungoma County, Kenya.	Experimental and cross-sectional	ELISA test to get the total positive samples expressed as a percentage. Descriptive statistics.
ii.	To determine the risk factors for the re-emergence of *Leptospirosis* in Bungoma County, Kenya.	Cross-Sectional	Descriptive statistics. Chi-square test.
iii.	To examine the knowledge, attitude and practices (KAP) associated with *Leptospirosis* in Bungoma County, Kenya.	Cross-Sectional	Descriptive statistics. Chi-square test. Univariate regression analysis
iv.	To evaluate the impact of *Leptospirosis* on public health programmes in Bungoma County, Kenya.	Summative Evaluation	Descriptive statistics.

(Source: Researcher, 2017)

CHAPTER FOUR

THE SEROPREVALENCE OF *LEPTOSPIROSIS* IN CATTLE IN BUNGOMA COUNTY, KENYA

4.1 Introduction

This chapter investigates the seroprevalence of bovine *Leptospirosis* in Kaptama Ward of Mt Elgon and Kimilili sub-counties in Bungoma County, Kenya.

4.2 Sero-prevalence of bovine *Leptospirosis* in Kimilili Sub-County Wards and Kaptama Ward Mt. Elgon Sub-County, Bungoma County, Kenya

Two hundred blood serum samples from cattle herds were collected from five wards of Maeni, Kamukuywa, Kibingei, Kimilili and Kaptama. Of these blood sera, thirty-eight (38) samples were collected from Kimilili slaughterhouse, which is the busiest slaughter facility at the study site. The cattle were aged one year and above. Records on the sex of the animals show that 111 cattle were male and 89 cattle were female. The competitive ELISA test was used to work out the seroprevalence of *Leptospirosis* in Kimilili Sub County wards and Kaptama ward of Mt Elgon Sub-County which constitute the study area.

Antibodies to *Leptospirosis* were detected in 32 out of 200 blood sera using ELISA test indicating an overall seroprevalence of 16% in cattle. Table 4.1 shows the seroprevalence of bovine *Leptospirosis* in the study area. The highest seroprevalence for *Leptospirosis* (21.0%) was reported in bovine sera obtained at the Kimilili slaughterhouse while the lowest was from Kibingei Ward (10.7%). The Chi-Square Test on the seroprevalence figures shows that there appears to be no significant difference ($p>0.05$) in figures in all the wards. However, there appeared to be a significant difference ($p<0.05$) in the seroprevalence figures for Kimilili slaughterhouse in relation to all the wards. Figure 4.1 shows the seroprevalence values for cattle in the five wards under study and Kimilili slaughterhouse.

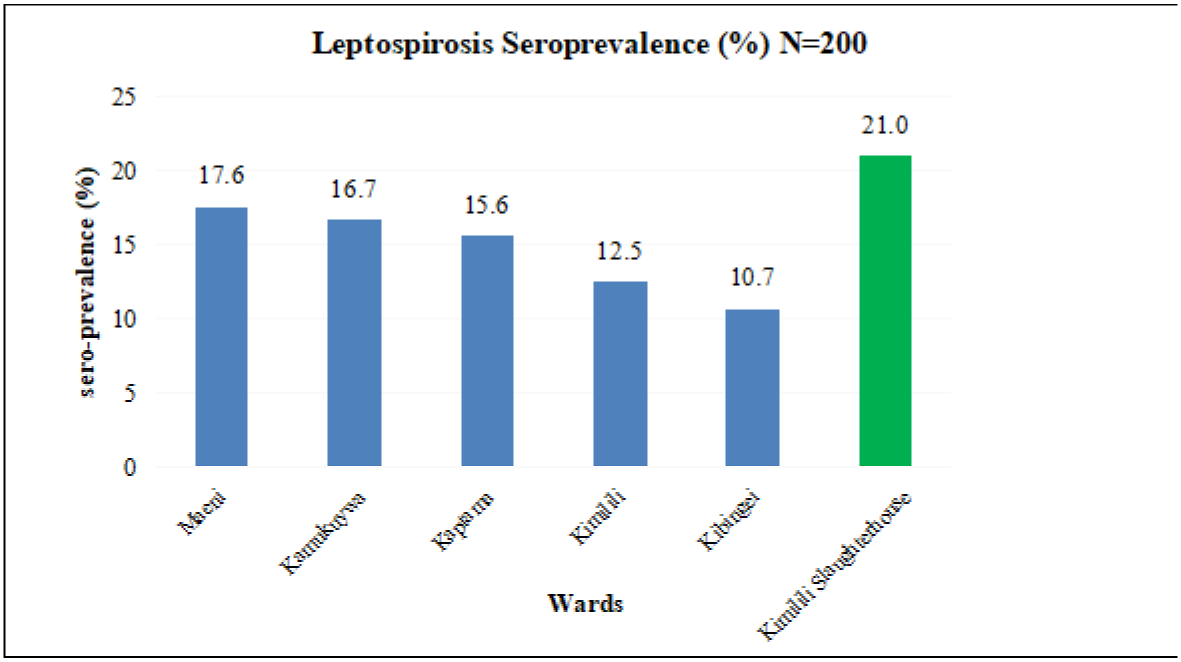


Figure 4.1: *Leptospirosis* seroprevalence in the Wards Kimilili and Mt Elgon Sub-Counties and Kimilili slaughterhouse in Bungoma County, Kenya

Source: Researcher, (2017)

The sex-related seroprevalence of *Leptospirosis* in the wards is presented in Table 4.1. A total number of 89 males and 111 females were tested for *Leptospirosis*. The results show that males had an overall seropositivity of 14.6% while the females recorded 17.1%. The distribution of males testing positive for *Leptospirosis* is shown in Table 4.1. The highest percentage of males testing positive is found in Kimilili slaughterhouse (24%), followed by Kamukuywa (16.6%) and Maeni (15.4%) wards respectively.

Table 4.1: Sex-Related Seropositivity of *Leptospirosis* in Cattle in Bungoma County, Kenya

Sub-County	Ward	Samples	Sex	(N)	Positive (%)
Kimilili	Kibingei	28	M	8	1(12.5%)
			F	20	2(10%)
	Kimilili	32	M	10	1(10%)
			F	22	3(13.6)
	Maeni	34	M	13	2(15.4%)
			F	21	4(19.0%)
	Kamukuywa	36	M	12	2(16.6%)
			F	24	4(16.6%)
	Kimilili slaughterhouse	38	M	29	7(24%)
			F	9	1(11%)
Kaptama	Kaptama	32	M	17	2(11.7%)
			F	15	3(20%)

Source: Researcher, (2017)

Figure 4.2 shows the seroprevalence of *Leptospirosis* in male cattle in the five wards under study and Kimilili slaughterhouse.

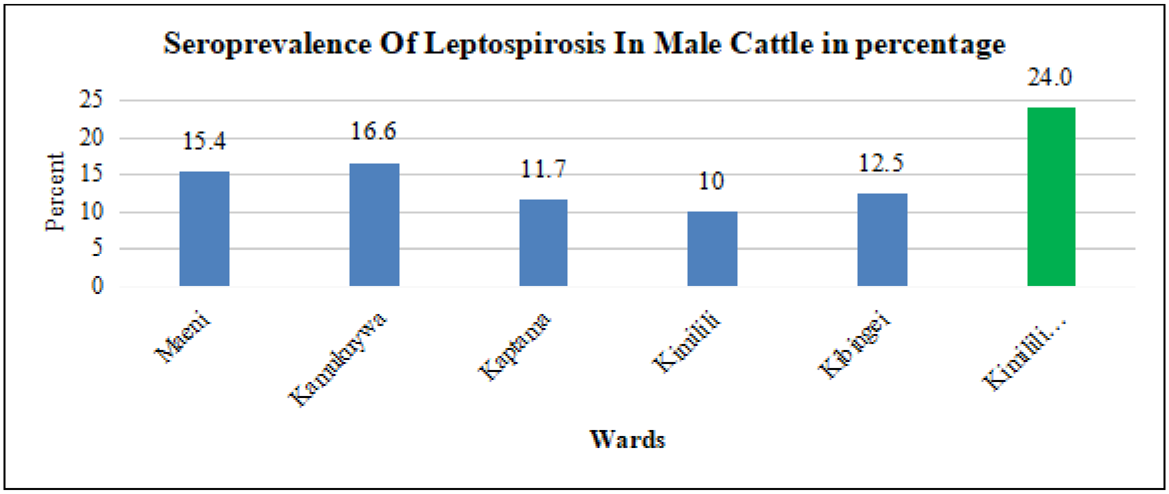


Figure 4.2: *Leptospirosis* seroprevalence in male cattle in Wards in Kimilili and Mt Elgon Sub-Counties and Kimilili slaughterhouse in Bungoma County, Kenya

Source: Researcher, (2017)

The distribution of females testing positive for *Leptospirosis* is shown in Figure 4.3. The highest percentage of females testing positive is found in Kaptama ward (20%), followed by Maeni (19%) and Kamukuywa (16.6%) wards respectively. The lowest percentage of females testing positive for *Leptospirosis* was found in Kibingei ward (10%).

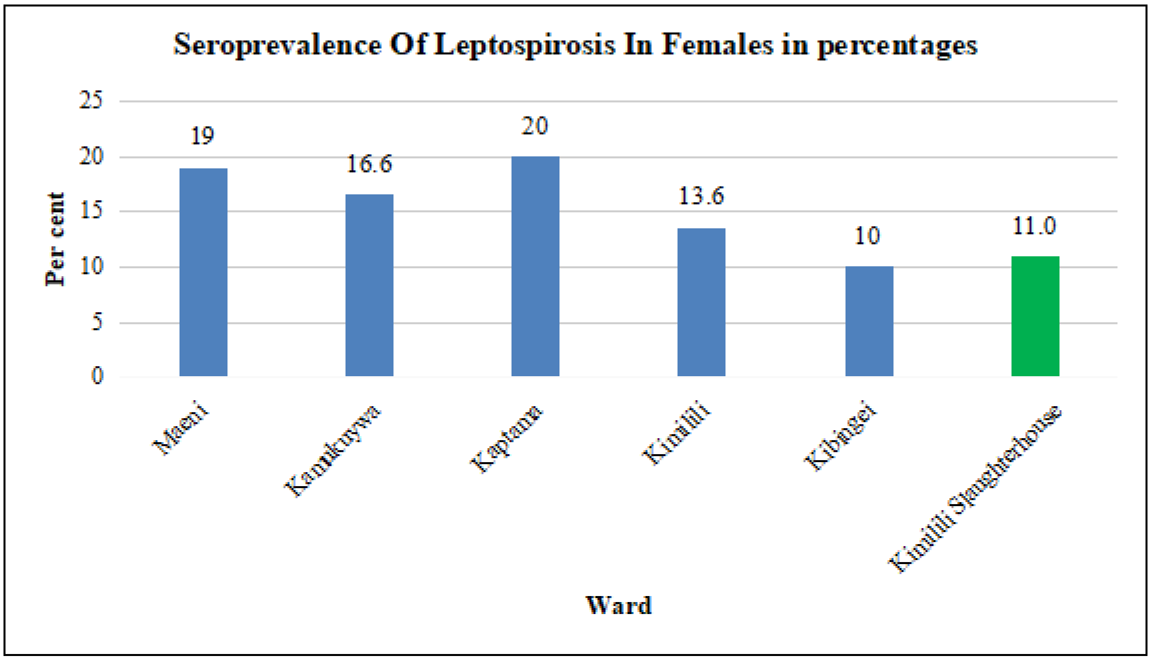


Figure 4.3: *Leptospirosis* seroprevalence in female cattle in Wards in Kimilili and Mt Elgon Sub-Counties and Kimilili slaughterhouse in Bungoma County, Kenya

Source: Researcher, (2017)

Since there is no history of vaccination of livestock against *Leptospirosis* in Bungoma County, the seropositivity figure obtained from the test is considered a reliable estimate for the cattle exposed to *leptospira* infection. The competitive ELISA test is highly sensitive (96%) and specific (97%) for biological diagnosis of *Leptospirosis* in animal sera for recent as well as past infections (Mythri, 2015). It is of particular value as a serological screening test because of its relative simplicity in comparison with the Microscopic Agglutination Test (MAT) (Mythri, 2015). However, the ELISA test does not indicate the infecting serovar (Bakhshandeh *et al*, 2021).

The high prevalence of *Leptospirosis* is consistent with other studies which showed that the prevalence of *Leptospirosis* among slaughterhouse workers in Western Kenya is 13.4% (Cook *et al*., 2017). It was also observed that cattle at the slaughterhouse presented the highest seroprevalence for *Leptospirosis*. This is because animals brought to the slaughterhouse originate from different localities ranging from as far as Turkana and West Pokot which are known to have the disease. It is also a common practice amongst farmers to sell off animals for slaughter which show any sign of sickness.

The seropositive animals were found in all the five wards under study with the highest seropositivity figures being reported in Maeni (17.6%), followed by Kamukuywa (16.7%), Kaptama (15.6%), Kimilili (12.5%) and Kibingei (10.7%) in that order (Table 4.1). This demonstrates how widespread the disease is in the study area. The high *Leptospirosis* seropositivity in cattle is explained by the fact that there is very high livestock movement in the region because of the very active livestock markets at Kimilili and Kamukuywa livestock sale yards and a very busy slaughter facility at Kimilili. The high flow of livestock into the area attracts livestock from areas which have a high risk for the disease. It was also observed that the highest seropositivity for *Leptospirosis* was recorded in cattle from Kimilili slaughterhouse. Key Informant Interviews confirmed that the majority of cattle brought to the slaughterhouse originate from as far as Trans Nzoia, West Pokot and Turkana, Studies and surveillance reports have demonstrated that *Leptospirosis* is highly prevalent in the mentioned regions (Macharia, 1989).

A similar study carried out in Kajiado has demonstrated that the seroprevalence of *Leptospirosis* in cattle is 21.8%. The seroprevalence of *Leptospirosis* is higher in Kajiado because of the nomadic lifestyle of the pastoralists where there is the widespread movement of livestock and they depend fully on livestock products such as milk, meat and blood for nutrition as compared to Bungoma setup. The high seroprevalence for *Leptospirosis* in cattle in Bungoma County demonstrates that there is a high risk of transmission of the disease to humans through contact with and consumption of livestock products from their livestock. Table 4.2 shows that the highest seropositivity for *Leptospirosis* in cattle was recorded in Maeni (17.6%) followed by Kamukuywa (16.7%), Kaptama (15.6%), Kimilili (12.5%) and Kibingei (10.7%) which when combined had a total seropositivity of 14.8%. Further Table 4.2 shows the seropositivity for Kimilili Slaughterhouse was 21%. This was key based on the fact that Kimilili Slaughterhouse is well equipped with sophisticated facilities which also accommodate high numbers of cattle whose catchment is within and outside the study area.

Table 4.2: *Leptospirosis* seropositivity in cattle using ELISA test in the study sites of Kimilili and Mt Elgon Sub-counties, Bungoma County, Kenya

Areas of focus		Ward	Number of Samples	Number of Positives	Percentage Positives
Sub-County	Kimilili	Kibingei	28	3	10.7
		Kimilili	32	4	12.5
		Maeni	34	6	17.6
	Mt Elgon	Kamukuywa	36	6	16.7
		Kaptama	32	5	15.6
		Sub-Total	162	24	14.8
Major		Kimilili	38	8	21.0

Slaughterhouse	Slaughter-house			
	Grand Total	200	32	16

Source: Researcher, (2017)

The chi-square test conducted to check the statistical relationship between sex and *Leptospirosis* seropositivity in cattle returned the results in Table 4.3. There was no statistical difference observed between male and female cattle.

Table 4.3: Chi Square Test for the Relationship Between Sex and *Leptospirosis* Seropositivity in Cattle in Bungoma County, Kenya

Chi-Square Tests

	Value	**df**	**Asymptotic Significance (2-sided)**
Pearson Chi-Square	6.333[a]	4	0.176
Likelihood Ratio	8.318	4	0.081
Linear-by-Linear Association	0.112	1	0.738
N of Valid Cases	178		

Source: Researcher, (2017)

Despite the high *Leptospirosis* seropositivity in cattle, there has been no case of *Leptospirosis* recorded in all the livestock in Bungoma County since the year 2000. In addition, surveillance for the disease is not carried out. However, abortion in livestock is reported to be a common problem in the study area (CDVS, 2016).

The Chi-Square test with a p-value of 0.176, which was larger than p<.05, showed that there were no significant associations between sex and Leptospira seropositivity in cattle in the study area. This finding is consistent with another finding in a study undertaken in pigs in Western Kenya (Ngugi *et al*., 2019). In another study carried out in Vietnam, fattening pigs showed similar findings (Lee *et al*., 2017). This finding is consistent with other studies which suggest that this is due to infection in the female reproductive tract which provides a reservoir for propagation and transmission of the disease (Boqvist *et al*., 2002). It is also a general practice amongst farmers to keep female animals for a longer time on the farm for milk while most male animals are disposed of earlier for sale leaving only a few for breeding and ploughing. This practice therefore allows females to stay on the farm for a longer time and therefore increases exposure to *Leptospirosis* (Boqvist *et al*., 2002, Lee *et al*., 2017). The high seroprevalence of *Leptospirosis* in males at the slaughterhouse on the other hand is attributed to the fact that most of the animals brought for slaughter are males. In addition, they originate from as far as Turkana and West Pokot, areas that are known to have a high prevalence of the disease (Macharia, 1989).

Secondary data from the CDVS reveals that abortion in cattle is common in both Kimilili and Mt Elgon Sub-counties (CDVS, 2016). Since abortion is one of the manifestations of *Leptospirosis*, it is necessary to carry out further tests to confirm the cause of abortions in cattle and possibly rule out *Leptospirosis*. The high seropositivity of *Leptospirosis* is an indication that *Leptospirosis* could be enzootic in the study area and many cases go undetected.

4.3 Trends of suspected human *Leptospirosis* cases as per hospital records in Bungoma County

Hospital records from Kimilili and Webuye hospitals were examined. Figures 4.2 and 4.3 show the disease trend as observed from the hospital records in Kimilili and Webuye health facilities respectively. There were no records at Bungoma County Hospital, Lugulu Hospital, Makhonge Health Centre and Kaptama Dispensary. The records were confined to the period between April and November 2004, the period when there was the outbreak. The cases were also limited to those who resided in Chesamisi and its environs. *Leptospirosis* is difficult to diagnose both in the clinic and the laboratory (Hartskeerl *et al*., 2016). Most *Leptospirosis* cases are undiagnosed or misdiagnosed due to a lack of awareness of the disease and difficulties in carrying out laboratory confirmation tests (W.H.O., 2011). It is estimated that 20% of undefined febrile illnesses are due to *Leptospirosis* (W.H.O., 2011). Data from studies of febrile illness in many tropical regions indicate that *Leptospirosis* can account for considerable proportions of febrile illnesses (Halliday *et al*., 2013). All the cases presented at the health facilities were treated for enteric fever, malaria, typhoid and meningitis.

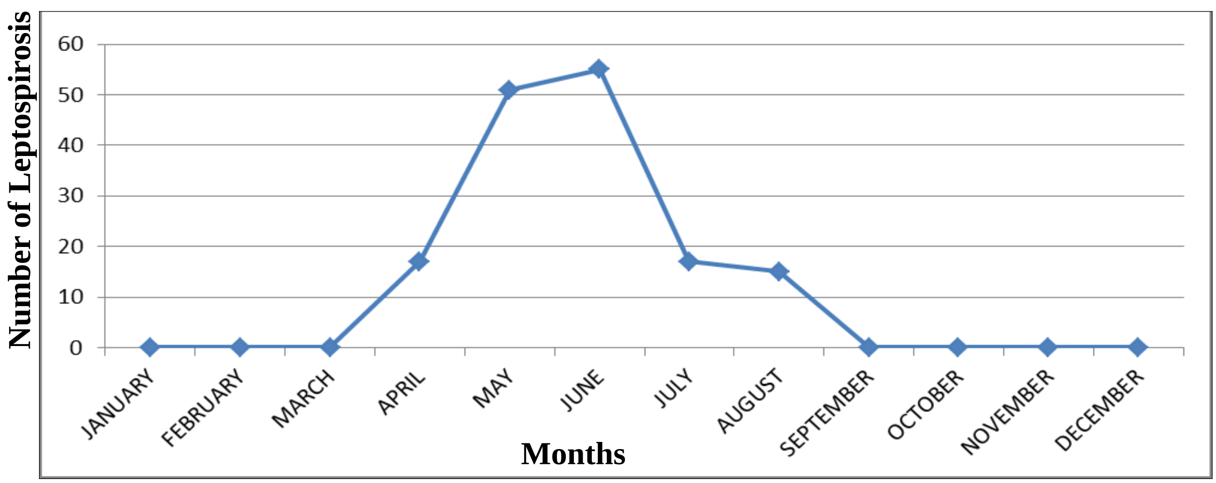


Figure 4.4: Number of suspected cases of *Leptospirosis* treated at Kimilili Health Centre in 2004 in Bungoma County, Kenya

Source: Researcher, (2017)

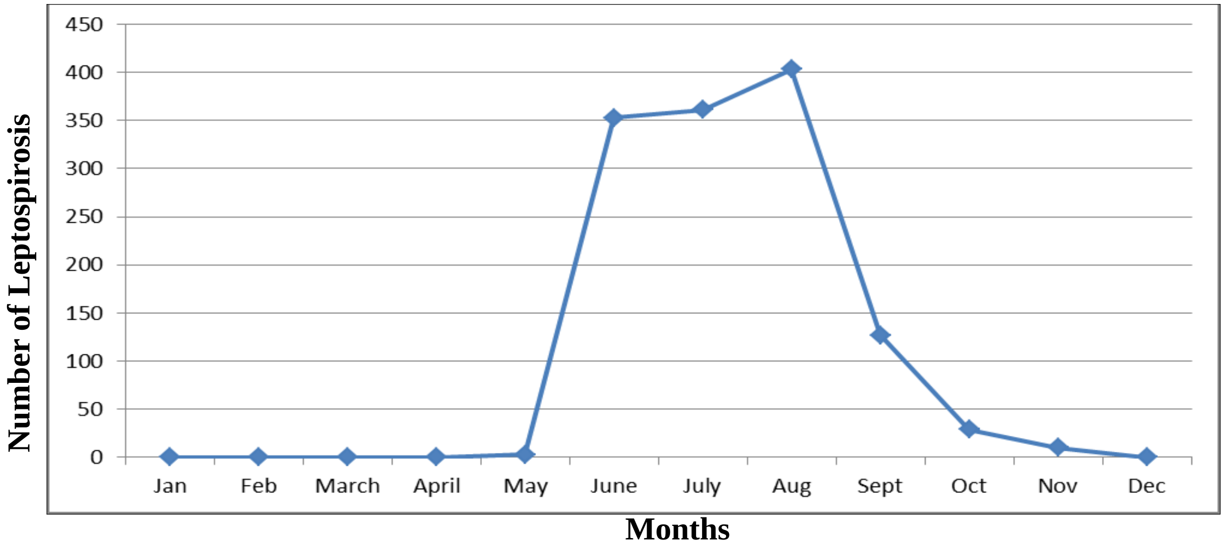


Figure 4.5: Number of suspected cases of *Leptospirosis* treated at Webuye Health Centre in 2004 in Bungoma County, Kenya

Source: Researcher, 2017

4.4 Daily Incidence of Suspected Cases of *Leptospirosis* at Webuye Health Centre

The first suspected case at Webuye Sub County Hospital was reported on 22nd May 2004. The second and third cases were reported on 24th and 25th May 2004 respectively. The three patients came from Chesamisi and Wabukhonyi areas of Kamukuywa Ward, Kimilili Sub-County. They were treated for malaria, typhoid and enteric fever. All three cases were not confirmed at the hospital.

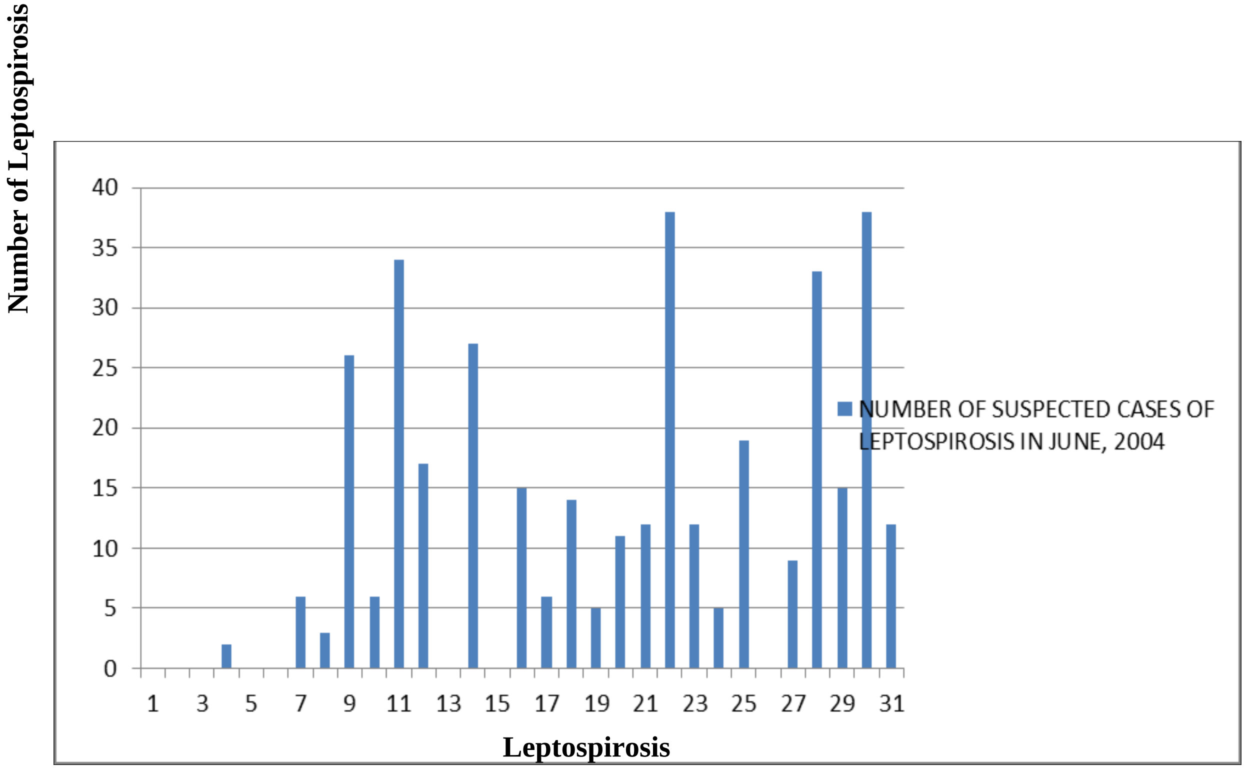
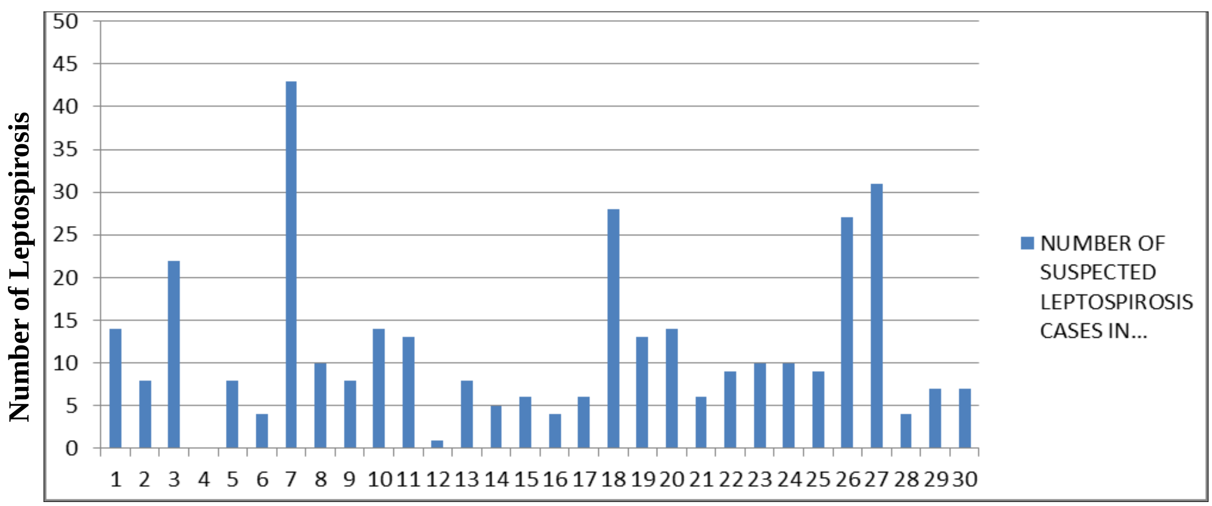


Figure 4.6: Daily incidences of suspected *Leptospirosis* cases at Webuye Health Centre, Bungoma County, Kenya in June 2004

Source: Researcher, (2017)

All five cases of 19th June 2004 were confirmed to be *Leptospirosis*.



Leptospirosis

Figure 4.7: Daily incidences of suspected *Leptospirosis* cases at Webuye Health Centre, Bungoma County, Kenya in July 2004

Source: Researcher, (2017)

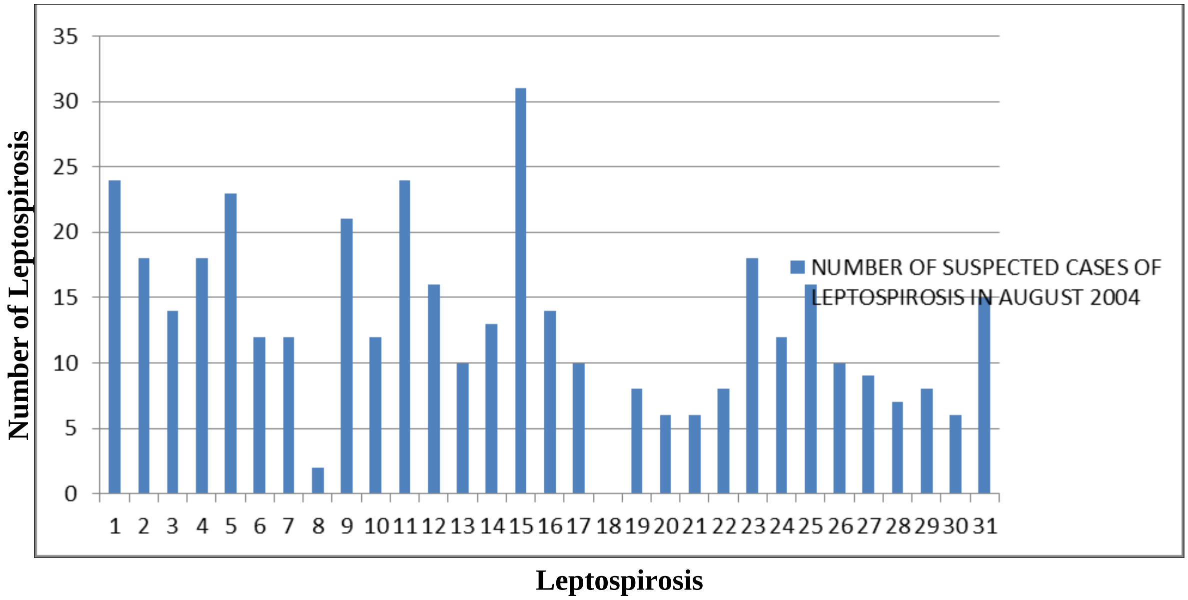


Figure 4.8: Daily incidences of suspected *Leptospirosis* cases at Webuye Health Centre, Bungoma County, Kenya in August 2004

Source: Researcher, (2017)

Plate 4.1: Researcher (first from left) with a Key Informant (second from left) and the Research Assistant (third from left).

Source: Researcher, (2017)

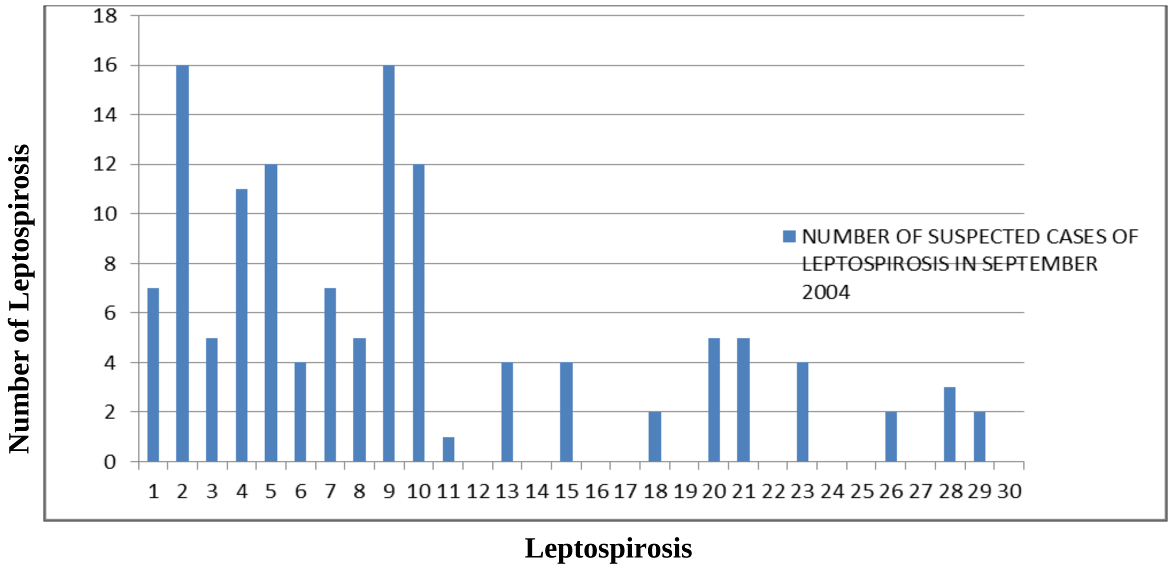


Figure 4.9: Daily incidences of suspected *Leptospirosis* cases at Webuye Health Centre, Bungoma County, Kenya in September 2004

Source: Researcher, 2017)

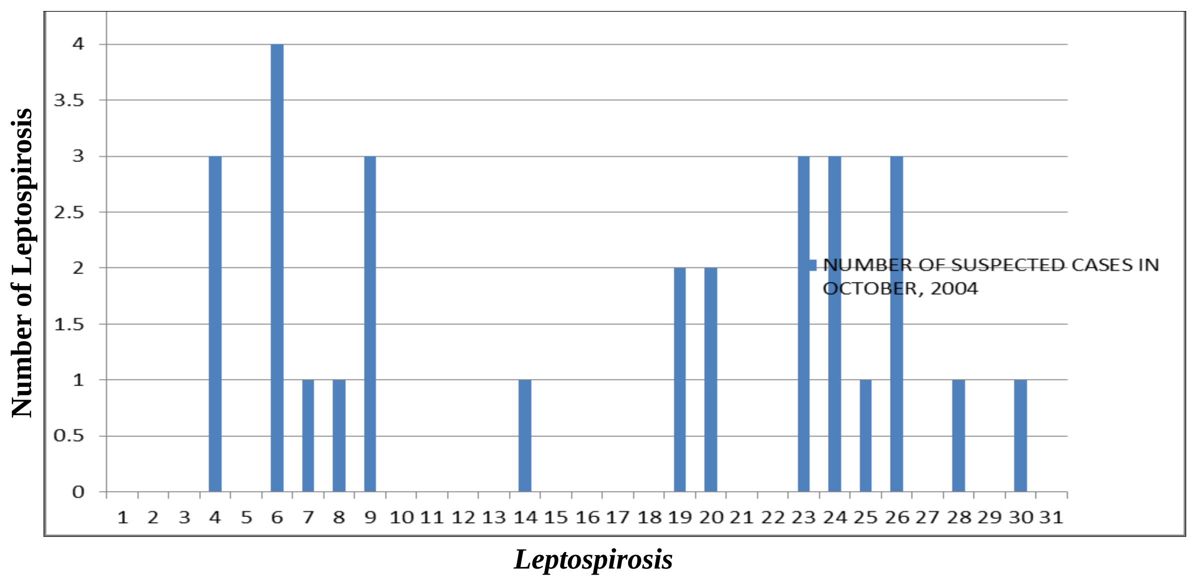


Figure 4.10: Daily incidences of suspected *Leptospirosis* cases at Webuye Health Centre, Bungoma County, Kenya in October 2004

Source: Researcher, (2017)

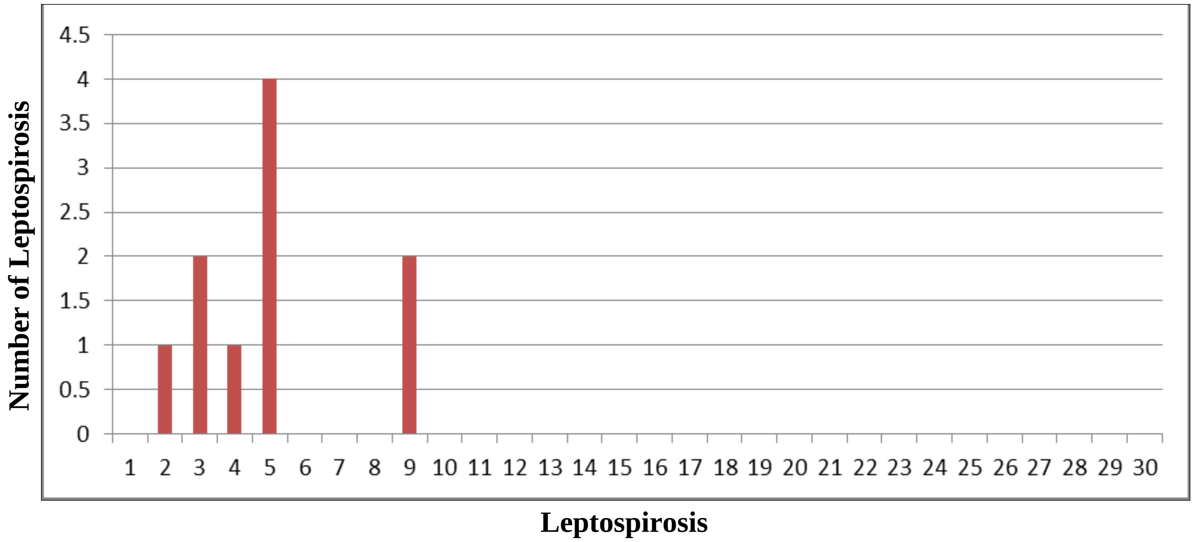


Figure 4.11: Daily incidences of suspected *Leptospirosis* cases at Webuye Health Centre, Bungoma County, Kenya in November 2004

Source: Researcher, (2017)

There were no cases of *Leptospirosis* recorded in December 2004. In Kimilili Sub-County Hospital, the first incidences were reported in April 2004 where there were 17 cases, all from Chesamisi village. This occurred at the time when students from Chesamisi High School were on holiday. The number of cases increased reaching a peak of 55 in June 2004 and thereafter subsiding to 15 cases in August 2004. There were no cases in September and subsequent months of 2004. However, in Webuye Sub-County Hospital, the first cases (three in number) were reported in May 2004, again from Wabukhonyi and Chesamisi villages in Mbongi Sub-location, Makhonge Location and Kamukuywa Ward. In June 2004, there were 353 suspected cases of *Leptospirosis* treated at Webuye Sub-County Hospital, most cases being treated for typhoid, unresolved malaria, enteric fever, meningitis and myalgia. However, the first diagnosis of *Leptospirosis* was made on 19th June 2004 and subsequently, there was a marked increase in reported cases of the disease.

Table 4.4: Origin of the cases encountered at Webuye Health Centre in June 2004, Bungoma County, Kenya

Village	Sub-County	No. of Suspected *Leptospirosis* Cases
Kamukuywa	Kimilili	4
Makhonge	Kimilili	6
Chesamisi	Kimilili	41
Kimilili	Kimilili	36
Mutukuyu	Kanduyi	1
Nandolia	Kanduyi	2
Teremi	Kabuchai	1
Namangofulo	Sirisia	1
Kaptama	Mt Elgon	1
Misikhu	Webuye West	1
Not recorded		259
Total		353

Source: Researcher, (2017)

Table 4.5: Number of suspected *Leptospirosis* reported at Webuye Hospital, Bungoma County, Kenya in July 2004

Village	Sub-County	No. of Suspected *Leptospirosis* Cases
Makhonge	Kimilili	1
Kamukuywa	Kimilili	2
Kimilili	Kimilili	5
Chesamisi	Kimilili	38
Matulo	Webuye West	10
Mbakalo	Tongaren	35
Wabukhonyi	Tongaren	5
Maliki (Maliki High school)	Tongaren	1
Trans Nzoia	Trans-Nzoia County	4
Kipkaren	Uasin Gishu County	1
Residence not recorded		259
TOTAL		361

Source: Researcher, (2017)

Of all the cases with residence recorded, the majority of the cases (45%) were from Kimilili Sub-County and Chesamisi area contributing a high proportion of the cases. At the height of the outbreak, Chesamisi High School was placed on quarantine, with restricted movement of the school community into and out of the school.

This was employed as a strategy to prevent further spread of the disease. However, six high school students and two pupils from the neighbouring Chesamisi primary school are reported to have succumbed to *Leptospirosis* (GoK, 2017). It was also reported that the six students from Chesamisi High School who succumbed violated the quarantine measures that had been imposed. This was done due to pressure from their parents who thought the school administration was not doing enough to contain the outbreak and thus they decided to seek alternative medical attention. It was also reported that a number of people from the surrounding community succumbed to the disease but the exact figure cannot be ascertained because of lack of records.

Using Focus Group Discussions, the respondents ranked the five wards on a scale of 5 to show the severity of the outbreak. A score of five (5) indicates the most severely affected and a score of one (1) indicates the least affected. The results are represented in Table 4.4. The results indicate that Kamukuywa Ward was the most severely affected (score of 24) followed by Maeni Ward (score of 20), then Kaptama (14), Kimilili (12) and Kibingei (5) in that order. This observation could not be verified through hospital records due to a lack of accurate records. In some instances, the records are totally lacking. The FGD scores on *Leptospirosis* severity during the outbreak in the wards were compared with the cattle seroprevalence report and the results show a significant correlation (0.034).

Table 4.6: Focus Group Discussions score on severity of *Leptospirosis* in affected wards of Bungoma County, Kenya

Focus Group Discussions	Kibingei	Kimilili	Maeni	Kamukuywa	Kaptama
FGD in Kibingei Ward	1	3	4	5	2
FGD in Kimilili Ward	1	3	4	5	2
FGD in Maeni Ward	1	2	5	4	3
FGD in Kamukuywa Ward	1	2	4	5	3
FGD in Kaptama Ward	1	2	3	5	4
Total Score	5	12	20	24	14

Source: Researcher, (2017)

Plate 4.2: Researcher (second from the right) while conducting a Focus Group Discussion at Kaborom village, Kaptama Ward, Mt.Elgon Sub-County, Bungoma County, Kenya

Source: Researcher, (2017)

Further examination of records at Kimilili and Webuye health facilities reveals that there has been no other report of suspected *Leptospirosis* cases in humans between the period 2000 and 2010. *Leptospirosis* does not feature among the top ten causes of morbidity and mortality in Bungoma County (Table 2.5). It is therefore necessary to carry out laboratory tests to confirm cases presented to rule out *Leptospirosis* which presents similar signs as malaria, typhoid and meningitis among other diseases.

CHAPTER FIVE

RISK FACTORS FOR *LEPTOSPIROSIS* IN BUNGOMA COUNTY, KENYA

5.1 Introduction

This chapter explores the risk factors that contribute to the re-emergence of *Leptospirosis* in humans in Bungoma County. The risk factors contributing to the perceived re-emergence or fluctuations of *Leptospirosis* prevalence are not completely understood (Silvania *et al*., 2017). There are a number of factors which are considered to have a role in the occurrence of *Leptospirosis* including the following: - living within urban and peri-urban areas (Bradley and Lockaby, 2023), flooding events (Ward, Kummu and Lall, 2016), contact with infected wild and domestic animals (Ward *et al*., 2016). less than ideal socio-economic conditions in areas where dogs reside [Dias *et al*., 2007), poor hygiene, the presence of rodents, the presence of potential pets as reservoirs and flood history (Tassinari and Pellegrini, 2008). The risk factors considered in this study include: - the weather patterns, the grazing and watering system, the level of awareness of livestock farmers about *Leptospirosis*, the handling of slaughtered animals and the level of interaction with extension staff.

5.2 Weather Patterns

Leptospirosis outbreak is associated with elevated rainfall patterns (Munoz and Jarquin, 1995; MandH articles, 2010; Lau *et al*., 2010). The annual rainfall pattern for Kimilili and Mt. Elgon sub-counties for the period 2000-2010 was obtained from the County Director of Meteorological services-Bungoma County (Bonzemo, Olago, Olaka, and Amwata, 2023). Thereafter, the monthly distribution of the rainfall was tabulated and used to relate with the time of disease outbreak in the study area of Kimilili and Mt Elgon Sub-Counties of Bungoma County.

Analysis of the annual rainfall patterns shows that the highest rainfall in Kimilili Sub-County was recorded in 2006 which recorded 1849mm followed by 2010 (1774mm) then 2007 with 1691mm. The amount of rainfall recorded in 2004 was 1272mm. The annual rainfall in Bungoma County ranges between 400mm (lowest) and 1,800mm (highest). Figures 5.1 and 5.2 indicate that the annual rainfall for the year 2004 falls within the range of 400mm and 1,800mm.

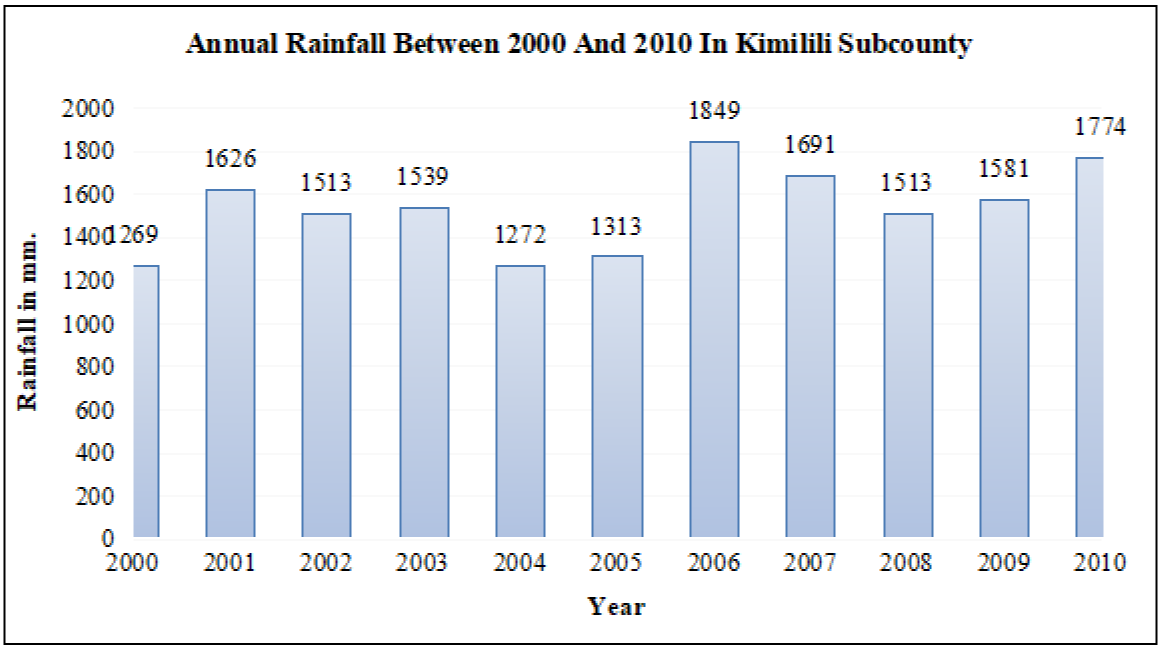


Figure 5.1: Annual rainfall in Kimilili Sub-County over the period 2000 and 2010, Bungoma County, Kenya

Source: Researcher, (2017)

A similar pattern is observed in the amount of rainfall recorded in Mt Elgon Sub-County where the highest amount of rainfall was recorded in 2006 followed by 2010 and 2007 respectively.

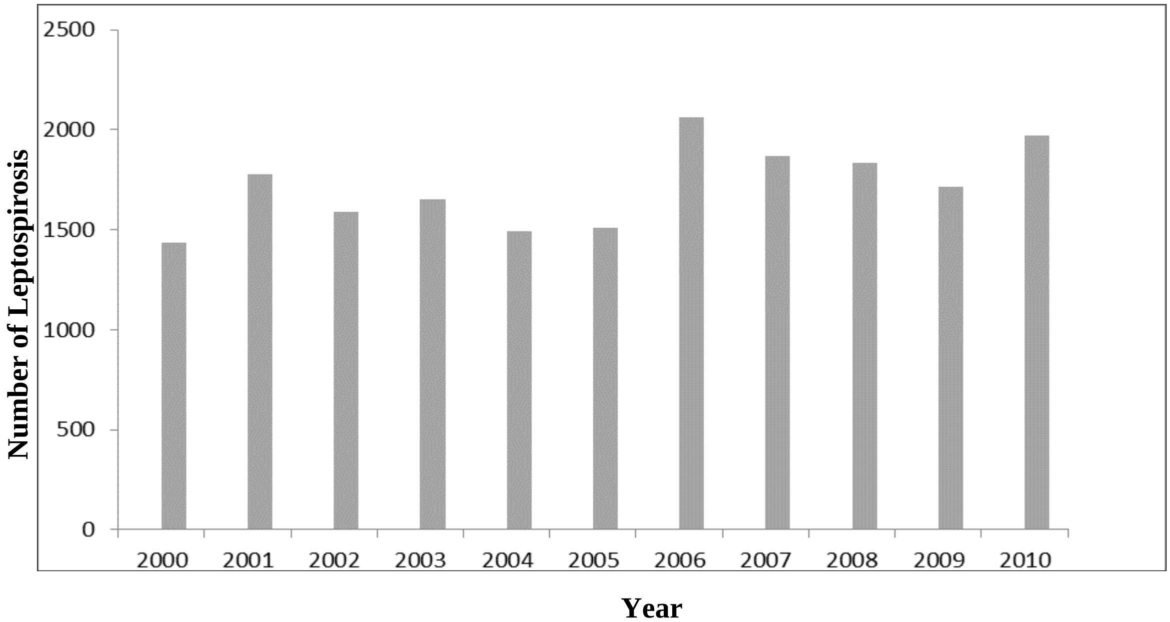


Figure 5.2: Annual rainfall in Mt. Elgon Sub-County between 2000 and 2010

Source: Researcher, (2017)

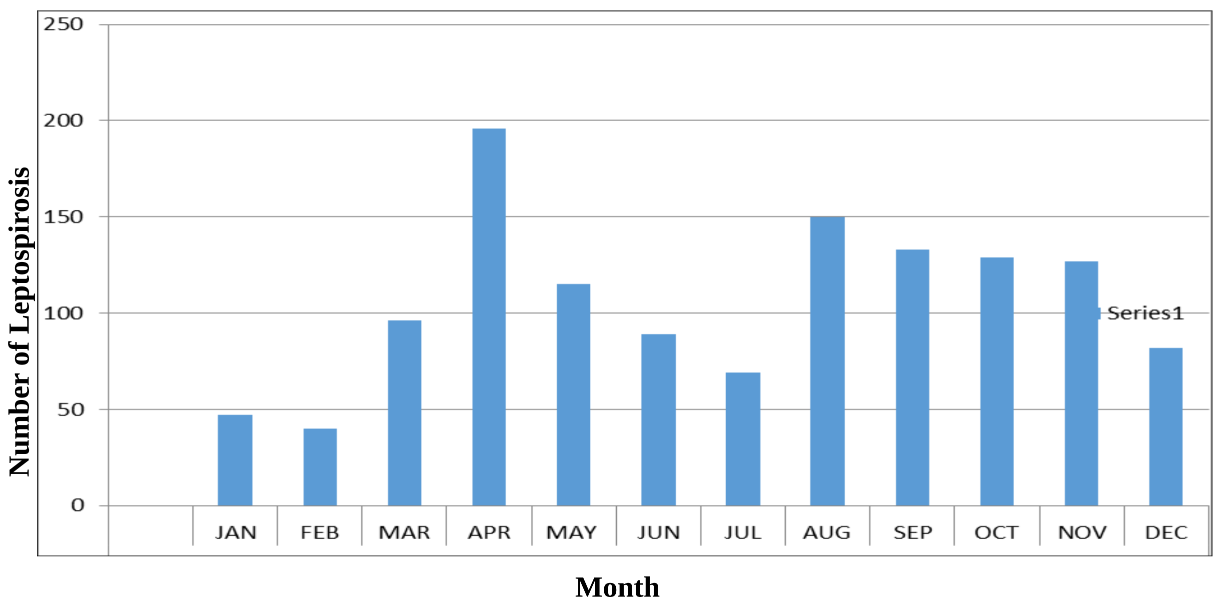
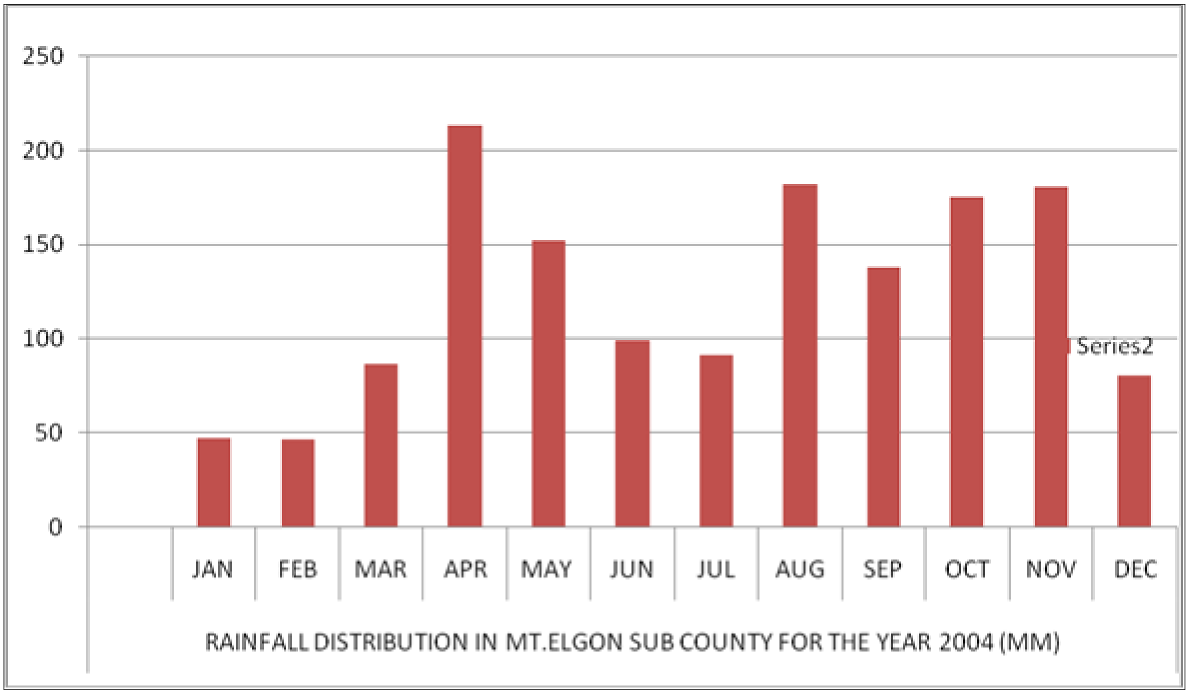


Figure 5.3: Monthly rainfall pattern for Kimilili Sub-County in 2004, Bungoma County, Kenya

Source: Researcher, (2017)

The monthly rainfall in both Kimilili and Mt Elgon Sub-Counties shows that the highest rainfall was recorded in the month of April 2004 which then went down up to July before increasing (Figures 5.3 and 5.4).



Month

Figure 5.4: Monthly rainfall pattern for Mt. Elgon Sub-County in 2004 in Bungoma County, Kenya

Source: Researcher, (2017)

The first suspected case of *Leptospirosis* was reported in Kimilili in April 2004 which also coincided with the onset of the rainy season. In both Kimilili and Mt. Elgon Sub-Counties, the highest rainfall occurred in April 2004. A Pearson Correlation analysis was done to determine the relationship between monthly rainfall and the corresponding number of cases and results presented in Table 5.1.

Number of Leptospirosis

Table 5.1: Pearson Correlation between monthly rainfall and the corresponding number of suspected *Leptospirosis* cases at Kimilili Hospital, in Kimilili Sub-County, Bungoma County, Kenya

		Cases	**Rainfall**
Cases	Pearson Correlation	1	0.043
	Sig. (2-tailed)		0.894
	N	12	12
Rainfall	Pearson Correlation	0.043	1
	Sig. (2-tailed)	0.894	
	N	12	12

Source: Researcher, (2017)

The Pearson Correlation of 0.894 shows that there was no significant association between rainfall pattern and number of *Leptospirosis* cases. It is of interest to note that the patients presenting themselves at the health centres, were treated for diseases such as malaria, typhoid, meningitis and enteric fever. No efforts were taken to undertake laboratory diagnosis. However, the FGD findings revealed that there was relatively heavier rainfall resulting in flooding of many parts of the study area especially in the surrounding swampy areas due to poor drainage.

This provides a conducive environment for *Leptospirosis*, which is also called "swamp fever." The FGD and Key Informant Interviews revealed that the high rainfall resulted in the contamination of food. It is also logical that increased rainfall and the poor drainage system in the area result in floods causing contamination of water sources. Depending on water sources for the households and public institutions in the study area, there are poor sanitation and hygienic standards fall resulting in waterborne diseases including *Leptospirosis*. *Leptospirosis* is strongly associated with heavy rainfall (Gaynor *et al*., 2007; Kawaguchi *et al*., 2008, De Vries *et al*., 2014).

Flooding assists in the spread of the disease (Wasinski and Dutkiewcz, 2013; De Vries *et al*., 2014). It was estimated in Brazil, that for each millimetre increase in maximum daily rainfall for the month above the average for the study area, there was an increase of 0.55% in the number of *Leptospirosis* cases relative to the average for that period (Kupek *et al*., 2000). Oliveira *et al*., (2001) have also demonstrated a positive correlation between rainfall and *Leptospirosis* outbreak. This means that one of the issues to be considered is the management of the drainage systems to avoid flooding and also the treatment of water for human consumption to avoid *Leptospirosis* outbreaks in future.

5.3 Livestock species kept in the study area

The study shows the livestock species kept by the households. All the households keep livestock, 88% keep cattle, 8.2% keep sheep and 2.3% keep other livestock which include pigs as shown in Figure 5.5.

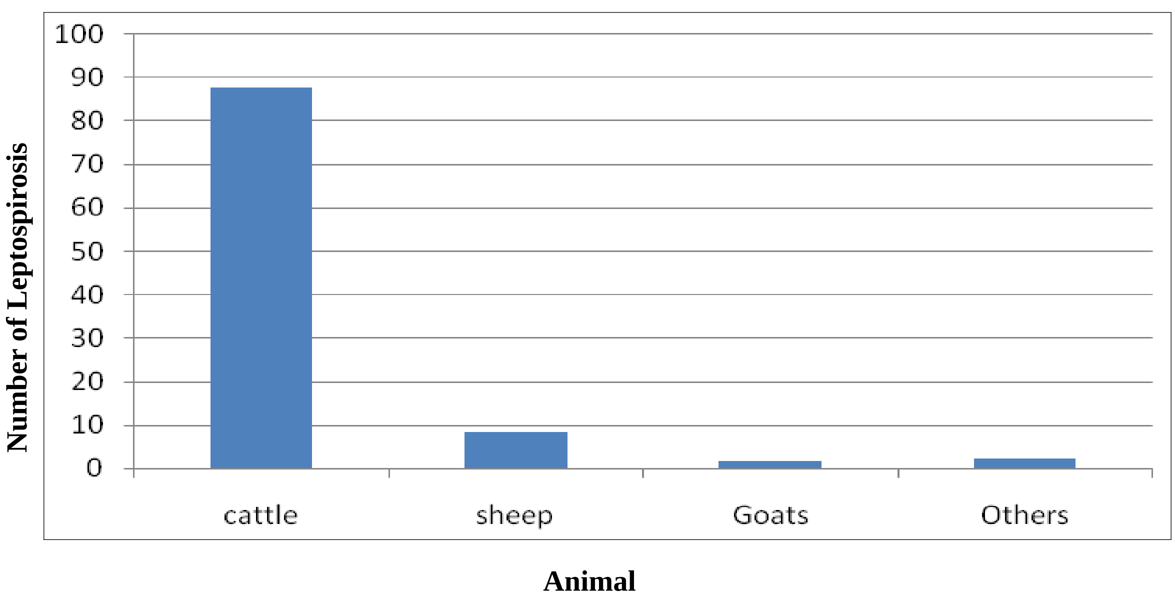


Figure 5.5: Livestock species kept in Kimilili Sub-County and Kaptama Ward of Mt Elgon sub-County, Bungoma County, Kenya expressed as a percentage

Source: Researcher, (2017)

This finding implies that the majority of the households in the study area rear cattle (87.9%) followed by sheep (8.2%) and goats 1.5%. Evidence for carriage of *Leptospirosis* has been demonstrated in all mammalian species which include the domestic animals. (Mgode *et al*, 2014). Livestock keeping makes the residents come in direct contact with animals thereby increasing chances of contamination with urine during routine animal husbandry practices such as cleaning pens, milking and assisting the animals during delivery. Kamath, Swain, Pattanshetty and Nair (2014) identified rearing of domestic animals at home as a risk factor for *Leptospirosis*. Studies in Indonesia have demonstrated that there is a significant association between contact with domestic animals and *Leptospirosis* infection in humans (Sakundarno, 2014).

The livestock species kept were subjected to a Chi-Square test and gave (X^2 = 8.22E2$^{\alpha}$) showing highly significant ($P < 0.001$) variation in their livestock species kept in the region. Given that all the livestock species have a role to play in the transmission of *Leptospirosis*, the study suggests that there is a possibility of other livestock species being a source of risk for *Leptospirosis*.

5.4 Other domestic animals kept

The other domestic animals which could contribute to a high risk for *Leptospirosis* were identified as indicated in Figure 5.6. The figure shows that 59.8% of the households reported to have kept dogs, 27.8% keep cats, 4.6% keep other domestic animals such as donkeys; while the remaining 7.7% of the respondents said they do not keep any other domestic animals.

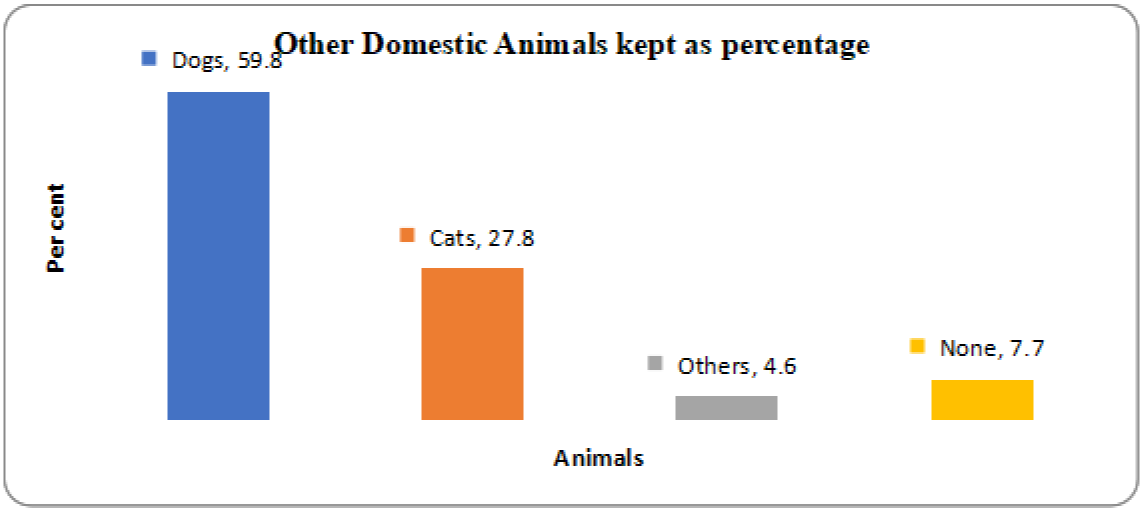


Figure 5.6: Other domestic animals kept in the study area, Bungoma County, Kenya

Source: Researcher, (2017)

A Chi-square test on other domestic animals was given (X^2 =2.998E2$^{\alpha}$) showing a highly significant (P< 0.01) variation in the distribution of other domestic animals kept in the region. This finding implies that other domestic animals could contribute to the high risk for *Leptospirosis* infection. Tilahun *et al*. (2013) has shown that dogs and cats are important reservoirs of *Leptospirosis* and act as a source of infection in humans. In another study conducted in Indonesia, it was demonstrated that even though dogs and cats are important reservoirs of *Leptospirosis*, they played a marginal role in disease transmission because only a few people kept the pets (Evangelista and Coburn, 2010). The relationship between knowledge of *Leptospirosis* and the keeping of other domestic animals was determined. Results reveal that the keeping other domestic animals such as dogs, cats and donkeys plays a marginal role (P>0.05) in determining knowledge of *Leptospirosis*.

5.5 Grazing systems

The study identified the common grazing systems in the study area and the results are presented in Figure 5.7.

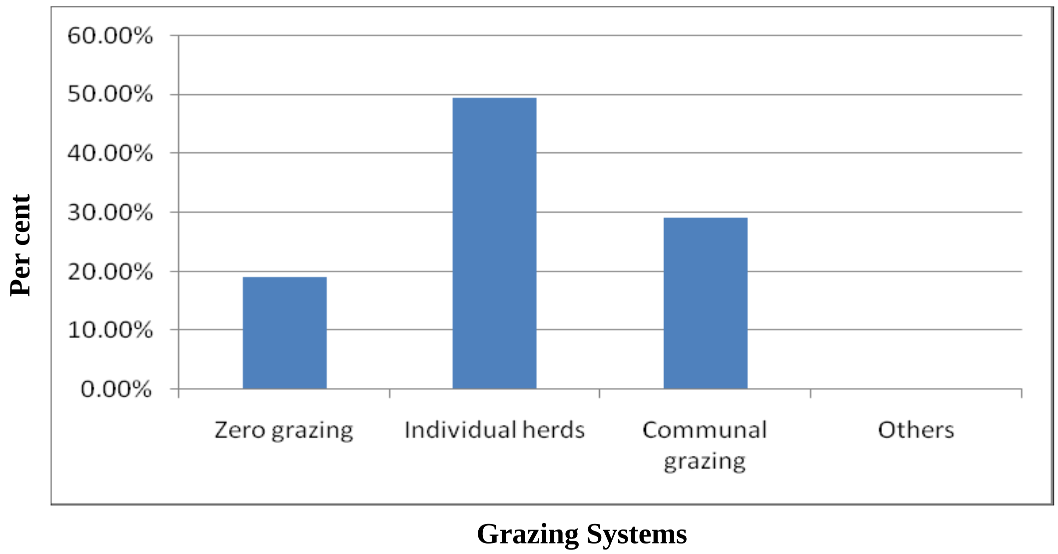


Figure 5.7: Grazing systems in Kimilili and Mt Elgon Sub-Counties, Bungoma County, Kenya

Source: Researcher, (2017)

From Figure 5.7, the households gave the common grazing systems in the study area. Most of the households practice individual herding at 49.5%, where the cattle graze in the open fields but they are not allowed to mix with herds from other households. Another 19.1% reported using zero-grazing where animals are confined in a small unit where grass and water are provided, 29.1% reported communal grazing; while the remaining 2.3% reported other forms of grazing systems such as semi-zero grazing. This study reveals that communal grazing is a common practice among the residents whereby animals from different households converge and mix freely on a grazing field.

A Chi-square test was subjected to the grazing system giving (X^2 =1.810E2$^{\alpha}$) and showed highly significant (P<0.01) distribution of grazing systems. Communal grazing is a risky practice because it is easy to introduce and spread disease in a clean herd. Nanyende (2010), in a study on brucellosis, demonstrated that cattle grazed communally are nine times more likely to contract the disease compared to those grazed individually.

5.6 Livestock watering system at the study site, Bungoma County, Kenya

The watering system of livestock in the study area is shown in Figure 5.8.

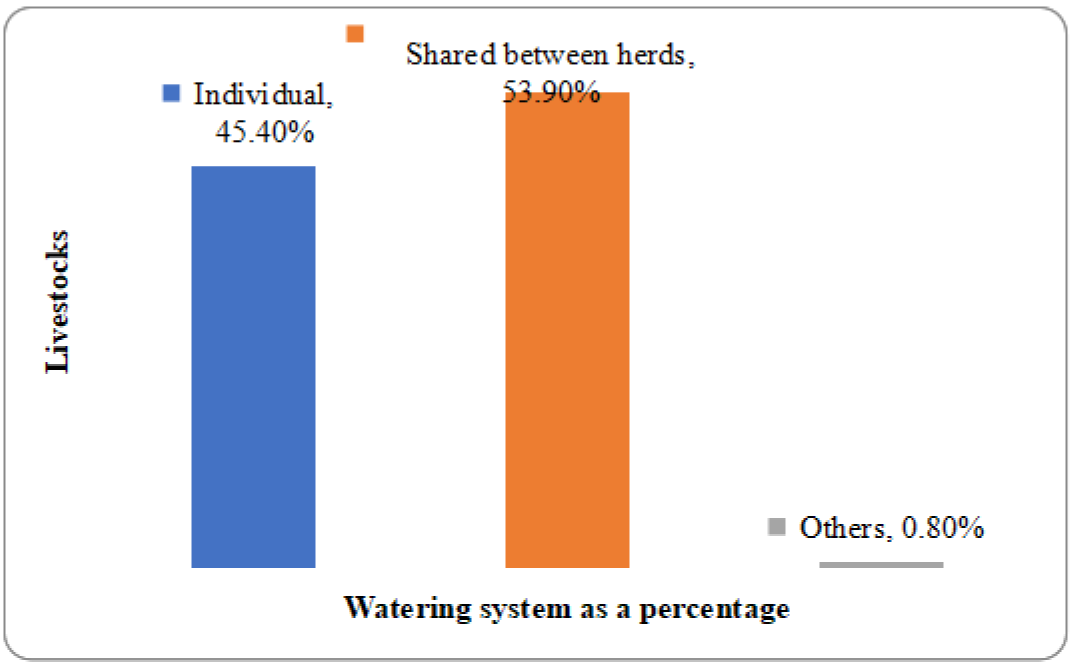


Figure 5.8: Watering systems in the study area

Source: Researcher, (2017)

Figure 5.8 shows that most of the households (53.9%) reported the use of shared watering points for their animals, 45.4% reported having individual herd watering points; the remaining 0.8% of the respondent reported other forms of watering such as fetching water from the rivers and taking to their herds.

It was also noted that a high proportion of households using individual herding systems were using watering systems which involve sharing between herds which still increases the risk of disease spread across herds. A Chi-square test of the watering system was found to be highly significant (X^2 =1.893E2$^{\alpha}$, P<0.01). Rivers have been shown to present a risk for *Leptospirosis* where the river water acts as a medium of *Leptospirosis* transmission (Evangelista and Coburn, 2010).

The vegetation on the river banks and its outskirts can be prone to flooding and are likely to be habitats for rodents thereby increasing the chances of *Leptospirosis* transmission (Rejeki *et al*., 2013). Plate 5.1 shows a communal watering point in Kimilili Sub-County where animals from different households take water. This practice is likely to introduce infections to clean herds.

Plate 5.1: A communal watering point at Namawanga village, Kibingei Ward being shared between livestock and humans in Kimilili Sub-County, Bungoma County, Kenya

Source: Researcher, (2017)

5.7 Rodent infestation

The study showed that 92.3% of all the households reported to have rodent infestation in their houses while 7.7% did not have the menace. Rodents are believed to be the most important primary reservoirs for a variety of *Leptospir*a serovars (Halliday, 2013). Indeed, rats are considered the major rodent reservoirs of *Leptospirosis* (Himsworth *et al*., (2013). Various studies conducted in different parts of the world such as Brazil, France and Indonesia have demonstrated a strong link between *Leptospirosis* in humans and rodents (Sarkah *et al*., 2002; Farida and Ristiyanto, (2008); Febrian and Solikhah, (2013) and Dupouey *et al*., (2014). A Chi-square test was subjected to rodent infestation and gave X^2 = (1, 0.01) implying that there is no significant variation (P>0.05) in the infestation of rodents among the respondents in Kimilili and Mt Elgon Sub-Counties, Bungoma County, Kenya.

Figure 5.9 shows the frequency of rodent infestation amongst households in the study area.

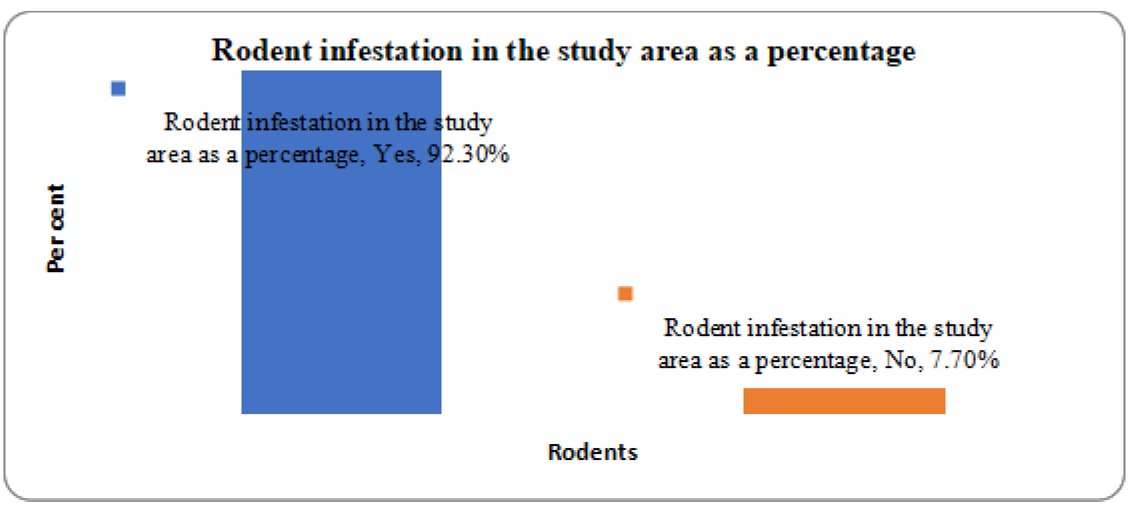


Figure 5.9: Rodent infestation among respondents in Bungoma County, Kenya

Source: Researcher, (2017)

Kamath *et al*. (2014) have shown that contact with rodents through using food materials which had been eaten by rats and contact with soil, water and food especially contaminated with the urine of rats is an important risk factor for *Leptospirosis*. When the relationship between rodent infestation and knowledge of *Leptospirosis* was worked out, it was observed that rodent infestation was not significant (P=0.638). This observation is corroborated from FGD which reveals that most households cannot tell any relationship between rodent infestation and *Leptospirosis* disease.

5.8 Slaughter of livestock at home

Slaughter of livestock at home is a common practice in the study area. Figure 5.10 shows that 83.8% of the households slaughter their livestock at home for consumption. FGDs revealed that the following occasions provided opportunities for the slaughter of livestock at home: - circumcision ceremonies, wedding ceremonies, funerals and very weak animals which are on the verge of death are slaughtered as a way of salvaging them. A Chi-square test revealed that the number of those slaughtering their livestock at home is highly significant (P<0.01) compared to those presenting their livestock for slaughter at designated slaughtering points (X^2 =176.918$^{\alpha}$).

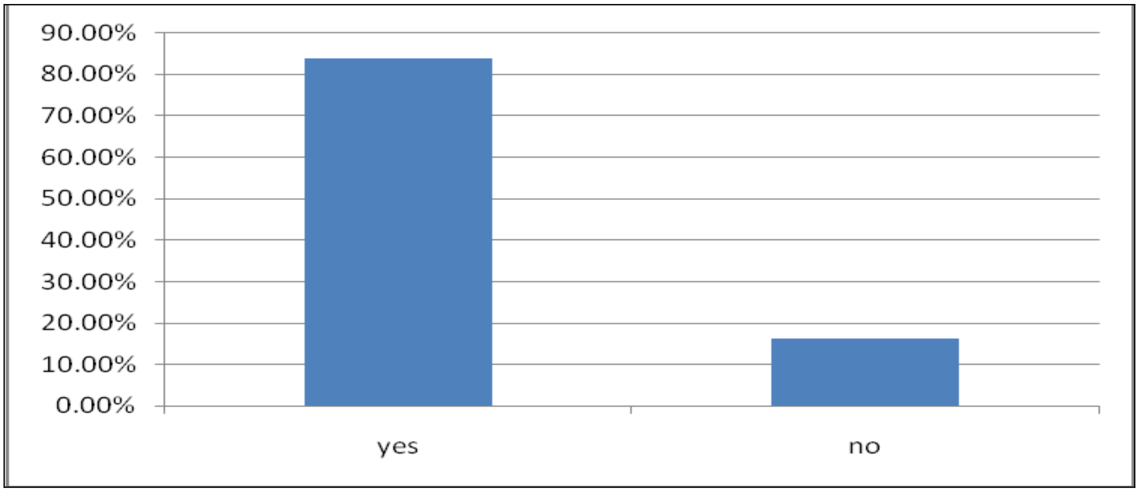


Figure 5.10: Slaughter of livestock at homes in Kimilili and Mt Elgon Sub-Counties, Bungoma County, Kenya

Source: Researcher, (2017)

Slaughter of livestock at none designated areas provides an avenue for the spread of zoonotic diseases such as *Leptospirosis* (Nanyende,2010). Amongst all the Households who slaughtered their livestock at home, only 1.5% had the meat inspected while the remaining 83% did not make any effort to have the meat inspected (Figure 5.11).

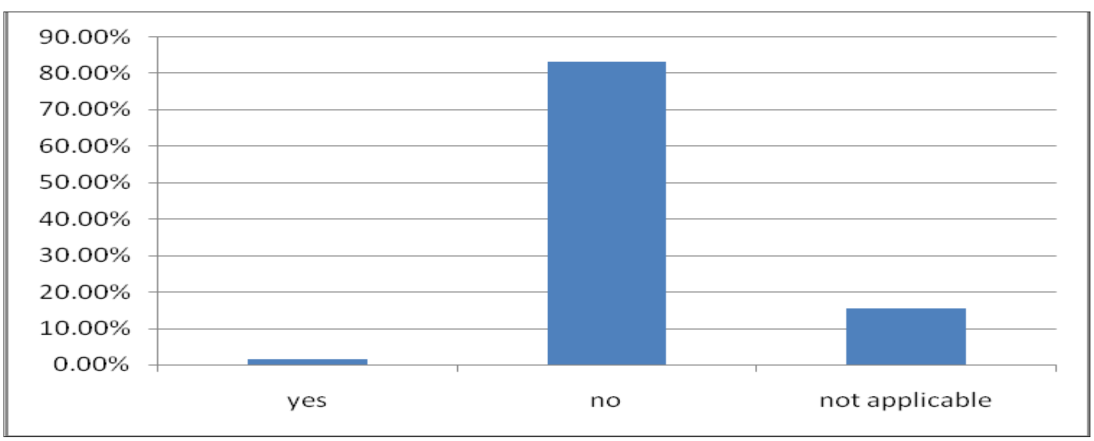


Figure 5.11: Frequency of meat inspection on animals slaughtered at home in Kimilili and Mt Elgon Sub-Counties, Bungoma County, Kenya

Source: Researcher, (2017)

A Chi-square test on the meat inspection variable revealed that there is a highly significant difference between those having meat inspected before consuming compared to those not presenting animals for inspection prior to slaughter points (X^2 =4.418E2$^{\alpha}$ and significance level of 0.000 at 2 degrees of freedom). Studies have demonstrated that people who slaughter animals have a high risk for *Leptospirosis*. They have contact with the viscera through cleaning of offals. The risk for *Leptospirosis* is most likely due to intimate contact with infected organs, poor personal hygiene, having wounds, eating and smoking while slaughtering and lack of protective clothing such as gumboots, aprons and gloves (Cook *et al*., 2017).

5.9 Level of contact between farmers and veterinary extension staff at the study site, Bungoma County, Kenya

The level of contact of the households with extension staff is provided in Figure 5.12. 63.7% of the households reported none or rare which denotes less than two visits in the last one year.

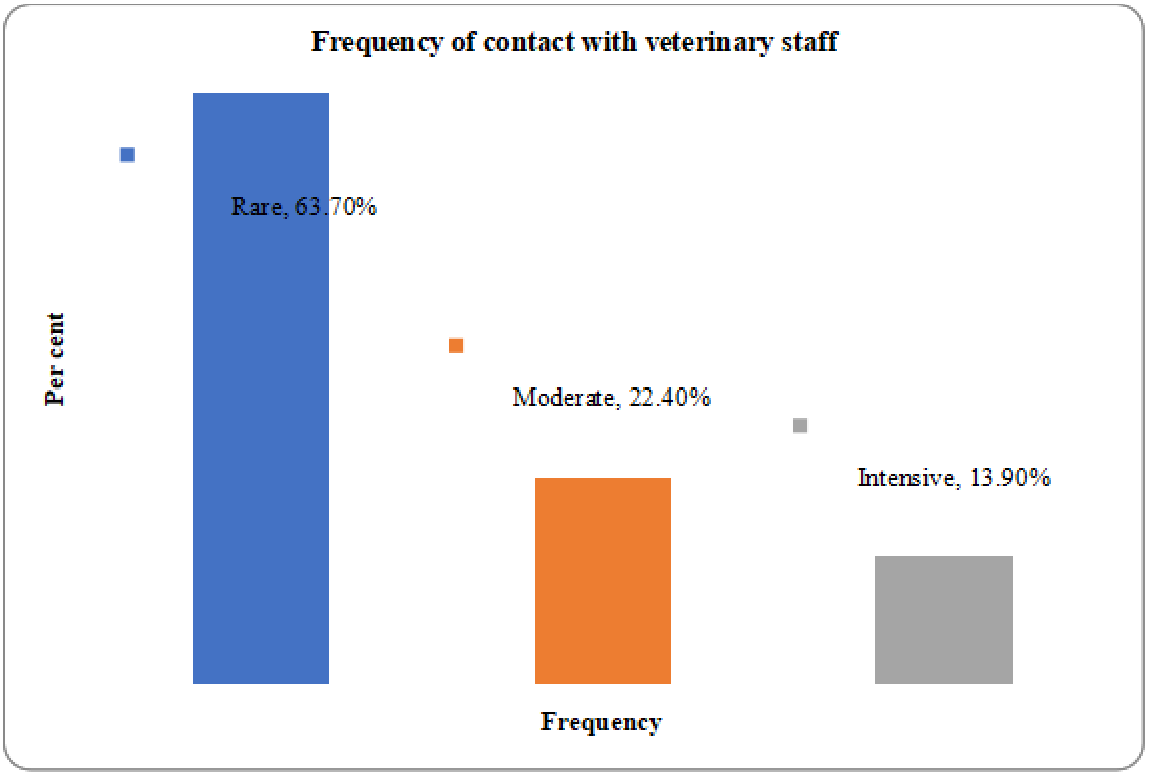


Figure 5.12: Frequency of contact of the households with veterinary staff in Kimilili and Mt Elgon Sub-Counties, Bungoma County, Kenya

Source: Researcher, (2017)

A Chi-square test showed that the level of contact between respondents and veterinary extension staff has a highly significant variation (X^2 =164.789$^{\alpha}$). Veterinary extension staff provide an avenue of reaching out to the farmers and informing them about common diseases and their management. Only 13.9% of the households reported intensive contact with extension staff which corresponds to more than four contacts in the last one year. The remaining 22.4% of the households recorded moderate contact with extension staff which corresponds to three to four contacts in the last one year. The limited contact between veterinary extension staff and farmers explains the poor knowledge and understanding of *Leptospirosis* and other livestock diseases in the study area.

Further probing revealed that households reporting moderate and intensive contact with extension staff occurred in 2014-2017 during the implementation of agricultural projects.

5.10 Livestock movement

Livestock movement is an important avenue for spreading diseases. Diseases are spread when sick animals are moved from place to place and mixed with healthy animals. Animal movements occur as the animals are taken to markets, slaughterhouses, for breeding purposes or in search of pastures. There are many active livestock markets in Bungoma County. Figure 5.14 shows the major stock routes in Bungoma County. The Key Informant Interviews revealed that the main source of livestock for the local market is Turkana, West Pokot, Trans Nzoia and Uasin Gishu. The animals are then transported across the many livestock markets and eventually into the neighbouring counties of Busia, Kakamega and even Uganda. The Key Informant Interviews revealed that during circumcision years, animals are for use during circumcision ceremonies and are sourced from West Pokot because they are considered cheap. Studies have shown that *Leptospirosis* is prevalent in Turkana and therefore the need for extra vigilance on animals originating from there (Macharia, 1989).

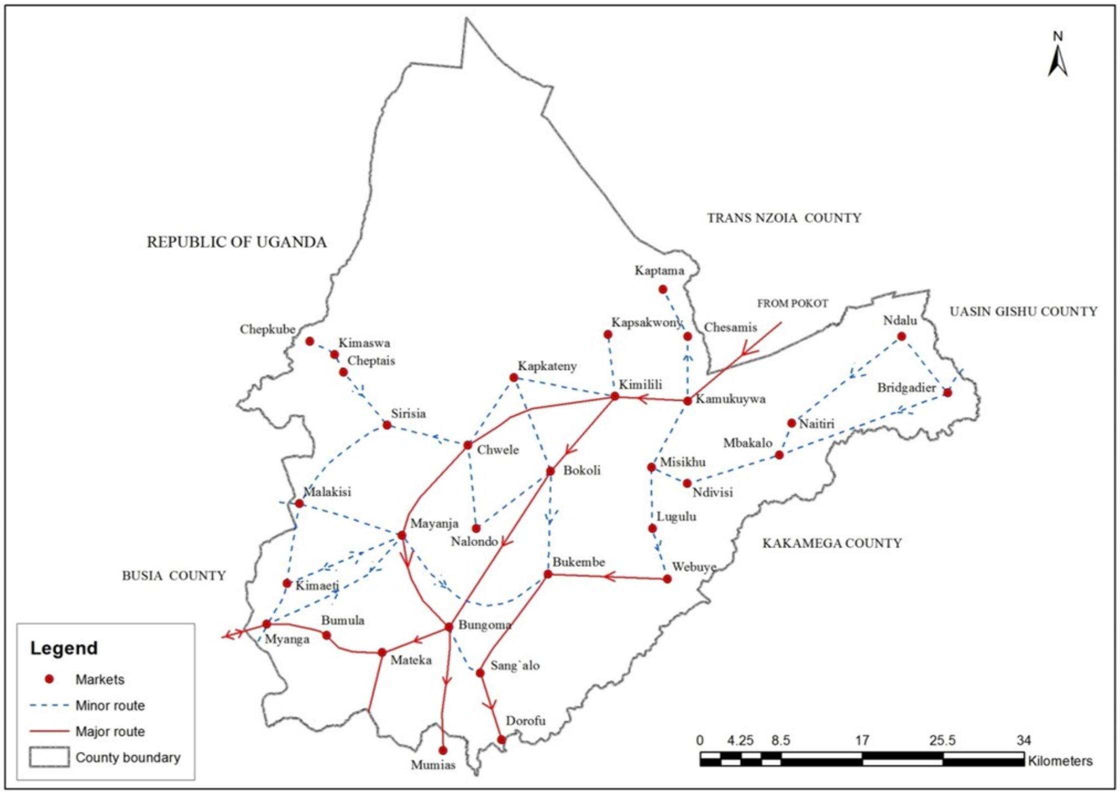


Figure 5.13 Livestock routes and markets in Bungoma County, Kenya

Source: Situma, (2016)

Figure 5.13 indicates that the active livestock markets are spread throughout the county. It is also known that animals can be moved across the many livestock markets by middlemen. Once the infection is introduced, there is a high possibility of spreading further throughout the county through the different livestock markets. The major livestock markets in the county include the following Kimilili, Kamukuywa, Chwele, Bungoma, Bokoli, Mayanja, Webuye, Bukembe, Mateka and Myanga (Table 5.2). The main sources of livestock for the markets are Trans Nzoia, West Pokot, Turkana, Uasin Gishu and Uganda (CDVS Annual Report, 2017). The major livestock (cattle, sheep and goats) are transported mainly on hoofs to the markets (CDVS Annual Report, 2017). Plate 5.2 shows one of the active livestock markets in the study site.

Table 5.2: Livestock Market Days in Bungoma County, Kenya

Name of Market	Market days
Mateka, Malakisi,Mbakalo, Chwele	Mondays
Mayanja Bitunguu, Sang'alo, Kamukuywa,Bokoli	Tuesdays
Dorofu,Myanga,Sirisia, Chebukwabi,Webuye,Ndalu,	Wednesdays
Nalondo, Kimilili,Kimaswa	Thursdays
Municipal, Lugulu,Tongaren, Cheptais, Chwele	Fridays
Kapkateny, Naitiri	Saturdays
Misikhu	Sundays

(**Source:** Situma, 2016)

Plate 5.2 Kimilili livestock market, Bungoma County, Kenya

Source: Researcher, (2017)

5.11 Role of bats in *Leptospirosis* disease incidence

During the study period, it was observed that there were many bats in Kimilili area (Plate 5.3 and 5.4). It was reported that they had moved from around Chwele. It was not clear as to what made them move. It has been established that bats are known reservoirs of *Leptospirosis* (Matthias *et al*., 2005; Tulsiani *et al*., 2011, Mgode *et al*., 2014).

Studies have also shown that bats which share habitats with humans increase the potential risk of transmitting *Leptospirosis* in humans (Daszak *et al*., 2000; Calisher *et al*., 2006; Mühldorfer, 2013). The role of bats in the seroprevalence of *Leptospirosis* was not however established.

Plate 5.3: Bats roosting on a tree at the Kimilili Sub-County, Bungoma County, Kenya

Source: Researcher, (2017).

Plate 5.4: Bats at Kimilili Sub-County office, Bungoma County, Kenya
Source: Researcher, (2017)

In conclusion, knowledge of the local risk factors for *Leptospirosis* is key to implementing an effective control and prevention programme. The risk factors under consideration in this study were observed in over 80% of the population.

5.12 *Leptospirosis* surveillance data at the Regional Veterinary Investigations Laboratory-Eldoret, Kenya

Data for surveillance on *Leptospirosis* was collected at the Regional Veterinary Investigations Laboratory-Eldoret and presented in Table 5.3. Samples were collected from Trans Nzoia, Uasin Gishu, Elgeyo Marakwet and Nandi counties and tested at the Central Veterinary Laboratories-Kabete. The samples were collected from animals suspected to be infected with *Leptospirosis*. Positive laboratory results were reported in 2007 from cattle on a farm at Ziwa, Uasin Gishu County.

Table 5.3: *Leptospirosis* surveillance records at Veterinary Investigations Laboratory- Eldoret, Kenya

	Year/Month	Location	County	Species	Results
1	November, 2007	ADC Katuke, Sabwani and Olgatongo.	Trans Nzoia	Bovine	Negative
2	November, 2007	Endebess, Chepchoina	Trans Nzoia	Bovine	Negative
3	November, 2007	Ziwa	Uasin Gishu	Bovine	Positive
4	May, 2008	Cherengany	Trans Nzoia	Bovine	Negative
5	May, 2008	Rimoi, Chepsigot	Elgeyo Marakwet	Caprine, Bovine	Negative
6	September, 2008	Lelmokwa	Nandi	Bovine	Negative
7	May, 2010	Ngeria	Uasin Gishu	Bovine	Negative
8	May, 2010	ADC Japata	Trans Nzoia	Bovine	Negative

Source: Researcher, (2017)

The findings from the laboratory reports conform with the Key Informant Interviews which showed that suspected cases of *Leptospirosis* are common in Trans Nzoia County. Positive cases in the North Rift region (Trans Nzoia, Uasin Gishu, West Pokot and Turkana) pose a serious threat to Bungoma County due to the livestock movement pattern.

CHAPTER SIX

KNOWLEDGE, ATTITUDE AND PRACTICES ASSOCIATED WITH *LEPTOSPIROSIS* AMONGST THE LOCAL COMMUNITY IN BUNGOMA COUNTY, KENYA

6.1 Introduction

The chapter assesses the knowledge, attitude, traditional beliefs and behavioural practices of the community in the study area with regard to *Leptospirosis*. This study collects information on what is known, believed and done in relation to *Leptospirosis*. The basis of this chapter is to identify knowledge gaps, cultural beliefs and practices that exacerbate disease or pose barriers to *Leptospirosis* control strategies. This is also important in designing targeted awareness campaigns and providing baseline information for planning and implementing *Leptospirosis* control strategies. The study provides appropriate information which in turn leads to behavioural change thereby saving lives from the risk of contracting *Leptospirosis*.

6.2 Demographic Characteristics of the Households

The study sought to establish the background information of the household heads and how this may affect the knowledge, attitude and practices with respect to *Leptospirosis*. The study was conducted on 388 households, all giving a response rate of 100%. The following household characteristics were considered in the study; gender, age, formal education level, occupation, marital status and size of the household. In addition, the size of each household was established.

6.2.1 Gender of Household Heads

The results on gender distribution among the respondents in each household showed that 54.9% were male while 45.1% were female, N=388 (Table 6.1).

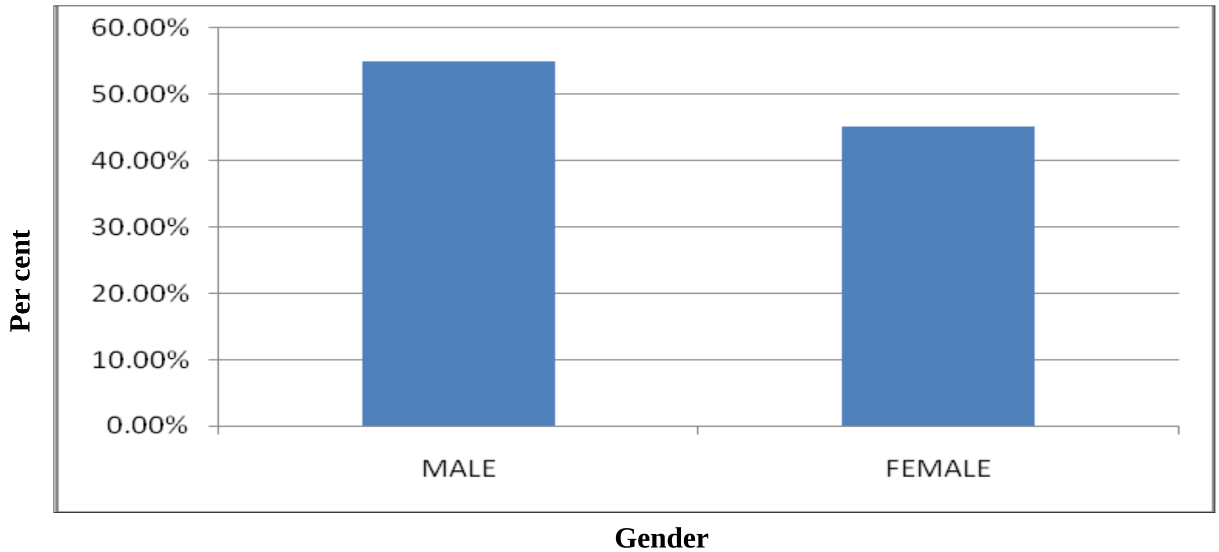


Figure 6.1: Gender distribution of the household heads in Kimilili and Mt Elgon Sub-Counties, Bungoma County, Kenya

Source: Researcher, (2017)

This is in agreement with the findings of Wabwoba (2013) which showed that many households in Bungoma County are headed by males. A Chi-square test was performed and gave $X^2 = 3.722^{\alpha}$ and a significance level of 0.054 at 2 degrees of freedom

6.2.2 Age distribution of household heads

The household heads were asked to state their ages in years and Figure 6.2 gives the summary of their percentage age distribution (N=388). A Chi-square test on this variable gave $X^2 = 76.763^{\alpha}$ and showed highly significant variation in age groups ($P<0.05$).

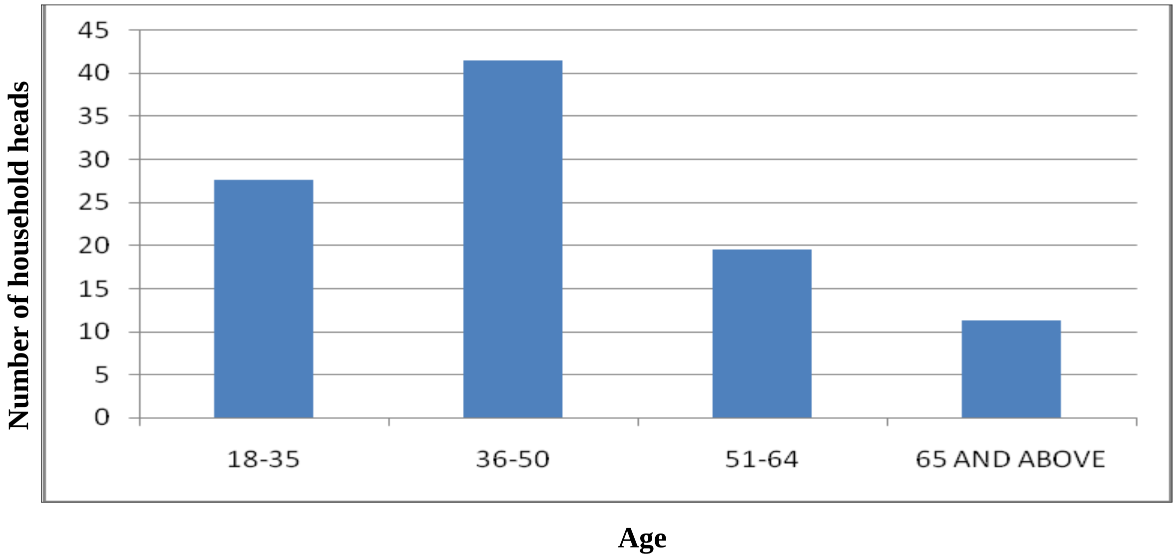


Figure 6.2: Percentage age distribution of household heads in Kimilili and Mt Elgon Sub-Counties in Bungoma, Kenya

Source: Researcher, (2017).

6.2.3 Level of formal education of the household heads

The household heads were asked to state their level of formal education. A small proportion of the household heads (6.2%) had not attained any formal education but the highest percentage of the household heads (36.6%) had attained primary level education. The FGD and Key Informants pointed out that were those that fell in the age bracket of 60 and above. It was noted that even without formal education, they were relied upon as opinion leaders on important issues and decisions in their respective communities. The formal education level of household heads is shown in Figure 6.3, (N=388). A Chi-square test showed that the educational groupings were highly significant (X^2 =137.979$^{\alpha}$ and P<0.01).

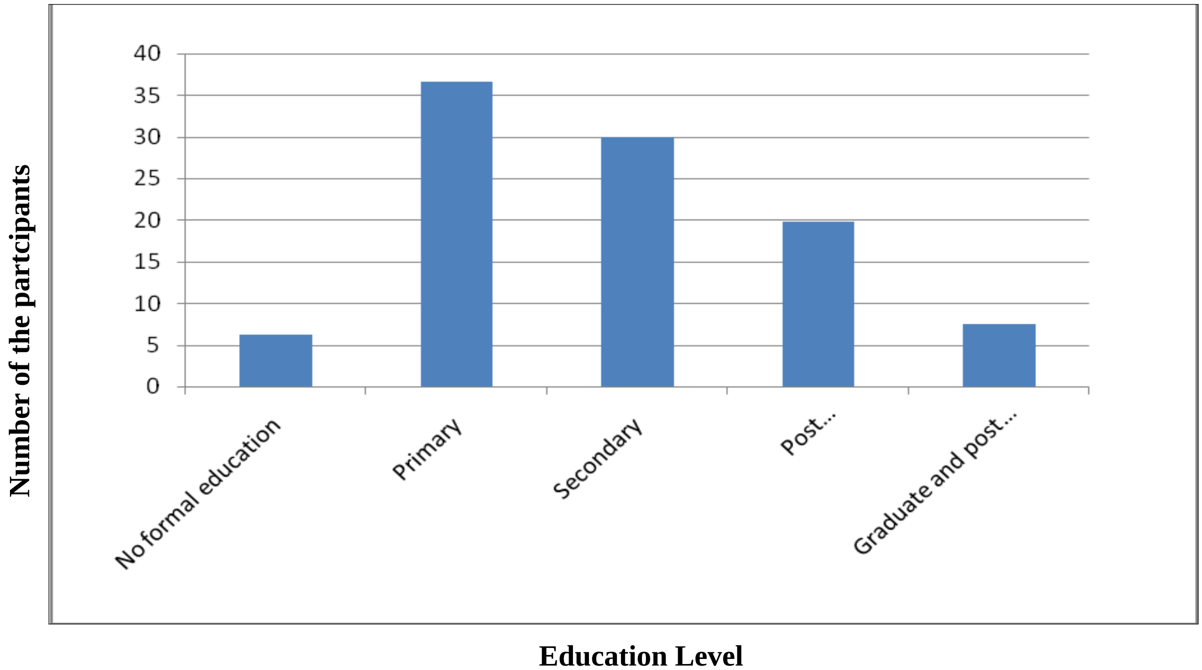


Figure 6.3: Level of formal education of respondents at the study site, Bungoma County, Kenya

Source: Researcher, (2017)

6.2.4 Occupation of the Household Heads

The household heads were asked to state their occupation and the results are shown in Figure 6.4. Most of the household heads (58.2%) are farmers (N=388). Farming in this questionnaire was meant to capture those dealing in both crop and livestock production. A Chi-square test was performed on this variable and gave X^2 =2.566E2$^{\alpha}$ and showed significant variation (P<0.01) in the number of household heads in the different occupations.

Studies have demonstrated that *Leptospirosis* as a human disease is a result of an interaction between humans, animals and the environment (De Vries *et al*., 2014). This puts the crop and livestock producers at a higher risk of contracting *Leptospirosis*. This group is at a higher risk of *Leptospirosis* as farmers deal in soils which if contaminated, they contract the disease.

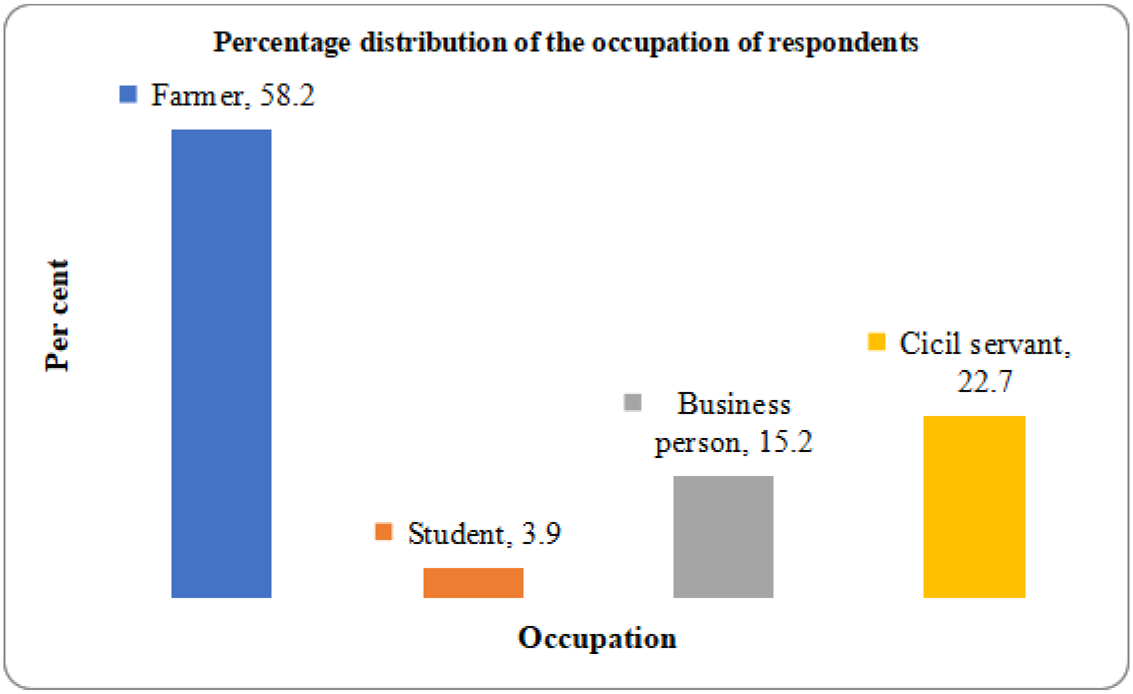


Figure 6.4: Distribution of the occupation of household heads in Kimilili and Mt Elgon Sub-Counties in Bungoma County, Kenya

Source: Researcher, (2017)

6.2.5 Marital status of the household heads

The household heads were asked to state their marital status and the findings are shown in Figure 6.5. It was observed that 84.8% of the respondents were married while 15.2% were single (N=388). Those categorized as single included the following categories: those who have never married, divorced, separated and widowed). A Chi-square test was performed on this variable and gave X^2 =1.879E2$^{\alpha}$ showing highly significant variation (P<0.01) in marital status distribution. It was also observed that 98% of the Key informants were married while 100% of the Focused Group Discussion members were married.

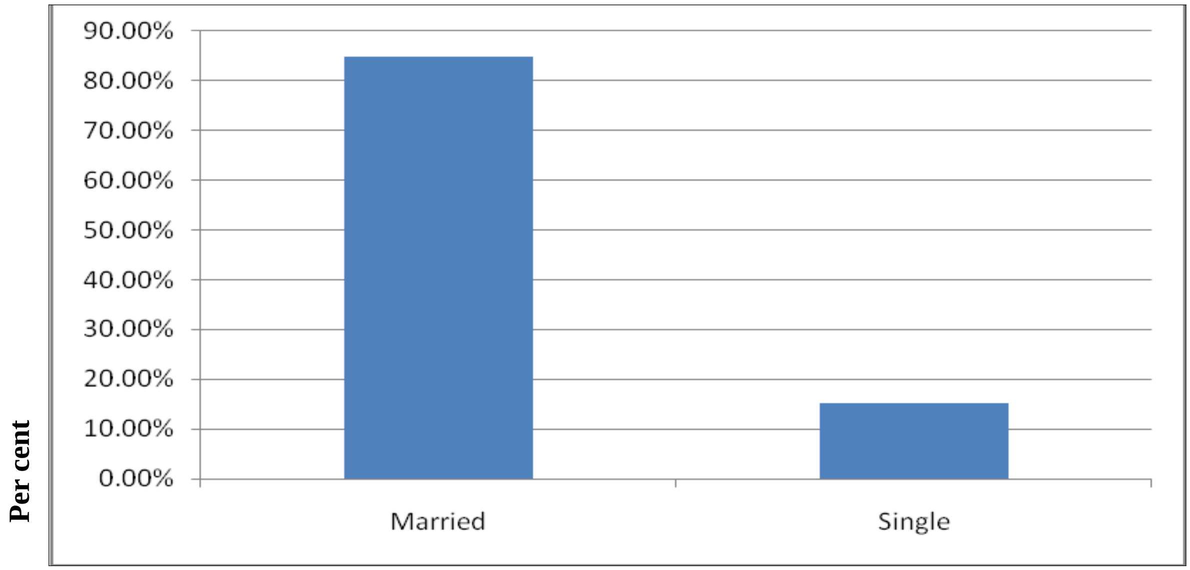


Figure 6.5: Marital status of household heads in Kimilili and Mt. Elgon Sub-Counties in Bungoma County, Kenya

Marital Status

Source: Researcher, (2017)

6.2.6 Household size

The household heads were asked to state the size of their households and the results are given in Figure 6.6. The highest household had six or more members (31.4%) followed by four to five (29.6%) and the lowest was the household with one member at 3.6%. A Chi-square test was performed on this variable and gave X^2 =1.085E2$^{\alpha}$ with a highly significant (P<0.01) showing that the number of respondents with different household sizes was significantly different.

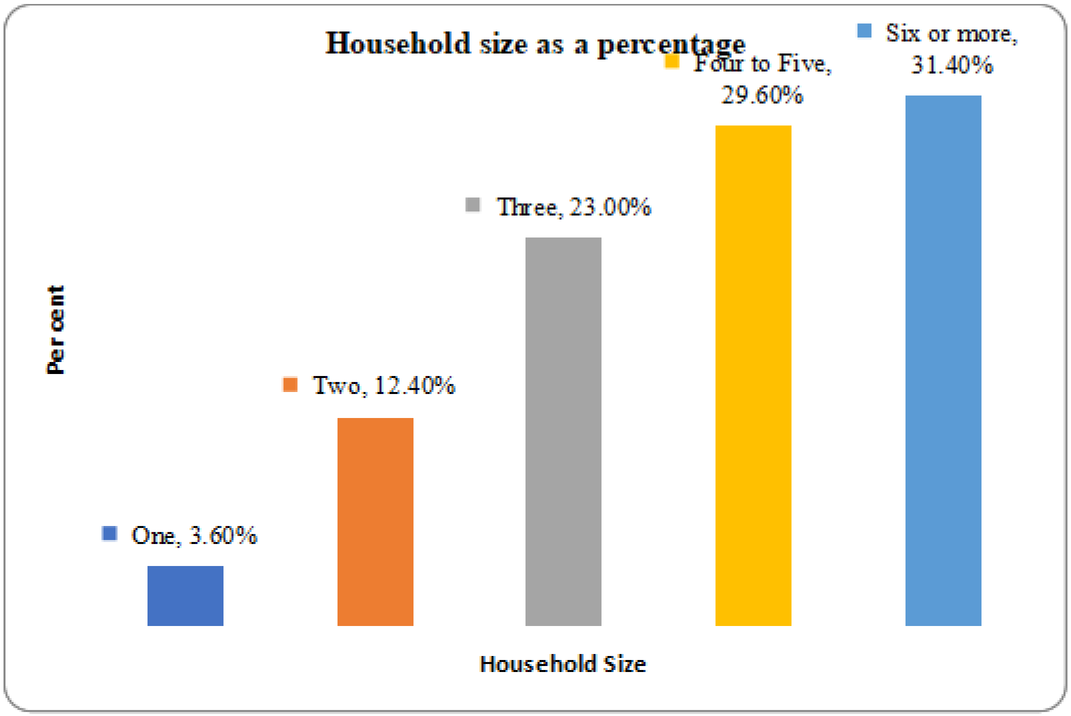


Figure 6.6: Household size in Kimilili and Mt Elgon Sub counties of Bungoma County, Kenya

Source: Researcher, (2017)

6.3 Awareness of *Leptospirosis*

Most of the household heads (85.8%, N=388) reported to be aware of the *Leptospirosis* (Figure 6.7). They referred to it as “Chesamisi fever”, “Chesamisiasis” and they have a vivid memory of the year of the outbreak and the dramatic events that followed. Respondents who did not have a direct experience with the 2004 outbreak reported having heard about *Leptospirosis*. Key Informant interviews revealed that following the outbreak, Chesamisi was drawn into the international limelight with the World Health Organization, Centre for Diseases Control (CDC) and the Ministry of Health taking necessary measures to contain the disease. Chesamisi High School was placed on quarantine and the Minister for Health, Hon. Charity Ngilu visited the area.

These events make the residents remember the disease. Key informant interviews revealed that temporary health facilities were created in the region to cater for the emergencies that followed. Special wards were created in Kimilili, Webuye, Lugulu and Bungoma hospitals to manage the cases. It was revealed that students from affected institutions and the general population from the surrounding areas were heavily stigmatized and their interaction was curtailed. Chesamisi High School and its environs were placed in quarantine. Even after the condition had subsided, still the students could not interact freely in inter-school events such as games and other extra-curricular activities.

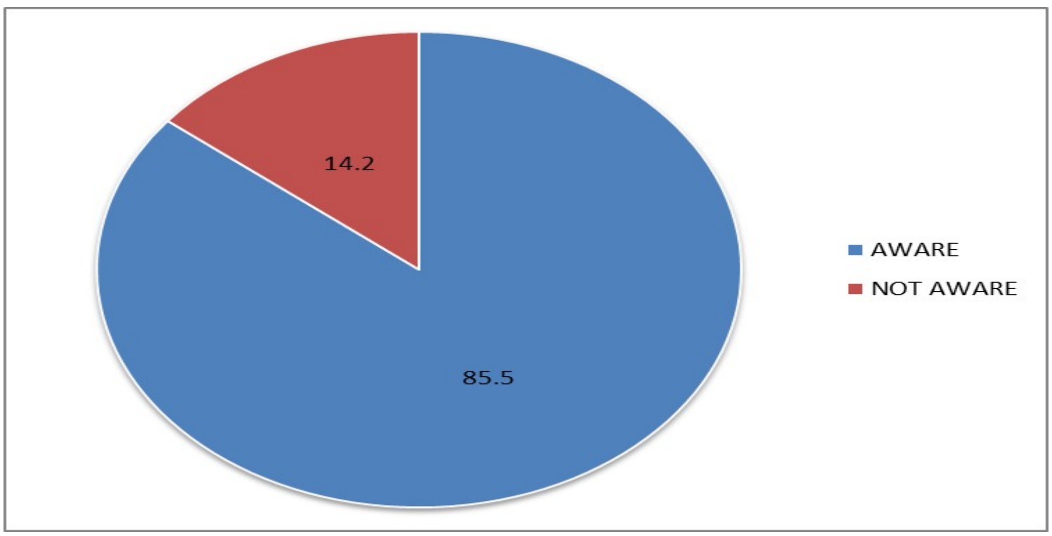


Figure 6.7: Level of awareness about *Leptospirosis* by households in Kimilili and Mt Elgon Sub-Counties, Bungoma County, Kenya

Source: Researcher, (2017)

6.4 Knowledge about *Leptospirosis*

Knowledge of *Leptospirosis* among the households was assessed to establish how it conforms to known biomedical information. The study was based on their understanding of basic facts about *Leptospirosis* which included the following: -

i. Cause of the disease.
ii. Risk factors of the disease
iii. Role of rats in the transmission of the disease
iv. Knowledge of *Leptospirosis* as a zoonosis
v. Clinical signs of *Leptospirosis*

Classification of respondents as knowledgeable was based on showing that the respondent understands any of the two facts stated above. The results are represented in Figure 6.8 with 54.1% (N=388) of the respondents having some basic understanding of *Leptospirosis* and they could identify the condition by giving the correct clinical signs in humans. A Chi-square test on this variable gave $X^2=2.639^{\alpha}$ with no significant variation ($P>0.05$) in the number of households with knowledge of *Leptospirosis* and those without the knowledge.

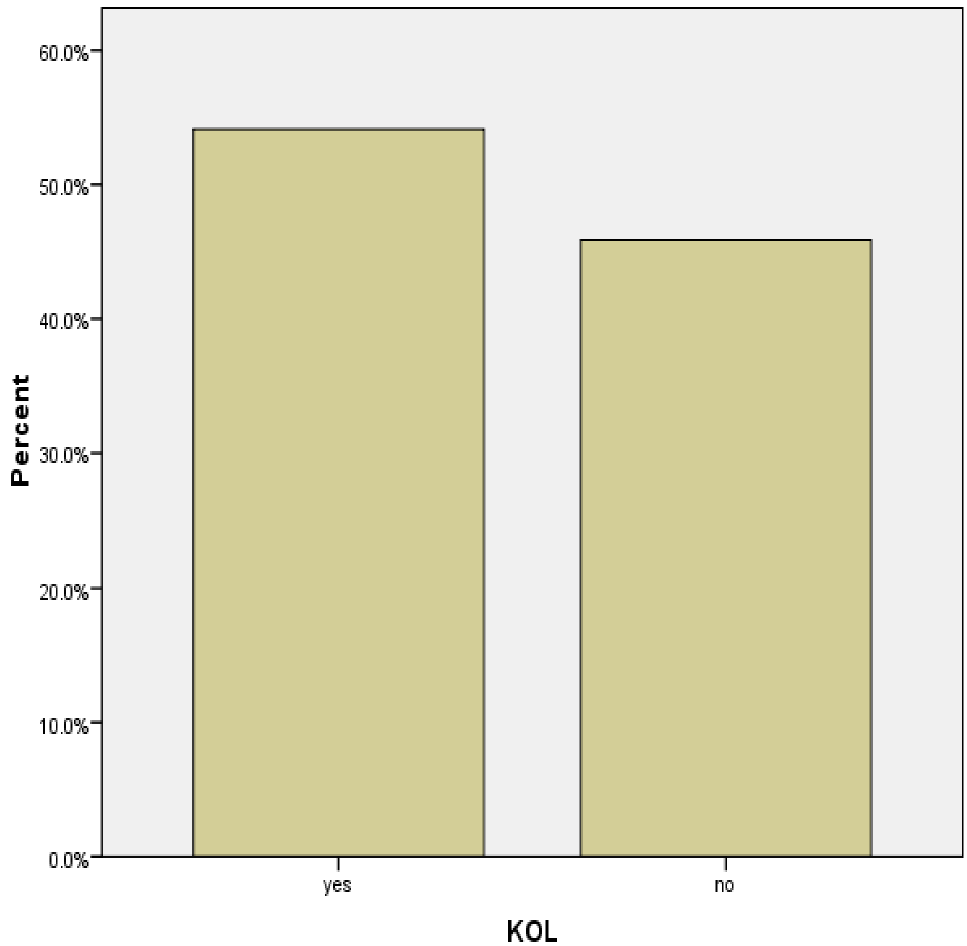


Figure 6.8: Knowledge about *Leptospirosis* (KOL) in households in Kimilili and Mt Elgon sub-Counties, in Bungoma County, Kenya

Source: Researcher, (2017)

This finding corroborates with the Focused Group Discussions which showed that despite the high number of those indicating to be aware of the disease, still many respondents could not tell the cause of the disease, mode of transmission and method of managing the condition. They also could not tell the relationship of the disease in humans with livestock.

The study reveals that overall; there is a lack of comprehensive knowledge about *Leptospirosis* and its cause, transmission, risk factors, the role of rodents, treatment and the fact that it is a zoonotic disease. This observation corroborates the finding on the level of contact of the respondents with the veterinary extension staff where the majority 63.7% of the respondents reported less than two visits in a year (Figure 5.11).

6.4.1 Cause of *Leptospirosis*

The household heads were asked to state the cause of *Leptospirosis* and the responses are presented in Figure 6.9. Being an open-ended question, multiple responses were given as shown.

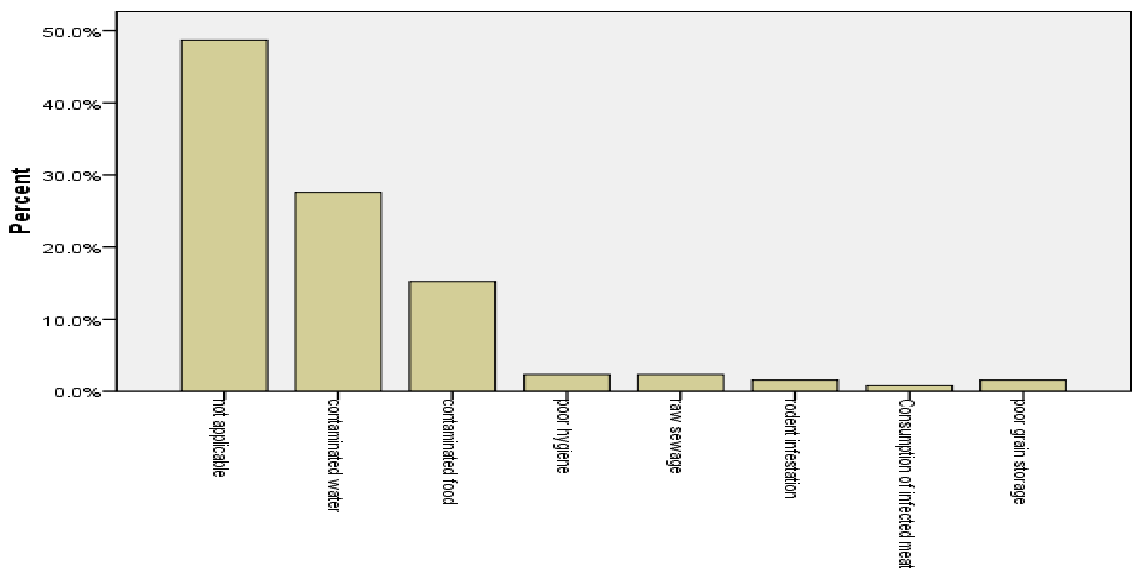


Figure 6. 9: Responses on "Cause of *Leptospirosis*" by household heads in Kimilili and Mt Elgon sub-counties, Bungoma County, Kenya

Source: Researcher, (2017)

A Chi-square test on this variable gave X^2=6.614E2$^{\alpha}$ showed a highly significant (P<0.01) variation indicating that the number of respondents enumerating the different causes of *Leptospirosis* is significantly different.

6.4.2 Clinical signs of *Leptospirosis*

The clinical signs of *Leptospirosis* in humans were enumerated as indicated in Figure 6.10 below. Most of the household heads (22.7%) named digestive disorders as the most pronounced clinical signs, followed by nervous signs (17.8%), fever (10.1%) sudden death, anaemia, respiratory distress, general body weakness, headache and sudden death in that order.

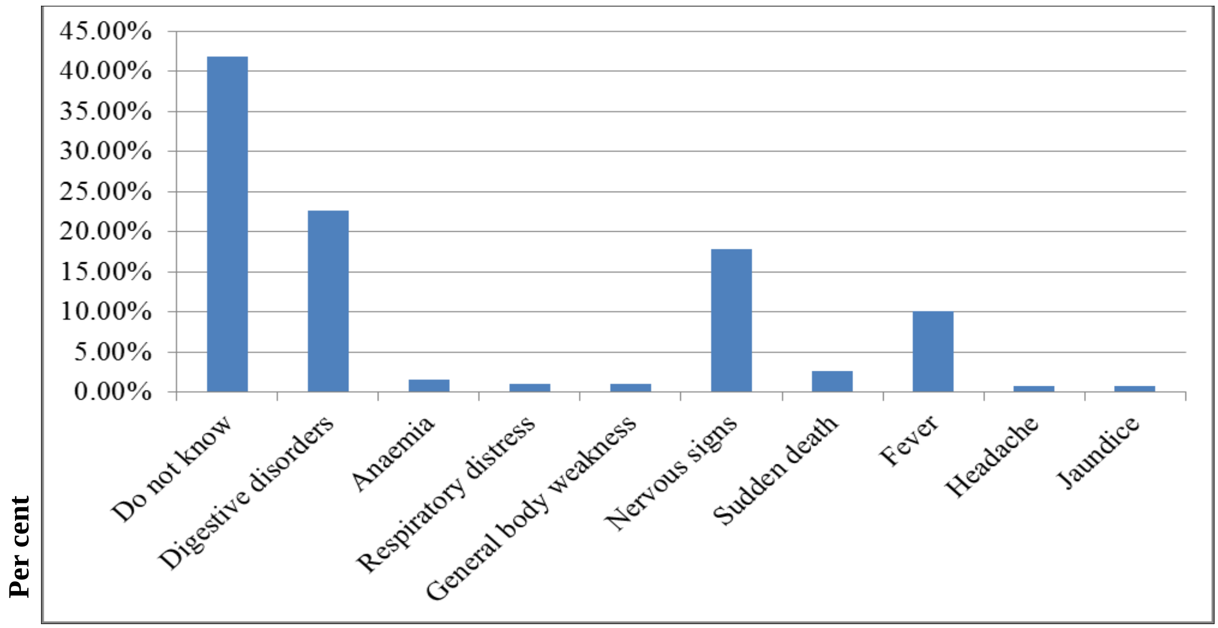


Figure 6. 10: Responses on "Clinical signs of *Leptospirosis*" by household heads in Kimilili and Mt Elgon Sub-counties, Bungoma County, Kenya

Source: Researcher, (2017)

Diseases

A Chi-square test on this variable gave X^2 =7.556E2$^{\alpha}$ with a highly significant (P<0.01) variation showing that the number of respondents enumerating the different clinical signs is significantly different.

6.4.3 Knowledge of *Leptospirosis* as a zoonosis

The level of awareness of diseases transmissible between livestock and humans (zoonoses) amongst the respondents was assessed. The majority of the respondents (65.5%) were aware of the zoonoses as indicated in Table 6.1.

Table 6.1: Knowledge of zoonotic diseases among heads of households in Kimilili and Mt Elgon Sub-Counties, Bungoma County, Kenya

Response	Frequency	Per cent
Yes	254	65.5
No	134	34.5
Total	388	100.0

Source: Researcher, (2017)

A Chi-square test on this variable gave $X^2 = 37.113^{\alpha}$ with a highly significant ($P<0.01$) variation between those who know about zoonoses compared to those who do not.

The respondents who reported to know zoonotic diseases were further probed to identify the common zoonotic diseases in the study area and the responses are presented in Figure 6.11.

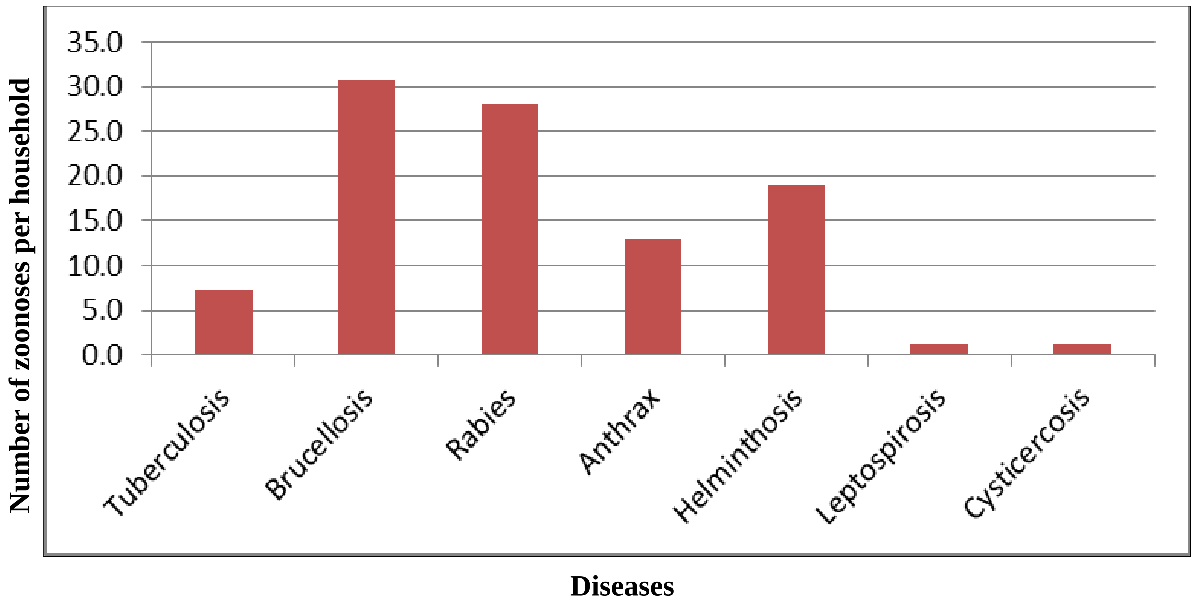


Figure 6.11: Common zoonoses reported by household heads in Kimilili and Mt Elgon Sub-Counties, Bungoma County, Kenya

Source: Researcher, (2017)

These findings show that only 1.2% of the respondents could identify *Leptospirosis* as a zoonotic disease. The findings are in agreement with Key Informant Interviews which showed that the common zoonoses are brucellosis, rabies and anthrax.

6.4.4 Association of rodents to *Leptospirosis* disease

It was noted that 92.3% of the respondents reported to have rodent infestation in their homes (Figure 6.12). However, when asked if they could associate rodents with any disease in humans, only 29.6% reported the affirmative (Figure 6.13).

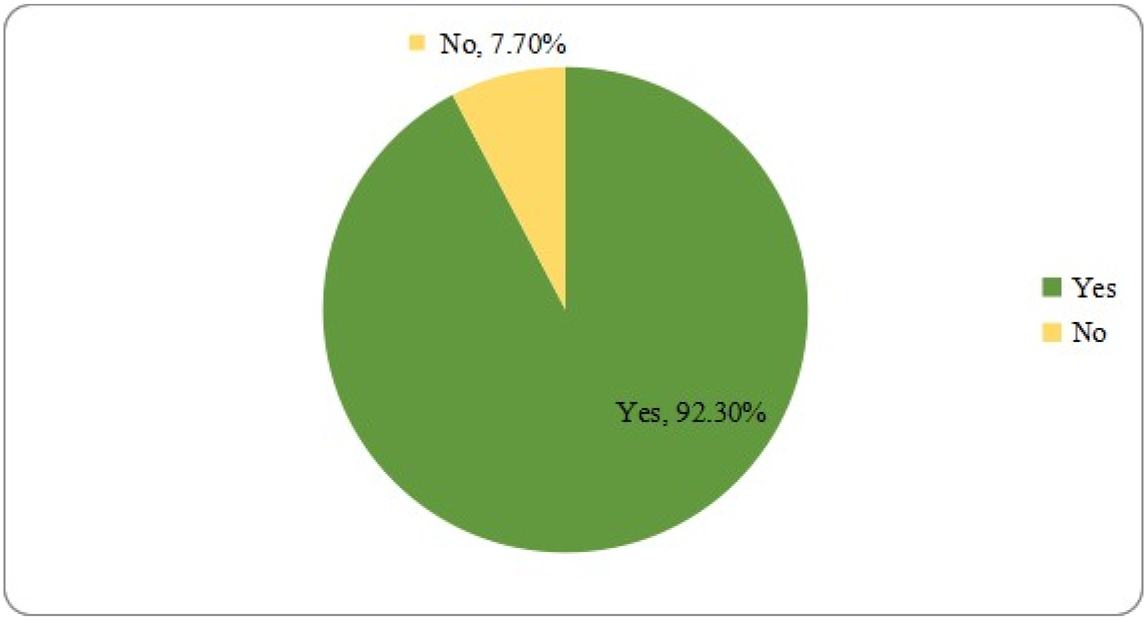


Figure 6. 12: Rodent infestation amongst household heads in Kimilili and Mt Elgon Sub-Counties, Bungoma County, Kenya

Source: Researcher, (2017).

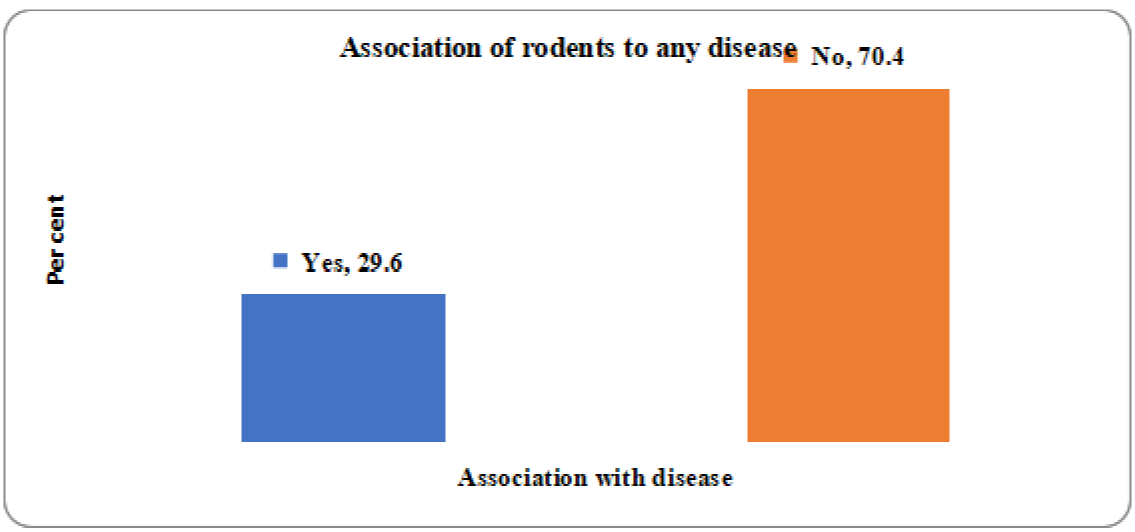


Figure 6.13: Association of rodents to any disease amongst household heads in Kimilili and Mt Elgon Sub-counties, Bungoma County, Kenya

Source: Researcher (2017).

A chi-square test on this variable revealed that there was a significant difference between respondents who associate rodents with disease compared to those who do not ($P<0.01$).

Those respondents who associated rodents with disease were further asked to name the diseases/conditions that could be attributed to rodents. The responses are as indicated in Figure 6.14.

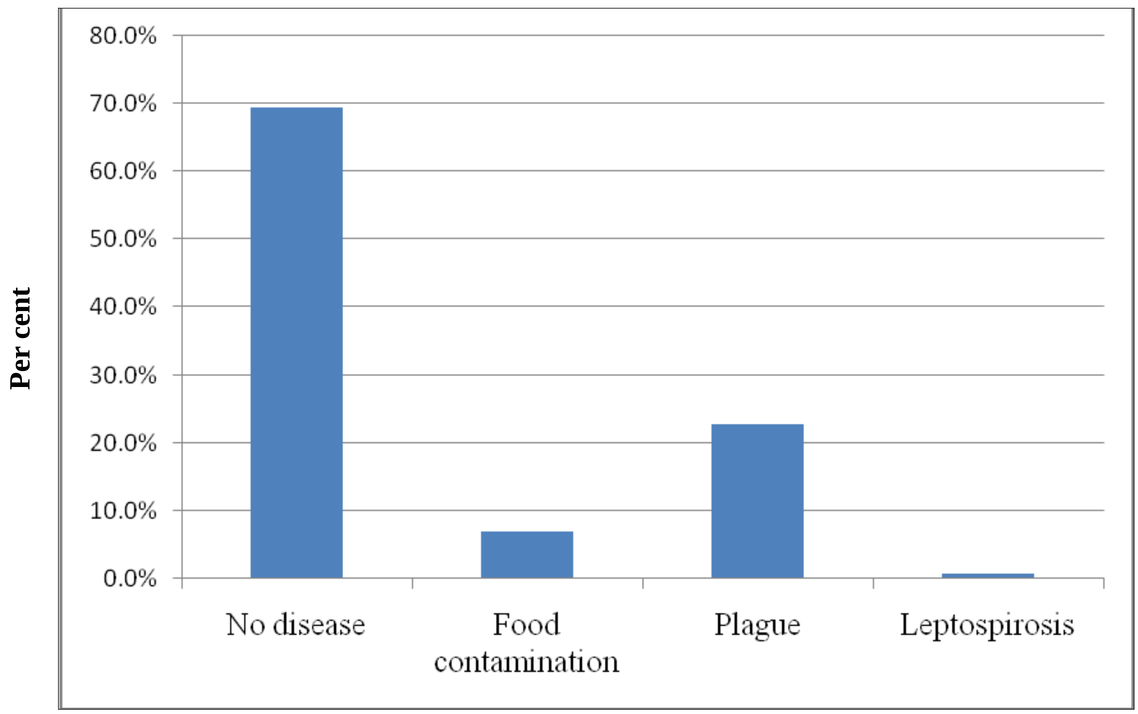


Figure 6.14: Conditions associated with rodents among household heads in Kimilili and Mt Elgon Sub-counties, Bungoma County, Kenya

Source: Researcher (2017).

A Chi-square test revealed gave $X^2=450.990^{\alpha}$ at 3 degrees of freedom with a significance level of ($P<0.01$) showing that there is a significant difference in the number of different conditions associated with rodent infestation.

6.5 Factors affecting knowledge of the *Leptospirosis*

Univariate regression analysis was carried out on demographic factors such as gender, age, and educational levels being independent variables and knowledge of *Leptospirosis* among the respondents being the dependent variable. The level of significance was calculated at a 95% confidence interval.

Table 6.2: Univariate regression analysis for social demographic characteristics in Kimilili and Mt Elgon Sub-Counties, Bungoma County, Kenya

	Independent variable	Degrees of freedom (df)	Significance level (p-value)	Standard error
1.	Gender	1	0.954	0.205
2.	Age	3	0.737	0.027
3.	Education Level	4	0.154	0.024
4.	Marital Status	1	0.385	0.071
5.	Household size	4	0.058	0.022
6.	Occupation	3	0.004	0.020
7.	Contact with extension staff	2	0.002	0.030

Source: Researcher, (2017)

6.5.1 Gender

It was observed that gender gave no significant association with knowledge of *Leptospirosis* (P>0.05) as shown in Table 6.2. This therefore means that gender does not influence knowledge of *Leptospirosis* in the study area. This is probably because *Leptospirosis* occurred as an outbreak in the area affecting the population across all genders.

6.5.2 Age

It gave a non-significant result (P>0.05). Age is therefore not significant in determining knowledge about *Leptospirosis*. This is probably because the condition was affecting the area for the first time. A study by De Vries *et al*., (2014) has demonstrated that there is rate of infection increases with age.

6.5.3 Education levels

Results for univariate regression analysis on educational levels gave a non-significant (P=0.154) regression coefficient. This implies that there is no association between education level and knowledge about *Leptospirosis*. Similar studies have revealed that educational levels influence the knowledge of infectious diseases including *Leptospirosis* (Wiwanitkit, 2006; Dias, 2007; Brown *et al*., 2011; Dhimal *et al*., 2014). This is probably suggesting that *Leptospirosis* being an emerging/re-emerging disease, appears not to be fully understood by the educated just as much as the less educated are. Community education on *Leptospirosis* should therefore be addressed to all members irrespective of educational level.

6.5.4 Marital status

The study shows that marital status is not a significant variable (P>0.05) in determining knowledge about *Leptospirosis*.

6.5.5 Household size

The study shows that the size of the household is not significant in determining if one knows *Leptospirosis* (P>0.05) at a 95% confidence interval.

6.5.6 Occupation

Univariate regression analysis showed that there is an association between occupation and knowledge about *Leptospirosis* (P=0.004). A similar study conducted among non-paramedical students revealed that occupation has a significant association with knowledge of *Leptospirosis* (Azfar *et al*., 2018). This is an expected observation given that farmers both crop and livestock and veterinarians are known to be at a higher risk of contracting *Leptospirosis*.

6.5.7 Contact with extension staff

Univariate regression analysis for contact with extension staff showed that there is a strong association and knowledge about *Leptospirosis* (P=0.002). A similar study reveals that improved access to veterinary services has a positive influence on knowledge, attitude and practices for anthrax (Kulpiisova *et al*., 2024). Public health education by field extension staff is a critical element in enhancing knowledge, attitude and preventive practices for *Leptospirosis* in the community. This should be embraced with a focus on the cause, clinical signs, transmission, rodent management and treatment of *Leptospirosis*.

6.6 Some beliefs about *Leptospirosis*

Key Informant interviews revealed that “chesamis” is a Sabaot word for “rotten” or “bad smell”.

According to Kitinyo (2017), Chesamis is a word associated with misfortunes and this explains the animosity amongst the residents of the place and the serious disease outbreaks. The Chesamisi area is occupied by the Bukusu sub-tribe and Sabaot ethnic communities who have always treated each other with a lot of suspicion which at times is manifested in ethnic animosity (UNDP, 2010). The Sabaot community occupies the highlands while the Bukusu sub-tribe of the Luhya tribe stays in the lower region thereby consuming water from water sources which are located within the Sabaot people. Key Informant Interviews revealed that some people believed that the disease outbreak was associated with water contamination in rivers upstream. Others suggested that the Sabaot community disposed of a dead donkey in River Sosio which also happens to be a source of drinking water in Chesamisi area and the surrounding villages.

> "… The poor relations between the Sabaot and the Bukusu communities are major because of land displacement, perceived historical injustices and political exclusivity given that the Sabaots consider themselves a minority group" (Chief Chengole, 2017).

It was also reported at the initial stages of the outbreak, that some members of the Bukusu community believed that the outbreak resulted from malicious poisoning of water in River Sosio. Those who propagated this idea said that this was a revengeful action to punish people consuming water downstream. The study also revealed that some people believe that prior to the outbreak, the sewage system at Chesamisi High School was emptied but was not disposed of well. This led to contamination of the environment and eventual outbreak of the disease which was mistakenly taken to be typhoid.

It was also revealed that another group in the community believe that the problem arose from poor grain storage at the school resulting in contamination and hence the disease outbreak. It was also reported that some people associated the problem with drinking water drawn from asbestos sheets. This can however be overruled by the fact that the disease was not confined to the school community. People from the surrounding areas who did not use water drawn from the asbestos sheets were similarly affected by the disease.

6.7 Attitude

Assessment of the attitude of the community towards *Leptospirosis* was adopted from Ul Haq *et al*., (2012) (Appendix VIII). Three questions were asked and the responses were indicated as shown in Table 6.8. Each question was labelled positive or negative attitude depending on the responses made.

Table 6.3: Questions for assessing the attitude of respondents towards *Leptospirosis* in Kimilili and Mt Elgon sub-Counties in Bungoma County, Kenya

	Attitude Item	**Responses**	**Per cent**	**Attitude**
1	Do you think you can get *Leptospirosis*	Yes	19%	Positive
2	What would be your reaction if you found that you have *Leptospirosis*?	No	81%	Negative
		Shame	65%	Negative
3	Who would you talk to someone about your illness?	Fear	35%	Positive
		Yes	65%	Positive
		No	35%	Negative
4	What will you do if you think that you have symptoms of *Leptospirosis*?	Go to a Health facility	38%	Positive
		Seek divine or traditional intervention	32%	
		Just stay at home	30	Negative
5	If you had symptoms of *Leptospirosis*, at what stage you go to the health facility?	As soon as I realised the symptoms of *Leptospirosis*	14%	Positive
		Own treatment fails	72%	
		Will not go to a physician	14%	Negative
6	How expensive do you think is the diagnosis and treatment of *Leptospirosis*?	Affordable	33%	Positive
		Expensive	52%	
		Don't know	17%	Negative
7	What worries you most if you will be diagnosed with *Leptospirosis*?	Fear of death	47%	Positive
		Cost of treatment	21%	
		Isolation from the society	32%	Negative

Source: Researcher, (2017)

A score of 1 was assigned to positive and 0 for negative with a range of 2 and 0. A score greater than 1 was classified as a positive attitude and equal or less than 1 was a negative attitude. It was observed that 81% (N=388) believed that they could never get infected with *Leptospirosis*. 41% of the respondents stated that they would be ashamed to get infected with *Leptospirosis*. The majority of the respondents (62%) indicated that they would use alternative systems of healthcare when infected with *Leptospirosis* as opposed to 38% who would visit a health facility. Overall, the respondents had a negative attitude to *Leptospirosis*. A positive attitude towards *Leptospirosis* is critical in the control and prevention of the disease (Samsudin *et al*., 2020).

6.8 Practices which pose a risk to *Leptospirosis*

Practices which could have a bearing on *Leptospirosis* were examined in the study. Through Key Informant interviews and FGDs, some practices which pose a threat to *Leptospirosis* outbreaks were identified. The focus was then laid on the practices associated with circumcision and funeral ceremonies. It was observed that the greatest risk arose from the feasting that accompanies these ceremonies. Circumcision is a rite of passage for young Bukusu boys and is commonly performed in August every year. The ceremony is characterized by celebration and feasting whereby animals are slaughtered. Resources for the elaborate ceremony were mobilized well in advance with the bulls for slaughter being purchased then. At that time, animals are purchased without taking into consideration the source and this is a risky practice for introducing livestock diseases into clean herds. Cattle from as far as West Pokot and Turkana counties are preferred for this purpose since they are relatively cheap.

Key Informant Interviews revealed that:

> "… During the ceremony, one bull is slaughtered by the uncles of the initiate, usually without inspecting the meat. After slaughtering the animal, part of the meat is put around the boy's neck which he carries to his home. This is another risky practice which has the potential of introducing disease in case the initiate has open wounds on his body. The second animal is slaughtered at the home of the initiate and this one in most cases is not inspected" (Key Informant, 2017).

The other risk practice is the smearing of mud from swamps, marshes and wetlands on the supposed initiative just prior to the surgical operation by the traditional practitioners (Wanyama and Egesah, 2015). Such swampy areas are sometimes contaminated with waste. The area is also bushy and infestation by rodents which play a major role in *Leptospirosis* transmission is a possibility (Wanyama and Egesa, 2015). Key Informant Interviews revealed that this is to make the body numb and thus bring about analgesic function. This practice however has the potential of introducing *Leptospirosis* if the mud which is contaminated with livestock or rodent urine is applied on the skin of the initiate which is not intact (Baharom *et al*., 2023). Ogundipe (2020), in his study, identified such cultural practices in Africa that have no scientific basis but instead pose negative health consequences.

Funeral rituals especially for adults are characterized by feasting whereby cattle are slaughtered. Usually, these animals are not inspected and this practice poses a risk of the spread of zoonotic diseases (Heuer *et al*., 2010). The practice of slaughtering and consuming un-inspected meat runs across all traditional ceremonies including weddings.

Sick animals are usually slaughtered at home and consumed. Those that die are slaughtered and consumed without any regard for the laid down protocol for safe handling and disposal of carcasses. Focused Group Discussions revealed that the practice of using protective clothing such as gumboots and gloves by farmers and livestock is not widely practised. Studies have shown that non-compliance with the use of protective equipment poses a high risk for *Leptospirosis* (Saputra *et al*., 2021). This is a very risky practice especially for livestock farmers when cleaning the livestock sheds to dispose of the dung and urine. Similarly, the crop farmers go to the farms with no protective clothing thereby increasing the chances of infection when in contact with contaminated soils.

It was also reported that boiling water is rarely practised even though sharing of water points between livestock and humans is common in the study area. A similar study on anthrax, which is a zoonosis like *Leptospirosis*, has shown that human behaviour is crucial in its epidemiology (Kulpiisova *et al*., 2024). Another study has linked socio-cultural practices involving slaughter, consumption or handling of meat, improper disposal of dead carcasses, or having close contact with animals or contaminated materials to high cases of zoonotic diseases in developing countries (Zorigt *et al*., 2021; Islam *et al*., 2024).

CHAPTER SEVEN

THE IMPACT AND CHALLENGES OF *LEPTOSPIROSIS* OUTBREAK ON PUBLIC HEALTH STRATEGIES IN BUNGOMA COUNTY, KENYA

7.1 Introduction

This was the fourth objective of the study in which public health programmes and strategies implemented in Bungoma County were identified. The programmes and strategies were then examined in relation to their implementation before and after the *Leptospirosis* outbreak. Key informants comprising of key stakeholders in the health and veterinary departments discussed their implementation, and challenges and made suggestions of how to improve the implementation of the strategies for efficient and effective management of outbreaks of public health importance. They also analysed the existing healthcare system which can then help healthcare teams to learn, and improve service delivery and this is important in formulating feasible and sustainable policies (Djulbegovic, 2014).

Healthcare interventions are a combination of activities or strategies which are designed to assess, improve, maintain, promote, or modify health among individuals or an entire population. Such interventions include educational and care programmes, policy changes, environmental improvements, or health promotion campaigns. Sometimes the interventions are multiple interacting components (Campbell *et al*., 2000). The impact of such interventions is likely to be shaped as much by the context in which they are implemented for example in communities, workplaces, homes, schools, or hospitals where they are delivered (Rickles, 2009; Hawe, 2015; Greenhalgh and Papoutsi, 2018; Pawson and Tilley, 1997.

7.2 Public Health Programmes in Bungoma County

Public health programmes and services in both humans and animals are characterized by planning and intervening strategies for better health in populations, including understanding and reducing the risks of disease, disability and death. During the period of the outbreak, the Government in partnership with AMREF (African Medical Research Foundation) and MSF (Medicines Sans Frontier)-Doctors without Boundaries put in place concerted efforts to control the outbreak. The public health programmes and strategies in Bungoma County were identified as follows:-

i. Imposing quarantine and isolation.
ii. Enhancing public health surveillance.
iii. Promoting hygiene and sanitation.
iv. Water treatment.
v. Meat hygiene.
vi. Promoting community health education.
vii. Stepping up of school health programmes.
viii. Promoting one health approach in the management of the disease outbreak.

7.2.1 Quarantine services

According to WHO, quarantine is described as "the restriction of activities or separation of persons who are not ill, but who may have been exposed to an infectious agent or disease, with the primary objective of monitoring symptoms and the early detection of cases" (WHO, 2020). Isolation, on the other hand, can be described as the parting of ill or infected persons from others, to avert the spread of infection or contamination. Originally, the term "quarantine" was used to refer to self-quarantine or quarantine of selective individuals who are suspected to be carriers of the infection, but currently, a new term "mass quarantine" is emerging, which primarily refers to the enforced quarantine of a population by the government to prevent the spread of a disease outbreak (Bergstresser, 2020). The main purpose of the mass quarantine is to flatten the curve of the spread of disease meaning that the rate of spread of a disease is slowed down (Specktor, 2020).

The Public Health Act (PHA) authorizes public health authorities to take various actions during public health crises which include declaring an infectious disease a "notifiable infectious disease" and taking the necessary prevention measures. Other powers accorded to health authorities for prevention of an infectious disease include search, seizure, and detention powers; as the power to designate any place as a quarantine area. On the other hand, the Animal Diseases Act (CAP 364) empowers the Director of Veterinary Services to impose a quarantine following an outbreak of a notifiable disease. Following the outbreak of *Leptospirosis*, Chesamisi High School was placed under quarantine. This meant that there was restricted movement into and out of Chesamisi High School only being limited to when patients are being referred for treatment.

According to one key informant, there were few cases which violated the regulations and through pressure from parents, students left the school to be attended elsewhere. It later turned out that all the deaths reported from Chesamisi High School were victims of the quarantine violation (Nyongesa, 2016).

According to the school administration, the quarantine and travel restrictions imposed during the outbreak led to stereotyping and prejudice against members of the school administration over a prolonged period. The members of the school could not freely interact with others in extra-curricular activities. According to Brooks *et al*., (2020), quarantine has a negative impact of leading to prejudicial treatment which is based on where one is originating from or ethnicity while disregarding scientific facts.

The quarantine was imposed for a prolonged period leading to panic and anxiety amongst the school community, the communities staying around the affected schools and the parents. Reports of symptoms of adverse mental health, anger and avoidance were encountered among members of the school community and the parents. Research has shown that quarantine of more than 10 days has resulted in significantly higher cases of post-traumatic stress symptoms compared to quarantine of less than 10 days (Hawryluck *et al*., 2004).

> "… The disease affected the students negatively leading to poor performance in academic and extra-curricular activities. This is majorly attributed to post-traumatic stress and low self-esteem among the students. According to one of the teachers who witnessed the outbreak. The affected students displayed emotional detachment and even some displayed suicidal tendencies" (Mr Masinde, Teacher at Chesamisi High School, 2017).

It was reported that because of quarantine, the students had prolonged separation from their parents and other family members thereby denying them the much-needed family coexistence. According to one of the parents, the quarantine led to a breakdown in family coexistence which is key for social and emotional support. One study reported that adolescents because of their age are more prone to the negative impacts of quarantine (Commodari and La Rosa, 2020).

7.2.2 Public health surveillance

Public health surveillance is the ongoing systematic collection, analysis, and interpretation of data, closely integrated with the timely dissemination of these data to those responsible for preventing and controlling disease (Thacker and Berkelman,1988).

Public health surveillance is a tool to estimate the health status and can directly measure what is going on in the population, it is useful both for measuring the need for interventions and for directly measuring the effects of interventions (Thacker and Berkelman,1988). The purpose of surveillance is to empower decision-makers to lead and manage more effectively by providing timely, useful evidence (Lee *et al*., 2012). During the outbreak, the medical team formed a surveillance team which collected data. The veterinary department on the other hand, also formed a separate surveillance team. Both the medical and veterinary surveillance teams used the active surveillance system where the teams regularly contacted the affected population to seek information about health conditions. The teams carried out intensive surveillance exercises in affected households, slaughterhouses, hotels and markets. The veterinary team was backed up by an investigating team from the Regional Veterinary Investigations Laboratory at Eldoret which was collecting samples from suspected cases for laboratory analysis. One of the most notable challenges encountered during this exercise was the lack of inter-disciplinary collaboration among the different actors in the health and public health domain, epidemiologic and statistical domain, and public health jurisdictions (Gilbert and Cliffe, 2016). The study has shown that disease rumours and suspected outbreaks are recorded in a rumour register, investigated and necessary follow-ups made.

> "… A rumour register is kept showing reports of suspected disease outbreaks, date when the report was made, source of the information, date of investigation, action taken and follow-ups made". (Key Informant at the VIL, 2017).

The study revealed that the Veterinary Investigations Laboratory at Eldoret had the capacity to undertake ELISA tests for *Leptospirosis* and other diseases that require simple serologic tests to ascertain the conditions. The laboratory is also backed up by a referral laboratory at the Kabete Veterinary Laboratories and the University of Nairobi's Public Health, Pharmacology and Toxicology Laboratory.

In terms of logistical support, it was observed that health and veterinary facilities have inadequate staff, inadequate transport facilities and basic surveillance equipment.

> "… Among the challenges encountered during disease surveillance include; the logistics of sample collection from the field because of the lack of basic sampling equipment, means of transport to reach out in the field and inadequate trained human resources and lack of proper coordination among different actors in disease surveillance" (Key Informant, 2017).

It is recommended that an integrated surveillance utilizing passive and active surveillance approaches using multi-disciplinary teams comprising veterinarians, medical staff and environmentalists would be ideal in addressing emerging zoonoses. In addition, the staff should be equipped with basic equipment and necessary logistical support for effective disease surveillance in the field.

7.2.3 Hygiene and sanitation

Promoting healthy behaviours such as hand washing, treatment of water reservoirs and personal hygiene practices is key in preventing infectious diseases. The benefits of these practices go beyond the containment of emerging zoonoses (Gozdzielewska *et al*., 2022). The outbreak of *Leptospirosis* made it necessary to promote these practices in the affected area. It is recommended that the public health authorities should make a concerted effort to capitalize on the momentum gained to sustain such healthy practices. Through partnership with Ace Africa, WASH (Water and Sanitation Hygiene) programmes are implemented where behaviour change commitment (BCC) is promoted. In this programme, volunteers are trained to reach out to all members of the community.

Trainings were conducted for the communities with a focus on the following aspects of hygiene and sanitation:

a) Handwashing: The stations were strategically established to promote hygiene.
b) Washing: fruits before eating and vegetables before cooking.
c) Promoting the use of latrines. The public was urged to use pit latrines. Every homestead had to have a pit latrine.
d) Waste pit use: Every homestead was requested to have a waste pit.
e) The construction of a utensil rack in every homestead was a requirement.

It was noted that there were high adoption rates of hygiene practices in the communities. This was attributed to the *Leptospirosis* outbreak. Studies have demonstrated that disease outbreak situations provide a perfect opportunity for promoting hygiene and sanitation practices among communities because of the perceived threat (Fleischman *et al*., 2011). However, the challenge was how to maintain consistent reinforcement of these practices beyond the outbreak period and thus diminishing over time.

Adoption of hygienic and sanitation ideas and practices is influenced by cultural beliefs, behavioural issues and gender biases (WHO, 2017). It was observed that the implementation of hygienic practices was influenced by differences in attitudes, beliefs, gender, lifestyles and whether it is a rural or urban setting.

Successful hygiene and sanitation programmes require a high level of political commitment (Fox *et al*., 2015). Political commitments should cover the following aspects; review of relevant policies, setting aside budgetary allocation and promoting capacity building.

> "… Currently most of the hygiene and sanitation programmes are jointly implemented by Non-Governmental Organizations and the County Government of Bungoma" (Key Informant, 2017).

7.2.4 Water treatment

During the *Leptospirosis* outbreak, it was suspected that the disease outbreak may be associated with the watering points which are shared between humans and livestock. The first step was therefore the separation of watering points for livestock and humans to minimize contamination. Effective management of water-related public health emergencies requires that all possible points of contamination be addressed which include water sources and storage (Wright *et al*., 2004). This was then followed by spring protection. Water treatment and chlorination were initiated at Chesamisi High School. All water sources were protected. Some of the Key Informants on public health interventions following the *Leptospirosis* outbreak are shown in Plate 7.1.

Plate 7.1: The Researcher (Behind row, 4th from the left) with members of Kaborum village, Kaptama Ward of Mt Elgon Sub-County, Bungoma County which was severely affected by the *Leptospirosis* outbreak.

Source: Researcher, (2017)

A new water source was set up at the Chesamisi High School compound to supply fresh water to the school community as shown on Plate 7.2.

Plate 7.2: A new water source drilled in Chesamisi High School compound, Kimilili Sub-County, Bungoma County, Kenya

Source: Field Data, (2017)

Members of the public on the other hand were supported to install chlorine dispensers at water sources, especially at the springs. Members of the public were encouraged to dispense 3ml of chlorine to 20 litres of water.

The challenge encountered was that there was inadequate chlorine dispensers compared to the population that was in need.

7.2.5 Meat Hygiene

This is a programme implemented by the Department of Veterinary Services to safeguard human health which would otherwise be compromised through infections following consumption of contaminated meat. According to the County Director of Veterinary Services, the main purpose of meat inspection is to detect and prevent public health hazards such as food-borne pathogens and chemical contaminants in meat. He further stated that meat inspection also plays an integral part in the monitoring system of certain animal diseases and therefore this constitutes an important control point for early detection of potential public health and animal health problems.

Infected animals once at the slaughterhouse, can be slaughtered and consumed thereby acting as a way of transmission. Studies have demonstrated that veterinarians and slaughterhouse workers are occupationally exposed to Leptospira spp. (Cook *et al*., 2017). Slaughterhouse workers have been shown to have seroprevalence values twice those of other non-risk occupations. The risk factors identified for *Leptospirosis* seropositivity in slaughterhouse workers are: smoking and drinking while at work and the role of the worker in the slaughterhouse such as cleaning or washing the offal (Cook *et al*., 2017).

Sources of animals for slaughter: During the study, it was observed that the busiest livestock markets in the study area are Kimilili and Kamukuywa townships. Key Informant Interviews revealed that the animals brought to these markets come from as far as Turkana, West Pokot, Trans-Nzoia, Uasin Gishu and Busia which are known to have the disease (Cook *et al*., 2017). During outbreaks of diseases of public health importance, slaughterhouses are closed to curtail the further spread of diseases at the slaughterhouse. However, Key informant Interviews reveal that no such action was undertaken.

“… During the *Leptospirosis* outbreak of 2004, slaughterhouses continued to operate” (Key Informant, 2017).

This is probably because the disease was not diagnosed early enough for relevant administrative officers to put this preventive measure in place. This therefore compromises the control of the disease.

Interviews with the meat inspectors showed that they are aware of *Leptospirosis* and the risks of contracting the disease. However, they do not take the necessary precautions to prevent contracting the disease because they are not provided with the necessary protective clothing and materials (Plates 7.3, 7.4 and 7.5). The rest of the slaughterhouse workers including slaughter men and flayers are not aware of *Leptospirosis* and its mode of transmission.

Plate 7.3: Meat inspection as done in a slaughterhouse in Kimilili Sub-County, Bungoma County, Kenya

Source: Researcher, (2017)

Plate 7.4: Slaughterhouse workers cleaning offals at a slaughterhouse in Kimilili Sub-County, Bungoma County, Kenya

Source: Researcher, (2017)

Plate 7.5: Researcher (the first from left, holding a notebook) conducting Key informants' interviews at a slaughterhouse in Kimilili Sub-County, Bungoma County, Kenya

Source: Researcher, (2017)

7.2.6 Community Health Education

Health education is a social science that draws from the biological, environmental, psychological, physical and medical sciences to promote health literacy and prevent disease, disability and premature death through education-driven voluntary behaviour change activities (Li *et al*., 2023). Studies have demonstrated that communities with higher health literacy levels are likely to embrace preventive healthcare measures and practices that reduce disease risk (Gardiner *et al*., 2013). This has also the power to empower target populations and improve health equity (WHO, 2017). This was undertaken during the outbreak period but was discontinued when the disease was managed. Respondents suggested that this be carried on to sensitize the community to the disease alongside other emerging zoonoses. Effective community health education which incorporates culturally sensitive features is key for the success of disease control interventions in rural populations with low literacy levels (Li, 2023).

> "… This intervention alongside the use of the media yielded a positive impact on *Leptospirosis* prevention and the promotion of healthy lifestyles among the vulnerable population in the rural setting. This was evident in the improved health literacy and information in relation to *Leptospirosis* and other common infectious conditions in their locality" (Key Informant, 2017).

7.2.7 School health programmes

A school health programme is designed to meet the health needs of pupils and students by providing a healthy environment, health education, and services and is guided by the Kenya School Health Policy of 2018.

> "… With the hindsight of the 2004 *Leptospirosis* outbreak, the school community in Chesamisi High School is more alert about disease occurrence. The school has employed a full-time nurse to handle health issues at the school. The school community also maintains a high hygienic standard" (Key Informant, 2017).

> "… A borehole has been drilled on the school compound and this ensures that there is unlimited access to clean water in the school. The use of water from River Sosio has continued but precautions are taken to ensure chlorination is been done" (Key Informant, 2017).

The school borehole is represented in Plate 7.2.

> "… The success of the programme is hampered by several challenges which include; a lack of basic cleansing supplies such as detergents and disinfectants, inadequate water storage facilities, weak collaboration among the implementing agencies being the Ministry of Education and Ministry of Health officials and a lack of reference materials for teachers and health workers to enhance health education and hygiene for sustainability" (Key Informant, 2017).

7.2.8 Multi-disciplinary (One health) approach

The challenge of emerging pandemics, as well as climate change, drug resistance, food and water security and safety, has caused a shift from an interdisciplinary approach, whereby experts collaborate across disciplinary boundaries, to a transdisciplinary approach that integrates society and science by including all stakeholders (Ledford, 2015). This transcends traditional boundaries and integrates knowledge and perspectives from scientific and non-scientific sources (Choi and Pak, 2006). The control of zoonotic diseases falls within the jurisdiction of both the veterinary and medical departments. One Health emphasizes the commonalities of human, animal, plant, and environmental health and thus captures the integrative approaches to health across these components (CDC, 2010).

This is an emerging concept and has not been fully embraced.in developing countries due to the strict adherence to independent disciplines. This study revealed that there is a clear disconnect in approaches to controlling zoonoses by the veterinary and medical personnel. The effects of the *Leptospirosis* outbreak demonstrated that there is a clear and urgent need for medical and veterinary professionals to work closely to tackle emerging infectious diseases. The Health Policy (2012-2030) recognizes the need for collaboration with other sectors whose functions impact human health. The veterinary policy expounds on the "One Health" approach that espouses interdisciplinary cooperation for successful intervention in matters that affect human, animal and environmental health. The veterinary and health policies thus synergize in relation to human and animal diseases with a focus on zoonoses and food safety among other areas of mutual concern.

> "… The challenges encountered during implementation of "One Health" initiatives include the following:- One Health initiatives run across multiple ministries and at different levels (national and county levels) which have different funding mechanisms and priorities; lack of a coordinating body able to promote collaboration and integration of structures and strategies; lack of legal framework to support integrated surveillance across different domains (environmental, animal and human health systems logistical challenges such as inadequate resources and trained personnel; lack of surveillance structure for sharing and integration of epidemiological and molecular data" (Key Informant, 2017).

CHAPTER EIGHT

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

8.1 Introduction

This chapter gives a summary of the research findings, conclusions and recommendations based on the research findings of the four research objectives of the study.

8.2 Summary of Findings

The overall seroprevalence of bovine *Leptospirosis* in Kimilili and Mt Elgon sub-Counties, Bungoma County, Kenya is 16%. In addition, positive cases of *Leptospirosis* in cattle were encountered in all five wards of the two sub-counties and Kimilili slaughterhouse. The highest seroprevalence figures were recorded from cattle at the slaughterhouse (21.0%) followed by Maeni Ward (17.6%), Kamukuywa Ward (16.7%), Kaptama Ward (15.6%), Kimilili Ward (12.5%) and Kibingei Ward (10.7%) in that order. Although there was no significant association between rainfall and the number of *Leptospirosis* cases, the outbreak coincided with the onset of the rainy season which resulted in flooding in some parts of the study area. The study also shows that the risk factors of *Leptospirosis* under consideration affect over 80% of the population in the study area. The risk factors include keeping domestic animals, and practicing communal grazing and watering systems. The other risk factors include the following rodent infestation in homes, slaughter of livestock at non-designated areas, lack of meat inspection, low contact with veterinary staff and rampant livestock movement across the study area.

The study also revealed that 65.5% of the respondents are reported to be aware of *Leptospirosis* but they lack comprehensive knowledge about the disease, especially with regard to cause, risk factors, clinical signs and awareness of the disease as a zoonosis. The study revealed that two factors have a significant association with knowledge about *Leptospirosis*.

The two factors were the occupation of the respondents and the level of contact with veterinary extension staff. The other factors such as age, gender, the size of the household, marital status and level of education of the respondent did not show a significant association with knowledge of the respondent to *Leptospirosis*. Following the outbreak of *Leptospirosis* in humans in 2004, the Ministry of Health implemented various public health programmes to control and prevent the disease. The success of any programme and strategy requires the involvement of the people at all levels for their buy-in. The outbreak provided an opportunity to assess the response capacities and the sanitary management systems. There were notable constraints in the management of the disease that led to a prolonged period of controlling the disease following the outbreak.

The official data reported to the County Director of Veterinary Services and County Director of Medical Services probably fails to reflect the actual *Leptospirosis* burden in Bungoma County because the disease is not identified by the field staff. Due to the non-specific symptoms in both humans and livestock, infected persons and animals may not be presented for treatment or even subjected to inappropriate treatment protocols. Improved surveillance coupled with laboratory diagnosis will provide better estimates of the *Leptospirosis* burden in Bungoma County.

8.3 Conclusions

i. The seroprevalence of *Leptospirosis* in cattle demonstrates that the disease is enzootic and there is a high risk for the disease in the study area. The disease is therefore enzootic in the study area thus presenting a serious public health problem in both humans and livestock. This scenario calls for concerted efforts in combating the disease using the one-health approach between veterinarians, health personnel and environmentalists.

ii. The study has demonstrated that the exposure to the risk factors of *Leptospirosis* is very high in the study area. The study demonstrated that a high proportion of the population in the study area has a close association with livestock and shares watering points with their livestock. They also have high rodent infestation and carry out slaughter of livestock from non-designated slaughter facilities and even so, meat inspection is not done. These are all risk practices.

iii. The study has also demonstrated the fact that a high proportion of the population in the study area lacks basic knowledge about *Leptospirosis* especially in relation to risk factors, causes, clinical signs, prevention and control. This should be addressed urgently given that the exposure to risk factors is very high; there is limited knowledge of the disease and lack of any preventive measures and the prevailing favourable environmental conditions for *Leptospirosis*. It was also observed that the level of knowledge about *Leptospirosis* is highly associated with contact with veterinary extension staff giving reason for optimism in addressing the disease.

iv. The study revealed that there is no specific public health programme directed towards addressing the neglected diseases which include *Leptospirosis* in both livestock and humans.

8.4 Recommendations

i. The County should initiate strategies for surveillance for *Leptospirosis* based on the risk the county is exposed to. Improved surveillance coupled with laboratory diagnosis in both humans and animals to confirm the disease will provide better estimates of the *Leptospirosis* burden in Bungoma County. All patients presenting with febrile signs should be tested for *Leptospirosis* for early and better of the disease.

ii. To address emerging and re-emerging zoonotic diseases such as *Leptospirosis* in the region, integrated surveillance teams and emergency response groups should be established.

iii. Efforts should be directed towards awareness creation and improving the knowledge of the people in the study area on the seriousness of the disease, cause of the disease, transmission, risk factors, role of rodents and methods of control and prevention.

iv. To implement successful public health programmes, efforts should be directed towards engaging the affected community for better results. Slaughterhouse workers and other veterinary personnel should wear protective gear.

8.5. Suggestions for further study

i. A more elaborate study to establish the seroprevalence of *Leptospirosis* in cattle, sheep, goats, swine and rodents in the entire Bungoma County. This should go further to identify the *leptospira* serovars and thus help in demonstrating the role of the different livestock species in the transmission and spread of *Leptospirosis* in both livestock and humans in the study area.

ii. The role of imported livestock in the high seroprevalence of *Leptospirosis* in the study area should be established.

iii. A study be conducted in humans to understand the relationship of the disease in animals and humans.

REFERENCES

Achoka J.S. and Maiyo J.K. (2008). Horrifying disasters in western Kenya impact on education and national development. *Research and Review Vol.3(3), pp. 154-161.*

Adom, D., Hussein, E. K., and Agyem, J. A. (2018). Theoretical and conceptual framework: Mandatory ingredients of a quality research. *International journal of scientific research*, *7*(1), 438-441.

Adugna, S. (2016). A review of bovine *Leptospirosis*. *Eur. J. Appl. Sci*, *8*(6), 347-355.

Agampodi, S., Gunarathna, S., Lee, J. S., and Excler, J. L. (2023). Global, regional, and country-level cost of *Leptospirosis* due to loss of productivity in humans. *PLOS Neglected Tropical Diseases*, *17*(8), e0011291.

Allan, K. J., Biggs, H. M., Halliday, J. E., Kazwala, R. R., Maro, V. P., Cleaveland, S., and Crump, J. A. (2015). Epidemiology of *Leptospirosis* in Africa: a systematic review of a neglected zoonosis and a paradigm for 'One Health'in Africa. *PLoS neglected tropical diseases*, *9*(9), e0003899.

Amatredjo, A., and Campbell, R. S. F. (1975). Bovine *Leptospirosis*.

Anand, A. C., and Garg, H. K. (2015). Approach to clinical syndrome of jaundice and encephalopathy in tropics. *Journal of clinical and experimental hepatology*, *5*, S116-S130.

Andre-Fontaine, G., Branger, C., Gray, A. W., and Klaasen, H. L. B. M. (2003). Comparison of the efficacy of three commercial bacterins in preventing canine *Leptospirosis*. *Veterinary record*, *153*(6), 165-169.

Andre-Fontaine, G., Branger, C., Gray, A. W., and Klaasen, H. L. B. M. (2003). Comparison of the efficacy of three commercial bacterins in preventing canine *Leptospirosis*. *Veterinary record*, *153*(6), 165-169.

Azfar, Z. M., Nazri, S. M., Rusli, A. M., Maizurah, O., Zahiruddin, W. M., Azwany, Y. N., ... and Aziah, B. D. (2018). Knowledge, attitude and practice about *Leptospirosis* prevention among town service workers in northeastern Malaysia: a cross-sectional study. *Journal of preventive medicine and hygiene*, *59*(1), E92.

Baharom, M., Ahmad, N., Hod, R., Ja'afar, M. H., Arsad, F. S., Tangang, F., ... and Osman, Y. (2023). Environmental and occupational factors associated with *Leptospirosis*: A systematic review. *Heliyon*.

Bakhshandeh, N., Tebianian, M., Khaki, P., Esmaelizad, M., and Saadatmand, S. (2021). Development of an In-house Indirect ELISA Test as a Diagnostic Tool for Bovine *Leptospirosis*. *International Journal of Enteric Pathogens*, *9*(2), 47-51.

Balamurugan, V., Veena, S., Thirumalesh, S. R. A., Alamuri, A., Sridevi, R., Sengupta, P. P., ... and Rahman, H. (2017). Distribution of serogroup specific antibodies against *Leptospirosis* in livestock in Odisha. *Indian J. Anim. Sci*, *87*(5), 546-551.

Benfield, C. T., Legnardi, M., Mayen, F., Almajali, A., Cinardi, G., Wisser, D., ... and Njeumi, F. (2023). Peste Des Petits Ruminants in the Middle East: Epidemiological Situation and Status of Control and Eradication Activities after the First Phase of the PPR Global Eradication Program (2017–2021). *Animals*, *13*(7), 1196.

Berger, P., and Luckmann, T. (2016). The social construction of reality. In *Social theory re-wired* (pp. 110-122). Routledge.

Bergstresser, S. M. (2020). Why a coronavirus quarantine in the US is a bad idea. *Last accessed on*. 1st October 2024.

Birnbaum, M. L., Daily, E. K., and O'Rourke, A. P. (2015). Research and evaluations of the health aspects of disasters, Part IV: framework for societal structures: the societal systems. *Prehospital and disaster medicine*, *30*(6), 633-647.

Bolin, C. A., and Cassells, J. A. (1992). Isolation of Leptospira interrogans serovars bratislava and hardjo from swine at slaughter. *Journal of Veterinary Diagnostic Investigation*, *4*(1), 87-89.

Bonzemo, S. B., Olago, D. O., Olaka, L. A., and Amwata, D. A. (2023). *Analysis of 30 years' historical climate change trends and variability in Mt. Elgon, Kenya, Africa*. Journal of Sustainability, Environment and Peace, 5(1). Retrieved from https://uonjournals.uonbi.ac.ke/ojs/index.php/jsep/article/view/1239

Boqvist, S., Chau, B. L., Gunnarsson, A., Engvall, E. O., Vågsholm, I., and Magnusson, U. (2002). Animal-and herd-level risk factors for leptospiral seropositivity among sows in the Mekong delta, Vietnam. *Preventive Veterinary Medicine*, *53*(3), 233-245.

Bradley, E. A., and Lockaby, G. (2023). *Leptospirosis* and the environment: A review and future directions. *Pathogens*, *12*(9), 1167.

Brooks, S. K., Webster, R. K., Smith, L. E., Woodland, L., Wessely, S., Greenberg, N., and Rubin, G. J. (2020). The psychological impact of quarantine and how to reduce it: rapid review of the evidence. *The lancet*, *395*(10227), 912-920.

Brown, P. D., McKenzie, M., and McGrowder, D. (2011). Environmental risk factors associated with *Leptospirosis* among butchers and their associates in Jamaica.

Buechler, S., Mekala, G. D., and Keraita, B. (2005). Wastewater use for urban and peri-urban agriculture. *Cities farming for the future, urban agriculture for green and productive cities*, 244-260.

Burdin, M. L., and Froyd, G. (1957). Bovine *Leptospirosis* in Kenya. *Nature*, *179*(4570), 1140-1140.

Buss, P. M., Fonseca, L. E., Galvão, L. A. C., Fortune, K., and Cook, C. (2016). Health in all policies in the partnership for sustainable development. *Revista Panamericana de Salud Pública*, *40*, 186-191.

Calisher, C. H., Childs, J. E., Field, H. E., Holmes, K. V., and Schountz, T. (2006). Bats: important reservoir hosts of emerging viruses. *Clinical microbiology reviews*, *19*(3), 531-545.

Campbell, M., Fitzpatrick, R., Haines, A., Kinmonth, A. L., Sandercock, P., Spiegelhalter, D., and Tyrer, P. (2000). Framework for design and evaluation of complex interventions to improve health. *Bmj*, *321*(7262), 694-696.

Catley, A. P. (2004). Validation of participatory appraisal for use in animal health information systems in Africa.

Catley, A., and Admassu, B. (2003). Using participatory epidemiology to assess the impact of livestock diseases. *Community-based Animal Health and Participatory Epidemiology (CAPE) Unit*.

Catley, A., and Mariner, J. (2002). Where there is no data: participatory approaches to veterinary epidemiology in pastoral areas of the Horn of Africa.

Center for Diseases Control [CDC]. (2010). One Health": A policy perspective - taking stock and shaping an implementation roadmap.

Center for Disease and *Leptospirosis* Prevention [CDLP]. (2016). *CDLP Annual Report, 2016*. Nairobi, Kenya.

Center for Disease and Veterinary Services [CDVS]. (2016). *CDVS Annual Report, 2016*. Nairobi, Kenya.

Center for Disease and Veterinary Services [CDVS]. (2017). *CDVS Annual Report, 2017*. Nairobi, Kenya.

Center for Disease Management and Surveillance [CDMS]. (2016). *CDMS Annual Report, 2016*. Nairobi, Kenya.

Chappel, R. J., Millar, B. D., Adler, B., Hill, J., Jeffers, M. J., Jones, R. T., ... and Skilbeck, N. W. (1989). Leptospira interrogans serovar hardjo is not a major cause of bovine abortion in Victoria. *Australian Veterinary Journal*, *66*(10), 330-333.

Chemarum, K. A. (2016). *Socio-economic impacts of the Kenya agricultural carbon project on farmers' livelihoods in Bungoma County, Western Kenya* (Master's thesis, Norwegian University of Life Sciences, Ås).

Choi, B. C., and Pak, A. W. (2006). Multidisciplinarity, interdisciplinarity and transdisciplinarity in health research, services, education and policy: 1.

Definitions, objectives, and evidence of effectiveness. *Clinical* and *Investigative Medicine*, *29*(6).

Commodari, E., and La Rosa, V. L. (2020). Adolescents in quarantine during COVID-19 pandemic in Italy: perceived health risk, beliefs, psychological experiences and expectations for the future. *Frontiers in psychology*, *11*, 559951.

Cook, E. A. J., de Glanville, W. A., Thomas, L. F., Kariuki, S., de Clare Bronsvoort, B. M., and Fèvre, E. M. (2017). Risk factors for *Leptospirosis* seropositivity in slaughterhouse workers in western Kenya. *Occupational and Environmental Medicine*, *74*(5), 357-365.

Costa, F., Hagan, J. E., Calcagno, J., Kane, M., Torgerson, P., Martinez-Silveira, M. S., ... and Ko, A. I. (2015). Global morbidity and mortality of *Leptospirosis*: a systematic review. *PLoS neglected tropical diseases*, *9*(9), e0003898.

County Government of Bungoma. (2013). *Bungoma County Integrated Development Plan 2013-2017*. Public Finance. Retrieved from https://repository.kippra.or.ke/handle/123456789/1179

Cousins, D. V., Ellis, T. M., Parkinson, J., and McGlashan, C. H. (1989). Evidence for sheep as a maintenance host for Leptospira interrogans serovar hardjo.

Daszak, P., Cunningham, A. A., and Hyatt, A. D. (2000). Emerging infectious diseases of wildlife--threats to biodiversity and human health. *science*, *287*(5452), 443-449.

de Sousa, R., Reusken, C., and Koopmans, M. (2014). MERS coronavirus: data gaps for laboratory preparedness. *Journal of Clinical Virology*, *59*(1), 4-11.

De Vries, S. G., Visser, B. J., Nagel, I. M., Goris, M. G., Hartskeerl, R. A., and Grobusch, M. P. (2014). *Leptospirosis* in Sub-Saharan Africa: a systematic review. *International Journal of Infectious Diseases*, *28*, 47-64.

Deka, R. P., Magnusson, U., Grace, D., and Lindahl, J. (2018). Bovine brucellosis: prevalence, risk factors, economic cost and control options with particular reference to India-a review. *Infection Ecology* and *Epidemiology*, *8*(1), 1556548.

Dhimal, M., Aryal, K. K., Dhimal, M. L., Gautam, I., Singh, S. P., *et al*. (2014). Knowledge, attitude and practice regarding dengue fever among the healthy population of highland and lowland communities in central Nepal. *PLoS ONE, 9*(7), e102028. https://doi.org/10.1371/journal.pone.0102028

Dias, J. P., Teixeira, M. G., Costa, M. C. N., Mendes, C. M. C., Guimarães, P., Reis, M. G., ... and Barreto, M. L. (2007). Fatores associados à infecção por Leptospira sp em um grande centro urbano do Nordeste do Brasil. *Revista da Sociedade Brasileira de Medicina Tropical*, *40*, 499-504.

Djulbegovic, B. (2014). A framework to bridge the gaps between evidence-based medicine, health outcomes, and improvement and implementation science. *Journal of Oncology Practice*, *10*(3), 200-202.

Dupouey, J., Faucher, B., Edouard, S., Richet, H., Kodjo, A., Drancourt, M., and Davoust, B. (2014). Human *Leptospirosis*: an emerging risk in Europe? *Comparative immunology, microbiology and infectious diseases*, *37*(2), 77-83.

Ellis, W. A., O'brien, J. J., Cassells, J. A., Neill, S. D., and Hanna, J. (1985b). Excretion of Leptospira interrogans serovar hardjo following calving or abortion. *Research in veterinary science*, *39*(3), 296-298.

Esteves, L. M., Bulhões, S. M., Branco, C. C., Carreira, T., Vieira, M. L., Gomes-Solecki, M., and Mota-Vieira, L. (2018). Diagnosis of human *Leptospirosis* in a clinical setting: real-time PCR high resolution melting analysis for detection of Leptospira at the onset of disease. *Scientific reports*, *8*(1), 9213.

Evangelista, K. V., and Coburn, J. (2010). Leptospira as an emerging pathogen: a review of its biology, pathogenesis and host immune responses. *Future microbiology*, *5*(9), 1413-1425.

Faine, S. (1994). Leptospira and *Leptospirosis* CRC press. *Inc. USA*.

Fajriyah, S. N., Udiyono, A., and Saraswati, L. D. (2017, February). Environmental and risk factors of *Leptospirosis*: a spatial analysis in Semarang City. In *IOP Conference Series: Earth and Environmental Science* (Vol. 55, No. 1, p. 012013). IOP Publishing.

Farida, D. H., and Ristiyanto, R. (2008). Distribusi dan faktor resiko lingkungan penularan *Leptospirosis* di Kabupaten Demak, Jawa Tengah. *Media Penelitian dan Pengembangan Kesehatan*, *18*(4), 160730.

Febrian, F., and Solikhah, S. (2013). Analisis Spasial Kejadian Penyakit *Leptospirosis* di Kabupaten Sleman Propinsi Daerah Istimewa Yogyakarta Tahun 2011. *Kes Mas: Jurnal Fakultas Kesehatan Masyarakat Universitas Ahmad Daulan*, *7*(1), 24942.

Fisman, D. (2012). Seasonality of viral infections: mechanisms and unknowns. *Clinical Microbiology and Infection*, *18*(10), 946-954.

Fleischman, D. S., Webster, G. D., Judah, G., De Barra, M., Aunger, R., and Curtis, V. A. (2011). Sensor recorded changes in rates of hand washing with soap in response to the media reports of the H1N1 pandemic in Britain. *BMJ open*, *1*(2), e000127.

Forrester, A. T. T., Kranendonk, O., Turner, L. H., Wolff, J. W., and Bohlander, H. J. (1969). Serological evidence of human *Leptospirosis* in Kenya.

Fox, A. M., Balarajan, Y., Cheng, C., and Reich, M. R. (2015). Measuring political commitment and opportunities to advance food and nutrition security: piloting a rapid assessment tool. *Health policy and planning*, *30*(5), 566-578.

Gardiner, P., Mitchell, S., Filippelli, A. C., Sadikova, E., White, L. F., Paasche-Orlow, M. K., and Jack, B. W. (2013). Health literacy and complementary and alternative medicine use among underserved inpatients in a safety net hospital. *Journal of Health Communication*, *18*(sup1), 290-297.

Gaynor, K., Katz, A. R., Park, S. Y., Nakata, M., Clark, T. A., and Effler, P. V. (2007). *Leptospirosis* on Oahu: an outbreak associated with flooding of a university campus. *The American journal of tropical medicine and hygiene*, *76*(5), 882-886.

Gilbert, R., and Cliffe, S. J. (2016). Public health surveillance. *Public health intelligence: issues of measure and method*, 91-110.

Giles, N., Hathaway, S. C., and Stevens, A. E. (1983). Isolation of Leptospira interrogans serovar hardjo from a viable premature calf. *The Veterinary Record*, *113*(8), 174-176.

Githinji, J. W. (2014). Strategic management practices adopted by the directorate of veterinary services, ministry of agriculture, livestock and fisheries, Kenya.

Goris, M. (2016). *Leptospirosis: Epidemiology, clinical aspects and diagnosis*.

Government of Kenya (2013). *Livestock population*. Kenya National Bureau of Statistics. Retrieved from https://www.knbs.or.ke/livestock-population/

Government of Kenya (2017). *Kenya national disaster risk management policy*. National Disaster Operations Centre. Retrieved from https://www.preventionweb.net/publication/kenya-national-disaster-risk-management-policy-2017

Government of Kenya (2020a). Reducing Health Emergencies of Droughts and Floods in Kenya. Kenya Institute for Public Policy Research and Analysis. KIPPRA Discussion Paper 247, 2020.

Government of Kenya (2020b). *Veterinary Policy: Sessional Paper No. 2 of 2020*. Ministry of Agriculture, Livestock, Fisheries and Cooperatives. Retrieved from https://kilimo.go.ke/wp-content/uploads/2023/11/Veterinary-Policy-Sessional-Paper-No_-2-of-2020-Final-1.pdf

Government of Kenya. (2010). *2010 National Climate Change Response Strategy*. Nairobi: Ministry of Environment and Natural Resources.

Government of Kenya. (2013). *Bungoma County Integrated Development Plan 2013-2017*. Kenya Institute for Public Policy Research and Analysis. https://repository.kippra.or.ke/handle/123456789/1179

Government of Kenya. (2017). *National Policy for Disaster Risk Management in Kenya, 2017*. Nairobi: Ministry of Interior.

Gozdzielewska, L., Kilpatrick, C., Reilly, J., Stewart, S., Butcher, J., Kalule, A., ... and Price, L. (2022). The effectiveness of hand hygiene interventions for preventing community transmission or acquisition of novel coronavirus or influenza infections: a systematic review. *BMC Public Health*, *22*(1), 1283.

Greenhalgh, T., and Papoutsi, C. (2018). Studying complexity in health services research: desperately seeking an overdue paradigm shift. *BMC medicine*, *16*, 1-6.

Haake, D. A., and Levett, P. N. (2015). *Leptospirosis* in humans. *Leptospira and Leptospirosis*, 65-97.

Haake, D. A., Dundoo, M., Cader, R., Kubak, B. M., Hartskeerl, R. A., Sejvar, J. J., and Ashford, D. A. (2002). *Leptospirosis*, water sports, and chemoprophylaxis. *Clinical Infectious Diseases*, *34*(9), e40-e43.

Halabi, S. F., Gostin, L. O., and Crowley, J. S. (Eds.). (2016). *Global management of infectious disease after Ebola*. Oxford University Press.

Halliday, J. E., Knobel, D. L., Allan, K. J., Bronsvoort, B. M. D. C., Handel, I., Agwanda, B., ... and Breiman, R. F. (2013). Urban *Leptospirosis* in Africa: a cross-sectional survey of Leptospira infection in rodents in the Kibera urban settlement, Nairobi, Kenya. *The American journal of tropical medicine and hygiene*, *89*(6), 1095.

Han, Z., Wang, L., Zhang, J., Weng, M., and Kang, M. (2021). Map design for public health emergencies: A novel conceptual framework for thematic content selection. *Journal of Geovisualization and Spatial Analysis*, *5*, 1-17.

Hawe, P. (2015). Lessons from complex interventions to improve health. *Annual review of public health*, *36*(1), 307-323.

Hawryluck, L., Gold, W. L., Robinson, S., Pogorski, S., Galea, S., and Styra, R. (2004). SARS control and psychological effects of quarantine, Toronto, Canada. *Emerging infectious diseases*, *10*(7), 1206.

Hayes, D., and Hayes, G. B. (2015). *Cowed: the hidden impact of 93 million cows on America's health, economy, politics, culture, and environment*. WW Norton and Company.

Heuer, C., Dreyfus, A., Wilson, P. R., Benschop, J., Subharat, S., Ayanegui-Alcerreca, A. M., ... and Midwinter, A. C. (2010). Epidemiology and control of *Leptospirosis* in New Zealand.

Himsworth, C. G., Parsons, K. L., Jardine, C., and Patrick, D. M. (2013). Rats, cities, people, and pathogens: a systematic review and narrative synthesis of literature regarding the ecology of rat-associated zoonoses in urban centers. *Vector-Borne and Zoonotic Diseases*, *13*(6), 349-359.

Huho, J. M., Mashara, J. N., and Musyimi, P. K. (2016). Profiling disasters in Kenya and their causes.

Hui, D. S. (2016). Super-spreading events of MERS-CoV infection. *Lancet (London, England)*, *388*(10048), 942.

Islam, S. S., Sarker, M. S., Akhter, A. T., Shanta, I. S., Rahman, A. A., and Sufian, M. A. (2024). Animal, human, and environmental perspectives on anthrax in Bangladesh. *Heliyon*, *10*(1).

Jaykaran, C., Deepak, S., Summaiya, M., and Preeti, Y. (2013). Antibiotics for the treatment of *Leptospirosis*: systematic review and meta-analysis of controlled trials.

Jung, B. Y., Lee, K. W., and Ha, T. Y. (2010). Seroprevalence of Leptospira spp. in clinically healthy racing horses in Korea. *Journal of Veterinary Medical Science*, *72*(2), 197-201.

Kamath, R., Swain, S., Pattanshetty, S., and Nair, N. S. (2014). Studying risk factors associated with human *Leptospirosis*. *Journal of Global Infectious Diseases*, *6*(1), 3-9.

Kawaguchi, L., Sengkeopraseuth, B., Tsuyuoka, R., Koizumi, N., Akashi, H., Vongphrachanh, P., ... and Aoyama, A. (2008). Seroprevalence of *Leptospirosis* and risk factor analysis in flood-prone rural areas in Lao PDR. *The American journal of tropical medicine and hygiene*, *78*(6), 957-961.

Khaki, P. (2016). Clinical laboratory diagnosis of human *Leptospirosis*. *Int J Enteric Pathog*, *4*(1), 1-7.

Klaasen, H. L. B. M., Molkenboer, M. J. C. H., Vrijenhoek, M. P., and Kaashoek, M. J. (2003). Duration of immunity in dogs vaccinated against *Leptospirosis* with a bivalent inactivated vaccine. *Veterinary microbiology*, *95*(1-2), 121-132.

Kleinman, A. (2010). Four social theories for global health. *The lancet*, *375*(9725), 1518-1519.

Kulpiisova, A., Aitpayeva, Z., Maimatayeva, A., Ussenova, L., Paritova, A., Zhanabayev, A., ... and Burambayeva, N. (2024). Knowledge, attitude and practice related to anthrax among livestock farmers in West Kazakhstan. *Veterinary Medicine and Science*, *10*(5), e1553.

Kupek, E., de Sousa Santos Faversani, M. C., and de Souza Philippi, J. M. (1991). The relationship between rainfall and human *Leptospirosis* in Florianópolis. *Brazil*, *1996*, 131-134.

Lamprey, R. H., and Reid, R. S. (2004). Expansion of human settlement in Kenya's Maasai Mara: what future for pastoralism and wildlife? *Journal of Biogeography*, *31*(6), 997-1032.

Lau, C. L., Smythe, L. D., Craig, S. B., and Weinstein, P. (2010). Climate change, flooding, urbanisation and *Leptospirosis*: fuelling the fire?. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, *104*(10), 631-638.

Lee, H. S., Khong, N. V., Xuan, H. N., Nghia, V. B., Nguyen-Viet, H., and Grace, D. (2017). Sero-prevalence of specific *Leptospira serovars* in fattening pigs from 5 provinces in Vietnam. *BMC veterinary research*, *13*, 1-7.

Levett, P. N. (2001). *Leptospirosis*. Clin. Microbiol. 14 (2): 296-326.

Li, B., Huang, Y., Ling, C., Jiao, F., Fu, H., and Deng, R. (2023). The effect of community-based health education programs on health literacy in severely impoverished counties in Southwestern China: Results from a quasi-experimental design. *Frontiers in Public Health*, *10*, 1088934.

Macharia, S. M. (1989). *A comparative sero-epidemiological survey for the prevalence of Leptospira antibodies in domestic animals and man in Nyandarua and Turkana districts of Kenya* (Doctoral dissertation, University of Nairobi).

Maleki, S., Sookhtehzari, A., and Abdollahpour, G. (2015). Serodiagnosis of *Leptospirosis* in Cattle in Khorramabad, west Iran. *Bull. Georgian Nat. Acad. ScI.*, *9*, 173-176.

Matthias, M. A., Díaz, M. M., Campos, K. J., Calderon, M., Willig, M. R., Pacheco, V., ... and Vinetz, J. M. (2005). Diversity of bat-associated Leptospira in the Peruvian Amazon inferred by bayesian phylogenetic analysis of 16S ribosomal DNA sequences. *The American journal of tropical medicine and hygiene*, *73*(5), 964.

Mbae, R., Kimoro, B., Kibor, B. T., Wilkes, A., Odhong, C., Dijk, S. V., ... and Khobondo, J. O. (2020). The Livestock Sub-sector in Kenya's NDC: a scoping of gaps and priorities.

Meslin, F. X. (2006). Impact of zoonoses on human health. *Vet Ital*, *42*(4), 369-379.

Mgode, G. F., Mbugi, H. A., Mhamphi, G. G., Ndanga, D., and Nkwama, E. L. (2014). Seroprevalence of Leptospira infection in bats roosting in human settlements in Morogoro municipality in Tanzania. *Tanzania Journal of Health Research*, *16*(1).

Miller, D. A., Wilson, M. A., and Beran, G. W. (1991). Relationships between prevalence of Leptospira interrogans in cattle, and regional, climatic, and seasonal factors. *American Journal of Veterinary Research*, *52*(11), 1766-1768.

Mühldorfer, K. (2013). Bats and bacterial pathogens: a review. *Zoonoses and public health*, *60*(1), 93-103.

Munoz, F., and Jarquin, C. (1995). Outbreak of acute febrile illness and pulmonary hemorrhage--Nicaragua, 1995. *MMWR: Morbidity* and *Mortality Weekly Report*, *44*(44), 841-843.

Murray, G. L., Lo, M., Bulach, D. M., Srikram, A., Seemann, T., Quinsey, N. S., ... and Adler, B. (2013). Evaluation of 238 antigens of Leptospira borgpetersenii serovar Hardjo for protection against kidney colonisation. *Vaccine*, *31*(3), 495-499.

Mythri, B. A. (2015). Laboratory diagnosis of *Leptospirosis*: a review. *Journal of Evolution of Medical and dental sciences*, *4*(50), 8759-8770.

Nakeel, M. J., Arimi, S. M., Kitala, P., Nduhiu, G., Njenga, J. M., and Wabacha, J. K. (2016). A sero-epidemiological survey of brucellosis, Q-fever and *Leptospirosis* in livestock and humans and associated risk factors in kajiado county-Kenya. *J Trop Dis*, *4*(3), 8.

Nanyende, D. W. (2010). *Estimation of the prevalence of brucellosis in humans and livestock in Northern Turkana district, Kenya* (Doctoral dissertation, University of Nairobi).

Ngugi, J. N., Fèvre, E. M., Mgode, G. F., Obonyo, M., Mhamphi, G. G., Otieno, C. A., and Cook, E. A. J. (2019). Seroprevalence and associated risk factors of *Leptospirosis* in slaughter pigs; a neglected public health risk, western Kenya. *BMC veterinary research*, *15*, 1-11.

Nguyen, G. T., Pu, J., and Watanabe, T. (2019). Floods and foods as potential carriers of disease between urban and rural areas. *Health in ecological perspectives in the anthropocene*, 133-144.

Nyongesa, N. (2016). Oral Report Office International des Epizooties [WOAH]. Manual of diagnostic tests and vaccines for terrestrial animals. WOAH; 2004. *Leptospirosis*.

Ogundipe, R. (2020). Cultural Practices and Health Consequences: Health or Habits, the Choice Is Ours. In *Public Health in Developing Countries-Challenges and Opportunities*. IntechOpen.

Oliveira, A. A. F., Mota, R. A., Langoni, H., Souza, M. I., Navegantes, W. A., Sa, M. E. P., and Pereira, G. C. (2001). Seroprevalence of bovine *Leptospirosis* in Garanhuns municipal district, Pernambuco State, Brazil.

Omondi, M., Ngere, I., and Ndeda, C. (2016). Report on the evaluation of surveillance systems relevant to zoonotic diseases in Kenya, 2015: A basis for design of an integrated human–livestock surveillance system.

Owuor, O. (2015). *Influence of preventive strategies on malaria prevalence in Mfangano Island, Mbita Sub County, Kenya* (Doctoral dissertation).

Palaniappan, R. U., Ramanujam, S., and Chang, Y. F. (2007). *Leptospirosis*: pathogenesis, immunity, and diagnosis. *Current opinion in infectious diseases*, *20*(3), 284-292.

Pappas, G., Papadimitriou, P., Siozopoulou, V., Christou, L., and Akritidis, N. (2008). The globalization of *Leptospirosis*: worldwide incidence trends. *International journal of infectious diseases*, *12*(4), 351-357.

Pawson, R. (1997). Realistic evaluation.

Plank, R., and Dean, D. (2000). Overview of the epidemiology, microbiology, and pathogenesis of Leptospira spp. in humans. *Microbes and infection*, *2*(10), 1265-1276.

Postic, D. (2000). *Biological diagnosis Leptospirosis-Lyme borreliosis* (Vol. 2). Institut Pasteur.

Prescott, J. F., McEwen, B., Taylor, J., Woods, J. P., Abrams-Ogg, A., and Wilcock, B. (2002). Resurgence of *Leptospirosis* in dogs in Ontario: recent findings. *The Canadian Veterinary Journal*, *43*(12), 955.

Pritchard, G. C., Borland, E. D., Wood, L., and Pritchard, D. G. (1989). Severe disease in a dairy herd associated with acute infection with bovine virus diarrhoea virus, Leptospira harjo and Coxiella burnetii. *The Veterinary Record*, *124*(24), 625-629.

Radostits, O. M., Gay, C. C., Blood, D. C., and Hinchcliff, K. W. (2000). Diseases caused by Leptospira spp. *Veterinary Medicine-A text book of the Diseases of Cattle, Sheep, Pigs, Goats and Horses*, *8*, 884-907.

Rahman, M. T., Sobur, M. A., Islam, M. S., Ievy, S., Hossain, M. J., El Zowalaty, M. E., ... and Ashour, H. M. (2020). Zoonotic diseases: etiology, impact, and control. *Microorganisms*, *8*(9), 1405.

Raja, V., and Natarajaseenivasan, K. (2015). Pathogenic, diagnostic and vaccine potential of leptospiral outer membrane proteins (OMPs). *Critical reviews in microbiology*, *41*(1), 1-17.

Rejeki, D. S. S., Nurlaela, S., and Octaviana, D. (2013). Pemetaan dan analisis faktor risiko *Leptospirosis*. *Kesmas*, *8*(4), 179-186.

Ricaldi, J. N., and Vinetz, J. M. (2006). *Leptospirosis* in the tropics and in travelers. *Current infectious disease reports*, *8*, 51-58.

Rickles, D. (2009). Causality in complex interventions. *Medicine, Health Care and Philosophy*, *12*, 77-90.

Robertson, A., Boulanger, P., and Mitchell, D. (1964). Isolation and identification of a leptospire of the hebdomadis serogroup (L. hardjo) from cattle in Canada. *Canadian Journal of Comparative Medicine and Veterinary Science*, *28*(1), 13.

Rono, D. K. (2021). *Health and environmental risks of using wastewater in vegetable production in urban and peri-urban areas of Nairobi City, Kenya* (Doctoral dissertation, MMUST).

Roth, E. E., and Galton, M. M. (1960). Isolation and identification of Leptospira hardjo from cattle in Louisiana.

Saha, S. K., Gupta, A. K. S., Surana, R., Jasuja, P., and Eslamian, S. (2023). Water Resources and Irrigation Practices of Contemporary India. In *Handbook of Irrigation Hydrology and Management* (pp. 261-289). CRC Press.

Sakundarno, M., Bertolatti, D., Maycock, B., Spickett, J., and Dhaliwal, S. (2014). Risk factors for *Leptospirosis* infection in humans and implications for public health intervention in Indonesia and the Asia-Pacific region. *Asia Pacific Journal of Public Health*, *26*(1), 15-32.

Samsudin, S., Saudi, S. N., Masri, N. S., Ithnin, N. R., TZMt, J., Hamat, R. A., ... and Osman, M. (2020). Awareness, knowledge, attitude and preventive practice of *Leptospirosis* among healthy Malaysian and Non-Malaysian wet market workers in selected urban areas in Selangor, Malaysia. *International journal of environmental research and public health*, *17*(4), 1346.

Saputra, R. K., Rahardjo, S. S., and Murti, B. (2021). The Effect of Personal Protective Equipment Uptake on the Risk of Leprosy in Adults: Meta Analysis. *Journal of Health Promotion and Behavior*, *6*(1), 21-31.

Sessions J.K. and Greene C.E. (2004). Canine *Leptospirosis*; Prevention, treatment and zoonosis. *Infectious Disease.* Vol 26, No 9.

Shearer, K. E., Harte, M. J., Ojkic, D., DeLay, J., and Campbell, D. (2014). Detection of Leptospira spp. in wildlife reservoir hosts in Ontario through comparison of immunohistochemical and polymerase chain reaction genotyping methods. *The Canadian Veterinary Journal*, *55*(3), 240.

Situma G., (2016). Evaluation of factors affecting Beef supply chain performance: A case of Bungoma County; PhD Thesis.

Slack, A. T., Symonds, M. L., Dohnt, M. F., and Smythe, L. D. (2006). The epidemiology of *Leptospirosis* and the emergence of Leptospira borgpetersenii serovar Arborea in Queensland, Australia, 1998–2004. *Epidemiology* and *Infection*, *134*(6), 1217-1225.

Specktor, B. (2020). Coronavirus: What is' flattening the curve,'and will it work. *Live Science*, *16*.

SPSS Inc. (2002). *SPSS 11.5 for Windows* [Computer software]. Chicago, IL: SPSS Inc.

Sullivan, N. D., and Stallman, N. D. (1969). The isolation of a strain of Leptospira, serotype hardjo, from cattle in Queensland.

Tan, C. G., Dharmarajan, G., Beasley, J., Rhodes Jr, O., Moore, G., Wu, C. C., and Lin, T. L. (2014). Neglected *Leptospirosis* in raccoons (Procyon lotor) in Indiana, USA. *Veterinary Quarterly*, *34*(1), 1-10.

Tassinari, W. S., Pellegrini, D. C., Sá, C. B., Reis, R. B., Ko, A. I., and Carvalho, M. S. (2008). Detection and modelling of case clusters for urban *Leptospirosis*. *Tropical medicine* and *international health*, *13*(4), 503-512.

Tesfaye, D., Fekede, D., Tigre, W., Regassa, A., and Fekadu, A. (2013). Perception of the public on the common zoonotic diseases in Jimma, Southwestern Ethiopia. *International Journal of Medicine and Medical Sciences*, *5*(6), 279-285.

Thacker, S. B., and Berkelman, R. L. (1988). Public health surveillance in the United States. *Epidemiologic reviews*, *10*(1), 164-190.

The OIE, now known as the World Organisation for Animal Health (WOAH). (2004). *Manual of Diagnostic Tests and Vaccines for Terrestrial Animals*. Retrieved from https://shorturl.at/O5Fka

Thiermann, A. B. (1984). *Leptospirosis*: current developments and trends.

Thursfield, M. (2005). Veterinary epidemiology 3rd ed. *UK. Black well science Ltd*, 183.

Tilahun, Z., Reta, D., and Simenew, K. (2013). Global epidemiological overview of *Leptospirosis*. *Int J Microbiol Res*, *4*(1), 9-5.

Torgerson, P. R., Hagan, J. E., Costa, F., Calcagno, J., Kane, M., Martinez-Silveira, M. S., ... and Abela-Ridder, B. (2015). Global burden of *Leptospirosis*: estimated in terms of disability adjusted life years. *PLoS neglected tropical diseases*, *9*(10), e0004122.

Tulsiani, S. M., Cobbold, R. N., Graham, G. C., Dohnt, M. F., Burns, M. A., Leung, L. P., ... and Craig, S. B. (2011). The role of fruit bats in the transmission of pathogenic leptospires in Australia. *Annals of Tropical Medicine* and *Parasitology*, *105*(1), 71-84.

UNDP Amani Papers, (2010). Mt Elgon Conflict: A Rappid Assessment of underpinning Socio-Economic, governance and security factors (Vol.1, No.1).

United Nations Office for Disaster Risk Reduction (UNDRR). (2015). *Sendai Framework for Disaster Risk Reduction 2015-2030*. United Nations Headquarters.

Vijayachari, P., Sugunan, A. P., and Shriram, A. N. (2008). *Leptospirosis*: an emerging global public health problem. *Journal of biosciences*, *33*(4), 557-569.

Wabwoba, M. S. (2017). Factors contributing to low productivity and food insecurity in Bungoma County, Kenya. *Biomedical Journal of Scientific* and *Technical Research*, *1*(7), 1813-6.

Wanyama, M., and Egesah, O. (2015). Ethnography and ethno-music of babukusutraditional male circumcision; messaging, symbolism and rationale. *Sociology and Anthropology*, *3*(1), 6-18.

Ward, P. J., Kummu, M., and Lall, U. (2016). Flood frequencies and durations and their response to El Niño Southern Oscillation: Global analysis. *Journal of Hydrology*, *539*, 358-378.

Wasinski, B., and Dutkiewicz, J. (2013). *Leptospirosis*-current risk factors connected with human activity and the environment. *Annals of Agricultural and Environmental Medicine*, *20*(2).

WHO (2017). *Promoting Health in the SDGs. Report on the 9th Global Conference for Health Promotion, Shanghai, China, 21–24 November 2016: All for Health, Health for All*. Geneva: World Health Organization.

WHO. (2009). Guidelines for measles Preparedness and Response, Geneva, Switzerland: *World Health Organization*.

WHO. (2015). Emergency Preparedness Response. *World Health Organization*, Geneva, Switzerland.

WHO. *(2020) Considerations for quarantine of individuals in the context of containment for coronavirus disease (COVID-19): Interim guidance, 19 March 2020.* World Health Organization; https://appswhoint/iris/handle/10665/331497 License: CC BY-NC-SA 30 IGO .

Winslow, W. E., Merry, D. J., Pirc, M. L., and Devine, P. L. (1997). Evaluation of a commercial enzyme-linked immunosorbent assay for detection of immunoglobulin M antibody in diagnosis of human leptospiral infection. *Journal of clinical microbiology*, *35*(8), 1938-1942.

Wiwanitkit, V. (2006). A note from a survey of some knowledge aspects of *Leptospirosis* among a sample of rural villagers in the highly endemic area, Thailand. *Rural and remote health*, *6*(1), 1-6.

World Health Organization. (2007). *Leptospirosis fact sheets*. https://iris.who.int/bitstream/handle/10665/205437/B4221.pdf?sequence=1

World Health Organization. (2014). *WHO Country Cooperation Strategy Kenya: medium-term support strategy 2014-2019*. World Health Organization, Kenya Country Office.

Wright, J., Gundry, S., and Conroy, R. (2004). Household drinking water in developing countries: a systematic review of microbiological contamination between source and point-of-use. *Tropical medicine* and *international health*, *9*(1), 106-117.

Zorigt, T., Ito, S., Isoda, N., Furuta, Y., Shawa, M., Norov, N., ... and Higashi, H. (2021). Risk factors and spatio-temporal patterns of livestock anthrax in Khuvsgul Province, Mongolia. *PloS one*, *16*(11), e0260299.

Zumla, A., Hui, D. S., and Perlman, S. (2015). Middle East respiratory syndrome. *The Lancet*, *386*(9997), 995-1007.

APPENDICES

Appendix 1

Informed Consent Form

Project name: PhD research entitled "Evaluation of the Re-Emergence Of *Leptospirosis* And Its Impact On Public Health Strategies in Bungoma County, Kenya"

Researcher: Dr. David W. Nanyende supervised by Prof. Jacob Wakhungu (Masinde Muliro University of Science and Technology), Prof Donald Siamba (Kibabii University) and Dr. Ferdinand Nabiswa, PhD (Masinde Muliro University of Science and Technology).

Collaborating Institutions: None.

Invitation to participate and description of the project

You are invited to participate in a research study that is designed to investigate the re-emergence of *Leptospirosis* and its impact on public health strategies in Bungoma County, Kenya. I would like to collect information regarding *Leptospirosis* outbreak of 2004 at Chesamisi, the likely source of infection, impact on the education and health (both human and livestock) sectors. This research is trying to understand the underlying spatial patterns of the distribution of the foci of the outbreak in relation to prevailing risk factors such as weather patterns, livestock movement patterns, hygiene standards, post-harvest storage, level of awareness about the disease and collaboration between veterinarians and medical personnel in the diagnosis of zoonotic diseases. Zoonoses are diseases transmitted between humans and their domestic livestock. This study aims to come up with a plan for addressing emerging zoonoses which if not addressed early have the potential to become a public health disaster.

Description of study procedures

If you decide to participate, the following things will happen:

1. Questionnaire for to the head of household.

   A questionnaire will be administered to the head of sampled households. We will ask you some questions about yourself (contact details), detailed questions about your livestock keeping, production and awareness of zoonotic diseases and specifically *Leptospirosis*.

2. Geolocation will be taken using a GPS: The geolocation of medical and veterinary facilities in the foci of the outbreak will be taken. In addition, the livestock markets, livestock movement routes, public health facilities including slaughter facilities, affected education institutions will also be georeferenced using a hand held GPS.

3. Key Informant Interviews

   Key informant interviews will be held with the heads of schools which were affected by the 2004 *Leptospirosis* outbreak, Sub-County Veterinary Officer and Medical officers in the affected sub-counties.

   Confidentiality

Any personal data disclosed during this interview will remain confidential to the research team, and not be used in any way that may lead to victimisation of the respondents in any way. Your identity will remain anonymous throughout.

The research team will record your answers to the questionnaire. Your answers will be given codes so that you cannot be identified from our database. All data are kept securely, and only the research team will have access to the database.

Your information will only be used for research purposes and no personal information will ever be published.

Participation and withdrawal

We would like to emphasize that your participation is voluntary. If you consent and then later decide that you would like to withdraw, you are free to do this at any point.

If you later decide that you do not want your information to be used in the study, you can contact the study team and ask that your contribution be withdrawn. Contact details are provided below.

If there is anything that you have not understood, please feel free to ask questions. You are welcome to ask us to go over any aspect of this form again before you decide whether or not to participate.

Authorisation

Project Name: PhD research entitled EVALUATION OF THE RE-EMERGENCE OF *LEPTOSPIROSIS* AND ITS IMPACT ON PUBLIC HEALTH PROGRAMMES IN BUNGOMA COUNTY, KENYA.

Researcher: Dr. David W. Nanyende supervised by Prof. Jacob Wakhungu (Masinde Muliro University of Science and Technology), Dr Donald Siamba (Kibabii University) and Dr Ferdinand Nabiswa (Masinde Muliro University of Science and Technology).

Please read the following information carefully. You may also request a copy for yourself.

Please fill the box

I confirm that I have read and have understood the information given for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.

I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my rights being affected.

I understand that, I can at any time ask for access to the information I provide and I can also request the destruction of that information if I wish. I understand that I may refuse to answer particular questions and individual privacy will be maintained in all published and written data from the study

I understand that photographs will be taken during this study and I give my consent for the use of my photographs in this study.

Name of Person giving consent	Date	Signature
______________________________	______	_________
Researcher	Date	Signature

Appendix II

Questionnaire for Head of Household in Bungoma County, Kenya

Date:………………………………….

Name:………………………………………………………………………..

Area:………………….Sub-location:……………………Location:…..……

Household no:……………………

Livestock species kept:……………………………………….

Other domestic animals kept: Dogs/cats.

The type of grazing system of livestock: Zero grazing /individual /communal/other(specify).

Is the watering of livestock carried out on individual herds or shared between herds: Individual/shared/ other (specify)……………

Are you aware of diseases transmissible between livestock and humans: Yes/No.

If yes, name them:………………………………………………

Are you aware of any outbreak involving such diseases? Yes/No.

If yes, name the diseases outbreak, the area affected and year:

Year	Disease	Area Affected.

In your opinion, what was the cause of outbreak?

…………………………………………………………………………………………

Are you aware of a condition called *Leptospirosis*?

What is the cause of the disease?...

…………………………………………………………………………………………

Have you encountered a problem of rodent infestation in your homes? Yes/No.

Are there any risks associated with rodents in your home? Yes/No.

If yes, name the risks associated with rodent infestation in the house………………………………………………………………………………

Do you carry out home slaughter of animals? Yes/No.

If yes, are they inspected? Yes/No.

How often did you come in contact with extension staff in the last one year?

None/Rare(less than two visits)/Moderate(3-4 times)/Intensive (More than 4 times).

Appendix III

Key Informant Interview Guide for Heads of Schools in Bungoma County, Kenya

Outbreak occurrence: Y/N.

Date of outbreak:………………

No. of students affected…………….

No. of deaths………………………….

Symptoms:………………………………………………………………………………

Environmental factors associated with the disease outbreak

………………………………………………………………………………………………

Suspected cause:…………………………………………………………………

……………………………………………………………………………………..

Effects of the disease:……………………………………………………………

Performance trends between 2000 and 2010.

Enrolment trends between 2000 and 2010.

Appendix IV

Key Informant Interview Guide for Sub-County Veterinary Officer in Bungoma County, Kenya

Have you ever encountered cases of *Leptospirosis* in the Sub-County? Yes/No.

If yes, what species are affected?

Indicate the number of cases per species in the table below:-

YEAR	**CASES**			
	CATTLE	**SHEEP**	**GOATS**	**PIGS**
2000				
2001				
2002				
2003				
2004				
2005				
2006				
2007				
2008				
2009				
2010				

What were the clinical signs observed?

……………………………………………………………………………………………

How was the diagnosis carried out?

Clinical (tentative). B) Laboratory diagnosis. C) Other (specify).

How were the cases managed/controlled?

Treatment. B) Vaccination. C) other (Specify).

Are there other conditions with similar manifestations in the district?

Yes. B) No.

If yes, what are they and when did they occur?

What are they:……………………………………………….

When did they occur:………..…………………………………

Do you have adequate extension staff to serve the farmers? Yes. B) No.

Is surveillance carried out for *Leptospirosis*? Yes. B). No.

State the type of surveillance: Passive/Active/abattoir surveillance.

Do you have adequate protective clothing/equipment for meat inspection.

Is meat inspection carried out for animals slaughtered at home? Yes. B) No.

What are the major sources of livestock into the Sub-County?

………………………………………………………………………………

Name the major livestock markets and routes in the Sub-County.

……………………………………………………………………………………………

Appendix V

Key Informant Interview Guide for Sub-County Medical Officer of Health in Bungoma County, Kenya

Have you ever encountered cases of *Leptospirosis* in the Sub-County?

Yes/No.

Indicate the number of cases per species in the table below:-

YEAR	CASES
2000	
2001	
2002	
2003	
2004	
2005	
2006	
2007	
2008	
2009	
2010	

What were the clinical signs observed?

……………………………………………………………………………………………
………………………………………………………………………………………

How was the diagnosis carried out?

Tentative B) Laboratory. C) Other (specify).

If laboratory diagnosis, which test?

Serological B) Blood culture C) Other (specify).

Are you aware of any animal involvement?

Yes/No.

If yes, which animal species were affected?

………………………………………………………………………………………………

……………………………………………………………………………………

What are the differentials for *Leptospirosis*?

…………………………………………………………………………………………

Appendix VI

Document Content Analysis from Hospital Records (Secondary Data) in Bungoma County, Kenya

Age, sex, geographical information, occupation

Clinical symptoms (morbidity, mortality)

Hospitalization

History and place of exposure (animal contact, environment).

Microbiological and serological data

Date of diagnosis

Rainfall, flooding

Aggregated data for reporting

Number of cases

Number of hospitalizations

Number of deaths

Number of cases by type (causative serovar / serogroup) of *Leptospirosis*.

Appendix VII

Number of Households and Heads of Cattle Sampled by Sub-County, Ward and Location in Bungoma County, Kenya

SUB-COUNTY	WARD	LOCATION	No. of HH SAMPLED	No. OF BOVINE SERA COLLECTED
Kimilili	Kibingei	Kibingei	6	6
		Kitayi	4	5
		Chebukwabi	10	8
		Kamusinga	16	9
	Kimilili	Kimilili	22	12
		Bituyu	10	10
		Khamulati	12	10
		Kimilili slaughterhouse	0	38
	Maeni	Kibisi	20	8
		Sikhendu	22	8
		Nasusi	29	9
		Kamasielo	31	9
	Kamukuywa	Makhonge	16	5
		Mapera	18	7
		Mbongi	24	8
		Nabikoto	18	6
		Musebe	16	5
		Kimakwa	16	5
Mt Elgon	Kaptama	Kaborom	22	6
		Kaptama	18	5
		Chesito	13	4
		Kongit	12	3
		Kaboiywo	13	4
		Kaptelelio	10	3
		Chemoge	10	3
		Chemuses	6	2
		Chemuses	6	2
			400	200

Appendix VIII

Checklist Questions During Focused Group Discussion in Bungoma County, Kenya

Introduce the research team as a group conducting an public health appraisal.

Identify the respondents and establish if they own livestock.

Establish the husbandry system and movement patterns (mapping).

What are the current disease problems in their livestock species

Use a mental checklist of key terms that refer to *Leptospirosis* or with reference to symptoms or syndromes of a similar nature. Identify and define any new terms introduced by the respondents.

What are the current livestock disease problems in the area?

Historically, what are the most important livestock disease problems?

If the target disease is economically important within the context of the communities production system and has occurred in their animal recently it will be mentioned.

Have they personally seen the *Leptospirosis* cases in their lifetime? What does it look like? Which species are affected? Does it affect humans?

Are there any associated or preceding events to *Leptospirosis* outbreak (environmental changes such as drought, heavy rainfall and drought, accidental or deliberate release of substances, livestock movement, livestock/wildlife interaction, introduction of new stock in the area).

How do humans get affected, the presentation of the disease in humans? How is the disease managed in humans? When was the last time their animals were affected? Where? Where did it come from? What were some of the effects of the disease outbreak?

Appendix IX

Table for Assessing Attitude of Respondents Towards *Leptospirosis* in Bungoma County, Kenya

	ATTITUDE ITEM	RESPONSES	%	ATTITUDE
1	Do you think you can get *Leptospirosis*	Yes		Positive
		No		Negative
2	What would be your reaction if you found that you have *Leptospirosis*?	Shame		Negative
		Fear		Positive
3	Would you talk to someone about your illness?	Yes		Positive
		No		Negative
4	What will you do if you think that you have symptoms of *Leptospirosis*?	Go to Health facility		Positive
		Seek alternative ways of healing: Divine or traditional		
		Just stay at home		Negative
5	If you had symptoms of *Leptospirosis*, at what stage you will go to the health facility?	Soon as I realize the symptoms		Positive
		Own treatment fails		
		Will not go to physician		Negative
6	How expensive do you think is the diagnosis and treatment of *Leptospirosis*?	Affordable		Positive
		Expensive		
		Don’t know		Negative
7	What worries you most if you will be diagnosed with *Leptospirosis*?	Fear of death		Positive
		Cost of treatment		
		Isolation from the society		Negative

Appendix X

Procedure for carrying out ELISA Test

Materials and reagents

Microplates for ELISA test. ELISA-specific 96-flat-well plastic microplates are used. At present, ELISA microtitre plates M 129 A (Dynatech) and Immulon A give the best results.

Phosphate-buffered saline (PBS).

KH_2PO_4 (2 g) and distilled water to a final volume of 1 litre. It should be autoclaved at 120 °C for 20 min and diluted 1/10 before use.

PBS-milk solution. This is prepared by adding 5% (w/v) of skimmed milk powder to PBS-wash buffer. It is best to prepare a fresh solution of PBS-milk just before use.

Conjugate. A number of manufacturers supply anti-IgM antibodies coupled to peroxidase. They are diluted 1/500 or otherwise according to the result of a block titration in PBS-milk buffer before use.

Substrate components. The enzyme activity is revealed by using a specific substrate in an appropriate buffer. A frequently used substrate is 2,2'-bis azine (3-ethylbenzyl-thiazoline 6-sulfonic acid) (ABTS) in the form of an ammonium salt (Sigma, Boehringer). A stock solution is prepared by dissolving 0.219 g in 10 ml of distilled H_2O.

N.B. This substrate is highly carcinogenic and must be handled with care. The substrate buffer consists of sodium acetate (13.6 g), NaH_2PO_4 (6.9 g) and water to a final volume of 1 litre. It should be autoclaved at 100 °C for 20 min. Dilute H_2O_2 solution (which should be prepared before use) is made by diluting 200 µl of 30% H_2O_2 in 7 ml of distilled H_2O.

Methodology.

Antigen preparation

A known Leptospira antigen at a density of 108–109 leptospires per ml as determined by darkfield Microscopy is mixed with formaldehyde at a final concentration of 0.2% and left on a bench for 3–4 hours.

Place in a water bath at 100 °C for 30 min.

Adjust the pH to 9.6.

Centrifuge at 10 000 g for 30 min.

Keep the supernatant which is the antigen source.

Coating the plates.

· Aliquot 150 µl of antigen into each well.

· Keep at 37 °C for 3–5 days until evaporation is completed.

These plates can then be stored in the dark at room temperature in a dry, air-tight box or a sealed plastic container.The antigen remains stable for about 1 year under these conditions.

Saturating non-specific sites.

· Wash the plates three times with PBS-milk just before use.

· Leave the wells in contact with the PBS-milk either overnight at 4 °C or for 1 hour at 37 °C.

· Empty the wells by inversion and dry by tapping the plates on filter paper.

Distributing the test sera

Each patient's serum is tested in duplicate at a dilution of 1/400 in PBS-milk. For every series of patient samples to be tested:

· 8 wells are reserved for the dilution range of the positive pool, from1/400 to 1/51200.

· 2 wells are reserved for the “threshold” control serum.

· 1 well is reserved for the antigen control.

· 1 well is reserved for the conjugate control.

· Incubate the plates at 37 °C for 1 hour.

Addition of the conjugate

· Empty the wells and wash three times with PBS-milk.

· Perform a block titration to determine the optimal dilution of the conjugate.

· Aliquot 150 µl of diluted conjugate in each well.

· Incubate at 37 °C for 1 hour.

Chromogenic detection

· Empty the wells and wash three times with 1x PBS.

· Prepare the substrate just before use:

– 1 ml of stock ABTS solution;

– 20 ml of substrate buffer;

– 200 µl of dilute H_2O_2 solution.

· Aliquot 150 µl of substrate into each well.

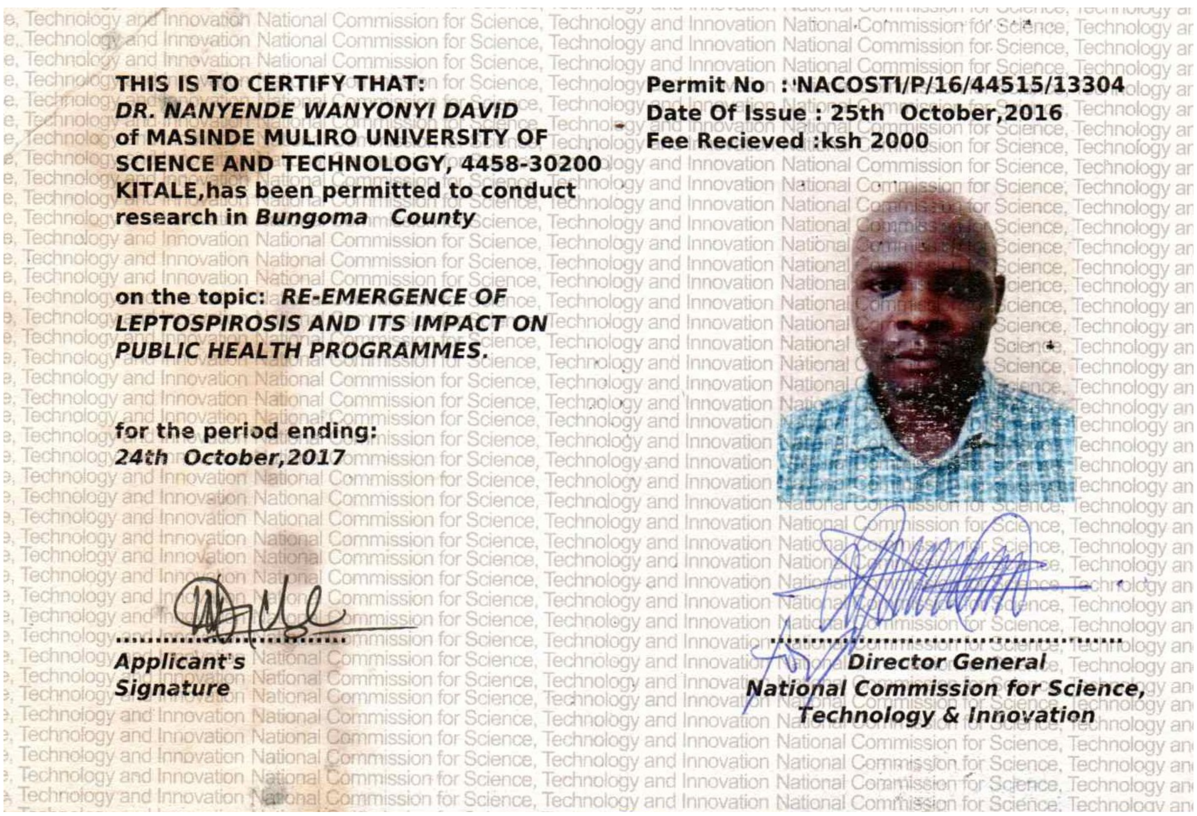
· Shake and incubate at room temperature for 10 min (check visually for a colour change). The reaction is stopped by the addition of 50 µl of 10% sodium dodecyl sulfate (SDS) per well.

Analysis.

Measure the optical density (OD) at 405 nm with a spectrophotometer equipped with a microtitre plate platform. A green colour in the well indicates that antibodies are present in the serum sample

Appendix XI

Research Authorization by National Council for Science, Technology and Innovation


THIS IS TO CERTIFY THAT:
DR. NANYENDE WANYONYI DAVID
of MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY, 4458-30200 KITALE,has been permitted to conduct research in *Bungoma County*

on the topic: *RE-EMERGENCE OF LEPTOSPIROSIS AND ITS IMPACT ON PUBLIC HEALTH PROGRAMMES.*

for the period ending:
24th October,2017

Permit No : NACOSTI/P/16/44515/13304
Date Of Issue : 25th October,2016
Fee Recieved :ksh 2000

Applicant's Signature

Director General
National Commission for Science, Technology & Innovation

CONDITIONS

1. You must report to the County Commissioner and the County Education Officer of the area before embarking on your research. Failure to do that may lead to the cancellation of your permit.
2. Government Officer will not be interviewed without prior appointment.
3. No questionnaire will be used unless it has been approved.
4. Excavation, filming and collection of biological specimens are subject to further permission from the relevant Government Ministries.
5. You are required to submit at least two(2) hard copies and one (1) soft copy of your final report.
6. The Government of Kenya reserves the right to modify the conditions of this permit including its cancellation without notice

HARAMBEE

REPUBLIC OF KENYA

NACOSTI

National Commission for Science, Technology and Innovation

RESEACH CLEARANCE PERMIT

Serial No.A 11366

CONDITIONS: see back page

Appendix XII

Research Authorization by County Director of Veterinary Services in Bungoma County, Kenya

REPUBLIC OF KENYA

MINISTRY OF AGRICULTURE, LIVESTOCK, FISHERIES & COOPERATIVE

COUNTY VETERINARY SERVICES

County Veterinary office,
P. O Box 135-50200
BUNGOMA.

REF: EDUC/11/9/1/VOL.V1/6

Date: 20th June, 2016.

TO WHOM IT MAY ONCERN:

Dear Madam/Sir,

DR. DAVID W NANYENDE CDM/H/001/012 PhD DEGREE RESEARCH.

The above named is a PhD student at Masinde Muliro University of Science and Technology. He is undertaking research in Bungoma County entitled "LEPTOSPIROSIS AND ITS IMPACT ON PUBLIC HEALTH PROGRAMME.

He will collect blood samples from cattle in Kimilili and Mt. Elgon Sub-counties of Bungoma county. He will also administer questionnaires to farmers and key veterinary personnel in Bungoma County.

Please accord him the necessary assistance. He will on his part observe all regulations and ethical considerations during his field work.

STATE VETERINARY OFFICER
BUNGOMA COUNTY
P.O. Box 135-50200
BUNGOMA.
DATE

Dr. Wangwe W.
County Director Veterinary Services.
BUNGOMA COUNTY.

Appendix XIII

Research Authorization by County Director of Medical Services in Bungoma County, Kenya

Received
3/1/2017

PN - 543218
V/N - 1186580

MEDICAL SUPERINTENDENT
BUNGOMA DISTRICT HOSPITAL
P.O. Box 14, BUNGOMA

Relevant department to assist researcher.

COUNTY GOVERNMENT OF BUNGOMA

MINISTRY OF HEALTH

Telegrams: "MEDICAL", BUNGOMA
Telephone: (055) 30230 Fax: (055) 30650
E-mail: sylvestermutoro@gmail.com
When replying please quote

COUNTY DIRECTOR OF HEALTH,
BUNGOMA COUNTY
P O BOX 18-50200
BUNGOMA

Our ref no. CG/BGM/CDH/RES/VOL.1/(3)

DATE: 12th January, 2017

Mr.NANYENDE WANYONYI DAVID
Masinde Muliro University of
Science And Technology
P.O BOX 190-50100
KAKAMEGA.

Dear Sir,

RE: RESEARCH AUTHORISATION

The Health Research Commitee is happy to inform you that your research on "**Re-emergence of leptospirosis and its Impact on public health programmes** in Bungoma County " has been approved.

The Commitee recommends you submit two(2) copies of your findings for feedback and retention purposes.

We wish you all the best.

J . AYONGA
For: COUNTY DIRECTOR HEALTH
BUNGOMA COUNTY.

HOD to assist.
17/1/17

MEDICAL SUPERINTENDENT
WEBUYE COUNTY HOSPITAL
P. O. Box 25 - 50205
WEBUYE

Appendix XIV

Research Authorization by County Director of Education in Bungoma County

REPUBLIC OF KENYA

MINISTRY OF EDUCATION, SCIENCE AND TECHNOLOGY
State Department of Education – Bungoma County

When Replying please quote
e-mail: bungomacde@gmail.com

Ref No: BCE/DE/19 VOL I/241

County Director of Education
P.O. Box 1620-50200
BUNGOMA
Dates: 30th November, 2016

The Sub – County Directors of Education
BUNGOMA COUNTY

RE: AUTHORITY TO CARRY OUT RESEARCH – DR. NANYENDE WANYONYI DAVID REF. NO – NACOSTI /P/16/44515/13304

The bearer of this letter Dr. Nanyende Wanyonyi David is a student of Masinde Muliro University of Science and Technology. He has been authorized to carry out research on "***Re-emergence of leptospirosis and its impact on public health programmes" for*** a period ending **24th October, 2017.**

Kindly accord him the necessary assistance.

CHRISTINE OWINO
FOR: COUNTY DIRECTOR OF EDUCATION
BUNGOMA COUNTY

Appendix XV

Ethical Approval to Conduct Research

MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY

Tel: 056-31375
Fax: 056-30153
E-mail: rel@mmust.ac.ke
Website: www.mmust.ac.ke

P. O. Box 190
Kakamega
50100
Kenya

Institutional Ethics Review Committee (IERC)

MMU/COR: 403009(1)

13th July, 2016

David Wanyonyi Nanyende
Registration No. CDM/H/01/2012
Masinde Muliro University of Science and Technology
P. O. Box 190-50100
KAKAMEGA

Dear Wanyonyi,

RE: ETHICAL APPROVAL TO CONDUCT RESEARCH

The IERC received your proposal titled ***"Re-Emergence of Leptospirosis and its Impact on Public Health Programmes in Bungoma County, Kenya"*** for review. Having reviewed your work, the committee has given ethical clearance for you to conduct research as proposed.

On behalf of IERC and the University Senate, my congratulations. We wish you success in your research endeavour.

Yours faithfully,

Dr. Nguka Gordon
Ag. Chairman, Institutional Ethics Review Committee

Copy to:

- The Secretary, National Bio-Ethics Committee
- Vice Chancellor
- DVC (PR&I)
- DVC (A & F)
- DVC (A&SA)