Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

**Faculty of Veterinary Medicine
and Animal Science**

Transboundary caprine diseases in Zambia

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Uppsala

2020

Degree Project 30 credits within the Veterinary Medicine Programme

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Degree Project in Veterinary Medicine

***Credits**: 30 HEC*
***Level**: Second cycle, A2E*
***Course code**: EX0869*
***Course coordinating department:** Department of Clinical Sciences*

***Place of publication**: Uppsala*
***Year of publication**: 2020*
***Online publication**: https://stud.epsilon.slu.se*
***Cover illustration:** Photo by Elin Johansson*

***Key words**: peste de petits ruminants, contagious caprine pleuropneumonia, foot and mouth disease, caprine*

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SUMMARY

Peste des petits ruminants (PPR), contagious caprine pleuropneumonia (CCPP), and foot and mouth disease (FMD) are highly contagious that can rapidly spread throughout a country. Due to the many health effects, and potentially high mortality, they have an extensive impact on the production system. In Zambia, most livestock are kept by small-scale farmers. The poverty level is high, and many rely on their animals both for generating food and income and suffer directly if their animals were to fall ill or die. Also, on a national level, major costs arise because of e.g. campaigns for surveillance and vaccination. For low- and middle-income countries, controlling and if possible eradicating diseases like PPR, CCPP, and FMD are of vital importance.

FMD is considered endemic in Zambia with reoccurring outbreaks. The previous research in Zambia has focused on FMD in cattle and to a lesser extent on smaller ruminants such as goats. Regarding PPR, seropositive animals have previously been found, but no cases with clinical disease have been confirmed. No published research has been conducted in Zambia regarding CCPP. Since both PPR and CCPP have been confirmed in neighboring countries, there is a significant risk of these diseases being either introduced or already circulating in Zambia undetected. Further research on these diseases in goats is therefore motivated.

In this study, goats were sampled in the Southern province in the districts of Monze and Mazabuka, as well as the Central Province in the district of Chibombo. In total, 482 serum samples were collected from 120 households. The samples were analyzed for serology using competitive ELISA. Internal factors such as gender, age and origin were noted for each animal. Each household was interviewed using a questionnaire to collect information on the management routines, for example, questions regarding grazing, contact with other animals, trade, signs of disease, medical treatment, and household conformation. Statistical analysis was conducted to correlate factors to the serological status of the animal and household.

The total, apparent seroprevalence for FMD was 18% (confidence interval (CI) 95% 15; 22) and for CCPP 4.2 (Cl 95% 2.7; 6.3). The seroprevalence of PPR awaits confirmation before publication. Contact with wild ruminants was found as a risk factor for PPR (p-value=0.014). Herds with less than 15 goats had increased risk for PPR seropositivity compared to larger herds (p-value=0.042). Nasal discharge within the last 12 months increased the risk for FMD seropositivity (p=0.043).

As a conclusion, to find goats seropositive for the sampled diseases is important, since previous knowledge of the diseases in Zambia is limited. These are serious diseases, both for the animals and their owners, and likely cause major socioeconomic consequences. Therefore, the result motivates effort to further understand the role of the diseases in Zambia and form effective control programs.

CONTENT

INTRODUCTION

Small ruminants, including goats, are versatile production animals apt for a wide range of farming systems. The advantages of these animals are many. For example, they can thrive under arid conditions, require relatively simple management are comparatively cheap, which makes them accessible to more people (FAO 2013; de Haan *et al.* 2015). These benefits have made small ruminants one of the most important livestock of resource-constrained families in low- and middle-income countries (FAO 2013; de Haan *et al.* 2015). By producing meat, milk, offsprings, and numerous by-products, they provide food and also generate income through trade and bartering (de Haan *et al.* 2015). Therefore, small ruminants have an important but often understated role, in the fight against poverty and food insecurity (FAO 2013).

During the last decades, the economic growth in Zambia has been high, however, poverty has remained a reality for large portions of the population (Central Statistical Office 2012). Agriculture, including animal keeping, is a major source of employment in developing countries (FAO 2013). In Zambia, the majority of small ruminants are kept by traditional farmers in small-scale production systems (Ministry of Fisheries and Livestock 2019). Recently, droughts have led to severe food shortages across Zambia (United Nations Office for the Coordination of Humanitarian Affairs *et al.* 2019). In these times, small ruminants can continue to provide food, since they can sustain themselves through foraging and are less impacted by crop-failures (FAO 2013). Since goats represent the bulk of the small ruminants in Zambia (Ministry of Fisheries and Livestock 2019), this study was focused on them.

Peste des petits ruminants (PPR), foot and mouth disease (FMD) and contagious caprine pleuropneumonia (CCPP) are considered transboundary diseases, due to their highly contagious nature and potential for rapid spread (OIE 2009a; OIE 2009b; OIE 2013). The pathogenesis and clinical manifestations differ between the three, yet they all have comprehensive impacts on human and animal welfare. In addition, these three diseases cost multiple billions of dollars annually worldwide (James & Rushton 2002; OIE 2009a; FAO 2013). Because of their importance, the OIE lists them as notifiable diseases (OIE 2019a). FMD is endemic in Zambia with often annual outbreaks. Goats have been tested positive to antibodies against PPR virus (PPRV) in the country (OIE 2016), but no clinical cases have yet been confirmed. CCPP has not been reported in the country (OIE 2019c). In neighboring countries, PPR, and CCPP have been confirmed (Mbyuzi *et al.* 2014; Torsson *et al.* 2017), yet limited research has been conducted in Zambia which motivates further studies.

The aim of this study was to estimate seroprevalence for PPR, FMD, and CCPP in goats and to correlate the result to information on e.g. management routines and disease signs observed in the herds, gathered through questionnaire interviews, to identify protective or risk factors. The fieldwork was conducted in Central and Southern Provinces of Zambia in the districts of Chibombo, Mazabuka, and Monze during September and October of 2019.

LITERATURE REVIEW

The situation and challenges of agriculture in Zambia

Zambia is a land-locked country in southern Africa which covers 752 000 km^2 (Central Statistical Office 2012) and has a population of approximately 17 million people (The World Bank 2019). Most of the population is living in rural areas, however, the urban population is increasing rapidly. In 2010, 60.5% of the population lived in poverty and 42.3% lived in extreme poverty. Poverty is most distinctive in rural areas, where the rates are three times higher than in urban areas (Central Statistical Office 2012). Agriculture is a cornerstone of the economy, and since Zambia has more grazing land than arable land, animal keeping is of vital importance. Traditional farmers own 94% of the 3.7 million cattle and 99% of the 3.5 million goats (Ministry of Fisheries and Livestock 2019). Animal keeping is mostly small scale, with each household holding 10 cattle and 7.4 goats on average (Ministry of Fisheries and Livestock 2019).

Climate change has led to decreasing amounts of rainfall and increased temperatures in Zambia. In 2019, the rainfall was all-time low leading to crop-failure. As a result, at the time of the dry season of 2019, approximately 15% of the Zambian population had severe food insecurity and 6% was estimated to be acutely malnourished (United Nations Office for the Coordination of Humanitarian Affairs *et al.* 2019). Providing nutrients for the population is a crucial challenge were livestock, not least small ruminants, play an essential role (FAO 2013; de Haan *et al.* 2015).

Small ruminants in relation to the sustainable development goals

By studying infectious diseases affecting small ruminants in developing countries, e.g. in the Zambian population of goats, there is an opportunity to contribute to several of the goals for sustainable development set by the UN (UN 2015).

Goal 1 is to end poverty (UN 2015). For people living in poverty in developing countries, the main livestock is small ruminants and poultry (de Haan *et al.* 2015). Sheep and goats provide income through trade in multiple ways. The obvious products generated are live animals, meat, milk, wool, and skins, but numerous other by-products are also produced such as manure, fuel and biogas, horns, and the service of weed control. The herd can reproduce without additional investment and creates a wealth accumulation (de Haan *et al.* 2015). If animals are lost to disease, poverty can escalate (FAO 2013). Since cattle are more expensive than goats or sheep, they require a significantly bigger investment per animal. By instead spreading the investment into multiple, cheaper animals such as goats, the production can continue even if one animal were to die (de Haan *et al.* 2015). Also, as some diseases, e.g. foot and mouth disease, can be transmitted between small and large ruminants, the health of goats and sheep affects cattle and vice versa.

Goal 2 is to eliminate hunger (UN 2015). Small ruminants have an important role in food security. Ruminants increase food access since they can convert fibrous plants under arid conditions into meat and milk. This means that high-grade nutrition is derived from otherwise indigestible plants for human beings. Also, they increase food availability, since they can provide food for its owners throughout the year, including seasons when crop production is low for climatic reasons such as droughts (FAO 2013). Altogether, the importance of small ruminants when it comes to fighting starvation cannot be overstated (FAO 2013).

Goal 3 is to ensure healthy lives and promote well-being (UN 2015). Some diseases affecting goats are zoonotic and can, therefore, have a direct effect on human health. Diseases on goats are in many cases treated with antibiotics, which can drive antibiotic resistance later affecting human health care.

Goal 5 is to achieve gender equality (UN 2015). Women are often responsible for the care of the goat and sheep since the duty is combined with other tasks around the household (FAO 2013; de Haan *et al.* 2015). Women are also more likely to be able to invest in small ruminants over large ruminants since the investment required is smaller (de Haan *et al.* 2015). When women are in charge of the small ruminant, they also control the produced resources, which most likely have a positive effect on the position of women in society and may provide a sense of social security (FAO 2013).

Goal 8 is to provide decent work and economic growth. Agriculture, including the keeping of animals, is a major source of employment in developing countries including Zambia (UN 2015).

Peste des petits ruminants

PPR in a global and national perspective

PPR causes extensive socioeconomic impacts as well as significant animal suffering. The disease is highly contagious and is considered one of the most severe diseases of goats. The direct effects include potentially major losses in animals. Naturally, there are also losses in meat and milk production. Also, there are indirect losses, in the form of unborn offsprings, costs of vaccines, future prevention campaigns and trade restrictions (de Haan *et al.* 2015). The effects are spilled over from farmers to other actors in the value chain, such as the fodder industry, transport sector, slaughterhouses, and meat processing plants. It has been estimated that PPR causes losses between 1.2 to 1.7 billion USD annually worldwide (FAO & OIE 2015).

Given the recent success in eradicating Rinderpest, there is increased confidence and interest globally in clearing the world from diseases (de Haan *et al.* 2015). Since PPR is closely related to Rinderpest (Amarasinghe *et al.* 2019), many lessons can be learned from the Rinderpest-campaign, and PPR makes for an excellent candidate for eradication. The Food and Agriculture Organization of the United Nations (FAO) and the World Organization for Animal Health (OIE) has committed to a global strategy to eradicate PPR by the year 2030. As part of this campaign, it is important to gather information on where PPR is present (FAO & OIE 2015).

PPR has been reported in many parts of the world, including African countries except for southern Africa, the Middle East including the Arabian Peninsula, and Central and Eastern Asia including India (OIE 2009b). The EU had its first case of PPR in Bulgaria during 2018 (Bulgarian Food Safety Agency 2018). PPR has been confirmed in countries neighboring Zambia, including Angola, Tanzania and the Democratic Republic of Congo (Mbyuzi *et al.* 2014; Kgotlele *et al.* 2016; Kgotlele *et al.* 2019; Torsson *et al.* 2017; OIE 2019c).

The status of the virus in Zambia is less studied. In 2015, the OIE received an immediate notification from the Ministry of Fisheries and Livestock that goats seropositive for PPR had been found (OIE 2015b). The seropositive animals were spread out along the border to multiple high-risk countries, including the Democratic Republic of Congo, Angola, and Mozambique. Surveillance followed, yet no clinical cases were confirmed. In a follow-up report (OIE 2016), the Zambian authorities proposed that the most likely cause for seroconversion was vaccination performed in other countries in animals, which were later illegally imported into Zambia. Therefore, vaccination campaigns were not implemented since PPRV was not suspected to be present in Zambia (OIE 2016).

In 2018, a seropositive animal was sampled in the district Nakonde along the border to Tanzania (Mitternacht 2019). This animal had within the last year displayed signs resembling PPR. However, the presence of antibodies has not been confirmed in a reference laboratory and could be a false positive. In southern Tanzania, close to Zambia, a study found the seroprevalences to be 2.9% (Wilén 2019). During 2019, more seropositive animals were found in Zambia, and several of these showed clinical signs resembling PPR (Sara Lysholm, personal communication, 2019). The total seroprevalence was 2.3%, with some variation between districts. On a district level, the seroprevalence was 2.5% in Chavuma situated in the North-Western Province, 0,8% in Chilialombwe situated in the northern Copperbelt Province, 2.5% in Siavonga in the Southern Province, and 3.3% in Vubwi in the Eastern Province (Sara Lysholm, personal communication, 2019). See Figure 1 below for a map of approximate locations of seropositive animals in Zambia.

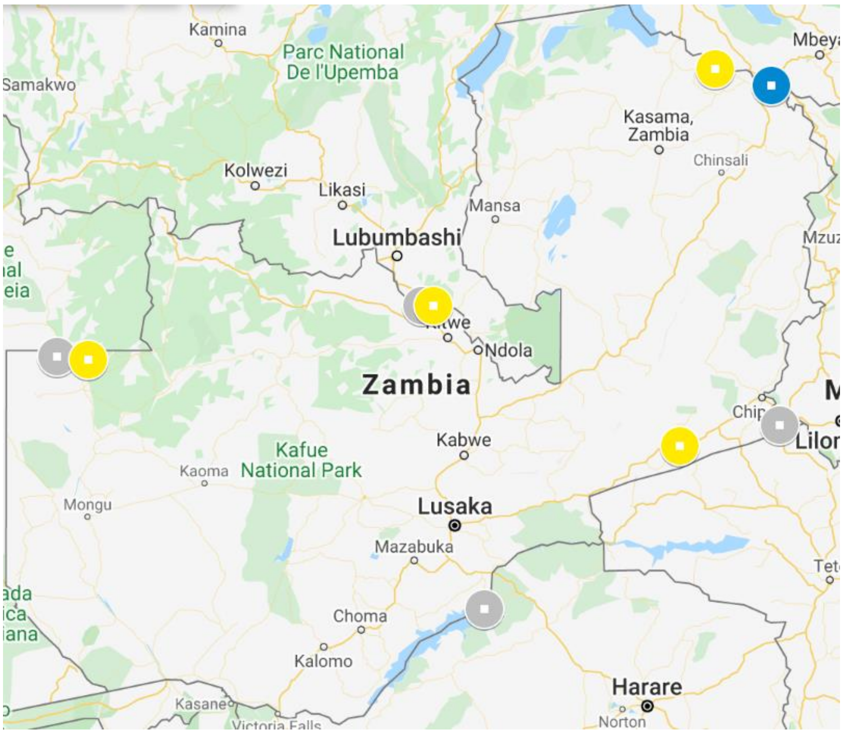

Figure 1. Districts where animals seropositive for PPR have been detected; yellow symbols for OIE (2015), blue symbols for Mitternach (2018), and grey symbols for Lysholm (2019).
The map was created in My Maps (Google Maps 2020).

Disease characteristics

PPR is caused by the morbillivirus PPRV, which is classified to the family *Paramyxoviridae* along with the now eradicated Rinderpest virus affecting cattle, measles virus affecting humans and canine distemper virus affecting dogs (Amarasinghe *et al.* 2019). PPRV affects mainly small ruminants, with more pronounced disease in goats (OIE 2009b). Cattle and camels can be infected (Abraham *et al.* 2005; Lembo *et al.* 2013; Schulz *et al.* 2019). Infected pigs can transmit the virus onwards to goats (Schulz *et al.* 2018). Several wild ungulates may be infected such as multiple gazelle and antelope species as well as American white-tailed deer (Hamdy & Dardiri 1976; Aziz-ul-Rahman *et al.* 2018). The link between disease in wild and captive animals is uncertain, yet, has the potential of being an important transmission route (Aziz-ul-Rahman *et al.* 2018).

PPRV is highly contagious and may spread both directly through air-born droplets, feces, and various secretions as well as indirectly for example by humans handling the animals (OIE 2009b; Smith 2009). There is no carrier state and PPRV is susceptible to most disinfectants (OIE 2009b).

The pathogenesis of PPR is not fully investigated and most information is based on related morbilliviruses (Khan *et al.* 2018). The virus is believed to enter the host animal usually through the respiratory mucosa, thereafter it targets lymphoid cells resulting in immunosuppression (Smith, 2009). A viremia follows with infection of multiple organs, including the gastro-intestinal and respiratory tract, liver and kidneys (Smith 2009b). Histologic changes in affected organs are characterized by severe degeneration and necrosis with depletion of lymphoid cells (Khan *et al.* 2018).

The incubation period is approximately 3-10 days (OIE 2009b). The severity of signs is believed to vary with the virulence of the particular PPRV strain, breed and immune status of the animal (OIE 2009b). A sudden onset of high fever and depression is followed by nasal and ocular discharge. A bronchopneumonia may develop with cough and dyspnea. Inflammation and necrosis of mucous membranes lead to oral and nasal ulceration as well as diarrhea, which may become severe and haemorrhagic (OIE 2009; Smith 2009b; Khan *et al.* 2018).

The morbidity rate can reach 90-100% with varying mortality rates but they can reach as high as 50-100% (OIE 2009; Smith 2009b). High rates of morbidity and mortality are reached especially when contact is made between a naïve population and endemic areas (OIE 2009b). In areas with few animals, such as rural villages, the population can be too small to host the virus endemically, leading to severe outbreaks when the virus is introduced (OIE 2009b). Milder outbreaks may arise, with lower morbidity and mortality, which may be overlooked (OIE 2009b).

Factors associated with PPR

Internal factors of the animal affect the likelihood of seropositivity for PPR. The species of animal impact the seroprevalence. Some breeds of goats appear to have a genetic resistance against the infection, e. g. imported Australian Boer goats had significantly lower morbidity and mortality rate compared to local Beetal goats in Pakistan (Khan *et al.* 2018). Older animals have higher seropositivity than kids in multiple studies, which the authors explaining it by older animals have had more time to be exposed to the virus (Kardjadj *et al.* 2015; Torsson *et al.* 2017). Females have higher seropositivity than males in multiple studies (Abubakar *et al.* 2009; Kardjadj *et al.* 2015; Torsson *et al.* 2017; Aziz-ul-Rahman *et al.* 2018). A proposed explanation by the authors is that gender is confounded by age since females are generally kept longer. Physiologic effects due to pregnancy and lactation are also discussed to potentially increase susceptibility in females.

Management routines, such as farming systems and patterns of animal movement appear to affect the seroprevalence of PPR. Mixed herds with both sheep and goats had an increased risk of seropositivity compared to herds with only sheep (Kardjadj *et al.* 2015). Another study also found an increased risk of seropositivity when sheep and goats where mixed, but only in the sheep and not in the goats (Al-Majali *et al.* 2008). Larger herds of animals had an increased risk of seropositivity (Al-Majali *et al.* 2008; Kardjadj *et al.* 2015). The risk also increased if the flock had generally more contact with other flocks (Kardjadj *et al.* 2015; Chota *et al.* 2019) and specifically if the animals visited markets with live animals (Al-Majali *et al.* 2008; Chota *et al.* 2019). Inadequate veterinary services increased the risk of seropositivity (Al-Majali *et al.* 2008). The risk also increased if the herd had contact with wild animals (Chota *et al.* 2019). Other studies have not seen an increased risk regarding contact with wild animals (Torsson *et al.* 2017).

Seroprevalence generally varies with geographic location within a country. In some cases, the most likely explanation is proximity to countries with a high prevalence (Al-Majali *et al.* 2008). In other cases, the explanation might be found in climatic conditions in different regions that affect grazing patterns (Abubakar *et al.* 2009; Aziz-ul-Rahman *et al.* 2016). In Ethiopia, seropositivity was higher in lowlands compared to highlands (Waret-Szkuta *et al.* 2008). The authors discussed that this might be due to differences in production systems since the lowland, especially during the dry season, have scarce amounts of fodder and water which leads to increased movements to access these resources. The incidence of PPR has been found higher in dry seasons in Pakistan (Abubakar *et al.* 2009) which might be due to an improved nutritional status during the wet season, which increases resistance to the disease. Also, movement patterns might differ between seasons.

The eradication of PPR

Several factors make the eradication of PPR in near time a plausible scenario. There are safe and effective vaccines (OIE 2019b). Diagnostic tests, such as competitive ELISA for serology, are effective and widely available. There is no carrier state that otherwise can harbor the virus and lead to a continuation of the spread. Also, only small ruminants are believed to form the major reservoir for the virus (FAO & OIE 2015). Unfortunately, there are also several difficulties. There is a current lack of information on small ruminants, both on a group and individual level, in many countries. Small ruminants are very mobile which increases the spread of the virus. The infrastructure in areas with PPR is often underdeveloped, making surveillance and vaccination campaigns difficult to conduct. The veterinary services are in many countries underdeveloped for the task. Vaccines require a cold chain, which in some areas is difficult to maintain. The high turnover rate of animals, given the relatively short reproduction cycle, can make flock immunity difficult to achieve through vaccination (FAO & OIE 2015).

Contagious Caprine Pleuropneumonia

CCPP in a global and national perspective

CCPP is considered one of the most severe diseases affecting goats (OIE 2009a). Due to its high mortality rate, it causes massive income-losses (OIE, 2014a). A Kenyan study, based in arid and semi-arid conditions, calculated the annual cost of CCPP in an average flock of a hundred animals to be 1,712.66 Euros (Renault *et al.* 2019).

CCPP is a notifiable disease to the OIE (OIE 2019a). However, its exact distribution is unknown, partly since it is difficult to diagnose. On mainland Europe, the first reported outbreak was reported in Turkey in 2004 (Ozdemir *et al.* 2005). CCPP is endemic in parts of Central and East Africa as well as the Middle East (OIE 2009a; Peyraud *et al.* 2014). CCPP has also been confirmed in central Asia (Peyraud *et al.* 2014).

In Tanzania and Angola, both neighboring to Zambia, CCPP has been confirmed (Mbyuzi *et al.* 2014; Kgotlele *et al.* 2019; Torsson *et al.* 2017; OIE 2019c). A study conducted in the southern parts of Tanzania detected seroprevalences in goats of 52.1% during 2007 and 35.5% during 2009 (Mbyuzi *et al.* 2014). Another study detected seroprevalences of 14.6% during 2014 and 18.8% during 2015 in northern and south-east Tanzania (Torsson *et al.* 2017). With the use of PCR-technique, CCPP was isolated in 5% of sampled animals in northern Tanzania (Kgotlele *et al.* 2019).

Previously, no studies have been published on CCPP in Zambia. A presently unpublished study detected total seroprevalence of 3.1% in Zambia and on a district level 2.5% in Chavuma situated in the North-Western Province, 0.8% Chililalombwe situated in the Copperbelt Province, 1.7% Siavonga situated in the Southern Province, and 7.5% in Vubwi situated in the Eastern Province (Sara Lysholm, personal communication, 2019). For the approximate location of the seropositive animals, see figure 2 below.

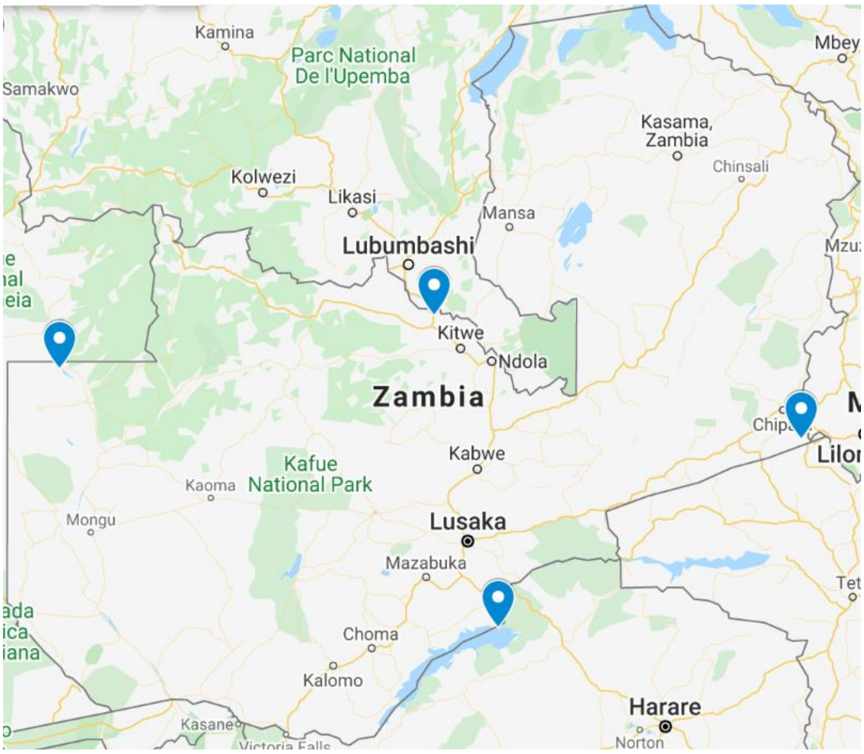

Figure 2. Districts were animals seropositive for CCPP have been detected by Lysholm (2019). Map was created in My maps (Google Maps 2020).

Disease characteristics

CCPP is an airway infection caused by the bacteria *Mycoplasma capricolum* subspecies *capripneumoniae* (Mccp) which can also be called biotope F38. Mccp belongs to the *Mycoplasma mycoides* cluster which also contains contagious bovine pleuropneumonia (CBPP) which is present in Zambia (OIE 2019c). CCPP is considered primarily a goat disease (OIE 2009a), however, multiple other species have been proven susceptible. The bacterium has been isolated in sheep, but clinical signs are more rarely developed (Litamoi *et al.* 1990; OIE 2009). Antibodies have been detected in cattle, buffalo, camels, and impala, also these without previous clinical signs (Paling *et al.* 1978, 1988). Mccp has also been associated with respiratory disease in wild goats, Vaal Rhebook, Nubian Ibex, Moufflon and Gerenuks (Nicolas *et al.* 2005; Arif *et al.* 2007).

Transmission is considered to mainly occur through direct contact when aerosols containing bacteria are inhaled (OIE 2009a). Chronic carriers are discussed as a likely source of transmission (Ruffin 2001; OIE 2009a), but this remains unproven.

The bacterium solely colonizes the lung and thoracic cavity and affects no other organs. Most cases show unilateral disease. First off, smaller nodules with hyperemia and edema are seen in the lung parenchyma. Later, the nodules increase in size and form necrotic centers resulting in pulmonary consolidation. A pleuritis is formed, which is characterized by hydrothorax as well as a thick yellowish fibrinous material covering the pleura (Kaliner & MacOwan 1976; Wesonga *et al.* 2004). The histological changes in fulminant cases include pulmonary and pleural fibrosis, extensive infiltration of inflammatory cells, hyperplastic bronchi, sometimes with necrotic tendencies, and hyperplasia in regional lymph nodes (Kaliner & MacOwan 1976; Wesonga *et al.* 2004).

In goats, the incubation time is 6 to 10 days or longer (Ruffin 2001; OIE 2009a). Clinical signs vary in endemic areas, with peracute, acute, and chronic forms (OIE 2009a). Acute cases show fever, coughing, nasal discharge, and fatigue (Kaliner & MacOwan 1976; Wesonga *et al.* 2004). Some goats survive the acute phase of the disease, yet, remain with chronic lung lesions (Kaliner & MacOwan 1976). The morbidity and mortality are reported to be high, reaching 80-100% (Ruffin 2001; OIE 2009a). However, milder forms of the disease with no acute mortality has also been observed (Wesonga *et al.* 2004).

CCPP provides multiple diagnostic challenges. The signs are often impossible to distinguish from other diseases with a similar clinical picture. The bacterium is difficult to cultivate from a sample. One study could isolate Mccp up to 16 days after onset of the disease, but no longer afterward, even though there were remaining lung lesions (Wesonga *et al.* 1998). Therefore, PCR is the diagnostic tool of choice (OIE 2009a). Serology is a possibility, with titers of antibodies being at highest at the time of fever and thereafter decreasing. However, some animals die before antibodies can be detected (Wesonga *et al.* 1998).

Factors associated with CCPP

CCPP affects animals of all ages and genders (OIE 2009a). However, there are contradicting results whether the risk differs between age groups and gender. Multiple studies have not found significant differences in seroprevalence based on age (Eshetu *et al.* 2007; Hadush *et al.* 2009; Kipronoh *et al.* 2016; Abrhaley *et al.* 2019). On the contrary, some studies have found that adult goats have significantly higher seroprevalence compared to kids (Mekuria & Asmare 2009; Fasil *et al.* 2015; Teshome *et al.* 2019). One proposed explanation is that the actual prevalence of the bacterium is the same in a flock, but kids have a higher mortality rate with fewer kids surviving as seropositive animals. Also, the authors discuss that adults have had more time to be exposed to outbreaks and develop antibodies. Regarding the effect of gender on seroprevalence, there are also contradicting results. Multiple studies found no significant difference between females and males (Hadush *et al.* 2009; Kipronoh *et al.* 2016; Abrhaley *et al.* 2019). Some studies have found females to have significantly higher seroprevalence than males (Fasil *et al.* 2015; Torsson *et al.* 2017). A proposed explanation is that the difference in prevalence between gender is likely to be confounded by age since females are usually kept longer than males (Fasil *et al.* 2015).

The disease is highly contagious through direct contact (OIE 2009a). Naturally, animal movement and increased contact have been shown to increase the risk of seroprevalence of CCPP in multiple ways. The introduction of new animals to the flock increases the risk of seropositivity (Mbyuzi *et al.* 2014). Also, the mixing of flocks has been shown to be a risk factor (Chota *et al.* 2019). Visiting markets with live animals have been shown to increase the risk of seroprevalence (Kipronoh *et al.* 2016). Movement of animals to the dry season feeding areas is also a risk factor for seropositivity (Kipronoh *et al.* 2016).

Outbreaks are suggested to occur after stressful events, such as transportation, and sudden climatic changes as heavy rain and cold spells (OIE 2009a), though, there are few studies to support this claim. An Ethiopian study interviewed farmers about what they consider to be the factor contributing most to outbreaks of CCPP (Fasil *et al.* 2015). The most common answers were wet season (41.6%), followed by grazing areas (18.7%), watering points (14.1%), flocks with more than 20 animals (13%), introduction of sick animals (11%), and purchase of animals in general (1.6%).

The management system has been proposed to affect CCPP prevalence. In some studies, sedentary systems had significantly higher seroprevalence compared to pastoral systems (Mekuria & Asmare 2009; Mbyuzi *et al.* 2014; Chota *et al.* 2019). Other studies could not find a statistically significant difference in prevalence between sedentary and pastoral systems (Fasil *et al.* 2015). Inadequate veterinary service has been identified as a risk factor (Kipronoh *et al.* 2016; Chota *et al.* 2019).

The geographic area can affect prevalence. In Ethiopia, one study detected higher seroprevalences in districts with more extensive management systems (Abrhaley *et al.* 2019). Another Ethiopian study detected higher seroprevalence in central areas and areas bordering other countries which, according to the author, had more animal movement (Teshome *et al.* 2019). Also, highland areas in Ethiopia had a higher risk of seroprevalence compared to midland and lowland (Mekuria & Asmare 2009). According to Mekura et al (2009), there is a constant influx of livestock from the lowlands to the highland and since transport leads to stress and mixing of flocks, the animals might have a higher risk of disease upon arrival.

Control strategies for CCPP

As direct contact represents the main transmission route, the most likely entryway for CCPP to a free country or a naïve flock is through the introduction of infected animals. Therefore, the bacterium can be controlled and later eradicated through the use of biosecurity measures, such as quarantine, movement restrictions, slaughter of infected and exposed susceptible animals and cleaning of premises (OIE 2009a).

There is a commercially available vaccine that gives immunity for at least one year (OIE 2009a). A study in arid and semi-arid lands in Kenya calculated that the economic benefits of biannual vaccinations, in the form of better goat health, were greater than the cost of the campaign (Renault *et al.* 2019). From a cost-benefit perspective, vaccines can, therefore, be motivated. However, only a few countries have implemented vaccinations in their eradication program for CCPP (OIE 2009a).

As for medical treatment, there are antibiotics such as tetracycline and tylosin, which may be somewhat effective if administered early. However, the risk is that the bacterium is not completely cleared, and the animal remains infectious (Ruffin 2001; OIE 2009a).

Foot and Mouth Disease

FMD in a global perspective

Due to the many negative health effects, FMD is considered impossible to have in high-intensity production systems (Geering & Lubroth 2002; James & Rushton 2002). It is one of the most contagious animal diseases and can rapidly spread throughout a country (OIE 2013). Therefore, there must be a zero-tolerance for the disease in countries striving for effective livestock production (James & Rushton 2002).

The economic losses caused by FMD are partly explained by the direct effects on production, but also by the indirect effects on trade (James & Rushton 2002). The international trade is haltered on multiple levels. Live animal export from countries with FMD to FMD-free countries is hindered by extensive rules. Also, the trade with livestock products, such as meat and skins, is restricted. The export of other products, such as crops, may also be affected. The domestic trade is limited by restrictions on animal movements. Some countries also have restrictions on the movement of humans (Geering & Lubroth 2002; James & Rushton 2002).

Another significant economic effect of FMD is the control programs. The extension of these varies between countries but usually consists of the following principles. Countries without the disease, have extensive surveillance programs and outbreaks are usually dealt with by stamping out. Countries that have circulating FMD, which is common in developing countries, usually implement expansive vaccination programs to control outbreaks and in some cases later eradicate the disease (Geering & Lubroth 2002; James & Rushton 2002).

FMD in Zambia

Most developed countries have eradicated the disease. However, FMD is endemic in many parts of Africa, Asia, the Middle East and some parts of South America (OIE 2013).

In Zambia, hotspots for reoccurring FMD-outbreaks has been identified. These are in Southern Province along the Zimbabwean, Namibian and Botswanan border, on the Kafue plains in Southern and Central province, and in the North East along the Tanzanian border (Hamoonga *et al.* 2014; Sinkala *et al.* 2014). Wild buffalos in Kafue and Lower Zambezi national parks are known reservoirs for FMDV (The Department of Research and Specialist Services 1999). Elevated areas have fewer outbreaks in Zambia (Hamoonga *et al.* 2014). Outbreaks have been seen during all seasons of the year (Hamoonga *et al.* 2014). Between 1981 and 2012, FMD-outbreaks occurred in 19 of 31 years, with some years peaking on 12 outbreaks a year (Hamoonga *et al.* 2014). During 2019, outbreaks of FMD started in the Central Province in the district of Chisamba, and then spread south to the Southern Province in the districts of Monze, Mazabuka, Pemba, Gwenbe and Choma (Dr. Musso Munyeme, personal communication, 2020). Another outbreak occurred in the Eastern Province in the district of Lundazi (Dr. Musso Munyeme, personal communication, 2020). For the location of the 2019 outbreaks, see figure 3 below.

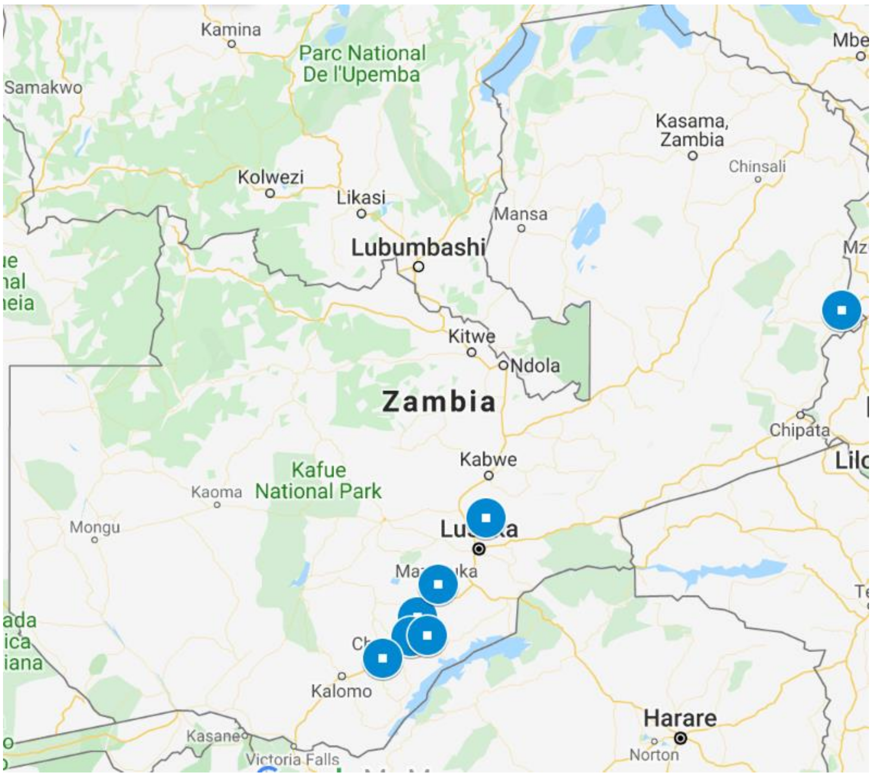

Figure 3. Locations for outbreaks of FMD during 2019 (Dr. Musso Munyeme, personal communication, 2020). Map created in My maps (Google Maps 2020).

In Zambian district bordering Tanzania, the seroprevalences in small ruminants were 1.3% sampled during 2018 (Mitternacht 2019). On the Tanzanian side of the border, seroprevalence was 16.9% in small ruminants sampled also during 2018 (Wilén 2019). In a currently unpublished study by Lysholm performed in Zambia on small ruminants the seroprevalence was in total 4.2% and on a district level 5.0% in Chavuma situated in the North-Western Province, 3.3% Chilialombwe in the northern Copperbelt Province, 5.0% Siavonga in the Southern Province, and 4.2% in Vubwi in the Eastern Province (Sara Lysholm, personal communication, 2019).

Disease characteristics

FMD is caused by the picornavirus FMDV, classified to the *Aphthovirus* genus (Zell *et al.* 2017). There are seven serotypes with different virulence. Infection with one serotype does not give immunity to another (OIE 2015a). All cloven-hoofed animals are susceptible to FMD, both domesticated and wild. This includes small ruminants such as goat and sheep, large ruminants such as cattle and a range of wild animals. Among the wild animals of southern Africa, only the African buffalo has been proven to be a long-term host with individual buffalos capable of carrying the virus for multiple years (Thomson *et al.* 2003),

Transmission routes are both directly between infected animals and indirectly through contaminated materials. Spread can also be air-borne with the virus traveling up to 60 km overland in optimal conditions (OIE 2013). During the disease, all secretions and excretions are infectious. Animals may become asymptomatic carriers of FMD (Alexandersen *et al.* 2003).

The length of the carrier state varies between species, and the OIE (2013) estimates that small ruminants will usually only carry the virus for a few months, cattle for six months, and the African buffalo for five years or more. Ingestion of contaminated milk and meat may lead to infections, which is mainly seen in calves and pigs (OIE 2013). FMDV may be preserved when frozen but is inactivated in temperatures over 50 °C. The virus persists for weeks under moist and cool conditions including fodder (OIE 2013).

The incubation period is 2 to 14 days (OIE 2013). The morbidity rate is high, reaching up to 100% (OIE 2013). The primary site of infection is usually the pharynx. Interestingly, this is also the location where the virus can persist in the carrier state (Alexandersen *et al.* 2003). From the pharyngeal areas, the virus spread to the regional lymph nodes and thereafter creates a viremia. The viremia is seen one to three days after infection and usually lasts for four to five days (Alexandersen *et al.* 2003). Viremia leads to infection of widespread squamous epithelia, including feet and mammary where the virus replicates fast and at high rates. Some viral replication occurs in the pharynx, but this is a lesser amount, which might explain why persistent carriers are less likely to transmit the virus than acutely sick animals. The myocardium of young animals may be infected (Alexandersen *et al.* 2003).

The severity of signs varies between species and breed of animal, the strain of the virus, exposure dose and host immunity (Alexandersen *et al.* 2003; OIE 2013). In sheep and goats, clinical signs are generally mild, yet they can spread the virus to other species such as cattle, which may then develop more severe signs (Alexandersen *et al.* 2003). The clinical signs are typically fever with the formation of painful vesicles on the mouth, feet, and genitals which later ruptures to form erosions. Complications may occur, including hoof deformations, mastitis, myocarditis, abortion, permanently decreased body weight and milk production, and loss of heat control (Alexandersen *et al.* 2003; OIE 2013). The mortality rate is low, with death seen mostly in young animals due to myocarditis (OIE 2013).

The disease results in significant production loss (OIE 2013). For example, a study by Bayissa *et al.* (2011) found that cows decreased their average milk yield during outbreaks to half a liter per day for 25 days. The cows that developed heat intolerance syndrome remained with low production for a prolonged time, producing on average 0.63 liter for the following 3.8 months. The calving interval also increased for the cows.

Factors associated with FMD

Internal factors have been shown to have some impact on the seroprevalence of FMD. Susceptibility varies between species, being highest in cattle followed by sheep and goat (Beyene *et al.* 2015). Seroprevalences also increases with increased age (Beyene *et al.* 2015; Torsson *et al.* 2017).

Outbreaks are more likely to occur where animals congregate for different reasons. Drier areas have more outbreaks since animals gather around water sources (Hamoonga *et al.* 2014). In areas with a higher density of animals, such as the Kafue wetlands in Zambia, outbreaks are more frequent (Hamoonga *et al.* 2014). Transportation routes, both international border crossing as well as major domestic roads and railways, have been shown to increase the frequency and intensity of outbreaks (Hamoonga *et al.* 2014; Elnekave *et al.* 2016).

Management systems affect the spread of FMD. Large herd size increases the risk of FMD-seropositivity (Bayissa *et al.* 2011; Beyene *et al.* 2015). Communal grazing and contact between different flocks increase the risk (Beyene *et al.* 2015). An Israelian study (Elnekave *et al.* 2016) had contradicting results on these points. Large-scale farms had a decreased risk of FMD compared to smaller herds. Also, grazing herds had lesser risk compared to non-grazing farms. A proposed explanation to this is that these management systems in Israel have better biosecurity, are often vaccinated, and that animal movements are reduced due to strict governmental control (Elnekave *et al.* 2016). Livestock markets can be a source of transmission, and villages situated close to them have been shown to have an increased proportion of seropositivity among animals (Beyene *et al.* 2015). Contact with wild ungulates also increases the risk of seropositivity (Beyene *et al.* 2015).

Control strategies for FMD

The epidemiology in a certain country dictates how control plans should be planned since the nature of an outbreak in a free area compared to an endemic area is dissimilar (Geering & Lubroth 2002). Therefore, control strategies need to be adapted to the disease status of the specific country (Souley Kouato *et al.* 2018). Interventions must also be modified to the serotype and strain that is causing the outbreak. E.g, areas endemic to certain serotypes can suffer a new outbreak if a new serotype or strain is introduced (Rweyemamu *et al.* 2008). Also, vaccines must be matched to the circulating strain for the most effective result (Geering & Lubroth 2002).

In free areas, the goal should be quick containment of the virus, and the recommendation is to perform stamping out of infected, recovered and susceptible contact animals (Geering & Lubroth 2002; OIE 2013). Stamping out in endemic areas would lead to vast losses of animals and is not financially viable on a large-scale where the virus is endemic (James & Rushton 2002).

A vaccination program for FMD needs to be planned and executed carefully to be successful (Geering & Lubroth 2002). Vaccinations have a role to play in both FMD-free and endemic areas. In a free area that has suffered an outbreak, vaccination is a useful tool to stop the spread of the virus and later eradicate it (Geering & Lubroth 2002). In endemic areas, vaccination can both be used to contain outbreaks and to later clear areas completely. Through vaccination, in addition to other control methods such as restriction of movement, an endemic area can become free (Geering & Lubroth 2002). Ring vaccination on the outskirts of an outbreak can halter the outbreak if restriction of movement is also performed. A comprehensive, blanket vaccination halter spread more effectively but can be difficult and expensive to perform especially in large areas with many animals (Geering & Lubroth 2002).

For sanitary measures, the protection of free zones should be upheld by surveillance and movement control. Quarantine of new animals is essential to avoid introducing the virus. To avoid indirect spread, measures must be taken to disinfect materials that may carry viruses, e.g. cars, clothes and water points (OIE 2013).

The national strategy of Zambia from the Department of Research and Specialist Services (1999) states that the prevention of FMD-outbreaks should focus on limiting the risk of introducing FMD from other countries through import control and limiting the spread from buffalo reservoirs also by vaccinating animals in high-risk areas. To pick up on outbreaks, field staff carry out physical examinations and abattoir monitoring in risk areas. If an outbreak is suspected, an immediate ban is placed on all movements from risk areas. Preventive vaccination is conducted bi-annually in high-risk areas where cattle have contact with buffalos. The FMDV circulating in buffalos in Kafue and Lower Zambezi national park has been typed to ensure that the vaccine is effective for the strain (The Department of Research and Specialist Services 1999). Vaccination is performed in the districts of Kazungula (Southern Province), Namwala (Southern Province), Itezhi Tezhi (Central District), Mbala (Northern Province), and Nakonde (Northern Province). Blanket vaccination is performed inside of these districts and around the districts in a 35km buffer zone. Cattle only is vaccinated, and not small ruminants or pigs (Dr. Musso Munyeme, personal communication 2020). For the location of the vaccinated districts, see figure 4 below.

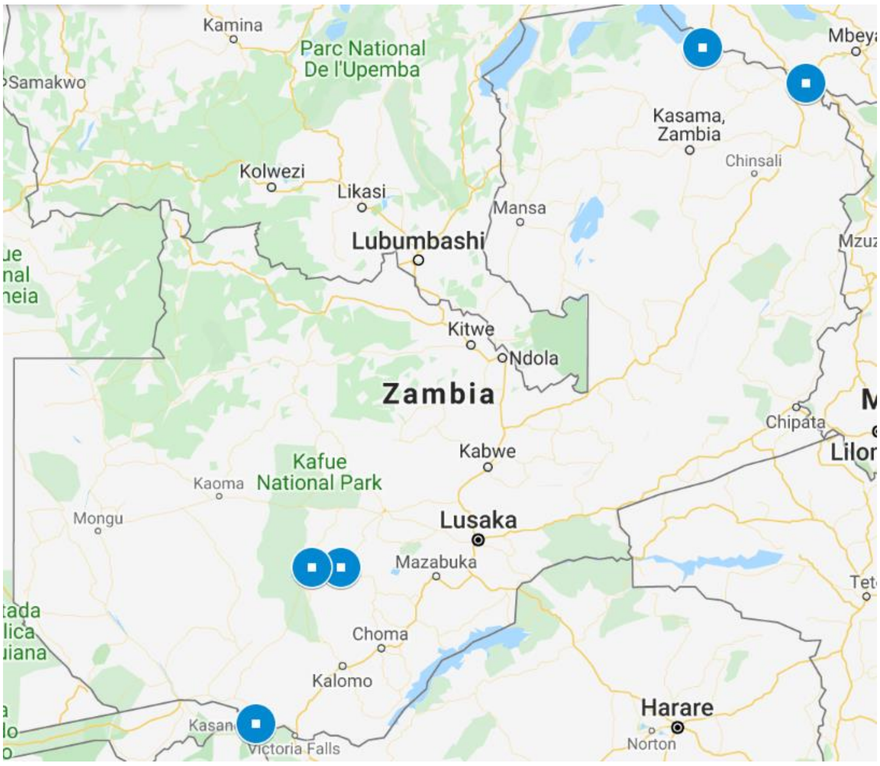

Figure 4. High-risk areas for FMD in Zambia where vaccinations are performed regularly (Dr Musso Munyeme, personal communication, 2020). Map created in My Maps (Google Maps 2020).

MATERIALS AND METHOD

Study design

The selection of districts was based on information on the animal population from the Central Statistics Office in Zambia to ensure that there were high numbers of goats. Also, districts that bordered to another country were excluded. Of the districts which fit these criteria, three districts were selected. The result was Monze and Mazabuka which are situated in the Southern Province, and Chibombo which are situated in the Central province. For the location of the districts, see figure 5. The local veterinary office provided a list of all accessible villages within the district and from this list, 10 villages per district, i.e. 30 in total, were chosen randomly. If the household was unfit, e.g. inaccessible or with too few goats, it was replaced with another randomly selected village. In each village, four households were selected using snowball sampling, meaning that the farmers themselves directed us onward to the next household (Given 2008). In each household, four goats were sampled, and one questionnaire interview was conducted. If the household had less than four goats, additional samples were taken from other households in the same village. The GPS coordinates were noted for each household.

Figure 5. The sampled districts of Chibombo, Mazabuka, and Monze (marked with a symbol in the noted order). Map created in My Maps (Google Maps 2020).

The sample size was calculated according to Humphry, Cameron, and Gunn (AUSvet 2004). In order to reach the maximum sample size, the predicted prevalence of 50%, the sensitivity and specificity of the PPR ELISA, and the desired precision of 5% was used for calculation. The result was a sample size of 444 which were later rounded up to a goal of 480 samples.

Collection of samples

Sampling was conducted over three weeks in September and October 2019. To avoid maternal antibodies interfering with the results, animals younger than four months were excluded from the study. The blood sample was taken from the jugular vein using a vacutainer system and serum tubes (BD vacutainer, Plymouth, United Kingdom). The samples were placed in a cooler box immediately after collection. The samples were left standing to coagulate and serum was thereafter transferred to cryotubes the same day. The serum was stored initially in a fridge for a maximum of four days and then transferred into a -80°C freezer awaiting laboratory analysis.

In total, serum samples from 484 animals were collected. Later in, two samples were lost during the fieldwork and 482 samples to be included in the study. For individual goat, internal factors such as age, sex, and breed were noted. Also, questions were asked regarding signs of disease, both current signs, and signs displayed within the last year.

Questionnaire

The person responsible for the management of the animals in the household was interviewed. The questionnaire was translated from English to the first language of the owner. The translation was performed by Christabel Chimba together with local veterinary assistants. In Monze and Mazabuka, the interview was conducted in the language Tonga. In Chibombo, the languages of Lenya or Nyanja were used. The questionnaire also included questions meant to be used in other research projects. The relevant questions were later compiled for the statistical analyses. Appendix 1 includes the questionnaire that was used.

Laboratory test

The samples were analyzed to identify antibodies for PPR, FMD and CCPP using commercial competitive enzyme-linked immunosorbent assay (ELISA).

For PPR, the *PPR Competition (*ID SCREEN, ID-vet, France) was used which detects antibodies to the nucleoprotein of PPRV with a sensitivity of 94.5% and a specificity of 99.4% (Libeau *et al.* 1995). The ELISA for PPR gives results as positive (competition percentage<50%), negative (competition percentage>60%) or doubtful (competition percentage 50-60%). Positive and doubtful results were re-analyzed again in nearly all cases to confirm the results. Only samples that were positive on both primary and secondary analyses were considered positive. If one of the analyses were doubtful, the result was considered doubtful.

For analyzing antibodies to FMDV, the *FMD NSP Competition I* (ID SCREEN, ID-vet, France) was used, which detects non-structural protein antibodies (NSP) for all seven serotypes of the virus. Since only infected animals develop NSP, and not vaccinated, the vaccine can be used as a DIVA-test (Differentiation Infected and Vaccinated Animals). The sensitivity is 100% and the specificity is 99.4% (ID Vet 2019).

Mycoplasma capricolum subsp. capripneumoniae (Mccp) Antibody Test Kit (IDEXX, France) detects antibodies to Mccp. Data for the sensitivity is lacking. The specificity is 99.6% (IDEXX Laboratories 2015).

Statistical analysis

Apparent and true seroprevalence was calculated both on the local level for each district and in total for all the districts combined. For calculations, Epitools (AUSvet 2019) online tool was used for Wilson's method to estimate confidence limits for apparent prevalence and Blaker's methods for confidence limits on true prevalence. The confidence level was set at 95%. The values for sensitivity and specificity from the manufacturer were used. True prevalence could not be calculated for CCPP since sensitivity data is lacking.

For factors varying between individuals, such as age and gender, the statistical analysis was performed on an individual level. To decrease the risk of false-positive affecting the analysis, only households with at least two positive individuals were considered as positive. Herds with only one positive individual was considered negative.

For analyzing risk factors, the Fischer's exact test was calculated using Minitab (2019). Analyses were performed on an individual level for the following factors,

- Gender
- Age. Information on the age of the animal was asked as a numeric value, but later divided into kids (<1 year) and adults (>1 year).

Analyses were performed on herd level for the following factors,

- The contact which the herd made with animals from outside of the herd; contact with other herds at least once a week, contact with cattle from other herds at least once a week, and contact with wild ruminants at least once a week compared to contact more rarely
- Trade; buying and selling goats at least once a week compared to more rarely, if international trade was conducted and if quarantine of newly arrived animals was used.
- Animal health; if the herd had displayed signs of diarrhea, coughing, sudden death during the last year and if sick animals were isolated from the rest of the herd.
- Household information; if the household had sheep, cattle, and pigs, if goats were housed together with sheep and, the household size. Herd size was categorized into three categories with small herds (<15 goats), medium herds (15-30 goats) and large herds (>31 goats).

RESULTS

Descriptive information

A total of 121 goatherds were sampled in which 41 herds were situated in Monze, 40 herds in Mazabuka and 40 herds in Chibombo. The herd size ranged between 4 and 185 goats with an average of 27 with a median of 22 animals. When the farmers were divided into groups based on herd size, 25% had small herds with less than 16 goats, 38% had medium-sized herds with between 16 and 30 goats, 24 % had large herds with more than 30 goats and 13% had an unknown herd size.

Of the sampled animals, 16% were males and 84% were females. Age-wise, 87% were adults (>1 year), 12% were kids (<1 year) and for the remaining percent, the age was unknown. All animals were of local breed.

Table 1. *Descriptive information on age and gender of sampled goats*

	Gender		Age		
	Males	Females	Adults (>1 year)	Kids (<1 year)	Unknown age
District					
Monze	41	121	135	27	0
Mazabuka	17	143	148	10	2
Chibombo	21	139	135	22	3
Overall					
n	79	403	418	59	5
%	16	83	86	12	1.0

Questionnaire

Grazing and contact

The farmers were asked about which grazing system was utilized with the following result. About 5.8% of the farmers utilized solely communal grazing (n=7), 92% utilized both communal and fenced grazing (n=110), 0.8 % utilized a combination of communal, fenced and tethered grazing (n=1), and 1.6 % utilized only fenced grazing (n=2).

When asked which other species in addition to goats were kept by the household, 19% had sheep (n=23), 90% had cattle (n=108), and 27% had pigs (n=32). Goats were housed together with sheep in 10% of the households (n=12).

The farmers were asked about how often contact was made between their goats and other animals. Contact with other goat herds was made approximately daily in 84%, once a week in 2.5%, once a month in 0.83%, more rarely than once a year in 2.5%, and never in 9.2% of the households with the remaining 0.83% representing farmers that did not answer the question. Contact with cattle from other herds was made daily in 75.8% of the households, once a week in 2.5%, more rarely than once a year in 5%, and never in 15% of the household with the remaining 1.7% representing the farmers that did not answer the question. Contact with wild ruminants was made daily in 12%, once a week in 2.5%, once a month in 2.5%, more rarely than once a year in 5.8%, and never in 70.1% of the households with the remaining 6.7% representing farmers that did not answer the question. The most common wild ruminant in question was the antelope Brown lechwe (*Kobus lechwe*). This information is also presented in table 4 below.

Table 2. *Frequency of contact with animals from outside the herd*

	Daily % (n)	Weekly % (n)	Monthly % (n)	Every six months % (n)	Yearly % (n)	More rarely % (n)	Never % (n)	Did not answer % (n)
Goats from other herds	84 (101)	2.5 (3)	0.83 (1)	0 (0)	0 (0)	2.5 (3)	9.2 (11)	0.83 (1)
Cattle from other herds	76 (91)	2.5 (3)	0 (0)	0 (0)	0 (0)	5 (6)	15 (18)	1.7 (2)
Wild ruminants	12 (14)	2.5 (3)	2.5 (3)	0 (0)	0 (0)	5.8	71 (85)	6.7 (8)

Trade

The farmers were asked how often the household receives new goats either through buying or bartering. This occurred approximately once a week in 2.5%, once a month in 8.3%, once every six months in 17%, once a year in 17%, more rarely than once a year in 11%, and never in 43% of the households with the remaining 2.5% representing farmers that did not answer the question. No household stated to have received goats from other countries nor were they aware of farmers in the community that have made international purchases of goats. When receiving new goats, 33% answered that the new goats are kept separated from the rest of the original herd in a form of quarantine.

The farmers also asked how often goats were sold. This occurred approximately once a week in 0.83%, once a month in 17%, once every six months in 37%, once a year in 23%, more rarely than once a year in 9.2%, and never in 5% of the households with the remaining 9.2% representing farmers that did not answering the question. The reason for selling was in the majority (96%) that the household required money, e.g. for school fees. Eight households, all situated in Chibombo representing 6.7% of the total households, stated that they sold goats to the Democratic Republic of Congo.

Table 3. *Frequency of requiring new goats through buying or bartering, and selling goats*

	Daily % (n)	Weekly % (n)	Monthly % (n)	Every six months % (n)	Yearly % (n)	More rarely % (n)	Never % (n)	Did not answer % (n)
Buying or bartering	0 (0)	2.5 (3)	8.3 (10)	17 (20)	17 (20)	11 (13)	43 (51)	2.5 (3)
Selling	0 (0)	0.83 (1)	17 (20)	37 (44)	23 (27)	9.2 (11)	5 (6)	9.2 (11)

Animal health and medical usage

The farmers were asked about which signs of disease had been observed within the last 12 months. Diarrhea had been observed in 53% of the herds. Coughing had been observed in 57% of the herds. Sudden death, meaning that the animal died within 24 hours of showing signs or without prior signs, had been observed in 24% of herds. Nasal and ocular discharges were observed in 35% of the herds. When an animal was sick, 20% of the household stated that the sick animal was isolated from the rest of the herd, in most of these cases both during the night and the day (83%).

None of the households stated that they had performed vaccinations of their goats. Besides from deworming and treatment for external parasites, 78 households representing 68% had treated their goats with a medication. This medication was in 77% of the cases the antibiotic oxytetracycline, given as either "hi-tet" or "oxy-ject", which had been used by 60 households.

Seroprevalence

Table 4. *Apparent and true seroprevalences on an individual level based on results from ELISA and values for sensitivity and specificity from the manufacturer*

	PPR seroprevalences % (CI 95%)		CCPP seroprevalences % (CI 95%)		FMD seroprevalences % (CI 95%)	
	Apparent	True	Apparent	True	Apparent	True
Monze	2.5 (0.96; 6.2)	2.0 (0.39; 6.0)	9.9 (6.2; 15)	-	33 (26; 40)	32 (26; 40)
Mazabuka	4.4 (2.1; 8.8)	4.0 (1.6; 8.7)	1.9 (0.64; 5.4)	-	18 (13; 25)	18 (12; 24)
Chibombo	25 (19; 32)	26 (20; 34)	0.62 (0.11; 3.5)	-	3.1 (1.3; 7.1)	2.5 (0.75; 6.6)
Total	11 (8.1; 14)	11 (8.0; 14)	4.2 (2.7; 6.3)	-	18 (15; 22)	18 (14; 21)

PPR

Table 5. *Results of serostatus of PPR from ELISA analysis*

	Positive individuals	Negative individuals	Doubtful individuals	Positive herds (≥2 positive individuals)	Negative herds (<2 positive individuals)
Monze	4	156	2	0	41
Mazabuka	7	140	13	0	40
Chibombo	40	80	40	10	30
Total	51	376	55	10	111

Overall, 51 of the 482 sampled individuals were seropositive for PPR when analyzed by ELISA, giving an apparent seroprevalence of 11% (95% CI 8.1; 14) and a true seroprevalence of 11% (95% CI 8.0; 14). In the central district of Chibombo, 40 out of 160 samples were positive, representing an apparent seroprevalence of 25% (95% Cl 19; 32) and true seroprevalence of 26% (95% Cl 20; 34). In Monze, 4 out of 162 samples were positive, representing an apparent seroprevalence of 2.5% (95% CI 0.96; 6.2) and a true seroprevalence of 2.0% (95% CI 0.39; 5.9). In Mazabuka, 7 out of 160 goats were positive, representing an apparent seroprevalence of 4.4% (95% Cl 2.1; 8.8) and a true seroprevalence of 4.0% (95% Cl 1.6; 8.7). The seroprevalence in the southern districts of Monze and Mazabuka was lower compared to the central district of Chibombo (p<0.001). Table 5 above presents the results on individual and herd level. Table 4 presents the apparent and true seroprevalences on both district and general level for PPR.

CCPP

Table 6. *Results of serostatus of CCPP from ELISA analysis*

	Positive individuals	Negative individuals	Positive herds (≥2 positive individuals)	Negative herds (<2 positive individuals)
Monze	16	146	4	37
Mazabuka	3	157	1	39
Chibombo	1	159	0	40
Total	20	462	5	116

In total, 20 of the 482 samples were positive for antibodies when tested with ELISA. The apparent seroprevalence in total was 4.2% (95% CI 2.7; 3.0). Since data on sensitivity is lacking, true seroprevalence could not be calculated. Mazabuka had three positive samples, giving the apparent seroprevalence of 1.9% (95% Cl 0.64;5.4). Chibombo had one positive sample and an apparent seroprevalence of 0.62% (95% Cl 0.11;0,35). Monze had 16 positive samples and an apparent seroprevalence of 9.9% (95% Cl 6.2;15). Table 6 above presents the results on individual and herd level. Table 4 presents the apparent seroprevalences on both district and general level for CCPP.

FMD

Table 7. *Results of serostatus of FMD from ELISA analysis*

	Positive individuals	Negative individuals	Positive herds (≥2 positive individuals)	Negative herds (<2 positive individuals)
Monze	53	109	15	26
Mazabuka	29	131	7	33
Chibombo	5	155	0	40
Total	87	395	22	99

In total, 87 samples were positive for antibodies when tested with ELISA, giving the apparent seroprevalence 18% (95% CI 15; 22) and the true seroprevalence of 18% (95% CI 14; 21). In Monze, 53 positive samples were positive, representing an apparent seroprevalence of 33% (95% Cl 26; 40) and a true seroprevalence of 32% (9 % Cl 26; 40). In Mazabuka, 29 samples were positive, representing an apparent seroprevalence of 18% (95% Cl 13; 25) and a true seroprevalence of 18% (95% 12; 24). In Chibombo, 5 samples were positive, representing an apparent seroprevalence of 3.1% (95% Cl 1.3; 7.1) and a true seroprevalence of 2.5% (95% Cl 0.75; 6.5). Table 7 above presents the results on individual and herd level. Table 4 presents the apparent and true seroprevalences on both district and general level for FMD.

Risk factors

No statistically significant association ($p>0.05$) was found regarding the internal factors of gender and age and seropositivity for PPR, FMD or CCPP.

Regarding grazing systems, there was no significant association found for the seropositivity of PPR, FMD or CCPP. Goats that had contact with wild ruminants at least once a week compared to never having contact had a statistically significant increased risk for PPR seropositivity ($p=0.014$). Contact with other herds and cattle from other herds did not have any significant association for any of the diseases.

Small herds (less than 15 goats) had an increased risk for seropositivity for PPR compared to medium and larger herds (p-value=0.042). Households where goats were housed together with other species, e.g. sheep, did not have a statistically significant increased risk of carrying any of the analyzed antibodies.

Regarding trade, no factor had a significant difference for any disease, both regarding selling and buying as well as international trade and quarantine of newly arrived animals.

Households with observed nasal and ocular discharge had an increased risk of seropositivity for FMD among the goats ($p=0.043$). Households that had not experienced diarrhea in their goats in the last year had an increased risk for PPR seropositivity ($p=0.046$). Households that had experienced coughing within the herd in the last year had an increased risk, yet not statistically significant, of having seropositive animals for CCPP ($p=0.07$). Isolating the sick animals could not be associated as a protective factor against seropositivity.

DISCUSSION

Seroprevalence

PPR

With PPR confirmed in multiple neighboring countries (OIE 2019c), there is a high risk of the virus spreading into Zambia (Chazya *et al.* 2014). Seropositive animals were detected as early as 2015 (OIE 2015b), and the virus might already be introduced. At that point in time, vaccinations performed in other countries were suspected as the reason for seroconversion. During 2018, one seropositive sample from a goat has been detected (Mitternacht 2019). Since then, more seropositive samples were detected in other districts (Sara Lysholm, personal communication, 2019). All of these positive animals were sampled in districts close to a border. However, these new findings of Mitternach (2019) and Lysholm (personal communication, 2019) have yet not been confirmed in a reference laboratory.

In this study, 51 samples out of 482 were positive for antibodies for PPR making the total true seroprevalence of approximately 11%. Most cases were found in Chibombo (n=40) giving an apparent seroprevalence of 25%. In Monze and Mazabuka, the apparent seroprevalences where 2.5% and 4.4%, which are similar to the seroprevalences of 0.8% to 3.3% detected by Lysholm (personal communication, 2019) in other districts of Zambia. How come Chibombo forms an exception with many seropositive animals? Perhaps the explanation is that Chibombo likely has the most movement of people and animals due to its central location near the capital of Lusaka. It was the only district included in this study where farmers conducted international trade. The two other sampled districts of Monze and Mazabuka, as well as the previously sampled districts by Mitternach (2019) and Lysholm (Sara Lysholm, personal communication, 2019), are more remotely situated with likely less movement than Chibombo.

Is it possible that PPR has circulated in these areas without an outbreak being identified? During the interviews, 24% of the household stated that they had suffered sudden deaths of goats within the last year, 57% had observed diarrhea, and 35% had observed nasal and ocular discharge. These are typical signs of PPR (OIE 2009b). Of course, multiple other diseases can cause similar signs and it is not possible to attribute the symptoms described by the farmers to any specific disease. PPR is known for its high mortality rates which can be close to 100%. Yet, also milder outbreaks may occur with lesser mortality rates (OIE 2009b) which might be the case in the seropositive herds.

The positive samples await confirmation in a reference laboratory. Nevertheless, the results are interesting and motivate increased surveillance to detect cases and also preparedness to cope with outbreaks.

CCPP

As CCPP is difficult to diagnose, it presents an epidemiologic challenge. No published studies have been conducted in Zambia previously. The results from this study found an apparent total seroprevalence of 4.2%. This seroprevalence is similar to the seroprevalence of 3.1%, which was found in other districts of Zambia, in a for the time being unpublished study by Lysholm

(Sara Lysholm, personal communication, 2019). These results indicate, however not yet confirmed, that CCPP is distributed in multiple districts, spread out in several areas of Zambia.

In Tanzania, the seroprevalence has varied between studies from 14.5% to 52.1% (Mbyuzi *et al.* 2014; Torsson *et al.* 2017). The higher seroprevalence was found in the southern parts of Tanzania (Mbyuzi *et al.* 2014) and therefore relatively close to Zambia. These Tanzanian seroprevalences are a lot higher than the 4.2% detected in this study and also the 3.1% detected by Lysholm in Zambia (personal communication, 2019) indicating that CCPP perhaps is less frequent in Zambia compared to neighboring Tanzania.

When the farmers were asked which signs have been displayed by the goats the last year, 57% had observed coughing and 35% had observed nasal and ocular discharge. These signs could be caused by CCPP, however further studies are required to monitor and detect clinical cases. As for PPR, the positive samples await confirmation.

The finding of animals in Zambia seropositive for CCPP has not been published before. Further studies are required to map the disease, to assess the epidemiology and form suitable control plan. For the sake of the health of small ruminants and the development of Zambia, keeping CCPP to a minimum is of essential importance.

FMD

FMD is considered endemic in Zambia with reoccurring and usually annual outbreaks. Finding seropositive animals is perhaps not surprising. In small ruminants, limited research has been published. In short, seroprevalences in small ruminants for FMD had previously ranged between 1.3% to 5.0% in the six districts sampled by Mitternacht in 2018 and Lysholm in 2019 (Mitternacht 2019).

In this study, the total seroprevalences were 18%. In Chibombo, the district which is situated close to the capital of Lusaka, the apparent seroprevalence was 3.1% and therefore similar to the results of Lysholm (2019) and Mitternach (2019). In Monze and Mazabuka, the apparent seroprevalence was 33% and 18%. During 2019, both Monze and Mazabuka had outbreaks of FMD (Dr. Musso Munyeme, personal communication, 2020) which could explain these findings of high seroprevalences.

Monze and Mazabuka are situated along the main route of transportation going south (T1). Proximity to main transportation routes has been associated as a risk factor for FMD-outbreaks (Hamoonga *et al.* 2014; Elnekave *et al.* 2016) since people and vehicles can indirectly transport the virus. The district sampled by Lysholm (personal communication, 2019) and Mitternacht (2019) is more remote with less traffic, which could further explain the low seroprevalences in these districts compared to Monze and Mazabuka.

During 2019, the temperatures were unusually high and rainfall all-time low in Zambia (United Nations Office for the Coordination of Humanitarian Affairs *et al.* 2019), especially in the southern province e.g Monze and Mazabuka. Dry climates have been shown to increase the risk for FMD (Hamoonga *et al.* 2014), likely due to increased movement since animals are forced to migrate to communal water points shared between multiple herds, which also creates contact between animals.

Mazabuka is situated closely to Kafue National park. This area around Kafue is considered a high-risk area since wild buffalos are suspected as subclinical carriers of the virus and capable of transmitting the virus to domestic animals (The Department of Research and Specialist Services 1999; Hamoonga *et al.* 2014). This factor might contribute to the seroprevalence of 18% in Mazabuka. Monze is also situated in the same province and relatively near to Kafue.

The common practice in Zambia is to utilize communal grazing of goats and sheep with exceptions during the rain season, which was the case for 92% of households included in this study. This management system has been shown to increase the risk of FMD (Beyene *et al.* 2015). During FMD-outbreaks, free-ranging animals can contact other herds and quickly both transmit and contract FMD.

In summary, multiple factors may contribute to the spread of FMD in Zambia, including the movement of animals and people, the management factors, wildlife in national parks and also climatic factors.

Risk factors

Since both CCPP and PPR have not been confirmed in Zambia, the criteria for representing a positive herd was set high to rule out false-positive herds. Only herds which had two seropositive animals were considered positive. Since the diseases are highly contagious, it should spread throughout the herd and more animals than only one should likely be seropositive if the herd has been infected. However, not all animals will seroconvert simultaneously. Also, older animals that carry antibodies may be seropositive, while younger animals are seronegative since they were not present at the time of the outbreak. By considering herds with only one seropositive animal as negative, there is a risk that true seropositive herds are missed. This can affect the statistical analysis since the herds are grouped incorrectly.

In multiple studies, internal factors have been associated with differences in seroprevalences for all studied diseases, yet no significant difference could be found in this study. The data was homogenous with relatively few animals deviating from the standard of being adult female goat of local breed. Only 16% were males and 12% were kids (<1 year of age). This forms a statistical problem where relevant risk factors can remain unidentified. For example, when age-groups were compared for their risk for seropositivity for PPR, 371 adults were negative, 47 adults were positive, 56 kids were negative, and 3 kids were positive. This means that 5% of kids were seropositive and 13% of adults. Adults have a somewhat increased risk of carrying PPR antibodies ($p=0.17$). Findings from other studies have seen the same correlation (Kardjadj *et al.* 2015; Torsson *et al.* 2017). Perhaps, if the data in the current study would have included more kids, the difference in risk might have been statistically significant. Another example regards the breed of the goats. A study found that the risk of seropositivity differs between breeds (Khan *et al.* 2018). Since all goats in this study were of local breed, there were no data from other breeds to compare with.

Multiple of the questions asked had similar answers altogether. For example, 93% of farmers had communal grazing in combination with fencing or tethering the animals. As most goats in Zambia are kept by traditional, small-scale farmers (Ministry of Fisheries and Livestock 2019), this is not surprising. In these cases, there is a lack of options to compare with and risk factors will be difficult to identify. However, other studies have seen a significantly higher risk for FMD if communal grazing is utilized (Beyene *et al.* 2015) and also for CCPP in sedentary compared to pastoral systems (Mekuria & Asmare 2009; Mbyuzi *et al.* 2014; Chota *et al.* 2019). Therefore, the lack of identified risk factors in this study does not rule out their importance.

Herds which had contact with wild ruminants at least once a week had increased risk of seropositivity for PPR compared to the herd which had contact more rarely (p=0.014). The wild ruminant was in most cases the antelope Brown lechwe (*Kobus lechwe*). This antelope has not been studied for its susceptibility to PPR. From a related antelope, The Nile lechwe (*Kobus megaceros*), PPR has been confirmed (OIE 2008; see Aziz-ul-Rahman *et al.*, 2018 table 1). According to the FAO & OIE (2015), no wildlife is believed to play a significant role in the transmission of PPR. Finding this association between seropositivity and contact with wild ruminants is interesting. Further research is needed to conclude its impact on the spread of PPR since it can be the result of bias.

In this study, small herds (≤15 goats) had an increased risk for seropositivity for PPR compared to larger groups (p=0.042). This association contradicts the finding of other studies where larger herds of goats had an increased risk of seropositivity (Al-Majali *et al.* 2008; Kardjadj *et al.* 2015). These studies were conducted in Algeria and Jordan. In the study by Al-Majali *et al.* (2008), herds with more than 100 animals were considered large. In the current study, very few herds measured that size, which implies that management routines differ between Jordan and Zambia. Other factors regarding management are likely to also differ between the countries and therefore might impact the seroprevalence.

Households where sheep were housed together with goats did not have an increased risk of carrying any of the analyzed antibodies. Associations between seropositivity for PPR and herds mixed with both goat and sheep have been seen in multiple studies (Al-Majali *et al.* 2008; Kardjadj *et al.* 2015). In the study by Kardjadj *et al.* (2015), the risk was increased for mixed herds compared to herds with sheep only. Al-Majali *et al*. (2008) found increased seropositivity for the sheep, but not for the goats, if the species were mixed. These findings indicate that goats might increase the risk of seropositivity in sheep, but there are no indications that sheep have a similar effect on goats. Goats are more susceptible to the disease and likely contribute more viral shedding than sheep. In Zambia, goats are the dominating small ruminant with approximately one sheep per twenty goats (Ministry of Fisheries and Livestock 2019). Therefore, the risk of goats transferring PPR to sheep is perhaps of lesser importance on a national level.

As mentioned in the literature review, trade has been associated with increasing seroprevalence for PPR, CPP and FMD in various studies, likely since it facilitates the spread of infectious agents to susceptible animals. In this study, no statistically relevant association could be found. As for the frequency of buying/bartering and selling goats, the question was asked with eight possible answers (see appendix 1 for further information). The data was analyzed using Fischer's exact test and to fit a two-by-two table, the data were categorized as at least once a week versus more rarely than once a week. This is a slightly rough division where associations might be missed. As for international trade, importing animals from countries where diseases are present form an obvious risk. International trade was however relatively uncommon with only 6.7% of households stating to have sold goats to other countries. The international trade consisted of only selling animals, and not buying animals, and the influx of goats from foreign countries likely to be minimal in the studied population. As a conclusion, trade is likely to impact the spread of the studied diseases in multiple ways in Zambia, even though the factors responsible were not identified by this current study.

Regarding the health of the animals, several interesting associations were found between factors and seropositivity. Households with observed nasal and ocular discharge within the last 12 months had an increased risk of seropositivity for FMD among the goats (p=0.043). Since outbreaks of FMD had occurred in the sampled districts, the farmers would likely observe signs of the disease.

Households that had not experienced diarrhea in their goats within the last year had an increased risk of seropositivity for PPR (p=0.046). This is contra-intuitive since diarrhea is one of the signs of PPR (OIE 2009b). The p-value is statistically relevant, however, it could still be the result of chance and not be a causal link.

Households that had experienced coughing within the herd in the last year had an increased risk, yet not statistically significant, of having seropositive animals for CCPP (p=0.07). This indicates that farmers to some degree are picking up clinical signs of pulmonary disease caused by CCPP. Naturally, many other diseases also manifest as coughing and there will be goats seronegative for CCPP which have displayed coughing. Taken together, these factors likely contribute to raising the p-value above a statistically significant level.

Households that implemented quarantine of newly arrived animals or isolation of sick animals did not have lesser proportions of seropositive animals for any of the studied diseases. Of the interviewed farmers, 20% stated to isolate sick animals and 33% stated to quarantine newly arrived animals. The facilities in which animals were isolated and quarantined were not examined and it is consequently difficult to draw any conclusions whether these were sufficient to stop the spread of disease.

In summary, multiple interesting risk factors for seropositivity were identified. Also, multiple factors that likely impact the spread of the studied diseases were not found statistically significant. Some risk factors, e.g. trade and grazing systems, are relevant for controlling the diseases none the less.

ACKNOWLEDGEMENTS

I would like to convey my gratitude to my supervisors, that all contributed greatly to the project. My main supervisor, Jonas Johansson Wensman, was always available for questions and support throughout the project. My assistant supervisor Sara Lysholm was an always useful and practical help in Zambia. Also, I thank my local supervisor, Musso Munyeme for giving a warm welcome to Zambia.

I would like to thank the contributors of funds that made this project possible. These include Swedish Research Council (grant no. 2016-05667 and 2018-03956), The Swedish International Development Cooperation Agency for the minor field study scholarship, the Elsa Paulsson's memorial fund, and the Michael Forsgren's memorial fund.

POPULÄRVETENSKAPLIG SAMMANFATTNING

Zambia är ett kustlöst land i södra Afrika där 60 % lever i fattigdom, varav 40 % lever i extrem fattigdom. Landet har drabbats hårt av klimatförändringar med efterföljande torka som påverkar livsmedelsproduktionen negativt. År 2019 var nederbörden varit rekordlåg vilket resulterade i att 15 % av befolkningen led av matbrist och 6 % led av akut näringsbrist år 2019. Eftersom landytan består av mer betesmark än åkermark är djurhållning av stor betydelse för livsmedels-försörjningen. Majoriteten av djurhållningen drivs av småskaliga, traditionella jordbrukare. Att skapa en hållbar livsmedelsproduktion är av yttersta vikt för att föda befolkningen.

Små idisslare, såsom getter, kan under torka livnära sig på buskar och annan vegetation. På så vis kan de fortsätta näringsförsörja sig själva och därmed även deras ägare. Eftersom de har ett lägre pris än nötkreatur är de tillgängliga för fler människor. De kräver relativt enkel omvårdnad. Dessa fördelar har gjort små idisslare, tillsammans med fjäderfä, till den huvud-sakliga boskapen i låg- och medelinkomstländer. Getterna producerar kött, mjölk, avkommor och flertalet andra biprodukter såsom skinn, vilket genererar handel och inkomst för bönderna. Sammanfattningsvis har små idisslare en viktig, men ofta underskattad roll, i kampen mot fattigdom och svält.

I denna studie provtogs getter i Zambia för tre olika sjukdomar. Dessa var peste des petits ruminants, smittsam pleuropneumoni och mul- och klövsjuka. Samtliga av dessa sjukdomar är mycket smittsamma och sprids snabbt vid ett utbrott. Dödligheten bland djuren kan vara mycket hög och produktionen påverkas kraftigt. Sjukdomarna har olika klinisk bild, men gemensamt är att de orsakar stora socio-ekonomiska samt djurvälfärds konsekvenser. Mul- och klövsjuka anses vara utbrett i landet, med utbrott både på getter men även andra djur såsom kor och grisar. Läget för PPR och CCPP är mindre känt. CCPP har aldrig bekräftats inom landet. Getter som bär på antikroppar av PPR har hittats i landet, men kliniska fall med symptom har aldrig bekräftats.

Arbetet utfördes i tre distrikt, varav distrikten Monze och Mazabuka ligger i den södra provinsen och Chibombo ligger i den centrala provinsen. Blodprov togs från 482 getter i 120 hushåll. Blodproven analyserades för att se om antikroppar fanns mot sjukdomarna. Anti-kroppar bildas antingen om djuret varit infekterad med eller vaccinerad mot sjukdomarna. Varje hushåll intervjuades angående deras djurhållning, till exempel om vaccinering, hur mycket kontakt getterna hade med andra djur, samt i vilken utsträckning bönderna handlade med djuren.

Djur med antikroppar hittades för alla tre sjukdomarna; 11 % av djuren var positiva för peste des petits ruminants, 4,1 % var positiva för smittsam pleuropneumoni och 18 % var positiva för mul- och klövsjuka. Flertalet av bönderna berättade under intervjuerna om symptom som överensstämmer med sjukdomarna.

Sjukdomarna har sannolikt en stor, och hittills underskattad, påverkan på getterna i Zambia. Detta påverkar de småskaliga böndernas matförsörjning och inkomst avsevärt. Eftersom fattigdomen är utbredd i landet är det många utsatta människor som drabbas. För det enskilda landet finns naturligtvis ett intresse att stoppa spridningen, men det finns även ett internationellt intresse att motverka fattigdom och svält, eftersom smittorna sprids över landsgränser. Ytterligare kartläggning bör ske och kontrollplaner utformas. Förhoppningsvis kan denna studie motivera till ett sådant initiativ.

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APPENDIX 1

QUESTIONNAIRE SMALL LIVESTOCK FARMERS

ID: 2019-ZM-

DATE: ___/___/2019

CHECK IF: Adequate project introduction has been done ____√ | and Consent is granted _____√

LOCATION

District:	**Town/Village:**	**GPS:** Latitude
		GPS: Longitude

Interview language	**Respondents first language(s)**

1. MANAGEMENT ROUTINES

1.1) What grazing system are you utilizing?

OBS: Remember to ask the farmer to specify the different grazing systems for ALL seasons

Grazing system	**Check the ones that apply**	**Comment** *E.g. season, animal type (kids, pregnant mothers..)*
Communal grazing		
Fenced grazing		
Tethering		
Herding		
Zero-grazing/Cut-and-carry		
Other, please specify; -------------------------		

1.2a) How often are your goats in contact with sheep and/or goats from other herds?
If the farmer uses several grazing systems, e.g. communal grazing during the dry period and tethering during the rainy season; remember to ask about the contact patterns of both grazing system

FREQUENCY	**Check the one that applies**
Daily	
At least once a week	
At least once a month	
At least once every 6 months	
At least once a year	
More rarely	
Never	
I do not know	

1.2b) <u>ASK only if respondent did not answer NEVER on 1.2a)</u>:
Does this vary over the year? If yes, how?
For example; more contact during dry season etc

1.2c) <u>ASK only if respondent did not answer never on 1.2a)</u>
Please describe this contact
For example grazing together, grazing on the same field but not together etc

1.3a) How often are your goats in contact with cattle from other herds?

If the farmer uses several grazing systems, e.g. communal grazing during the dry period and tethering during the rainy season; remember to ask about the contact patterns of both grazing system

FREQUENCY	**Check the one that applies**
Daily	
At least once a week	
At least once a month	
At least once every 6 months	
At least once a year	
More rarely	
Never	
I do not know	

1.3b) <u>ASK only if respondent did not answer never on 1.3a)</u>:
Does this vary over the year? If yes, how?
(For example; more contact during dry season etc)

1.3c) <u>ASK only if respondent did not answer never on 1.3a)</u>
Please describe this contact
(For example grazing together, grazing on the same field but not together etc…)

1.4a) How often are your goats in contact with wild ruminants?

If the farmer uses several grazing systems, e.g. communal grazing during the dry period and tethering during the rainy season; remember to ask about the contact patterns of both grazing system

FREQUENCY	Check the one that applies
Daily	
At least once a week	
At least once a month	
At least once every 6 months	
At least once a year	
More rarely	
Never	
I do not know	

1.4b) <u>ASK only if respondent did not answer never on 1.4a)</u>
What species of wild ruminant(s)?
If the respondent does not know the English name, write the local name

1.4c) <u>ASK only if respondent did not answer never on 1.4a)</u>
Does this vary over the year? If yes, how?
(For example; more contact during dry season etc)

1.4d) <u>ASK only if respondent did not answer never on 1.4a)</u>
Please describe this contact

(For example grazing together, grazing on the same field but not together etc…)

2. MEDICINES

2.1a) How often do you dip and/or spray your goats for external parasites such as ticks and flies?

FREQUENCY	**Check the ones that apply**	**Comments** *E.g. in the rain season at least once a week, in the dry season at least once a month etc*
At least once a week		
At least once every two weeks		
At least once a month		
At least once every three months		
At least once every six months		
At least once a year		
More rarely		
I never dip or spray them		

2.1b) <u>ASK ONLY IF THE RESPONDENT DID NOT ANSWER NEVER ON 2.1a)</u>
When do you decide that it is time to dip/spray your goats?

2.2a) How often do you deworm your goats?

FREQUENCY	**Check the ones that apply**	**Comments** *E.g. in the rain season at least once a week, in the dry season at least once a month etc*
At least once a week		
At least once every two weeks		
At least once a month		
At least once every three months		
At least once every six months		
At least once a year		
More rarely		
I never deworm them		

2.2b) <u>Ask ONLY if the farmer did not answer NEVER on question 2.2.a)</u>How do you decide that it is time to deworm the goats?

2.3a) When was the last time you treated your goats with a medicine that was not a dewormer or a spray/dip for external parasites?

FREQUENCY	**Check the one that applies**
This week	
This month	
These last six months	
This year	
More than one year ago	
I have never treated my goats for anything other than deworming and tick spray	

2.3b) Ask only IF YES to 2.1a)
What drug did you use at the last time?

NAME and TYPE of drug: ___________________________

2.3c) Ask only IF YES to 2.1a)
What symptoms/disease did the goats have at this time?

2.4a) Do you vaccinate your goats?

YES	**NO**

2.4b) <u>Ask ONLY if the respondent answered YES to 2.4.a</u>

For what diseases do you vaccinate your goats?

2.4c) <u>Ask ONLY if the respondent answered YES to 2.4.a</u>

When was the last time you vaccinated the goats?

2.4d) <u>Ask ONLY if the respondent answered YES to 2.4.a</u>

How often do you vaccinate them?

2.5) When one or a few of your goats are sick, do you keep it/them separated from the rest of the herd?

YES, during daytime	**YES, during night time**	**YES, both day and night time**	**NO**

3. TRADE

3.1a) How often do you <u>buy</u>/barter or in any other way get new goats to your herd?
This question is about all ways to get new animals to the herd except through birth from animals that are already part of the herd

FREQUENCY	**Check the one that applies**
At least once a week	
At least once a month	
At least once every six months	
At least once a year	
At least once every two years	
More rarely	
I have never bought/bartered a goat	

3.1b) ASK ONLY if the respondent did not answer "I have never…" on question 3.1a

What kind of people do you buy/barter or in any other way get new goats to your herd from?

Write 1 or 0 and rank the alternatives

TYPE OF PEOPLE	**Check the ones that apply**	**RANKING** *1= most common, 2= second most common etc*
Farmers		
Traders		
Other; specify; ----------------------		

3.1c) ASK ONLY if the respondent did not answer "I have never…" on question 3.1a. Where are these goats from?

Write 1 or 0 and rank the alternatives

LOCATION	**Check the ones that apply**	**RANKING** 1= most common, 2= second most common etc
From my village		
From other villages in my district		
From other districts If YES, specify; ---------------------------		

From markets If YES; Please specify location of the market(s) ----------------------------		
Other, please specify; ----------------------------		

3.2) Have you ever bought or received one or several goats from other countries?

YES	**NO**
• Which countries? ____________________ • When was the last time you bought or received a goat from another country? _____________________	

3.3) Are you aware of farmers in your community who are buying or receiving sheep and/or goats from other countries?

YES	NO
If YES; Which countries?	

3.4) After acquiring new goats, do you let them mix with your original herd immediately?

YES	**NO**
	If NO; what do you do? *For example; keep them separated for a day, deworms them then release them with the rest etc*

3.5) When do you decide to sell goats?

3.6) How do you decide which goats to sell?

3.7a) How often, approximately, do you sell goats?

FREQUENCY	**Check the one that applies**
At least once a week	
At least once a month	
At least every six months	
At least once a year	
At least once every two years	
More rarely	
I have never sold goats	

3.7b) ASK ONLY if the respondent did not answer "I have never…" on question 3.7a. What kind of people do you sell your goats to?

Write 1 or 0 and rank the alternatives

TYPE OF PEOPLE	**Check the ones that apply**	**Ranking** 1= most common, 2=second most etc
Farmers		
Traders		
Home consumers (People buying for home consumption)		
At markets (to people who buy at markets)		
Restaurants		
Slaughterhouse		
Other If YES; please specify;		

3.7c) ASK ONLY if the respondent did not answer "I have never…" on question 3.7a. To where do you sell the goats?

LOCATION	**Check the ones that apply**	**RANKING** 1= most common, 2= second most common
Within my village		
Within my district		
To other districts If YES, specify _______________		
To other countries If YES, specify ________________		
Other, please specify;		

3.8) Have you ever sold goats to other countries?

YES	NO
If YES; Which countries?	

3.9) Are you aware of farmers in your community who are selling goats to other countries?

YES	NO
If YES; Which countries?	

3.10) Which diseases is it OK for a goat to have and it can still be sold?

First ask the question as it is and write the answer in the free space, then probe for the alternatives below and note down the answers in the table

Probe for;	**1=YES** **0=NO**
Runny eyes and nose	
Coughing	
Diarrhea	
Abortion	
Other, please specify;	

3.11) What diseases would you say that it is OK for the goat to have and you would still buy it?

First ask the question as it is and write the answer in the free space, then probe for the alternatives below and note down the answers in the table

Probe for;	**1=YES** **0=NO**
Runny eyes and nose	
Coughing	
Diarrhea	
Abortion	
Other, please specify;	

3.12) Are there any risks with trading sick animals?

Answer	Check the one that applies
Yes	If YES; what are the risks:
No	
I do not know	

4. ANIMAL HEALTH

4.1) What signs of disease did you observe in your goats, in the last 12 months?

1. Ask what signs of disease the farmer experiences in his/her animals and indicate below
2. Ask farmer if the occurrence of the disease varies over the year or if it occurs at a constant rate
3. Ask the farmer to rank the diseases from the most common disease to the least common.

4. Ask what the farmer does when he or she experiences this symptom/disease

Disease/Symptom	YES = 1, NO = 0	Rank from most common (1) to least common (Top 5)	Seasonality	What do you do when you experience this?
4.1a.Diarrhea				
4.1b.Coughing				
4.1c.Abortion				
4.1d.Dying kids				
4.1e.Sudden death (dying suddenly within 24 hours of showing symptoms or not showing symptoms at all)				
4.1f.Runny eyes and nose				

4.2) What disease would you say have the highest impact on you as a farmer? Why this disease?

4.3) Do you ask anyone for help when your goats are sick and if YES, who do you ask?

TYPE	**CHECK THE ONE THAT APPLIES**	**RANK** (1= most common, 2=second most common etc)
I do not ask for help		
Other farmers		
Vet shop/Agri shop		
Veterinary personnel (vet, vet assistant, livestock assistant etc)		
Pharmacy		
Other		

5. ANIMAL SPECIES IN HOUSEHOLD

6.1) Are the goats housed together with any other species? If Yes, which species?

YES *If YES; Please specify species;*	**NO**

6.2) What species other than goats do the household have?

Type of species	**Present in household?** 1=YES 0=NO	**Comments**
Sheep		
Cattle		
Pigs		
Horses/Donkeys		
Poultry		
Other;		

6.3) Details of goats owned

	Adult males	Adult females	Kids/Lambs
Number			
Breeds			

6.4) Details of sheep owned

	Adult males	Adult females	Kids/Lambs
Number			
Breeds			

6. INTERVIEW DETAILS

7.1) Interviewee role in the household and in taking care of the goats

7.2) How long has your household been keeping goats?

7.4) Gender

Male	**Female**

7.4) Farmers first name and telephone number (optional for farmer – this is so that we can give them feedback about the results)

Do you have any questions for me/us?