BINDURA UNIVERSITY OF SCIENCE EDUCATION FACULTY OF AGRICULTURE AND ENVIRONMENTAL SCIENCE DEPARTMENT OF ANIMAL SCIENCE

The role of small ruminants in the spread of Foot and Mouth Disease in Mbire district of Mashonaland Central Province.

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A dissertation submitted in partial fulfilment of the requirements for the Bachelors of Agricultural Science Honours Degree in Animal Health and Production Extension.

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APPROVAL PAGE

I hereby declare that the research project entitled "**The role of small ruminants in the spread of Foot and Mouth Disease in Mbire district of Mashonaland Central Province**" submitted to Bindura University of Science Education, Department of Animal Science is a record of an original work done by me under the guidance of my project supervisor. This work is submitted in partial fulfillment of the requirements for the award of the Bachelor of Agricultural Science Honours Degree in Animal Health and Production Extension. The results embodied in this dissertation have not been submitted to any University or Institute for the award of any degree of diploma.

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The undersigned certified that they have supervised and recommended to Bindura University of Science Education for acceptance of the dissertation entitled "**The role of small ruminants in the spread of Foot and Mouth Disease in Mbire district of Mashonaland Central Province**". Submitted in partial fulfillment of the Bachelor of Agricultural Science Honours Degree in Animal Health and Production Extension.

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ABSTRACT

Foot and mouth disease (FMD) is an economically and highly contagious viral disease that affects all cloven-hoofed domestic and wild animals. Although adult animals generally recover, the morbidity rate is high in naïve populations, and significant pain occurs in other species. A cross sectional study was conducted in Mbire District (Gonono and Bonga dip tanks) between April and May 2022, to determine the sero-prevalence and identify potential risk factors associated with FMD in goats and sheep. Results of the study showed that out of the 100 goats and sheep sampled, 39 animals tested positive for FMD virus antibodies in the two study areas representing an overall sero-prevalence of 39 % (95%, CI =29.4-48.58). At Gonono dip tank the sero-prevalence was 48% (95%, CI= 34.15-61.84), while at Bonga dip tank, the sero-prevalence was 30% (95%, CI=17.29-42.7). There was no significant difference in sero-prevalence between the two study areas (p >0.05). Antibodies to two Southern African Territories (SAT) serotypes (SAT 2 and SAT 3) were detected in the goats and sheep in the study areas. The results revealed that, there was no significant association between risk factors and sero-prevalence of foot and mouth disease in goats and sheep. However, males, ovine and mature animals are more likely to be sero-positive compared to females, caprine and young animals, respectively. These results show that FMD is prevalent in goats and sheep in Mbire District and that goats and sheep may play an important role in the epidemiology of the disease. It is therefore, recommended that these animal species should also be included in the routine vaccination programmes against FMD.

DEDICATION

I dedicate this report to my family for their unwavering support and for believing in me especially in my studies.

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CHAPTER 1

INTRODUCTION

1.1 Background study

Livestock husbandry in developing countries like Zimbabwe is critical for ensuring food security and for poverty alleviation (Falvey, 2015). Livestock are a source of meat, milk, hides and compost manure as well as an insurance against emergencies (Wanyoike, 2009). Sheep and goats (small ruminants) are sometimes preferred by farmers compared to large ruminants because of the small space they occupy and less feed requirements. In addition, goats have high adaptability to harsh climates which makes them suitable for husbandry in marginal areas (Kosgey *et al*., 2008). Small ruminant population in Zimbabwe stands at 522 955 sheep, 4 360 838 goats, of which 97 of the small ruminants are found in communal areas (MoLARR, 2020). Sheep breeds include Sabi sheep, Dorper, the Black Head Persian and the Suffolk (FAO, 2004). Among goats' breeds, the Small East African (Matabele and Mashona goat) is most dominant although other breeds include Boer, Saanen, Angora and the Kalahari goats are also found (Ndlovu *et al*., 2020). Small ruminant production is constrained by several infectious diseases including Foot and Mouth (FMD).

FMD is an acute highly contagious, transboundary disease caused by foot and mouth disease virus (FMDV). It affects cloven-hoofed domestic animals such as cattle, goats and pigs, as well as wild ruminants (Arzt *et al*., 2011). It severely affects livestock production leading to disruption of trade in animals and their products at regional and international level. A global strategy for the control of FMD was endorsed in 2012 to minimize the burden of FMD in endemic settings and maintain free status in FMD-free countries (OIE, 2018).

In Zimbabwe, FMD outbreaks have been recorded since the end of the 18th century (Latham and Marawanyika, 2018). The role of wildlife in spreading the FMD virus in Zimbabwe has been suspected for a long time (Anderson *et al*., 1993; Dawe *et al*., 1994). In 2018, Zimbabwe's Department of Veterinary Services (DVS) placed two districts in Mashonaland Central Province under quarantine and stopped the movement of all cattle in or out of the districts after FMD was detected in the southern Rutenga region and the Midlands areas of Kwekwe and Redcliff are these the only districts affected by the disease in 2018? (Latham and Marawanyika, 2018).

The FMDV is classified into the Picornaviridae family and the genus Apthovirus. It is a small non-enveloped virus with an encoder for four structural proteins and ten nonstructural proteins (Mahmoud *et al*., 2019). The disease is among the World Organization for Animal Health (OIE) listed diseases requiring immediate reporting and investigation in order to control its spread (OIE, 2018). The incubation period for foot-and-mouth disease is 3–8 days in small ruminants (Mahmoud *et al*., 2019).

The disease is characterized by high fever within two to three days, formation of vesicles and erosions inside the mouth leading to drooling of saliva. Vesicles are also on the nose, teats and when on the feet may rupture and cause lameness. It also causes several months of weight loss in adults and significant temporary or permanent reduction in milk production (Radostits *et al*., 2007). In sheep the disease persists for up to nine months and in goats for up to six months (Stenfeldt *et al*., 2014). FMD in adult sheep and goats is frequently asymptomatic, but can cause high mortality in young animals. Clinically the disease in young lambs and kids is characterized by death without the appearance of vesicles, due to heart failure following myocarditis (Barnett and Cox, 1999). Lameness is often characterized by unwillingness to rise and move (Mahmoud *et al.,* 2019). The disease can easily be missed unless individual animals are carefully examined for disease lesions. Small ruminants can therefore be responsible for the introduction of FMD into previously disease-free herds (Kitching and Hughes, 2002). Listed as a notifiable disease by the World Organization for Animal Health (OIE), FMD is therefore an important transboundary animal disease with consequences for international trade. With a few exceptions, FMD outbreaks have historically been observed in most areas in Zimbabwe where significant livestock productions occur.

1.2 Problem statement

Small ruminants (SR) have generally been neglected with regard to their epidemiological role in FMD transmission in cattle. This is partly due to the often-unapparent nature of the disease in these hosts. Nevertheless, their ability to become carriers represents a reservoir for further infection and spread of disease, and so trade of live sheep and goats present a major risk of entry of FMD to disease-free countries and herds. The monitoring and control of FMD in Zimbabwe is majoring on cattle neglecting possible risks that can be brought by small ruminants. Also, the deterioration in the socio-economic situation witnessed in Zimbabwe at the end of the last century, resulted in a drastic reduction of veterinary services' ability to control the disease, and eventually, in an upsurge of FMD outbreaks. This was a result of the change in land ownership, land-use and farming systems. Land reform program has resulted in the removal of disease control fences and they became irrelevant because of settlements on both sides of the fence.

1.3 Justification

Small ruminants can play an important role in the spread of FMD virus (FMDV) but it is not clear whether the virus can be maintained in these species for long periods in the absence of infection in cattle (OIE, 2008). Natural infection and carrier status has been reported in both sheep and goats (Ganter *et al.*, 2001). There are no confirmed reports of distinct FMD outbreaks in sheep and goats in Zimbabwe. Should small ruminants be involved as reservoirs or amplifiers of virus this would be indicated by a significant incidence of carrier animals and of those showing positive for FMDV antibodies on serological tests. Nevertheless, due to their ability to become carriers and act as reservoirs of infection, this poses major risk of entry of FMD to disease free countries through trade in these animals. There are reports that the silent nature of FMD in small ruminants transmits the virus causing outbreaks by the movement of infected sheep and goats. Although small ruminants are also affected by FMD and are herded together with cattle, they are not usually vaccinated (Nyaguthii *et al.*, 2019). Some studies have been carried out on FMD in cattle and buffaloes but no studies on the prevalence and associated risk factors in small ruminants have been done in Zimbabwe. This study investigated the sero-prevalence and potential risk factors associated with FMD in domestic small ruminants in Mbire district of Mashonaland central province in Zimbabwe.

1.4 Main objective

To determine the role of sheep and goats in the spread of Foot and Mouth diseases in Zimbabwe.

1.5 Specific objectives

i. To compute the sero-prevalence of FMD in goats and sheep in Mbire district

ii. To investigate potential risk factors associated with FMD occurrence in goats and sheep in Mbire district

1.6 Research questions

i. What is the sero-prevalence of FMD in goats and sheep in Mbire district?

ii. What are the determinants of FMD in goats and sheep?

CHAPTER 2

LITERATURE REVIEW

2.1 Importance of Livestock

Livestock are crucial to meeting the Millennium Development Goals (MDGs), as 70% of the rural poor rely on some form of livestock for their livelihoods (Richards, 2010). Livestock production has been known to reduce poverty among vulnerable and marginalized people. According to Heffernan (2004), attempts to put a more human face on poverty, usually portray the poor as victims of a hostile political, institutional, social and economic environment. A beck (2005), also notes that if considerations to eradicate poverty among poor livestock keepers arise, the capabilities and agency of the poor are not ignored. Livestock are the main means to enhance the poor people's potential. Vulnerability of households to normal seasonal food and income deprivations are reduced through selling and consumption of animal products.

Maburutse *et al.* (2010) postulated that livestock production will be sustainable if there is harmony among the stockman, livestock and the environment. The attitude and goal of the stockman are reflected in his management and breeding practices. FAO (2008) stated that the adaptation of the livestock to their environment is reflected in their productive efficiency. One can therefore note that it is the relationship among man, cattle and veld that can determine the sources of cattle production systems. Betterncourt (2013) believed human beings, through their control of the breeding and management of livestock as key to the question of harmony between man and his immediate environment. As such, the human being is either the problem or the solution. It is the type and quality of his or her stock and land that are a reflection of his attitude and ability. There are many constraints which are limiting the growth of livestock in many countries including Zimbabwe. Foot and Mouth disease is one of the limiting factors due to different wildlife productions systems in Zimbabwe, including lack of boundaries between wildlife and domestic animals especially in areas with large numbers of buffaloes. The buffaloes are known to be the reservoirs host for FMDV (Hedger *et al.,* 1972). Livestock raised in the vicinity of these areas are at constant risk of becoming infected with FMDV (Hyera *et al*., 2006). However, the veterinary administration in Zimbabwe has introduced a fencing policy for all livestock ranches in the country to avoid the contact of livestock with wildlife, especially the African buffalo (Baipoledi *et al*., 2004).

2.2 Aetiology of Foot and Mouth Disease

The FMDV is a member of a family Picornaviridae, genus Aphthovirus (Andrews *et al.*, 1978; James *et al*., 2012). It has a single-stranded, positive-sense RNA genome of approximately 8.4 Kb. There are 7 immunologically distinct serotypes of FMD with a large number of variants spread over several regions in the world (Alexandersen *et al*., 2003; Grubman and Baxt, 2004). These are O, A, C, SAT 1, SAT 2, SAT 3 and Asia 1 (OIE, 2007). Of these seven FMDV serotypes, O is the most prevalent worldwide (Reid *et al*., 2001). All the serotypes produce a disease that is clinically indistinguishable but immunologically distinct. There is no cross-immunity among serotypes (FAO, 2002). They can be differentiated by various serological tests, including the virus neutralization test (VNT), the complement fixation test (CFT) and ELISA (FAO, 2002). Within each serotype there is a spectrum of antigenic variation with strains of close or distant relationship to each other. Antigenic variation tends to be greatest within type A. Analysis of strains of FMDV by antigenic and genetic profiles is important in epidemiological studies and for the selection of the most appropriate vaccine strains for a region where vaccination is practiced (FAO, 2002).

2.3 Worldwide distribution of Foot and Mouth Disease

Foot and Mouth Disease is endemic in the Middle East, Iran, the Southern countries of the former Soviet Union, India and South East Asia and Africa (Aiello, 1995). Table 2.1 below shows worldwide distribution of foot and mouth disease serotypes.

Table 2.1: worldwide distribution of foot and mouth Disease serotypes

Serotype	**Representative country (ies)**	**References**
SAT 1	South Africa, Southern Zimbabwe, Mozambique	Vosloo *et al*. 1995 Bastos *et al*. 2001
	Botswana, Namibia, Zambia, Western Zimbabwe	
	Zambia, Malawi, Northern Zimbabwe	
SAT 2	South Africa, Mozambique, Southern Zimbabwe	Bastos *et al*. 2003b Vosloo *et al*. 1995
	Namibia, Botswana, Northern and Western Zimbabwe	
	Botswana, Zambia Zimbabwe	
SAT 3	South Africa, Southern Zimbabwe	Vosloo *et al*. 1995 Bastos *et al*. 2003a
	Namibia, Botswana, Western Zimbabwe	
	Malawi and Northern Zimbabwe	
	Zambia	
O	Brazil, Angola, Tanzania, Uganda	Sahle, 2003 Sangare *et al*. 2001
	Iran	
	Philippines	
	South Africa	
A	Mauritania, Mali, Côte d'Ivoire, Ghana, Niger, Nigeria, Cameroon, Chad, Senegal, Gambia, Sudan	Knowles and Samuel, 2003

	Angola, Algeria, Morocco, Libya, Tunisia, Malawi	Knowles and Samuel 2003
	Ethiopia	Knowles *et al*. 1998
	Uganda, Kenya, Ethiopia, Sudan, Eritrea	
C	Kenya	Reid *et al*. 2001 Knowles and Samuel 2003
	Ethiopia, Kenya	
	Angola	
C	Angola	Knowles and Samuel, 2003 FAO, 2007
	Kenya	
	Ethiopia	
Asia 1	Afghanistan, Bahrain, Iran, Pakistan, Turkey	OIE, 2011

The Pacific nations and the Caribbean are free from the disease (FAO, 2002). In the Sub-Saharan Africa, Madagasca, Mauritius and Seychelles are free from FMD, with a recognized status of FMD freedom without vaccination (Vosloo *et al*. 2002). Six serotypes, namely O, A, C and SAT 1, SAT 2 and SAT 3 are endemic in most sub-Saharan African countries with marked difference in distribution (Kitching, 1998; Vosloo *et al*. 2002). Serotypes SAT 1, SAT 2, A and O are the most frequently occurring, while serotype C rarely occurs (Rweyemamu *et al.*, 2000; Vosloo *et al.*, 2002). In some parts of Africa, virus persistence in wild African buffalo (*Syncerus caffer*) makes eradication unfeasible. Several studies in Southern Africa have shown that the African buffalo is capable of maintaining silent infection of serotypes SAT 1, SAT 2, SAT 3 and one buffalo can become infected with all three of the SAT serotypes of FMD virus and this poses a threat of infection to other susceptible cloven-hoofed animals (Bengis, *et al.*, 1986; Hargreaves *et al.,* 2004, Vosloo, 2002). Most living populations of African buffalo in Southern Africa have high infection rates with SAT serotypes of FMDV (Esterhuyse *et al.*, 1995). In the Kruger National Park in South Africa, rates of persistent infection of buffalo are estimated to be as high as 60% (Hedger *et al.,* 1972; Hedger *et al.,* 1976). These animals are usually persistently infected in the oropharynx, sometimes with multiple serotypes and often for long periods (Condy *et al*., 1985).

In Zimbabwe clinical FMD has not been observed in African buffaloes and all SAT serotypes of the virus have been isolated from clinically healthy animals of this species (Hedger *et al*., 1969; Mapitse, 1998). Consequently, cloven-hoofed livestock particularly cattle being raised in the vicinity of the areas where buffaloes reside are at constant risk of becoming infected with SAT type of FMD virus (Hyera *et al.,* 2006). Sporadic outbreaks of FMD have occurred in disease-free countries, with the exception of New Zealand, Greenland, Iceland and the smaller islands of Oceania. The last United States outbreak occurred in 1929 (OIE 2007). The map below distribution of FMD sero-types between 1990 and 2002.

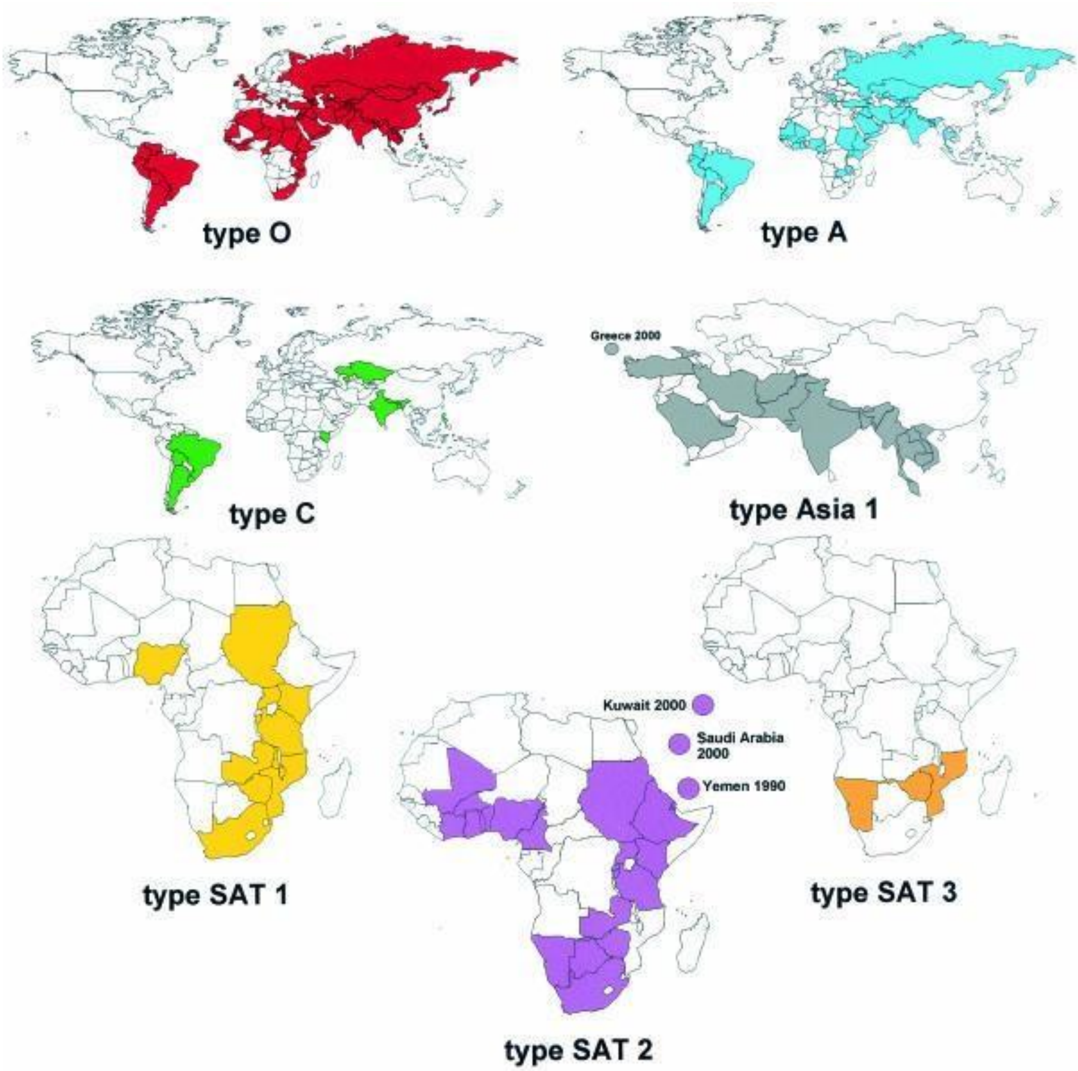

Figure 2.1; Distribution of FMD sero-types between 1990 and 2002 Sourced from; http://www.ncbi.nlm.nih.gov/core/lw/2.0/html/tileshop_pmc_inline.

2.4 History of Foot and Mouth in Zimbabwe

Over a 70-year period, from 1931 up to and including the outbreaks in 2001 and 2002, there have been 87 recorded primary outbreaks of FMD in Zimbabwe (Department of Veterinary Services (DVS) 1989, update), an average of about 1.2 per year. Over the past 20 years, when routine control measures have been at their best, there have been 17 an average of about 0.85 per year (Perry *et al*., 2003). This includes seven years when no outbreaks were recorded (1992-1996, 1998, and 2000). Between 1991 and 2000 there were only six outbreaks. In 2001 there were at least two primary outbreaks of FMD in the south of the country, with spread during the period August 2001 to July 2002 to at least a further 18 outbreaks. There have been distinct phases in the occurrence of FMD in Zimbabwe, reflecting changing capacity to control the disease effectively. From the early 1930s, when the disease reappeared in the country, there was increasingly effective control until the mid-1970s, when the civil war that preceded independence caused severe disruption to animal disease control efforts (Lawrence *et al*., 1980). Following independence, increasing levels of control led to Zimbabwe opening up export markets of beef to the European Union (EU) in 1985, and despite occasional outbreaks, including one that led to an 18-month interruption of meat exports to the EU between 1989 and 1991, the incidence of FMD in the country has been relatively low (Perry *et al*., 2003). Nevertheless, when compared to most of the other beef-exporting countries in the region with comparable levels of control, there has been a relatively high number of FMD outbreaks in Zimbabwe. This probably reflects the difficulty of maintaining the separation between domestic cattle and wildlife when the latter occupy extensive areas on the periphery of commercial farming areas in both the north and the south of the country. Since 2001 the incidence is again on the increase, with declining capacity to control the disease (Perry *et al.,* 2003).

Guerrini *et al*. 2019 carried out a study for the FMD outbreaks in Zimbabwe during the period 1931 to 2016. In the study major FMD drivers were also investigated which are; i. Distance from the protected areas ii. Seasons iii. Water availability iv. Political and economic.

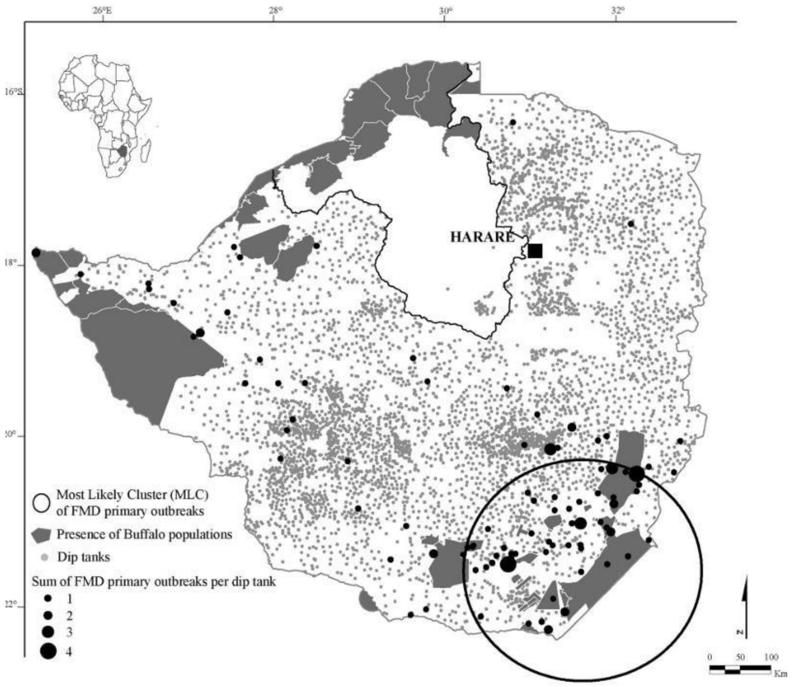

Figure 2.2: Foot and Mouth Outbreaks in Zimbabwe from 1931 to 2016(Guerrini *et al.*, 2019). The graph shows black dots which represent primary outbreaks and protected areas represented as grey areas (this is where African Buffalo resides).

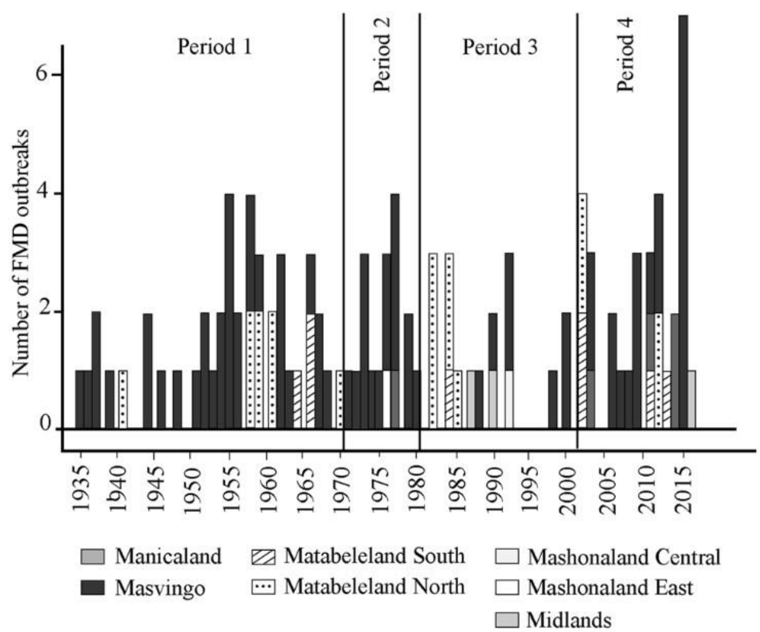

Figure 2.3 shows the numbers of outbreaks from the period 1931 to 2016.

2.5 Epidemiology

The epidemiology of FMD is influenced by a cycle in which wildlife plays a role in maintaining and spreading the disease to other susceptible domestic animals and wild ungulates and a cycle that is maintained within domestic animals that is independent of wildlife (Thomson *et al*., 2003). Outbreaks of FMD in cattle caused by SAT serotypes are usually associated with wild buffalo known to be the reservoir host (Thomson *et al*., 2003). According to Condy and Hedger, (1969), FMDV infections may be maintained in cattle sub-clinically by strengthening of the virus through serial passage in the same species and depending on the density of naïve cattle, epidemics may occur.

Potential risk factors which have been found to be associated with FMD include, farming system, age category of animals, breed type, sex and seasonal influence (Sarker *et al*., 2011). Other risk factors pointed out by Intha, (2009) include management of the farm, feed source of the animal, trade of animal and husbandry practices. The semi-intensive farm systems or smallholder livestock in developing countries are prone to FMD. The reasons might stem from either the increased contact between animals infected and animals susceptible to the infection or from higher virus survival in the more humid microclimate around water sources (Geering and Lubroth, 2002; Williams, 2003). Furthermore, raising goats with cattle may increase the risk of FMD infection because goats are highly susceptible to the FMDV and spread the virus via aerosol (Kitching and Hughes, 2002). This may be the mode of virus transmission to other animals that are raised together in the same area. Once an animal is infected, the virus can be disseminated into the environment including field pastures, water resources and soil. Sharing of pasture and water source is common in most African countries especially Botswana where farmers (small holder) feed their animals by letting the animals roam freely in communal pastures. This promotes the spread and infection of FMD. Moreover, FMDV infection in cattle is mainly transmitted via infected animal and susceptible animals in the same area by aerosol, because cattle are sensitive to respiratory infections (Kitching, 2005).

Purchasing cattle from animal markets is believed to be a risk factor of outbreaks of FMD into a herd. Bronsvoort *et al.* (2004) reported that cattle raised in a herd that brought in new cattle from other places were more likely to have the disease when compared to the cattle in a herd that did not bring in new cattle. Recently, the danger of spread of FMD by animal movement was clearly illustrated by a shipment of sheep from the UK that disseminated the virus to other animals in a rest-station in western France (Sutmoller *et al*., 2003). In addition, the chances of an animal getting infected increases with the age of the animal (Gelaye *et al*., 2009, Sarker *et al*., 2011). This had been attributed to younger animals being herded in homestead while adults are out most of the time, constantly being re-exposed to infection (Mackay *et al*., 1998).

The use of molecular epidemiology to elucidate the source of the FMDV has become common in recent years (Knowles and Samuel, 2003). Molecular epidemiology using phylogenetics relates FMDV isolates from outbreaks or persistently infected animals with viruses available at the viral gene bank at Onderstepoort Veterinary Institute (OVI) in Pretoria, South Africa, and World Reference Laboratory (WRL) for FMD at Pirbright in the United Kingdom. However, this does not reflect the true epidemiology of the disease because it does not account for the underlying factors. Bronsvoort *et al.* (2004) suggested structured sampling of endemically infected populations to understand complex epidemiological situations with multiple serotypes of FMDV and various degrees of diversity within serotypes circulating in a region or herd.

2.5.1 Susceptible species

Domestic livestock species susceptible to FMD include cattle, water buffaloes, pigs, sheep, goats and deers (FAO, 2002). The disease is generally most severe in cattle and pigs. Camelidae (camels, llamas and vicuñas) have a low susceptibility. Although rare, FMD in elephants, hedgehogs and some rodents has been documented (FAO, 2000). African buffaloes (Syncerus caffer) commonly become infected with FMD virus of the SAT serotypes. Human infections have been reported but are extremely rare and mild. However, people may harbor the virus in their respiratory tract for more than 24 hours without ever developing clinical disease (FAO, 2002).

2.5.2 FMD in animal products

Although the FMD virus is inactivated in the meat carcasses that undergo the normal post-slaughter acidification processes, it can retain infectivity for very long periods in frozen or chilled lymph nodes, bone marrow and residual blood clots, and for shorter periods in offals (FAO, 2000). Other products in which the virus can retain infectivity for long periods include uncooked salted and cured meats, green-salted hides, unpasteurized milk and some other dairy products (FAO, 2002)

2.5.3 The role of domestic animals in the Epidemiology of FMD

The role of domestic animals in the maintenance and spread of FMD in sub-Saharan Africa has not been studied in detail. However, it is accepted that domestic animals play a significant role in the epidemiology of FMD in East and West Africa due to uncontrolled domestic animal movement within and between countries, inadequate vaccination coverage to prevent disease transmission, and the fact that cattle, sheep, and goats can become FMD carriers (Vosloo *et al.*, 2002). In Zimbabwe for example, FMD spread seemed to have been perpetuated by domestic animal populations since the initial possible spread from buffalo in September 2001 (Vosloo *et al*., 2002).

Small ruminants can also play an important role in the epidemiology of FMD (Ganter *et al*., 2001). In adult sheep and goats, FMD is frequently mild or unapparent and the cardinal signs mimic other diseases which makes a clinical diagnosis difficult. However high mortality can result in young animals (Kitching and Hughes, 2002). Their ability to become carriers represents a reservoir for further infection and spread of disease, and so trade of live sheep and goats present a major risk of entry of FMD to disease free countries (Barnett and Cox, 1999). In Turkey, 18.5% of the total FMD cases reported in 1996 were associated with small ruminants (Taylor *et al*., 1996), and in Greece, during the 1996 FMD epidemic, 5,000 sheep and goats were destroyed (Kitching and Hughes, 2002). In the 2001 epidemic in Great Britain, the first species infected on the affected farms was almost always sheep (53%) or cattle (45%) rather than pigs (Ferguson *et al*., 2001). In an epizootiological study of FMD, in Sudan conducted by Habiela *et al*. (2010), liquid phase blocking ELISA revealed that antibodies to four serotypes (O, A SAT 1 and SAT 2), were present in goats and sheep. In Botswana the role that small ruminants play in FMD transmission is not known although previous studies had reported evidence of exposure to the virus in goats (Hyera *et al*., 2006).

2.6 The spread of FMD

FMDV can be found in all secretions and excretions from acutely infected animals, including expired air, saliva, milk, urine, faeces and semen. Pigs, in particular, produce large quantities of aerosolized virus (OIE, 2007). Animals can shed FMDV for up to four days before the onset of clinical signs (OIE, 2007). The virus can also be transmitted on fomites including vehicles, as well as mechanically by animals and other living vectors. Airborne transmission can occur under favourable climatic conditions. FMDV is thought to have been transmitted via aerosols from Brittany to Jersey (approximately 30 miles or 48 km) and for approximately 70 miles (113 km) from Jersey to the Isle of Wight (Bartley *et al*., 2002).

Infected herds which practice transhumance or are nomadic can spread the infection to other herds long before diagnosis of the disease is established (Ganter *et al*., 2001). Shipping and trade with live sheep and goats are much more common than in other FMD susceptible species (Ganter *et al*., 2001). Ability to become carriers for a period of time represents a reservoir for further infection and spread of the disease, and so trade of live sheep and goats presents a major risk of entry of FMD to disease-free countries (Barnett *et al*., 1999). Lack of registration of all sheep and goat herds (especially of small hobby herds) and lack of individual identifications signs (ear tags) may result in difficulties in controlling the disease (Ganter *et al*., 2001). Another important factor in the transmission of FMD virus is its relative stability under the right environmental conditions (Cottral, 1969). Relative humidity levels above 55%, cool temperatures and approximately neutral or slightly alkaline conditions favour prolonged survival of infective aerosols and fomites (Donaldson, 1986). In cattle, the incubation period varies from two to 14 days, depending on the dose of the virus and route of infection. In pigs, the incubation period is usually two days or more, but can be as short as 18-24 hours (OIE, 2007). The incubation period in sheep is usually 3 to 8 days. Incubation periods as short as 24 hours and as long as 12 days have been reported in this species after experimental infection (OIE, 2007).

2.7 Clinical signs of FMD

Clinical signs of FMD are more severe in cattle and intensively reared pigs than in sheep and goats, resulting in the disease being frequently ignored or misdiagnosed in small ruminants (Aiello, 1995). Although the disease is frequently mild or unapparent in adult cattle, sheep and goats, FMD can cause high mortality in young animals (Kitching *et al*., 2002). In the mouth, vesicles are particularly prominent on the tongue, dental pad and gums. In severe cases, most of the mucosa of the dorsal surface of the tongue may slough. The painful stomatitis associated with unruptured and freshly ruptured vesicles causes excess salivation, lip smacking and cessation of eating. There is rapid loss of body condition (FAO, 2000). According to Radostits *et al*. (2000), vesicles are also formed around the coronary band and skin of interdigital spaces. Fluids from ruptured vesicles spread to areas of abraded skin, for example that of mammary glands. Vesicles often rupture rapidly, becoming erosions. Pain and discomfort from the lesions lead to a variety of symptoms including depression, anorexia, excessive salivation, lameness and reluctance to move or rise. Lesions on the coronary band may cause growth arrest lines on the hoof (OIE, 2000).

2.8 Prevention and control

The most important resource in the prevention of FMD is the informed animal owner or manager. Livestock owners at all levels of production, and traders should be familiarized with the basic features of FMD, including the recognition of the essential signs of the disease, how and where to seek help if they suspect the disease (FAO, 2002).

Many countries free of FMD have a policy of slaughter of all affected and in-contact susceptible animals and strict restrictions on movement of animals and vehicles around infected premises. After slaughter, the carcasses are either burned or buried on or close to the premises and the buildings are thoroughly washed and disinfected with mild acid or alkali and fumigated (Aiello, 1995).

In endemic countries, vaccination is the best control strategy that may be applied with quarantine. Vaccines must be formulated taking into account the virus type and subtypes prevalent in the area. Vaccination programmes must cover not less than 80% of the susceptible population, preferably 100% of cattle so as to maintain a reliable hard immunity status (OIE, 2000).

Research and epidemiological studies continue to be necessary in order to both prevent the entry of the virus and to assist in control should the disease reoccur (Bannert and Cox, 1999). Vaccines with oil adjuvant were found to elicit a better immune response at any time than did aluminium hydroxide gel vaccine, and the response developed quicker (Patil *et al*., 2002). The animals maintained their neutralizing antibody titers at >3 log (10) for the duration of the trial (90 days). Sheep have been found to be late responders to serotypes A, C, and Asia-1; a clear upward shift in titer was observed at 60 days post vaccination. However, development of the immune response to serotype O in sheep has been found to be superior to that in cattle and goats (Patil *et al*., 2002).

The following control measures are important in reducing the spread of foot and mouth these are;

I. Early detection and reporting of the FMD to limit the spread of the disease

II. Quarantining of the infected animals at the premised where it was detected

III. Containing the spread of the disease by restricting the movement of the animals from the premises.

IV. Vaccination of cattle to eradicate the disease

V. Continuous surveillance in the FMD prone diseases

CHAPTER 3

MATERIALS AND METHODS

3.1 Study site

The study was conducted in Mbire District of Mashonaland Central Province in Zimbabwe. Communal lands are a land category that is characterized by communal land ownership, and they are subdivided into administrative or management units called wards. The study area is located between 30° 00 and 31° 45 E and 16° 00 and 16° 30 S. Mbire has a dry tropical climate, with a low and erratic annual rainfall of between 350 and 1300 mm and a mean annual temperature of 25°C. The average altitude is 400 m above mean sea level (a.m.s.l.) (CIRAD-Emvt 2002). The soils of the study area vary from eutric leptosols, to tropically leached iron-bearing soils and calcic luvisols. The natural vegetation of Mbire district is mainly deciduous dry savannah, dominated by mopane trees (*Colophospermum mopane*) (Gaidet *et al*., 2003). Mbire district has 17 wards and a total of 27 dip tanks.

Most human settlements in Mbire district are along the Angwa and Manyame rivers in a wildlife conservation frontier. The wildlife is mainly concentrated in areas that are tsetse infested, while humans are settled mainly in tsetse-free areas (Cumming and Lynam, 1997, Murwira and Skidmore, 2005). The major human activity in this district is livestock rearing and dryland farming of cotton, maize and sorghum, and often results in human–wildlife conflicts. Due to erratic rainfall, the ward like Kanyemba is considered unsuitable for dry-land cropping, and as a result floodplain crop cultivation is practiced. Goats are the major livestock kept in the area since the area is infested with tsetse flies which make livestock rearing difficult. Cattle are a preferred host of tsetse flies. The area is suitable for livestock production under extensive production systems and for wildlife production (FAO, 2006). Figure 3.1 shows the map of Mbire District

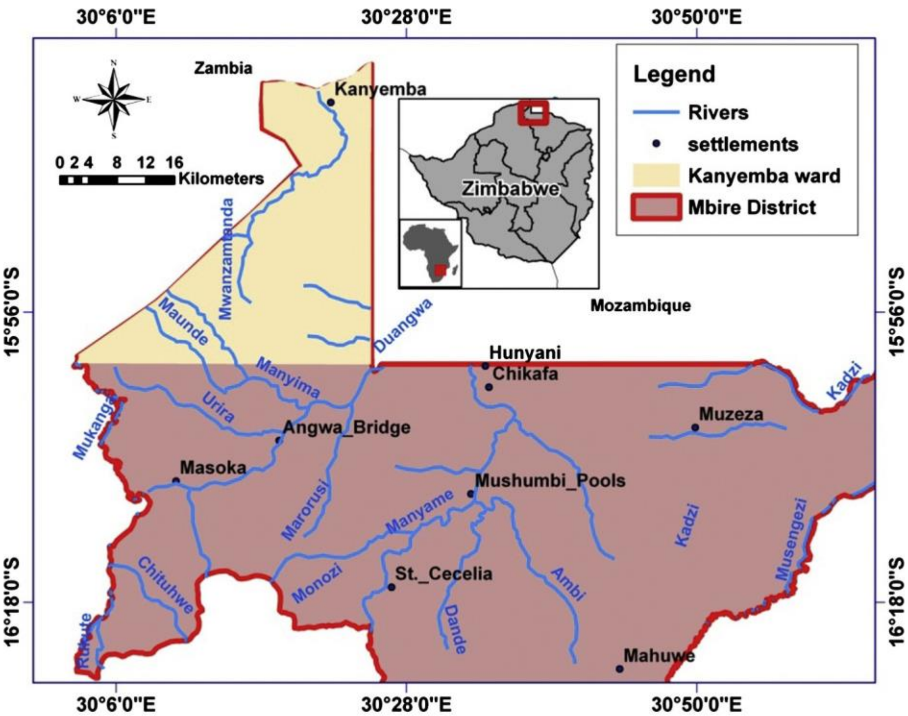

Figure 3.1: Map of Mbire district

3.2 Study design and Sampling

A cross-sectional study was undertaken from April to May 2022. The sampling unit was the flock of sheep and goats. The sampling was conducted at Gonono and Bonga dip tanks of Mbire district. A total of 20 farmers were selected for both goats and sheep sampling. The samples were taken from corresponding kraals of the affected cattle with Foot and Mouth disease. A total of 50 goats and 50 sheep were sampled. The total number of goats and sheep sampled was determined using the formula described by Dohoo *et al.* (2003). To maximize the number of goats and sampled, the sample size was estimated by assuming a prevalence of 50%. The precision was decided to be 5% and the confidence level at 95%. The minimum sample size after adjusting for the loss (by a factor of 1.1) and stratification by a factor of 0.5 was 424. However, a total of 100 goats and sheep from the district were sampled in the study. Blood samples were collected from goats with no history of FMD vaccination. Blood samples were collected from individual goats and sheep aseptically from the jugular vein into 10 ml sterile plain vacutainer tubes. Consent was always sought from the owner before sampling and samples were only collected from those where permission was granted. The owner(s) and the veterinary paraprofessional (VEW), manually restrained the animals during sampling. Each tube used was identified clearly. After collecting the blood samples were allowed to clot by placing them over night at room temperature. Serum was harvested from the clotted blood into 5ml cryo tubes. The cryo tubes were properly labeled and delivered to the Zimbabwe Central Veterinary Laboratory (DVS) on ice in cooler boxes. At the laboratory, it was stored at -20 ^{o}C until analyses.

At the same time as blood sampling, a questionnaire was administered to individual farmers to help in the identification of possible risk factors. Variables under consideration included, the breed, location of the animals, system of rearing, husbandry practices, proximity to national parks and types of animals kept with goats and sheep, roaming wild life, watering points and mixing with other animals.

3.3 Laboratory testing

A solid-phase solid phase blocking enzyme-linked immunosorbent assay (ELISA) was used in the laboratory analysis of the serum samples. It was used to determine the level of exposure to the South African Territories (SAT) serotypes (SAT1, SAT2 and SAT3) of the foot and mouth disease virus (FMDV) of apparently healthy, unvaccinated indigenous goats and sheep of Mbire district.

The procedure adopted for the solid-phase competition ELISA (SPCE) was as follows (50 µl reagent volumes were used throughout, ELISA plates [Nunc Maxisorp immunoplates] incubated for 1 hour in 37^{o} C on a rotary shaker, unless otherwise stated, and plates washed three times with phosphate buffered saline [PBS, pH 7.4] containing 0.05% Tween 20 after each incubation step). Plates were coated with an optimal dilution of rabbit antiserum to FMD virus in carbonate/bicarbonate buffer, pH 9.6 and incubated overnight at $+4^{o}$ C. Next an optimal dilution of 146S antigen of FMD virus homologous to the rabbit antiserum was diluted in PBS containing 0.05% Tween 20 and phenol red indicator (PBST) and added to each well. Duplicate, two-fold dilutions of each test serum (from an initial dilution of 1:2.5) in PBST containing 10% normal serum of the species under test and 5% normal rabbit serum (blocking buffer 3) were performed in plates. Immediately homologous guinea pig antiserum, diluted to the optimal concentration in blocking buffer, was added to each well. After plate incubation, an optimal dilution of rabbit anti-guinea pig immunoglobulins conjugated to horse radish peroxidase in blocking buffer was added to each well. Substrate (0.05% H2O2)/chromogen (orthophenylene diamine) in citrate/phosphate buffer, pH 5.0 was next added. After 15 min incubation the reaction was stopped by adding 1.25 M sulphuric acid. The optical density (OD) of each well was read by using a spectrophotometer (Dynatech) with a 492 nm filter. Antibody titres were expressed as the last dilution of serum showing 30% inhibition of OD compared to the mean OD of the reaction control wells where serum was absent. The procedure was done for all the South African Territories (SAT) serotypes (SAT1, SAT2 and SAT3) of the foot and mouth disease virus (FMDV).

3.4 Data analysis

Data collected was entered into Microsoft Excel and coded for analysis and imported from Microsoft excel to SPSS for analysis, with all the potential risk factors analyzed. Descriptive statistics were generated for each of the variables under investigation. The binary logistic regression was used to find out which factor is a determinant to Foot and Mouth disease. The step-wise binary logistic regression model was used to determine predictors (risk factor) of being serologically positive for FMD. The Logit link function reported the coefficient, p value, odds ratio (OR) and 95% lower and upper confidence interval values for the OR. All statistical tests were considered significant at $p<0.05$.

CHAPTER 4

RESULTS

The cross-sectional study was carried out from August to September 2022 at two dip tanks (Gonono and Bonga) in Mbire district. In the study, 20 herds were sampled yielding 100 samples. 40 farmers were asked to fill the questionnaires and all were completed.

4.1 Animal and herd level descriptive statistics of Mbire District

4.1.1 Animals kept by farmers

Farmers indicated various animals they were keeping in their homes, including cattle (97%), Sheep (45%), Goats (100%), Pigs (97.5) and poultry (97.5) (Table 4.1).

Table 4.1: Animals kept by farmers in Mbire District

Variable	Frequency	Percentage
Cattle	39	97.5
Sheep	18	45
Goats	40	100
Pigs	39	97.5
Poultry	31	97.5

4.1.2 Number of Goats and Sheep kept by farmers

Farmers in Mbire District indicated that they have an average of 9 Goats and 5 Sheep per household (Table 4.2).

Table 4.2: Number of Goats and Sheep kept by farmers in Mbire District

Animal	Mean	Standard Deviation
Goats (total)	9	6.54
Bucks	2	1.06
Does	11	8.46
Goat weaner	2	2.95
Kids	5	6.38
Sheep (total)	4	2.56
Rams	1	1.52
Ewes	5	6.97
Sheep weaner	1	1.83
Lambs	2.05	3.18

4.2 Social characteristics of goat and sheep farmers in Mbire District

All the respondents indicated that, they kept Goats and Sheep to provide them with meat, manure and as a source of income (Table 4.3). Of the 40 farmers interviewed, 16 (40%) indicated that they were given permits to sell their animals beyond the boundaries of Mbire District. Almost all of the respondents (97.5%) indicated that they use extensive farming system for their animals. Farmers also indicated that, they mix goats and sheep with cattle (97.5%) and with animals of neighbours (100%) when grazing.

Of the 40 respondents interviewed, 42.5% indicated that they use own/community borehole to provide goats and sheep drinking water while others go to the river. Farmers also indicated that these water drinking points are also a source of drinking water to cattle (97.5%) and wildlife (65%).

Of the 40 farmers interviewed, 62.5% indicated that they house their goats and sheep separately, while 35% were mixing with other animals. A few farmers (7.5%) indicated that their animals mix animals from neighboring countries (Mozambique).

Table 4.3: Social characteristics of goat and sheep farmers in Mbire District

Variable	**Frequency**	**Percentage**
Purpose of Goat and Sheep		
Milk	0	0
Meat	40	100
Manure	40	100
Source of income	40	100
Authorization when selling		
Permit to sell to other places	0	0
Permit within	16	40
Type of farming		
Extensive	39	97.5
Semi-intensive	1	2.5
Do you mix your flock with cattle when grazing (Yes=1)	39	97.5
Animals mix with animals from other kraals (Yes=1)	40	100
Do you have a borehole		
Yes	17	42.5
No	23	57.5
Other animals drinking from the same borehole		
Cattle	39	97.5
Wildlife	26	65
Any wildlife in the area (Yes=1)	30	75
Housing animals		
Separately	25	62.5

Mixing	14	35
No housing	1	2.5
Any chance of your animals mixing with animals in neighboring countries		
Yes	3	7.5
No	37	92.5

4.3 Diseases for Goats and Sheep

Farmers in Mbire District indicated various diseases which were affecting goats and sheep, including Coenurosis, Foot rot, Pulpy Kidney, Lumpy Skin and Foot and Mouth disease. Of the 40 farmers interviewed, only 2.5% had experience with foot and mouth disease in goats and sheep. All farmers indicated that they had more experience with foot and mouth disease in cattle, whereas 20% indicated that they have vaccinated their goats and sheep against other diseases mentioned above. Farmers indicated various symptoms of foot and month in cattle, including lameness, salivation and blisters on the muzzle, mouth and tongue, and soars on hooves. Due to high prevalence of internal parasites, all farmers indicated that they use deworming as a control of these parasites.

Table 4.4: Diseases for goats and sheep in Mbire District

Variable	**Frequency**	**Percentage**
Do you vaccinate your goats and sheep against any disease		
Yes	8	20
No	32	80
Who does the vaccination (Yes=1)		
Veterinary officers	8	20
Other treatments methods (Yes=1)		
Deworm	40	100
Experience with FMD in goats and sheep		
Yes	1	2.5
No	39	97.5
Which animals are mostly affected		
Goats	1	2.5
Which age is affected		

Adult	1	2.5
Do you vaccinate your goats and sheep against FMD		
Yes	1	2.5
No	39	97.5
If no, which animals do you vaccinate against FMD		
Cattle	39	97.5

4.4 Prevalence of Foot and Mouth Diseases in Mbire District

Table 4.5 shows the percentage prevalence of foot and mouth disease of small ruminants (goats and sheep) captured at Gonono and Bonga dip tanks of Mbire District and the 95% confidence intervals. For variables with more than two categories, chi-square reported in Tables 4.5 is for sero-prevalence for all categories. The chi-square reported in the ensuing text are for pair-wise comparison of sero-prevalence. The overall prevalence of foot and mouth disease was 39% where 39 goats and sheep were affected by foot and mouth disease. Ovine (42%) had higher prevalence compared to Caprine (36%), although there was no statistical difference ($p > 0.05$) between animal species prevalence ($\chi^2 = 0.38$; p value= 0.539). Sero-prevalence in male animals (45%) was higher than in female animals (37.5). There was no statistical difference ($p > 0.05$) between the prevalence of male and female animals ($\chi^2 = 0.38$; p value= 0.539).

The heard from Gonono (48%) had higher prevalence compared to the animals from Bonga dip tank (30%). There was no statistical difference ($p > 0.05$) between the prevalence in Gonono and Bonga dip tanks ($\chi^2 = 3.4$; p value= 0.065). The sero-prevalence was higher in mature animals (40%) which were above 1 year compared to young animals (34.78%). Statistical analysis revealed no significant difference ($p > 0.05$) between the prevalence of mature and young animals ($\chi^2 = 0.22$; p value= 0.637).

Table 4.5 Prevalence of Foot and Mouth Diseases in Mbire District

Risk factors	Animals examined	Prevalence (%)	95 % CI	*Chi-sq.*	P value
Overall	100	39	29.4-48.58		
Animal species					
Caprine	50	36	22.6-49.03	0.38	0.539
Ovine	50	42	28.31-55.68		
Sex					
Male	23	45	23.19-66.8	0.38	0.539
Female	80	37.5	26.89-48.11		
Dip tank					
Bongo	50	30	17.29-42.7	3.4	0.065
Gonono	50	48	34.15-61.84		
Age					
Mature	77	40	29.3-51.21	0.22	0.637
Young	23	34.78	15.31-54.24		

4.5 Serotypes detected in Gonono and Bonga dip tanks

SAT serotypes (SAT 2 and 3) were detected in both animals tested. For caprine, 26% tested for serotype SAT 2 and 16 tested for serotype SAT 3. For ovine, 16% tested for serotype SAT 2 and 20% tested for serotype SAT 3.

Table 4.6 Serotypes detected in Gonono and Bonga dip tanks

Foot and Mouth Disease	STA 1 (%)	SAT 2 (%)	SAT 3 (%)
Caprine	0	26	16
Ovine	0	16	20

4.6 Association of the risk factors and foot and mouth disease

The most parsimonious mixed effects logistic regression model showing the association between FMD sero-positivity in small ruminants and risk factors as well as the relevant interactions are in Table 4.7. Interpretation of OR for risk factors that were negatively associated with FMD sero-positivity was after finding the inverse of OR (1/OR) as specified by Bland and Altman (2000). All risk factor were not significantly associated (p >0.05) with FMD prevalence. Therefore, with reference to mature animals, young animals were 0.82 less likely to be sero-positive for FMD. Compared to Gonono dip tank, Bonga dip tank had 1.63 less likely to be sero-positive. Female animals were 0.83 less likely to be sero-positive compared to male animals. Caprine species (goats) were 1.18 less likely to be sero-positive compared to Ovine species.

Table 4.7 Association of the risk factors and foot and mouth disease

Risk factor	**Variable**	**Odds Ratio**	**P value**	**95% CI**
Age				
	Mature	Ref		
	Young	0.82	0.609	-0.98-0.57
Dip tank				
	Bonga	Ref		
	Gonono	1.63	0.138	-0.15-1.14
Sex				
	Male	Ref		
	Female	0.83	0.629	-0.93-0.56
Species				
	Ovine	Ref		
	Caprine	1.18	0.6	-0.46-0.80

CHAPTER 5

DISCUSSION

Small ruminants (SR) have generally been neglected with regard to their epidemiological role in Foot and Mouth Disease (FMD) transmission. This is partly due to the often-unapparent nature of the disease in these hosts. Nevertheless, their ability to become carriers represents a reservoir for further infection and spread of disease, and so trade of live sheep and goats present a major risk of entry of FMD to disease-free countries and herds. The current study was based on blood samples of goats and sheep taken an Bonga and Gonono dip tanks of Mbire District. Farmers in Mbire District indicated that they have an average of 9 Goats and 5 Sheep per household, where they use these animals as a source of meat, manure and income (especially for school fees).

The overall average prevalence of this study was found to be 39% similar to what has been found by Raletobana, (2014) in Botswana. It is however higher than reported in somewhere: 3.5-13.4%

in Botswana (Hyera *et al*. 2006), 21.8% in Nigeria (Lazarus *et al*. 2012), 28.57% in Sudan (Habiela *et al*., 2010), 13% in Uganda (Balinda *et al*., 2008, 2009) and 22.5% in Kenya (Chepkwony *et al*., 2021). Similarly, sheep had higher prevalence of 42% compared to 36% of sheep and this was even higher compared to prevalence of FMD in goats (24%) and sheep (21.9%) reported in Kenya (Chepkwony *et al*., 2021). The differences noted could probably be due to different testing methods used. The susceptibility of goats and sheep to FMD can vary with the breed and virus strain (Kitching and Hughes 2002) and this could also probably explain the differences noted. A previous study in cattle in Kenya showed much higher sero-prevalence in cattle at 52.5% (Kibore *et al*., 2013). This means sheep and goats could be less susceptible to Foot and Mouth Disease Virus (FMDV) compared to cattle despite the fact that they are normally herded together in endemic settings of Zimbabwe. This was also observed through the questionnaire where most of the farmers (97.5%) indicated that they mix goats and sheep with cattle during grazing.

In the absence of vaccination, sero-prevalence to FMDV can be an indicator of presence of FMD. Sero-prevalence was higher in Gonono dip tank (48%) compared to Bonga dip tank (30%). This may be attributed to a high level of herd mobility, contact of animals at grazing and watering points, dynamism of herds (frequent additions) and frequent contact with the livestock of neighbouring countries through cross-border contact as Gonono is very close to Mozambique boundaries. In the process of movement, they also come in contact with other animals from different areas which are an important factor for the transmission of the disease as all farmers interviewed use extensive production system.

There were differences in observed in sero-prevalence of FMD among mature (40%) and young goats and sheep animals (34.78%), although no statistical differences were observed. This is in agreement with the results of others (Torsson *et al*., 2017, Casey-Bryars, 2016) although the sero-positivity levels in our study were lower. The difference in sero-positivity between age groups may be due to the fact that mature animals may have experienced more exposures to FMD at grazing, watering point and at market than in age group less than one year. Therefore, adult animals might have acquired infection from multiple strains and serotypes thus producing antibodies against multiple virus incursions of FMD. It could also be due to cumulative sero-positivity through repeated infection in their longer life time. The low prevalence in young animals may also be indicative of persistent passive immunity and less frequency of exposure of the animal to the disease as the farmers keep their lambs and kids in the homesteads. Males showed higher sero-prevalence at 45% than females (37.5%). These results are similar to Ethiopian studies where 15.7% and 8.3% sero-conversions were reported in male and female animals respectively (Jenbere *et al*., 2011) and 8.9% in female while 3.0% in male (Mesfine *et al*., 2019).

In spite of many variables showing differences in proportions of sero-positive animals across the categories, all variables showed non-significant negative correlation with FMD sero-positivity in goats and sheep. Goats and sheep are not routinely vaccinated against any of the FMDV serotypes in Zimbabwe. Hence, the demonstration of FMD antibodies in goats during the present study is indicative of infection by the field FMDV. Goats and sheep are known to become carriers after exposure to FMDV and are estimated to maintain the live virus for 2-3 months (Anderson *et al*., 1976). The transient appearance of lesions and their similarity to those caused by other common diseases of ruminants makes clinical diagnosis of FMD in goats difficult (Kitching and Hughes 2002). Hence, the disease may be present in a flock for a considerable time prior to discovery. It is therefore possible that goats and sheep could be playing an important role in the epidemiology of FMD in the country

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusions

The overall average percentage prevalence of foot and mouth diseases in small ruminants (goats and sheep) in Mbire District was 39% and that figure was much higher compared to the previous sero-prevalence study on small ruminants conducted in Zimbabwe.

The current study revealed that, there was no significant association between risk factors and sero-prevalence of foot and mouth disease in goats and sheep. However, males, ovine and mature animals are more likely to be sero-positive compared to females, caprine and young animals, respectively.

6.2 Recommendations

It is recommended that goats and sheep must also be included in the vaccination programmes against the disease to reduce transmissibility of the disease to naive animals. Routine FMD inspections in small ruminants and inclusion of these animals in serological surveillance in boarders must be mandatory. Strictly monitoring the trade and movement of these animals in boarder areas to reduce FMD transmission. Further studies should be conducted to determine how long the goats and sheep in Zimbabwe can remain carriers of the disease. Experimental studies need to be conducted to find out if goats and sheep are able to transmit FMDV to other susceptible species especially cattle. Farmers also need to be made aware of the fact that goats and sheep also can get FMD and there is a possibility that they can even spread it to other species like cattle.

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Appendices

Appendix 1: QUESTIONNAIRE FOR FARMERS IN MBIRE DISTRICT

My name is **Chonde Deria**. I am student at the Bindura University of Science Education (BUSE) studying towards a degree in Animal Health and Production Extension. I am conducting research on the topic entitled "**The role of small ruminants in the spread of Foot and Mouth**

Disease in Mbire district of Mashonaland Central Province." I kindly ask for your assistance in filling out this questionnaire**.** The research is purely for academic purposes and shall not be used for any other purpose without the permission of the participants. Ethical considerations of confidentiality and privacy are honoured and guarantee of anonymity of respondents is assured. I value and appreciate your willingness to help me in my research process.

GENERAL INSTRUCTIONS

Kindly attempt all indicated questions and complete the questionnaire by completing in the blank

SECTION 1

FARMER'S DETAILS

Age…………………………….

District..

Ward ....

Village of Farm…………………………………….

Diptank

1. Number of children and dependents--

2. Occupation --

Section 2

LIVESTOCK PRODUCTION

1.Which animals do you keep on your farm

a. Cattle ☐

b. Goats and Sheep☐

c. Pigs ☐

d. Poultry ☐

e. Others, specify---

2. Number of goats---------------------------------

3. Breeds--

Goat Population dynamics

Adult females------------- Adult males-------------- Kids------------- Weaners ---------------

4. Number of sheep---------------------------------

5. Breeds--

Sheep Population dynamics

Adult females------------- Adult males-------------- Kids------------- Weaners ---------------

SECTION 3

GENERAL QUESTIONS

6. Do you depend on your animals for payment of their school fees? **Yes** ☐ **No** ☐

7. How long ago did you sell animals? ---

8. When you sell animals across borders or across the region do you get release or authority from the Veterinary department or you just sell.

9. Apart from livestock rearing what do you do for a living? ---

10. What type of farming/grazing do you practice?

a. Extensive ☐

b. Intensive ☐

c. Semi-intensive ☐

11. If it's extensive farming does your flock mix with cattle? **Yes** ☐ **No** ☐

11. Do your animals mix with animals from other kraals when grazing? **Yes** ☐ **No** ☐

12. Do you have a borehole? **Yes** ☐ **No** ☐

13. If no where do your animals drink? ---

14. Are they any other animals drinking from the same water source? ---------------------------------
----

15. If yes what other animals use the same water source? **Yes** ☐ **No** ☐

16. Is there any roaming wildlife in your area? **Yes** ☐ **No** ☐

17. Are they any national parks and game reserves in your area? **Yes** ☐ **No** ☐

18. How do you house your livestock?

Separately ☐ mixing ☐ no housing structure ☐

19. Are there any possibilities for your livestock to mix with the neighboring country's' livestock

Yes ☐ No ☐

SECTION 3

Disease control

20. What are the common diseases of goats and sheep in the area?

....

....……………………………………………………………………

…………..

....

21. Do you vaccinate against any of these diseases? **Yes** ☐ **No** ☐

22. If yes, who does the vaccination?

…………..

23. What other disease control methods do you employ in your flock (list diseases and possible control methods)?

....

....……………………………………………………………………

…………..

........…………..

....

24. Have you ever experienced foot and mouth disease in your flock? **Yes** ☐ **No** ☐

25. If yes, what are the signs and symptoms of FMD

....

....……………………………………………………………………

…………..

.......…………...

....

26. If yes, which animals are affected by FMD

....

....

25. If yes how many animals were affected?

a. goats ....

b. sheep ....

26. What ages were affected?

....

....……………………………………………………………………

…………..

27. Did you experience FMD in any other animals other than goats/sheep? **Yes** ☐ **No** ☐

28. If yes, which animal was the disease noticed first?

....

....

29. Do you vaccinate your animals for FMD? **Yes** ☐ **No** ☐

30. How often do you vaccinate? Weekly ☐ Forty night ☐ Monthly ☐

Yearly ☐

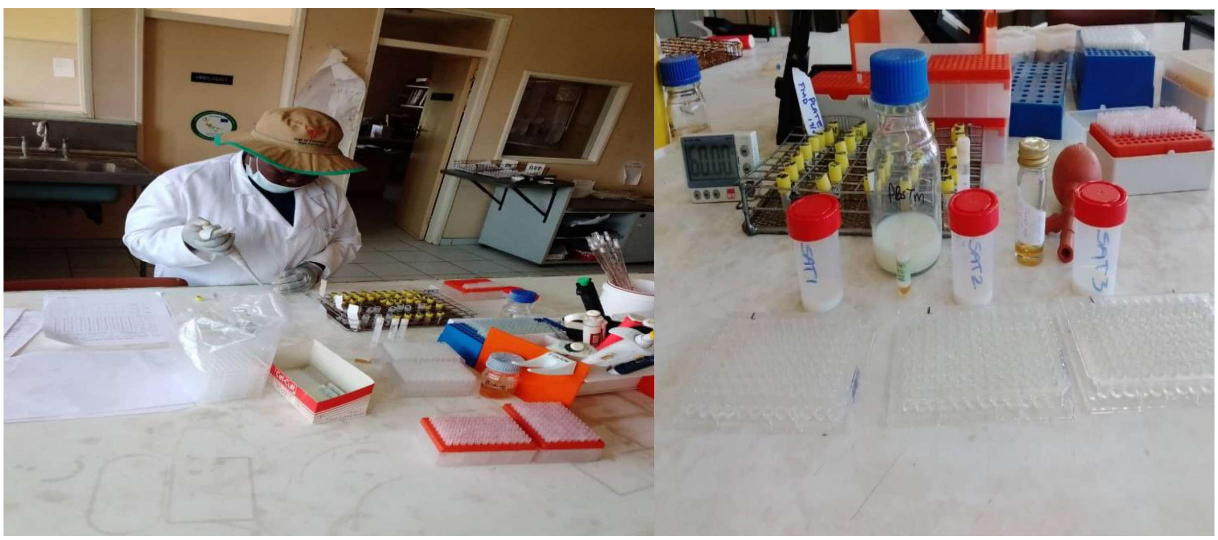
31. Which species do you vaccinate?

....

....

Appendix 2: Pictures taken during data collection

Blood samples taken from goat and sheep at Gonono and Bonga dip tank, respectively.



Blood testing at Zimbabwe National Veterinary Laboratory