

CHAPTER 1: INTRODUCTION

1.1 Background

Peste des petits ruminants (PPR) was first reported in 1942 in the Ivory Coast (Gargadennec and Lalanne 1942), and the PPR virus (PPRV) was later isolated in Senegal in 1962 (Gilbert and Monnier 1962), after which the disease seemed to have become endemic in West and Central Africa (Scot, 1981). It is an acute and highly contagious viral disease of small ruminants, particularly sheep and goats, characterized by high fever, erosive stomatitis, mucopurulent nasal and ocular discharge, pneumonia, necrosis and ulceration of mucous membranes and inflammation of gastrointestinal tract leading to severe diarrhoea (Sarker and Islam 2001). The name Peste des petits ruminants is a French phrase for “disastrous disease of small ruminants” (Snow *et al.* 2011). PPRV is biologically and antigenically related to rinderpest virus and clinically, the disease mimics rinderpest in goats (Kulkarni *et al.* 1996).

PPR is a disease of increasing economic importance in Africa and Asia wherever small ruminants form an important component of agricultural food production. The disease can affect a broad range of species, including some species of antelope (Roeder and Obi 1999). It is classified in the order Mononegavirales, family Paramyxoviridae, subfamily Paramyxovirinae, genus *Morbillivirus*. This is on account of its genetic similarity with other members of the genus *Morbillivirus* that includes measles virus (MeV), Rinderpest virus (RPV), canine distemper virus (CDV) and a number of other viruses that infect aquatic mammals (Banyard *et al.* 2010).

Once thought to be a comparatively restricted problem in West Africa, PPR is now known to have spread to most of West, Central and East Africa, reaching eastwards through Western and South Asia. Recently, the disease has been found to have a wide geo-graphical distribution in sheep and goats. It has since been reported in sub-Saharan equatorial Africa, Sudan (El Hag Ali and Taylor 1984), Kenya, Uganda (Wamwayi *et al.* 1995) and Ethiopia (Roeder *et al.* 1994). The virus has also been identified as the cause of several serious epidemics in small ruminant populations over the last three decades. Since 1993, the Arabian Peninsula, the Middle East and major parts of the Indian subcontinent have reported major outbreaks. The virus is now considered endemic across

this region (Dhar *et al.* 2002). Much of this increased recognition is owing to greater awareness and the availability of new laboratory diagnostic tests. However, it is possible that the disease has actually spread, rather than just being more frequently recognized (Roeder and Obi 1999).

Until recently, PPR was considered absent from the SADC region, and as such most countries have not developed strategies on how to stem the spread of the disease in the event of an incursion (SADC 2012a). If the disease were allowed to spread from the DRC and Tanzania into the whole of the 15 nation SADC area, it could potentially devastate the livelihoods and food security of millions of vulnerable smallholder farmers and agro-pastoralists (SADC 2012a). Consequently, southern African countries have been cautioned to take the PPRV situation in southern Tanzania very seriously as enough justification exists to prepare for the worst (Decapua 2010).

1.2 Statement of the Problem and Study Justification

PPR is a disease that threatens the national food security of affected countries and also results in economic losses due to sanitary related trade embargoes. The disease has high morbidity and mortality rates and significant economic impacts in developing countries (Wambura 2000). In the Southern African Development Community (SADC) region, the disease was officially reported in Tanzania in 2008 (Swai *et al.* 2009) where it was confined to the northern zone until 2010 when cases were suspected in the southern part of the country (Decapua, 2010). In 2010, The Democratic Republic of Congo (DRC) reported outbreaks of PPR in the provinces of Bas-Congo and Kinshasa (FAO, 2013a). The country further reported that since its emergence in 2010 to June 2012, PPR had caused the death of almost 120,000 small ruminants valued at US\$5.3 million. This does not take into account the socioeconomic impact and other benefits of goats and sheep to the smallholder farmers (SADC, 2012a). In October, 2012, Angola also reported an outbreak of PPR in Cabinda province through illegal movement of a herd of 55 sheep/goats brought from DRC despite the prohibition of imports from PPR affected countries (OIE, 2012b).

In case of Zambia, PPR is a notifiable disease which has not been reported despite the country being close neighbours to Tanzania, DRC and Angola where recent outbreaks were reported (SADC 2012a). Amidst this disease threat, trade in livestock and livestock products continues to exist between Tanzania and Zambia. In their daily routines, veterinarians and other workers in the livestock industry are faced with situations where they have to make decisions to authorise either movement of animals or animal products into the country from other countries, including Tanzania. These decisions are often based on available information. In the absence of sufficient information, the decision making process becomes very difficult. However, because of the need to engage in trade or facilitate movement of animals and animal products, decisions have to be made despite the paucity of data. Risk analysis provides a major tool to informed decision-making on risk management. Despite the imminent risk of PPR spreading from Tanzania into northern Zambia, there has been no objective risk assessment conducted to determine the actual risk of pathogen introduction into the country or its impact.

In view of the possible risk posed by PPR virus introduction into Zambia through livestock trade, there is need to carry out a risk assessment to determine the current level of risk and evaluate how that risk could be better managed and communicated to all stakeholders. This requires identifying and plotting of trade routes for goat movements into the country presenting the risk of PPRV introduction; and identifying mitigation measures that could be applied at various critical points of the pathway. Despite the imminent risk of PPR spreading from Tanzania into northern Zambia, there has been no objective risk assessment conducted to determine the actual risk of pathogen introduction into the country through importation of livestock commodities from Tanzania into Zambia. It is envisaged that once carried out, the risk assessment report will be used as a basis for recommendations to the Government of Zambia, FAO, OIE, SADC, the scientific community, the private sector, and other stakeholders and will inform decision makers on epidemic preparedness in case of an outbreak.

1.3 Aim and objectives of the study

1.3.1 Aim of the study

The aim of the study was to determine the annual risk of introduction of Peste des petits ruminants (PPR) into northern Zambia through importation of live goats from Tanzania and map possible entry points and spread of the disease in Zambia.

1.3.2 Specific objectives

- (a) To conduct qualitative and quantitative risk assessments, estimating the annual risk of PPRV introduction into Northern Zambia, particularly Nakonde, Mpulungu, and Mbala districts through the importation of live goats from Tanzania.
- (b) To identify and map the trade routes which may serve as possible entry points of the disease into Zambia;
- (c) To identify possible risk mitigation measures that could be applied at various critical points along the pathway;
- (d) To make recommendations on the emergency preparedness on PPRV in Zambia to decision makers and other stakeholders.

CHAPTER 2: LITERATURE REVIEW

2.1 Historical Background

PPR has historically been associated with outbreaks across West, Central and East Africa, India and the Middle East (OIE, 2012). It was first described in Ivory Coast in West Africa in 1942 (Gargadenec and Lalanne 1942). Gradually, it was realized that several clinically similar diseases occurring in other parts of West Africa shared the same cause - the virus now called Peste des petits ruminants. Investigators soon confirmed the existence of the disease in Nigeria, Senegal and Ghana. For many years it was thought that it was restricted to that part of the African continent until a disease of goats in the Sudan, which was originally diagnosed as Rinderpest in 1972, was confirmed to be PPR (Roeder and Obi 1999). PPRV is now also considered to be endemic across North Africa, China and parts of the Far East. Increased awareness of the disease and reporting systems have highlighted the presence of PPR in areas previously thought to be clear of the virus (OIE, 2012a).

2.2 Global Distribution

PPR has been reported in many of the African countries that lie between the Atlantic Ocean and the Red Sea. The affected area extends north to Egypt and south to Kenya, in the east, and Gabon, in the west. PPR has not been recognized in most of Northern and Southern African countries. In some of the countries where the disease has not been confirmed, there are serological and/or clinical indications that the infection is, nevertheless, present (Roeder and Obi 1999). In recent years the disease has been seen in the Near East and the Arabian Peninsula, in countries including the Islamic Republic of Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Saudi Arabia, the United Arab Emirates and Yemen, and there is serological evidence from the Syrian Arab Republic and Turkey (Figure 1). Outbreaks of PPR are now known to be common in India, Nepal, Bangladesh, Pakistan and Afghanistan (Roeder and Obi 1999).

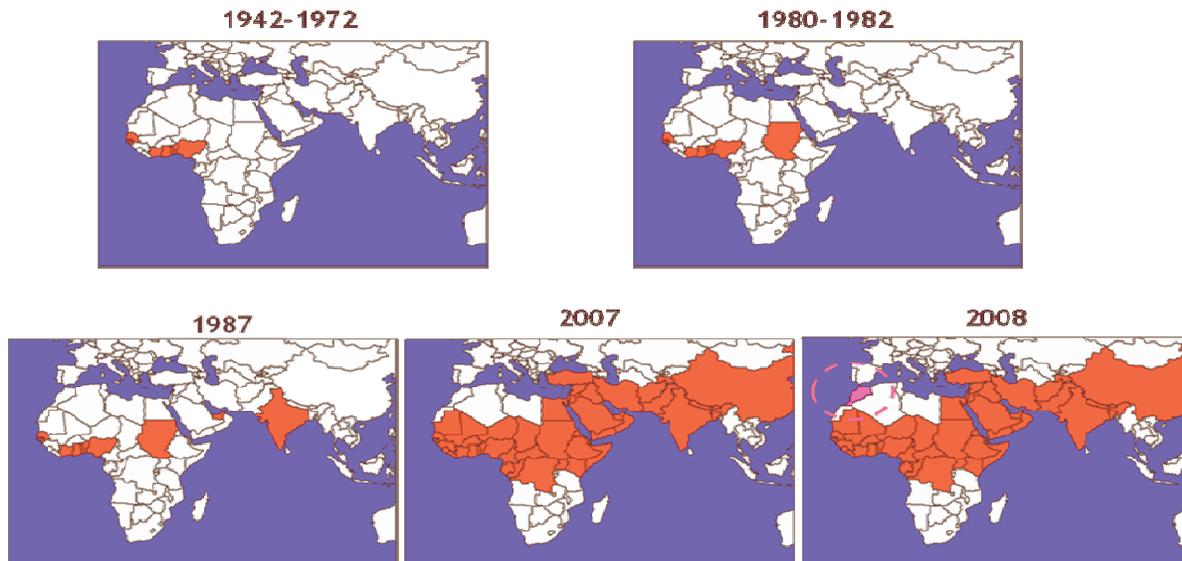


Figure 1: Map showing progressive spread of PPR in the world since 1942 when it was first reported. PPR outbreak areas are marked in red and white are free areas (FAO, 2009).

NB: This distribution is before the invasion of Tanzania and Angola by PPR.

2.2.1 Regional distribution

More recently, confirmation of endemicity of PPRV across East Africa has been shown through the detection of antibodies to PPRV in Kenya in 1999 and 2006, and Uganda in 2005 and 2007 (Banyard *et al.* 2010). PPRV was more recently detected again in Kenya in 2009 in the Turkana district. In Kenya, the disease rapidly spread to 16 districts, including several where it has been associated with severe socioeconomic consequences for food security and has impacted on the livelihoods of the local population (Banyard *et al.* 2010). The disease was first reported in Tanzania in 2008 when it was confined to the Northern zone in districts bordering Kenya (Kivaria *et al.* 2009; Swai *et al.* 2009). After the first confirmation in 2008, PPR was confined to the northern zone until 2010 when cases were suspected in the southern part of the country (Epaphras *et al.* 2011). Epaphras *et al.* (2011) suggest that PPR was introduced to Southern Tanzania for the first time in goats and sheep in February 2009. They further observed that PPR introduction was through newly purchased goats from the Pugu livestock Market located about 679 km from Dar es

Salaam. These animals were brought in about one week prior to the disease outbreak. Furthermore, Epaphras *et al.* (2011) reported that with PPR being present in Southern Tanzania, Southern African countries, especially Mozambique, Zambia and Malawi, were at risk.

2.2.2 Distribution of PPRV according to molecular diversity

The current molecular characterization of PPRV isolates divides them into four genetically distinct lineages: lineage I being represented mainly by Western African isolates from the 1970s and recent isolates from Central Africa; lineage II by West African isolates from the Ivory Coast, Guinea and Burkina Faso; lineage III by isolates from East Africa, the Sudan, Yemen and Oman; lineage IV includes all viruses isolated from recent outbreaks across the Arabian Peninsula, the Middle East, southern Asia, and recently, across several African territories (Banyard *et al.* 2010), See Figure 2 and 3.

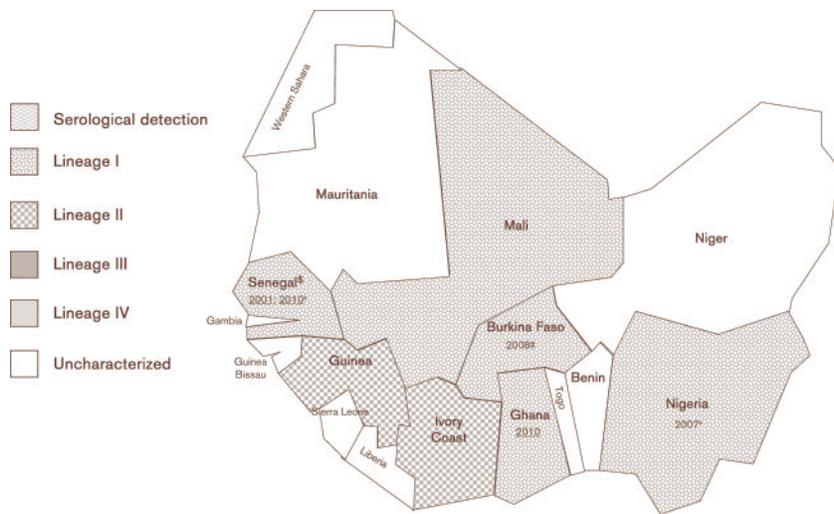


Figure 2: Distribution of PPRV across West Africa (2000–2010) - (Banyard *et al.*, 2010)

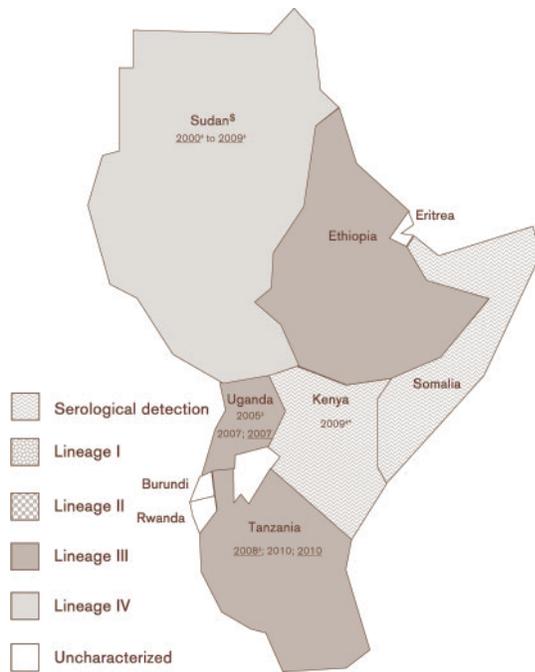


Figure 3: Distribution of PPRV across East Africa (2000–2010) - (Banyard *et al.* 2010)

2.3 PPRV threat in SADC region and Zambia in particular

Incursion of PPRV from Tanzania into Mozambique, where outbreak of PPR occurred close to the border with Mozambique, may not be a major, immediate threat as earlier perceived (Decapua 2010; Diallo *et al.* 2011). With the virus circulating in the southern highlands of Tanzania, though there are no active cases, there is a probability that the virus will find its way into Zambia and Malawi” (Decapua 2010). As a result, southern African countries have been cautioned to take the situation in southern Tanzania very seriously as enough justification exists to prepare for the worst (Decapua 2010). Trade in livestock and livestock products are to a large extent informal between the two countries. The Zoosanitary inspectorate unit of the Ministry of Livestock and Fisheries Development in Tanzania confirmed that there has not been much formal trade in livestock and livestock products between the two countries in the recent past (Ministry of Livestock and Fisheries Development, 2012). However, illegal movements along the border areas between the two countries are rife. This poses an increased threat to incursions of PPR from southern Tanzania into Zambia through uncontrolled or illegal movement of goats.

In Zambia, PPR is a notifiable disease which has not been reported despite the country being close neighbours to Tanzania, DRC and Angola where recent outbreaks have been reported (Fig 4) .The working group of the SADC Livestock Technical Committee (LTC) on PPR classified Zambia, Mozambique, and Malawi to be high risk countries (SADC, 2012a).

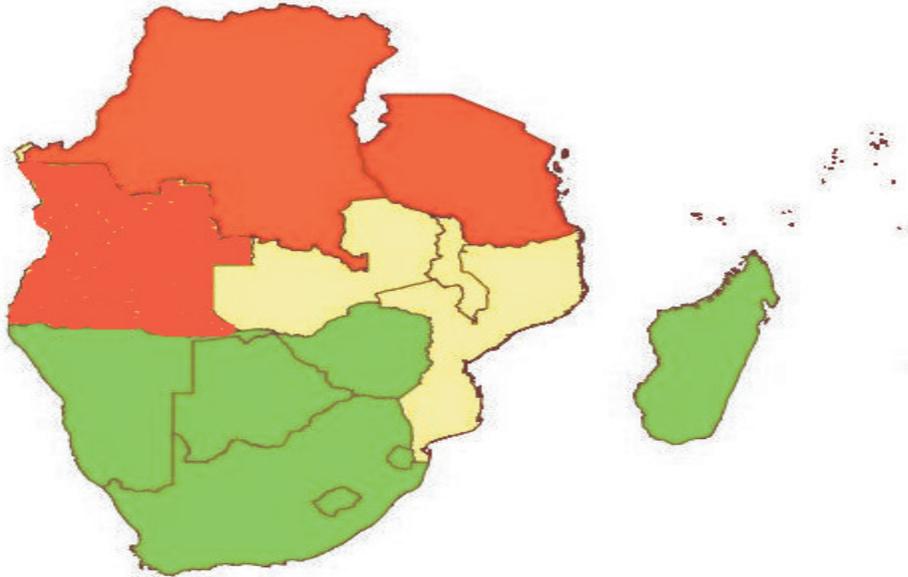


Figure 4: Map of SADC region as per PPR risk classification showing; infected-DRC, Tanzania, and Angola (in red); High risk –countries sharing a border with the infected (Zambia, Malawi, and Mozambique) (in yellow), and low risk-rest of SADC (in green) (SADC, 2012a).

2.4 Social economic significance of PPRV

The socio-economic significance of PPR is a result of heavy losses at production level and market effects along the value chain. It is estimated that 10% of the total impact of the disease is on trade and public expenditure and 90% on herd productivity (DFID, 2001-2002). In Nigeria, an outbreak that occurred in 1979 killed 10-20% of the national small ruminant flock that was estimated at US\$ 75 million (Wakhusama *et al.* 2011). In Ethiopia, FAO estimated that losses associated with PPR reached an average of US\$ 375 per flock per year, with an average of 143 small ruminants per flock (an average loss of more than US\$ 2 per animal) (Wakhusama *et al.* 2011).

In the 2008 outbreak in Kenya, the cost of vaccines used was estimated at € 4.8 million out of a total vaccination campaign cost of €12 million (Njagi, 2009).

The DRC reported that since its emergence in 2010 to June 2012, PPR had caused the death of almost 120,000 small ruminants. It estimated the direct loss; i.e. value of dead sheep and goats to be US\$5.3 million. This estimate did not take into account the socio-economic impact and other benefits of goats and sheep to the smallholder farmers (SADC, 2012b).

The important direct economic losses caused by PPR are often further aggravated by sanitary measures imposed by authorities in controlling animal movement and trade restrictions on their by-products (Wakhusama *et al.* 2011). Control of PPR is highly beneficial. A cost benefit analysis conducted in Niger in 1993 to assess the benefit of vaccination against PPR concluded that an investment of US\$ 2 million on vaccination would generate US\$ 24 million in return for a five year vaccination program (Stem, 1993).

2.5 The livestock sector in Zambia

Livestock production is the most important agricultural activity in most of the countries in Southern Africa (Mamabolo and Webb 2005). Goats play an important socioeconomic role in rural areas, especially among women who are among the most resource poor farmers in Africa. Goats and sheep are prolific and require low capital inputs for a moderate level of production, reaching maturity early and are profitable to keep (Devendra and Burns 1970).

In Zambia, exports of animal products were about US\$ 1.4 million, US\$ 4.4 million, US\$ 3.1 million in 1995, 1999 and 2001, respectively. Traditional livestock activities account for 83%, 64% and 97% of cattle, sheep and goat production, respectively (Aregheore 2006). Daka (2002) reported that the livestock sector was increasingly becoming an important component of Zambia's economy and its contribution to the National Gross Domestic Product (GDP) in 1996 and 1997 was estimated at 6.4 and 6.5%, respectively. In 1997, the livestock sector accounted for 33% of agricultural exports. About 23% of the per capita supply of protein comes from animal products (Aregheore 2006). The population of goats in Zambia has been increasing steadily over the last 5 years (Table 1).

Table 1: Baseline data (2007 to 2012) on livestock population for selected species (% Annual change indicated in parenthesis).

	2007	2008	2009	2010	2011	2012
Cattle	2,799,965	2,457,563 (-12.31)	231,5327 (-5.79)	3,038,000 (+31.21)	3,498,498 (+15.16)	3,694,766 (5.6)
Goats	1,762,461	956,304 (-45.74)	746,143 (-21.98)	758,501 (+1.66)	1,380,100 (+81.95)	1,839,650 (33.3)
Sheep	117,930	101,191 (-14.19)	485,033 (379.32)	466,506 (-3.82)	765,508 (+64.09)	92,490 (-87.98)
Pigs	398,637	538,393 (+35.06)	704,832 (+30.91)	711,707 (+0.98)	1,108,192 (+55.71)	815,685 (-26.39)

(NALEIC. 2012)

2.6 Epidemiological Framework for PPR

2.6.1 PPRV Characteristics

2.6.1.1 Aetiology

The disease is caused by the PPR virus (PPRV) which belongs to the genus *Morbillivirus* under the family Paramyxoviridae (Wambura, 2000). PPRV is an RNA virus, which is closely related to the Measles, Rinderpest and Distemper viruses (Geerts, 2009). There is only one serotype of PPR, but there are at least 4 lineages distinguishable by nucleic acid sequencing. The virus is not very resistant and is rapidly inactivated at environmental temperatures by solar radiation and desiccation (Geerts, 2009).

2.6.1.2 Transmission

Transmission of PPR from infected to susceptible animals is achieved by direct contact, close contact or through respiratory and oral routes (Chauhan *et al.* 2009). PPRV targets epithelial cells and pneumocytes leading to respiratory lesions including interstitial pneumonia and bacterial bronchopneumonia or ũbrinoid pneumonia (Aruni *et al.* 1998) as well as bronchiointerstitial pneumonia (Nussieba *et al.* 2009). The lymph nodes are characterized by oedema (Nussieba *et al.* 2009). Close contact with an infected animal is necessary for virus transmission. Although oral

transmission is possible (ingestion of contaminated feed and water), infection is transmitted mainly by aerosol (droplets containing virus particles in the expired air) or by contact with secretions or excretions of infected animals (saliva, faeces, urine, vaginal, nasal or ocular discharges). PPR virus is shed by infected animals during a relatively short period (Geerts, 2009). Trade in small ruminants, at markets where animals from different sources are brought into close contact with one another, affords increased opportunities for PPR virus transmission, as does the development of intensive fattening units (Roeder and Obi 1999). There are frequent outbreaks during the rainy season or the cold dry season. Outbreaks are also associated with increased local trade in goats (OIE, 2009). It is thought that hot and humid weather as well as cold periods, for example, the harmattan season in west Africa seem to increase chances of pathogen survival and spread. Cold weather promotes close contact of animals which assists in the spread of the virus to susceptible hosts. The rain season may help in dispersing the virus being shed from all body secretions such as tears, urine, faeces, and the mouth. It is suspected that infectious materials can also contaminate water and feed troughs and bedding, turning them into additional sources of infection (Roeder and Obi, 1999). The UV lability and temperature sensitivity of the virus reduce the likelihood of transmission *via* routes other than droplet spread. Transmission *via* infected bedding, water, feeding troughs and other inanimate objects (fomites) is possible but is thought to occur at a very low level. There is currently no evidence for vertical transmission of PPRV (*i.e.* mother to offspring) (OIE, 2012).

2.6.1.3 Host characteristics

Clinical disease is seen in sheep and goats and has been described in zoological garden collections of wild small ruminants including Laristan sheep (*Ovis gmelini laristanica*), Dorcas-type gazelles (*Gazella granti*), gemsbok (*Oryx gazelle*), and the Nubian ibex (*Capra ibex nubiana*). Cattle, buffaloes, camels and pigs can become infected but there is little or no evidence of disease associated with their infection (Hamdy *et al.* 1976; Roeder and Obi 1999). In endemic areas, most of the sick and dying animals are over four months and up to 18 to 24 months of age (Roeder and Obi 1999). Morbidity and mortality rates are high. Thus, this disease is a serious problem for the small ruminant industry. The disease is most prevalent in animals less than one year of age.

The role of wildlife species in the transmission of the virus remains unclear although zoological collections in Saudi Arabia and various wildlife species across Africa have been shown to be susceptible *e.g.* Arabian oryx (*Oryx leucoryx*), Dorcas gazelle (*Gazella dorcas*), Laristan sheep (*Ovis orientalis laristanica*), gemsbok (*Oryx gazelle*), Nubian ibex (*Capra nubiana*), Thomson's gazelle (*Eudorcas thomsonii*), Grey duiker (*Sylvicapra grimmia*), Kobs (*Kobus kob*) and Bulbal hartebeest (*Alcelaphus buselaphus*). Camels are also susceptible to infection and can display signs of clinical disease. Infection of other large ruminants (*e.g.* cattle and buffalo) and pigs has been reported although infection is generally subclinical in these species and viral excretion is unlikely (Hamdy *et al.* 1976; OIE, 2012). Cattle, buffaloes, camels and pigs can become infected but there is little or no evidence of disease

associated with their infection. PPRV antigen has been detected in an outbreak of respiratory disease in camel and sick domestic buffaloes (Taylor *et al.* 1990; Scot, 1981; Abraham, 2005).

2.6.1.4 Clinical signs

The symptoms of PPR are very similar to those of rinderpest and these include; fever, anorexia, depression, nasal and ocular discharges, difficult respiration, necrotic lesions on gum, lips and tongue resulting in salivation, erosions on the nasal mucosa and finally diarrhea (Roeder and Obi, 1999), Figure 5.

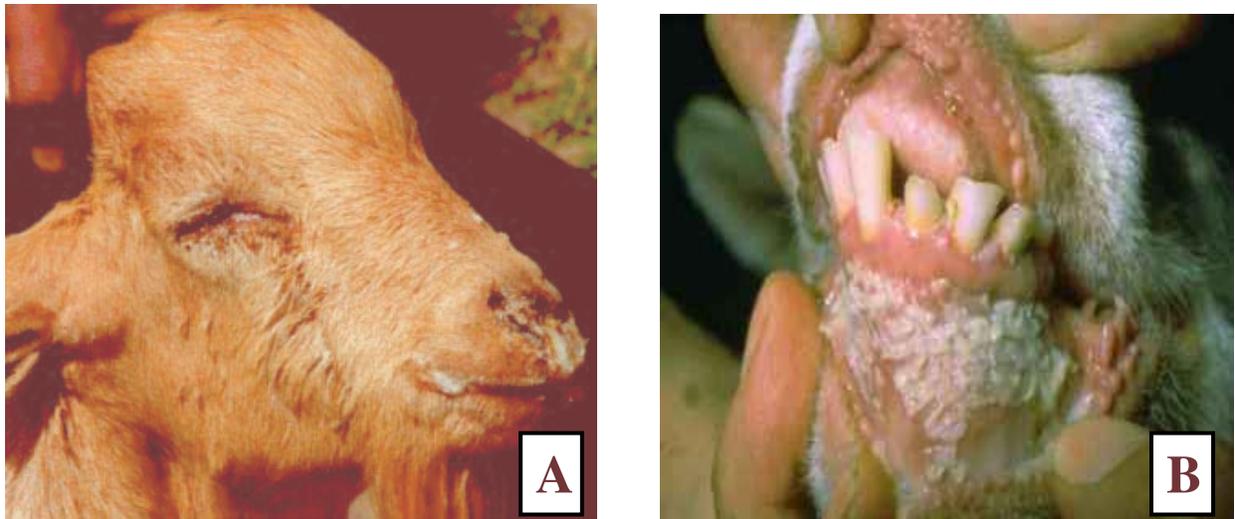


Figure 5: PPR in a goat: purulent eye and nasal discharges (A); and early mouth lesions showing areas of dead cells(B) (Roeder and Obi 1999).

There are differences however between the two diseases. The formation of small nodular skin lesions on the outside of the lips around the muzzle and the development of pneumonia during the later stages of the disease are frequently seen in PPR but not in rinderpest. Mild cases also occur with less marked clinical symptoms and absence of one or more of the cardinal features (Geerts, 2009). When PPR occurs in an area for the first time, acute high fever with extreme depression and death occur before any other typical signs are seen. A more typical picture, however, is that of a fast-spreading syndrome in sheep and/or goats characterized by the sudden onset of depression, discharges from eyes, nose and mouth, abnormal breathing with coughing, diarrhoea and death (Roeder and Obi 1999). The morbidity rate is 100 % and in severe outbreaks mortality reaches 100 % (Radostits *et al.* 2000). Morbidity up to 100 % and mortality rates between 20 and 90 % are common, except in endemic areas or when mild disease occurs (Geerts, 2009).

2.6.2 Diagnosis

Anamnesis, clinical and pathological signs are highly suggestive of PPR, but for a definitive diagnosis the virus or specific antigen or antibodies need to be demonstrated (Geerts, 2009).

The collection of specimens at the correct time is important to achieve diagnosis by virus isolation and they should be obtained in the acute phase of the disease when clinical signs are apparent. The recommended specimens from live animals are swabs of conjunctival discharges, nasal secretions,

buccal and rectal mucosae, and anticoagulant-treated blood (OIE, 2013). There are several methods available for the diagnosis of PPR, some of which are direct while others are indirect.

2.6.2.1 Direct methods

As virus isolation remains particularly tricky within a lag time of three weeks, rapid identification of the virus directly from field samples is possible using other methods including genome-based amplification, that are highly sensitive and specific. These are the conventional reverse transcription-polymerase chain reaction (RT-PCR) and the real time RT-PCR (rRT-PCR) for quantification of viral loads. Conventional RT-PCR provides a template for sequencing and subsequent phylogenetic analysis (CIRAD, 2013).

The following direct methods for routine diagnosis are used:

(a) Virus isolation: Detection of the virus is done by isolation of the PPR virus in cultured cells. This method of diagnosis can be very valuable as it provides live virus for biological characterization studies. If facilities are available, it should always be attempted and isolated viruses stored for later studies (Roeder and Obi 1999). Lymphoid tissues or blood leucocytes from suspected animals are inoculated into cell cultures. Cytopathogenic effects appear after 4 days. Virus isolation in cell culture can be attempted with several different cell lines where samples permit. Although Vero cells have been the choice for isolation and propagation of PPRV, it is reported that B95a, an adherent cell line derived from Epstein-Barr virus transformed marmoset B-lymphoblastoid cells, is more sensitive and support better growth of PPRV lineage IV as compared to Vero cells. More recently, Vero cells expressing the signalling lymphocyte activation molecule (SLAM) receptor have been used as an effective alternative for isolation in cell culture (Abubakar *et al.* 2012). It has been shown that human, canine, bovine and Caprine signaling lymphocyte activation molecules SLAMs; also known as CD150 act as cellular receptors for MV, CDV, RPV, and PPRV respectively. SLAM proteins not only function as co-receptors for lymphocyte activation and/or adhesion but also functions as a cellular entry receptor for Morbilliviruse (Sannat *et al.* 2012). SLAM family is a newly appreciated group of immune-cell specific receptors that has the ability to regulate the function of several immune cell types. Recent studies show that the SLAM-related receptors mediate intracellular protein tyrosine phosphorylation signal (Veillette and Latour 2003). The fragility of *morbillivirus* virions generally

renders techniques such as virus isolation redundant for routine diagnostic use, especially where sample quality is poor (Abubakar *et al*, 2012).

(b). PCR: RT - PCR can be used to identify the PPR virus (Geerts, 2009). Detection of virus genetic material is performed by the RT PCR which requires specialist facilities and expertise. Despite its high cost, it is now one of the tests used most frequently in reference centres, together with enzyme linked immunosorbent assay (ELISA), because it is rapid, accurate, and highly sensitive and can discriminate between PPR and rinderpest. Combining this test with nucleotide sequencing provides virus characterization information that is useful in epidemiological studies.

(c). Antigen detection: PPR antigen can be demonstrated using the agar-gel immunodiffusion test (AGID), the counter-immunoelectrophoresis test, sandwich ELISA or immunohistochemical staining (Geerts, 2009). Detection of virus antigens by the agar gel immunodiffusion test (AGIDT) is a relatively simple, fast and cheap process. It is extremely useful as an initial test, but it does not discriminate between PPR and rinderpest viruses and further tests are needed to do this (Roeder and Obi 1999). Histopathology combined with immunohistochemical staining (e.g. immunoperoxidase) is a useful procedure because it is performed on formalin-fixed material and can discriminate between PPR and rinderpest when performed with specific monoclonal antibodies. Virus antigens can also be detected by immunocapture ELISA (ICE) which is rapid and sensitive, and differentiates between PPR and rinderpest. Standardized reagent kits are commercially available for AGIDT and ICE. RT-PCR coupled with ELISA have also been used to increase the analytical sensitivity of visualization of RT-PCR products and to overcome the drawbacks of electrophoresis-based detection such as use of ethidium bromide, exposure to UV light and others (Abubakar *et al*, 2012). The assay is reported to detect viral RNA in infected tissue culture fluid with a virus titre as low as 0.01 TCID₅₀/100 µL and has been reported as being 100 and 10,000 times more sensitive than the sandwich ELISA and RT-PCR, respectively (Abubakar *et al*, 2012).

2.6.2. 2 Indirect methods

For PPR antibodies detection, the competitive ELISA (C-ELISA) is the most suitable choice as it is sensitive, specific, reliable, and has a high diagnostic specificity (99.8%) and sensitivity (90.5%) (Abubakar et al, 2012). Serological diagnosis is classically realized using C-ELISA. Specific antibodies in serum can be detected using a monoclonal antibody based C-ELISA or virus neutralisation test (Geerts 2009). Virus neutralisation test (VNT); the prescribed test for international trade, is sensitive and specific but time-consuming. The standard neutralization test is carried out in roller-tube cultures of primary lamb kidney cells, or Vero cells when primary cells are not available. A cross-neutralisation test is carried out with rinderpest virus and a serum is considered to be positive for PPR when the neutralisation titre is at least twofold higher for PPR than for rinderpest. The test can also be performed in 96-well microtitre plates (OIE, 2009).

2.6.3 Mitigation Measures

2.6.3.1 Prevention and control

There are several methods that are used to prevent and control PPRV infections. These include: surveillance; movement control; vaccination and stamping out.

2.6.3.2 Surveillance

When analysing the surveillance options to employ, determining the objectives of the surveillance is important. Ideally, surveillance should aim to: define the extent of the disease, detect new outbreaks, establish disease free zones, monitor disease trend, and inform decision making at various disease control critical points (SADC, 2012b).

Risk based surveillance is the most cost effective way of detecting and monitoring the PPR disease incursions. High risk (risk based) surveillance should focus on detection of incursions i.e., early warning surveillance at “hot spots” (SADC 2012b). In low risk areas (free from PPR), surveillance should focus on early disease detection and response. Zambia has not reported any

outbreaks of PPR to the OIE and SADC (NALEIC 2010). As a result, the only preventive measure in place is periodic active surveillance exercises carried out in northern Zambia.

2.6.3.3 Animal movement control

In the face of a contagious disease, the natural reaction of pastoralists in most countries is to withdraw apparently healthy animals from infected areas and to secure them somewhere else. This attitude can contribute to the spread of the pathogen (Wakhusama et al. 2011). The main mode of PPR virus transmission is animal movement, either illegal or under permit. With the advent of free movement of people and goods (including livestock and livestock products) as the SADC region moves ever closer to a borderless region, it is no longer enough for a country to rely on national animal movement controls of its neighbour to stem the spread of transboundary animal diseases (TADs). Rather movement control for TADs requires a regional of approach (SADC, 2012b). When control of animal movement is used as one of the arms of an effective control of transboundary animal diseases (TADs), it should be implemented in a very careful and strict manner (Wakhusama et al. 2011). As a solution to this, one suggestion by SADC is the concept of zoning, which could be split into the following; infection zone, protection and surveillance zone, and a vaccination zone. It is recommended that, when PPR is suspected, State and federal authorities should be notified. Eradication is recommended when the disease appears in countries previously free of PPR. Rinderpest eradication methods are useful in controlling PPR (Merck Veterinary Manual, 2005).

2.6.3.4 Vaccination

Animals recovered from PPR infection or immunized by vaccination are not a PPRV carrier and do not play a role in maintaining virus circulation in an area. Animals that are not ‘immunized’ against the virus through natural infection or vaccination can be subclinically infected and constitute a high risk in maintaining and diffusing the virus without apparent clinical signs (Wakhusama *et al.* 2011). Control of PPR outbreaks relies on movement control (quarantine)

combined with the use of focused ("ring") vaccination and prophylactic immunization in high-risk populations (Roeder and Obi 1999). Ring vaccination is conducted in areas surrounding a PPR outbreak. This involves vaccinating susceptible animals in a given zone, forming a buffer of immune individuals that then limit disease spread. The other method is vaccination of high-risk populations in high-risk areas (prophylactic immunization) as a preventative measure (OIE, 2012). Animals that are vaccinated and those that recover from infection with PPRV generate a long lasting immunity that may last the lifetime of the animal (OIE, 2012). An attenuated PPR vaccine has been prepared in embryonic caprine kidney cell culture which affords protection from natural disease for approximately one year. Rinderpest cell culture has also been used successfully for immunization against PPR (Merck Veterinary Manual, 2005). Recently, a homologous PPR vaccine was developed and the vaccine seed is available through the Pan African Veterinary Vaccine Centre (PANVAC) at Debre Zeit, Ethiopia, for Africa, or CIRAD-EMVT at Montpellier, France, for other areas. This vaccine of choice is becoming increasingly available. The vaccines can protect small ruminants against PPR virus for at least three years (Roeder and Obi 1999). The Basic Reproductive Number (R_0) for PPR is 6.8 (Zahur *et al.* 2008). Therefore in order to stop PPR from spreading in a population, it is necessary to vaccinate at least 85.3% (given by $1 - 1/R_0$).

Vaccination of the entire susceptible population should result in the virus dying out, thereby allowing discontinuation of vaccination after only a couple of years (SADC, 2012b). The effectiveness of the vaccination strategy should be reviewed within an appropriate timeframe. It is suggested that initially 3-to-5 years of vaccination should be completed before assessment of its effectiveness (SADC, 2012b).

2.6.3.5 Treatment

There is no specific treatment for PPR but antibiotics and other supportive treatment may prevent secondary infections and decrease mortality (OIE 2012).

2.6.3.6 Emergency preparedness

Emergency preparedness in dealing with an impending invasion of PPR virus into a country is of utmost importance. The country at risk should have an action plan in place stipulating roles that different stakeholders should play in the case of an outbreak. SADC (2012b) recommends the following considerations for a PPR control strategy:

- (a). Nature of disease
- (b). Risk analysis for PPR
- (c). Prevention strategies
- (d). Early warning contingency plan
- (e). Strategies for control and eradication of PPR
- (f). Support plans-resources, legislation etc.
- (g). Action plans and budgets
- (h). Monitoring and evaluation

2.6.3.7 Stamping out

Stamping-out programs involve the eradication of a disease by the destruction of all infected animals. When outbreaks occur, protection and surveillance zones are established around the outbreak area, and animals in the protected zone are destroyed. The level of surveillance in the area should be increased and the movement of animals from surveillance zone should be restricted. Stamping-out programs tend to be applied when there is no known vaccine or it is not available, when the disease has reached a low level of incidence following other forms of control, or when a country wants to maintain its access to export markets that require certification of being disease-free without vaccination (FAO, 2013b).

The ability to regain previous disease free status quickly and therefore be able to trade again is the biggest advantage of stamping out. However, this option is favoured only in situations where the infected population is small and well defined and the government has mechanisms in place to compensate affected farmers (SADC, 2012b). Stamping out is best suited for high risk areas with low density of animals and for low risk areas (SADC, 2012b). The main disadvantage of this option is that it is usually an expensive and

therefore unattractive exercise for the State and as a result there is little political will to implement it. Furthermore, if there is no compensation for stamping-out, then producers, particularly small-scale producers, are reluctant to participate. If they participate, it may mean that they no longer can afford to produce. In order to avoid de-capitalization, small-scale producers who rely solely on their animals for income may move their animals across the border rather than killing them, further spreading infection (FAO 2013b). Even with compensation, stamping out has devastating socioeconomic consequences for affected communities. Other disadvantages linked to stamping out include the loss of genetic material; diminished national herd; difficult enforcement due to the absence of fences and zones to curtail movement in the event of an outbreak; and it is highly political, which makes it very difficult to implement (SADC 2012b).

In the event of the appearance of PPR in new areas such as Zambia, where the disease has not been reported, eradication is recommended. Methods that have been successfully applied for Rinderpest eradication in many areas would be appropriate for PPR. These should include quarantine, slaughter, and proper disposal of carcasses and contact fomites, decontamination, and restrictions on importation of sheep and goats from affected areas (SADC 2012b).

2.6.3.8 Risk assessment in disease control

Movement of animals and animal products involves a degree of disease incursion risk to the region where the commodity is being transported. This risk may be represented by one or several disease agents. The principal aim of risk assessment with respect to animal movements is to provide the person with the responsibility of authorising movements of animals from one region of the country or from outside the country with an objective and defensible method of assessing the disease risks associated with the movement (importation) of animals, animal products, animal genetic material, feedstuffs, biological products and pathological material (Armstrong *et al.* 2002). This is necessary so as to provide clear reasons for the imposition of specific sanitary measures such as movement/import ban or refusal to give a movement or import permit. Risk assessment therefore, provides some of the major attested tools and methodologies important in facilitation of decision-making and management of risks. To support decisions-making, it is applied to

accumulate and organise existing information for the prioritisation of relative risks in the face of uncertainty.

Risk assessment can be quantitative, providing a numeric estimate of the probability and the magnitude of the consequences, or qualitative – using a descriptive approach. Although quantitative assessments provide more detailed information, both types of assessments are equally valid and can withstand scrutiny if challenged, provided they are based on good quality data and address all the defined stages of the process (Zepeda, 2002).

2.6.3.8.1 Qualitative and quantitative risk assessment

Risk assessment is any method that assesses, or attempts to assess, a risk. Qualitative assessments are descriptive or categorical treatments of information, whereas quantitative assessments are mathematical analyses of numerical data (Wooldridge and Kelly 1996).

A qualitative assessment is often undertaken as part of a first evaluation to determine if the risk is significant. Once it has been established that the risk is significant, a more detailed qualitative assessments may be conducted, in some circumstances to provide the decision support needed by the person making the decision (risk manager). In case the information obtained in a qualitative analysis is considered inadequate, quantitative assessment is usually the preferred approach if there is sufficient data, time and resources to support it. It is often recommended to do a literature review or summary of the issues (the risk profile) as a first step in the assessment (Muma and Makungu 2011). That literature review or summary should follow the same systematic approach as a quantitative assessment and identify factors that contribute to exposure and how those factors affect the level of exposure (Muma and Makungu 2011).

2.6.3.8.1.1 Qualitative risk assessment

Qualitative risk assessment (RA) is an assessment of risk based on nominal evaluation of data to arrive at some conclusion about the likelihood of occurrence of outcomes; magnitude of any consequences and/or any reduction strategies that have been proposed. Therefore, it is not simply

a literature review or description of all of the available information about a risk issue, but rather a systematic analysis of the available data to arrive at a conclusion needed to guide the decision making process (Wooldridge and Kelly 1996). If the available data are inadequate to develop a quantitative assessment, a qualitative assessment may be developed by assigning descriptive ratings of probability and severity such as ‘negligible’, ‘low’, ‘medium’ or ‘high’ to the exposure factors (Wooldridge and Kelly 1996; Zepeda, 1998). If such an approach is used, specific definitions of the assigned ranges for each rating must be clearly described and justified.

Although the resources required for undertaking a qualitative assessment are often much less than those for a quantitative assessment, it is not necessarily a simple process. It is difficult to assign qualitative statements to the data collected (Wooldridge and Kelly 1996; Zepeda, 1998). Often elicitation of the knowledge and opinion of experts will be used in qualitative risk assessment (Wooldridge and Kelly 1996) and estimating risk from expert knowledge can be challenging and difficult to know, for instance, what is low or high in case of a disease prevalence. A second difficulty that can arise in qualitative risk assessment is the combining of qualitative statements at each stage. Careful thought must be given to the type of variables being combined. For example, are two probabilities to be combined, or a probability and a number?

Examples of combining the assessed values at different stages might include: If the probability of an individual animal being infected with a pathogen is ‘high’ and the probability of the animal excreting the pathogen (if infected) is also ‘high’, then the overall probability of any random animal excreting the pathogen might be considered to be ‘high’. It is more difficult to combine the assessed values when one value is high and the other is low, because it may be difficult to assess whether the contribution of one factor outweighs that of the other factor. Then it may be more relevant to assess exposure by considering a range of individual scenarios (Wooldridge and Kelly 1996; Zepeda 1998). In general, qualitative exposure assessments are more reliable at predicting high or low levels of exposure but are much less reliable at assigning intermediate levels of exposure (Wooldridge and Kelly 1996).

2.6.3.8.1.2 Quantitative assessment

Quantitative assessments provide numerical estimates of exposure, although most models use combinations of mathematics and logic statements (FAO/WHO, 2008). Quantitative exposure assessments require the development of mathematical models in which all relationships between factors affecting exposure can be described mathematically and using logical tests and conditional statements in the model (FAO/WHO, 2008).

In mathematical model, 'input' variables are those that determine the type and magnitude of the response or 'output' variable. The output variable in assessment is the frequency and magnitude of exposure to the hazard. In an exposure assessment, input variables would include factors such as time, temperature, prevalence, volume of trade or production volume and dilution during processing (FAO/WHO, 2008). 'Parameters' quantify the relationship between the input variables and the output(s), and can be fixed values or a distribution. Quantitative assessments can be divided into two categories: deterministic and stochastic, sometimes also referred to as 'point-estimate' and 'probabilistic' exposure assessments (Wooldridge and Kelly 1996).

It should be noted that, although evaluating such likelihood in terms of statistical probability contributes to accuracy, a quantitative assessment is not indispensable to complete a valid risk analysis. Risk may be assessed qualitatively only, according to the circumstances and data available (Wooldridge and Kelly 1996; Zepeda, 2002).

Disease prevention and control requires application of tools such as risk analysis to inform policy decisions. A review of literature shows a general lack of risk assessment publications on PPR and in particular in sub-Saharan Africa and in the SADC region to be specific. Makungu (2008), reports that this scenario has resulted in risk analysis having minimal input in deriving effective disease control policy within African countries. It is recommended that, for PPR control to be effective the approach must be risk based (SADC, 2012b). Any country seeking to protect its territory from PPRV invasion should be conversant with risk estimation techniques so that efforts can be concentrated on critical points of the disease transmission cycle to make sure that chances of success and impact of control strategies are maximised (SADC, 2012b).

CHAPTER 3: METHODOLOGY

3.1 Study Area

Northern Province is one of Zambia's ten provinces located at latitude 10°33'58" south and longitude 30°48'06" east (Figure 5). The province is made up of 9 districts, namely Kasama (the provincial capital), Chilubi, Kaputa, Luwingu, Mbala, Mporokoso, Mpulungu, Mungwi and Nakonde. It shares borders not only with four other provinces - Central, Eastern, Muchinga, and Luapula, but with three countries as well; the DRC in the north, Tanzania in the north-east, and Malawi in the east. Kasama, the provincial capital, is home to 12.8% of the provincial human population, which is the highest of all the 9 districts (FAO, 2004). Next are Mbala and Nakonde with 11.5% and 10.9% respectively. In terms of the annual population growth rate per district, Nakonde ranks first with 11.9%, seconded by Mungwi with 6.6% and then Mporokoso with 6.0%, while Luwingu has the lowest with 1.5%. The rest are as follows: Kaputa 5.0%, Mpulungu 4.1%, Mbala 3.8%, Kasama 3.7% each, and Chilubi 3.0%. The population is predominantly rural. The rapid annual population growth is attributed to various factors. For instance, the high growth rate in Nakonde is due to the free cross-border trade between Zambia and Tanzania, which has triggered rapid settlement in the district (FAO, 2004). This has implications for the risk of transboundary incursion of diseases such as PPR into Zambia. Further, the Tanzania–Zambia Railway line (TAZARA) passes through three districts in the province – Mpika, Kasama and Nakonde. TAZARA provides passenger services, as well as transportation of goods which may include small ruminants between Zambia and the Tanzanian port of Dar es Salaam.

The three districts, namely; Mbala, Nakonde, and Mpulungu were the focal areas of this risk assessment study. The selection of the districts was based on their relative proximity to Tanzania and human and animal traffic between Zambia and Tanzania through the three districts. The location of the 3 districts in northern Zambia is depicted in Figure 6.

The geographical position of Mbala is latitude 8°50'0" south and longitude 31°23'0", that of Mpulungu is latitude 8°46'0" south and longitude 31°8'0" east, while that of Nakonde is latitude 9°20'0" south and longitude 32°46'0" east.

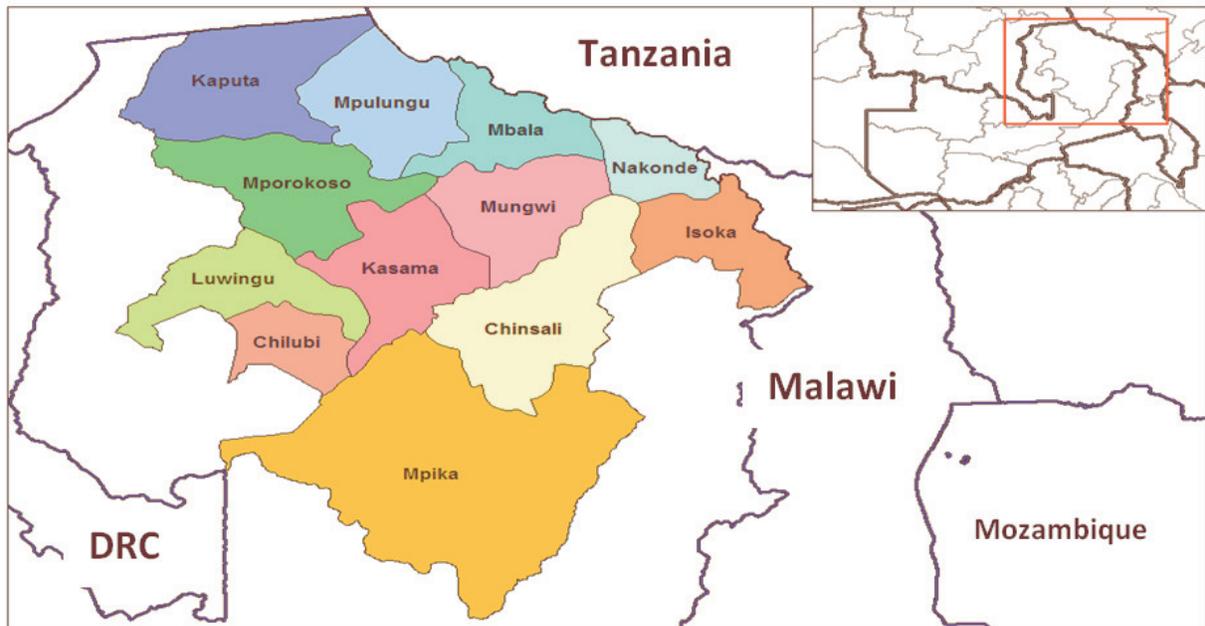


Figure 6: Location of Mpulungu, Mbala, and Nakonde districts in relation to other districts of Northern Zambia and Tanzania on North West (<http://www.google.co.zm/imgres>).

The total goat and sheep population for the three districts is estimated at 36,662 and 1,148 respectively (Table 2).

Table 2: Goat and sheep populations in the study area of Northern Province of Zambia (2011)

District	Goat and Sheep population	
	Goats	Sheep
Mpulungu	8,198	494
Mbala	19,420	575
Nakonde	9,044	79
Total	36,662	1,148

Source: (Wakhusama *et al.* 2011)

3.2 Qualitative Risk Assessment

The methods used to conduct this risk assessment were based on the OIE qualitative risk assessment framework and the work of Zepeda Sein (Zepeda 1998). Evaluation of the following factors, both in the country of origin (Tanzania) and destination (Zambia) was also conducted: organisation of the veterinary structure; presence and capability of diagnostic facilities; epidemiological surveillance systems; disease status in Northern Province, animal populations and movements; and the legal framework.

3.2.1 Organisation of the Veterinary Structure

The official veterinary network in both countries, i.e. Tanzania and Zambia is well structured and covers the whole country in terms of territory. In Zambia, districts are divided into veterinary camps run by veterinary assistants (VA's) who in turn report to District Veterinary Officers (DVOs). In Tanzania, the equivalent of a veterinary camp is a ward, which is sub-divided into villages. Wards are run by Livestock field officers (LFOs) who in turn report to DVOs. DVOs run districts and are in charge of all disease control activities in their territories. However, in Tanzania, district veterinarians are under the local government, hence at times it is difficult for the Department of Veterinary Services (DVS) to get information from them. For example, in 2009 during the PPRV outbreak, it took almost one year from suspicion to disease confirmation (Ministry of Livestock and Fisheries Development 2012). This clearly presents challenges in disease surveillance. In Zambia, there are VAs on the ground but not all veterinary camps are manned. A number of districts have got this problem which impacts negatively on disease control activities. Moreover, veterinary camps are too large for one VA to effectively manage it compared to agricultural camps. For example, in the study area, Mpulungu district has only one veterinary camp against 14 agricultural camps for the same territory. The staffing situation for the study area is reflected in Table 3 below:

Table 3: Staffing levels of veterinary camps in Mbala, Mpulungu and Nakonde (2012)

s/n	District	Number of vet camps	Number manned	Number unmanned	Comment
1	Mbala	8	5	3	Only 60% of the camps are manned
2	Nakonde	9	4	5	Less than 50% manned
3	Mpulungu	1	1	0	The whole district is 1 vet camp

3.2.2 Diagnostic Facilities

The Ministry of Livestock and Fisheries Development (MLFD) in Tanzania has zonal (regional) laboratories and one central laboratory. Capacity of the laboratory staff to diagnose PPR is good as most laboratory staff were trained under Vaccines for the Control of Neglected Animal Diseases in Africa VACNADA project that supported the laboratories. Also more key laboratory staff was trained under the SADC-TADS project whose objective was to strengthen laboratory capacity and surveillance. Three regional laboratories and one central laboratory are able to diagnose PPR. Recently, the central laboratory has acquired capacity to conduct molecular diagnosis of PPR. The common test used by the laboratories in Tanzania is C-ELISA. The C-ELISA kits are acquired from the United Kingdom though at times the ministry has some problems acquiring these kits (Ministry of Livestock and Fisheries Development 2012).

Zambia has five regional laboratories namely; Chipata, Mazabuka, Ndola, Mongu, and Isoka and one central veterinary laboratory. The regional laboratory in northern Zambia (Isoka) is non functional. Out of all these laboratories, only the Central Veterinary Research Institute (CVRI) has capacity to diagnose PPR. CVRI has four members of staff who have been trained in PPR diagnosis using C-ELISA.

3.2.3 Surveillance Systems

The surveillance system in Tanzania employs the use of Animal Disease Surveillance Forms and Monthly reports (Kuya et al. 2011). The MLFD (2012) has enough staff on the grounds who are now using mobile phones to report diseases. The problem however is response from the central

government and the DVS. From the number of expected veterinary monthly reports from 2005 to 2010, only 11.2% were submitted (Kuya *et al.* 2011). This shows a trend of not reporting disease occurrence to the relevant authorities.

In Zambia, the National Livestock Epidemiological and Information Center (NALEIC) is the unit of the Department of Veterinary Services mandated to coordinate surveillance and information processing activities. The surveillance system employs the use of Disease Outbreak Report Forms and Monthly reporting to NALEIC. However, Sinkala (2011) reported that animal disease surveillance in Zambia has not been effective. Some of the reasons cited for this were; lack of contact points with the farmers i.e. number and frequency, poor coordination and collaboration between disease control and laboratory, lack of contact/surveillance points, i.e. poor infrastructure and legal mandate to support the actions, lack of a proper outlined surveillance protocols with standard operating procedures (SOPs) outlining objectives, roles and responsibilities, targets, indicators and intended benefits, lack of motivation of field staff, and lack of reporting from some districts among others.

3.2.4 Disease Status in Northern Province

PPR has not been reported in the Northern Province of Zambia and hence it remains officially free of the disease. In our survey, we observed that the common diseases affecting goats in this province are mange, diarrhoea, and helminthosis.

3.2.5 Animal Population and Movements

Tanzania has one of the largest populations of livestock in Africa (Table 4).

Table 4: Livestock population in Tanzania (2011)

S/n	Species	Number
1	Cattle	21, 257, 000
2	Sheep	6,397,000
3	Goats	15,244,000
4	Pigs	1,900,000

Source: (Partner States, 2013)

(at www.eac.int/statistics/index.php?option=com_docman&task)

In Tanzania, whenever a disease occurs, quarantine is imposed in the affected area to prevent animals moving out or into the area. Inability to control animal movements is still a challenge and one of the main factors responsible for the fast and extensive spread of TADs such as Foot and Mouth Disease (FMD), Contagious Bovine Pleuropneumonia (CBPP), Contagious Caprine Pleuropneumonia (CCPP), and PPR. Measures taken by the Government to address this problem included establishment of a fully fledged Zoosanitary section within MLFD and strengthening of both internal and border checkpoints. The Presidential Circular No 1 of 2002, Animal Diseases act No 17 of 2003 and regulations of 2007 provided guidance and reinforcement on livestock movements in the country (Sokoine University of Agriculture, 2010).

Under the Zambian law, animals can only move under stock movement permit after clearance by the District Veterinary Officer. The law states, “No person shall move any animals, animal products, animal by-products and articles specified in the Fourth Schedule to any part of Zambia without a permit from a Veterinary Officer in the area of origin” (ANIMAL HEALTH ACT No. 27 of 2010). On the importation of animals, the law states, “The consignment of animals shall be accompanied by a valid import license issued by the Director of Veterinary Services, Zambia or the State.” The animals must be accompanied with a valid Veterinary Health Certificate written in English issued within 7 days of export by the competent Veterinary Officer of the Veterinary Authority of the exporting country certifying that the exporting country is officially free from Contagious Bovine Pleuropneumonia, Contagious Caprine Pleuropneumonia, Peste des Petits Ruminants, East Coast Fever, Goat & Sheep Pox and Scrapie and has Zone Freedom for Foot and Mouth Disease. There is little official documentation of movements of livestock from Tanzania into Zambia except for pet animals (Ministry of Livestock and Fisheries Development 2012). A questionnaire survey revealed informal movement of livestock between the two countries in the border areas.

3.2.6 Legal Framework

PPR has been classified as a notifiable disease in Zambia and this mandates the central government to respond in case of an incursion or outbreak. However, there is no appropriate PPR policy that allows for the successful and expedient handling of a PPR incursion in the

country. Zambia has not developed disease control protocols for PPR which should clearly spell out different roles that each stakeholder should play in case of an insurgence of the disease.

3.2.7 OIE Risk Assessment Framework

The qualitative risk assessment was carried out according to the guidelines of the World Organisation for Animal Health (OIE) Terrestrial Animal Health Code 2001: for import of animals and their products. The technical steps in a risk analysis as per (OIE, 2001) guidelines are as follows:

- a). Frame the question
- b). Hazard identification
- c). Model the pathways:
 - Outline conceptual model
 - Develop the risk scenario trees
- d). Collection of data and information:
 - Qualify inputs and impacts
 - Probability combination
- e). Assessment of the risk
 - Release assessment
 - Exposure assessment
 - Consequence assessment
 - Estimating the risk
- f). Describe uncertainties in the qualitative model

3.2.7.1 Frame the question

The question we were attempting to answer is; “What is the annual risk of introducing PPR virus into northern Zambia through importation of live goats from Tanzania?”

3.2.7.2 Hazard identification

The hazard identified is the *morbillivirus* causing Peste des petits ruminants (PPR) in goats and sheep.

3.2.7.3 Conceptual model for the movement of live goats from Tanzania into Zambia

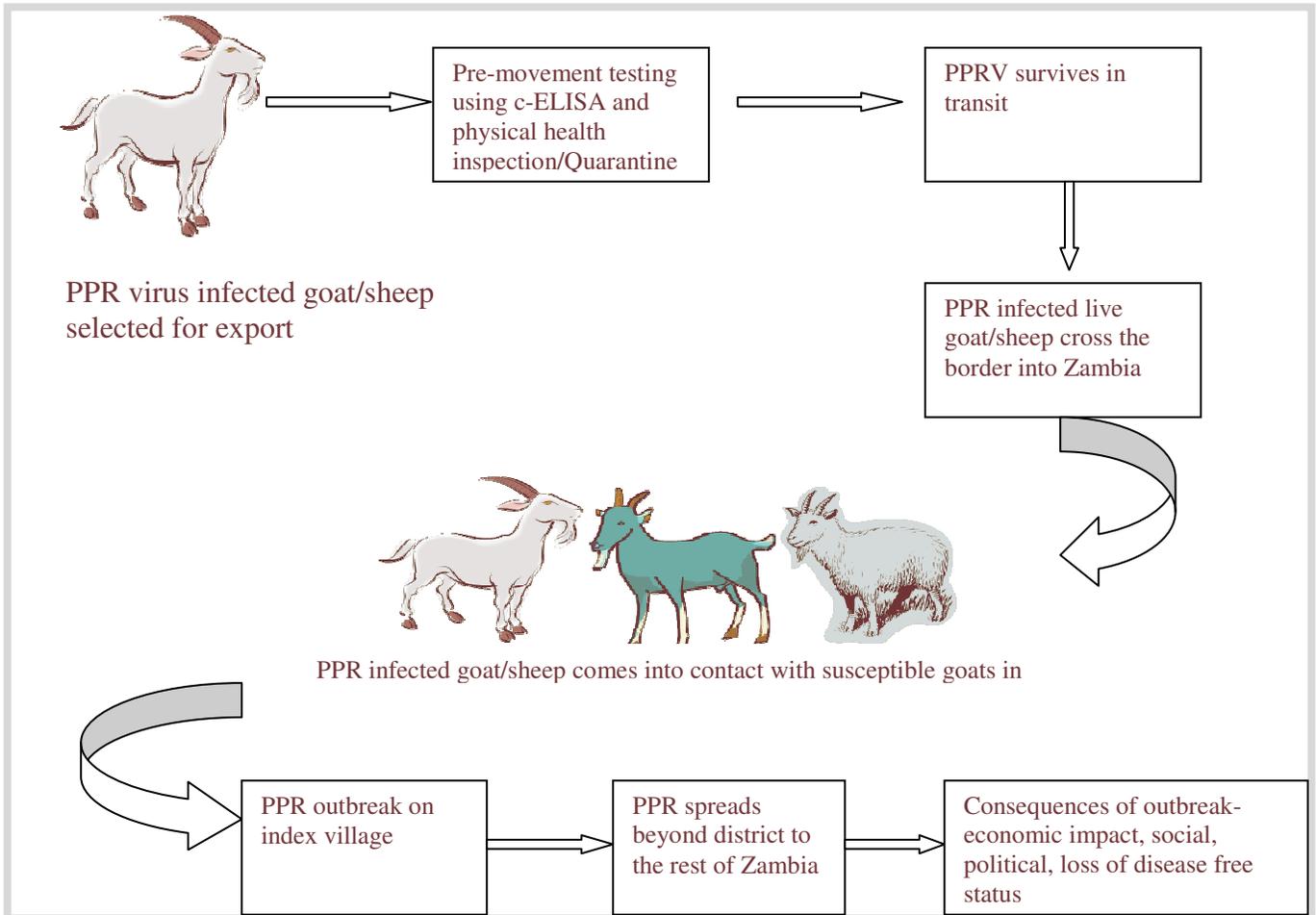


Figure 7: Conceptual model of the PPR outbreak in Zambia from source in Tanzania showing activities along the movement path way

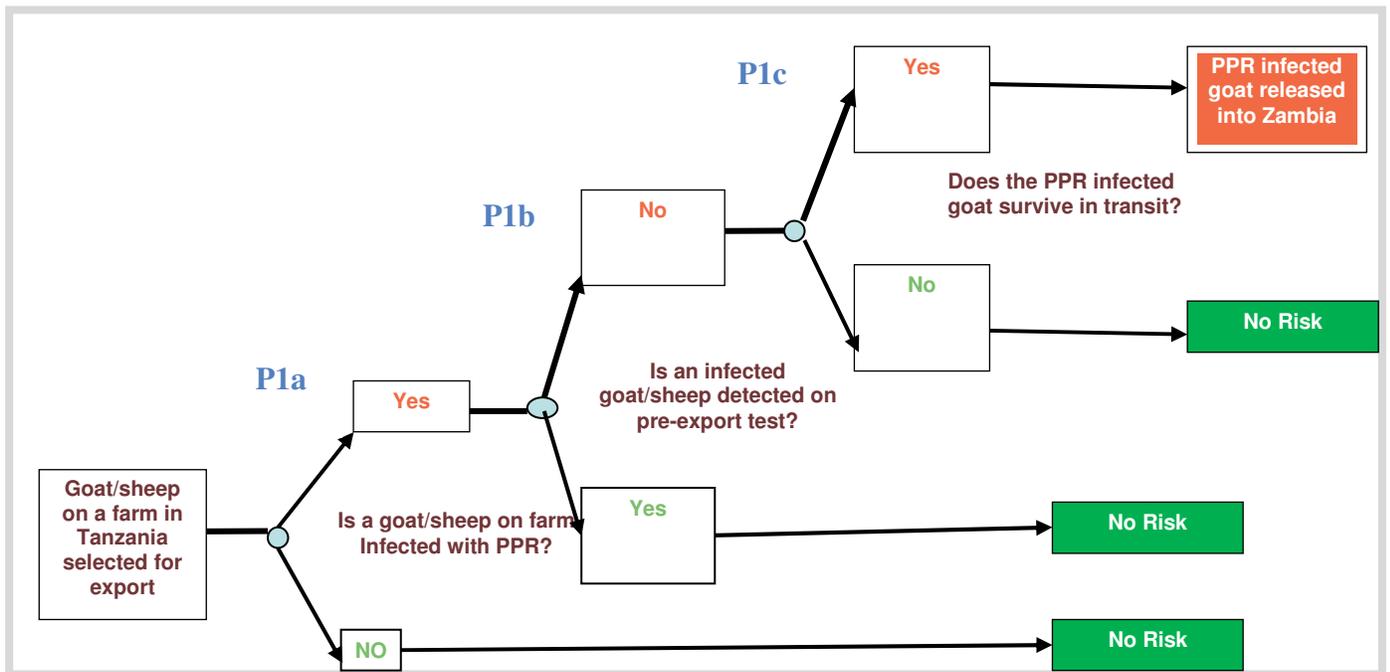


Figure 8: Scenario tree for release of PPR into Northern Province of Zambia

Key: P1a=Probability that a goat on a farm is infected with PPR; P1b=Probability that an infected goat is not detected; P1c=Probability that an infected goat survives in transit.

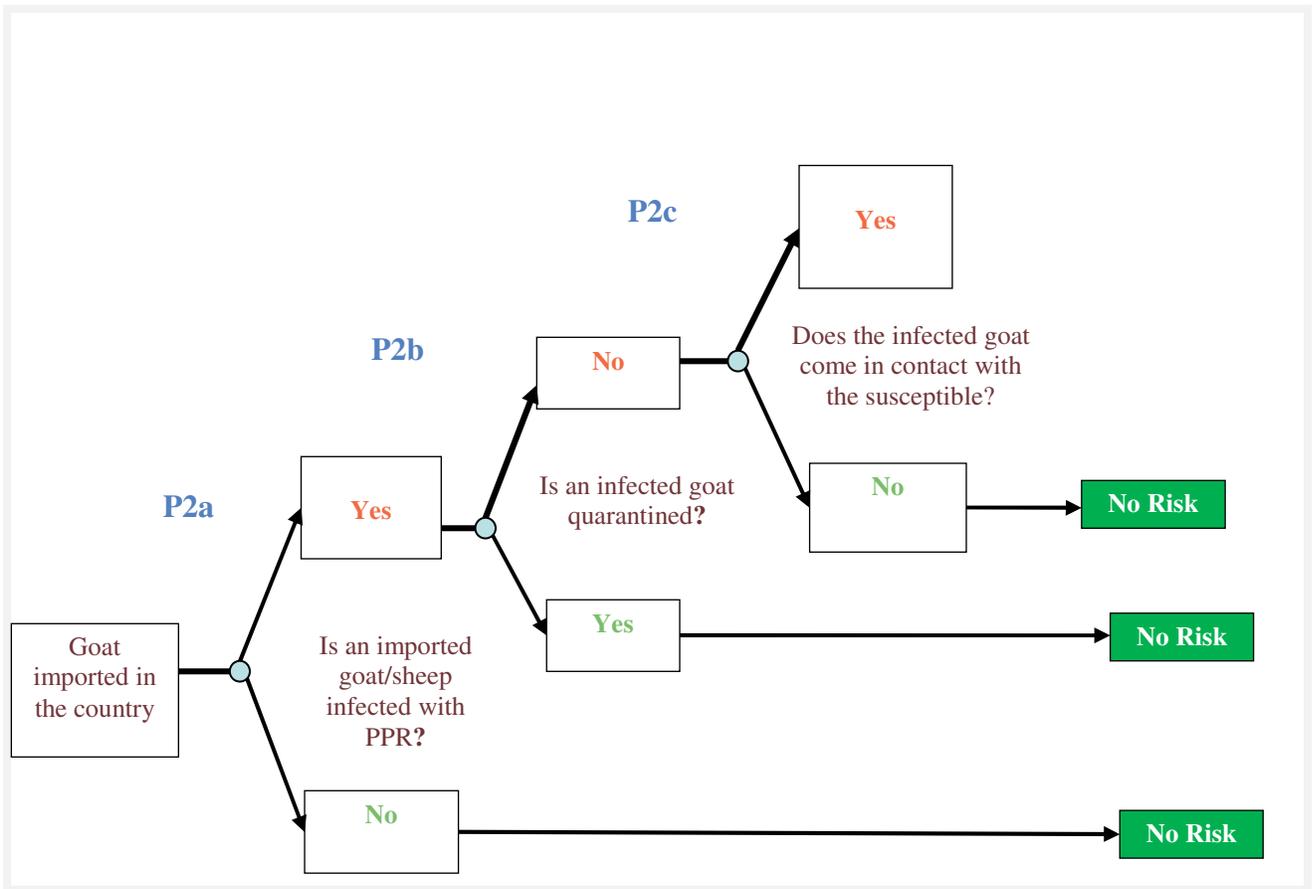


Figure 9: Scenario tree for PPR exposure to goats in northern Zambia

Key: P2a=Probability that an imported goat is infected; P2b=Probability that an infected goat is quarantined; P2c=Probability that an infected goat comes into contact with the susceptible.

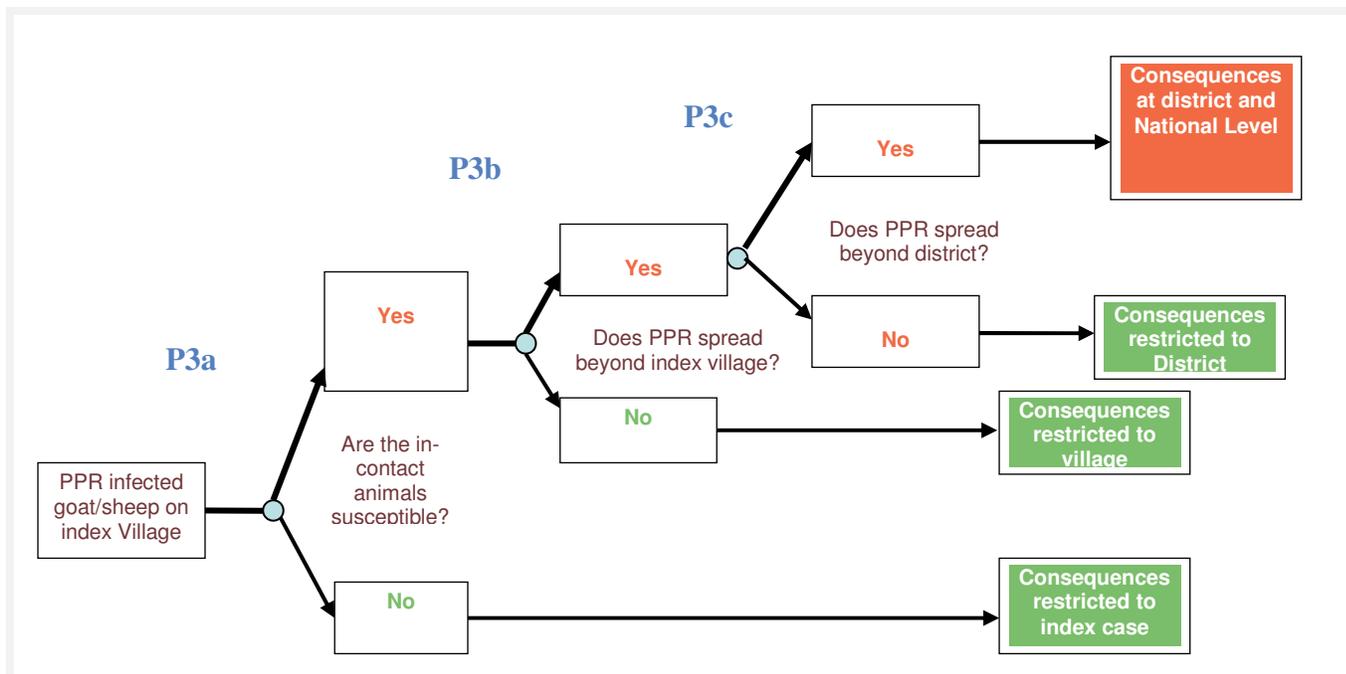


Figure 10: Scenario tree for PPR consequence assessment

Key: P3a=Probability of susceptibility of the contact goats; P3b=Probability of PPR spread beyond the index village; P3c=Probability that PPR spreads beyond district.

3.2.7.4 Collection of Data and Information

Data used to estimate the model input parameters for the risk assessment was collected during a study visit to Tanzania from 17th to 24th October 2012. While in Tanzania, discussions were held with officials from the National Epidemiological Unit in the MLFD in Tanzania. During these discussions, relevant documentation was obtained, as well as linkages to other officers involved in PPR control such as the Zoosanitary section involved in import and export of livestock and livestock products.

Data was collected on disease prevalence, disease distribution in the country, control measures, livestock movement patterns between Zambia and Tanzania, PPR vaccination coverage, and other relevant epidemiological and surveillance data.

Further data was collected through a questionnaire survey conducted along the border areas of Zambia and Tanzania from 10th to 24th October 2012. This included Sumbawanga and Tunduma districts in Tanzania and Mbala, Mpulungu, and Nakonde districts of Zambia. Livestock farmers,

veterinary staff, border staff and other stakeholders were interviewed. A structured questionnaire with different sections for farmers/traders, veterinary staff and border staff was used to collect data. The type of sampling employed in selection of respondents was purposive sampling method (snowball). The area veterinary assistants helped in identifying small ruminant farmers and traders in the camps bordering Tanzania. Questionnaires were administered on one on one basis with the interviewer sitting down with the respondents. When interviewing the farmers, local languages (Mambwe, Namwanga and Bemba) were used. In-depth oral interviews were also conducted with District Veterinary Officers for Nakonde, Mbala, and Mpulungu with a focus on gathering data on livestock populations; common diseases in goats and sheep, husbandry practices by farmers, movement patterns of livestock between the two countries, surveillance methods used knowledge on PPR, and capacity of the veterinary department to conduct surveillance. Ethical approval was not required in this approach of data analysis. Data from the questionnaire was coded and entered into a spreadsheet using Microsoft Excel™. Data obtained from oral interviews was transcribed and transferred into Microsoft Word™ for further analysis. GIS coordinates were entered into a spreadsheet using Microsoft Excel™.

Other sources of information were published literature; grey literature; on-line publications through internet searches (key terms: PPR risk*, PPR surveillance* PPR prevalence* PPR control*, PPR >> policy* Peste de petit ruminant* and specific databases such as Pubmed, Google scholar etc) and expert opinion. Geographical positions (Coordinates) were collected using Global Positioning System (GPS) equipment, capturing the latitude and longitude of all informants, potential risk areas, and animal movement routes between the two countries.

3.2.7.5 Qualifying inputs and Impacts

Each parameter was analysed on the basis of all available information according to guidelines provided by (Moutou *et al.* 2001). The probability of occurrence of each event was assessed for classification by means of the following descriptive scale (Table 5):

Table 5: Practical interpretation of qualitative probability ratings (Zepeda, 1998)

Term	Meaning for probability of event occurrence	Meaning for consequence	Meaning for risk estimated
Negligible	Probability of occurrence of the event is possible only in exceptional circumstances	Low or no impact	Allow import without restrictions
Low	Occurrence of an event is a possibility in some cases	Minor impact	Authorise with specific measures to reduce the risks
Moderate	Occurrence of the event is a possibility	Average impact	Provide assessment of mitigation options before authorising Prohibited until measures to reduce the risk have proven their efficiency (implement and audit)
High	Occurrence of the event is clearly a possibility	Serious impact	

Combination of probabilities at each stage of the pathway, i.e. release, exposure, and consequence, was done using a combination matrix as reflected in Table 6 below.

Table 6: Matrix showing probabilities when two parameters are combined [Zepeda, 1998]

Results of the assessment of <i>Parameter 1</i>	Results of the assessment of <i>Parameter 2</i>			
	Negligible	Low	Moderate	High
Negligible	Negligible	Low	Low	Moderate
Low	Low	Low	Moderate	Moderate
Moderate	Low	Moderate	Moderate	High
High	Moderate	Moderate	High	High

3.3 Quantitative Risk Assessment

The quantitative risk assessment was conducted according to the guidelines of (Miller *et al.* 1993) who proposed the following:

- a) State the question
- b) Identify the hazard of interest
- c) Develop a scenario tree which outlines the pathway of expected events and all the failures which could occur, culminating in the occurrence of the identified hazard.
- d) Label the scenario tree and assign units
- e) Gather and document evidence
- f) Assign values to the branches of the scenario tree
- g) Perform the calculations to summarize the likelihood of the hazard occurring
- h) Consider risk management options
- i) Prepare a written report.

From (a) above to (e), the steps followed were not different from what was done under the qualitative risk assessment guidelines (OIE, 2001). The actual probabilities of release, exposure, and consequences were estimated from the survey data, published literature and expert opinion and were assigned to each event in the pathway. The probabilities of occurrence and the ultimate risk were calculated using a software programme for risk assessment called @riskTM.

3.4 Mapping of Trade Routes in Northern Zambia

Geographical positions (Coordinates) used in mapping of possible entry points of the disease (high risk camps) and trade routes was collected using Global Positioning System (GPS) equipment which was used to capture the latitude and longitude of all informants, potential risk areas, and animal movement routes between the two countries. Maps were produced showing the distribution of the disease in Tanzania and the possible routes of entry into Zambia. Arc ViewTM software was used to come up with maps.

CHAPTER 4: RESULTS

4.1 Qualitative Risk Assessment

4.1.1 Probability of Release/entry (P1)

The release assessment was evaluated using the following 4 parameters:

- (a) Probability of an infected goat/sheep being selected for export
- (b) Volume of goat/sheep trade consignment
- (c) Probability of pre-export screening on C-ELISA and quarantine missing an infected goat/sheep
- (d) Probability of pathogen survival during transit

4.1.1.1 Probability of infection of a goat selected for export

Probability of infection of a goat selected for export depended on the following factors:

1. Prevalence of PPR from the area of origin
2. Organisation of the veterinary structure and the epidemiological surveillance system
3. Diagnostic facilities
4. PPR vaccination coverage.

PPR was first officially confirmed in northern Tanzania in 2008 although available information suggests the disease could have been present at least 4 years before official confirmation (Kivaria *et al.* 2009; Swai *et al.* 2009; Karimuribo *et al.* 2011). A seroprevalence study carried out in 7 geographical administration authorities of northern Tanzania (Ngorongoro, Monduli, Longido, Karatu, Mbulu, Siha and Simanjiro) indicated an overall seroprevalence of PPR virus infection in small ruminants of 45.8%. Highest seroprevalence (42.6–88.02%) was observed in Mbulu, Siha,

Longido, Ngorongoro districts, while antibodies less than 40% to none were found in serum from Monduli, Karatu and Simanjiro, respectively (Karimuribo *et al.* 2011).

PPR was suspected to have been introduced in southern Tanzania in 2010 (Decapua, 2010; Muse *et al.* 2012). Factors which contributed to spread of PPR included communal grazing and the cheap prices of sick animals bought by livestock keepers for slaughtering in other villages. Laboratory findings confirmed presence of PPR in the area by RT-PCR and serological analysis revealed that seroprevalence was 31% (Muse *et al.* 2012). This study was conducted in Tandahimba and Newala districts of Mtwara region following a suspected outbreak of PPR in the area. The presence of PPR poses a risk of southward spread of the disease to other southern African countries in the SADC region. This calls for concerted and collaborative efforts in disease prevention and control to avoid losses (Muse *et al.* 2012). In 2012, Tanzania reported an outbreak of PPR in Singida district located in central Tanzania and 100,000 PPR doses of vaccines were dispatched for ring vaccination (SADC, 2012a).

Although farmers in northern Tanzania were aware of efforts made to control the disease, only 32% had their animals vaccinated against PPR (Karimuribo *et al.* 2011). The low vaccination coverage suggests continued prevalence of PPR in the study area. It is concluded that there is limited capacity with respect to veterinary disease surveillance, reporting and control of transboundary and emerging diseases which need to be addressed in the country (Karimuribo *et al.* 2011).

The in-depth interviews with veterinary officials in Tanzania indicated that the department of Veterinary services were targeting and achieving vaccination coverage of 80% in high risk areas. They also indicated that initially, the department was conducting a blanket vaccination which has since been replaced with targeted vaccinations. However, in 2012, the department only vaccinated once and was struggling to vaccinate a second time. The second round vaccinations were used to target newly born kids which would remain naive to new infections. The Basic Reproductive Number (R_0) for PPR is 6.8 (Zahur *et al.* 2008). Therefore in order to stop PPR from spreading in a population, at least 85.3% of the animals need to be vaccinated (given by $1 - 1/R_0$).

Vaccination coverage of 80% in high risky areas may give some adequate cover against the disease basing on the minimum vaccination coverage requirement of 85% for PPR.

The officials also indicated that capacity for PPR diagnosis in the country was good through support from the Vaccines for the Control of Neglected Animal Diseases in Africa (VACNADA) project. Personnel had been trained in laboratory diagnosis and hence able to diagnose PPR. However, it was noted that there were some challenges faced, such as the C-ELISA kit being unavailable sometimes as it is procured from the United Kingdom. The Central Veterinary Laboratory of Tanzania has the capacity to carry out molecular diagnosis. PPR lineage III has been isolated from northern Tanzania. The capacity for field staff to conduct surveillance was rated around 70%. There were adequate field staff in the camps for early disease detection and reporting using mobile phones but the challenge was on the response from the central government and the department of veterinary services. MLFD also indicated that there were clear challenges in surveillance. The district veterinarians in Tanzania are under local government, hence at times, was difficult for the department to contact them.

Based on the above gathered information, i.e., the probability that any one animal selected for export will be infected with PPR virus was determined to be **high**.

4.1.1.2 Volume of goat movement/trade

An interview with the head of the Zoosanitary Inspectorate unit of the MLFD in Tanzania revealed that there was very minimal formal trade/export of live animals from Tanzania into Zambia. Records only showed much movement of pet animals and goat hides from Zambia and Malawi into Tanzania. The officials working in the unit however indicated that informal movement between the two countries especially along the border areas have existed though volumes have not been documented. The questionnaire survey conducted along the border areas between Zambia and Tanzania indicated the following:

1. One hundred and thirty eight (138) farmers, twelve (12) veterinary staff working in border areas, and three (3) border staff, were interviewed;

2. On average, each farmer purchased two goats in a year (95% Confidence, Confidence Interval (CI):1-3).
3. Forty eight (48) farmers bought goats in the last 1 year (215 goats in total);
4. Goat Sources: 95.6% (95% Confidence, CI: 92.2-99.0) bought within the village, 2.2% (0-4.6) bought within district,1.4% (0-3.5) bought within the province;
5. Twenty two (22) goats were purchased from Tanzania by 17 farmers, on average each farmer bought 1 goat in a year;
6. An interview of the 11 veterinary staff working in the border areas estimated that 4,612 goats (95% CI: 2,296 to 11,520) were imported into the country in the last one year.

The in-depth interview with the veterinary staff working in the border areas revealed the following on the direction of goat/sheep movement:

- 36.4% indicated movement of goats were from Tanzania into Zambia
- 18% indicated movement was from Zambia into Tanzania
- 36.4% indicated movement was either direction
- 9% were not aware of any movement between the two countries.

The customs officers working at Kasesya border post (Mbala and Sumbawanga) and Mpulungu harbour (Mpulungu) did not have any knowledge of goat/sheep movements between Zambia and Tanzania regardless of the direction. Both officers have worked at the border for over 5 years. The customs officer at Nakonde border indicated knowledge of goat movements though the direction was from Zambia into Tanzania.

Based on the above import estimations from the veterinary staff, the probability of entry as determined by trade volume was rated **moderate**.

4.1.1.3 Probability of C-ELISA and Quarantine screening missing an infected goat

Control of PPR outbreaks relies on movement control (quarantine) combined with the use of focused ("ring") vaccination and prophylactic immunization in high-risk populations (EMPRES, 2009).

OIE's recommendation for importation of domestic small ruminants from countries infected with PPR is the following:

Veterinary Authorities should require the presentation of an international veterinary certificate attesting that the animals:

1. showed no clinical signs of PPR on the day of shipment;
2. were kept since birth, or for the past 21 days, in an establishment where no case of PPR was officially reported during that period, and that the establishment was not situated in a PPR infected zone ; and/or
3. were kept in a quarantine station for the 21 days prior to shipment;
4. have not been vaccinated against PPR; or were vaccinated against PPR:
 - a) not less than 15 days and not more than 4 months prior to shipment in the case of animals for breeding or rearing; or
 - b) not less than 15 days and not more than 12 months prior to shipment in the case of animals for slaughter (OIE, 2010).

There are 19 quarantine facilities for farm animals and 28 wildlife quarantine facilities under supervision of Veterinary Services in Tanzania (Zoosanitary inspectorate Services, MLFD). Field staff in Tanzania are now able to diagnose clinical cases of PPR (Ministry of Livestock and Fisheries Development 2012). This implies that an infected animal which manifests clinical signs of PPR during quarantine would be removed from the consignment and destroyed. C-ELISA has a relative specificity of 98.4% and a relative sensitivity of 92.4%. Sensitivity of C-ELISA for PPR sero-surveillance could further be increased to 95.4% if the target population is non-vaccinated (Singh *et al.* 2004).

A relative specificity of 98.5% and sensitivity of 93.4% for the rapid C-ELISA has been reported (kang *et al.* 2005).. Therefore, the probability that both C-ELISA test and a 21 day Quarantine period would miss an infected goat was determined to be **negligible**.

4.1.1.4 Probability of pathogen survival during transit

The disease was first reported in Tanzania in 2008 when it was confined to the northern Zone in districts bordering Kenya (Kivaria *et al.* 2009; Swai *et al.* 2009). Muse *et al.* (2012) reported that small ruminants in southern Tanzania and SADC countries were at risk from PPR incursions. The disease shows capability to move quickly across long distance and large areas due to quick movement of small animals.

The PPR virus survives for long periods in chilled and frozen tissues. Tears, nasal discharges, coughed secretions, and all secretions and excretions of incubating and sick animals are all sources of the virus (OIE, 2009). This implies that an infected goat will be able to carry the virus over long distances and will be able to shed it to in-contact susceptible goats through body secretions and excretions. This may occur at market places where goats come into close proximity or in common grazing areas as practiced in villages. The PPR virus can equally be carried through frozen meat and is able to survive for long periods. When such meat comes into contact with susceptible goats and sheep, it's likely that infection would occur. Based on the evidence that suggests survival of the pathogen in live goats, and the distance travelled across the border, the probability that the virus will survive during transit is **high**

4.1.2 Release Assessment (P1)

Using the probability combination matrix (Table 6) proposed by Zepeda (1998), the probability of release (entry) is a function of the combination of risks relating to prevalence (**high**), contact due to cross-border movement and trade (**moderate**), C-ELISA and quarantine screening missing an infected animal (**negligible**), and survival of pathogen in transit (**high**); thus the probability of release (entry) was rated **high**.

4.1.3 Probability of Exposure (P2)

The parameters used in determining the probability of exposure were as follows:

- (a) The probability of the post transit quarantine screening missing a positive animal
- (b) Probability of an infected animal coming into contact with susceptible ones in the index village

- (c) Proportion of susceptible contact animals.
- (d) Probability of transmission of PPR virus to susceptible animals.

4.1.3.1 The probability of the post transit quarantine missing a positive animal

An in-depth interview with the DVOs for Mbala, Mpulungu, and Nakonde revealed that there were no quarantine facilities in the 3 districts, instead on-farm quarantine was employed when need arose. On-farm quarantine involved restricting mixing of imported and local animals. The herd/flock or individual animals were placed under observation for a period of not less than 21 days. The animals were monitored by the veterinary assistant for development of any clinical signs/disease under the supervision of the district veterinary officer (DVO). The DVO authorized the end of the quarantine period after certifying that the animal/s in question did not exhibit clinical signs of the suspected disease/s. The challenge with this type of quarantine was that there were no properly fenced quarantine facilities that could adequately restrict the movement of the animals under quarantine. Monitoring was also infrequent as at times, the veterinary department did not provide resources at camp level to do this effectively. As a result, the camp officers relied on farmers' compliance. There was a clear possibility that animal mixing could still occur under this type of quarantine arrangement.

An interview with the head of the Zoosanitary Inspectorate unit of the MLFD in Tanzania revealed that there was minimal formal trade/export of live animals from Tanzania into Zambia. This means that almost all trade relating to livestock between the two countries was done informally. This situation makes it difficult to carry out quarantine and inspection of imported goats/sheep into Zambia from Tanzania. On-farm quarantine under supervision of veterinary services for formal movements into northern Zambia remains the only option, while informal movement's remains a challenge. This quarantine was only employed in situations where the veterinary department had information of illegal movement of livestock.

Based on the evidence that suggested lack of quarantine facilities, most animals moved illegally without veterinary clearance (informal), and that on-farm quarantine was unsecure (no fences) and

poorly monitored, the probability of post transit quarantine screening missing an infected animal was **high**.

4.1.3.2 Probability of contact with goats in index village

PPRV is considered to be highly infectious, often spreading rapidly between groups of susceptible animals. Wherever animals are in close contact the potential for transmission exists *e.g.* markets (OIE, 2012). The appearance of clinical PPR in an area may be associated with: the introduction of animals from another area; the general movement of animals; contact with livestock returning unsold from market; contact with traded livestock or nomadic animals (*e.g.* shared grazing, water, housing); and husbandry changes (OIE, 2012).

The questionnaire survey revealed the following on goat sources from the veterinary camps visited:

Goat sources: 95.6% (95% CI: 92.2 to 99.0) of the farmers and traders interviewed bought within the village, 2.2 % (95% CI: 0 to 4.6) bought within the district, and 1.4 % (95% CI: 0 to 3.5) bought within the province.

From the questionnaire survey conducted in northern Zambia, 61.8% (95% CI: 51.3 to 72.5) of 84 respondents indicated that goats bought from Tanzania did not mix with the local goats while 38.1% (95% CI: 27.5 to 48.7) indicated knowledge of mixing. An interview of the 11 veterinary staff working on the border areas estimated that 4,612 goats (95% CI: 2,296 to 11,520) were imported into the country in the last one year. However, most of these goats were imported into Nakonde and were slaughtered in restaurants (8 per day in 4 restaurants) significantly reducing the risk of contact with susceptible goats. Thus the risk of susceptible goats in the index village in northern Zambia coming into contact with an imported infected goat from Tanzania was considered to be **low**.

4.1.3.3 Proportion of susceptible contact goats

There have never been reported outbreaks of PPR in goats and sheep in Northern Province of Zambia. Therefore, small ruminant populations were expected to be naive to PPR virus infection. This naivety is exacerbated by the fact that vaccinations to prevent PPR outbreaks are not being practiced in the province. We therefore determined that the proportion of susceptible goats in the recipient flock was **high**.

4.1.3.4 Probability of transmission of PPR virus to susceptible goats

PPR is a highly contagious and infectious viral disease of domestic and wild small ruminants. It is a severe, fast-spreading disease of mainly domestic small ruminants (Roeder and Obi 1999).

The appearance of clinical PPR may be associated with any of the following:

- history of recent movement or gathering together of sheep and/or goats of different ages with or without associated changes in housing and feeding;
- introduction of recently purchased animals; contact in a closed/village flock with sheep and/or goats that had been sent to market but returned unsold;
- change in weather such as the onset of the rainy season (hot and humid) or dry, cold periods (for example the harmattan season in West Africa);
- contact with trade or nomadic animals through shared grazing, water and/or housing;
- a change in husbandry (e.g. towards increased intensification) and trading practices (Roeder and Obi 1999).

Transmission of PPR is achieved by direct close contact from infected to susceptible animals or through respiratory and oral routes (Chauhan et al. 2009). Up to 100 % of the animals in a flock may be affected in a PPR outbreak with between 20 and 90 % mortality (Roeder and Obi 1999). We therefore determine the probability of transmission to be **high**.

4.1.4 Assessment of Exposure (P2).

The probability of exposure resulting from a combination of the four parameters, namely; post transit quarantine screening missing an infected animal (**moderate**), probability of contact with susceptible (**low**), proportion of susceptible contact goats (**high**), and probability of transmission (**high**), is considered **high**.

4.1.5 Probability of Occurrence

Probability of occurrence is a product of two probabilities; the probability of release/entry (P1) which was rated high and the probability of exposure (P2) which was rated high. The probability of occurrence of a risk considered as high and one considered as high is thus **high**.

4.1.6 The Consequences

The magnitude of the consequences of PPR virus introduction into northern Zambia was assessed using the following 3 parameters:

- 1) The probability of PPR virus spreading beyond index village
- 2) The probability of PPR virus spreading beyond district
- 3) Impact of PPR introduction and establishment

4.1.6.1 The probability of PPR spread within index village

PPR is an acute, highly contagious and infectious disease specific to small ruminants and small wild stocks (Nussieba *et al.* 2009). The disease is characterized by high morbidity and mortality (50% – 80%) in naive sheep and goat populations. PPR occurs in an epizootic form, it may have dramatic consequences with morbidity of 80-90% and mortality between 50 and 80% (Lefevre *et al.* 1991). Transmission of PPR is achieved by direct contact from infected to susceptible animals by close contact or through respiratory and oral routes (Chauhan *et al.* 2009).

The spread of PPR from northern to southern Tanzania was due to introduction of new animals and contact during communal grazing and housing (Muse *et al.* 2012). The disease was first introduced in Likuna village (Newala district of southern Tanzania) in February 2009 through

newly purchased goats from the Pugu livestock market (about 679 km in Dar es Salaam city). The disease rapidly spread to neighboring villages by communal grazing and sale of sick animals. Cheap prices of infected goats also enhanced rapid spread (Epaphras *et al.* 2011). In Zambia, majority of small ruminants are kept under traditional farming systems where there is close contact during grazing and through night housing. Different age groups are reared together and share the same housing at night.

In northern Zambia, it was discovered that goats in close families in communities usually grazed together. The questionnaire survey revealed that 95.6% (95% CI: 92.2-99.0) bought breeding goats and sheep from within the village from fellow farmers. It is reasonable to assume that when PPR is imported into the village/community, it would easily spread from the index flock to affect other flocks going by the production system practiced in northern Zambia. We therefore determine the probability of PPR virus spread within index village to be **high**.

4.1.6.2 The probability of PPR spread beyond district

From the questionnaire survey conducted in the study area, out of 127 respondents only 13% (95% CI: 3.4 to 6.2%) sold their goats to well established markets. These markets were mainly in the township areas of the same district. Only 10.2% (95% CI: 4.9 to 15.6) sold their goats to established markets while the rest 89.8% (95% CI: 84.4 to 95.1) sold them within villages. The export of goats within Northern Province was rated as moderate (Expert Opinion). Thus we determine the probability of PPR spreading beyond the district to be **moderate**.

4.1.6.3 Impact of PPR introduction and establishment

Diseases, including PPR have been recognized as one of the major factors limiting small ruminants' production in a wide range of agro-climatic zones (Sumberg and Mack 1985; Kusiluka and Kambarage 1996). They reduce productivity on a clinical and sub-clinical level. They cause production losses such as reduced weight gains, impairing growth, lowered milk and meat production, high veterinary costs and mortalities, especially in the young (Swai *et al.* 2009).

It is estimated that 10% of the total impact of the disease is on trade and public expenditure and 90% on herd productivity (DFID 2001-2002).

- (a) In Nigeria, an outbreak that occurred in 1979 killed 10-20% of the national small ruminant flock that was estimated at US\$ 75 million.
- (b) A cost benefit analysis conducted in Niger in 1993 to assess the benefit of vaccination against PPR concluded that an investment of US\$ 2 million on vaccination would generate US\$ 24 million in return for a five year vaccination program (Stem, 1993).
- (c) In Ethiopia FAO estimated that losses associated with PPR reached an average of US\$ 375 per flock per year, with an average of 143 small ruminants per flock (an average loss of more than US\$ 2 per animal).
- (d) In the 2008 outbreak in Kenya, the cost of vaccines used was estimated at € 4.8 million out of a total vaccination campaign cost of €12 million (Njagi, 2009).
- (e) The DRC reported that since its emergence in 2010 to June 2012, PPR had caused the death of almost 120,000 small ruminants. It estimated direct loss, i.e. value of dead sheep and goats, to be US\$5.3 million. This estimate did not take into account the socio-economic impact and other benefits of goats and sheep to the smallholder farmers (SADC, 2011b).

The important direct economic losses caused by PPR are often further aggravated by the sanitary measures imposed by authorities in controlling animal movement and trade restrictions on their by-products (Wakhusama *et al.* 2011). The consequences of PPR outbreak are solely economic since the virus is not zoonotic. In this case, public health consequences were rated negligible based on the scale used in this study. In the border districts of Northern Province, goats are mainly kept by traditional farmers on a very small scale. Indirect consequences are likely to have far reaching effects. Presence of PPRV in the area may not only affect trade in goats and small ruminants from these areas, but the cattle and the pig industries in the area are likely to suffer trade restrictions in case of an outbreak.

When PPR occurs for the first time in a new area, there is loss of disease free status which may take a long time to be reclaimed. This affects a country's ability to trade and major losses in revenue may be incurred. The total goat and sheep population for Northern Province was 69,760 and 6,174, respectively (Personal Communication: Provincial Veterinary Officer, Northern Province, 2012). This represented a percentage of 3.8 and 6.7 of the total goat and sheep population in Zambia. The total goat and sheep population in the 3 districts where the study was done was 36,662 and 1,148 respectively representing 54% and 18.6% of the total goat and sheep population for the province; 2% and 0.1% of the national population respectively.

Once the disease is introduced in northern Zambia, the rest of the county could easily get infected considering the limited disease surveillance efforts and inadequate veterinary service delivery. Such an outbreak could be challenging to control considering there is no emergency preparedness in place. Therefore, the whole Zambia could easily suffer a ban on export of live animals or animal products from susceptible animals. In this context, the possible impacts of PPRV outbreak were considered **high**.

4.1.7 Assessment of consequences

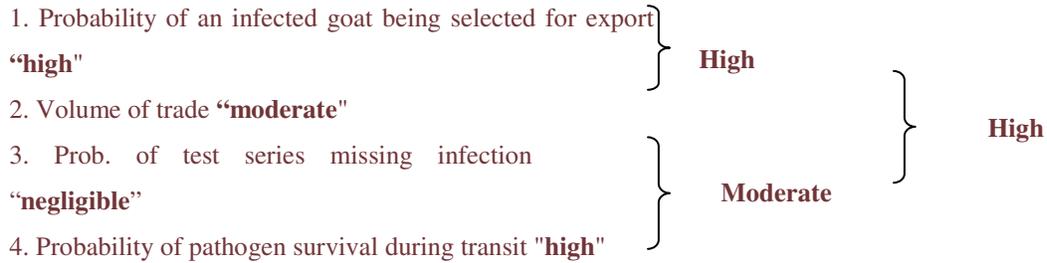
The magnitude of consequences resulting from a combination of the three parameters, namely; probability of spread within index village (**high**), probability of spread beyond district (**moderate**), impact of consequences of PPR introduction and establishment (**high**), is considered **high**.

4.1.8 Ultimate/Assessed Risk of PPRV Introduction into Northern Zambia

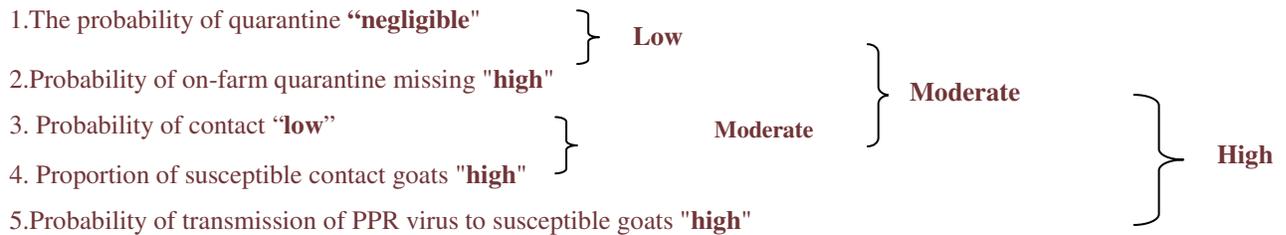
The assessed risk is a combination of the probability of occurrence (**high**) and the magnitude of the consequences of occurrence (**high**), and is thus rated "**high**." From the interpretation of the probability scale provided by Zepeda (1998) (Table 5), high implies; prohibit import until measures to reduce the risk have proven their efficiency and adequate verification procedures are available to ensure safe implementation.

4.1.9 Risk Estimation Process

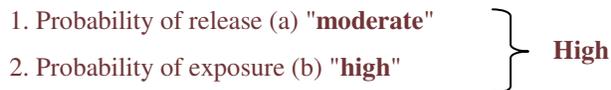
A. PROBABILITY OF RELEASE



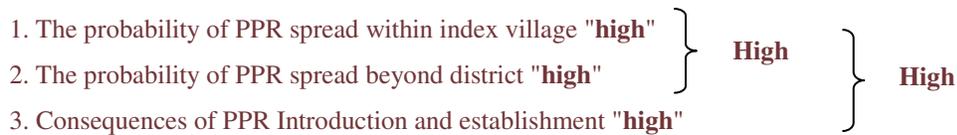
B. PROBABILITY OF EXPOSURE



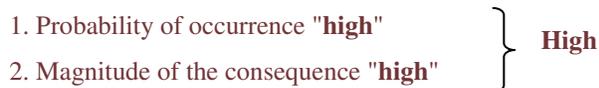
C. PROBABILITY OF OCCURRENCE



D. CONSEQUENCES



E. RISK ESTIMATION



4.1.9.1 Description of uncertainties in the qualitative model

Table 7: Description of model uncertainties

Assessment component	Uncertainty description	Direction of error	Magnitude
Release	Probability of C-ELISA and quarantine missing an infected goat	There is little formal movement of goats/sheep from Tanzania into Zambia, hence most goats will not undergo testing and quarantine	Underestimated risk High
	Volume of trade	Most movements are illegal due to the porous border resulting in many trade routes	Underestimated risk Moderate
Exposure	The probability of the quarantine missing a positive animal	There are no known quarantine stations in northern Zambia. On-farm quarantine is difficult to enforce in cases where illegal animal movements are not detected	Underestimated risk High

4.1.9.1.2 CONCLUSION ON QUALITATIVE RISK ASSESSMENT

The probability of occurrence of PPR virus in Northern Province of Zambia was determined to be **high**. The magnitude of the consequences of occurrence of PPRV in Northern Province of Zambia was also determined to be high. The assessed risk is a combination of the probability of occurrence (**high**) and the magnitude of the consequences of occurrence (**high**), and is thus rated “**high**”.

4.2 QUANTITATIVE RISK ASSESSMENT

The Question:

The question we were attempting to answer under this analysis is the same as stated under the qualitative method, that is; “What is the annual risk of introducing Peste des petits ruminants (PPR) virus into northern Zambia through importation of live goats from Tanzania?”

4.2.1 General approach

The design of the quantitative risk assessment was divided into six consecutive steps: (1) description of the scope of analysis, (2) model formulation, (3) definition of distributions for input variables (4) estimation of the likelihood of hazard occurrence, (5) analysis of results and (6) model environment and software.

4.2.1.1 Description of the scope of analysis

The risk of introduction of PPR through importation of live goats into northern Zambia from Tanzania was evaluated. Description of the source of goats/sheep and destinations are described under the qualitative approach.

4.2.1.2 Model formulation

This risk assessment follows the proposed protocol that is normally followed by formal import of goats as described by the Veterinary Department in Zambia. The protocol outlined includes: inspection procedures, quarantine procedures; specifications on screening tests; veterinary inspections and supervision of quarantine. In the assessment of risks, we took into account available scientific evidence; relevant processes and production methods; relevant inspection, sampling and testing methods; the prevalence of PPR; the existence of disease – free areas; the relevant ecological and environmental conditions; quarantine and other treatments.

4.2.1.3 Building a risk assessment model

A scenario tree (flow diagram) was constructed based on the specific questions that were asked (Figures; 7, 8, and 9). This was then followed by identification of critical or risky points in the pathway. A critical or risky point was any point in the transportation pathway where the PPR virus could be introduced or released (depending on the question) into or from the pathway. This depended on the scenario diagram for release assessment (Figure 7).

4.2.1.4 Definition of the distribution of model input variables

The information used to estimate the risk was collected from published scientific literature and also unpublished sources, such as reports from field surveys, reports from the wildlife authorities and the Ministry of Livestock Development, and field observations. This has been described fully under the qualitative approach. The only difference is that additional numerical data was collected and utilised in this assessment as opposed to the qualitative data that was utilised in the qualitative assessment (Table 8 below).

4.2.1.5 Assessment of different probabilities critical in the risk pathway

Assessment of the probabilities of release, exposure, and consequences were evaluated using different factors which were identified to be critical in the pathway of release, exposure and magnitude of consequences of PPRV occurrence, introduction and establishment from Tanzania into northern Zambia. The estimates which were evaluated are captured below:

4.2.1.5.1 Estimates of the likelihood of hazard release (P1)

- a) Prevalence of infection (P1a)
- b) Number of animals to be imported (P1b)
- c) Probability of false negative (P1c)
- d) Probability of pathogen survival in transit (P1d)

4.2.1.5.2 Estimates of the likelihood of exposure to hazard (P2)

- a) Probability of an imported goat being quarantined (P2a)
- b) Probability of on-farm quarantine missing a positive animal (P2b)
- c) Probability of contact with other goats/sheep(P2c)
- d) Probability of contact with susceptible goats/sheep (P2d)
- e) Probability of transmission (P2e)

4.2.1.5.3 Estimates of the likelihood of hazard occurrence (P3)

- a) Probability of release (P1)
- b) Probability of exposure (P2)

4.2.1.5.4 Estimates of the likelihood of economic consequences (P4)

- a) Probability of PPR spread beyond index village (P4a)
- b) Probability of spread beyond district (P4b)
- c) Probability of PPR establishment (P4c)
- d) Probability of causing huge financial loss (P4d)

4.2.1.5.5 Estimates of the likelihood of hazard introduction and establishment into northern Zambia (Assessed Risk)

- a) Probability of hazard occurrence (P3)
- b) Probability of economic consequences (P4)

Table 8: Quantitative estimates of model parameters

Parameter	Minimum	Most Likely	Maximum	Distribution	Estimate	Certainty Level	Reference
Probability of release (P1)							
Prevalence of infection (P1a)	0.31	0.45	0.88	Risk pert	0.89	Certain	Karimuribo <i>et al</i> , 2011; Muse <i>et al</i> , 2012
Annual volume of trade (P1b)	215		4612	Risk uniform	2500	Somehow certain	Questionnaire survey results.
Probability of false negative (sensitivity) (P1c)	0.046	0.066	0.076	Risk pert	0.40	Certain	Singh <i>et al</i> , 2004; Kang, 2005
Capacity to survive in transit (P1d)	0.8	0.9	1	Risk pert	0.18	Certain	Expert opinion
Probability of release (P1)= P1a* P1c*P1d= 0.038 (95% CI: 0.01869 to 0.04768)							
Number of imported goats likely to be infected=P1*Volume of trade=P= 74.28=Approx. 75 (95% CI: 1 to 271)							
Probability that atleast 1 imported goat is infected: P=1-(1-P)^ n=1 (95% CI: 0.99994 to 1.00000)							
Probability of exposure (P2)							
	Minimum	Most likely	Maximum	Distribution	Estimate	Certainty level	Reference
Probability of an imported goat being quarantined (P2a)	0.01	0.05	0.1	Risk triangle	0.81	Certain	Expert opinion; DVS
Prob. of post transit quarantine missing an infected animal (P2b)	0.15		0.20	Risk uniform	0.20	Somehow certain	Singh <i>et al</i> , 2004; Kang, 2005
Probability of contact (P2c)	0.40		0.60	Risk uniform	0.27	Somehow certain	Questionnaire survey results
Proportion of susceptible contact goats (P2d)	0.5	0.8	0.9	Risk triangle	0.27	Certain	Chauhan <i>et al</i> , 2009; Lefevre and Diallo, 1990; Muse <i>et al</i> , 2011
Probability of transmission (P2e)	0.5	0.9	1	Risk triangle	0.31	Certain	Chauhan <i>et al</i> , 2009; Lefevre and Diallo, 1990
Probability of exposure (P2)= P2a*P2b*P2c*P2d*P2e= 0.00274 (95% CI: 0.0090 to 0.00539)							
Probability of occurrence (P3)= Probability of release × Probability of exposure=P1*P2= 8.437×10⁻⁵ (95% CI: 24.9 to 188.4 ×10⁻⁵)							

Magnitude of consequences (Mc)	Minimum	Most likely	Maximum	Distribution	Estimate	Certainty level	Reference
Prob. of PPR spread beyond index village (P4a)	0.5	0.8	0.9	Risk triangle	0.43	Certain	Expert opinion; Nussieba et al. 2009; Epaphras et al, 2011; Muse, Karimuribo <i>et al.</i> 2012
Prob. of spread beyond district (P4b)	0.5	0.75	1	Risk triangle	0.51	Somehow certain	Expert opinion
Prob. of PPR establishment (P4c)	0.5	0.75	1	Risk triangle	0.51		Expert opinion
Prob. of causing huge financial loss (P4d)	0.5	0.75	1	Risk triangle	0.51	Certain	DFID, 2002; <u>Stem</u> , 1993; Njagi L, 2009; SADC, 2012; Wakhusama, <i>et al</i> , 2011
Probability of consequences (P4)= P4a*P4b*P4c*P4d= 0.310 (95% CI: 0.173 to 0.494)							
Assessed Risk= Probability of occurrence× Probability of consequences=P3*P4= 2.617×10⁻⁵(95% CI: 6.6 to 65.1×10⁻⁵)							

4.3.1 Data

The model was run in @Risk version 5.7 Palisade Corporation, 1996–2007) on Microsoft Excel (Microsoft Office Edition, 2007) using Monte Carlo simulation with 10,000 iterations. For the variables where quantitative data could not be accessed, qualitative data was used to estimate the likely quantitative estimate using the matrix in Table 9.

Table 9: Quantitative estimates of qualitative parameters

SN	Probability rating	Quantitative estimates
1	Negligible	0-1%
2	Low	2-5%
3	Moderate	6-50%
4	High	$\geq 50\%$

4.3.2 Probability of PPR release into Northern Zambia from Tanzania

In estimating the probability of release, the following input variables were taken into account prevalence of infection, probability of missing an infected animal during quarantine, and pathogen survival in transit (Table 8). The probability of release, which is a product of the individual probabilities of the above mentioned variables, was estimated at 0.038 (95% CI: 0.01869 to 0.04768), (Figure 11).

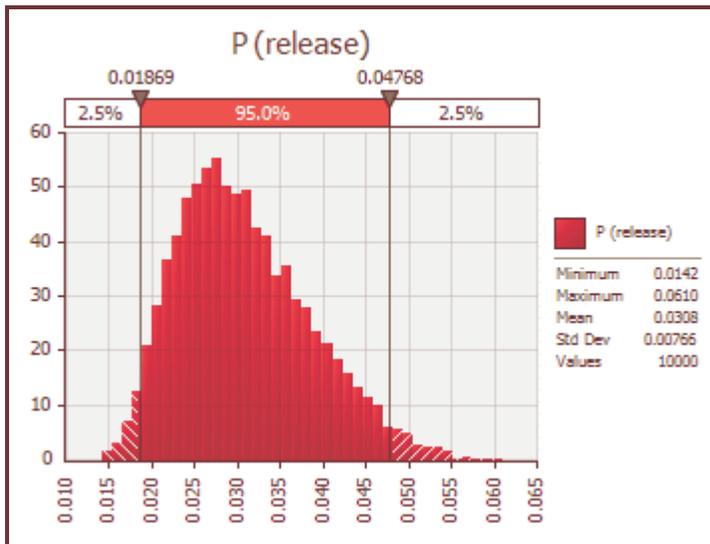


Figure 11: Graph showing output for release assessment

4.3.2.1 Number of imported goats likely to be infected in the annual consignment

The number of imported goats/sheep in the annual consignment (n=4612) likely to be infected with PPRV was estimated at 74.28=approximately 75 (95% CI: 1 to 271), Figure 12.

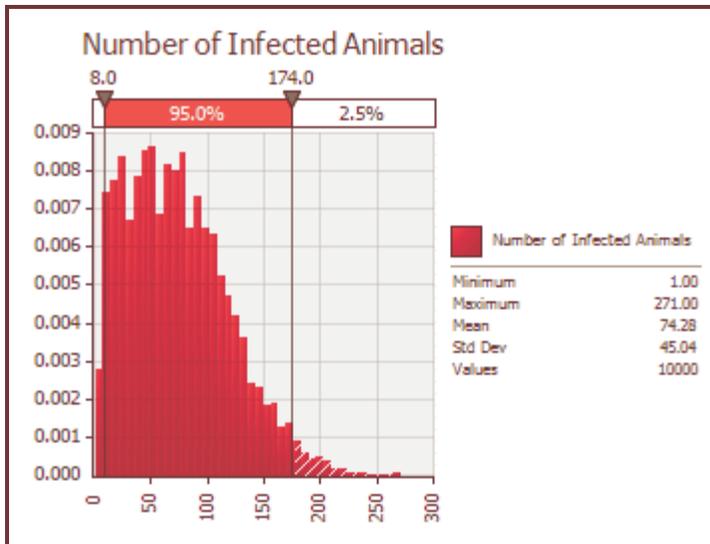


Figure 12: Graph showing the output for number of imported animals that are likely to be infected with PPR in the annual consignment (n=4612).

4.3.2.2 Probability of at least one animal being infected with PPRV

The probability that at least one imported goat/sheep out the annual consignment of 4612 was estimated using the formula $P=1-(1-P)^n$; where P=probability of release, n=the estimate of the most likely number of animals to be imported, i.e. 2500 (most likely), and was found to be 1 or 100% (95% CI: 0.99994 to 1.00000), Figure 13.

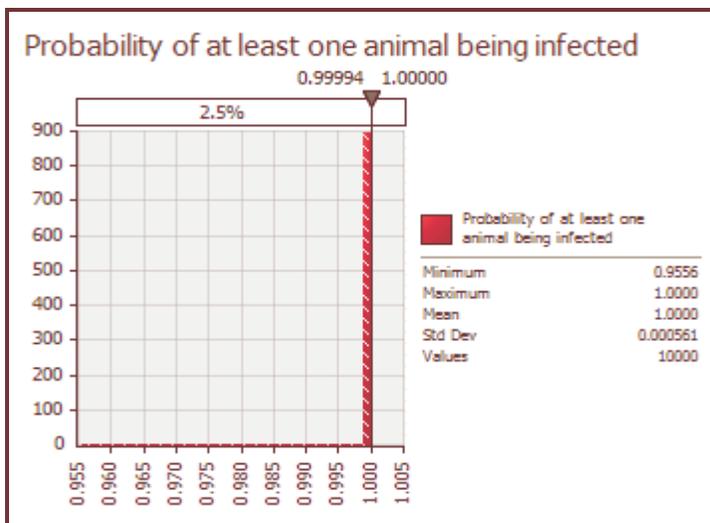


Figure 13: Graph showing the output for probability of at least one animal in annual consignment being infected with PPRV.

4.3.3 Probability of Exposure

In estimating this probability, the following input variables were taken into account; probability of on-farm quarantine, probability of quarantine missing an infected animal, probability of contact, proportion of susceptible animals, and probability of transmission. The probability of exposure, which is a product of the individual probabilities of the above mentioned variables was estimated at 0.00274 (95% CI: 0.0090 to 0.00539) (Figure 14).

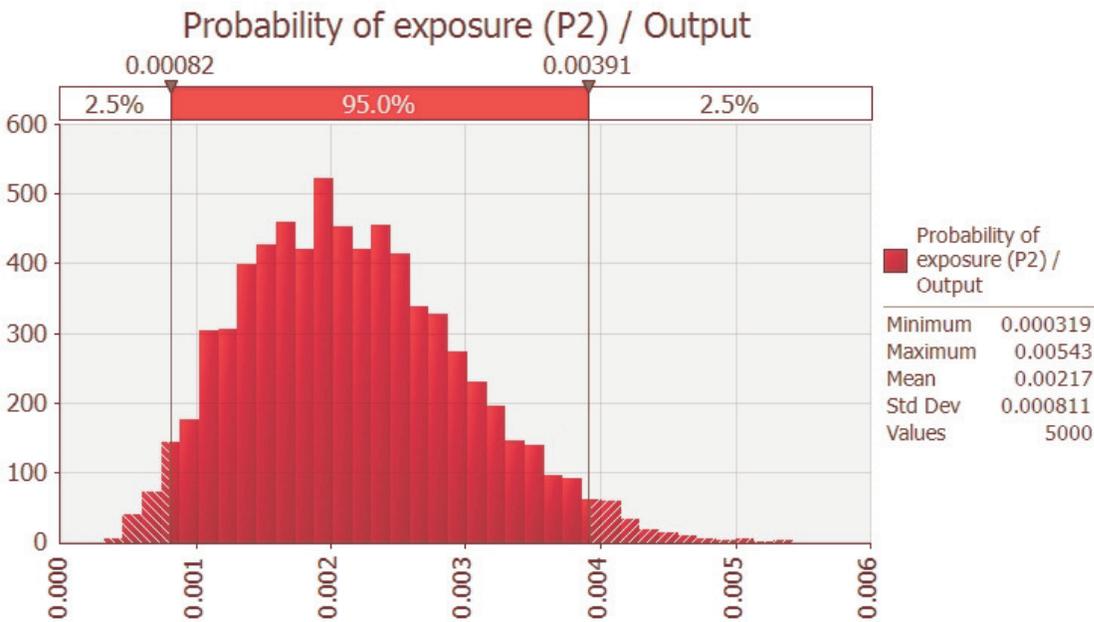


Figure 14: Graph showing output for exposure assessment and the 95% confidence interval

4.3.4 Probability of PPRV Occurrence (P1*P2)

In estimating this probability, the following input variables were taken into account; probability of release (P1) and probability of exposure (P2). The probability of occurrence, which is a product of the individual probabilities of the above mentioned variables was estimated at 8.437×10^{-5} (95% CI: 24.9 to 188.4×10^{-5}), Figure 15.

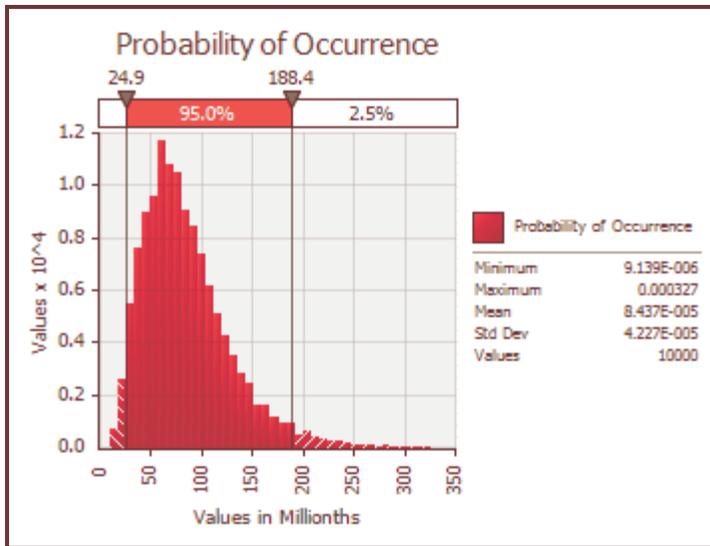


Figure 15: Graph showing the output for hazard occurrence (value in millionths) and the 95% confidence interval

4.3.5 Probability of consequences of PPRV Occurrence

In estimating this probability, the following input variables were taken into account; probability of PPR spread within index village, probability of PPR spread beyond district, and the consequences of PPR introduction and establishment. The probability of consequences, which is a product of the individual probabilities of the above mentioned variables, was estimated at 0.310 (95% CI: 0.173 to 0.494), Figure 16 and Table 8.

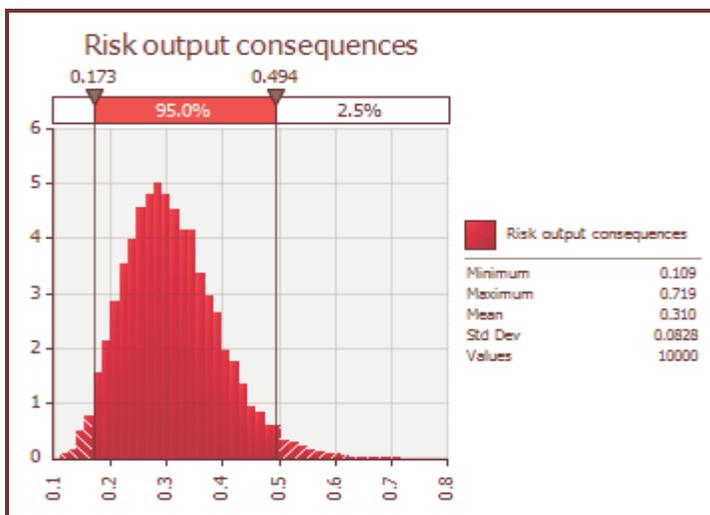


Figure 16: Graph showing output of economic consequence assessment and the 95% confidence interval

4.3.6 Assessed (ultimate) risk of PPRV introduction into Zambia from Tanzania

In estimating this probability, the following input variables were taken into account; probability of hazard occurrence (P3) and the probability of economic consequences (P4). The assessed risk, which is a product of the individual probabilities of the above mentioned variables, was estimated at 2.617×10^{-5} (95% CI: 6.6 to 65.1×10^{-5}), Figure 17.

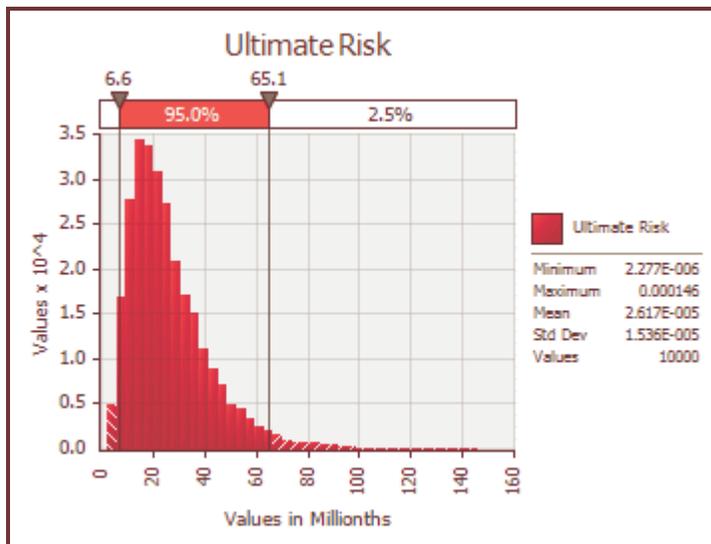


Figure 17: Graph showing the output of the assessed risk with 95% confidence intervals

4.3.7 Sensitivity Analysis

The variable that are likely to influence the final estimated variable were analysed using the Tornado graph (Figure 18). Lack of quarantine in Zambia, and prevalence of the disease in Tanzania, were the major contributors to the estimated risk.

The main idea of the tornado chart is that the longer the bar or the larger the coefficient, the greater the impact that particular input has on the output that you are analysing. A positive coefficient, with bar extending to the right, indicates that this input has a positive impact: increasing this input will increase the output. A negative coefficient, with bar extending to the left, indicates that this input has a negative impact: increasing this input will decrease the output.

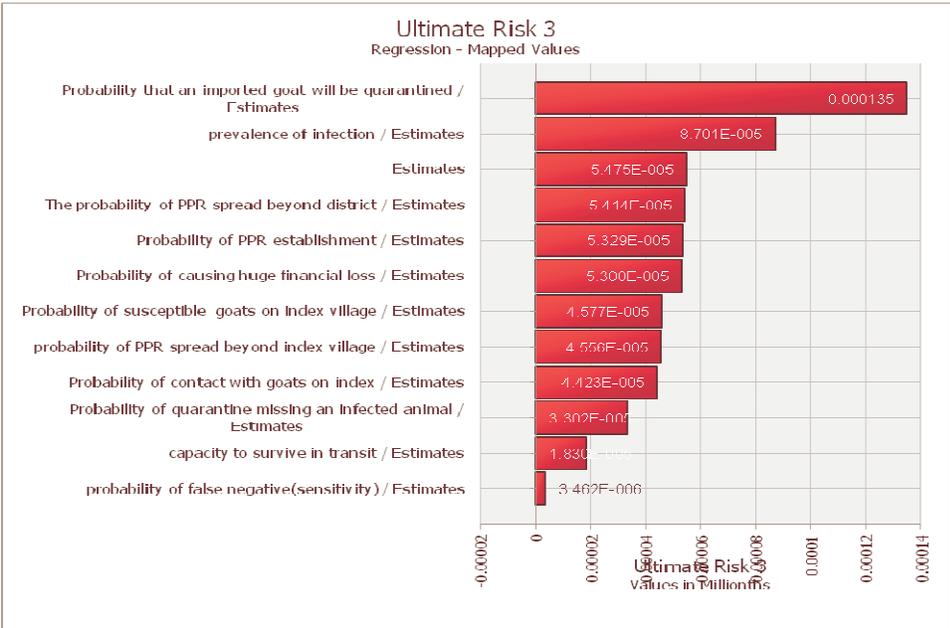


Figure 18: Tornado chart showing the output of sensitivity analysis for model parameters

4.4 CONCLUSION IN QUANTITATIVE RISK ASSESSMENT

At 95% level of confidence, the annual risk of introducing PPR from Tanzania into Zambia through importation of at least one infected live goat from an annual consignment of 4612 animals from Tanzania was evaluated to be 100%. The number of imported goats/sheep in the annual consignment likely to be infected with PPRV was estimated at 75. The probability of importing at least one PPRV infected goat/sheep out of the annual consignment of 4612 was estimated to be 1 or 100%. Therefore, the probability that PPRV virus will be introduced in Zambia through importation of live goats from Tanzania under the described circumstances is **high**.

The sensitivity analysis, reviewed that reducing the prevalence of PPR in goats/sheep in Tanzania, or sourcing from the disease free areas could significantly reduce the risk. It further showed that quarantining the animals in Zambia and screening with C-ELISA could further reduce the risk.

4.5 MAPPING OF TRADE ROUTES IN NORTHERN ZAMBIA-RESULTS

Following the possible entry of PPR from Tanzania into northern Zambia due to the close proximity of the two countries as shown in Figure 19, and animals movements between the countries, the data collection mission to Tanzania and Zambia collected geo-referenced data for the veterinary camps at high risk from PPR incursion and the possible routes of entry as shown in Appendices II (a) and (b).

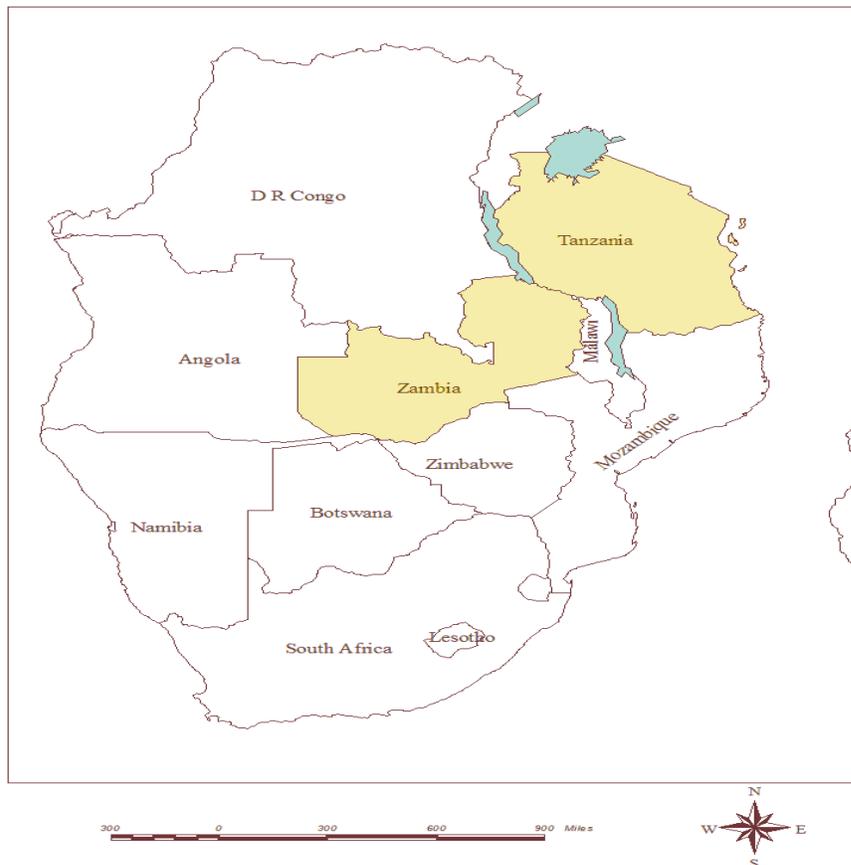


Figure 19: Mapping showing the relative position of Zambia and Tanzania in the SADC region

4.5.1 PPR Outbreak areas and trade routes in Tanzania

A map was produced showing PPR disease outbreak areas (districts-in pink colour) between 2008 and 2010 in Tanzania and the animal trade routes in Tanzania based on the work of Diallo et al, 2011. Based on this map, another map was produced to show the possible entry points of the disease in northern Zambia based on the identified animal movement routes across the border between the two countries, Figure 20.

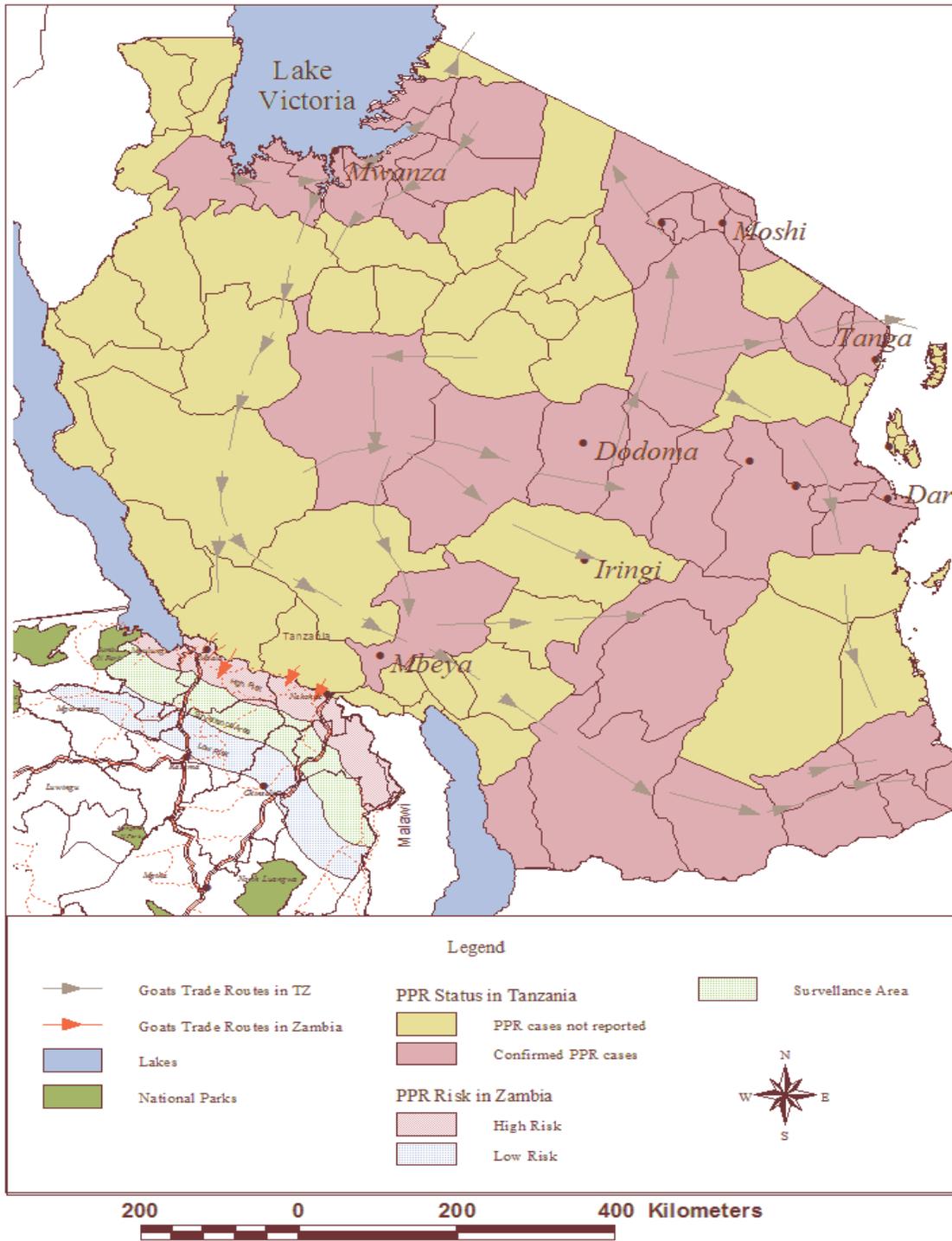


Figure 20: Outbreak areas in Tanzania (in purple) and trade routes (green arrows); and high risk area in Zambia (pink) and entry trade routes into Zambia (red arrows).

4.5.2 Veterinary camps at risk in northern Zambia

The camps closest to the border were identified to be at highest risk for PPR entry as they had direct entry of the animal movement routes from Tanzania into Zambia, Figure 18. These routes were mainly paths for animal movements across the border and filtering into feeder roads or main access roads into the district. These camps were Mbala central, Kawimbe, Kaka, and Mwamba in Mbala district; Mpulungu central veterinary camp in Mpulungu; Ilola, Nakonde central, Mwenzo, and Nteko in Nakonde district, Figure 21.

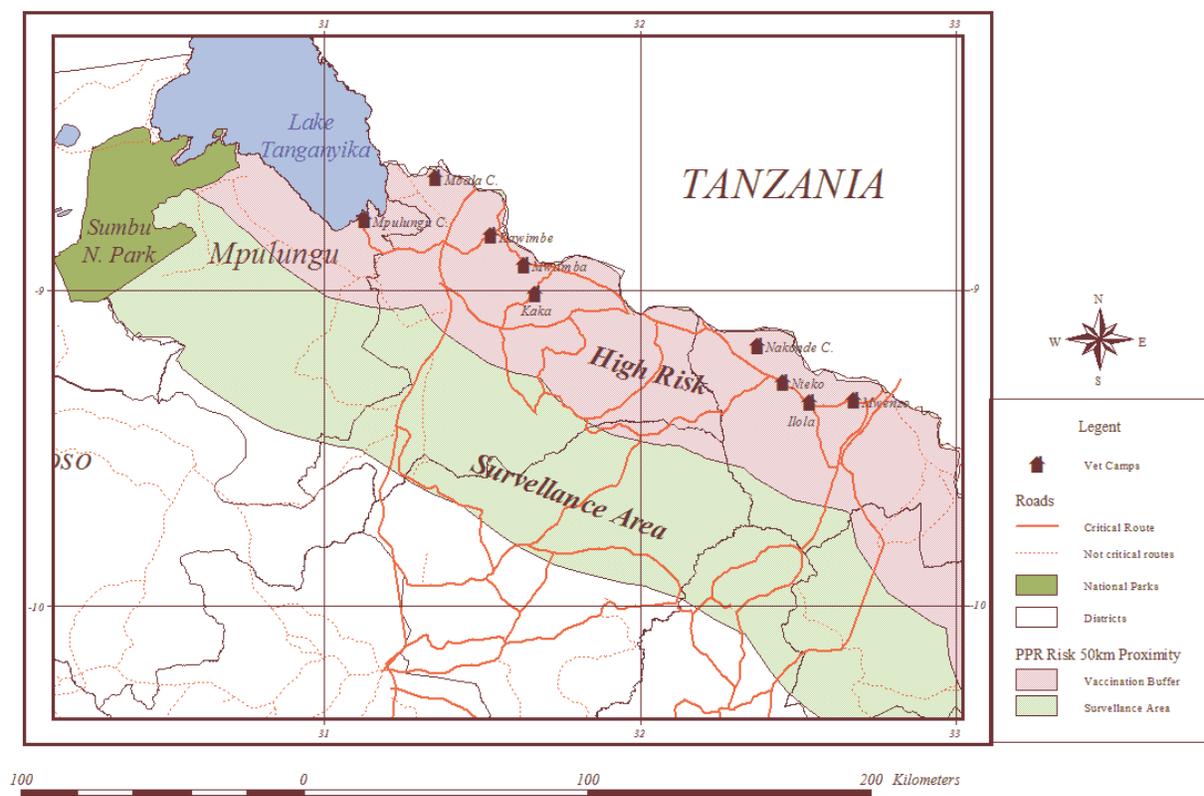


Figure 21: High risk zone comprising of Mbala, Mpulungu, and Nakonde showing veterinary camps at risk

4.5.3 Critical routes for PPRV entry across the border

In Nakonde, the significant routes of entry were identified as; (1) Tewele-kapwila road and (2) Mikulya-chozi road. In Mbala, the significant routes of entry were identified as (1) Kaseshya

road (2) Mutula road, and (3) Musangano-lobo-kaka road. In Mpulungu, the significant route of entry was the Kaseshya-Chipoma-Kati-Muswilo-Isoko_Mpulungu road, Figures 22 and 23.

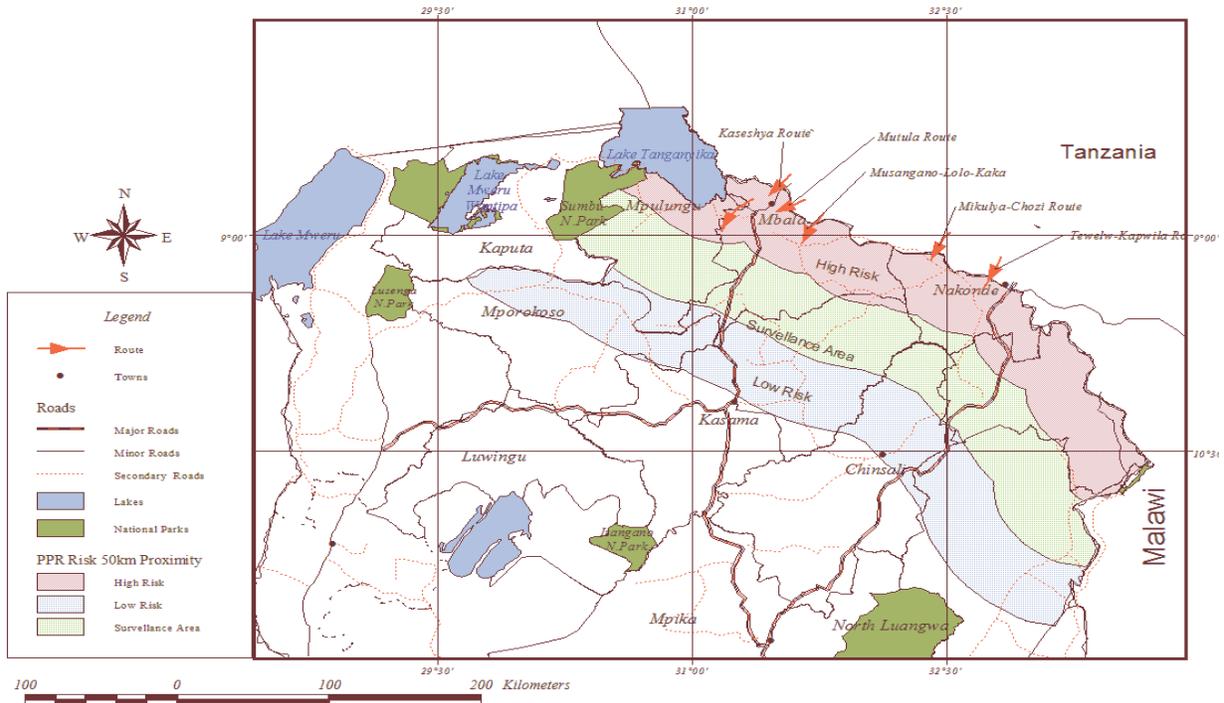


Figure 22a: Critical routes for PPRV entry across the border



Figure 22b: Critical routes for PPRV entry across the border

4.5.4 Critical routes for PPRV dissemination into Northern Province

Animal movement is a major cause of disease spread. In the case of an outbreak of PPR in northern Zambia, the critical routes within Northern Province through which PPR could spread were identified and mapped, Figure 21 above. These critical routes within Northern Province were; (1) Mpulungu-Mbala-Kasama road. This route was critical in that it's the main road to the provincial capital Kasama where the human population is high and better markets available, (2) Nakonde-Chinsali-Mpika road. This route was critical in that it gives market access to the provincial capital of Muchinga province (formerly part of Northern Province but still part of northern Zambia by location) and Mpika district.

4.6 CONCLUSION ON MAPPING OF TRADE ROUTES IN NORTHERN ZAMBIA

The risk mapping identified the following veterinary camps to be at high risk for PPR incursion; (1) Mbala central, Kawimbe, Kaka, and Mwamba in Mbala district; (2) Mpulungu central veterinary camp in Mpulungu; (3) Ilola, Nakonde central, Mwenzo, and Nteko in Nakonde district, Figure 21. The study also identified the following routes to be critical for the entry or introduction of PPR into the northern part of the country; in Nakonde, the significant routes of entry were identified as; (1) Tewele-kapwila road and (2) Mikulya-chozi road; in Mbala, the significant routes of entry were identified as (1) Kaseshya road (2) Mutula road, and (3) Musangano-lobo-kaka road; in Mpulungu, the significant route of entry was the Kaseshya-Chipoma-Kati-Muswilo-Isoko_Mpulungu road, Figure 22 a and b.

The routes which were identified to be critical in the spread of PPR to the rest of northern Zambia were; (1) Mpulungu-Mbala-Kasama road. This route was critical in that it's the main road to the provincial capital Kasama where the human population is high and provides access to better markets, (2) Nakonde-Chinsali-Mpika road. This route was critical in that it gives market access to the provincial capital of Muchinga province (formerly part of Northern Province but still part of northern Zambia by location) and Mpika district, Figure 21.

CHAPTER 5: DISCUSSION AND RECOMMENDATIONS

The quantitative risk assessment results compliments the results from the qualitative risk assessment whose overall risk was estimated to be high. Thus the two assessments are in agreement with each other.

From the qualitative risk assessment, the probability of occurrence of PPR virus in Northern Province of Zambia was determined to be **high**. The magnitude of the consequences of occurrence of PPRV in northern province of Zambia was also determined to be high. The assessed risk is a combination of the probability of occurrence (**high**) and the magnitude of the consequences of occurrence (**high**), and is thus rated “**high**”.

From the quantitative risk assessment, the probability of the virus being released into northern Zambia from Tanzania was evaluated to be 0.038 (3.8%), the probability of PPR occurrence was evaluated to be 8.437×10^{-5} , the probability of economic consequences was evaluated to be 0.310 (31%). The number of animals likely to be infected in the annual consignment of 4,612 was estimated to be 75 and the probability of at least one animal being infected was 1 (100%). Therefore, the probability of PPR introduction and establishment is high. From the interpretation of the probability scale provided by Zepeda (1998) (Table 5), high implies; prohibit import until measures to reduce the risk have proven their efficiency and adequate verification procedures are available to ensure safe implementation.

5.1 Risk Management/Mitigation Measures

The main drivers of the high risk of PPRV introduction in Zambia as identified from the sensitivity analysis was lack of quarantine facilities in Zambia and the prevalence of the disease in Tanzania. Establishment of disease quarantine facilities in the border districts of Zambia would help avert the likely incursion of PPR. Quarantine should be regarded as one of the most important core functions of government veterinary services. FAO advocates a quarantine period of 21 days for PPR. PPR has an incubation period of 4-5 days during which the animal is considered to be highly infectious. The quarantine period of 21 days as recommended by the OIE

will ensure maximum period of observation during which infected animals are likely to manifest clinical disease. The same period gives ample time to inexperienced animal health workers who have not experienced PPR to diagnose the disease and implement immediate disease control measures. This aspect is important in ensuring that the disease is restricted from further spread in the case of resurgence. Quarantine should be coupled with intense stock movement controls especially along the border areas with Tanzania. Animals recovered from PPR infection or immunized by vaccination are not a PPRV carrier and do not play a role in maintaining virus circulation in an area (Diallo *et al* 2011). Hence a long quarantine period will help control spread of PPR. There is real need to intensify on border controls to prevent the smuggling or uncontrolled entry of animals, animal products and other potentially dangerous goods.

Importation of animals from disease free districts in Tanzania would help reduce the risk of PPR introduction significantly. This could be done in combination with pre-export quarantine.

Other risk management measures include strengthening veterinary services and capacity to conduct epidemiological surveillance. It seems that livestock movements to and from Zambia or Malawi take place by lorry or by foot and without official export/import permit in many cases (Wakhusama *et al.* 2011). Since most of the crossborder movement of goats and sheep are informal, there is need for the departments of veterinary services along the border on both sides to intensify on surveillance, monitoring, and livestock movement controls. A joint surveillance system by both Tanzanian and Zambian veterinary authorities should be put in place. This would help prevent the introduction and establishment of the PPR virus into Zambia. A strong surveillance system for PPR for early warning and preparedness cannot be overemphasised for Zambia looking at the risk posed by PPR introduction into the country. In this regard, a Standard Operating Procedure (SOP) for the epidemiological surveillance of PPR for the country should be developed as soon as possible.

Another important measure of mitigating the risk is to create a vaccination buffer/zone of 50km from the border into the high risk areas to avert a possible incursion of PPR (SADC, 2012b), Figure 22 above. The vaccination buffer was identified to be the area at high risk for PPR incursion and this includes; parts of Mbala, Mpulungu, Nakonde, and Isoka. The surveillance

zone should include parts of Mpulungu, Mbala, Nakonde, Isoka, Chinsali, Kasama, and Chama districts.

The department of veterinary services need to intensify efforts of prevention of PPR entry in the area that was identified to be the high risk zone, that is, the area within a radius of 50km from the border line, Figure 23. The high risk area was the same area identified as the vaccination buffer. This area is recommended for vaccination to prevent the entry of the PPRV. The area within 50km radius from the outer boundary of the vaccination buffer is the surveillance zone where the department can carry out regular and scheduled active surveillance (Figure 22 above). The rest of the area from the outer boundary of the surveillance zone was identified to be at low risk.

PPR vaccine has been proved to be protective to small ruminants for a period of atleast 3 years (Roeder and Obi 1999), hence most animals will only need vaccination twice in their lifetime. Subsequent vaccinations should be targeted at naive newly born kids/lambs. Atleast 85% of the small ruminant population should be vaccinated in the high risk zone; this includes Mbala, Nakonde, Mpulungu, and possibly Isoka. Most of the owners in this area are mainly agro-pastoralists with small numbers of animals per household. In such circumstances, losing 2–3 animals for these herders may be more serious than the loss of 100 head for an owner with big flock in the Tanzania . Considering the number of small ruminant populations in these southern regions , the cost of vaccination will not be very expensive (Wakhusama *et al.* 2011). If the strategy of vaccinations is taken up, there will be need to build laboratory capacity to carry out the differentiation of vaccinated from infected animals (DIVA) animals. In the absence of this, proper animal identification will be required, e.g. ear tagging or branding of all vaccinated animals.

Strengthening laboratory capacity cannot be overemphasised. Scientific evidence shows that PPR may exist in a silent manner – a situation discovered only during sero-surveillance by the detection of PPR antibodies in apparently healthy animals. This means that for early detection and containment, improving laboratory diagnostic capabilities is crucial to be able to run diagnostic tests without delay (Wakhusama *et al.* 2011). There is therefore need for the following measures; i) upgrade laboratory equipment where needed; ii) train laboratory staff in conducting

competitive and immuno-capture ELISA (and PPR PCR if equipment and reagents are available) as soon as possible and before the first clinical case is confirmed. The Central Veterinary and Research Institute (CVRI) should be implement competitive and immuno-capture ELISA as part of their routine tests.

Zambia needs to develop an emergency preparedness plan which clearly spells out what actions must be taken in the event of a PPR outbreak. The outline of the contingency plan must include surveillance, risk factors, and stakeholder identification and analysis and action plans (SADC, 2012b). It is recommended that PPR must be endorsed as a notifiable disease in all countries either by being mentioned as such or in reference to the OIE list. This is a prerequisite to ensure that funds will be released by governments in the event of an outbreak. Policies should be backed up by appropriate legislation to cover the actions of the veterinary authorities in the execution of their duties in the event of an outbreak (SADC, 2012b). Governments must also have a clear policy on compensation in the event of a stamp out exercised where some animals may need to be destroyed. For such a policy to be a useful tool in disease control, it should be clear, unambiguous and easy to fast track payments to the affected farmers (SADC, 2012b).

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7.0 APPENDICES

Appendix I: Questionnaire



**THE UNIVERSITY OF ZAMBIA
SCHOOL OF VETERINARY MEDICINE
DEPARTMENT OF DISEASE CONTROL**

PPR Introduction into Northern Zambia via trade: A Quantitative Risk Assessment and Risk Mapping Study.

Confidentiality of information Supplied

Thank you for agreeing to participate in this study. I would like to assure you that all the information you will provide shall be treated as confidential and will only be used for the purpose of this study.

RESEARCHER: DR.RICKY CHAZYA

COMPUTER #: 531002005

SUPERVISOR: DR.BWALYA MUMA

CO-SUPERVISORS: DR.MARTIN SIMUUNZA, PROF. ESRON KARIMURIBU

PART 1

Name of the Interviewer: -----
Province: -----
District: -----
Veterinary Camp: -----
Village/Farm: -----
Geographical Coordinates
Latitude: -----
Longitude: -----
Name of Respondent: -----
Date of Interview: -----

PART 2: SOCIAL DEMOGRAPHIC INFORMATION OF INFORMANTS

Thank you for agreeing to participate in this study. I would like to assure you that all the information you will provide shall be treated as confidential and will only be used for the purpose of this study.

1. Respondent ID -----Village-----

1. Sex of respondent Male Female

2. Age of respondent (if less than 18 years old end the interview and thank the respondent for his or her time) -----years

3. What is your main source of livelihood? -----

Kindly respond to the questions in the appropriate section

Section A- Farmers and Livestock Traders

1. Do you own any livestock? YES NO

2. What type of livestock do you own? (tick)

Cattle Sheep Goats Pigs Poultry Others.....

3. Quantify your livestock

Cattle.....Sheep.....Goats.....Pigs.....Poultry.....Others.....

4. Where do you usually get your livestock for breeding/sale? -----

5. How many goats and sheep have you bought in the last 1 year and from where? -----

6. Do you buy any animals from the neighboring Tanzania? Yes No

7. Do you get any Veterinary clearance before you move your livestock? Yes No

8. Which route is most convenient for the movement of your Goats and Sheep? -----

9. Are you aware of any other farmers/traders who buy Goats & Sheep from the neighboring country?

10. If yes, what could be your estimate of the number of farmers that brought in goats in the last 1 year? -----

11. What could be your estimate of the number of goats brought it by the farmers? -----

12. Does your livelihood depend primarily on livestock? -----

13. Do you supply goats to any well established market for live goats? Yes No

14. If yes to (13), are you aware of goats bought from this market being taken to farms for breeding? Yes No

15. Are you aware of any risks associated with buying goats and sheep from Tanzania? (Please specify)

16. Do the animals bought from Tanzania end up mixing with the other farm animals? If yes, how?

17. Did any of the animals you bought from Tanzania fall sick in the last 1 year? Yes No

18. Did you report the sick animals to the Veterinary department? Yes No

19. If your answer to 13 is Yes, what signs did you notice?-----

20. Do you move animals from one area to another area in any part of the year in search of pasture or better markets? Yes No

21. If yes in (16) are you aware of any livestock regulations related to animal movements?
Yes No

22. Do you have any question for me? -----

Section B- Veterinary Staff

1. Respondent ID-----District/Camp-----

2. How long have you worked in the Veterinary field?

1-5

5-10

10-15

>15

3. Are you aware of goat and sheep movements between Zambia and Tanzania? Yes No

4. If Yes in (3), what is the direction of the movements? -----

5. Have the movements been accompanied by stock movement permits? Yes No

6. If yes in (5), what are the statistics in the last 1 year? -----

7. If no in (5), can you estimate the number of these movements in the last 1 year? -----

8. What do you think could be the reasons driving these cross-border movements?

9. Are you aware of the routes used by farmers/traders to move these livestock? Yes No

10. If yes in (9), give details-----

11. Have you ever heard of the disease Peste des petits ruminants (PPR)? Yes No

12. Are you aware of its presence in Tanzania? Yes No

13. Are you familiar with the clinical manifestation of the disease to the extent that you can diagnose it in case of an outbreak? Yes No

14. If yes in (13), what are some of the clinical signs of the disease? Please specify-----

15. What is the goat and sheep population in your catchment area? -----

16. What are the common diseases affecting goats and sheep in your area? -----

17. How do you handle reports of goat/sheep diseases? -----

18. Do you have the capacity to conduct PPR surveillance in your area? Yes No

19. What things do you think would help to improve on your surveillance system?

20. Do you have any question for me? -----

Section C- Border Staff

1. Respondent ID-----Border-----

Occupation-----

2. How long have you worked at the border?

1-5

5-10

10-15

>15

3. Are you aware of any movements of goats and sheep across the border? Yes No

4. What is the direction of the movements? -----

5. Are the movements accompanied by stock movement permits? Yes No

6. What could be the volume of goat movements into Zambia in the last 1 year? -----

7. Are you aware of movements of goats by truckers? Yes No

8. What could be an estimate of the number of goats moved by truckers on a daily basis in to

Zambia? -----

9. Are you aware of any other way in which goats are moved across the borders? Yes No

10. If yes in (9), give details-----

11. In your own opinion, what could be the factors driving the cross border movements of the goats and sheep?-----

12. Are you aware of any physical inspections on the goats carried out by the Veterinary

department before goats are allowed into the country? Yes No

13. Do you have any question for me? -----

END OF QUESTIONNAIRE, THANK YOU FOR YOUR COOPERATION

Appendix II (a): Veterinary camps bordering Tanzania and their geographic location

Veterinary camps bordering Tanzania and their geographic location				
SN	District	Camp	Latitude (Eastings)	Longitude (Northings)
1	Mbala	Mbala C.	318683	9044162
3	Mbala	Kawimbe	337960	9024153
4	Mbala	Kaka	353406	9003813
5	Mbala	Mwamba	349418	9013866
6	Mpulungu	Mpulungu C.	293906	9029441
8	Nakonde	Ilola	449020	8966196
9	Nakonde	Nakonde C.	430646	8985743
10	Nakonde	Mwenzu	40.55	20.695
11	Nakonde	Nteko	439461	8973326

Coordinate System: Geographic, datum D_WGS_1984, Spheroid WGS 1984

Appendix II (b): GPS coordinates for trade routes

SN	District	Name of route	L1		L2		L3		L4		L5		L6		L7	
			Lattitude	Longitude												
1	Mbala	Kaseshya road	334067	9039669	328224	9035734	331853	9038344								
2	Mbala	Mutula road	345531	9027926	345127	9027519	344033	9027009	341857	9026594						
3	Mbala	Musangano-lobo-kaka road	359657	9010189	358692	9013571	350800	9014975	345477	9018787						
4	Mpulungu	Kaseshya-chipoma-kati-muswilo-isoko-mpulungu road	334067	9039669	302950	9025824	305476	9027161	306386	9028694	311004	9027426	3132297	9028425		
5	Nakonde	Tewele-kapwila road	444138	8970810	444756	8972611	444823	8973127	444880	8975418	446136	8979714	446136	8979716	442519	8989094
6	Nakonde	Mikulya-chozi road	441448	8990999	437397	8990679	435587	8984748	434471	8980205	434500	8976110				