UNIVERSITY OF NAIROBI

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RIFT VALLEY FEVER DISEASE SURVEILLANCE AND CONTROL STRATEGIES IN MARIGAT SUB COUNTY, BARINGO COUNTY, KENYA

By

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DECLARATION

This thesis is my original work and has not been presented wholly or partly for the award of any degree or academic honours elsewhere.

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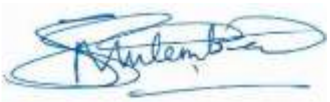
Signature: ___  ______ Date: ______4/12/23________

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DEDICATION

To my beloved daughter, Nandi Chebet, whose unwavering love, and inspiration fuelled my determination to persevere and diligently contribute to the success of this thesis.

I extend my heartfelt gratitude to my entire family, Dad Jackson Lang'at, Mum Hellen Lang'at, for their devoted parenthood and encouragement. Special appreciation goes to my brothers, Benson Lang'at and Enock Lang'at, and my sister, Susan Lang'at, for their continuous support and encouragement throughout my academic journey. May God shower His blessings upon each one of you.

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ABBREVIATIONS

AUROC	Area under the receiver operating characteristic
CDC	Centre for Disease Control
CI	Confidence interval
DNA	Deoxyribonucleic Acid
DVS	Directorate of Veterinary Services
EAC	East African Community
ELISA	Enzyme-linked Immunosorbent Assay
FAO	Food and Agriculture Organisation
FGD	Focus Group Discussions
ITCZ	Intertropical convergence zone
KAP	Knowledge Attitudes and Practices
KCSAP	Kenya Climate Smart Agriculture Project
KII	Key informant interviews
KNBS	Kenya National Bureau of Statistics
MALF	Ministry of Agriculture and Livestock and Fisheries
MOH	Ministry of Health
NGO	Non- Governmental Organizations
OIE	World Organisation for Animal Health
OR	Odds Ratio

PCR Polymerase Chain Reaction

RVF Rift Valley Fever

RVFV Rift Valley Fever Virus

SPSS Statistical Package for Social Sciences

WHO World Health Organization

WOAH World Organization for Animal Health

ZDU Zoonotic Disease Unit

ZTWG Zoonoses Technical Working Group

ABSTRACT

Rift Valley fever (RVF) a viral disease of ruminants, camels and humans transmitted by mosquitoes that belong to the *Aedes* and *Culex* genera. The disease causes a high economic impact because of livestock sickness and deaths. The government of Kenya is currently implementing a National Contingency Plan for RVF which is intended to serve as a national guideline to RVF preparedness and response activities within the Republic of Kenya. It stipulates the information, tasks, and procedures that would be necessary to facilitate the decision-making process regarding RVF control and management. Despite the existence of an RVF surveillance and control strategy, named the National Contingency Plan for Rift Valley Fever, RVF outbreaks have been occurring in Baringo County and other parts of Kenya during all the above-average rainfall seasons. This study therefore aimed to assess the enablers and barriers of the existing contingency plan to build its resilience to avert the numerous economic losses associated with RVF outbreaks not only in Baringo County but in Kenya as a whole. A cross-sectional household survey was conducted in Marigat subcounty targeting households and participants in areas where previous outbreaks had occurred. The selection of households was purposive and stratified based on their convenient accessibility. A majority of the respondents (64%) notified the appropriate veterinary authorities about disease outbreaks. Further, fewer than half of the participants (46.25%) had participated in campaigns aimed at raising awareness about RVF and other diseases. Mobile phones emerged as the primary means of reporting disease outbreaks (48%). A significant majority of the participants (95%) believe that RVF is a perilous disease that can be prevented through animal vaccination. In conclusion, increased involvement of the community in RVF awareness campaign, improved veterinary service delivery and harnessing the use of mobile phones in RVF surveillance will help improve the existing RVF contingency plan.

CHAPTER ONE: INTRODUCTION

1.1 Study background

Rift Valley fever (RVF) a viral disease of ruminants, camels and humans transmitted by aedes and culex mosquitoes (Linthicium *et al.,* 2016). The disease is caused by the Rift Valley Fever virus (RVFV), which is a member of the Bunyaviridae family (Flick *et al.,* 2005). The virus is transmitted through the bite of infected mosquitos that belong to the *Aedes* and *Culex* genera (Tantely *et al.,* 2015). When an infected mosquito bites an animal or human, the virus can be transmitted through the mosquito's saliva. Additionally, people can become infected with RVFV by handling or consuming contaminated animal products, such as raw meat or unpasteurized milk, or by encountering body fluids of infected animals, such as blood, milk, and urine. It is important to note that human-to-human transmission of RVFV is rare, and the virus is not spread through casual contact or respiratory droplets. The RVFV is endemic in sub-Saharan Africa but can also be found in the Arabian Peninsula where it causes a high economic impact because of livestock sickness and deaths (Rich and Wanyoike, 2010).

Rift Valley Fever virus was first identified in the Rift Valley of Kenya in 1930 when an outbreak occurred among sheep on a farm in the Rift Valley of Kenya. Since then, the virus has caused several epidemics in Africa and the Arabian Peninsula (Pepin *et al.,* 2010). The most significant outbreak occurred in Egypt in 1977 when more than 200,000 human cases were reported. It was reported that the virus was introduced to Egypt via trade of livestock along the Nile irrigation system (Pepin *et al.,* 2010).

The primary hosts of RVFV are domestic animals such as sheep, cattle, goats, and camels. The virus can cause severe disease in animals, leading to high mortality rates in young animals and abortion in pregnant animals (Smith *et al.,* 2013). Transmission of RVFV from animals to humans can occur through contact with infected animals or through the bite of infected mosquitoes. In humans, RVF can cause a range of symptoms, from mild flu-like illness to severe haemorrhagic fever with a high mortality rate (Woods *et al.*, 2002).

In animals, RVFV infection can cause severe disease, including abortions in pregnant animals and high mortality rates in young animals. In humans, RVFV infection can range from mild flu-like symptoms to severe haemorrhagic fever, encephalitis, or eye disease. The incubation period for RVFV in humans is typically 2 to 6 days but it can range from 1 to 12 days (Woods *et al.*, 2002). In humans, the initial symptoms of RVFV infection include fever, headache, muscle pain, and weakness. These symptoms are like those of many other viral illnesses and can be difficult to diagnose without laboratory testing. In severe cases, RVFV infection can cause haemorrhagic fever, which is characterized by bleeding from the nose, gums, and other mucous membranes. It can also cause encephalitis, which is inflammation of the brain, and eye disease, which can lead to blindness (Smith *et al.*, 2013).

A range of laboratory tests, such as PCR (polymerase chain reaction) and ELISA (enzyme-linked immunosorbent assay), can be employed to detect RVFV (Rift Valley fever virus) infection. These tests can detect the presence of the virus in blood, serum, or other body fluids (Flick *et al.*, 2005).

There is no specific treatment for RVFV infection, and the primary treatment is supportive care. This includes rest, hydration, and management of symptoms, such as fever and pain. In severe cases, hospitalization may be necessary (Meegan *et al.*, 2019).

Currently, there is no vaccine for RVFV infection in humans, but several vaccines are available for animals (Faburay *et al.*, 2017). These vaccines are used to control outbreaks of the disease in livestock. RVF prevention in humans primarily involves reducing exposure to infected animals and mosquitoes. This includes using insect repellent, wearing protective clothing, and practicing good hygiene, such as washing hands regularly. RVF outbreaks control involves several measures which include surveillance and monitoring, vector control, animal vaccination and public health education (Faburay *et al.,* 2017).

The global impact of RVF is significant, with outbreaks having severe consequences for human and animal health, food security, and economic stability. The United States National Institute of Allergy and Infectious Diseases has categorized RVFV as a Category A pathogen, highlighting its capacity to present a substantial risk to public health and national security. The World Health Organization (WHO) has listed RVF as a priority disease under its Blueprint for Action, highlighting the need for increased research, surveillance, and preparedness measures (Smith *et al.,* 2013).

Globally, Kenya has reported the largest number of RVF epidemics involving both humans and livestock since the first report in 1912 (ZDU, 2014). Major livestock and human outbreaks of RVF have previously occurred in Africa following heavy rainfall and flooding which create favourable conditions for mosquito breeding. Significant and devastating Rift Valley Fever outbreaks have occurred in different regions. One such outbreak took place in Egypt between 1977 and 1979, impacting more than 200,000 individuals and leading to the unfortunate loss of over 600 lives. Similarly, another notable outbreak occurred in East Africa from 1997 to 1998, affecting Kenya, Somalia, and Tanzania (Woods *et al.,* 2002). In Kenya alone, this outbreak affected over 100,000 people, resulting in more than 450 fatalities (Woods *et al.,* 2002). Outbreaks have also occurred in Mauritania, Senegal, Sudan, Madagascar, South Africa, and in the Middle Eastern countries of Saudi Arabia and Yemen (Smith et al., 2013).

Episodes of RVF (Rift Valley Fever) outbreaks in livestock have been observed in East Africa at intervals ranging from 4 to 10 years. These occurrences have shown a strong correlation with periods of above-average rainfall during the warm phase of the El Niño/Southern Oscillation phenomenon (Anyamba *et al.,* 2012). Rift Valley Fever outbreaks are usually associated with heavy and persistent rainfall leading to flooding and the appearance of mosquitoes, the main vector. Mosquitoes lay their eggs in stagnant water, and flooding can create large areas of stagnant water, providing ideal breeding conditions for mosquitoes. It is expected that climate change will have impact on the distribution of conditions suitable for breeding of mosquitos responsible for RVF transmission and maintenance (Arndt *et al.*, 2012).

In late 2006 through early 2007 after a period of heavier than usual rainfall leading to widespread flooding, an RVF outbreak occurred in East Africa majorly affecting Kenya and Tanzania (Jost *et. al.,* 2010). The most recent Major RVF outbreak occurred in Kenya in 2018 with reports of mass abortion and mortality of sheep and goats reported to the Kenya Directorate of Veterinary Services (Hassan *et al.*, 2018).

RVF outbreaks are typically observed after periods of abundant and intense rainfall, which coincide with the formation of a robust intertropical convergence zone (ITCZ). The ITCZ refers to the area in the equatorial tropics where air masses from the northern and southern hemispheres converge, leading to the generation of rainfall (Nicholson *et al.*, 2018). To control outbreaks of RVFV during periods of heavy rainfall and flooding, public health and veterinary authorities in affected countries typically implement measures to reduce mosquito breeding, such as spraying insecticides and draining stagnant water sources. Animal movement restrictions and quarantine measures may also be put in place to prevent the spread of the virus between farms and regions (Balenghien *et. al.,* 2013).

The government of Kenya is currently implementing a National Contingency Plan Rift Valley (ZDU, 2014). It was enacted and last updated in December 2014. The purpose of this plan is to establish a nationwide framework for preparing and responding to Rift Valley Fever (RVF) within the Republic of Kenya. It outlines the essential information, tasks, and procedures required to support decision-making processes related to RVF control and management. The plan serves as a guide for the Ministry of Health (MOH), the Ministry of Agriculture and Livestock and Fisheries (MALF), and other stakeholders involved in RVF control. By bringing together multiple agencies and organizations, the contingency plan aims to foster collaboration and achieve the following objectives:

- Contribute to an effective national and county level preparedness and response to a RVF outbreak.
- Reduce morbidity and mortality in humans and livestock.
- Mitigate RVF outbreak on economic and social related impacts.
- Facilitate post-RVF outbreak recovery operations.

The purpose of this plan is to act as a comprehensive national framework for enhancing preparedness and response efforts regarding Rift Valley Fever (RVF) in Kenya. The plan offers guidance regarding the information, tasks, and procedures required to facilitate the decision-making process at both the National and County levels of government. The objectives of the National Contingency Plan for Rift Valley Fever Control are:

- Serve as a national reference tool for RVF outbreak response.
- Provide information on risk including hot spots of the disease in the country and persons at an increased risk.
- Provide information on actions to be taken during the different phases of RVF disease.
- Provide coordination structures particularly with the human and animal health sector and other agencies.
- Identify needs and facilitate the mobilization of resources for preparedness and response.

Kenya has developed a comprehensive national strategy for disaster management that is applicable at all levels of governance and across various functional disciplines (ZDU, 2014). This approach facilitates collaboration between the national and county governments, enabling them to effectively prepare for, respond to, and recover from domestic incidents, regardless of their cause, size, or complexity. The existing national disaster policies and plans clearly define the roles and responsibilities of different stakeholders at the national, county, and local levels. These policies and plans also establish the fundamental operational framework for disaster response and delineate the functional roles and responsibilities of various government entities (ZDU, 2014).

The National Contingency Plan for Rift Valley Fever follows the command-and-control structure outlined in these national policies and plans. In the event of an RVF outbreak, the Ministry of Health (MOH) and the Ministry of Agriculture, Livestock, and Fisheries (MALF), through the Zoonoses Technical Working Group (ZTWG), will serve as the lead agencies for the government's response. However, it is important to note that an RVF outbreak is not solely a public health emergency, as its socio-economic impacts can be significant. Therefore, it is crucial for the national government to treat a severe RVF outbreak as it would any other national disaster and allocate all necessary resources to preparedness and response efforts (ZDU, 2014).

The focus of RVF control efforts has been on implementing measures to reduce the risk of transmission from animals to humans. These efforts include vaccination campaigns, surveillance programs, and strategies for controlling the vectors responsible for spreading the disease. However, the global spread of Rift Valley Fever Virus underscores the necessity of a coordinated, multidisciplinary approach to effectively address the complex and dynamic nature of this disease (Balenghien *et. al.,* 2013).

Livestock losses occasioned by RVF have had numerous negative consequences to the pastoralist communities of Baringo Kenya, which according to Munyua *et al.,* (2016), is classified as a high-risk county for Rift Valley Fever outbreak. Despite the repeated RVF outbreaks, minimal effort has been made to assess the effectiveness of the existing Rift Valley Fever surveillance and control strategy in Kenya and specifically in Baringo County. This study therefore aimed to assess the enablers and barriers of the existing contingency plan to build its resilience to avert the numerous economic losses associated with RVF outbreaks not only in Baringo County but in Kenya as a whole.

In conclusion, RVF is a zoonotic disease caused by the RVFV that affects animals and humans, with significant implications for public health, food security, and economic stability. Efforts to control the disease require a global perspective, with collaboration between veterinary, public health, and environmental experts to develop effective strategies for prevention, detection, and response. It is expected that the findings of this research will help influence policy framework on disease surveillance in Kenya.

1.2 Problem Statement

Marigat Subcounty in Baringo County is dominated by livestock keeping communities that largely depend on livestock for their livelihood. In the last major RVF outbreak of 2018, pastoralists were hard hit by the rapidly spreading disease leading to devastating economic effects through losses in trade of animals and their products. Communities face numerous consequences due to RVF outbreak, resulting in significant losses of livestock (Rich *et al.,* 2010). Previous RVF epidemics in Baringo County were evidenced by immense livestock abortions and death. This led to great financial losses due to animal quarantines and both local and international trade restrictions (Mutua *et al.,* 2018). The fear surrounding RVF outbreaks leads to a significant reduction or complete avoidance of animal source protein consumption

(Smith *et al.*, 2013). This, in turn, triggers intercommunity conflicts, reduces household assets, and diminishes social and cultural identity (Omollo, 2010).

1.3 Justification

Despite the existence of an RVF surveillance and control strategy, named the National Contingency Plan for Rift Valley Fever, RVF outbreaks have been occurring in Baringo County during all the excessive rainfall seasons. It is therefore important to assess the existing National Contingency Plan for Rift Valley Fever to build its resilience with the aim of averting the numerous economic losses associated with RVF outbreaks not only in Baringo County but in Kenya as a whole. Assessing the existing RVF surveillance and control strategy will help build its resilience.

1.4 Research objectives

1.4.1 General objective

To assess the Rift Valley Fever surveillance and control strategies in Marigat Sub County, Baringo County.

1.4.2 Specific objectives

1. Evaluate surveillance and control plan of RVF in Marigat Sub County, Baringo County.

2. To analyse the enablers and barriers of the RVF surveillance and control strategies.

CHAPTER TWO: LITERATURE REVIEW

2.0 What is Rift Valley Fever

Rift Valley Fever is an infectious disease transmitted by mosquitoes, which primarily affects livestock such as cattle, goats, sheep, and camels. (Linthicum *et al.* 2016). Humans acquire the infection when they get into contact with blood and tissues of infected animals or when bitten by infected mosquitoes (Peter, 2000). RVF outbreaks usually occur following floods which provide suitable conditions for infected mosquitoes to transmit the virus (Linthicium *et al.*, 2016).

RVF epidemics presents a major threat to global health owing to the high morbidity and mortality it causes in humans above losses brought about by livestock deaths and prohibition of trade (Domenech 2006). The World Organization for Animal Health (WOAH) founded as OIE considers RVF to be a significant notifiable disease due to the potential of RVF to rapidly spread quickly across international borders leading to devastating economic effects through losses in trade of animals and their products, (OIE 2016). Epidemics related to RVF are usually evidenced by immense livestock abortions and death; this leads to great financial losses due to animal quarantines and both local and international trade restrictions (Alomar *et al.*, 2023). These animals are important for both meat and milk production and trade. It is estimated that the 2006 - 2007 RVF epidemic in Kenya caused losses amounting to US $32 million (Rich *et al* 2010). The causative agent of RVF is Rift Valley Fever Virus which belongs to the genus *Phlebovirus* in the family *Bunyaviridae* (Meegan *et al.*, 2019). The most recent confirmed RVF outbreak was reported in 2018 in Northern Kenya, resulting in documented human fatalities and reports of widespread incidents of mass abortions and mortality among young sheep, camels, and goats (Hassan *et al.*, 2020).

Rift Valley Fever is classified as a notifiable disease by the WOAH. According to the guidelines outlined in chapters 1.1 and 8.15 of the Terrestrial Animal Health Code, any outbreaks of Rift Valley Fever must be reported to WOAH. Due to the significant time gaps between occurrences of RVF outbreaks, this disease is considered to be a re-emerging threat (WOAH, 2022).

2.1 Rift Valley Fever Vectors

Rift Valley Fever Virus primarily spreads via mosquito bites, with over 53 species across eight genera within the Culicidae family identified as hosts of the virus. Among these species, the Aedes and Culex genera are recognized as the primary vectors responsible for transmission. The following provides an in-depth analysis of the involvement of these mosquitoes in transmitting RVF (Salman *et al.,* 2014).

2.1.1 Culex Mosquitoes as RVF vectors:

Culex mosquitoes are known to be one of the primary vectors for RVF. A study conducted by Eifan *et al.,* (2021) in Egypt found that *Culex pipiens* and *Culex tritaeniorhynchus* mosquitoes were the most abundant mosquito species in the RVF outbreak areas. These mosquitoes were also found to have a high infection rate with RVF virus, indicating their crucial role in the transmission of the disease. Culex mosquitoes are known to feed on both animals and humans, which makes them capable of transmitting the virus to both. Culex mosquitoes are known to transmit a wide range of arboviruses, including RVFV. Culex species, such as *Culex poicilipes, Culex antennatus, Culex univittatus,* and *Culex quinquefasciatus,* have been implicated in RVFV transmission in Africa (Tchouassi *et al.,* 2013).

A study carried out in Kenya discovered that Culex mosquitoes were the most prevalent type of mosquito in regions affected by RVF. The study also determined that these mosquitoes had a substantial prevalence of RVF virus infection, indicating that they played a crucial part in the transmission of the illness. Additionally, the study revealed that Culex mosquitoes were more active at night, when human and animal movements were highest, thereby increasing the likelihood of transmission (Sang *et al.*, 2017).

2.12 Aedes Mosquitoes as RVF vectors:

Aedes mosquitoes are also known to be potential vectors for RVFV transmission. A study conducted in Sudan found that *Aedes vexans* and *Aedes aegypti* mosquitoes were abundant in the RVF outbreak areas (Seufi *et al.*, 2010). These mosquitoes were also found to have a high infection rate with RVF virus, indicating their significant role in the transmission of the disease. Aedes mosquitoes are known to feed on both animals and humans, making them capable of transmitting the disease from sick animals to humans and vice versa (Salman *et al.*, 2014).

The Aedes mosquitoes lay their eggs in low-lying plains or areas with suitable conditions. The eggs can dry out and remain viable for an extended period. This characteristic of the Aedes mosquito eggs allows the virus to survive in the environment for an extended duration (Foster *et al.*, 2019). As a result, RVFV can persist in these eggs, waiting for the right environmental conditions to trigger an outbreak. When favourable conditions, such as heavy rainfall, create suitable breeding sites for mosquitoes, these infected eggs can hatch, and the virus can be reintroduced into the mosquito population. This phenomenon helps explain the long interepidemic periods associated with RVFV, where the virus can remain dormant for several years before causing new outbreaks when conditions are conducive (Poueme *et al.*, 2020).

Numerous studies have investigated the role of Aedes mosquitoes in the transmission of RVFV. A research investigation carried out in Kenya discovered that *Aedes mcintoshi* and *Aedes ochraceus* were the two most prevalent species of mosquito in regions that experienced RVF outbreaks. Both species were found to be competent in transmitting RVFV, with *Aedes mcintoshi* being identified as the most effective vector. (Sang *et al.*, 2017).

Another similar study conducted in Senegal discovered that *Aedes vexans* and *Aedes ochraceus* were the most abundant mosquito species in the areas where RVFV was detected. Both species were found to be competent vectors of RVFV, with *Aedes vexans* being more efficient at transmitting the virus than *Aedes ochraceus* (Van den Bergh *et al.*, 2022).

A study conducted in Sudan by Mohamed *et al.*, (2017) found that *Aedes caspius* was the most abundant mosquito species in the areas where RVFV outbreaks were reported and confirmed. The study found that *Aedes caspius* was a competent vector of RVFV and could transmit the virus.

In addition to Aedes species mosquitoes, other mosquito species have also been implicated in the transmission of RVFV. For example, a study conducted in South Africa found that Culex species mosquitoes were capable of transmitting RVFV (McIntosh *et al.*, 1973)

2.2 RVF Risk factors in humans and animals

Anyangu *et al.* (2007) investigated the risk factors for RVF infection in humans during the 2006-2007 outbreak in Kenya. The study discovered that individuals who lived near livestock were at higher risk of RVF infection, as were individuals who handled animal products or participated in animal slaughter. The study also found that older individuals were more likely to be infected with RVF.

A study by Kemunto *et al.*, (2018) analysed the risk factors for RVF infection in animals in Kenya. According to the study, animals in areas with high rainfall and dense vegetation, which are considered high-risk areas, were more prone to RVF infection. In addition, certain breeds of animals, such as cattle and sheep, were found to be more vulnerable to RVF compared to other breeds. Dense vegetation provides shelter and resting places for mosquitoes which often rest in shaded areas during the day, and dense vegetation can offer protection from harsh weather conditions, making it an ideal habitat for them. This has been shown to be the reason for RVF outbreaks outside flooding events (Arum *et al.,* 2016).

Tigoi *et al.,* (2015) conducted a study to investigate the risk factors for RVF infection in humans and animals in Tanzania. The study discovered that individuals who consumed unpasteurized milk or raw meat were at higher risk of RVF infection, as were individuals who had close contact with sick animals. The study also found that animals in areas with high vegetation cover were more likely to be infected with RVF.

A study to investigate the risk factors for RVF infection in humans in Sudan found that individuals who lived near water sources, such as rivers or lakes, were at higher risk of RVF infection, as were individuals who had close contact with infected animals. Furthermore, the research discovered that specific professional categories, including farmers and herdsmen, faced a greater susceptibility to RVF infection compared to other occupational groups (Hassan *et al.,* 2011).

A study by Anyamba *et al.* (2010) investigated the risk factors for RVF infection in pregnant women during the 2006-2007 outbreak in Kenya. The study found that pregnant women who had contact with livestock or who lived in rural areas were at higher risk of RVF infection. The study also found that RVF infection in pregnant women was associated with adverse pregnancy outcomes, such as foetal loss and premature delivery.

Nanyingi *et al.,* (2015) assessed the socio-economic and environmental risk factors that influenced RVF outbreaks in Kenya. The systematic literature review found that RVF outbreaks were exacerbated by poor public health infrastructure and inadequate disease surveillance systems.

The study also found that the outbreak was associated with high levels of poverty and low levels of education in affected communities (Nanyingi *et al.,* 2015).

Existing research highlights the existing complex interplay of environmental, socio-economic, and behavioural factors that directly contribute to the risk of RVF infection in both humans and animals (Rissmann *et al.,* 2020). To achieve efficiency and efficacy, RVF prevention and control strategies should consider the multiple drivers of disease transmission and involve the integration of veterinary and public health interventions, such as vaccination campaigns, vector control measures, and improved disease surveillance systems (Rissmann *et al.,* 2020).

2.3 Clinical presentation of Rift Valley Fever in Animals and Humans

According to study conducted by Evans *et al.,* (2008) and Adeyeye *et al.,* 2011, RVF causes severe disease in both humans and animals. Below is a detailed description of the different clinical presentation of RVF.

2.3.1 Clinical Signs in animals

Rift Valley Fever exhibits a wide range of clinical symptoms in animals, which are influenced by various factors such as the animal's species, age, immune system status, and the virulence of the virus. RVF is generally characterized by a spectrum of clinical signs that can range from mild to severe, and is classified into three clinical forms: mild, moderate, and severe (Busquets *et al.,* 2010)

In the mild form of RVF, animals may not show any clinical signs, or they may show mild symptoms such as fever, decreased appetite, and lethargy. In some cases, mild respiratory signs such as coughing and nasal discharge may be present. The mild form of the disease is often asymptomatic and may go unnoticed, which can make RVF difficult to diagnose (Busquets *et al.,* 2010).

In the moderate form of RVF, animals may show more severe clinical signs such as fever, anorexia, depression, and weight loss. Additionally, animals may develop ocular signs such as conjunctivitis and corneal opacity. In some cases, animals may develop neurological signs such as ataxia, tremors, and seizures. The moderate form of RVF can also cause abortions in pregnant animals, which can result in significant economic losses for livestock farmers (Busquets *et al.,* 2010).

The severe form of RVF is characterized by more severe clinical signs such as high fever, anorexia, depression, and weight loss. Additionally, animals may develop haemorrhagic signs such as petechiae, ecchymoses, and hematomas. The severe form of the disease can also cause liver and kidney damage, which can lead to jaundice, dehydration, and death (Smith *et al.,* 2012).

2.3.2 Clinical Signs in humans

Although the majority of human RVF cases are mild, a small proportion of individuals can develop a more severe form of the illness. Clinical manifestations of RVF in humans can vary from mild flu-like symptoms to severe conditions such as haemorrhagic fever, encephalitis, and ocular disease. The extent of symptoms is influenced by factors such as an individual's age, immune system status, and the virulence of the virus (LaBeaud *et al.,* 2011).

Generally, the clinical features of RVF in humans can be classified into three forms: the ocular form, the meningoencephalitis form and the haemorrhagic fever form. The febrile phase of RVF usually persists for 4-7 days, during which the individual experiences fever, headache, muscle and joint pain, and weakness. In some instances, patients may also exhibit gastrointestinal symptoms such as nausea, vomiting, and diarrhoea. The intensity of symptoms during the febrile phase can range from mild to severe (Meegan *et al.*, 2019)

The ocular phase of RVF is characterized by the development of retinal lesions, which can lead to vision loss or blindness. The ocular phase usually occurs 1-2 weeks after the onset of the febrile phase and can last for several weeks or months. The ocular phase is particularly concerning when the lesions occur in the macula leading to long-term disability. Death in patients presenting with only the ocular form of the disease is uncommon (Meegan *et al.*, 2019).

The meningoencephalitis form of RVF generally occurs 1 to 4 weeks after the onset of the initial symptoms. Patients with this form of the disease exhibit a variety of clinical signs, including headache, memory loss, confusion, hallucinations, disorientation, vertigo, lethargy, convulsions, and coma. In some cases, neurological complications may arise in patients after more than 60 days of being afflicted with the severe form of the illness (Meegan *et al.,* 2019).

The manifestations of the haemorrhagic variant of the ailment manifest themselves within 2 to 4 days following the start of the illness, initially presenting as indicators of liver dysfunction like jaundice. Subsequently, symptoms related to blood abnormalities become apparent, such as blood in vomit, blood passage in faeces, nose and gum bleeding, bleeding from venipuncture sites, and extended bleeding during menstruation. RVF has a recovery phase characterized by a gradual improvement in symptoms, although some patients may continue to experience fatigue, joint pain, and weakness for several weeks or months (Odendaal *et al.,* 2021).

2.4 Transmission of Rift Valley Fever Virus

Inter-epizootic intervals refer to the period between outbreaks of an infectious disease among animals, known as an epizootic. Epizootics are a sudden outbreak or increase in the number of cases of a particular infectious disease in a specific population of animals (Paweska *et al.,* 2014). During the inter-epizootic interval there are no cases of the disease among the animal population or only a few sporadic cases. The length of the inter-epizootic interval varies depending on the disease and the characteristics of the animal population (Paweska *et al.,* 2014).

Understanding the inter-epizootic interval is important in the prevention and control of infectious diseases in animal populations. It can help to identify the time frame during which preventive measures, such as vaccination, should be implemented to reduce the risk of a new outbreak. Additionally, studying the length and frequency of inter-epizootic intervals can provide insights into the transmission dynamics of the disease and help to develop effective control strategies (WOAH, 2022).

2.4.1 Rift Valley Fever Virus transmission in animals

Studies have shown that RVF in Baringo County is mainly transmitted by four mosquito vectors namely *Mansonia uniformis, Mansonia africana, Culex pipiens,* and *Culex univittatus.* (Ondiba *et al.,* 2017).

A study to investigate the transmission of RVF in a cattle herd in Mauritania found that the transmission of RVF in the herd was strongly associated with the presence of mosquitoes, particularly the Aedes and Culex species. The study also found that transmission occurred more frequently in younger animals (El Mamy *et al.,* 2011).

Another study by Rissmann *et al.,* (2020) investigated the transmission dynamics of RVF in a sheep flock in Senegal during the 1987-1988 outbreak. The study found that the transmission of RVF in the flock was influenced by various factors, including the presence of mosquitoes, the age and immune status of the animals, and the timing of infection in relation to the mosquito breeding cycle. The study also found that the presence of pregnant ewes in the flock increased the risk of transmission.

A study by Evans *et al.* (2008) investigated the role of wild animals in the transmission of RVF in Kenya. The study found that wild animals, particularly buffalo and impala, were infected with RVF virus and could serve as a reservoir for the disease. The study also found that the presence of wild animals in areas where livestock grazed increased the risk of transmission to domestic animals.

A study by Chevalier *et al.* (2011) investigated the transmission of RVF in a cattle herd in Madagascar during the 2018 outbreak. The study found that the transmission of RVF in the herd was influenced by various factors, including the density of mosquito populations, the age and sex of the animals, and the presence of comorbidities. The study also found that the implementation of vector control measures, such as insecticide treatment of animals and the use of mosquito nets, was effective in reducing the risk of transmission.

A study by Nanyingi *et al.* (2017) on ecological niche modelling of RVF virus vectors in Baringo County found that the outbreak was driven by various factors, including the increased movement of livestock, the expansion of irrigation schemes, and the proliferation of mosquito breeding sites. The study also found that the outbreak was exacerbated by poor veterinary services and inadequate disease surveillance systems.

2.4.2 Rift Valley Fever Virus transmission in humans

A study to investigate the risk factors associated with human RVF infections during the 2006-2007 outbreak in Kenya found that being a livestock worker, contact with blood or other tissues of infected animals, and the consumption of raw milk were significant risk factors for human RVF infection. The study also found that the use of mosquito nets and mosquito repellent were protective against RVF infection (Anyangu *et al.*, 2007).

A study by Tigoi *et al.* (2020) investigated the seroprevalence of RVF virus infection among a group of pastoralists and their livestock in northeastern Kenya. The study found that the prevalence of RVF virus infection was higher among pastoralists who were involved in livestock slaughter and had contact with animal blood or tissues. The study also found that the prevalence of RVF virus infection was higher among older individuals who had lived in the area for a longer period.

Wilson *et al.,* (1994) investigated the risk factors associated with human RVF infections in Senegal. The study found that being a male, working in the animal industry, and the consumption of raw milk were significant risk factors for human RVF infection. The study also found that living near an infected animal and exposure to mosquito bites were significant risk factors.

A study by Nguku *et al.* (2010) investigated the transmission of RVF in humans during the 2006-2007 outbreak in Kenya. The study found that the virus was transmitted through direct contact with infected animal tissues and through the inhalation of aerosolized virus particles. The study also found that the use of protective measures, such as mosquito nets and masks, was effective in reducing the risk of infection. Al Azraqi et *al.,* (2019) investigated the seroprevalence of RVF virus infection among a group of abattoir workers in Saudi Arabia. The study found that the prevalence of RVF virus infection was high among abattoir workers and that the use of personal protective equipment, such as gloves and masks, was effective in reducing the risk of infection.

2.5 Diagnosis, Prevention, and Control of Rift Valley Fever

Rift Valley Fever lacks a targeted antiviral therapy, making supportive care the primary approach for treating both humans and animals affected by the disease. Nonetheless, in the case of animals, vaccination plays a crucial role in managing and curbing the spread of RVF (Bird *et al.,* 2008).

Treatment for RVF in animals is primarily focused on supportive care, which includes hydration, management of fever and other symptoms, and the administration of anti-inflammatory drugs. Several studies have investigated the use of antiviral drugs, such as ribavirin, for the treatment of RVF in animals, but the results have been inconclusive (Dungu *et al.,* 2018).

Preventing RVF outbreaks requires a One Health approach that addresses the disease in animals, humans, and the environment (Fawzy *et al.,* 2019). Vaccination is one of the most effective ways to prevent RVF in animals. Several vaccines are available for use in livestock, including inactivated and live attenuated vaccines. The timing and frequency of vaccination can vary depending on the animal species and local epidemiology of the disease. Vaccination programs should be combined with other prevention measures, such as vector control, to reduce the risk of RVF transmission (Dungu *et al.,* 2018).

The most widely used vaccine is the inactivated vaccine, which is produced by inactivating the RVF virus with formalin. The vaccine has been shown to provide effective protection against RVF in livestock, and several studies have investigated its efficacy in different animal species (Faburay *et al.,* 2017). A study by Moiane, (2007) investigated the efficacy of the inactivated

RVF vaccine in cattle in Mozambique found that the vaccine provided complete protection against RVF in both sheep and goats.

Another vaccine that has been developed for RVF is the live-attenuated vaccine, which is produced by attenuating the RVF virus through passage in tissue culture (Daouam *et al.*, 2015). The live-attenuated vaccine has been shown to provide effective protection against RVF in animals, and several studies have investigated its safety and efficacy (Daouam *et al.*, 2015). A study by Ikegami et *al.*, (1931) investigated the safety and efficacy of the live-attenuated RVF vaccine in livestock found that the vaccine was safe and provided effective protection against RVF in both sheep and cattle. A suggestion has been put forth that even just one infected animal entering a country without prior exposure could lead to a significant outbreak of Rift Valley fever virus before it can be detected (Balenghien *et al.*, 2013). Balenghien *et al.*, (2013 concluded that if vaccines are not accessible and broadly utilized to restrict its spread, RVF will remain a serious concern for the health of both humans and animals in the Indian Ocean region.

More recently, researchers have been exploring the development of new vaccines for RVF, including the use of recombinant DNA technology. A study by Morrill *et al.* (2011) investigated the efficacy of a DNA vaccine encoding the RVF virus glycoproteins in goats. The study found that the DNA vaccine provided effective protection against RVF in goats, and that the vaccine was safe and well-tolerated.

Vector control is an important component of RVF prevention, as mosquitoes are the primary vector of the virus. Mosquito control measures can be categorized as chemical or non-chemical methods, and both methods can be used in an integrated approach for maximum effectiveness (Corbel *et al.*, 2019). Chemical methods of mosquito control involve the use of insecticides, which can be applied through aerial or ground spraying or by treating mosquito breeding sites.

However, the use of insecticides should be done with caution, as it can have adverse effects on the environment, including non-target organisms and human health (Shaukat *et al.,* 2019).

Non-chemical methods of mosquito control include the removal of mosquito breeding sites, such as stagnant water sources, and the use of mosquito nets or screens. Environmental modification, such as changes in land use or irrigation practices, can also impact mosquito populations and RVF transmission. For example, the construction of drainage ditches can help to eliminate stagnant water and reduce mosquito breeding sites (Shaukat *et al.,* 2019).

Vector control may face challenges such as limited resources, logistical complexities, and difficulties ensuring community compliance during an active RVF outbreak (Milestone *et. al.,* 2015). The varied characteristics and adaptability of mosquito vectors further complicate control endeavours. Successfully managing vectors during the RVF outbreak requires a cohesive and interdisciplinary strategy, involving close cooperation between public health, veterinary services, environmental agencies, and the active engagement of the community (Milestone *et. al.,* 2015).

In addition to vector control measures, other prevention and control measures include vaccination, quarantine, movement restrictions, and culling of infected animals. Animal carcasses should be disposed of properly to reduce the risk of environmental contamination. Appropriate personal protective equipment and infection control measures should be used to reduce the risk of human infection (Breiman, 2010).

The success of mosquito control measures in reducing RVF transmission depends on several factors, including the effectiveness of the control method, the timing of the intervention, and the environmental conditions that affect mosquito populations (Corbel *et al.,* 2019). Effective prevention and control of RVF requires the integration of data from animal and human health systems, alongside environmental and social sciences, through a comprehensive One Health approach (Shaukat *et al.,* 2019).

Community engagement and education are also critical components of RVF prevention and control. Local communities can be trained to recognize signs of the disease in animals and to report suspected cases to authorities. In addition, education campaigns can help to raise awareness of the disease and its transmission, as well as promote safe animal handling practices (Vanlerberghe *et al.,* 2009).

Treatment for RVF in animals is primarily focused on supportive care, which includes hydration, management of fever and other symptoms, and the administration of anti-inflammatory drugs. Several studies have investigated the use of antiviral drugs, such as ribavirin, for the treatment of RVF in animals, but the results have been inconclusive (Atkins *et al.,* 2017).

Vaccination is an important strategy for controlling RVF in animals. The most widely used vaccine is the inactivated vaccine, which is produced by inactivating the RVF virus with formalin. The vaccine has been shown to provide effective protection against RVF in livestock, and several studies have investigated its efficacy in different animal species. A study by Fafetine *et al.* (2007) investigated the efficacy of the inactivated RVF vaccine in sheep and goats in Mozambique. The study found that the vaccine provided complete protection against RVF in both sheep and goats.

Another vaccine that has been developed for RVF is the live-attenuated vaccine, which is produced by attenuating the RVF virus through passage in tissue culture. The live-attenuated vaccine has been shown to provide effective protection against RVF in animals, and several studies have investigated its safety and efficacy. A study by Daubney *et al.* (1931) investigated the safety and efficacy of the live-attenuated RVF vaccine in sheep and cattle in Kenya. The study found that the vaccine was safe and provided effective protection against RVF in both sheep and cattle.

More recently, researchers have been exploring the development of new vaccines for RVF, including the use of recombinant DNA technology (Kitandwe *et al.,* 2022). A study was investigated the efficacy of a DNA vaccine encoding the RVF virus glycoproteins in goats. The study found that the vaccine provided effective protection against RVF in goats, and that the vaccine was safe and well-tolerated (Faburay *et al.,* 2017).

2.6 Rift Valley Fever; Public Health Risk and One Health

One Health embodies a cooperative, multifaceted, and interdisciplinary strategy operating across various scales—local, regional, national, and global—to attain the best possible health outcomes. It acknowledges the interconnectedness between humans, animals, plants, and their shared environment (Queenan et al., 2017). The One Health approach promotes the need for global multidisciplinary collaboration to ensure that human livelihood is safeguarded through better environment and food safety (Hassan *et al.*, 2014).

One Health approaches have been recognized as an effective way to address zoonotic diseases, including RVF (WHO, 2019). By bringing together experts from different fields, such as human and animal health, environmental science, and social science, a more comprehensive understanding of the disease and its transmission can be obtained. This can lead to more effective prevention and control strategies (Hassam *et al.,* 2014). For example, a study was conducted to examine the use of a One Health approach in controlling RVF in Tanzania. The study found that integrating data from human and animal health systems improved the ability to detect and respond to RVF outbreaks. The study also emphasized the importance of engaging communities in prevention efforts, as social and cultural factors can impact disease transmission and control (Kayunze, 2014). The integration of the environmental health sector is crucial in addressing the epidemiology of Rift Valley Fever (RVF) due to the significant influence of ecology and environmental factors. These factors, including temperature and humidity, play a pivotal role in the transmission dynamics of the RVF virus. Incorporating the environmental health sector into the one health strategy creates an opportunity to comprehensively address the broader ecological context and better understand how environmental conditions contribute to the proliferation of mosquito vectors and the spread of the virus (Muturi *et al.,* 2023).

Another study by Linthicum *et al.,* (2016) examined the use of a One Health approach to assess the risk of RVF in East Africa. The study brought together experts from human and animal health, as well as environmental science, to develop a risk assessment model that integrated data on climate, animal populations, and mosquito populations. The study found that the model was able to accurately predict areas at risk of RVF outbreaks and identified the need for targeted surveillance and control efforts.

Similarly, a study by Hassan *et al.* (2017) emphasized the importance of a One Health approach in addressing RVF in Sudan. The study brought together experts from human and animal health, as well as social and environmental sciences, to develop a comprehensive framework for RVF prevention and control. The framework included strategies such as integrated surveillance systems, community engagement, and targeted vector control measures.

The best way to address RVF is through the One Health approach because the epidemiology and impact of RVF is highly determined by the environmental, animal and human interconnection. RVF outbreaks also have a great impact on the economy, livelihood and human wellbeing (FAO 2018). Evidently, the RVF aspects of epidemiology which include environment, ecology, practices, knowledge and both human and animal health highlight the essence of using a One Health approach to address it (Hassan *et. al.,* 2017).

Overall, these studies highlight the importance of a multidisciplinary, One Health approach in addressing RVF. By bringing together experts from different fields, a more comprehensive understanding of the disease and its transmission can be obtained, leading to more effective prevention and control strategies.

2.7 Rift Valley Fever and Climate

Rift Valley Fever outbreaks have been linked to climate variability, including rainfall patterns and temperature changes, which can alter the abundance and distribution of mosquito vectors and their hosts (Martin et al., 2008). Several studies have investigated the impact of climate change on RVF.

A study by Mosomtai *et al.,* (2016) using satellite data to analyse the relationship between climate variables and RVF outbreaks in Kenya found that RVF outbreaks were associated with above-average rainfall in the previous year, which provided suitable breeding sites for mosquito vectors. The study also found that outbreaks were more likely to occur in areas with high vegetation cover, which may have provided suitable habitats for the animal hosts of the virus.

Climate change has been found to affect the distribution of mosquito vectors that transmit RVFV. A study by Martin *et al.,* (2008) found that the distribution of Aedes mosquitoes in Kenya had expanded to higher altitudes, possibly due to climate change. Aedes mosquitoes are known to transmit RVFV.

Another study to investigate the climate and environmental factors that contributed to the 2006-2007 RVF outbreak in Kenya found that heavy rainfall in late 2006 had created large pools of standing water, which provided ideal breeding sites for mosquito vectors. The study also found that the expansion of irrigation schemes in the affected areas may have contributed to the severity of the outbreak by creating additional breeding sites for the mosquitoes (Sang *et al.,* 2010). A study by Sang *et al.,* (2010) analysed the genetic diversity of the RVF virus in Kenya from 2006 to 2008. The study found that the virus had undergone genetic changes during this period, which may have been influenced by environmental factors, such as changes in temperature and humidity.

Epizootic outbreaks are often linked to warmer seasons when temperatures rise above the norm. These conditions create an ideal environment for the hatching of Aedes mosquito eggs carrying the virus, which can trigger the virus's circulation (Himeidan *et al.,* 2014). Consequently, a significant number of secondary vectors, mainly from the Culex genus, can become infected, ultimately giving rise to epidemic or epizootic outbreaks. This explains why Rift Valley Fever outbreaks can occur even in the absence of excessive rainfall (Himeidan *et al.,* 2014).

Another study by Mpeshe *et al.,* (2014) used a mathematical modelling approach to analyse the impact of climate change on RVF transmission dynamics. The study found that RVF transmission was highly sensitive to changes in temperature and rainfall, and that the frequency and severity of outbreaks were likely to increase under future climate change scenarios. The impact of climate change on the control of RVF has also been investigated.

Finally, a study by Mosomtai, *et al.,* (2016) analysed the ecological factors that influence RVF outbreaks in Kenya. The study found that the outbreak was associated with heavy rainfall, which had led to flooding and the creation of suitable breeding sites for mosquito vectors. The study also found that the outbreak was exacerbated by poor public health infrastructure and inadequate disease surveillance systems.

In conclusion, the existing research highlights the complex interplay between climate variability, environmental factors, and socio-economic factors in the emergence and spread of RVF in Kenya.

2.8 Socioeconomic burden of Rift Valley Fever in Kenya

Rift Valley Fever outbreaks has a significant impact on the socioeconomic status of affected communities. Rift Valley Fever outbreaks in Kenya have been associated with significant economic losses in the livestock industry, which is a major source of income for many rural communities. During outbreaks, livestock mortality rates can reach up to 30%, leading to significant losses in income and food security for affected communities. In addition, movement restrictions and trade bans placed on livestock during outbreaks can further exacerbate the economic impact on affected communities (Rich *et al.,* 2007).

The impact of RVF on human health can also have significant socioeconomic consequences. RVF outbreaks in Kenya have been associated with increased healthcare costs, as well as loss of income due to illness and death. The disease can also lead to long-term health complications, such as blindness, which can have further socioeconomic impacts on affected individuals and communities (Rich *et al.,* 2007).

In addition, RVF outbreaks can have wider economic impacts on affected regions, such as the loss of tourism revenue due to travel restrictions and fear of the disease. This can further exacerbate the economic impact on affected communities, particularly those that rely on tourism as a source of income (Peyre *et al.,* 2015). Rich and Wanyoike, (2010) conducted a value chain analysis in Kenya with an aim to describe the loss attributable to the 2006-2007 RVF outbreak. The North Eastern part of Kenya and specifically the pastoralist communities were hard hit by the latest outbreak. According to the research, it was discovered that Rift Valley Fever (RVF) has resulted in significant economic losses. These losses are primarily due to the impact on various stages of the value chain, affecting livestock producers, traders, slaughterhouses, and butchers. The consequences include reduced sales of livestock, the need for quarantines, increased mortality rates, and an increase in abortions among the affected animals (Peyre *et al.,* 2015). Other impacts associated with the outbreak include loss of production, loss of employment especially among butcheries and abattoir workers. The analysis estimated the losses associated with the RVF on the Kenyan economy to be KSh 2.1 billion, due to its adverse impacts on the agricultural sectors and other dependant sectors like transport (Rich *et al.,* 2010).

Socioeconomic factors can also contribute to the spread of RVF. For example, poverty and lack of access to healthcare can increase the risk of exposure and transmission of the disease. In addition, cultural practices, such as the consumption of raw or undercooked animal products, can also increase the risk of RVF transmission (Sindato *et al.,* 2011).

2.9 RVF Disease Surveillance

2.9.1 RVF institutional frameworks for surveillance and control

Rift Valley Fever is a zoonotic disease that poses a significant threat to public health and the economy. In response, many countries and international organizations have established institutional frameworks for RVF surveillance and control. These frameworks typically involve a combination of animal and human health agencies, as well as other stakeholders, such as ministries of agriculture, livestock, and environment (FAO, 2018).

At the international level, the WHO plays a key role in coordinating global efforts to prevent and control RVF outbreaks. The WHO provides technical assistance and guidance to member states on RVF surveillance, diagnosis, and control, and works closely with other international organizations, such as the Food and Agriculture Organization (FAO) and the WOAH, to promote a One Health approach to RVF prevention and control. These international partnerships have been instrumental in promoting a coordinated response to RVF outbreaks and facilitating the exchange of information and resources among member states (Domenech *et al.,* 2006).

At the national level, many countries have established institutional frameworks for RVF surveillance and control. These frameworks vary widely in terms of their structure and scope, but typically involve a combination of animal and human health agencies working together to develop and implement surveillance and control strategies. For example, in Kenya, the Ministry of Health and the Ministry of Livestock and Fisheries have established a joint RVF task force to coordinate RVF surveillance and control efforts (ZDU, 2014). The task force is responsible for developing and implementing RVF control strategies, conducting public health education and awareness campaigns, and coordinating laboratory and diagnostic services. The Kenya government is presently carrying out a National Contingency Plan for RVF (Rift Valley Fever), aiming to provide comprehensive guidance for RVF preparedness and response efforts. This plan outlines the essential information, tasks, and procedures required to facilitate effective decision-making concerning the control and management of RVF in the country.

In some regions, such as the East African region, institutional frameworks for RVF surveillance and control have been strengthened through the establishment of regional networks and partnerships. The East African Community (EAC), a regional intergovernmental organization, has established an RVF Task Force that brings together representatives from member states, the WHO, and other stakeholders to coordinate regional RVF surveillance and control efforts (EAC, 2007). In addition, the EAC has established a regional RVF laboratory network to enhance the diagnosis and surveillance of the disease in the region.

Despite the establishment of these institutional frameworks, there are still significant challenges to effective RVF surveillance and control. One of the major challenges is inadequate funding and resources, which can limit the ability of agencies to implement effective control strategies and conduct timely surveillance and diagnosis. In addition, there is often a lack of coordination and communication between different agencies and stakeholders, which can lead to duplication of efforts and suboptimal use of resources **(**FAO, 2018**).**

Disease surveillance involves gathering data on the incidences and patterns of disease. The data collected helps professionals in the health sector to make timely decisions and take appropriate action while active surveillance of diseases safeguards people's livelihoods and health and by extension the national economy (FAO, 2018).

There are various RVF surveillance techniques that can be used. They include:

a.) Syndromic surveillance.

This type of surveillance detects diseases whose signs match a set of clinical sings as opposed to a particular disease. Syndromic surveillance involves actively seeking clusters of symptoms, indicators, or disease patterns instead of focusing on individual diseases (Cameron *et al*., 2015). Syndromic surveillance is meant to detect most incidences that show the primary clinical sings of the disease in focus. RVF syndrome is a set of medical signs and symptoms that includes death in young ones and abortion, combined with suitable environmental conditions and presence of mosquitos, the main vector (FAO, 2018).

Syndromic surveillance encompasses a disease monitoring approach that focuses on tracking general clinical symptoms or disease syndromes, such as fever, headache, or respiratory illness, instead of targeting specific diseases (May et *al.,* 2009). This approach has been increasingly used in the surveillance of infectious diseases, including RVF.

Rift Valley Fever syndromic surveillance involves the monitoring of clinical syndromes that are associated with RVF infection, such as fever, headache, and myalgia. These syndromes are typically monitored using electronic health records, hospital and clinic visit data, and other sources of health information (Hassan *et al.,* 2020). The goal of RVF syndromic surveillance is to detect increases in the incidence of these clinical syndromes, which may be indicative of a RVF outbreak, in a timely and efficient manner. One of the key strengths of RVF syndromic surveillance is its ability to detect early warning signals of RVF outbreaks before laboratory confirmation of RVF infection is available (May et *al.,* 2009). This early warning system can provide public health officials with valuable time to implement control measures, such as vaccination campaigns and vector control before the outbreak becomes more widespread. In addition, RVF syndromic surveillance can help to identify geographic hotspots of RVF transmission, which can be used to guide targeted interventions and control efforts (Hassan *et al.,* 2020).

However, there are also several challenges associated with RVF syndromic surveillance. One of the major challenges is the lack of specificity of clinical syndromes, which can lead to false positive signals and over-diagnosis of RVF. In addition, the sensitivity of RVF syndromic surveillance can be affected by factors such as changes in healthcare seeking behaviour and reporting practices, which can make it difficult to accurately detect increases in disease incidence. Furthermore, the availability and quality of health data can vary widely across different regions and healthcare systems, which can limit the effectiveness of RVF syndromic surveillance (Nakadio *et al.*, 2021).

To address these challenges, there is a need for improved standardization of RVF syndromic surveillance methods and protocols, as well as increased investment in health data infrastructure and capacity building. Standardization of methods and protocols can help to ensure that RVF syndromic surveillance data are comparable across different regions and time periods, which can improve the accuracy and reliability of disease detection. In addition, increased investment in health data infrastructure, such as electronic health records and data sharing platforms, can help to improve the availability and quality of health data, which is essential for effective RVF syndromic surveillance (Nakadio *et al.*, 2021).

RVF syndromic surveillance is a promising approach to RVF surveillance that has the potential to improve the early detection and control of RVF outbreaks. While there are several challenges associated with RVF syndromic surveillance, including lack of specificity of clinical syndromes and variability in health data quality and availability, these challenges can be addressed through improved standardization of methods and protocols, increased investment in health data infrastructure, and can eventually become an increasingly valuable tool (Nakadio *et al.,* 2021).

b.) Participatory surveillance

Participatory surveillance is a community-based approach to disease surveillance that involves the active participation of local communities in the monitoring and reporting of disease outbreaks (Azhar *et al.,* 2010). Rift Valley Fever participatory surveillance includes training of community members to recognize clinical signs of RVF infection in animals and humans, as well as the establishment of reporting mechanisms for community members to report suspected cases of RVF to local health authorities. This is meant to promote the participation of people leading to their improved perception of their awareness of risk, surveillance options, control and health assessment in people. To ensure its success, it should be carried out with trust and respect. This will make sure the process is accepted and owned by the community (FAO, 2018). Participatory epidemiology started because of embracing rural appraisal procedures to challenges facing animal health (Mariner and Paskin, 2000). This approach has been increasingly used in the surveillance of infectious diseases, including Rift Valley Fever (RVF), which is a zoonotic disease that poses a significant threat to public health and the economy (FAO, 2018). The goal of RVF participatory surveillance is to improve the early detection and reporting of RVF outbreaks, as well as to increase community engagement and ownership of disease control efforts (FAO, 2018).

One of the key strengths of RVF participatory surveillance is its ability to engage local communities in disease surveillance and control efforts (Karimuribo *et al.,* 2017). By involving communities in the monitoring and reporting of RVF outbreaks, participatory surveillance can help to build trust and cooperation between local communities and public health authorities, which can improve the effectiveness of disease control measures. In addition, RVF participatory surveillance can help to improve the accuracy and timeliness of disease reporting, which is essential for effective disease control (Azhar *et al.,* 2010).

However, there are also several challenges associated with RVF participatory surveillance. One of the major challenges is the lack of resources and capacity for community-based disease surveillance and reporting. In many low-income settings, where RVF is most prevalent, there may be limited resources available for training and equipping community members for participatory surveillance activities. In addition, the accuracy and reliability of community-reported disease data can be affected by factors such as reporting biases and the variability of community health-seeking behaviours (Jost *et al.,* 2010)

To address these challenges, there is a need for increased investment in community-based disease surveillance and reporting capacity, as well as improved standardization of participatory surveillance methods and protocols. Increased investment in community-based disease surveillance can help to improve the accuracy and reliability of disease reporting, as well as to build the capacity of local communities to participate in disease control efforts. Standardization of methods and protocols can help to ensure that participatory surveillance data are comparable across different regions and time periods, which can improve the accuracy and reliability of disease detection (Mariner *et al.,* 2014).

Another area of research that is important for the future of RVF participatory surveillance is the integration of digital technologies into participatory surveillance systems. Digital technologies, such as mobile phones and data sharing platforms, have the potential to improve the timeliness and accuracy of disease reporting, as well as to facilitate real-time communication between community members and public health authorities. In addition, digital technologies can be used to develop predictive models of RVF outbreaks, which can help to guide early intervention and control efforts (Karimuribo *et al.,* 2017).

In conclusion, RVF participatory surveillance is a promising approach to RVF surveillance that has the potential to improve the early detection and reporting of RVF outbreaks, as well as to increase community engagement and ownership of disease control efforts. While there are several challenges associated with RVF participatory surveillance, including limited resources and capacity for community-based disease surveillance and reporting, these challenges can be addressed through increased investment in community-based disease surveillance capacity, improved standardization of methods and protocols, and the integration of digital technologies into participatory surveillance systems. By addressing these challenges, RVF participatory surveillance can become an increasingly valuable tool for disease surveillance and control in low-income settings (Karimuribo *et al.*, 2017, Mariner *et al.*, 2014).

c.) Risk-based surveillance

Risk-based surveillance is a strategy for disease monitoring that centre around the identification and continuous monitoring of populations and regions with a high likelihood of experiencing disease outbreaks. This approach has been increasingly used in the surveillance of zoonotic diseases such as RVF (Arsevska *et al.*, 2016). This is surveillance that focuses on localities, people, animals, or times with the highest risk of disease burden. Risk-based surveillance is meant to boost the likelihood and swiftness of detection of disease and to promote better utilization of resources which are limited (FAO, 2018).

Rift Valley Fever risk-based surveillance involves the identification and monitoring of high-risk populations and areas for RVF outbreaks. This can include monitoring animal populations that are known to be susceptible to RVF, such as livestock and wild animals, as well as human populations that are at increased risk for RVF infection, such as farmers, herders, and abattoir workers. The objective of RVF risk-based surveillance is to enhance the prompt identification and notification of RVF outbreaks, while also providing guidance for focused disease control measures (Arsevska *et al.*, 2016).

One of the key strengths of RVF risk-based surveillance is its ability to focus disease surveillance and control efforts on high-risk populations and areas. By identifying and monitoring high-risk populations and areas, RVF risk-based surveillance can help to improve the accuracy and timeliness of disease detection and reporting, which is essential for effective disease control. In addition, RVF risk-based surveillance can help to reduce the overall cost and burden of disease surveillance by focusing resources on high-risk areas and populations (FAO, 2018).

However, there are also several challenges associated with RVF risk-based surveillance. One of the major challenges is identifying high-risk populations and regions prone to for RVF outbreaks (Tumusiime *et al.,* 2018). In many low-income settings, where RVF is most prevalent, there may be limited resources available for surveillance and data collection, which can make it difficult to identify high-risk areas and populations. In addition, the accuracy and reliability of disease data can be affected by factors such as reporting biases and the variability of disease surveillance methods (Tumusiime *et al.,* 2018).

To address these challenges, there is a need for increased investment in RVF risk-based surveillance capacity, as well as improved standardization of surveillance methods and protocols (FAO, 2018). Increased investment in RVF risk-based surveillance can help to improve the accuracy and reliability of disease data, as well as to build the capacity of public health authorities to monitor and respond to disease outbreaks. Standardization of methods and protocols can help to ensure that disease data are comparable across different regions and time periods, which can improve the accuracy and reliability of disease detection. (Arsevska *et al.,* 2016).

Another area of research that is important for the future of RVF risk-based surveillance is the integration of new technologies into disease surveillance systems. For example, remote sensing technologies, such as satellite imagery, can be used to monitor environmental factors that are known to be associated with RVF outbreaks, such as rainfall and vegetation cover. In addition, digital technologies can be used to improve the timeliness and accuracy of disease reporting, as well as to facilitate real-time communication between public health authorities and high-risk populations (Tumusiime *et al.,* 2018).

In conclusion, RVF risk-based surveillance is a promising approach to RVF surveillance that has the potential to improve the early detection and reporting of RVF outbreaks, as well as to guide targeted disease control efforts. While there are several challenges associated with RVF risk-based surveillance, including the identification of high-risk populations and areas and the variability of disease surveillance methods, these challenges can be addressed through increased investment in RVF risk-based surveillance capacity, improved standardization of methods and protocols, and the integration of new technologies into disease surveillance systems. By addressing these challenges, RVF risk-based surveillance can become an increasingly valuable tool for disease surveillance and control in low-income settings (Arsevska *et al.*, 2016).

2.9.2 Disease Surveillance and Governance

Disease surveillance is an essential tool for public health governance, providing timely and accurate information to guide disease control measures (Miller *et al.,* 2018). Effective surveillance can improve public health decision-making and response, reducing the impact of infectious disease outbreaks. Governance structures can impact the success of disease surveillance efforts, with effective leadership and coordination playing a crucial role in the prevention and control of disease (Miller *et al.,* 2018).

Effective disease surveillance requires a well-functioning public health system, with strong governance structures in place to guide surveillance efforts. Governance refers to the set of processes and structures that determine how decisions are made and implemented within a system. Good governance provides a clear framework for decision-making, accountability, and transparency (Hunter *et al.,* 2012).

In the context of disease surveillance, governance structures can impact the quality of surveillance data, the effectiveness of response measures, and the overall success of disease control efforts. For example, the lack of coordination between different government agencies and departments can lead to a fragmented surveillance system, making it difficult to identify and respond to disease outbreaks effectively (Dutta *et al.,* 2021). Studies have found that effective governance structures are associated with better disease surveillance outcomes. For example, a study on disease surveillance in Ethiopia found that a coordinated and integrated surveillance system, guided by strong governance structures, was more effective in detecting and responding to disease outbreaks (Jima *et al.,* 2012).

2.9.3 Disease Surveillance and Governance in the COVID-19 Pandemic

The COVID-19 pandemic has brought into focus the significance of proficient disease surveillance and governance. Countries with strong governance structures and well-coordinated public health responses have generally been more successful in controlling the spread of the virus (Dutta *et al.*, 2021). For example, countries which have well-established public health systems and strong governance structures, were able to quickly identify and respond to the COVID-19 outbreak, implementing effective testing and contact tracing measures to limit transmission (Ayouni *et al.*, 2021). In contrast, countries with weaker governance structures, struggled to control the spread of the virus, with fragmented public health responses and inconsistent messaging from government officials (Lal *et al.*, 2021).

The pandemic has further underscored the significance of international collaboration and organization in disease monitoring and management. The World Health Organization has assumed a crucial role in harmonizing the worldwide efforts against COVID-19, offering guidance and technical assistance to nations across the globe. However, the pandemic has also exposed weaknesses in the WHO's governance structures, with criticisms of its handling of the outbreak and calls for reform to improve its effectiveness (Kokudo *et al.*, 2020).

In conclusion, disease surveillance and governance are closely linked, with effective governance structures playing a critical role in the success of surveillance efforts. Good governance provides the framework for effective decision-making, accountability, and transparency, ensuring that surveillance data is of high quality and that response measures are implemented promptly and effectively.

The COVID-19 pandemic has highlighted the importance of effective disease surveillance and governance, with well-coordinated public health responses and strong international cooperation key to controlling the spread of the virus. As the world continues to grapple with the pandemic, improving governance structures and strengthening disease surveillance systems will be crucial in protecting public health and preventing future outbreaks.

Theoretical Framework

This work will rely upon the coordination theory. This theory sets out principles of how actors can work together harmoniously (Malone, 1988). Coordination theory focuses on understanding how organizations and individuals collaborate to achieve common goals. It explores the mechanisms and processes that facilitate effective coordination and communication among different actors involved in complex tasks. In the context of RVF surveillance, coordination theory can be applied to understand how various stakeholders work together to prevent, detect, and respond to RVF outbreaks.

Conceptual Framework

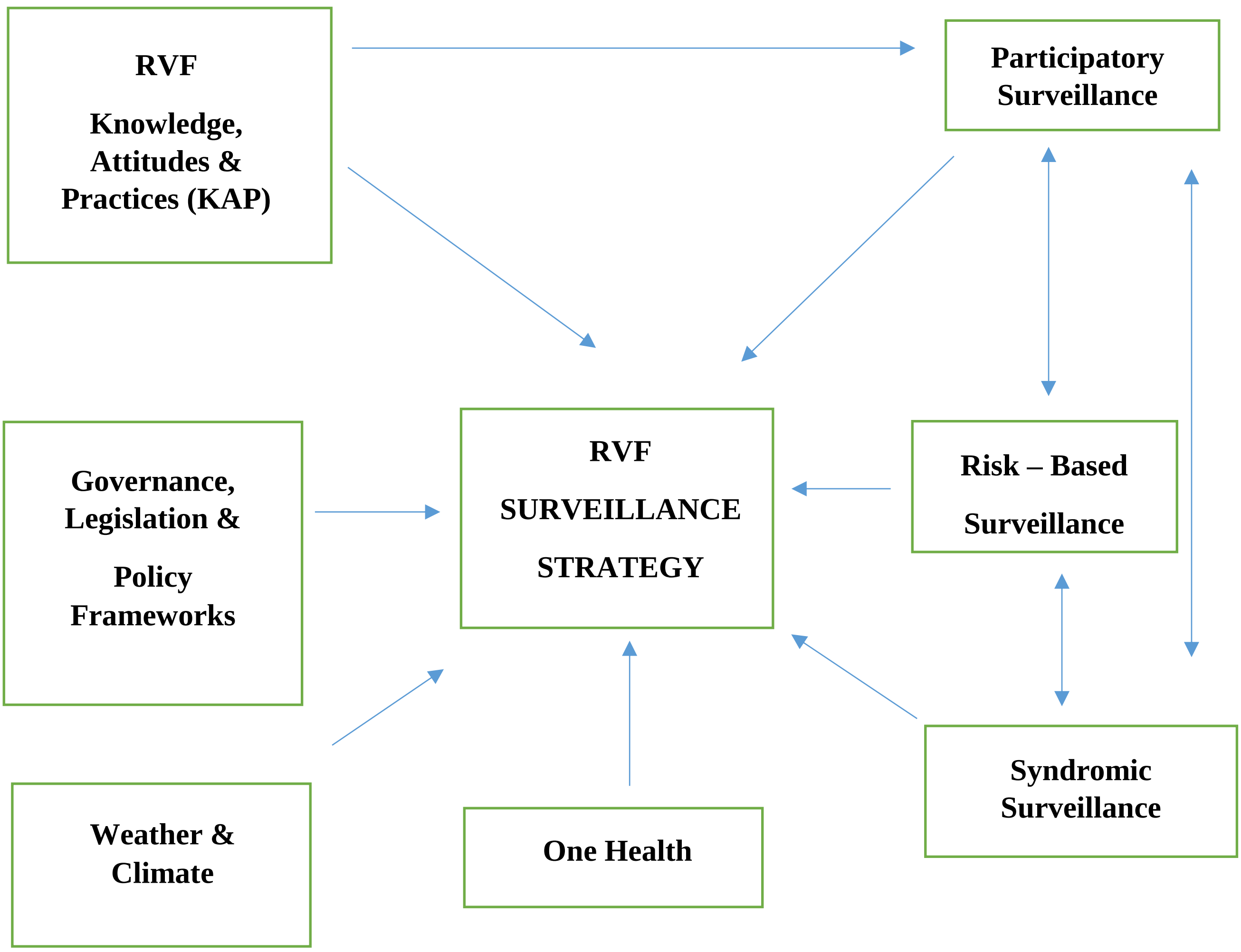

Figure 1: Conceptual framework, Source: Author

CHAPTER THREE: MATERIAL AND METHODS

3.0 Study area

Baringo County, Kenya located at 04º 0’N 00’E coordinates is an arid and semi-arid area located within the expansive Rift Valley region in Kenya. It is considered one of the most expansive counties in Kenya stretching from Kabarnet all the way to the boarders of Turkana County, West Pokot, Samburu, and Laikipia Counties. Baringo County covers a total area of 11,015.3 $KM^{2.}$

This study was conducted in Marigat Subcounty, Baringo county located at 0.4695° N, 35.9832° E coordinates. Baringo county receives an average 650 mm of rainfall annually. Marigat subcounty consists of Mochongoi, Marigat, Ilchamus and Mukutani wards.

In Baringo County, the temperature typically varies between 10 ºC as the lowest and 35 ºC as the highest on average. Among the geographical features, Lake Baringo and Lake Bogoria serve as the lowest water points in the county. Additionally, the county has a significant livestock population, as indicated in the table 1 below.

Table 1: Livestock distribution by district

County	District	Cattle	Sheep	Goats	Camels
Baringo	Baringo Central	68,595	72,260	168,852	13
	Baringo North	38,143	30,446	128,364	28
	East Pokot	787,209	380,125	1,474,617	67,036
	Koibatek	96,952	67,988	100,644	6
	Total	990,899	550,819,	1,872,477	67,083

Source: KNBS, 2010

Agriculture stands as the primary economic activity in Marigat Sub County, as well as in Baringo County as a whole, mirroring the situation observed in rural regions (GOK, 2013).

Map of the study area

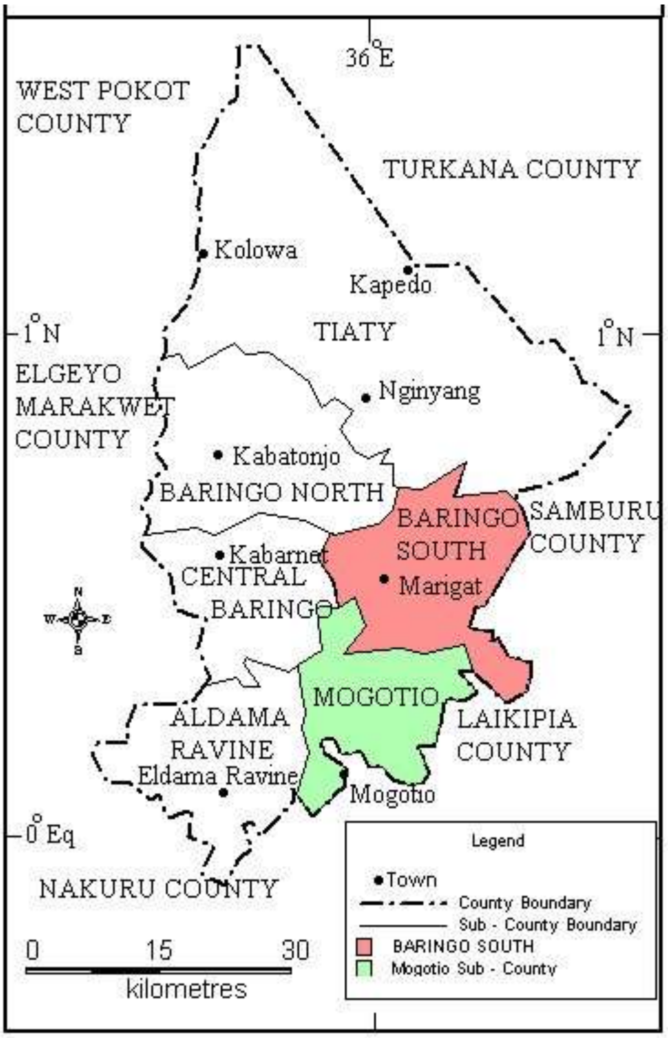

Figure 2: Map of Baringo County showing Marigat Subcounty as the study area.

3.1 Study design

A household survey was carried out to gather data from households and participants in areas where previous outbreaks had occurred. The selection of households was done purposefully, taking into consideration their accessibility and convenience. The study population was the community in the four wards in Marigat Sub County while the target population was the pastoralist communities. Purposively sampling was employed to include human populations residing in the chosen areas, ensuring representative coverage. This study employed Criterion-based Sampling. The inclusion criteria for participating in the study included having kept livestock for the past 10 years, being the head of the household and being a resident of either of the four wards in Marigat Sub County. In the absence of the head of the household, the most senior individual above the age of 18 years was involved.

3.1.1 Sample size determination

The household was used as the unit of sampling for this study. The sample size was determined using the simple random sampling technique, applying Fisher's formula as outlined by Yamane (1967) and Mugenda and Mugenda (2003).

$$n = \frac{N}{1 + Ne^2}$$

Where n is the sample size, N is the target population and e the desired level of precision or confidence level (e= 5%).

The population in Marigat Sub County, Baringo County is 89,210 (KNBS 2019), therefore N=89,210. The calculation for the sample size will therefore be displayed as follows:

$$n = \frac{89210}{1 + 89210(0.05)^2} = 400$$

The sample size of 400 was proportionally distributed among the wards in Marigat Sub County based on ease of access and convenience.

3.2 Data collection

Data collection involved the utilization of quantitative methods.

3.2.1 Questionnaire

A semi structured physical questionnaire was designed and pretested before the actual data collection was done. Questionnaires were specifically used to conduct a survey of the participants’ knowledge, attitudes, and practices of RVF incorporating aspects of the existing RVF surveillance strategy. The demographic and educational backgrounds of the participants were evaluated. To engage the participants, face-to-face physical interviews were conducted using a physical semi-structured questionnaire. The questionnaire covered various topics, including the participants' knowledge of the causes of RVF preventive measures, the types and breeds of livestock they owned, the impact of RVF outbreaks on both livestock and human health, the financial losses incurred due to livestock deaths, and the constraints faced in sustaining their livelihoods. The questionnaire also explored the strategies employed in response to RVF outbreaks, the accessibility and proximity of water sources, the means of restocking animals after disease-related losses, and the sources of information used for preparedness. Additionally, the study examined how the community reported cases of the disease to the relevant authorities. While the questionnaire was initially deployed in English, translations were provided in Kiswahili or Tugen as needed. The questionnaire is available in the appendices section. A copy of the questionnaire is attached is the appendix section (Appendix 1).

3.3 Data analysis

3.3.1 Quantitative analysis

Data collected was entered into Microsoft Excel and analysed using R software version 4.2.1. Descriptive analysis was performed to generate summary statistics such as proportions and generate visualization tools. All variables were assessed independently for association with whether RVF outbreak was previously experienced or not. Here, test for proportion and chi-square tests were implored to assess significant differences in the distribution of responses within the categorical variables. Variables with p-value less than 0.2 were considered for model development.

To assess for factors significantly associated with RVF outbreak, binary logistics regression was performed in a stepwise approach. First, the input variables were modelled qualifying from the chi-square tests independently in simple binary logistic regression and fed variables with p-value less than 0.05 in a multiple adjusted binary logistic regression. The saturated model was then taken through backward stepwise regression to a final model with independent variables that explain the highest variation in the dependent variable.

A check for model assumptions such as multicollinearity and homogeneity of variables was done before comparing the performance of the final model with the saturated model using likelihood ration test. Area under the receiver operating characteristic (AUROC) was then plotted for the best model to check for percentage amount of variation in RVF outbreak explained by our variables.

3.4 Expected outputs

- A thesis submitted in partial fulfilment of MSc in Environmental Governance.
- To build resilience in the existing RVF surveillance system in Baringo County hence increasing livestock productivity.
- It is expected that the findings of this research will influence policy framework on disease surveillance in Baringo County.

CHAPTER FOUR: RESULTS

4.1 Socio-demographic characteristics of participants

Below is the baseline demographic characteristics of the sample population in Marigat Sub County, Baringo county. A total of 400 respondents participated this study.

A total of 400 participants from Ilchamus (38.25%, 153), Marigat (24%, 96), Mukutani (26%, 105), and Mochongoi (11.5%, 46) wards were interviewed. This represented a 100% response rate as the calculated sample size was 400 respondents (400/400 × 100 = 100%). The median age was 36 years old (18-78) with the proportion of male respondents significantly higher compared to female respondents (69% vs 31%: X^2 value – 56.25, degree of freedom, df – 1, p-value <0.0001). Majority of the respondents had received formal education; secondary (31%, 124) and primary (123, 30%) school levels, while 18%, 71 did not receive any formal education. The remaining 82, 21% had received college/university education.

A significantly high proportion (97%, 386) of respondents depend on livestock as a primary source of livelihood (p-value <0.0001. While 44%, 178 of the respondents received an average monthly income of range KSH. 500 to KSH. 5,000 at the time we conducted the interviews, only 6%, 27 reported to earn above KSH. 50,000 on monthly basis. The remaining 50% were equally distributed into categories, those earning between KSH. 5,000 - KSH. 15,000, and above KSH. 15,000 to KSH. 50,000. Table 2 provides a summary of the demographic variables for the four wards.

Table 2: Demographic characteristics described by ward.

Gender	Ilchamus (%)	Marigat (%)	Mukutani (%)	Mochongoi (%)
Female	44(28.76)	34(35.42)	31(29.53)	16(34.78)
Male	109(71.25)	62(64.58)	74(70.47)	30(65.22)
Level of Education				
None	26(17.00)	17(17.71)	23(21.90)	5(10.87)
Primary	48(31.37)	21(21.87)	38(36.20)	16(34.78)
Secondary	58(37.91)	35(36.46)	21(20)	10(21.74)
College/University	21(13.72)	23(23.96)	23(21.90)	15(32.61)
Primary source of livelihood				
Farming	1(0.65)	1(1.04)	1(0.95)	5(10.87)
Business	0(0)	0(0)	0(0)	3(6.52)
Employment	0(0)	0(0)	1(0.95)	1(2.17)
Fish Farming	1(0.65)	0(0)	0(0)	0(0)
Livestock	151(98.70)	95(98.96)	103(98.10)	37(80.44)
Secondary source of livelihood				
None	1(0.65)	3(3.13)	1(0.95)	0(0)
Agriculture	148(96.73)	87(90.63)	103(98.10)	36(78.26)
Business	2(1.31)	2(2.08)	0(0)	2(4.34)
Employment	0(0)	1(1.04)	1(0.95)	4(8.70)
Fish Farming	2(1.31)	2(2.08)	0(0)	0(0)
Livestock	0(0)	1(1.04)	0(0)	4(8.70)
Average monthly income				
500 -< 5000	76(53.15)	30(31.25)	45(42.86)	27(58.70)

Average monthly income				
5000 -< 15000	29(20.28)	25(20.04)	29(27.62)	9(19.57)
15000 < 50000	27(18.88)	29(30.21)	2725.71)	10(21.73)
>=50000	11(7.69)	12(12.50)	4(3.81)	0(0)

4.2 Perception of effect of weather on livestock

The participants were tasked to give their opinion on the effect of severe weather changes on three major livestock kept in the area that is sheep, cattle, and goats. Severe weather was described as extreme and adverse weather conditions like drought, floods and extreme temperatures that can significantly impact their livelihood, which is primarily based on animal husbandry and livestock management. Majority of the respondents perceived cattle to be either moderately or severely affected by severe weather conditions (76.5%, 306). Of the three major livestock species kept, sheep was perceived to be the most severely affected by severe weather condition (44.5%, 178). Additionally, majority of the participants believed that goats experienced minimal or no significant effect due to severe weather conditions (38.5%, 154). There was a general significant association between the perception on the effect of severe weather and livestock species kept (chi = 31.302, p – value < 0.0001) as displayed in table 3 below. Ward-specific chi square test for independence were significant for Ilchamus, Marigat and Mukutani wards. This was, however, not the case for Mochongoi ward (chi = 4.4605, p-value = 0.3473) implying an insignificant association in the relationship between animal species kept and the perception of the residents on effect of severe weather (Table 3).

The responses given for the perception of weather effects on the different species of animals were compared to assess whether there were significant differences in the feedback recorded across the wards. SA bigger proportion (38.7%, 155) reported that their animals have been severely affected by weather with 31.5%, (126) and 29.8%, (119) recording moderately affected and minimal/no effect respectively. In Ilchamus ward, over 42%, (168) of the respondents perceived that the animals are severely affected by weather where sheep was the most affected species. A significant number of the respondents (38.5%, 154) recorded goats to be minimally affected by weather. A similar trend was observed in Mukutani and Mochongoi wards where over 40% reported weather to have severe effect on the animals, especially on bovine. Most of the respondents did not show significant differences on the perceptions in the different wards. This was, however, not true for cattle weather effect where there were significant differences in perceptions of moderate effect of weather ; Marigat – 61.5 % (59) vs Ilchamus – 41.8% (65) vs Mukutani 21.9% (23) vs Mochongoi 19.6% (9); p-value <0.001) as well severe weather effect; Mochongoi 56.5% (26) vs Mukutani 55.2% (58) vs Ilchamus – 36.6% (56) vs Marigat – 11.5% (11) ; p-value <0.001. Significant difference in the responses across wards was also observed on the perception of weather effect on sheep on minimal or no effect; Mukutani 36.2% (38) vs Mochongoi 32.6% (15) vs Marigat – 27.1% (26) vs Ilchamus – 20.3% (31); p-value <0.035) and severely affected; Ilchamus – 54.9% (84) vs Marigat – 39.6% (38) vs Mochongoi 39.1% (18) vs Mukutani 32.6% (38) ; p-value <0.011. Table 3 shows the responses given all for the perceptions on the effect of weather on cattle, sheep and goats in all the four wards (Table 3).

Table 3: Perception of weather effects on the different species of livestock kept.

Effect of weather	Wards Ilchamus n (%) *(n = 153)*	Marigat n (%) *(n = 96)*	Mukutani n (%) *(n = 105)*	Mochongoi n (%) *(n = 46)*	*p-value*
Cattle weather effect					
Minimal or no effect	33 (21.6)	26 (27.1)	24 (22.9)	11 (23.9)	0.794
Moderately affected	64 (41.8)	59 (61.5)	23 (21.9)	9 (19.6)	<0.0001
Severely affected	56 (36.6)	11 (11.5)	58 (55.2)	26 (56.5)	<0.0001
Sheep weather effect					
Minimal or no effect	31 (20.3)	26 (27.1)	38 (36.2)	15 (32.6)	0.035
Moderately affected	38 (24.8)	32 (33.3)	29 (27.6)	13 (28.3)	0.547
Severely affected	84 (54.9)	38 (39.6)	38 (36.2)	18 (39.1)	0.011
Goat weather effect					
Minimal or no effect	61 (39.9)	31 (32.3)	45 (42.9)	17 (37.0)	0.462
Moderately affected	38 (24.8)	33 (34.4)	28 (26.7)	12 (26.0)	0.411
Severely affected	54 (35.3)	32 (33.3)	32 (30.4)	17 (37.0)	0.829

4.3 Patterns and trends of reporting of disease outbreaks

Majority of the respondents (64%, 256) indicated to report outbreak (X^2 value - 31.36, degree of freedom – 1, p-value < 0.0001). This was observed in all the wards where the proportion of those who report RVF outbreak was higher than those who do not report outbreak. In reporting outbreaks of RVF showed a significantly higher (65%; p-value < 0.001) patterns of reporting to an animal health profession, either veterinarian (40%, 165) or animal health assistant (25%, 98). However, a notable percentage (36%, 144) did not report outbreaks. (Table 4).

Table 4: Participant reporting of disease outbreaks and who they report to.

	Ilchamus n (%)	Marigat n (%)	Mukutani (%)	Mochongoi (%)
Report outbreak				
Yes	89 (58.2)	62 (64.6)	71 (67.6)	34 (73.9)
No	64 (41.8)	34 (35.4)	34 (32.4)	12 (26.1)
Who do you report to?				
AHA	37 (24.2)	23 (24.0)	29 (27.6)	9 (19.6)
None	64 (41.8)	32 (33.3)	29 (27.6)	12 (26.1)
Neighbour	1 (0.1)	2 (2.1)	1 (1.0)	0 (0)
Veterinarian	51 (33.3)	39 (40.6)	46 (43.8)	25 (54.3)

4.4 Disease outbreak reporting channels and time taken for response.

Despite the availability of various medium of communicating disease outbreaks, including communicating in person and in public barazas, majority of the residents (49.75%, 199), in Marigat Sub County reported outbreaks through making telephone calls. (Table 5).

The time taken for an animal health professional to respond to a call took up to one month (30%, 120). A considerable number (16%, 64) of the respondents reported not to receive any response. It is worth noting that majority of animal health professionals (85.5%, 342) were located more than 2 km from the point of call. Table 6 shows time taken by animal health care workers to respond to disease outbreaks and the distance travelled. (Table 6).

Table 5: Disease outbreak reporting channels

	Ilchamus (%)	Marigat (%)	Mukutani (%)	Mochongoi (%)
Communicate in person	22 (14.4)	11 (11.5)	16 (15.2)	23 (44.2)
None	61 (39.9)	31 (32.3)	30 (28.6)	7 (13.5)
Public baraza	1 (0.7)	2 (2.1)	2 (1.9)	1 (1.9)
Telephone	69 (45.1)	52 (54.2)	57 (54.3)	21 (40.4)

Table 6: Time taken by animal health care workers to respond to disease outbreak and distance covered by the respondent.

Time taken to respond	Ilchamus (%)	Marigat (%)	Mukutani (%)	Mochongoi (%)
Never	28(18.3)	15(15.6)	15(14.3)	6(13.0)
Within one day	43(28.1)	35(36.5)	35(33.3)	19((41.3)
Within one week	5(3.3)	1(1.0)	4(3.8)	3(6.5)
Within one month	43(28.1)	31(32.3)	33(31.4)	13(28.3)
Distance covered to seek veterinary assistance				
Unsure of the distance	7	8	8	4
within 2km	8	12	9	2
more than 2km	138	76	88	40

4.5 Practices regarding Rift Valley fever prevention and control

Less than half of the participants (46.25%, 185) had been involved in RVF and other disease awareness campaigns. Almost all the participants (88.5%, 394) believed that RVF is a dangerous disease. Ilchamus ward stood out with the highest number of respondents (95.4%, 146) who acknowledged vaccination as the most effective method for managing RVF and other livestock diseases, according to participants' reports. Most of the participants believe that vaccination protects animals from contracting RVF (Table 7).

Table 7: Community practices on RVF prevention and control.

	Ilchamus (%)	Marigat (%)	Mukutani (%)	Mochongoi (%)
Disease_awareness_involvement	69(45.1)	52(54.2)	41(39.0)	23(50.0)
RV F is a dangerous disease?	148(96.7)	96(100.0)	104(99.0)	46(100.0)
History of RVF infected_herd	98(64.1)	36(37.5)	58(55.2)	23(50.0)
Perception of whether RVF animals vaccination protects	146(95.4)	91(94.8)	99(94.3)	44(95.7)

4.6 Binary logistics regression model

When modelling for factors associated with previous history of RVF, several factors showed to be significant in both the simple and multiple binary logistic regression models. The factors associated significantly reduced odds of having a history of RVF outbreak in the bivariate logistics regression were Marigat ward (OR: 0.337, CI: 0.197-0.568; p-value <0.0001); and those earning between KSH. 15,000 and KSH. 50,000 on average (OR: 0.536, CI: 0.327 - 0.873; p-value 0.013) (Table 8). Those significantly associated with increased odds of history of reporting RVF outbreak on the other hand included respondents that recorded to have lost an animal due to extreme weather conditions (OR: 4.654, CI: 1.654 - 16.559; p-value 0.007); those whose cattle were severely affected by weather conditions effect (OR: 1.746 CI: 1.036-2.953; p-value 0.037); persons who report disease to veterinarians (OR: 2.042, CI: 1.230-3.415, p-value 0.006); those involved in disease awareness campaigns (OR: 2.332, CI: 1.561-3.507; p-value <0.0001); and those aware that human spread of RVF can be prevented (OR: 3.936, CI: 1.609-11.066; p-value 0.005). All these factors remained significant when we adjusted for potential confounders in the multiple binary logistics regression (Table 8).

After adjusting for potential confounders in the multiple binary regression model, Marigat ward recorded 66% less odds of reporting history of RVF outbreak (OR: 0.339, CI: 0.178-0.632; p-value <0.0001) while Mochongoi ward had 70% less odds of having a history of RVF outbreak (OR: 0.295, CI: 0.122-0.692; p-value 0.006). This was relative to Ilchamus ward. Compared to households earning an average of KSH. 500 to KSH. 5000, the odds of having history of RVF outbreak were less in those earning above KSH. 5,000 and below KSH. 15,000 by 54% (OR: 0.465, CI: 0.245-0.874; p-value 0.0108) and those earning above KSH. 15,000 and below KSH. 50,000 on average by 57% (OR: 0.431, CI: 0. 233- 0.788; p-value 0.007). The odds of having experienced past RVF outbreak in respondents that recorded to have lost an animal due to extreme weather conditions was 7 times compared to those without record of losing an animal (OR: 7.052, CI: 2.018- 33.273; p-value 0.005) (Table 8).

There were twice as high odds of previously reported RVF outbreak in those who reported that their cattle were severely affected by weather conditions compared to those exposed to minimal weather effect (OR: 2.261 CI: 1.160-4.450; p-value 0.017). Unlike in the binary model, sheep severely affected by harsh weather conditions was significantly associated with history of reported RVF outbreak with double the odds of sheep minimally affected by harsh climate (OR: 2.060, CI: 1.105-3.899, p-value 0.024). It was also observed that persons who report disease to veterinarians had twice odds of having experienced RVF outbreak before compared to those who report to animal health assistants (OR: 2.005, CI: 1.056-3.845, p-value 0.034). The case was similar in those involved in disease awareness campaigns relative to those who don’t (OR: 2.804, CI: 1.654-4.830; p-value <0.0001), as well as those aware that human spread of RVF can be prevented (OR: 3.847, CI: 1.394-11.194; p-value 0.013)

(Table 8).

Table 8: Binary logistic regression

	Simple (unadjusted) binary logistics regression				Multiple (adjusted) binary logistics regression			
Variable	Odds Ratio	LCI	UCI	Pr(>|z|)	Odds Ratio	LCI	UCI	Pr(>|z|)
(Intercept)	1.162	0.955	1.415	0.134	0.020	0.003	0.124	0.0001***
Ilchamus ward (baseline)	_	_	_	_	_	_	_	_
Marigat Ward	0.337	0.197	0.568	0.000***	0.339	0.178	0.632	0.0008***
Mukutani Ward	0.693	0.417	1.15	0.156	0.905	0. 491	1.67	0.7490
Mochongoi Ward	0.561	0.287	1.094	0.089	0.295	0.122	0.692	0.0055**
Agriculture as main source of livelihood (baseline)	_	_	_	_	_	_	_	_
Business as main source of livelihood	0.899	0.165	4.909	0.897	0.541	0.074	4.234	0.5404

Table 8: Binary logistic regression

	Simple (unadjusted) binary logistics regression				**Multiple (adjusted) binary logistics regression**			
Variable	Odds Ratio	LCI	UCI	Pr(>|z|)	Odds Ratio	LCI	UCI	Pr(>|z|)
Employment as main source of livelihood	1.797	0.346	13.075	0.502	4.051	0.592	40.136	0.1787
Fish Farming as main source of livelihood	5.173e+06	3.022e-30	NA	0.983	1.7258 e+08	3.1202e-40	NA	0.9843
Livestock main source of livelihood	5.173e+06	2.273e-23	NA	0.981	1.6663e+07	3.6401e-38	NA	0.9866
Liveli_2N/A as main source of livelihood	0. 599	0.078	3.654	0.577	1.422	0.112	21.29	0.7876
Av. monthly Income 500 to <5000 (baseline)	_	_	_	_	_	_	_	_
Av. Monthly Income 5000 to <15000	0.608	0.365	1.009	0.055	0.465	0.245	0.874	0.0180*
Av. Monthly Income 15000 to <50000	0.536	0.327	0.873	0.013*	0.431	0. 233	0.788	0.0067**
Av. Monthly Income >=50000	1.327	0.577	3.250	0.516	1.295	0.467	3.741	0.6232

Table 8: Binary logistic regression

	Simple (unadjusted) binary logistics regression				Multiple (adjusted) binary logistics regression			
Variable	Odds Ratio	LCI	UCI	Pr(>|z|)	Odds Ratio	LCI	UCI	Pr(>|z|)
No of sheep owned	1.004	0.998	1.012	0.197	1.007	0.998	1.017	0.134
Animals lost to extreme weather conditions-YES	4.654	1.654	16.559	0.007**	7.052	2.018	33.273	0.005**
Cattle minimally affected by severe weather condition (baseline)	_	_	_	_	_	_	_	_
Cattle Moderately affected by severe weather condition	0.867	0.519	1.449	0.587	0.825	0.439	1.544	0.547
Cattle Severely affected by severe weather condition	1.746	1.036	2.953	0.037*	2.261	1.160	4.450	0.017*

Table 8: Binary logistic regression

	Simple (unadjusted) binary logistics regression				Multiple (adjusted) binary logistics regression			
Variable	Odds Ratio	LCI	UCI	Pr(>|z|)	Odds Ratio	LCI	UCI	Pr(>|z|)
Sheep minimally affected by severe weather condition	_	_	_	_	_	_	_	_
Sheep Moderately affected by severe weather condition	1.113	0.657	1.887	0.690	1.276	0.679	2.405	0.450
Sheep affected by severe weather condition	1.312	0.814	2.117	0.265	2.060	1.105	3.899	0.024*
Persons who report diseases to AHA (baseline)	_	_	_	_	_	_	_	_
Persons who do not report disease outbreaks	1.459	0.868	2.465	0.156	1.982	1.063	3.750	0.033*
Persons who report outbreaks to neighbours	2.221e-07	NA	3.56e+29	0.983	1.004929e-07	NA	1.813e+44	0.988
Persons who report disease to Veterinarian	2.042	1.230	3.415	0.006**	2.005	1.056	3.845	0.034*

Table 8: Binary logistic regression

	Simple (unadjusted) binary logistics regression				Multiple (adjusted) binary logistics regression			
Variable	Odds Ratio	LCI	UCI	Pr(>|z|)	Odds Ratio	LCI	UCI	Pr(>|z|)
Who spearheads vaccination campaigns?	6.736e+05	2.747e-42	NA	0.98	2.43488e+08	2.126e-204	NA	0.994
Involvement in disease awareness campaigns-YES	2.332	1.561	3.507	0.000***	2.804	1.654	4.830	0.000***
Prevention of spread of RVF to humans-YES	0.9	0.162	4.243	0.896	0.472	0.055	2.982	0.446
Human Spread Prevented-YES	3.936	1.609	11.066	0.005**	3.847	1.394	11.194	0.013*

CHAPTER FIVE: DISCUSSION, CONCLUSSIONS, RECOMMENDATIONS

5.1 DISCUSSION

Surveillance is an integral part of disease detection, where it involves gathering data on the incidences and patterns of a particular disease to safeguard people's livelihoods and health (FAO, 2018). The objective of this study was to evaluate the factors that facilitate or hinder the surveillance strategy for Rift Valley fever (RVF) in Baringo County, with a specific emphasis on Marigat Sub County. Public health surveillance plays a crucial role in collecting accurate and evidence-based information, which is vital for making informed decisions and implementing appropriate public health interventions (Nsubuga *et al.*, 2011).

In this study, the results suggest that most farmers (64%, 256) reported disease outbreaks to the relevant veterinary authorities. The data presented illustrates the farmers' readiness to engage in disease surveillance, which plays a crucial role in ensuring the effectiveness of any surveillance program (Oyas *et al.*, 2018). To enable the farmers to participate effectively in disease surveillance programs, it is important to empower them to be able to identify and solve the health problems (FAO, 2018). One of the ways to empower the community is through involvement in disease awareness programs. This study significantly associates participation in disease awareness campaigns with increased chances of reporting diseases outbreaks (OR: 2.332, CI: 1.561-3.507; p-value <0.0001). This finding is similar to study conducted by Hasanov *et al.*, (2018) which assessed the impact of public education on zoonotic diseases where respondents in awareness campaigns reported correct disease symptoms compared to areas which had not been targeted with campaign awareness activities.

This study further observes that persons who report disease to veterinarians had twice odds of having experienced RVF outbreak before compared to those who report to animal health assistants (OR: 2.005, CI: 1.056-3.845, p-value 0.034). This further demonstrates that having experienced the disease similar to having been imparted with knowledge on the disease improves the participation of communities in disease surveillance programs (Oyas *et al.,* 2018). The case was similar in our study whereby participants involved in disease awareness campaigns (OR: 2.804, CI: 1.654-4.830; p-value <0.0001) reported animal disease outbreak to veterinarians compared to participants who were not involved in the campaigns. This study reports that less than half of the participants (46.25% 185), had been involved in RVF and other disease awareness creation campaigns. In Kenya, the current approach to routine livestock surveillance is predominantly passive. Both public and private veterinarians rely on farmers to report instances of animal illness before acting and documenting the cases (Oyas *et al.,* 2018).

Despite the availability of various means of communicating disease outbreaks, including communicating in person and in public barazas, majority of the residents in Marigat Sub County reported outbreaks through making telephone calls (48%, 47). Mobile phones have become prevalent worldwide, even in remote regions of Africa such as Baringo County. This widespread adoption presents a valuable chance to enhance both medical and public health practices, specifically in terms of surveillance data collection and communication (Robertson *et al.,* 2010). According to a study conducted by Thumbi *et al.* in 2019, it was found that implementing a surveillance system using mobile phones has a greater likelihood of accurately reporting disease events. This indicates that a passive surveillance system aided by mobile phones can surpass an active surveillance system (Robertson *et al.,* 2010). The study also reveals that owning a mobile phone does not necessarily determine the utilization of the phone-based surveillance system. This demonstrates the effective interaction between widespread phone ownership and the ability to access phones for reporting disease events, even in households that do not own phones. These findings explain why residents of Marigat Sub

County preferred to use mobile phones the means of reporting disease outbreaks in (Robertson *et al.,* 2010).

A notable percentage of participants (36%, 144), however, did not report outbreaks to the relevant authorities. This calls for interventions aimed at improving behaviour change interventions such as awareness creation. Even after reporting outbreaks to the relevant veterinary authorities, it majorly took one day and as much as long as one month for the respondents to receive interventions. Delayed response means that the pastoralists who highly depend on their livestock for their livelihood suffer a loss in production. The loss of livelihood not only affects the livestock keepers. It has a substantial impact on the whole value chain affecting the livestock keepers, traders, slaughterhouses, and butchers (Peyre *et al.,* 2015). 19%, (76) of the respondents reported not to receive any response bringing out the gap in veterinary care in the area and response to outbreaks. It is worth noting that majority of animal health professionals as reported by 85.5% (342) of the respondents were located more than 2 km from the point of call. In a study conducted in Baringo County on the delivery of veterinary services, the research identified limited transport, insufficient funding, and an inadequate number of professionals as key factors contributing to the poor delivery of veterinary services. The study highlighted the presence of only nine government veterinarians on-site, supported by 26 certificate-level officers, emphasizing the challenges associated with the scarcity of resources and personnel in the region (Shivairo, 2013). This calls for an improved service delivery of animal health professionals in Marigat Sub County and Baringo county in general.

Majority of the participants interviewed had heard about RVF and they believed that it was a very dangerous disease (394, 88.5%).These was not strange, considering that Baringo County was among the districts, now counties, that experienced severe impact from the disease during the outbreaks of 1997/1998 and 2006/2007 in Kenya (Lichoti *et al.,* 2014). A majority of the respondents (380, 95%) acknowledge vaccination as the most efficient method for managing

RVF and other livestock diseases. This finding of increase knowledge of RVF prevention practices aligns with the results of a study conducted among livestock keepers in Tanzania and Kenya (Jost *et al.,* 2010). The study aimed to compare the 2006/2007 RVF outbreak in both countries. The findings revealed that Somali pastoralists in Kenya were able to provide more precise and comprehensive information about the diseases affecting their livestock, as well as the preventive measures, in comparison to the Maasai pastoralists in Tanzania.

5.2 CONCLUSIONS

- The respondents that had been involved in disease awareness campaigns reported incidences of outbreaks, therefore, creation of public awareness seemingly has a great impact on increased knowledge and awareness of RVF in Marigat Sub County.
- The use of mobile phones in disease reporting seemed to be the preferred mode over the other channels.
- There exists a gap in veterinary care. It takes up to a month for some of the respondents to receive veterinary care while some respondents do not receive veterinary response at all.

5.3 RECOMMENDATIONS

- There is need for improved delivery of veterinary care to residents of Marigat Sub County by improving on response time and bringing the veterinary services closer to the people.
- There is need to harness technology in RVF disease surveillance by incorporating the use of mobile phones.
- The veterinary and human health teams should work together to create community awareness on various zoonotic diseases including RVF.
- To increase the effectiveness of diseases public awareness campaigns the study recommends timing of such campaigns to precede government-led vaccination campaigns.

CHAPTER SIX: REFERENCES

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APPENDIX

1. QUESTIONNAIRE

HOUSEHOLD QUESTIONNAIRE

Title: Assessment of Rift Valley Fever Surveillance and Control Strategy in Baringo County, Marigat Sub County – Kenya

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CONSENT

I ____ have understood the objectives of this project and consent to this interview. **Signature** ____________________

A. General household information (Biodata)

A1. Date: ____/_____/ 2020

A2. Interviewer name: ____

A3. Household GPS reading: ____

A4. Household Code/Number: ____

A5. Respondent (Head of household) _______________ If other specify __________________

A6. Name: _______________ **A7**. ☐ Gender: ☐ Male Female **A8.** Age: ______________

A9. Level of Education

☐ None ☐ Primary ☐ Secondary ☐ College/University

A.10. Number of people in the household

☐ 0 – 5 ☐ 5 – 10 ☐ >10

A11. What is your main source of livelihood and income? (Can choose more than one)

☐ Livestock ☐ Agriculture ☐ Business ☐ Fish Farming

☐ Other, specify ____________________

A12. Average monthly income:

☐ 500 <5,000 ☐ >5000 – 15,000 ☐ >15,000 – 50,000 ☐ >50,000

B. <u>Livestock and Climate Change</u>

B 1. How many of these animals do you have? (cattle, sheep, goats) do you have?

1. Cattle: ____ **2**. Sheep: ____ **3**. Goats: ____ **4**. Other: ____

B 2. a. Have you lost any animals due to harsh weather or climate? ☐ Yes ☐ No

B 2. b. If yes, how many?

1. Cattle: ____ **2**. Sheep: ____ **3**. Goats: ____ **4**. Other: ____

B 3. In your opinion, how are these animals affected by extreme weather conditions?

1. **Cattle**: ☐ Severely affected ☐ Moderately affected ☐ Minimal or no effect
2. **Goats**: ☐ Severely affected ☐ Moderately affected ☐ Minimal or no effect
3. **Sheep**: ☐ Severely affected ☐ Moderately affected ☐ Minimal or no effect
4. **Camel**: ☐ Severely affected ☐ Moderately affected ☐ Minimal or no effect
5. **Chicken**: ☐ Severely affected ☐ Moderately affected ☐ Minimal or no effect

B 4. What conditions/diseases in order of frequency (most frequent to least frequent) have you encountered during the harsh climatic period?

1________________ 2________________ 3________________

4________________ 5________________ 6________________

B 5. What are the major effects of extreme weather conditions on livestock?

☐ Disease ☐ Reduced Production ☐ Reduced Reproduction ☐ None

☐ Do not know ☐ Other: ____

6 Livestock disease prevention and control

C 1. How do you know when your animals are sick?

____

____

____

____

C 2. Do you report disease outbreaks? ☐ Yes ☐ No

C 3. If yes, to whom do you report disease outbreaks? (More than one response allowed)

☐ Veterinarian ☐ Animal Health Assistants (AHA) ☐ Neighbours

☐ Community Based Animal Health Worker (CBAHW) ☐ Other__

C 4. How do you report sick/dead animals?

☐ Telephone (call and sms) ☐ Communication in person (Physically) ☐ Public Baraza

Other (specify) ____

C 5. What do you do when your animals fall sick?

☐ Call the veterinarian ☐ Attempt to treat the animal ☐ Other: _______________

C 6. Who do you receive intervention from when animals fall sick?

☐ Veterinarian ☐ Animal Health Assistants ☐ Neighbours

☐ Community Based Animal Health Worker (CBAHW)

C 7. Typically, how long does it take to get response from animal health workers?

☐ Within one day ☐ Within one week ☐ Within one month ☐ Never

C 8. How far in distance do you seek assistance when animals fall sick?

☐ Near- within 2 km ☐ 2. Far: >2km ☐ Both

C 9. Do you have livestock insurance cover?

☐ Yes ☐ No

C 10. Is vaccination of animals against diseases a common practice in your area?

☐ Yes ☐ No

C 11. What are the common diseases that animals are vaccinated against?

____

____

____

____

____

____

C 12. Who spearheads the vaccination process?

☐ County Government ☐ Non-Governmental Organizations

Other (specify)

____

C 13 Have you been involved in any livestock disease awareness program.

☐ Yes ☐ No

7 Attitudes towards Rift Valley Fever

D 1. RVF is a dangerous disease. ☐ Yes ☐ No

D 2. Have you had a history of RVF infection among your herd? ☐ Yes ☐ No

D 3. You are at risk of RVF infection. ☐ Yes ☐ No ☐ Don't know

D 4. Do you believe that spread of RVF from animals to humans can be prevented?

. ☐ Yes ☐ No ☐ Don't know.

D 5. Do you believe vaccination protects animals against RVF? ☐ Yes ☐ No

2. NACOSTI RESEARCH LICENSE

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Date of Issue: **09/October/2020**

RESEARCH LICENSE

This is to Certify that Dr.. Nickson Lang'at of University of Nairobi, has been licensed to conduct research in Baringo on the topic: Assessment of Rift Valley Fever Surveillance and Control Strategy in Marigat Sub County, Baringo County, Kenya for the period ending : 09/October/2021.

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