EPIDEMIOLOGY OF BOVINE TRYPANOSOMIASIS IN KILIFI AND KWALE COUNTIES, COASTAL KENYA

BY

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DECLARATION

Declaration by the candidate

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DEDICATION

To my lovely son, parents and my siblings for their moral encouragement, motivation throughout the tiring toils in this incessant pursuit of education.

ABSTRACT

Trypanosomiasis is a neglected tropical disease of human and animal populations in sub saharan Africa. Tsetse fly is the cyclical vector that transmits trypanosome parasites to animals and humans causing Animal African Trypanosomiasis (AAT) and Human African Trypanosomiasis (HAT) respectively. Biting flies like Stomoxys and Tabanids are the mechanical vectors of the parasites. The main objective of this study was to determine the factors influencing prevalence of trypanosomiasis among the bovine and determine its social economic impacts to the people in Coastal Kenya. Bovine blood samples were analyzed microscopically for the infection and the disease prevalence was determined using 593 bovines (329 and 264) during dry (Dec-Feb) and wet (Jul-Sep) seasons respectively. The bovine body condition, age, sex and Packed Cell Volume (PCV) were determined. The density of the tsetse vectors was determined by deploying NGU standard sampling trap device using a total of 112 traps, 56 during wet and dry seasons respectively in each sampling site. Fly numbers were recorded and categorized to species, sexed and sorted as either tenerals or non-tenerals. Socioeconomic impact of tsetse and trypanosomiasis was investigated using structured questionnaire administered to 138 consenting respondents during the study. Data was analyzed using SPSS Version 20.0. Descriptive statistics was used to summarize the data and qualitative data was presented using frequency tables and figures. Analytical statistics (t-test, chi-square, Kruskal Wallis test and linear regression) were used to compare quantitative data. Results identified two species of trypanosome parasites namely *Trypanosome congolense* and *Trypanosome vivax* infecting the bovine population in the study areas. The overall prevalence of the infection was 12.54% and 9.80% in Kilifi and Kwale respectively. There was no significant difference in the prevalence of *T. vivax* and *T.congolense* between the two counties. The occurrence of trypanosomiasis was significantly associated with season (P=0.000), Breed (P=0.000) , Sex (P=0.000),age (P=0.000) and the PCV(P=0.003). The cumulative infection rate was highest in cattle with poor body condition (64.29% and 42.11%) followed by fair body condition (29.35% and 11.88%) in Kilifi and Kwale respectively. Adult animals significanly had the higher rate of infection at 75.76% (Kilifi 42.42%; Kwale 33.34%).Wet season was associated with the higher infection rate at 65.16% (Kilifi 31.82% and Kwale 33.34%). The seasonal variations in the prevalence of infection was significant ($P < 0.05$).Three species of tsetse,namely *Glosina longipennis, G. pallidipes,* and *G. austeni* and two genera of biting flies *Stomoxys* and *Tabanus* were identified. Fly/Trap/Day (FTD) captured in Kilifi was:5.2 and 2.93 during the wet and dry seasons respectively, whereas in Kwale it was 27.98 and 1.43 during wet and dry seasons. Various vector control approaches are used by the farmers in the area and they include animal spraying, bush clearing, use of insecticde impregnated targets, netting of zero grazing units and restriction of animals from tsetse infested areas. Poverty in the study area is strongly associated with AT. The study recommends that the national and county governments should prioritize trypanosomiasis control to boost livestock production in the coastal region. There is need for further study to determine the level of purchase of the trypanocidal drugs from agro-vet shops to contribute to disease surveillence in the coastal counties.

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LIST OF ABBREVIATIONS AND ACRONYMS

AAT - Animal African Trypanosomiasis

ASF - Arabuko Sokoke Forest

AT - Africa Trypanosomiasis

DA - Diminazene aceturate

FAO - Food and Agricultural Organization

HAT - Human African Trypanosomiasis

ISMM - Isometamidium chloride

KENTTEC - Kenya Tsetse and Trypanosomiasis Eradication Council

NGU - Nguruman

NTD - Neglected Tropical Diseases

PATTEC - Pan-Africa Tsetse and Trypanosomiasis Eradication Council

PCV - Packed Cell Volume

SHNR - Shimba Hills National Reserve

SS - Sleeping Sickness

WHO - World Health Organization

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CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Tsetse flies are the primary vectors of African Trypanosomiasis (AT), a disease of paramount importance to both livestock and humans across the African continent (Devisser and Messsina, 2009: Simo *et al.,* 2015). Trypanosomiasis is a protozoal disease that can be either Animal African Trypanosomiasis (AAT) also known as nagana in animals (Gibson *et al*., 2017) or zoonotic Human African Trypanosomiasis (HAT), also referred to as sleeping sickness (SS) in humans (Simarro *et al.*, 2011;Malele, 2011). Disease transmitted biologically by different species of *Glossina* flies is called AT(Degneh *et al*., 2018) and mechanically by biting dipteran flies such as *Stomoxys calcitrans* and *Tabanus* species (Alemayehu *et al*., 2012) which act as flying syringes (Bouyer *et al*., 2018).

African Trypanosomiasis disease is caused by unicellular (Mammo *et al*., 2013) parasites known as *Trypanosoma* parasites protozoal. The parasites are present in the tissues of all vertebrates, including humans, and their blood (Gibson *et al*., 2017), livestock and other wild life (Mammo *et al*., 2013).The illness often affects animals like buffalo, antelope,elephant,rhinos and wild suids also large reptiles like crocodiles and monitor lizards (Gibson et al., 2017).

Tsetse flies (Glossina species), commonly referred to as "poverty flies" or "flies of death" (FAO, 2008), are insects that belong to the family Glossinidae, order Diptera, and genus Glossina (Malele, 2011). Unlike other dipteran vectors, both sexes of the tsetse sucks and feed onblood (Gibson *et al*., 2017). Distinguishing features are that; tsetse flies have special cells on their wings known as the hatchet cell and also when the tsetse fly is at rest, one wing rests on top of the other in a scissor like formation.

Tsetse flies occur in 37 sub-Saharan countries (Wamwiri *et al.,* 2013; Albert *et al.,* 2015; Meyer *et al.,* 2016) covering nearly 10 million km^2, a region that roughly equates to one-third of all of Africa's lands .The AT illness is spread throughout a region of around 10 million km2 (Degneh *et al.*, 2017) in 37 sub-Saharan nations (Messina et al., 2012), which are located between latitudes 14°N and 29°S (Alemayehu *et al*., 2012; Mammo *et al*., 2013) covering across several countries. Most domesticated animals are susceptible to trypanosome infection but the disease is most significant in bovines. Bovine trypanosomiasis is caused by *Trypanosoma vivax, T. congolense.* and *T. brucei brucei (*Grady *et al.*, 2011).

Half of the population in tsetse infested countries suffers from food insecurity with an estimated 85% being from the rural areas whose main source of livelihood is agriculture, livestock keeping and fishing(Mattiole et al.,2004). In tropical Africa, AAT is seen to be the biggest obstacle to the cultivation of cattle and mixed crops and livestock (Bouyer et al., 2011). Most sub-Saharan African nations with tsetse infestations see a major negative impact on economic growth as a result of the disease (Degneh *et al*., 2017). There is a possibility of the illness spreading to around 50 million cattle and other livestock (Alemayehu *et al*., 2012). AT causes dead of approximately 3 million cattle (Grady *et al.*, 2011) and other domestic livestock (Alemayehu *et al*., 2012) every year. Degneh *et al.*, (2017) stated that the overall economic loss due to trypanosomiasis in Africa is estimated to be 4.5 billion USD. Thus, AT constitutes a major threat to food security and livestock production in several countries of sub-Saharan Africa, Kenya included.

The fly and the disease occur in the world's poorest countries with 32 out of 37 tsetse infested countries being ranked the poorest in the world (FAO,2002). This affect the poorest of the poor rural inhabitants in Africa's most indebted nations, and is a barrier to the establishment of sustainable agricultural systems in the area (FAO, 2002). Additionally, trypanosomiasis hinders the development of livestock breeds and the expansion of animal output in Africa, more so in areas where it coexists with tick-borne illnesses (Meyer *et al.*, 2016).

Animal infection with the AAT disease results in retarded agricultural development in large areas of the African continent as a result of its direct and indirect effects. Direct effects of the disease include animal mortality, abortion, reduced fertility, reduced milk and meat production, reduced traction power in animals especially in areas where oxen are used in land ploughing. Indirect costs result from uneven land use brought on by the presence of tsetse flies and the illness trypanosomiasis in low lands, such as the exclusion of livestock and animal power based agricultural production in the generally populated and degraded high areas (Alemayehu *et al*., 2012).

Human African Trypanosomiasis (HAT)is one of the diverse ranges of Neglected Tropical Diseases (NTD) in Sub-Saharan Africa (Bouyer *et al*., 2011) with approximately 60 million of the 400 million inhabitants (Esterhuizen *et al*., 2011) at risk of contracting the diseases in endemic and non-endemic countries. DeVisser and Messina (2009) projected that at least 300,000 cases of HAT were underreported decades later after 1986 due to a lack of surveillance plus the maintenance of infection in animal reservoirs, deteriorating environmental conditions, and rising parasite drug resistance in their report (Uba et al., 2016). In response to these restrictions, the World Health Organization (WHO) begin surveillance in 2001 with the help of public and commercial partnerships. During that time, 25,000 new cases were recorded annually on average.

Human African Trypanosomiasis(HAT) is a highly focal disease in rural areas (Wamwiri and Changasi, 2016) caused by the two subspecies of *Trypanosoma* parasites; *Trypanosoma brucei gambiense* (gHAT) and *T. b. rhodesiense* (rHAT). The chronic anthroponotic form of HAT, caused by *Trypanosoma brucei gambiense* (gHAT) occurs in west and central Africa and accounts for about 98% of cases reported (Esterhuizen *et al*., 2011),whereas rHAT is the acute zoonotic form of the disease (Muse *et al.,* 2015) which occurs in East and South Africa and accounts for 2% of reported cases.The two differ in aetiology, epidemiology, clinical manifestation, and treatment regimes.

As a major source of sickness and mortality in both animal and human populations, the disease has devastating effects. Additionally, because it impacts visitor arrivals, it causes economic losses (Muse et al., 2015). According to global data, 75 %international HAT cases from 1995 to 2010 were travelers who had previously visited African nations (Muse *et al.*, 2015; Büscher *et al*., 2017)

Tsetse and trypanosomiasis eradication programmes,such as the Pan African Tsetse and Trypanosomiasis Eradication Campaign, were initiated as a result of the economic losses associated with AAT and HAT (PATTEC) (Simo *et al.,* 2015), coordinated by the African Union (Ngari *et al.,* 2020). Campaign was initiated by the African Heads of State and

Government begin in 2000 with an aim of eradicating tsetse and trypanosomiasis from Africa. Kenya started the project, and the PATTEC Unit was created under the Department of Veterinary Services in 2005. Up until 2011, the PATTEC projects led initiatives to eradicate tsetse and trypanosomiasis in Kenya. To protect the progress gained under the PATTEC initiative, expand interventions to additional priority regions (such as the Coast region), and coordinate tsetse and trypanosomiasis eradication at the national level, the Kenya Tsetse and Trypanosomiasis Eradication Council (KENTTEC) was founded in 2012. (Ngari et al.

Successful control of tsetse and trypanosomiasis will encourage large scale livestock farming and rearing of improved breeds of cattle with high productivity rate. Increased animal population and animal productivity results in improved living standards of the communities. This will translate to improved food security level. Also high quality of animals products gets higher demand in the global market hence the country will get better revenue returns.

1.2 Statement of the problem

Agriculture is the mainstay of Kenya's economy. Livestock rearing plays a crucial role in agricultural production both directly as food and income sources and indirectly as source of manure for fertilization and a source of traction power for crop production. Productive livestock rearing is however largely absent in the vast fertile areas of the tsetse infested countries in Africa and infested counties in Kenya as well. As a result, the fly is seen as a contributing factor to poverty in countries infested by it in Sub-Saharan Africa.

The loss of production brought on by poverty and inadequate socioeconomic development is one of the disease's socioeconomic effects. More frequently than not, those in the labor market are impacted. Additionally, it has a greater impact on those who travel about a lot, work in rural regions, or carry out household tasks, particularly those who are in close proximity to watercourses. Outdoor activities including farming, hunting, fishing, or clothing washing might cause HAT transmission. HAT is a crippling illness that, if ignored, can have significant mortality rates.

While animal diseases restrict the supply of meat and milk and deprive African farmers of draught animal power, human illnesses reduce labor resources, significantly reducing agricultural yield. Children who are afflicted by the illness experience significant delays in their mental development, which has a severe influence on their academic achievement and career success.

The ongoing high risk of HAT in the most popular tourist spots poses a serious danger to the region's and the world's rival tourism industries. Given that the tourist industry contributes between 17.5% and 25% of GDP and foreign currency, respectively, and is one of the top economic sectors, it requires proper attention to handle the HAT risk, particularly in National Parks. If there are fewer visitors, there will undoubtedly be less money made from tourism. Therefore, there are significant and complex political and socioeconomic repercussions of HAT for the Kenyan tourist sector and economy as a whole.

Communities in these counties experience varying levels of poverty and food security, which is a reflection of the effects of a number of limiting factors, such as Tsetse and trypanosomiasis, on the current agricultural production process, human wellbeing, as well as the potential for overall household development. In addition to direct losses due to the disease and the financial requirements for control operations, animal trypanosomiasis also indirectly affects human health through protein deficiency caused by the shortage of meat and milk (Munyua, 2006). The disease also causes a decrease in livestock productivity since it prevents the introduction of improved breeds and causes overstocking in tsetse free areas.

The impact of trypanosomiasis on the country's agriculture is most obviously felt at herd level as reduced milk and live animal disposal at lower prices and reduced work efficiency of oxen used for cultivation. Trypanosomiasis limits the number of oxen that farmers possess and lowers the average area sown per family by as much as 50% in mixed farming systems when the disease is prevalent (Munyua, 2006). AT is considered the most important economically debilitating diseases in not only in Kenya but also in most of Sub-Saharan Africa and mostly contributes to poverty, hunger (Bouyer *et al*., 2009), and underdevelopment in the affected countries. Successful control strategies are required and this needs the epidemiological knowledge for effective targeted interventions. The risk factors for bovine trypanosomiasis in Kenyan Coast have not been documented. The socio-economic impacts of the disease have also not been assessed. This study aimed at determining the risks for bovine trypanosomiasis in Kilifi and Kwale Counties and also asses its socio-economic impacts to residents in the Kenyan coast region.

1.3 Justification for the study

Animal Trypanosomiasis is one of the important diseases in Kenya especially in the coastal region affecting both domestic and wild animals (Paling *et al*., 1987; Cheruiyot 2013)

For the majority of agricultural activities, livestock is a crucial source of energy. They provide traction, cultivation, and transport power. Because agriculture supports the vast majority of rural areas, eliminating a significant development issue like TT would enable more local agricultural productivity, socioeconomic growth, and market expansion, all of which will reduce hunger and poverty. Additionally, livestock serves as protection for savings, making it a crucial source of income for rural impoverished people.

Determination of the rate of fly per trap per day distribution will inform on the suitable control strategies and measures to be deployed. Rural self-sufficient agriculture requires a continual reduction in agricultural constraints so that productive livestock may supply milk, meat, and draught power to plough the land, which will eventually lead to increased revenue and market prospects (Okello et al., 2015).

Community involvement in the control exercise is vital in the achievement of tsetse and trypanosomiasis free country. The study established measures adopted by the communities to cushion the impact of the flies and the disease on their agricultural production systems.

The impact of the tsetse and trypanosomiasis on agriculture eventually affects the socio-economics of the associated communities. The study also aimed at determining the impacts of the trypanosomiasis on the socio-economic status of the communities in Kilifi and Kwale Counties.

1.4 Objectives

1.4.1 Broad objective

To investigate the factors influencing prevalence of bovine trypanosomiasis and evaluate its socio-economic impact on the people in Kwale and kilifi coastal counties in Kenya.

1.4.2 Specific objectives

1. To determine and compare the causative species and prevalence of bovine Trypanosomiasis in Kilifi and Kwale Counties
2. To determine the correlation between bovine body condition, season, bovine sex and age and the prevalence of bovine trypanosomiasis in the study area
3. To determine seasonal and spatial distribution and abundance of the trypanosomiasis vector, *Glossina* species and biting flies in Kilifi and Kwale Counties
4. To assess the socio-economic impact of bovine trypanosomiasis on human communities in Kilifi and Kwale Counties

1.5 Null Hypotheses

1. There is no difference in the causative species and prevalence of bovine Trypanosomiasis between Kilifi and Kwale Counties
2. There is no correlation between body condition, season, sex , age and the prevalence of bovine trypanosomiasis in the study area
3. There is no difference in the seasonal and spatial distribution and abundance of trypanosomiasis vector, *Glossina* species and biting flies between Kilifi and Kwale Counties.

4. There are no impacts of bovine trypanosomiasis on the socio-economic status of the human communities in Kilifi and Kwale Counties

CHAPTER TWO

LITERATURE REVIEW

2.1 Tsetse and Trypanosomiasis

Tsetse flies are the primary vectors that transmit African Trypanosomiasis (AT), a disease of paramount importance to both livestock and humans across the African continent (Devisser and Messsina, 2009). Tsetse are flies of medical and veterinary importance since they are known to be cyclical vectors of trypanosomes parasites; the causative agent of Animal Africa Trypanosomiasis (AAT) or nagana in animals and Human Africa Trypanosomiasis (HAT) or sleeping sickness (SS) in humans (Kagabadoun *et al*., 2018).

The tsetse fly, also known as the "fly of death" (Bouyer *et al*., 2018) or the "poverty fly," is considered one of the root causes of hunger and poverty (Bouyer *et al*., 2015) and constitutes a serious impediment to sustainable agricultural rural development in the rural areas of tsetse infested countries (Kagabadoun *et al*., 2018). Tsetse infestation in these areas is one of the most important constraints to rural development since the disease affects agriculture and livestock production which are the mainstay of the rural communities in sub-Saharan Africa (Lesila *et al*., 2014).

African trypanosomiasis (AT), is among the highly neglected tropical disease (NTD) (Bouyer *et al*., 2009; Devisser and Messina, 2009; Bouyer *et al*., 2018) and devastate livestock (Devisser and Messina, 2009) and agricultural development (FAO, 2018) hence impacting on nutritional and livelihoods in approximately 10 million square kilometers (FAO, 2002) of tsetse infested countries.

Trypanosomiasis is a parasitic infection of domestic animals, humans and wild animals (Massina *et al*.,2012). An estimate of 50-70 million animals are at risk of AT infection (Degneh *et al*., 2017) and sixty million people are at risk of contracting sleeping sickness. Bouyer *et al*., (2018) estimated that the total losses to agricultural production alone due to trypanosomias is in Africa to be $4.5 billion per year (Bouyer *et al*., 2018).

2.2: Disease transmission

The contact rate between hosts and vectors is an important aspect in determining the contribution of each specific host species to the reservoir host population for vector-borne illnesses affecting several host species (Esser et al., 2019). The host species that the flies feed on may be determined by identifying the host species in their bloodmeals. Studies in various environments determined that the most significant preferred hosts for G. *pallidipes* were buffalo, bushbuck, warthog, and bushpig *(*Auty *et al*., 2016*)*

The three main species of tsetse flies that transmit trypanosome parasites are *Glossina morsitans,* which favors the open land of the savanna, *Glossina palpalis*, found on the shaded habitats adjacent to rivers and lakes (Lehane *et al*., 2016); and finally, Glossina *fusca*, which prefers the highly dense forested areas (Muse *et al*., 2015; Nthiwa *et al*., 2015). Some biting flies have been shown to be the mechanical vectors of trypanosomiasis and they include flies of the genus *Liperosia*, *Chrysops*, *Tabanus*, *Stomoxys*, and *Haematopota* flies have also been implicated (Mammo *et al*., 2013; Nthiwa *et al*., 2015)

According to the work of Dolan (1998,) the Kenyan Coast Region in particular, Kilifi County is dominated by four *Glossina* species namely *Glossina pallidipes*, *G. longipennis*, *G. brevipalpis* and *G. austeni*.

Chagas disease is another form of Human Trypanosomiasis also considered as NTD. It is a major public health problem in Brazzil and Latin America (Martins-Melo *et al*., 2013) and an emerging problem in North America and Europe due to increasing international migrations. Chagas disease is also known as American Trypanosomiasis (WHO 2019). This form of disease is caused by *Trypanosoma cruzi* parasites which are transmitted by insect vector known as triatomine bugs or 'kissing bugs' by contact with faeces or urine of the triatomine bugs (Martins-Melo *et al*., 2013).

Trypanosomes are single celled (Devisser *et al*., 2010) haemoprotozoan (Gona *et al*., 2016) parasites of genus *Trypanosoma* (Nthiwa *et al*., 2015) in the family Trypanosomatidae. The parasite lives and multiplies extracellularly in the blood and tissue fluids of mammalian hosts and are transmitted by a bite of an infected fly (Wanga, 2015).

The causative agents of AT in both human and animals are classified into three most important sub species; Subgenus *Nannomonas* which comprise of *Trypanosoma congolense*, subgenus *Duttonella* which include *T. vivax* , the only trypanosome parasites species transmitted both biologically by tsetse flies and mechanically by the biting flies, hence is present worldwide even in non-tsetse infested areas (Bouyer *et al.*, 2018).

Subgenus *Trypanozoon* which include the sub species of *T. brucei; T. brucei brucei, T. brucei rhodensiense* and *T. brucei gambiense. T. b. brucei,* causes AAT whereas the other two sub species *T. b. rhodensiense* and *T. b. gambiense* causes HAT. Though the two causes Sleeping sickness (SS) and are morphologically similar, they can be distinguished by their distinct disease patterns in humans, clinical signs and difference in disease management regime (Franco *et al*., 2014). *T. b. gambiense*, causes chronic form of African trypanosomiasis also known as *Trypanosoma brucei gambiense* (gHAT) (Surdash and Brown 2015). It is known to occur in Central and West Africa and it accounts for 98% of SS cases reported (Wamwiri and Changasi,2015). In 2012, The Democratic Republic of the Congo (DRC) reported the majority of gHAT cases, accounting for up to 84% of all recorded endemic cases. Whereas *T. b. rhodesiense* occurs in 13 East and South Africa countries (Büscher *et al.*, 2017), it causes acute African trypanosomiasis or *rhodesiense*-HAT (rHAT) and it account for less than 2% of reported cases (Lehane *et al*., 2016). Both of these parasites are non-pathogenic in domestic animals but are epidemiologically important as they act as basins hosts of the human infectious trypanosomes (Hamill *et al*., 2017; Büscher *et al.*, 2017). With domestic livestock overflow generating human rHAT, the long-term and persistent prevalence of T. brucei rhodesiense in cattle as a reservoir of human infection is of great public health relevance (Muhanguzi et al., 2014). According to Büscher et al. (2017), the third subspecies of T. b. brucei predominantly parasitizes cattle and other domestic and wild animals. Uganda is unusual in that it is the only nation where both rHAT and gHAT have been documented (Hamill *et al*.,2017). According to Krinsky (2018), because some species of tsetse flies do not readily feed on people, sleeping sickness is not present everywhere tsetse flies are known to be dispersed, but nagana is. The trypanosomes that cause African animal trypanosomiasis are often not contagious to humans.

Climate, the existence of flora, the presence of water, and the availability of appropriate hosts, i.e., people and animals, all affect the ecological spread of tsetse flies. Different kinds of tsetse flies live in what is sometimes referred to as the "tsetse belt," which extends throughout Africa's humid and sub-humid zones (Shaw *et al*., 2014).

2.3 Biology of theVector

The hematophagous insects known as the tsetse can spread trypanosomes to both sexes (Franco et al., 2014). The tsetse fly is viviparous, the female releases a fully mature larva that burrows into the ground, pupates, and emerges as an adult fly a month later (Büscher et al., 2017). Tsetse flies are one of the few K-strategist insects with low fertility rates, relatively extended life spans in comparison to other insects, and greater survival rates for their progeny (McCord et al., 2012). The 31 tsetse species and subspecies are divided into three groups based on their preferred habitats: forests, rivers, and savannahs (Wamwiri and Changasi, 2015; Büscher *et al.*, 2017). The *fusca* group of subgenus Austenina (Devisser and Messina, 2009; Bouyer *et al*., 2018), with the unusual exception of G. longipennis, which inhabits poorly vegetated dry places, are generally regarded as forest tsetse species (Nthiwa *et al*., 2015). *Glossina* species are divided into three groups depending on their ecological zones namely;, fusca group, palpallis group and morsitan group (Malele, 2011; Grady *et al.,* 2011). In Kenya, the fusca group has three species: G. *brevipalpis*, G. *fuscipleuris*, and G. *longipennis*. (Ngari *et al*., 2020).

The *palpalis* group belong to sub genus *Nemorhina*, a riverine species group (Bouyer *et al*., 2010), with only one species, *G. Fuscipes*. The species of this group are responsible for 90% of cases reported on acute HAT (Oloo *et al*., 2014) caused by *Trypanosoma brucei rhodesiense* and of the chronic form caused by *T. b. gambiense* (Sudarshi and Brown, 2015). The third category is the subgenus Glossina sensu stricto morsitans group, sometimes referred to as the woody savannah tsetse species. Kenya is home to four species of the Morsitans genus: G. *pallidipes*, G. *austeni*, G. *morsitans*, G. *swynnertoni* (Devisser; Messina, 2009).

The interaction of the following factors; distribution, climate (Nnko *et al*., 2021) and abundance of the vectors and the availability of the hosts influences the prevalence of disease (Nthiwa *et al*., 2015). These components are crucial in identification of the pathogenicity of the parasite, susceptibility of the host (both animals and human) and how they vary to affect disease persistence (Ngonyoka *et al.,* 2017).

Tsetse flies are susceptible to trypanosome infections, but their vectorial capacity vary from one group to another (Wamwiri *et al.,* 2013) due to refractoriness to trypanosome infection as the palpalis group being poorer vectors of trypanosome compared to morsitan group. Africa Trypanosomiasis and its vector control can be achieved through the manipulation of fly endosymbionts. This approach has proven successful in reducing of triatomine bugs that transmit *T.cruzi* parasite and in the control of *Leishmania* and in malaria control (Wamwiri *et al.,* 2013).

Lack of precise and current data on the geographical and temporal distribution of target insects has impeded efforts to manage the trypanosomiasis illness. Tsetse ecology and pertinent fly distribution information are essential to developing management and, eventually, elimination, strategies for the trypanosomosis issue. However, it has been ten years since the most recent continental-scale tsetse distribution maps were created (Chikowore *et al.,* 2017)

Tsetse fly are non host specific disease vectors, they show wide range of feeding with ability to feed on other species of animal in absence of their preferred host (Munang'andu *et al*., 2012).Mubanga *et al.*, (2011). Trypanosome parasites also demonstrate the ability to infect several hosts, making them a genuine reservoir of infection for both humans and domestic animals, according to Malelel (2012). The relative quantity of wild hosts, the host's daily and seasonal movements, its feeding patterns, and its nocturnal and waking habits all have an impact on the host species that the tsetse fly chooses as its source of blood meal (Munang'andu *et al*., 2012). Munang'andu *et al*., (2012) further indicated that since tsetse flies are diurnals feeders, most grassers and browsers animals are bitten by the fly when the animals are grazing in tsetse habitats.

2.4: Factors influencing tsetse distribution

Tsetse flies' broad range is influenced by a number of variables, such as the temperature, altitude, vegetation, and the existence of appropriate mammalian hosts (Mammo et al., 2013; Nthiwa et al., 2015).

The temperature, soil moisture, vegetation, and fauna are examples of environmental elements that have an impact on tsetse dispersion (Grady et al., 2011). (Ngonyoka et al 2017). These elements have a direct impact on the vector's birth, death, or migration rates, which in turn have an impact on population size (Munyua, 2006). In 1973, ttsetse flies were estimated to inhabit 22% of the Kenya land cover and by 1996 the amount of land estimated to be tsetse infested had risen to approximately 34% of the total land mass (Devisser and Messina 2009; McCord *et al*., 2012).

The tsetse fly's geographic distribution differs all over Sub-Saharan Africa and is narrowly related to changes in land use and cover through time (DeVisser; Messina, 2009). Tsetse flies require woody vegetation, hereafter referred to as land covers with flora more than 3 cm in diameter and 1 to 4 meters in height (Devisser and Messina 2009). The ecosystem's distribution and quantity of wildlife reservoirs and tsetse flies are both influenced by the kind of habitat (Ngongolo et al., 2020) The existence of biologically appropriate habitat, such as climate and land cover types, is essential for tsetse dispersal (McCord *et al*., 2012**)** Tsetse prefer riparian and woody savannah ecosystems as their preferred habitats, although other acceptable land cover types such as semi-arid grass savannah, wet mangrove, and tropical rain forest are also suitable. to lessen the impact of hot weather and/or dry circumstances **(**McCord *et al*., 2012**).**

Temperature influence reproductive behavior and the feeding habits of the fly (Albert *et al.,* 2015). Since *Glossina* species has diurnal feeding behavior, its movement pattern in search of the suitable host is determined by the Land Surface Temperature (LST) (Dicko *et al.,* 2014). High feeding among most *Glossina* species occurs in the morning when the temperatures are moderately low and feeding decreases when the temperature rises and feeding resumes in the evening. Tsetse flies thrive in areas with average temperatures of 20 to 30°C (Albert *et al.*, 2015) and its survival decreases in areas with temperatures below 19°C or above 31ºC. Tsetse survival rate in high altitude areas is low whereas in areas with low altitude (Muna ng'andu *et al*., 2012) favours its survival. Hatching process in low altitude occurs within a short period of time due to the impact of altitude on the temperature. Munang'andu *et al*., (2012) reported that flies in the low lands have high infective capacity as compared to those in the highland and this explains the reasons why TT persists in the Coastal belts, especially in Kenyan Coastal belt.

Rainfall indirectly affect the rate of infection by altering the seasonal abundance of the host in its niche. During the dry season, riverine vegetation not only serves as the resting place of the riverine species of tsetse fly but also acts as the main source of green leaves and grass for browsing and grazing for the herbivorous animals. This provides direct interaction between animals-tsetse-animals allowing for the transmission of the parasites (Munang'andu *et al*., 2012). Munang'andu *et al*., (2012) .added that during the rainy season bovids and suids are evenly distributed due to abundant availability of pastures and water reserves.

The current tsetse distribution belts reflect outdated data and methodologies (Langley and Messina, 2011) and this inaccuracy are as result of limited tsetse distribution particularly in terms of global climate change. These changes have shifted tsetse habitats, though the degree to which this is occurring is unknown (Langley and Messina, 2011).

On the contrary human activity such as crop cultivation and settlement influences the distribution and abundance of tsetse fly in the area. For instance, in Maasai steppe ecosystem of Tanzania, tsetse flies are abundant (Ngonyoka *et al.*, 2017). Through the removal of vegetation during farm preparation, crop cultivation modifies ecological habitat components. The quantity and spread of tsetse flies, which operate as the trypanosome parasites' vector, are severely impacted by the change of ecosystems for farming. This effect on the changed ecosystems might either be favorable or detrimental (Ngongolo et al., 2020). Therefore, it is crucial for trypanosomosis control to comprehend the direction of affects on trypanosome infection.

2.4.1: Spatial distribution of tsetse flies in Kenya

Tsetse flies are found in 37 Africa countries. In Kenya, eight species of *Glossina* genus; *G. longipenis, G. pallidipes, G.brevipalpis, G. austeni, G. swynnertoni, G. fuscipes fuscipes G. fuscipleuris, and G. morsitans submorsitans* (KENTTEC, 2019) are found and are distributed in what is known as tsetse fly belts (Cheruiyot, 2013). According to Messina *et al.,* (2012) tsetse fly belts regions in Kenya are the North and South belts near Mt. Kenya, the South Rift, Lake Victoria basin, Central Kenya, Trans Mara-Narok, and the Coastal belts (Devisser and Messina, 2009; Messina *et al*., 2012; Cheruiyot, 2013). Devisser and Messina, (2009) reported that studies carried out in selected regions of Kenya, showed that the Coastal region had the highest trypanosomes infection rate of 15.6 % among the cattle followed by Rift Valley with 12.9%, and finally, Western Kenya, with 8.3%.

In Kenya, approximately 138,000 km^2 of land is tsetse infested with 38 counties out of 47 counties being tsetse infested (Figure 2.1). Tsetse infested land coverage is roughly 25 percent of Kenya's land. Sixty percent (60%) of this land is productive rangeland. Total of 11 million people are at risk of HAT infection (KENTTEC, 2019).

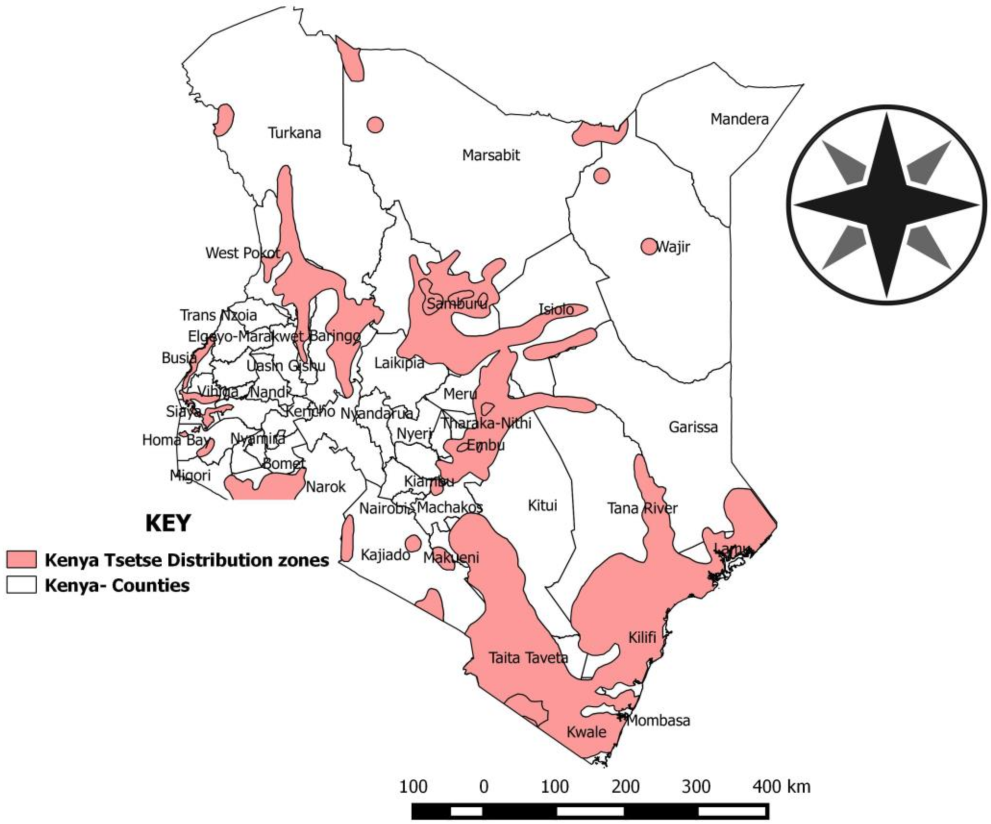

Figure 2.1: Tsetse distribution zones in Kenya (Caren Kikwai; using shape-files)

2.5 Tsetse control

Due to broad and growing trypanosome drug resistance, toxicity, relatively high cost, and the use of substandard medications in some places, chemotherapy's ability to control AAT has not been sustained (Olaide et al., 2019). Olaide et al. (2019) went on to show that the presence of wildlife trypanosome reservoirs, which actively sustain the transmission sequence that includes livestock raising in regions near parks and in protected areas, has put chemotherapy treatments in danger (Omonona et al., 2021). Additionally, because to the complicated process of antigenic variation of the African trypanosome infection (Lehane et al., 2016), there are no vaccines against it. To guarantee their survival and completion of their life cycles inside their hosts, the parasites employ a number of immune evasion techniques (Onyilagha, Uzonna, 2019). Last but not least, the adoption of trypanotolerant cattle may not be successful due to their limited geographic range and potential loss of trypanotolerance at high tsetse numbers. According to La Greca and Magez (2011), the ability to manage parasitemia, which is independent of the hematopoietic system, and the ability to restrict anemia, which is mediated by hemopoietic cells, are the two distinct processes that lead to trypanotolerance in cattle.

Due to these difficulties, tsetse control initiatives (Lehane et al., 2016) form the basis of disease eradication and suppression plans.

For the treatment of diseases, there are many vector control techniques. The following sub sections provide descriptions of them.

2.5.1 Artificial baits (insecticide-treated traps/targets)

Tsetse have a high metabolic rate and only feed on vertebrate hosts, therefore finding and coming across suitable victims is essential to their survival. Technologies for artificial visual-olfactory bait have shown a lot of promise in tsetse fly control operations (Wachira et al., 2021). It is preferable to use tactics that take advantage of tsetse flies' chemical and visual preferences (Byamung et al., 2018). This management method can prevent tsetse re-invasion from surrounding regions, has a low environmental impact, a high degree of community acceptance, and is reasonably specific. It is the most affordable and offers the best chances of controlling disease vectors (McCord et al., 2012; Lehane et al., 2016). Additionally, the methods are eco-friendly and may be applied together in and around restricted areas (Byamungu *et al*., 2018; Wachira *et al.*, 2021).

Adult tsetse flies locate hosts using a combination of olfactory and sight cues, with the latter being more important for landing. Blue and black-colored traps and targets along with host attractants have managed to decrease the tsetse population by over 90% by influencing this host-seeking behavior (Olade et al., 2019). Tsetse flies are drawn to the blue traps and targets, the black panel causes landing reactions, and the odor signals draw them farther away from the trap or target (Santer *et al.*, 2019)

The effectiveness of insecticide-impregnated targets has been demonstrated in the successful eradication of tsetse from topographically isolated pockets, such as the Lambwe Valley in Kenya. Insecticide-impregnated targets work by removing persons from the emerging tsetse population (Cheruiyot 2013). (Byamungu et al., 2018). The targets' efficacy relies on how long the device is in use and the likelihood that a fly will come into contact with it and be killed by it. The device's resilience to environmental deterioration is one of the criteria that determine how long it will function (Lehane *et al*., 2016), For instance, wind and damage from large animals, theft (Byamung et al., 2018), degradation such as color fade, depletion of odor baits, and loss of insecticidal activity (Kuzoe, Schofield, 2005: Cheruiyot, 2023) are just a few examples. As a result, it is important to check on them frequently to make sure they are being properly maintained (McCord et al., 2012).

This idea has been used in the creation of traps and targets that closely resemble the characteristics of host animals in order to draw tsetse in order to kill or catch them (Byamungu *et al*., 2017).

Visual devices made of fabrics, impregnated with insecticide (targets) have the potential of controlling tsetse (Kuzoe; Schofield, 2004) and preventing disease transmission. Kenya Trypanosomiasis Research Institute (KETRI) scientists demonstrated that insecticide impregnated targets baited with octenol and acetone odours reduced *Glossina pallidipes* tsetse population by 99.9% in Lambwe Valley, Lake Victoria basin in the first year of deployment (Cheruiyot, 2013). Tsetse flies' capacity to identify and find suitable hosts from which to feed is crucial for their survival and procreation, according to Musonye et al. (2019). They accomplish this via both long-range and short-range olfactory perception. The tsetse vector has been demonstrated to improve host location by detecting odors from a variety of sources, including but not limited to urine, feces, skin surfaces, manure, and cow breath (Musonye et al., 2019; Wachira et al., 2021).

According to Wachira et al. (2020), phenolic chemicals found in the urine of cow and buffalo are pungent and extremely alluring to tsetse fly larvae. The two phenols that appeal to Glossina spp. the most are 4-cresol and 3-n-propylphenol out of the many that are found in the urine of animals like cattle and buffaloes. Therefore, phenolic chemicals in urine are responsible for tsetse species' attraction to cattle and animals.

The likelihood that a fly will come into contact with the device and either be killed or captured depends on the number of targets in relation to the local tsetse population's abundance as well as the target species' unique foraging and dispersal habits. For example, G. morsitans flies can travel up to 500 meters in a single day (Cheruiyot, 2013).

2.5.2 Trypanocide and epicutaneous mass treatment

The trypanocide treatment consists of curative treatment with deep intramuscular injection (diminazene aceturate) shadowed by a defensive handling administered for three weeks' period after treatment with isometamidium (Percoma *et al*., 2018)

Mass epicutaneous treatment involves the use of discharge on and animal spraying and trypanocide treatment of sheep, donkeys and cattle to control trypanosomes transmission (Percoma *et al.*,2018). Epicutaneous treatments constitute live baits for tsetse control. Insecticides-treated domestic animals, principally, cattle are used as attractive, mobile, living targets. Synthetic pyrethroids such as deltamethrin are commonly used. They have high toxicity against tsetse even with very small contact, good levels of persistence on the treated animal and low mammalian toxicity makes them safe to apply to the target animal: likewise, the meat and milk from treated animals can be used for human consumption, even immediately after treatment (Cheruiyot, 2013). The synthetic pyrethroids are supplied in formulations so that they can be applied through dipping, spray-races, hand spraying or as pour-on.

2.5.3 Tsetse repellents

A promising management strategy is to use natural insect repellents from non-preferred hosts of tsetse flies in interventions (Olade et al., 2019). It is possible to alter a vector's behavior to keep it out of areas where prospective livestock or human hosts may be present (Wilson et al., 2020). By minimizing the frequency of host-vector interactions, this change eliminates or lowers the danger of pathogen transmission cycles.

Saini et al. (2017) went on to explain that disease vectors like Glossina species exhibit host-oriented behavior that is not only dependent on kariomones from preferred vertebrate hosts but also increasingly suggests that these vectors avoid unsuitable or un-preferred animals by emitting distinctive chemical odors. Therefore, the identification of "non-host" compounds or repellents as well as "host" attractants is required for the differential attraction of biting insects throughout the host localization process, particularly during the differentiation between various hosts and even individuals within a host species.

For effective control of *Glossina* species from a non-host animal, the waterbuck, *Kobus ellipsiprymnus defassa*, has recently been evaluated. Waterbuck is common in tsetse habitat (Saini *et al.,* 2017). Saini *et al*., (2017) further stated that waterbuck repellent compounds comprise of geranylacetone, pentanoic acid, guaiacol and δ-octalactone (patent application). Innovative collar-mounted chemical release system for individual cattle has been tested (Olaide *et al*., 2019). It has been demonstrated that the collars employed offer livestock significant defense against trypanosome infections (Olaide *et al*., 2019) by reducing disease levels by above 80% in protected herd (Saini *et al.,* 2017). Farmers may graze their cattle wherever, including in tsetse-infested areas and in the early morning and late evening when tsetse flies are most active, and it has also led to a considerable reduction in medication use (Cheruiyot ,2013,).

2.6: Biocontrol of Tsetse Flies

The principal obligatory symbionts of tsetse flies, Wigglesworthia glossinidia, Wolbachia pipientis, and Sodalis glossinidius, are among the symbiotic bacteria they inhabit. (Hamidou Soumana *et al.,* 2014; Wamwiri *et al*., 2013) Further research by Hamidou Soumana *et al*. (2014) revealed that Wigglesworthia and Sodalis bacteria coexist with trypanosomes in the midgut where they influence the establishment and progression of trypanosome parasite infection while Wolbachia species causes reproductive effects in the infected flies (Wamwiri *et al*., 2013). According to studies, all Glossina species depend on the fertility and immunity provided by the obligatory main symbiont Wiggleworthia glossinidia (Hamidou Soumana *et al*., 2014).

The three bacterial endosymbionts, which are phylogenetically unique, are passed maternally to offspring (Dale and Welburn, 2000, Wamwiri, 2013). By affecting the effectiveness of the tsetse immune system, Sodalis glossinidius has been found to contribute to the potentiation of sensitivity to trypanosome infection in tsetse (Dale and Welburn, 2000).

2.7: Factors Affecting Trypanosome Maturation in Tsetse Flies

In the tsetse fly, trypanosomes of various species go through developmental cycles of variable complexity, changing from bloodstream forms to procyclic non-mammalian infective forms in the fly midgut. The end of their life cycle Trypanosoma brucei brucei and T. b. rhodesiense and T. b. gambiense, the agents that cause human African trypanosomiasis, must move from the fly's midgut and change into infectious metacyclic forms in the salivary glands. According to Macleod *et al*. (2017), a fraction of midgut infections develop into infections of the salivary glands. This process is sex-limited, with male tsetse developing much more midgut infections than females.

Reports have shown that trypanosome genotype impacts infection maturation process with trypanosomes resistant to human serum *T. b. rhodesiense* being less likely to produce mature infections than human serum sensitive *T. b. brucei* parasites (Macleod *et al*., 2017).

Studies have demonstrated that interactions with tsetse lectins play a significant role in the development of infections (Macleod *et al*., 2017). It is understood that in tsetse, trypanosomes can only colonize the fly midgut if the parasites are able to resist the effects of nacetyl-D-glucosamine (GlcNAc). When the tsetse fly eats, a particular trypanocidal lectin called GlcNAc is produced. By producing lectin-inhibitory sugar (GlcNAc), which is known to build up during tsetse pupal growth as a result of this bacterium's chitinolytic activity, sodalis is hypothesized to affect lectin activity. A significant quantity of GlcNAc is released during the first bloodmeal, which inhibits lectins and increases trypanosome infection in tsetse (Macleod *et al*., (2017).

Therefore, understanding the influence of endo symbionts bacteria on the nature of interactions between tsetse and trypanosomes is vital in the control process as it provides a foundation of engineering tsetse fly that cannot transmit trypanosome parasites. This approach has proven successful in reducing of triatomine bugs that transmit *T.cruzi* parasite and in the control of *Leishmania* and malaria (Wamwiri *et al.,* 2013).

2.8: Socio-economic impacts of Trypanosomiasis

African trypanosomiasis typically affects economically active people and occurs in distant rural regions where health systems are poor or nonexistent (Bukachi *et al*., 2017). According to Welburn *et a.,* (2016), trypanosomiasis, and particularly HAT, is only found in a small number of places that are distant, neglected, and frequently among political unrest or armed conflict (Tong *et al*., 2011). It mostly affects the world's poorest people and tends to occur when there are few medical professionals and pharmaceuticals, plenty of hunger and little food security, low salaries, little access to health information, and a large deal of unmet human need (Bukachi *et al*., 2017).

According to FAO estimates, the effects of tsetse and trypanosomiasis cost Africa up to US$1.5 billion yearly (Bukachi *et al*., 2017). Additionally, Bukachi *et al.,* (2017) research showed that African trypanosomiasis reduces labor resources, prevents the growth of the livestock industry because high-yielding animals are less likely to recover from the disease, affects the availability of meat and milk, and denies farmers access to draught power.

The illness typically strikes economically active persons in distant rural regions with inadequate or nonexistent health institutions (Bukachi *et al*., 2017). The consequent strain on the extended family is significant, since sick persons become unproductive in addition to spending time being treated and cared for by close family members. The family's finances may be severely strained by the time and money spent on obtaining care. If the illness is not treated, the patient will eventually die, but the disease's insidious and crippling character will also have terrible effects on homes, communities, and quality of life. For young, emerging countries like Kenya, which are mostly dependent on agriculture, the illness has expensive economic implications. (Bukachi *et al*., 2017).

AAT decreases food security in the impoverished rural areas where it occurs by restricting the best use of rich soils and reducing the exploitation of animal draught power (Cecchi, *et al*., 2014). The disease also hinders the expansion of the livestock business since high-yielding animals are less likely to survive it, which reduces the supply of meat and milk and robs farmers of draught power (Bukachi *et al*., 2017).

One of the most significant economic barriers in Kenya Coast today is trypanosomiasis in cattle, which poses a serious risk to food security. By prohibiting access to grazing pastures, rich land, and by limiting the use of draught power, it lowers the quantity of crops that can be produced. It denies cattle large areas for gracing especially the Tana delta and forest galleries of Pate Island (Cheruiyot, 2013). Animals are also restricted to grazing for specific hours between midmorning and mid-afternoon that coincide with the time when tsetse fly activity is low due to high temperatures. This affects the quality of body condition of the animal and this would determine the market price which is usually low compared to animals from tsetse free areas. Coastal region has a human population of 2.3 million, about 1 million cattle, 2 million sheep and goats, over 50,000 camels and over 30,000 donkeys all being at risk of trypanosomiasis (Cheruiyot 2013).

AT has a negative effect on how households operate. These negative effects include rising poverty, a decline in agricultural production that frequently results in famine or a lack of basic food security, disruptions to children's education, and a general reversal of role expectations that, more often than not, increases the burdens on women and children (Bukachi *et al.,* 2017).

More recent research from Botswana, South Africa, and Zimbabwe revealed that compared to milk, market sales, and dung, draught cattle produced the largest share of livestock-derived revenue, up to 75% (Okello *et al.,* 2015). Farmers in eastern Africa who used animal traction had larger yields and were more economically efficient than those who used hand-held hoes (Guthiga *et al*., 2007; Okello *et al*., 2015). Okello *et al*., (2015) further shown that in Ethiopia, greater cultivated land per home was directly correlated with better health and more work oxen.

HAT screening and treatment are challenging and resource-intensive processes that are made more challenging in unsafe environments with limited resources (Tong *et al*., 2011).

2.9: Successes on tsetse control in Africa

Tsetse flies (Diptera: Glossinidae) have been successfully eliminated from a large part of their original distribution areas in Senegal, Zimbabwe and Botswana (Bouyer *et al*., 2019; Lundeberg**,** 2019).

In Zimbabwe, tsetse was cleared over the past 65 years (Bossche *et al*., 2001) and odour - baited, insecticide treated target were created as a barrier to prevent reinvasion of cleared areas. An area of approximately 180,000 km^2 of the total 390,757 km^2 was deemed to be ecologically suitable for tsetse before the rinderpest epizootic of 1896 (Shereni *et al*., 2016). Since 1900 the most prominent methods used to combat tsetse flies, have ranged from game destruction, bush clearing, aerial and ground spraying, baited and insecticide treated targets to insecticide treated cattle. Most of this region was cleaned of tsetse flies as a consequence of persistent interventions; since 1980, almost 50,000 km2 have been removed (Chikowore *et al*., 2017).

Populations of *Glossina morsitans centralis* have been eliminated in the Okavango Delta of Botswana using the aerial spraying (Kgori *et al.*, 2006) and Sequential Aerosol Technique (SAT) (Kgori *et al*., 2009). In 2001 and 2002, Sequential Aerosol Technique (SAT) control approach was re-introduced (Kgori *et al*., 2009) using comparatively modern approach involving integration of Geographic Information System (GIS) tools to improve navigation to tsetse ecological sites. The operation was extremely successful, clearing tsetse fly from the area over a period of two years.

Tsetse fly populations in isolated parts of Senegal, like the Niayes, have also been exterminated. Under the auspices of the Pan African Tsetse and Trypanosomosis Eradication Campaign (PATTEC), the government of Senegal launched a campaign in 2005 to eradicate a Glossina palpalis gambiensis population from the 1,000 km2 Niayes region (Ciss *et al*., 2019). Sterile insect technique (SIT) was included into an area-wide integrated pest control (AW-IPM) approach. Other methods were used as well, including the use of insecticide-impregnated traps/targets and "pour-on" for cattle that included a combination of pesticides and insect repellents, which was followed by the release of sterile males to eradicate the last few relic fly pockets (Ciss *et al*., (2019).

Tsetse control or elimination strategies rely on the understanding of tsetse ecology and suitable fly distribution data (Dicko *et al.*, 2014) especially in the implementation of an AW-IPM control strategy. Recent advances in geospatial technology have enabled the development of models in the study of diseases and their vectors (Dicko *et al.*, 2014). The design and execution of treatments against human and animal African Trypanosomiasis have a lot of promise when using georeferenced datasets and spatial analytic tools. Geographic Information Systems (GIS)-based distribution mapping can assist in pinpointing micro-level hotspots where ecologically friendly, species-specific management actions can be reinforced (Chikowore *et al*., 2017).

Currently, the control options for the control of tsetse and trypanosomiasis are based on three principal strategies; use of trypanocidal drugs (Tekle *et al*., 2018; Wangwe *et al.*,

2019) against the trypanosome parasite which is the primary control technique, tsetse fly control or eradication (Meyer *et al.*, 2016) and rearing of trypanotolerant cattle (Maichomo *et al*., 2009; Traoré *et al.*, 2017).

The current study therefore, will bridge the gap by providing information on the status of tsetse distribution and abundance and the prevalence of trypanosomiasis during wet and dry seasons in the two Coastal counties. The study will also unveil the socio-economic impacts of the disease to the coastal communities. The finding of the study will be useful for policy making on enhancement of various vector control approaches employed in the affected counties and other tsetse infested counties in the country. Success in the control of disease vector will result in the improvement of communities' socio-economic status since most people depend on livestock keeping and crop farming as their source of income, for ploughing and education among other needs. Along with SDG 1, which aims to end extreme poverty in all of its forms for all people worldwide, livestock raising considerably enhances household income and helps to reduce poverty. Thus assessing the disease prevalence and risk factors for trypanosomiasis will inform priority basis to its control and therefore alleviate poverty amongst affected populations.

CHAPTER THREE

MATERIALS AND METHODS

3.1 The Study Area

This study was conducted in Kilifi and kwale of the Kenyan Coastal Region.

3.1.1: Kilifi County

Kilifi County lies between latitude $2^0$20” and $4^0$0” south, and between longitude $39^0$05” and $40^0$14” East.It borders Kwale County to the South west, Taita – Taveta County to the West (mainly Tsavo East), Tana River County to the North, Mombasa County to the South and the Indian Ocean to the East. (Mwangi *et al*., 2019). The County covers an approximate area of 12,539.7Km^2 and has a population of 1,217,892 in 2012 as projected from the Kenya Population and Housing Census 2009. The county is made up of seven sub counties; Kilifi North, Kilifi South, Malindi, Magarini, Rabai, Kaloleni and Ganze.

The average annual rainfall in the area ranges from 1,300mm in the Coastal belt to 300mm in the hinterland (Wekesa *et al*., 2017). The mean annual temperature ranges between 21-30^0C in the Coastal belt and 30-34^0C in the hinterland (Wekesa *et al.*, 2017). The area receives long and short rains over the year. Long periods of rain start around March and last into July, while the short rainy period starts around October and lasts until December. Over the last 5 years’ rainfall patterns have not been consistent due to the effect of global climate change.

Numerous towns in the county rely on livestock raising as a significant source of income. The County Integrated Development Plan (CIDP) 2018–2022 states that main types of livestock managed by subsistence farmers in the county include cattle, sheep, goats, and poultry. Each household of small-scale farmers has at least 10 cattle. The most popular livestock varieties retained by smallholder farmers are indigenous breeds, primarily Zebu and Boran. Commercial dairy farmers in the county raise exotic varieties of cattle, such as Kilifi Plantation, which is 3 kilometers from the coast and has more than 600 purebred and hybrid cattle.Cattles breeds re-served includes: Freshian, Ayshire, Brown Swiss, Fleckvier, Sahiwal, Jersey, and several crosses between these and the Boran .The two most common breeds of goat kept are the Galla and the Small East African Goat. On the other hand, Blackhead Persian and indigenous sheep breeds are the most prevalent in the county. Poultry, both domestic and foreign, is raised primarily for its meat and eggs. The most common breeds of rabbits in the county are the Califonia White and Chinchila.

Physical features in kilifi county includes ;Goshi River, Kilifi River,Chonyi Hill, The Kilifi coastal plains ,Kazuri plains,Bonje Valley,Nyika Plateau. Types of natural vegetation includes; Forest vegetation.e.g Arabuko Sokoke Forest, Kaya forest.

3.1.2: Kwale County

Kwale County is located in the Southern tip of Kenya and lies between Latitudes 30.05º to 40.75º South and Longitudes 38.52º to 39.51º east. The county has approximated population of 866,820 and land area of 8,267.1Km^2 according to Kenya Population and Housing Census (2019). It has four sub counties namely; Matuga, Msambweni, Kinango and Lunga Lunga.

The County experiences high temperatures of 25 °C in March during the inter monsoon season and lowest temperatures of 21 °C in July, one month after the commencement of the southwest monsoon. The average temperature is around 23 °C. The seasons for rainfall are bi-modal, with the short rains occurring from October to December and the long rains occurring from March/April to July. A large portion of the County's central to western region experiences 500–750 mm of precipitation on average per year, whereas eastern (coastal) areas of the County receive more than 1000 mm. Less than 500 mm of precipitation fall in several locations along the western part of the County each year. As a result, agricultural risks in the County, particularly in the central and western regions, are greatly increased by heat stress, dry periods, and drought. However, flooding brought on by heavy rainfall has also happened in the past, and as a result, it poses a concern to the County, particularly in its central and eastern regions (which include the shore).

The primary economic activity in the drier regions of the county, where rainfall averages less than 700mm, is livestock raising. About two thirds of the county is comprised of this region. According to CIDP 2018-2020, Kwale County is home to an estimated 190,988 zebu cattle, 5,475 dairy crossbreeds, 3,371,126 goats, 54,578 sheep, and 725,000 chickens. The two livelihood zones in the county are home to the majority of the area's livestock species. Around 25% of the county's income comes from keeping livestock, which is raised for both food and profit.

The investigation in Kilifi County was conducted in and around the Arabuko Sokoke Forest and along the River Sabaki, which are thought to be tsetse-infested locations. The investigation was conducted in Kwale in the vicinity of Buda Forest and Shimba Hills.

The coastline in Kwale County stretches for roughly 250 kilometres, which consists of corals, sands and alluvial deposits.

The Coastal Plain, the Foot Plateau, the Coastal Uplands, and the Nyika Plateau are the four principal topographical features of Kwale County.

Behind the Coastal Plain lies the Foot Plateau at an altitude of 60-135 meters above sea level.

From the Foot Plateau, the Coastal Uplands (also known as "Shimba Hills"), ascends steeply, reaching an altitude of 135-462 meters above the sea level. This geographical area consist of numerous sandstone hills, which include the Shimba Hills (420m), Tsimba (350m), Mrima (323m) and Dzombo (462m).

On the western boundary of the county, the Nyika Plateau (commonly referred to as the "hinterland") gently climbs from roughly 180 meters and covers more than half of the county. A basement rocks system lies beneath the plateau, which also contains random reddish sand soils patches. Since the soil in these regions are semi-arid and low-fertile, livestock rearing became the main activity at the hinterland.

Seven major rivers and numerous minor streams form the county's drainage system. The main rivers and streams are Ramisi, Marere, Pemba, Mkurumuji, Umba, Mwachema and the Mwachi River. Out of these seven rivers, three are permanent (Marere, Mwaluganje, and the Ramisi River). All these rivers flow into the Indian Ocean.

3.2: Research design

The study adopted a cross sectional study design in order to capture data on the epidemiology of trypanosomiasis infection and its socio-economic impacts in the two counties. During the entomological surveys, tsetse traps were set in all areas which had suitable conditions for tsetse habitation; for example, along the water streams, in the forests and in open savannah areas. The traps were set twice, during dry and rainy season on arch and July respectively (2019). The traps remained in the field for forty-eight hours before fly harvesting was undertaken.

Epidemiological survey included collection of blood and analysis for trypanosome infection from the sampled bovine population in both study counties. Blood was collected from the animals early in the morning as from 06.00 to 09.00 hours.

Socio-economic information was obtained by administering structured questionnaire to 138 randomly recruited consenting farmers in the study area.

3.3 Target population

The two counties of kilifi and kwale were selected because of the trypanosomiasis favorable conditions such as, availability of adequate tsetse habitats and the presence of the reservoir hosts in Arabuko Sokoke Forest (ASF), Sabaki River in Kilifi County and Shimba Hills Forest in Kwale County.The questionnaire was administered to 138 consenting randomly selected dairy farmers in both study counties,

3.4: Sampling method and sample size determination

Bovine herds chosen to graze on the same piece of land were treated as strata throughout the sampling process. During the study four strata were identified for study. Representative sample of animals was taken from each stratum. Simple random sampling technique was used during the process.

Parameters such as sex, age, breed sampling period and area were recorded for each individual animal during blood specimen collection. Age information was obtained from the farmers and categorized into three (calf < 1 year, grower 1 to 2 years and adult > 2 years) age groups also aging by teeth inspection is used.

3.4.1: Sample size determination

Sample size for enrolled households was estimated at an expected proportion (p) of livestock keeping households in semi-arid areas. To achieve this, a formula described by Pfeiffer (2009) was adopted

$n = Z2\ [p(1-p)/\ L2]$

Where:

n = sample size

Z = Z-value reflecting desired level of confidence

L = desired precision

p = expected proportion

n=1.962[0.1 (1-0.1)/0.052]

=1.962X36 = 138

Thus, 138 households were selected for study and representative numbers of livestock owned by the households were included in the study and tested for trypanosomiasis. In households with less than 5 bovines, all the bovines were included and in those with more than 5 bovines, only 5 were selected randomly for the study. A total of 593 bovines were selected for the study from the 138 households in both Kilifi and Kwale Counties.

3.5 Research instruments of data collection

Blood analysis equipment, tsetse traps, questionnaire/oral interview and observations were used as the main tools for data collection. The selection of the research tools was guided by the nature of the data required as well as the objectives of the study. Quantitative and qualitative data was collected from 138 livestock farmers 98 and 40 in Kilifi and Kwale respectively and 593 bovines 287 and 306 Kilifi and Kwale Counties respectively.

3.5.1 Questionnaire

Data on the effects of trypanosomes and the use of trypanocidal medications in the research regions were gathered using a questionnaires. The key elements of the questionnaire on which the interview was centered were the trypanocidal drug kinds utilized, the drug suppliers, the frequency of therapy, and the people engaged in the treatment of trypanosomiasis cases. 138 household heads who gave their assent were chosen at random and questioned using a standardized questionnaire. The respondents' homes were chosen at random from the research areas' household population.

3.6: Parasitological Study

To ascertain the prevalence of bovine trypanosomosis in the two Counties, a parasitological cross-sectional survey was carried out in the months of March and July 2019, during the dry and rainy seasons, respectively. Whole blood sas collected espevially from jugular vein of the selected bovines and analysed from packed cell volume (PCV), Whose results were compared. Native Zebu, Boran, crossbreed, and exotic breed populations from the two research counties of Kilifi and Kwale were among the animals selected. Selected populations of study are typically raised in zero-grazing units. Under the research regions, the livestock husbandry system relies on natural grazing, agricultural wastes, and cattle managed in a traditional community management system, with some being zero grazed. Animals get their water from seasonal rivers during the wet season, but during the dry season, they get it from distant perennial rivers that run through their region and some of them get it from boreholes.

3.7: Ethical Considerations

The study was conducted with the approval of the institutional Research Ethics Committee (REC) University of Eastern Africa, Baraton (**REC: UEAB/2/2/2018**) Consent was obtained from the farmers who were interviewed and those who allowed their animals to be used in the study.Respondets were free to withdraw from the study without any conditions. The farmers who declined to consent were not included in the study and their livestock were not sampled.

3.8: Epidemiological Data

Blood was taken into heparinized haematocrit capillary tubes and transported to the lap in a cooler box. The haematocrit capillary tubes were then filled to 3/4 of their height and Cristasealed. The capillary tubes were first centrifuged at 12000 rpm for 5 min and the PCV reading taken. The capillary was then cut 1 mm below the buffy coat to include the top layer of red blood cells before its contents were put onto a clean glass slide,covered with a 22 mm cover slip for microscopic examination as described by Paris *et al*., (1982).

3.8.1. Parasites identification

On the basis of how the trypanosomes moved in the microscopic field, the prepared slide was checked for trypanosomes. Giemsa staining and oil immersion microscopy inspection employing keys, as described by Paris et al., were followed by the confirmation of trypanosome species by morphological criteria (1982).

3.8.2 Determination of the disease prevalence

Prevalence rate is the proportion of animals in a population with a particular disease or attributed at a specified point in time or over a specified period of time.

Prevalence is therefore the total number of cases of a disease existing in a population divided by the total sampled population at one point in time Benita *et al.*, 2006.

Prevalence was determined for the two counties during the dry and wet seasons respectively.

$$\text{Prevalence \%} = \frac{\text{Number of animals with the disease}}{\text{Number of animals sampled}} \times 100$$

3.9 Entomological Data

3.9.1: Fly Collections

Systematic sampling was used for tsetse survey. Tsetse fly trapping was done as described by FAO (1992). Briefly NGU trap(trap by nguruma) was used as the standard sampling tool. A total of 112 traps were deployed; 28 traps deployed in every county during each trapping season. All traps were baited with a sachet of phenol and acetone, dispensed at 500mg/h (acetone release rate) using glass bottles with an aperture of 2mm at the top. The trap posts were greased to prevent ants and other crawling insects from accessing and damaging the tsetse catches. All trap positions were geo-referenced using GPS. Catch collections were harvested after every 48 hours.

Flies from each trap were counted and categorized according to species, sexed and sorted as either tenerals or non-tenerals. A teneral insect is one that has recently moulted and its exoskeleton is yet to harden and get its final colouration.

3.9.2: Fly Identification

3.9.2.1: Morphological Distinction of Tsetse from other Flies

Three immediately obvious characteristics separate tsetse flies apart from other big flies and biting insects. The first is that Tsetse entirely fold their wings while they are at rest, allowing one wing to lay on top of the other. Another unique characteristic of the wings is that some of the veins take the appearance of cells that resemble hatchet or machete blades. These cells may also be used to gauge a tsetse fly's size. Thirdly tsetse have a lengthy proboscis that projects directly forward and is connected to the bottom of their head by a characteristic bulb (FAO, 1992). Trypanosomes of various species of cattle trypanosomes, including the main diseases Trypanosoma congolense and T. vivax, develop in the proboscis (Gibson *et al*., 2017).

Using a taxonomic key and their outward traits that are apparent to the human eye, different species and sexes of Glossina were identified.

3.9.2.2: Using Taxonomic Key to Identify Tsetse Species

The following taxonomical key was used in the identification of the trapped tsetse flies as described by FAO (1992) description. The features that were used included:

1. Apex of thecal bulb darker than the base, when seen from beneath...go to 2

2. a. Dark colour on hind tarsi limited to last two segments...***G. pallidipes***

2 b. Dark colour on hind tarsi not limited to the last two tarsal segments...***G. austeni***

3 a. Dorsal side of thorax marked with four dark spots arranged in a rectangle and two more central spots. ....go to 10

3 b. Dorsal surface brown (not reddish brown), with or without well-marked banding on abdomen..go to 4

4.a.Dorsal surface reddish brown, not strongly banded on abdomen..go to 6

5. General colour darker brown..go to 2.b

6.On front leg, all tarsal segments pale. Antennal fringe visible with x10 hand lens...go to 9

7. Pale pink-or yellow-brown insect..go to

8. Small flies (7.5–8.5 mm). ....go to 2

9. Thecal bulb uniformly pale brown, when seen from beneath..go to 11

10. Third antennal segment more than 4 times as long as wide, and with a well-developed curved projection at the end..go to 13

11. Thorax not having four distinct dark spots arranged in a rectangle..go to 12

12. Wing having a dark spot at the anterior cross vein......................... ....***G. brevipalpis***

13. Wing without a dark spot at the anterior cross vein**..** ***G. longipennis***

3.9.2.3: Using Genitalia to Separate Tsetse Sexes

Male and female tsetse fly can be distinguished by observation of useful features. Male fly has a highly folded structure at the posterior tip of the abdomen known as hypopygium while female fly has no equivalent obvious structure but simply a small hole surrounded by variable number of small flat chitinous plates. In addition to hypopygium, male have hairy plates called hectors. These structures are used by males to hold onto the female's abdomen during mating (FAO, 1992)

3.9.2.4: Species Distinctions

Glossina austeni are small flies (7.5-8.5mm) with reddish ochraceous dorsal surface, most of the tarsal segments of the hind leg are dark in colour.

Glossina longipennis are pale species (light yellowish brown) with a conspicuous dark brown spot on the dorsal view of the thorax.

In *Glossina pallidipes* all the tarsal segments on the front leg are pale and the third antennal segment is more than four times as long as wide and with a well-developed curved projection at the end (FAO, 1992)

3.9.3: Estimation of tsetse fly density

The average number of flies collected per trap per day (flies/trap/day or FTD) was used to express the apparent density, which is related to the NGU sampling trap utilized (Saini and Simarro's 2008).

The apparent density was estimated by multiplying the total number of tsetse flies that were caught (F) by the sum of the number of traps that were active throughout the relevant period of time (T) (D):

$FTD = \Sigma F/T \times D$

Where;

FTD = Fly traped per day

T = Number of functional traps

D = Number of days the traps were operational

3.10 Data management

The data was coded and transferred into an electronic format using the double entry approach. The database with the data was encrypted and protected by a password system only accessible to one person, the investigator. The farmer’s personal data was de-identified and coded before entry. Back-up copies of the database was also created and stored protected by a password system.

3.11 Data analysis

Data analysis was done using SPSS Version 20.0. Descriptive statistics was used to summarize the data and all qualitative data was presented using frequency tables and bar charts. Spatial distribution of the prevalence of bovine trypanosomiasis was analyzed by

Kruskal-Wallis test. The significant difference between trypanosome species and the disease prevalence in the two counties were analyzed using the chi- square test.

The influence of bovine body condition, season, bovine sex and age on the prevalence of bovine trypanosomiasis in the study areas was analyzed using chi-square. The combination of factors influencing prevalence of trypanosomiasis among the bovines was analyzed using linear regression.Factors influencing the abundance and distribution of tsetse flies were determined using Kruskal-Wallis test.

The apparent tsetse density for each study area was determined based on the average number of tsetse flies caught per trap per day.

Inferential statistics was used to interpret the data and determine the level of statistical significance. In all analyses, $p \leq 0.05$ was considered significant.

CHAPTER FOUR

RESULTS

4.1: The species and overall prevalence of trypanosomiasis in Kilifi and Kwale Counties

A total of 593 (287 from Kilifi and 306 from Kwale) bovines were sampled in different sampling sites of Kilifi and Kwale counties to determine the prevalence of trypanosomiasis in the two coastal counties. Two species of trypanosome parasites were identified from the sampled bovine population in Kwale and Kilifi counties, namely; *Trypanosome congolense* and *Trypanosome vivax*.

Out of the 593 cattle examined in the two coastal counties; Kilifi and Kwale, the overall prevalence of Trypanosome infection was 12.54% and 9.80% in Kilifi and Kwale respectively as shown in Table 4.1. There was no significant difference in trypanosome species infection and in the overall disease prevalence between the two counties (X^2 =0.5455, df =1, P= 0.075). However, there was a significantly (P = 0.01) higher prevalence *T. congolense* species infection in Kilifi county.

Table 4.1: Trypanosomiasis species prevalence in Kilifi and Kwale Counties

Counties	N	Number Infected (Prevalence %) by *Trypanosoma* species			
		T. congolense	*T. vivax*	*Totals*	P value
Kilifi	287	34 (11.1)	2 (1.4)	36 (12.54)	0.01
Kwale	306	21 (6.9)	9 (3.0)	30 (9.80)	0.48
Totals	593	55 (5.9)	11 (4.45)	66 (0.5454)	0.075

4.2: Association between trypanosomiasis and the parasite species, body condition, sex, age, breed and the Packed Cell Volume

The associations between infection and study variables; age, sex, body condition and the Packed Cell Volume (PCV) (Appendix iv).

High infection of trypanosome was recorded in Kilifi County with 36 positive cases of trypanosomiasis while Kwale County recorded 30 positive cases.

Of the 66 cattle positive for trypanosomes in both Kilifi and Kwale counties, 34 (11.1%) and 2 (1.4%) in Kilifi; 21 (6.9%) and 9 (3.0%) in Kwale were caused by *T. congolense*, and *T. vivax*, respectively.

The infection was also high in cattle with poor body condition 64.29% and 42.11% and fair body condition (29.35% and 11.88%) in Kilifi and Kwale respectively. Similarly, infection was higher in adult animals compared to the growers and calves 12.54% , 9.8% and 3% respectively.

The study found out that most of the infected animals in both counties were female; 45.4% and 27.2% in Kilifi and Kwale respectively. Male infection rate was 18.18% in Kwale and 9.1% Kilifi.

On sex differences, females' bovines had higher infection rate compared to males' bovines. Using the goodness of fit test, there was no significant correlation between sex and the trypanosomiasis infection in bovines (P-value 0.075).

From the study animals with poor body condition had the largest infection rate 74.2% (Kilifi 43.9%; Kwale30.3%) followed by those with fair body condition 22.7% (Kilifi 10.6%; 12.1%) and the least infection was found in bovines with good body condition with infection rate of only 3% in Kwale.

However, the observed differences in infections were significant (P <0.01) that the body condition of the bovine does influence the prevalence of trypanosomiasis infection.

Adult animals had the highest number of infection 75.76% (Kilifi 42.42%; Kwale 33.34%) and the calf had the least infection rate. There was significant difference of infection between age groups at 0.05% confident level that age influences the susceptibility of animals to trypanosomiasis infection (P = 0.01).

Packed Cell Volume was another factor under investigation to determine its influence on the prevalence of trypanosomiasis infection in bovines. All of the positive cases were reported in all animals that had packed cell volume (PCV) of less or equal to 24% as shown Table 4.2

Table 4.2: Association of Packed Cell Volume Differences and Bovine Trypanosomes Species Infections in Kilifi and Kwale

			Trypanosomes					
County			**No examined**	***T. congolense***	***T. vivax***	**Total**	**Mean PCV**	**S.dev**
Kilifi		**Anemic (<24)**	**92**	**32 (48.48%)**	**4(6.06%)**	**36 (39.13)**	**21.45**	**2.67**
		Normal (>24)	**195**	**0 (0%)**	**0 (0%)**	**0 (0)**	**30.69**	**4.46**
	Total		**287**	**32**	**4**	**36**		
Kwale		**Anemic (<24)**	**134**	**21 (31.8%)**	**9(13.64%)**	**30 (22.39)**	**20.52**	**3.33**
		Normal (≥24)	**172**	**0 (0%)**	**0(0%)**	**0(0)**	**31.19**	**4.67**
	Total		**306**	**21**	**9**			

Key:

PVC – Packed Cell Volume

T. – Trypanosoma

The study showed (appendix iii) that there was significant association between animal packed cell volume and the occurrence of parasitaemia (P = 0.01).

For the seasonal effect on the trypanosomiasis infection, wet season recorded the highest infection rate (65.16%) in Kilifi (31.82%) and Kwale (33.34%) respectively. During the dry season, fewer cases of infection were observed with Kwale having the lower rate of 11.64% while Kilifi had 21.22%. During both seasons *T. congolese* was the most dormant trypanosome parasite infection in the herds.

Using goodness of fit, seasonal infection difference was found to be significant (P = 0.01) in both counties.

Table 4.3: Trypanosome species infection cases during dry and wet seasons in Kilifi and Kwale Counties

County	**Season**	**No Examined**	*T. congolense*	*T. vivax*	**Total**	**P-Value**
Kilifi	**Dry**	**182**	**6 (9.1%)**	**2(3.04)**	**8(12.12%)**	**0.90**
Kwale	**Dry**	**147**	**5 (7.58%)**	**1(1.5%)**	**6 (9.09%)**	
Kilifi	**Wet**	**105**	**24 (36.4)**	**4(6.06%)**	**28(42.42)**	**0.95**
Kwale	**Wet**	**159**	**19 (28.8%)**	**5(7.58%)**	**24(36.36%)**	
Total		**593**	**54**	**12**	**66**	**0.01**

The study showed that there was significance that body condition of the animal influences the susceptibility of animal to parasitic infection. The P value is less than 0.05 confidence level.

4.3: Entomological results

Three species of *Glossina* (*G. longipennis, G. pallidipes, and G. austeni*) and two genera of biting flies (*Stomoxys* and *Tabanus*) were identified during the entomological survey in both Kwale and Kilifi Counties.

The overall *Glossina* species caught per 48 hours with sex proportion in different peasant associations (PA's) Tsetse fly and other biting fly's populations.

Fly density (Fly/Trap/Day) of the flies captured in Kilifi was: 5.2 and 1.41 during the wet and dry seasons respectively, whereas in Kwale it was 8.61 and 1.53 during wet and dry seasons respectively.

G. longipennis was the most dominant *Glossina spp* in Kilifi County followed by *G pallidipes*. In Kwale County the three *Glossina spp; G. longipennis, G.pallidipes* and *G. austeni* were present.

During the wet season in Kilifi, out of 208 flies trapped, 109 were female while 99 were male. In Kwale, out of 1679 flies trapped, 1,404 were female and 275 male (Appendix iii). High number of tsetse flies was caught during the wet season accounting for 79.4%, Kilifi contributing 21.2% while Kwale contributed 58.2%. The dry season tsetse fly numbers accounted for 20.6% of flies caught distributed at 9.9% and 10.7% in Kilifi and Kwale respectively. Kwale had the highest fly/trap/day (FTD) of trapped flies in both trapping seasons (wet 8.61; dry 1.53) as compared to Kilifi (wet 5.2; dry 1.41) as shown in Figure 4.1. Using Kruskal Wallis Test, there was significant indication that season influence the abundance of tsetse fly in the study counties (P value < 0.05).

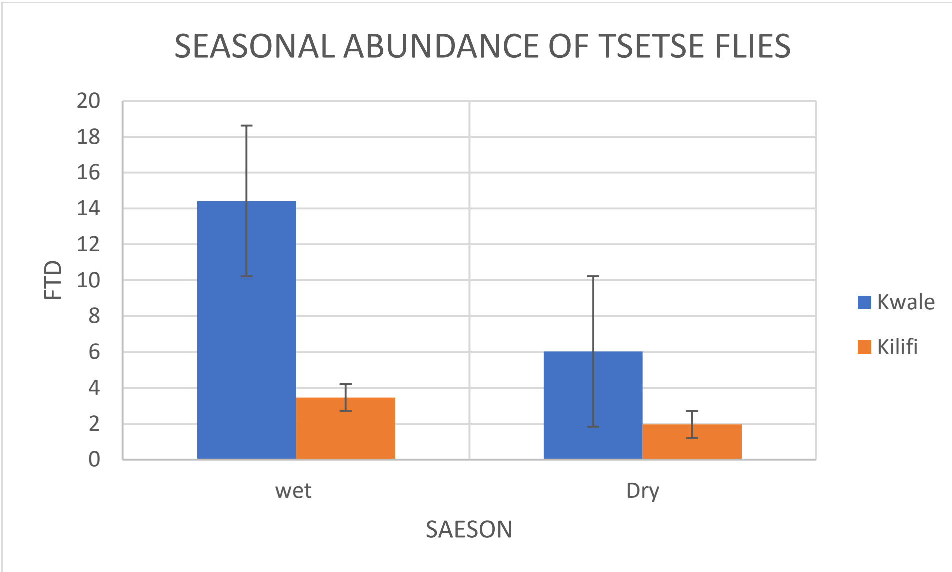

Figure 4. 2: Tsetse fly density comparisons between Kilifi and Kwale during wet and dry seasons

Key:

FTD – Fly/Trap/Day

4.5: Socio-demographic Information

4.5.1: Respondents' Educational Level

Generally, most of the respondents had informal or primary level education 60.6% and 57.1 % in Kilifi and Kwale Counties respectively. Secondary level 14.6% and 28.6% and tertiary level 24.7% and 14.2% in Kilifi and Kwale Counties respectively (Figure 4.2).

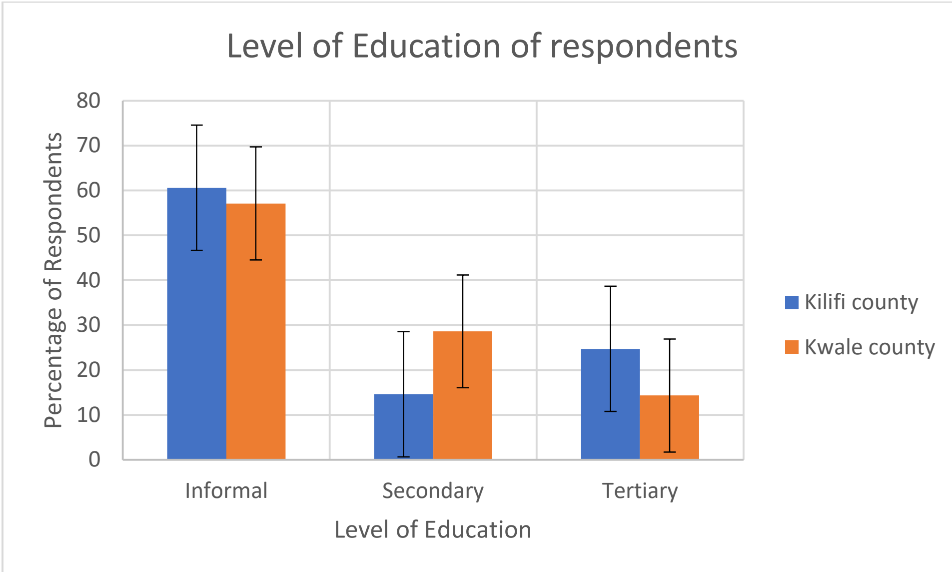

Figure 4. 3: Education level of the respondents

4.5.2: Respondents' demographic characteristics

A total of 138 respondents were interviewed in the study; 66.4% and 83.7% of the respondents were male and 32.6% and 16.3% were female in Kilifi and Kwale Counties respectively.

81%of the respondents were in the age group 20–59 years in both the study counties, with 57% being 51 years and above Figure 4. 3.

In Kilifi, 51 and above years accounted for 54.4% followed by 41-50 years (27.78%) and the least were between 21-30 years (4.4%) .

In lKwale 51 and above years accounted for 53.3% followed by 41-50 year (21.1%) and the least also were 21-30 year (6.67%).

The household sizes of the respondents also varied, 41.10% and 37.78% in Kilifi and Kwale respectively having 5-7 members.

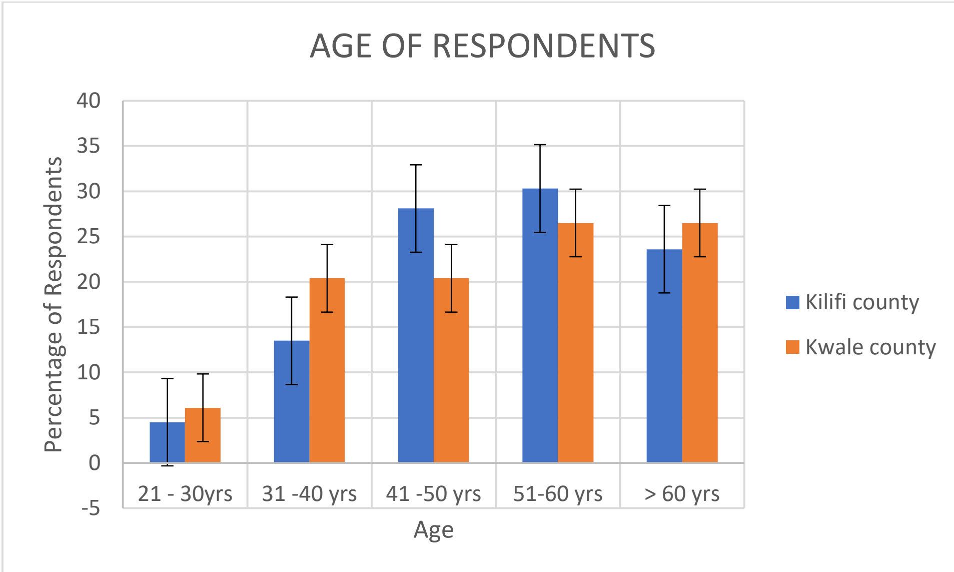

Figure 4. 4: Age of the respondents in the study Counties

Table 4.4: Demographic characteristics of the respondents in Kilifi and Kwale Counties

Attributes	Stratification	Kilifi county Frequency(%)	Kwale county Frequency(%)	t-Value Kilifi	t-Value Kwale	P-Value
Gender	**Male**	**60 (66.67)**	**75 (83.33)**	**26.683**	**29.533**	**.000**
	Female	**30 (33.33)**	**15 (16.67)**			
Age	**21 – 30yrs**	**4 (4.44)**	**6 (6.67)**	**38.487**	**34.334**	**.000**
	31 -40 yrs	**12 (13.33)**	**17 (18.89)**			
	41 -50 yrs	**25 (27.78)**	**19 (21.11)**			
	51-60 yrs	**28 (31.11)**	**27 (30.00)**			
	> 60 yrs	**21 (23.33)**	**21 (23.33)**			
Education	**Primary**	**53 (58.89)**	**42 (46.67)**	**28.054**	**27.201**	**.000**
	Secondary	**13 (14.44)**	**27 (30.00)**			
	Tertiary	**22 (24.44)**	**11 (12.22)**			
	None	**2 (2.22)**	**10 (11.11)**			
Household size	**2_4**	**24 (26.67)**	**15 (16.67)**	**31.588**	**32.675**	**.000**
	5_7	**37 (41.11)**	**34 (37.78)**			
	8_10	**19 (21.11)**	**21 (23.33)**			
	>10	**10 (11.11)**	**20 (22.22)**			

4.6: Socio-economic impacts of bovine trypanosomiasis

Demographic information

Majority of the respondents were 51 years and above representing 57% of the sampled population, followed by 41-50 years (25.4%) the third was those between 31-40 years that accounted for 15.9% of the sampled respondents and the least proportion of the respondents was between 21- 30 years of age (5.1%)

The household sizes of the farmer respondents varied from one household to another. 21.0% represented households with population size of 8-10. About 23.9% represented the households with less than 5 members. The highest household size was 6-7 member representing 39.9% of the total sampled households.

The respondents had various sources of income including crop farming, livestock rearing, small businesses while a few of the respondents have formal employment. Some also do fishing as a source of income.

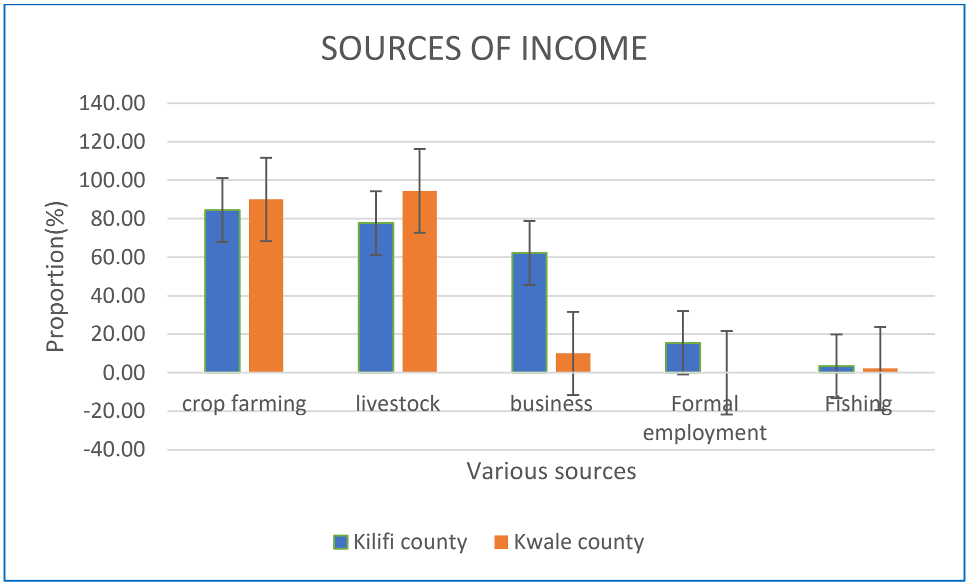

Figure 4.5: Sources of income for residents in Kilifi and Kwale Counties

Majority of the respondents (51.4%) earned less than one thousand Kenya shillings per week while 47.8% earned above one thousand per week.

Trypanosomiasis has direct impact on livestock productivity by reducing meat and milk productivity, increase calf mortality and livestock management especially the number of livestock kept by farmers, the breed and species composition of the livestock herd, loss of draft power, mortality, abortion and cost of trypanocidal drugs and insecticides.

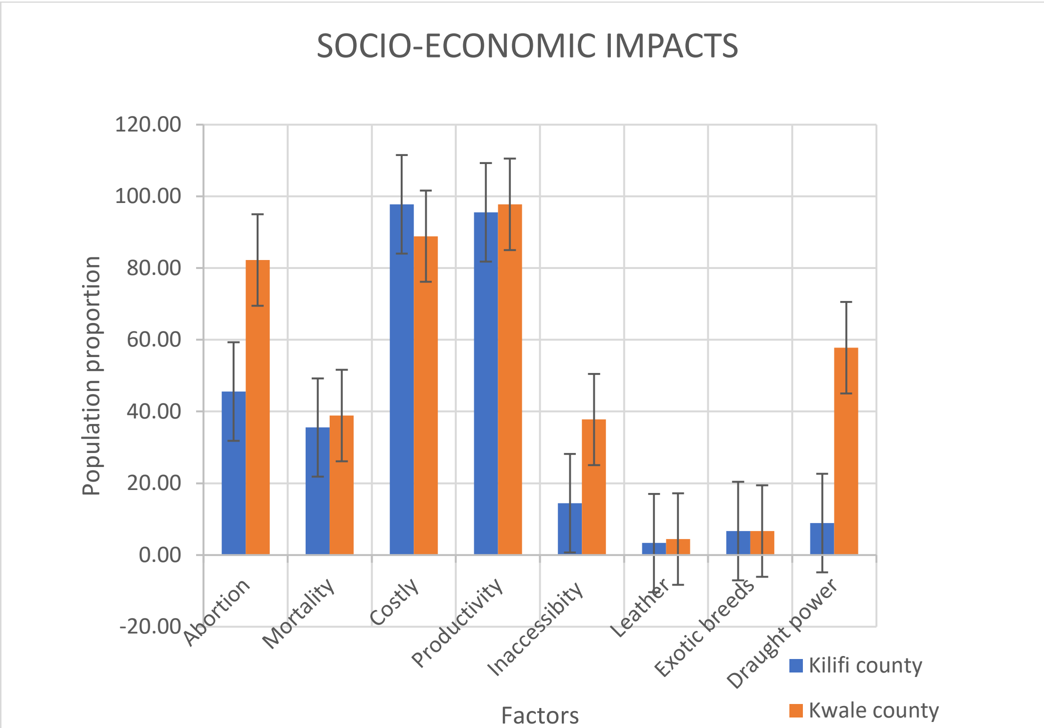

Figure 4.6: Socio-economic impacts of tsetse and trypanosomiasis

4.6: Respondents' knowledge and practices on tsetse control methods and trypanosomiasis treatment

Respondent knowledge on the presence of trypanosomiasis was high in Kwale (34.7%) compared to Kilifi that had 30.3% respondents having knowledge on trypanosomiasis. Tsetse flies are known to most of the farmers as it was shown that 95% to 100% of the respondents in both assessed counties knew and have observed tsetse flies in the field.

The results indicated that 100% of respondents in Kwale and 82.2% respondents in Kilifi County apply pyrethroids acaricides/insecticides on their animals as a control measure against ticks and tsetse flies. About 66.7% and 74.4% of respondents in Kwale and Kilifi respectively use bush clearing, about 65.6% and 77.8% in Kilifi and Kwale respectively restrict animal movement as tsetse control technique. Respondents in Kilifi had not adopted

Insecticide Impregnated Target while in Kwale 15.6% of the respondents had adopted the technique. Netting of zero grazing units had equally been adopted by the respondents in both counties; in Kilifi 10% and Kwale 11.1%.

In Kwale County, most of the farmer respondents have embraced technique of pyrethroid application for the control of ecto-parasites with most respondents spraying their animals four times per month (55.1%). In Kilifi, the highest number of respondents spray their animals only once per month (30.3%).

Table 4.5: Responses on trypanosomiasis and tsetse control in the study Counties

Question	Response	Kilifi (%)	Kwale (%)
Presence of trypanosomosis	**High**	**9**	**34.7**
	Moderate	**38.2**	**55.1**
	Low	**30.3**	**10.2**
Presence of tsetse flies	**Yes**	**95**	**100**
	No	**5**	**0**
Tsetse flies control methods	**Insecticide application**	**82.2**	**100**
	Bush clearing	**66.7**	**74.4**

Question	Response	Kilifi (%)	Kwale (%)
	Insecticides Impregnated Target	0	15.6
	Netting of zero grazing unit	10	11.1
	Restrict animals' movement	65.6	77.8
Pyrethroid application frequency (per month)	Once	30.3	12.2
	Twice	10.1	18.4
	Thrice	12.4	14.3
	Four times	11.2	55.1
	Don't spray	14.6	0

4.7: Status of trypanocidal drug use

Kilifi County had the higher percentage of chemotherapy drug (Veriben) consumption though there was no much difference in chemotherapy use in Kwale. Prophylactic drugs; Samorin was no largely administered. However, the use of both chemoprophylaxis and chemotherapy drugs was higher in Kwale County (Figure_4.6).

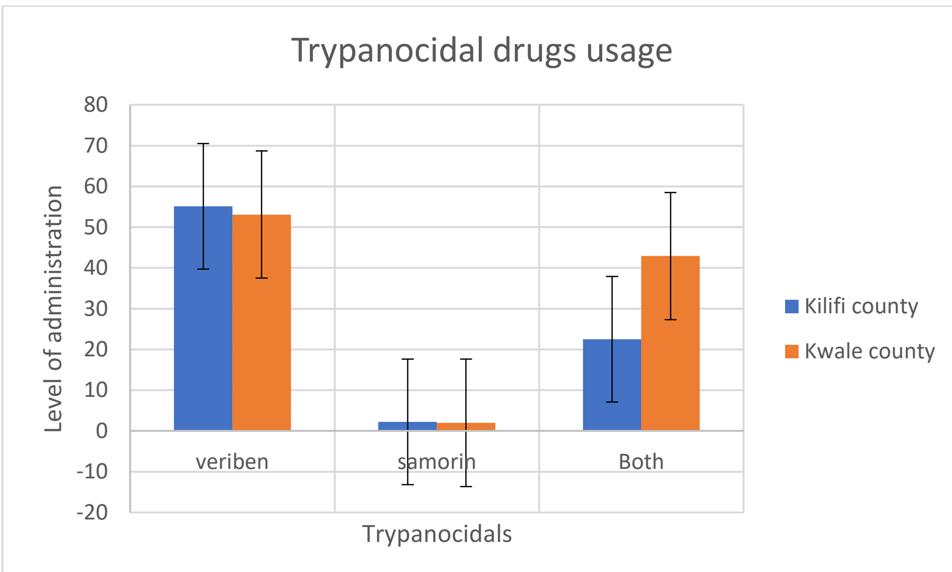

Figure 4. 7: Proportion of trypanocides use in Kilifi and Kwale Counties

In Kilifi and Kwale, respectively, 2.2 and 2.0% of farmer responders used chemotherapy to manage trypanosomosis. On the other side, chemotherapy was mentioned as a control measure by 55.1% and 53.1% of respondents from Kilifi and Kwale, respectively. The remaining 22.5% and 42.9% of respondents from Kilifi and Kwale, respectively, said they alternately use chemotherapy and chemoprophylaxis for tsetse control. Isometamidium chloride (ISMM) (Samorin) was the most commonly used prophylactic drug while diminazene aceturate (DA) (Veriben) was used for chemotherapy as shown in Table 4.6.

Table 4.6: Trypanosomiasis control strategies adopted by respondents in Kilifi and Kwale Counties

Question	Response	Kilifi (%)	Kwale (%)
Trypanosomosis control method	**Tsetse control**	**0**	**45**
	Chemoprophylaxis	**2.2**	**2.0**
	Chemotherapy	**55.1**	**53.1**
	Tsetse control with Chemoprophylaxis and/or chemotherapy	**22.5**	**42.9**
Drug used	**ISMM**	**5**	**45**
	DA	**95**	**30**

Key:

ISMM – Isometamidium chloride (Samorin)

DA - diminazene aceturate (Veriben)

CHAPTER FIVE

DISCUSSIONS

5.1: Parasitological Risk Factors

In this study, two species of trypanosomes were found among infected bovines, namely *T. congolense* and *T. vivax.* In Kilifi County the overal disease prevalence during the study period was 12.5% while in Kwale County, it was 9.9 %.

Trypanosome infections in cattle are linked to the prevalence of Glossina species and other biting flies in the research sites, which are potential fly vectors. During the late rainy and dry seasons there were no discernible variation between the two counties, suggesting that the illness is perennially transmitted in both of the evaluated coastal counties.

A higher proportion of bovines with *T. congolense* infections in the study areas are due to the vectoral efficiencies of the major cyclical vectors of Savannah tsetse flies; *Glossina pallidipes* and fusca group species; *G. longipennis* found in Kwale and Kilifi respectively which are effective transmitters of *T. congolense*. The presence of *T. vivax* infection in the bovine sample population confirms the presence of other potential haematophagus insect vectors like *tabanus* and *stomoxys spp* captured during the study. Tabanidae and Stomoxinae can continue to transmit the parasites mechanically—that is, by acting as a flying syringes (Mbahin *et al*., 2013; Bouyer *et al*., 2018). These other vectors are responsible for seasonal epidemic patterns in low tsetse density areas as previously observed **(**Nthiwa *et al*., 2015**)**. Another species of trypanosomes parasites known to be transmitted by the non-cyclical vectors is *T. evansi* (Aregawi *et al*., 2019).

Bouyer *et al*., (2018) further stated *Trypanosoma vivax* only, has worldwide distribution even in places where tsetse flies are not present. *T. vivax* is the only example of a trypanosome species transmitted both biologically by tsetse flies and mechanically by other insects, and this species does not affect human beings (Kasozi *et al*., 2021).

T. congolense and *T. vivax* are the major causes of clinical AAT in cattle with low packed cell volume (PCV) being an indicator of infection (Mulenga *et al.,* 2020). *T. congolense* causes disease in cattle, camels, horses, dogs, sheep, goats, and pigs while, *T. vivax* causes disease in cattle, sheep, goats, and horses (Kulohoma *et al.,* 2020). Howeve,only cattle were assessed during this study

T. congolense, *T. vivax* and *T. brucei brucei* causes disease to several groups of wild mammals, for example buffaloes and wildebeests (Kulohoma *et al.,* 2020). Buffaloes are present in forest reserves in the study area and may be the reservoir hosts for the parasites. The results of this investigation showed a correlation between cow body condition and trypanosome infections. Since trypanosomiasis is marked by gradual weight loss, the majority of the afflicted animals exhibit clinically poor body condition (Lelisa *et al*., 2014). Poor physical health, however, can be brought on by various infections and dietary stress in addition to trypanosomiasis.

The mean PCV of cattle with trypanosomiasis is much lower than that of animals without the disease, according to this study's findings. According to Mbahin *et al*., (2013), one of the signs of trypanosomiasis in cattle is anemia, which is best assessed by PCV. Additionally, studies have shown that the microhaematocrit buffy coat method is more sensitive than direct smear testing for finding trypanosomes in blood (Montpellier, 2017).

The findings of this study are consistent with those of Gebisa *et al*., (2020), who noted that the Chora regions of Ethiopia's Oromia Region had the greatest frequency of trypanosomosis in anemic cattle. The tested animals likely also had additional illnesses such helminthosis, tick-borne infections, and nutritional imbalances, which may have contributed to the greater proportion of infected animals with anemic conditions.

Contrary to research by Abdi and Gona (2016), which suggested that male animals and older animals are frequently more afflicted than female and young animals, the study showed that more female cattle had trypanosomiasis than the male cattle. Given that most families choose greater milk-producing herds, this discrepancy may be explained by the lower sample size of male cattle in the current study compared to female cattle.

According to research by Simukoko *et al.,* (2010), the risk of AAT infection and seasonal fluctuations in tsetse populations determine whether or not to treat sheep with trypanocides. These results show that tsetse and AAT management programs must concentrate on seasonal variations in the risk of AAT infection when tsetse challenge is highest and infection is noticeably greater at the start of the rainy season.

The prevalence of trypanosomiasis was statistically different ($P < 0.05$) across the different categories of body conditions. The findings of this study are in line with those of Gebisa *et al.,* 2020, which found that trypanosomiasis prevalence varied significantly depending on the body condition of cattle in Kindo Koysha district, Wolayita Zone, and Botor Tolay district, Jimma Zone, respectively.

This is an indication that cattle continue to face the Glossina issue when they are herded to pasture and water sources, where they assemble. It seems that the increase in temperature is associated with increase in fly apparent density (Lukaw *et al*., 2016)

5.2 Entomological determinants

Coastal region is known to be infested by four species of tsetse fly; *Glossina pallidpies, G. longipennis, G austeni* and *Glossina brevipalpis* (Grady *et al*., 2011) but in this study, the entomological findings showed that three species of tsetse fly;*Glossina pallidpies, G. longipennis, G austeni* were observed in the study counties. The other haematophagus flies collected with the tsetse flies were *Stomoxys* and *Tabanus* species.

In Kilifi County *G.longipennis* and *G.pallidipes* was captured while *G.pallidipes* and *G.austeni* was captured in Kwale County. The finding was in line with the studies carried out in Kwale by Mbahin *et al.,* (2013) who found out that Kwale is infested by *G.pallidipes, G.austeni* and *G. brevipalpis.* Ngari *et al*., (2020) also confirmed that *G. longipennis* is common in the Coastal region while *G. pallidipes* is a species found in most tsetse fly belts. Glossina pallidipes, which transmits trypanosomes linked to animal trypanosomiasis, was the main vector species.

These savannah-dwelling animals can find a suitable home thanks to the area's mixed kind of flora. A higher number of female tsetse flies 227 (55.4%) were caught compared to male 183 (44.6%), which agrees with findings of work carried out in Ethiopia (Daya and Abebe, 2008; Kumela Lelisa *et al*., 2014; Kumela Lelisa *et al*., 2015). According to Peacock *et al*., (2012), tsetse fly sex affects the fly's vulnerability to trypanosomes infection, with male fly being far more sensitive to T. brucei than female fly. The results corroborate recent research by Kulohoma *et al*., (2020) Male tsetse flies are more susceptible to infection than female flies because they do not recover from trypanosome infection over their lifespan, which accounts for their smaller population.

Great variability in tsetse apparent densities observed in the current study could be explained by the disintegration of tsetse habitats along diverse vegetation cover due to anthropogenic factors.

A higher population of female *Glossina* spp was captured in both counties during the two sampling seasons. A higher proportion of female *Glossina* species was caught than male. This could be as a result of the longer lifespan of female compared to male *Glossina* (Haile *et al*. 2016) but this is opposed to the finding by Lukaw *et al* (2016) who reported that male flies had immediate response to static objects and traps which leads to high percentage of male catches.

In Kwale County, high tsetse abundance is attributed to suitable tsetse habitats provided by the Shimba Hills National Reserve (SHNR) environments. The diverse kind of vegetation found in this area offers suitable habitats for savannah-dwelling *Glossina* spp*; G. pallidipes* and *G. austeni* (Wamwiri *et al*., 2013). Higher numbers of trapped flies were influenced by the sampling tool, the NGU trap. Studies have revealed that this trapping device is more effective for the capture of *G. pallidipes* than of *G. austeni (*Wamwiri *et al*., 2013).

G. pallidipes was also trapped in Kilifi which contrast the work done by Wamwiri *et al*., (2013) that no *G. pallidipes* was observed since much of the work was done in ASF habitat that is composed mainly of dense indigenous forest.

Tsetse abundance was strongly linked with different sampling season and habitat type as also observed previously (Ngonyoka *et al.,* 2017). The riverine vegetation and savannah habitats dominant in the study areas are very important for the widespread occurrence of *Glossina* species (Lelisa *et al.,* 2014). Ngonyoka *et al., (*2017) observed that most of *G. pallidipes* were collected in the riverine and higher vegetation areas of open woodland and swampy areas. During the current study, tsetse abundance was observed be associated with forested areas,

In Kwale *G. pallidipes* was significantly highest in abundance during wet season. This was attributed to higher vegetation cover with many trees and tall grasses which provide suitable vegetation cover favoring their survival while in Kilifi sampling was done on open woodland and along the riverines.

In Kilifi, *G. longipennis* had higher abundance during wet season but there was no significant difference (P Value > 0.05) in fly abundance between the different sampling seasons. *G. longipennis* are known to inhabit sparsely vegetated arid lands (Devisser; Messina, 2009) and thorn bush riverine thickets near acacia woodlands (Nthiwab *et al*., 2015).

Since the puparium contains significant water reserves and the pupal membranes have a limited permeability, G. longipennis is a unique species of the fusca group that establishes in drier places more often than any other tsetse of the fusca group. Kilifi provided G. longipennis with all of these ecological conditions necessary for its existence.

As previously noted, tsetse flies were more numerous during the dry season than they were during the rainy season (Lukaw *et al*., 2016). The extensive plant cover during the rainy season suggests that many places get waterlogged, which might attract predators like spiders, dragonflies, and ants to tsetse flies. This could explain why there are fewer flies visible during the wet season (Lukaw *et al*., 2016).

Although this is not always the case in other afflicted nations, the spread of AAT closely mirrors that of tsetse. For instance, mechanical transmission by other vectors (such as tabanids and stomoxys) as well as animal mobility (owing to pastoralism) in the Sahel and Sudanian savannahs of northern Africa spreads the illness well beyond the tsetse belts (Sereni *et al.,* 2021)

Poor populations that depend on conventional techniques of livestock husbandry and small-scale food production are most affected by tsetse flies and trypanosomiasis (Adungo *et al*., 2020).

5.3 Socio-economic impacts of trypanosomiasis

Communities residing in tsetse-infested areas have continued to experience poor food security. Trypanocides can be used to treat affected animals and insecticides can be used to combat tsetse flies to lessen the impact of AAT. In order to battle the disease, cattle ranchers in African regions where trypanosomiasis is widespread have turned to severe usage of trypanocides (Mulenga *et al*., 2020). Communities and visitors that live close to or in national parks and game reserves are at danger from wildlife trypanosomiasis hosts.

In sub-Saharan Africa, trypanosomiasis has a significant negative influence on production and health.

G. palpalis (Rayaisse *et al*., 2010) is most the most hazardous species and it transmit AAT.

As a result of widespread usage of the trypanocides Diminazene aceturate and Isometamidium chloride, this research's findings suggest that animal trypanosomiasis is still regarded as a serious animal illness in the study locations. Many research participants admitted that trypanosomiasis existed in their communities (Tekle *et al*., 2018).

The development of drug resistance is thought to be associated with improper storage, handling, and administration procedures as well as poor medication quality, which significantly lowers the efficacy of chemotherapy (Tekle *et al.*, 2018). Tekle *et al.*, (2018) also said that drug resistance to ISM is more common than to DA, however reports of multiple drug resistance are growing from many regions of Africa.

The respondents' educational backgrounds varied with the majority having just completed elementary school. Comparatively speaking, respondents from Kilifi had a greater degree of literacy than those from Kwale. This also correlated with the respondents' capacity to comprehend illnesses, disease vectors, numerous effective and efficient control strategies to utilize, animal therapy, and medicine usage. Respondents in Kilifi County appeared to know more about the illness and how to treat it than those in the Kwale County.

Although differences in temperature and humidity between the dry and wet seasons may have affected the density of the tsetse fly population in different places. It should be noted that the widespread and consistent use of trypanocidal medications, as well as the trypanosome populations' susceptibility to these medications, may have adversely influenced not only the conclusions reached regarding the PCV values found in the various cattle populations, but also the prevalence of trypanosomiasis in the Counties.

Respondents in both counties had knowledge of tsetse and trypanosomiasis despite having different degrees of formal education. A significant number of respondents claimed to be able to recognize tsetse flies and trypanosomiasis-infected animals based on the given signs and symptoms.

The homeowners were aware of the management methods, and a bigger percentage suggested using pesticides as an alternative to removing brush, netting zero-grazing units, and using target panels. The use of pyrethroids insecticides to concurrently reduce tsetse flies and illnesses transmitted by ticks was favorably received by respondents in all research regions.

Additional information provided by the farmers revealed that the frequency of pesticide applications varied among them, ranging from monthly to weekly intervals of spraying, with the majority of farmers using this technique of control. The restricted use of a pesticide that employs live cattle as bait to control tsetse in underdeveloped regions has increased productivity by $30 per head of cattle yearly and the average annual income per household by $110. Live bait has been discovered as a better long-term and community-friendly means of lowering disease vectors, according to Waiswa *et al*. (2020).

This investigation found that trypanocides were used extensively in parasite control procedures. Chemoprophylaxis and chemotherapy were considered as methods of controlling trypanosomiasis, but farmers primarily used chemotherapy, in which trypanocides were provided after the disease was discovered. These results support Giordani et al(2016) .'s conclusions that chemotherapy and chemoprophylaxis are the cornerstones of animal trypanosomiasis management, maintaining animal health and productivity in enzootic nations. According to estimates, sub-Saharan Africa uses up to 35 million doses of trypanocides each year to combat animal trypanosomiasis (Ngumbi and Silayo, 2017).

According to this study, isoetamidium chloride is the medicine that is most frequently preferred for preventative usage whereas diminazene aceturate is the drug that is most commonly used for therapeutic purposes. It is considered a form of mass therapy when curative trypanocidal medications like Diminazene are used to prevent infection in both diseased and non-infected animals. While treating sick animals leads in an added immunity against the local stocks of trypanosomes, treating uninfected animals results in extra costs to animal production. Trypanocides are utilized across the study areas, primarily for therapeutic purposes but sometimes occasionally for prophylactic as seen in other tsetse-infested regions of Africa (Ngumbi and Silayo, 2017). Ngumbi and Silayo (2017) have provided more evidence that the African market makes it unlikely that new treatments would be developed for use against trypanosomoses. This is because the drugs are not appealing to the pharmaceutical sector.

Farmers of cattle have been forced to use trypanocides on a regular basis due to a lack of governmental commitment to tsetse and African trypanosomiasis control programs. In order to protect their livestock, livestock producers in GMAs or close to NPs where tsetse challenge is prevalent frequently used trypanocide (Dagnachew *et al*., 2017), which may have major effects associated to trypanosome resistance (TR) to trypanocides (Mbewe *et al.*, 2015 study in Zambia verifies. For the majority of cattle producers, chemotherapy and chemoprophylaxis are the principal management techniques for AAT (Kulohoma *et al.*, 2020). Due to the fact that AAT is primarily a herd health issue, AAT management techniques are typically unsustainable and expensive in the long term (Mulenga *et al*., 2020). Unfortunately, due to lack of access to laboratories and frequent inspections by neighborhood veterinarians, the majority of farmers in tsetse-infested areas treat their animals based only on clinical indications and symptoms. In this instance, the majority of infections are still present in their livestock herds and may be to blame for continuing occasional cases of African trypanosomiasis in their localities (Mulenga *et al*., 2020).

Despite being used to treat and control trypanosomiasis, the drug is plagued by a number of issues, such as a lack of readily available medications, the development of trypanosome drug resistance, and a lack of industry interest in the discovery and development of new trypanocidal medications for use in the field (Ngumbi and Silayo, 2017).

About 70 million doses of medications are purchased by farmers each year in sub-Saharan Africa (Kulohoma *et al*., 2020), despite growing worries about the rapidly evolving, widespread, multi-drug resistance to the few available trypanocidal medications, which are primarily used by farmers Diminazene aceturate (DA) and isotamidium chloride (ISM) (Dagnachew *et al.*, 2017). Since both of these medications have been available for more than 50 years, the resistance of the parasites to them is rising (Tekle *et al*., 2018), which has a negative impact on the effectiveness of therapy. The availability of trypanocidal medications in black markets and treatment failures lead farmers to have the pharmaceuticals in their backyard due to the establishment of drug resistance, which is associated with improper handling and use methods as well as poor drug quality (Tekle *et al.*, 2018). (Dagnachew *et al*., 2017). Kulohoma *et al*. (2020) added that selection pressure is exerted at the drug-targeted trypanosome genes by repeatedly administering the same trypanocides to animals with trypanosome infections. As a result, trypanosomes develop mutations that provide resistance to trypanocidal drugs.

In this research region, many farmers give trypanocidal medications by themselves or members of their family; very few farmers seek the advice of veterinary or paraprofessional professionals. This result is consistent with studies by Tekle *et al*., 2017 and Dagnachew *et al*., 2017. This medication self-administration is thought to increase the chance of trypanocidal resistance in the parasites. The greater frequency of respondents choosing unauthorized/illegal sources to conveniently get trypanocidal medications at a lower cost has been attributed to inadequate veterinary services and the higher cost of drugs from legal sources (Tekle *et al.*, 2018). This behavior might result in the use of out-of-date medications or unlicensed medications with questionable dose levels.

Similar to this, KENTTEC supports an integrated pest management (IPM) strategy that includes other instruments including the use of tsetse fly traps and targets, farmers' education on tsetse and trypanosomiasis, and the treatment of afflicted livestock.

Vector control continues to be the most effective method for the long-term management of these diseases due to the unavailability of affordable and effective HAT medications as well as the development of AAT parasite drug resistance.

The findings of the present study suggest that three species of Glossina and other biting flies can support trypanosomiasis in cattle by acting as possible vectors for trypanosomes. Therefore, it is important that measures be made to manage these vectors.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1: Conclusions

In this study cases of bovine trypanosomiasis was reported in both counties; Kilifi and Kwale. The trypanosome parasites observed were *Trypanosome congolense* and *Trypanosome vivax*. Three species of *Glossina*; *G. longipennis, G. pallidipes, and G. austeni* and two genera of biting flies *Stomoxys* and *Tabanus* were identified during the entomological survey in both Kwale and Kilifi Counties.

During the study period, Kilifi County had higher prevalence of trypanosomiasis of 12.54% and Kwale County had lower prevalence rate of 9.8%. The overall prevalence of the disease is considered to be higher since some of the animals' act as the reservoir host of the parasites especially those infected with *Trypanosome congolense* which may not show any signs of infection. Bovine trypanosomiasis infection in animals from the study was correlated to various factors such as the animal body condition, breed of the animals, age, Packed Cell Volume (PCV) and the season.

Trypanosome vivax kills within the shortest time of infection.

Bovine trypanosomiasis infection in animals from the study was influenced by various factors such as the animal body condition, breed of the animals, age, Packed Cell Volume (PCV) and the season. Animals spraying technique has been highly embraced by the farmers not only to control tsetse borne diseases but also tick borne and other vector borne diseases.

G. longipennis was the most dominant *Glossina spp* in Kilifi County. Kwale had higher Fly/Trap/Day of 8.61 and 1.53 during wet and dry seasons respectively. Kilifi fly density was 5.2 and 1.41 during the wet and dry respectively. During the wet season the number of flies trapped doubled the number of flies trapped during the dry season in both counties. Tsetse and trypanosomiasis in Coastal Kenya continues to be a major setback to livestock production and agricultural development in the region.

Livestock farmers in the region have embraced tsetse control measures to curb the impact of the disease on their livestock productivity.

Additionally, livestock farmers have also been using chemotherapy diminazene aceturate (Veriben) as treatment method with a significant numbers of farmers administering the trypanocidal drugs by themselves or using their family members with few farmers consulting the veterinary experts. The use of the drug without consultation with the experts exposes the drug to more risk of resistance by the parasites.

6.2: Recommendations

The study urges more research to examine how trypanosomiasis and other vector-borne illnesses in the area are affected by entomological and epidemiological factors related to climate change.

The prevalence of cattle trypanosomiasis was examined, and the abundance of *Glossina* species that were captured suggested a significant issue in the Coastal Counties. To decrease the impact of trypanosomiasis in the area, progressive management strategies targeted at lowering the *Glossina* species load are advised. When the tsetse fly population is large during the rainy season, vector control should be strengthened. The commitment of local and national governments to prioritize issues and strong community involvement are necessary for the success of control alternatives. In order to lessen the effects of the illness and boost animal output, community mobilization and increased participation in control efforts might be crucial.

Futher study to determine the level of purchase of the trypanocidal drugs from agro-vet shops in the Coastal counties to monitor the disease trends and community response is recommended.

Farmer training and sensitization on tsetse and trypanosomiasis and their control approaches need to be done by the county and other vector control institutions to enlighten the farmers on various control strategies.

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APPENDICES

APPENDIX I: QUESTIONNAIRE FOR FARMERS

Instruction: Tick the choice or write the answer on the space provided [ ]

Respondent name ………………………………………………….................

Gender: M [ ] F [ ]

Age: < 20 [ ] 21-30 [ ] 31-40 [ ] 41-50 [ ] 51-60 [ ] 60 >

Education: (i)Primary [ ] (ii) Secondary [ ] (iii) Tertiary [ ]

Number of members in household: (i)<2 (ii)3-5 (iii)5-7 (iv)8-10 (v) >10

What is your marital status

Married ………. Single ……………. Divorced…………..Others(specify)………

Household source of income

(i) Crop farming [___] (ii) Livestock farming [___] (iii)Formal employment [___]

(i) Fishing [___] (iv) Bee keeping [____] (v)Small businesses [___]

(vi) Land leasing [___] (vii) Other (Specify) [___]

What is your house hold income per month?

(i)< 500 [ ] (ii)501- 1000 (iii) >1000

T&T

1. What types of livestock do you own in your HH?

(i) Cattle [ ] (ii) Sheep [ ] (iii) Goats [ ] (iv)Donkeys [ ] (v) Poultry [ ] (vi) Pigs

(vi) Other Specify [___________]

The number of livestock in the farm.

Livestock	Number
Cattle	
Sheep	
Goats	
Poultry	
Donkeys	
Pigs	
Others	

2. Which breed of cattle do you keep?

(i) Exotic cattle [ ] (ii) Indigenous cattle [ ]

3. How would you rate tsetse and Trypanosomiasis problem in the area?

(i) Very high [ ] (ii) High [ ] (iii) Moderate [ ] (iv) Low [ ] (v) Not a problem [ ]

Can you be able to differentiate between tsetse and biting flies? (i) Yes (ii) No

Are you able to tell an animal infected with trypanosomiasis? [_________] 1= Yes, 2=No

If yes what are 2 major symptoms shown by trypanosomiasis infected animal

[____]

T&T CONTROL

1.Name and rank the major methods which you use in tsetse and trypanosomiasis control on your farm1 highest 9 lowest

Rank Tsetse control methods

Rank	Tsetse control

(i)mechanical (bush-clearing) (ii)targets (iii)restrict livestock movement (iv)crop farming intervention (v)pour-ons (vi)dipping (vii)spraying (viii)Livestock protective fence (LPF)

(x) other (specify) ________________________

2. In terms of spraying or dipping, how many times do you spray/ dip your animals per month?

(i)Do not spray [ ] (ii)Once (iii) Twice [ ] (iv) Three times [ ] (v) Four times

Rank Trypanosomiasis control method

Rank	**Trypanosomiasis control**

1= Trypanocidal drugs 2= Tsetse control 3=Ethno Veterinary Practice

4= other (specify) ______________________

4.Which seasons (months of the year) are tsetse densities and trypanosomiasis most prevalent; indicate appropriately.

4=High 3=moderate 2=low 1=none

Season	Tsetse	Trypanosomiasis

January		
February		
March		
April		
May		
June		
July		
August		
September		
October		
November		
December		

5.Which drugs do you most frequently use for treatment, prevention and both prevention and treatment

(i)veriben (ii)samorin (iii)homidium (iv)ethidium

APPENDIX II: SEASONAL ABUNDANCE OF *GLOSSINA* SPP IN COASTAL COUNTIES (KWALE AND KILIFI)

		G. longipennis		*G. pallidipes*		*G.austeni*			
County	Season	M	F	M	F	M	F	Total	FTD
Kilifi	Wet	92	106	7	3	0	0	208	5.20
	Dry	45	49	7	16	0	0	117	2.93
	Total	137	155	14	19	0	0	325	
Kwale	Dry	0	0	18	63	0	5	86	1.43
	Wet	0	0	237	1124	38	280	1679	27.98
	Total	0	0	255	1287	38	285		

APPENDIX III: BITING FLIES' SPECIES AND APPARENT DENSITY (FLIES/TRAP/DAY - FTD)

Sampling County	Trapping season	Biting flies	Sum	FTD
Kwale	Dry	Tabanus	75	1.25
		Stomoxys	66	1.10
	Wet	Tabanus	173	3.60
		Stomoxys	136	2.83
Kilifi	Dry	Tabanus	51	1.28
		Stomoxys	126	3.15
	Wet	Tabanus	91	2.28
		Stomoxys	92	2.30

n: Number of flies; FTD: Fly/Trap/Day (apparent density of flies)

FTD- Fly/Trap/Density

APPENDIX IV: VARIOUS SOURCES OF INCOME FOR RESIDENTS IN KILIFI AND KWALE COUNTIES

County	crop farming	livestock	business	Formal employment	Fishing
Kilifi county	84.44	77.78	62.22	15.56	3.33
Kwale county	90.00	94.44	10.00	0.00	2.22

APPENDIX V: SOCIO-ECONOMIC IMPACTS OF TSETSE AND TRYPANOSOMIASIS IN KILIFI AND KWALE COUNTIES

County	Abortion	Mortality	Costly	Productivity	Inaccessibility	Leather	Exotic breeds	Draught power
Kilifi	45.56	35.56	97.78	95.56	14.44	3.33	6.67	8.89
Kwale	82.22	38.89	88.89	97.78	37.78	4.44	6.67	57.78

APPENDIX VI: ASSOCIATION OF BOVINE TRYPANOSOMIASIS INFECTION WITH THE FOLLOWING PARAMETERS: BODY CONDITION, AGE, SEX, BREED AND PARASITE SPECIES

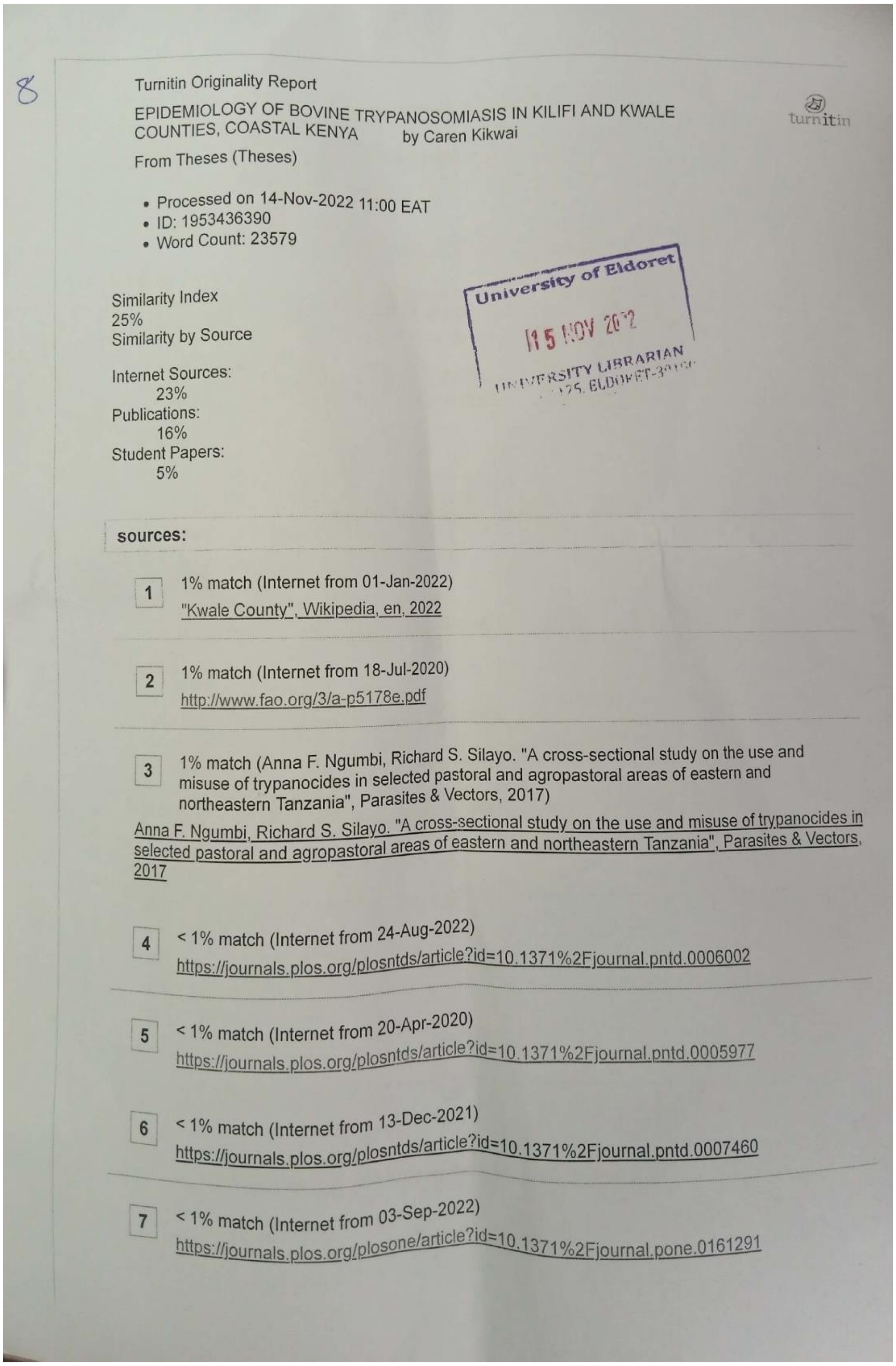
			Number Infected (Prevalence %)				
Counties	**Parameters**		**N**	***T. congolense***	***T. vivax***	**Total**	**P Value**
Kilifi	**BC**	**Good**	**181 (0)**	**0 (0%)**	**0 (0%)**	**0**	**0.01**
		Fair	**92(29.35%)**	**6 (9.1%)**	**1 (1.5%)**	**7**	
		poor	**14 (64.29%)**	**26 (39.4%)**	**3 (4.5%)**	**29**	
Kwale		**Good**	**167 (1.2%)**	**2(3.0%)**	**0 (0%)**	**2**	
		Fair	**101 (11.88%)**	**6 (9.1%)**	**2 (3.0%)**	**8**	
		poor	**38 (42.11%)**	**13 (19.7%)**	**7 (10.6%)**	**20**	
Kwale	**Age**	**Adult**	**222 (12.61)**	**25 (37.88%)**	**3(4.55%)**	**28**	**0.01**
		Growers	**52 (15.38)**	**7(10.61%)**	**1(1.52%)**	**8**	
		Calf	**12 (0)**	**0 (0%)**	**0 (0%)**	**0**	
Kilifi		**Adult**	**196 (9.69)**	**15 (22.73%)**	**7(10.61%)**	**22**	
		Growers	**33 (18.18)**	**5(7.58%)**	**2(3.03%)**	**7**	

		Calf	**77 (6.49)**	**1(1.52%)**	**0 (0%)**	**1**	
Kilifi	**Breed**	**local**	**138**	**16(5.57)**	**3(1.05)**	**19**	**0.75**
		cross	**98**	**8(4.30)**	**1(0.35)**	**9**	
		saiwal	**24**	**0 (0)**	**0 (0)**	**0**	
		fresian	**16**	**6(37.5)**	**0(0)**	**6**	
		gernsey	**5**	**0 (0)**	**0 (0)**	**0**	
		arshire	**6**	**2(40)**	**0 (0)**	**2**	
Kwale		**local**	**186**	**9(2.94)**	**6 (1.96)**	**15**	**0.25**
		cross	**84**	**4(1.31)**	**3(098)**	**7**	
		saiwal	**16**	**2(0.65)**	**0(0)**	**2**	
		fresian	**12**	**6 (1.96)**	**0 (0)**	**6**	
		gernsey	**5**	**0 (0)**	**0 (0)**	**0**	
		arshire	**3**	**0 (0)**	**0 (0)**	**0**	
			306	**21**	**9**	**30**	
		Total		**159**	**39**	**198**	

Key: BC – Body Condition; N – Sample size; *T.* –*Trypanosoma*

APPENDIX VII: TSETSE FLY TRAPS SETTING IN THE FIELD

APPENDIX VIII: SIMILARITY REPORT



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