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A RETROSPECTIVE ANALYSIS OF THE EPIDEMIOLOGY AND CONTROL MEASURES OF CONTAGIOUS BOVINE PLEUROPNEUMONIA IN THE NORTHEN COMMUNAL AREAS OF NAMIBIA FROM 2001 TO 2013

BY

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A dissertation submitted to the Department of Veterinary Tropical Diseases,

Faculty of Veterinary Science

University of Pretoria

In partial fulfilment of the requirements for the degree of

MSc (Animal/Human/Ecosystem Health)

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Declaration

I, *Pricilla Mbiri,* do hereby declare that for this retrospective analysis of the epidemiology and control measures of contagious bovine pleuropneumonia in the NCA of Namibia from 2001 to 2013 all the data that was used was obtained from the epidemiology section of the directorate of veterinary services in Namibia. The permission to make use of this data was granted to me by the director of veterinary services of Namibia Dr A.F Maseke.

Except where acknowledgements indicate otherwise and the normal advice from my supervisors, this dissertation is my own original work. Neither the full dissertation nor any part of it has been, is being, or is to be submitted for another degree at this or any other University.

This dissertation is presented in partial fulfilment of the requirements for the degree of Master of Science (Animal/Human/Ecosystem Health) in the Department of Veterinary Tropical Diseases, University of Pretoria.

Signed……

Date…….

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Abbreviations

CCPP	Contagious Caprine Pleuropneumonia
CBPP	Contagious Bovine Pleuropneumonia
CVL	Central Veterinary Laboratory
DRF	Disease Report Form
DVS	Directorate of Veterinary Services
ELISA	Enzyme linked immunosorbent assay
FAO	Food and Agriculture Organization
GPS	Global Positioning System
IHC	Immunohisto chemistry
MmmSc	*Mycoplasma mycoides* subspecies *mycoides* "small colony"
NamLITS	Namibia Livestock Identification and Traceability System
NCA	Northern Communal Areas
OIE	World Organization for Animal Health
PCR	Polymerase Chain reaction
QGIS	Quantum Geographic Information Systems
SC	"small colony"
SSA	Sub-Saharan Africa
VCF	Veterinary Cordon Fence

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Summary

A RETROSPECTIVE ANALYSIS OF THE EPIDEMIOLOGY AND CONTROL MEASURES OF CONTAGIOUS BOVINE PLEUROPNEUMONIA IN THE NORTHEN COMMUNAL AREAS OF NAMIBIA FROM 2001 TO 2013

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Department: Veterinary Tropical Diseases

Degree: MSc (Animal/Human/Ecosystem Health)

Contagious bovine pleuropneumonia (CBPP) caused by *Mycoplasma mycoides* subspecies *mycoides* (small colony) is an insidious pneumonic disease of cattle and poses a challenge to cattle production in sub-Saharan Africa. It is transmitted by direct contact and can manifest as peracute, acute or chronic disease. It has been described as one of the trans-boundary animal diseases of cattle known to pose trade barriers throughout many countries in Africa (Jores *et al*., 2013).

This study describes the occurrence of CBPP in the northern communal areas (NCA) of Namibia from 2001 to 2013. All the data was collected from annual reports at the epidemiology section of the Division of Veterinary Services. The annual reports captured all outbreak foci together with their GPS coordinates and this facilitated the analysis of temporal and spatial occurrence of the disease. The suspected cases that were not confirmed at the laboratory but had clinical manifestation typical of CBPP were also recorded.

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A total of 70 outbreaks were recorded from 2001 to 2013. The highest number of outbreaks was recorded in 2005 with 11 laboratory confirmed outbreaks. Zambezi and Kunene North regions were the most affected. From 2002 to 2004, six outbreaks were recorded for each year and in 2006 eight outbreaks were reported. It's important to note that from 2007 up to 2012; isolated outbreaks with less than five laboratory confirmed cases were recorded.

Measures of risk including incidence and mortality rates, as well as vaccination coverage of the population at risk were calculated and described per year for each of the different regions in the NCA.

CBPP is confined to the NCA especially in regions that share open border with Angola and Zambia. Zambezi, Oshikoto, Ohangwena, Omusati, Kunene and Kavango are the hot spots of CBPP in the NCA. Despite good vaccination coverage, outbreaks still occurred hence the disease cannot be eradicated with annual vaccinations alone. Other factors such as the open border between Namibia and Angola that facilitates free movement of animals between the two countries have to be addressed first.

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Chapter 1

Literature Review

1.1. Background

Contagious bovine pleuropneumonia (CBPP) has been described by Amanfu (2009), as an 'insidious pneumonic disease of cattle commonly called lung sickness". It is a big challenge in cattle production and is known to be transmitted by direct contact between infected animals and susceptible cattle (Turner, 1959; Masiga *et al.*, 1996; Schneider *et al.*, 1994). The pathogen can stay for as long as 40 days in the nasal cavities of infected animals before they become serologically positive.

CBPP is found in Africa and the Middle East and it also been reported in some parts of Asia and in the Iberian Peninsula of southern Europe (Figure 1-1).

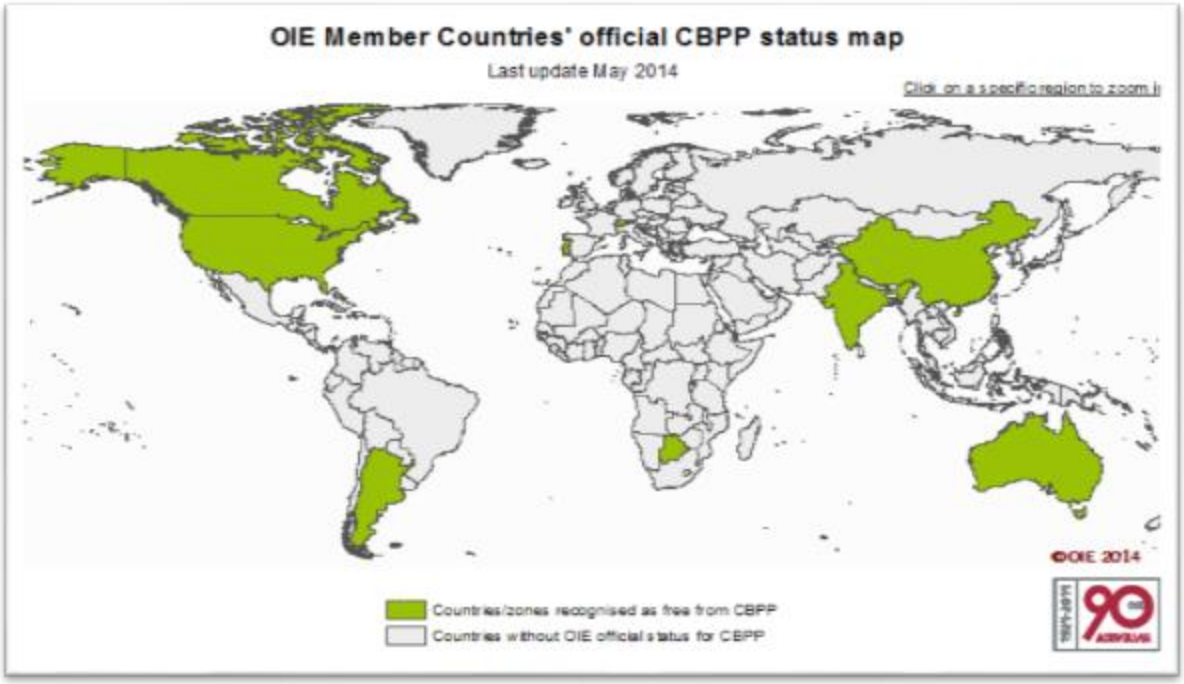

Figure 1-1 OIE Member countries official CBPP status. (http://www.oie.int/en/animal-health-in-the-world/official-disease-status/cbpp/en-cbpp-carte/)

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In Africa CBPP is known to be endemic in the western, central and eastern Africa, and in Angola and northern Namibia. (FAO, 2002). It is the mandate of the Directorate of Veterinary Services in Namibia to conduct annual vaccination campaigns in the NCA of Namibia to control the disease. There have been isolated cases of CBPP that have been reported, therefore knowing the incidence will assist to assess the effectiveness of the control measures.

Having a clear picture of the occurrence of CBPP, that is having knowledge on the temporal and spatial distribution of the disease in Namibia can give a picture of whether the disease is limited to a specific area or if it is spreading to new areas previously unaffected. This can aid in developing a more efficient disease preparedness program and control measures and also aid in exploring the feasibility of eradication.

Information gathered from this study can also be used as a reference to gain political will in implementing policies that will aid in the prevention, control or even eradication of the disease

1.2. Disease Definition

Contagious bovine pleuropneumonia can be described as an acute, subacute or chronic disease affecting cattle and occasionally water buffalo (Penrith, 2014). The causative agent is *Mycoplasma mycoides* subspecies *mycoides "*small colony" (MmmSC). Several pathological changes may result in the lungs and other parts of the respiratory tract causing high mortality and morbidity (Windsor and Wood, 1998). The most common forms of the disease are the subacute and chronic forms and usually cause subclinical infections responsible for continuing spread of the disease (Provost *et al*., 1987). Cattle with acute to subacute disease develop serofibrinous pleuropneumonia and severe pleural effusion. In animals that develop the chronic form of the disease or recover from acute disease persistent pulmonary sequestra occur but their ability to transmit the disease is uncertain (Thiacourt *et al* 2004).

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1.3. History of Contagious Bovine Pleura Pneumonia

Until the 16th century, CBPP was a European disease that spread to the west and south of the continent as a result of cattle movements due to wars and importations. The disease also reached the United States of America (USA) and Canada in the second half of the 19th century.

Due to the importation of cattle from England in 1858, Australia was affected by CBPP and the disease spread to Asia in the 20th century. Europe managed to eradicate the disease by the end of the 19th century through enforcing measures such as movement control and stamping out via slaughtering of the affected cattle (Provost *et al.*, 1987), except in Germany and Austria which had CBPP in the 1910s and 1920s. In 1973, Australia eradicated the disease through massive CBPP campaign for more than 10 years.

CBPP has been described as one of the biggest challenges in cattle rearing and trade in the world and affects the economy in sub-Saharan Africa. The importation of cattle from Netherland introduced CBPP into South Africa in 1854 and from there it spread to other countries in the region (Provost *et al.*, 1987).

It has been reported from 29 countries in west, central, east and southern Africa in the period 2005 to 2014. This is an increase from the 27 countries that reported it between 1995 and 2001 (Thiacourt *et al* 2004). The southernmost countries currently affected are Angola, northern Namibia, western Zambia, DRC and Tanzania. The presence of CBPP is a constraint for economic and rural development and most countries lack the necessary resources to achieve control and eradication (Thiacourt *et al* 2004).

CBPP has been present in East Africa before the colonial era and its introduction into South Africa is believed to have resulted from a Friesland bull or bulls from the Netherlands that landed at Mossel Bay now the Western Cape Province in 1853 (Thiacourt *et al* 2004). From the Western Cape Province the disease was spread by trek oxen along transport routes throughout the country, soon reaching the Northern provinces where it is said to have killed more than 100 000 head of cattle. CBPP was already endemic in southern Africa in 1896 to 1897 when rinderpest appeared (Thiacourt *et al*, 2004).

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CBPP spread into Namibia around 1856 when a localized outbreak occurred at Warmbad in the south (Thiacourt *et al,* 2004). Quarantine measures were adopted by missionaries in the area and they successfully managed to contain the outbreak but in 1859, there were cattle introductions from either South Africa or Botswana which resulted in the infection reaching the central cattle-raising districts (Thiacourt *et al,* 2004). These outbreaks (in Namibia) caused very high mortalities and the Herero people referred to 1860 as 'otjipunga', the year of the lung. Around 1861, the disease crossed the borders across Limpopo River resulting in severe losses of cattle in the southern parts of Zimbabwe around Matebele land (Thiacourt *et al,* 2004).

CBPP was confirmed in Angola in 1888 (Thiacourt *et al,* 2004) and it is believed to have been introduced by infected cattle that came from South Africa in the early 1880s (Thiacourt *et al,* 2004). By the year 1914 CBPP had spread throughout the whole country probably as a result of extensive use of draught oxen. The disease also was introduced into Zambia from Angola and they managed to eradicate it in 1946. CBPP was again introduced in 1969 causing high mortalities and morbidity in affected herds (Thiacourt *et al,* 2004). After being eradicated in 1978 CBPP was reintroduced in 1997, again from Angola, and continued to be reported regularly from the Western Province (Thiacourt *et al,* 2004). In Zambia, CBPP is mostly present in the Western Province and the CBPP infected cattle from Angola which always come into the country cause outbreaks in this area. The disease is present in most parts of the country going southwards to Sesheke (Amanfu 2009).

Tanzania became infected in 1961 and eradicated CBPP in 1964 but it was reintroduced again in 1990 (Thiacourt *et al,* 2004). In countries such as Burundi, Rwanda, Kenya and Tanzania, the control measures for CBPP were not that effective and hence the disease is endemic in some parts of East and Central Africa and is a risk to Malawi, Mozambique and northern Zambia (Amanfu 2009).

The outbreak of rinderpest overshadowed the effects of CBPP and killed many cattle that were infected with CBPP. It was only at the turn of the century that the persistence of CBPP in southern African cattle populations again became evident, and strict control measures were introduced in most countries of the region (Thiacourt *et al,* 2004). These were, however, hampered by other events that

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occurred about that time, such as the South African War, the introduction of East Coast fever, the Herero War and the 1918 human influenza pandemic (Thiacourt *et al*, 2004). In Zimbabwe, CBPP was eradicated in 1904 and South Africa managed to eliminate the disease in 9124 and Botswana in 1939. However, Angola and the adjacent part of Namibia remained infected. Botswana was re-infected in 1995 from Namibia, and the disease was eradicated by 1997 by stamping out, with compensation, of all the cattle in the northern infected area (Thiacourt *et al*, 2004).

Angola, Democratic Republic of Congo, Namibia, Tanzania and Zambia all reported CBPP to the OIE for most years from 2005 to 2013 (Penrith, 2014). In Namibia the high risk areas are the districts north of the veterinary cordon fence that separates the southern, foot and mouth disease (FMD) free zone from the NCA; the Kunene and Kavango regions that share borders with Angola are particularly at risk (Thiacourt *et al*, 2004). The Zambezi region to the east of them experienced no CBPP outbreaks after 1939 until an outbreak occurred there in 2003, in spite of regular vaccination campaigns since 1997 that combine CBPP and FMD vaccination (Thiacourt *et al*, 2004). By 2005 a survey showed that 15 herds were infected in spite of continued vaccination. The outbreak was finally eradicated after treatment of clinically affected and in-contact cattle with an effective antimicrobial was added to the control strategy (Thiacourt *et al*, 2004).

1.4. Aetiology

The bovine biotype of *Mycoplasma mycoides* subsp. *mycoides* "small colony" (MmmSC) which is a member of the family *Mycoplasmataceae*. *M. mycoides* SC (bovine) is responsible for causing CBPP (The Center for Food security and Public Health, 2008). There are two major lineages with isolates from Europe and Africa (The Center for Food security and Public Health, 2008)

The virulence of the strains varies; there can be the hypervirulent and velogenic causing severe epidemics and the non-pathogenic, hypovirulent or lentogenic strains. It has been observed that the virulence gradually decrease as the epidemic progresses (Provost *et al*., 1987).

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The *M. mycoides* is not likely to thrive in the environment in African climates and the organism will survive for only for few a days outside the host in most tropical regions. It all depends on the medium in which the organism is suspended. At 40°C, the causative agent is inactivated within 240 min and within 60 min if suspended at 50°C. It is believed to take less than 2 minutes to be inactivated if suspended at 60°C. (Provost *et al*., 1987). Knowing these characteristics is of importance in Africa, especially for the preservation of vaccines.

1.5. Epidemiology

1.5.1 Source of contagion

M. mycoides can be isolated from the lung and the pleural fluid of an infected animal. Many other organs for example the brain, uterus and foetal membranes may be infected if the mycoplasmas enter the bloodstream at the beginning of the infection (Provost *et al*., 1987). In the acute form of the disease, the causative organism is mainly found in aerosols. The urine may be a source of infection if there are kidney lesions, and the foetal fluids can pose risk if the foetus is infected (Provost *et al*., 1987).

Sick animals virtually spread the infection and carrier animals including those that are subclinically infected may harbour the causative agent in their lung lesions (sequestra) for some several months to years. These animals are thought to be a source of infection and shed organisms, particularly when stressed. Some have argued that 'lungers' or chronic carriers play a role in the transmission of CBPP when they eventually break down and shed organisms into the environment (Provost *et al*., 1987). The aerosols from the coughing animals remain the main source of infection and the pathogen can be isolated in urine, nasal discharges and foetal fluids of sick animals. (Provost *et al*., 1987).

1.5.2 Methods of transmission

In most cases, CBPP is transmitted through the inhalation of infected droplets from coughing animals the acute cases, subacute forms and chronic carriers. The animals have to be close to each other with repeated direct contacts between infected and susceptible cattle (Lesnoff *et al*., 2004a). There have been reports of transmission of infective Flugge-type droplets over distances such as 50 m to 200 m,

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carried by the wind. Since the causative agent does not persist for long in the environment, the role of fomites is negligible in the transmission of CBPP (OIE, 2008).

There are risk factors that facilitate the spread of the disease and these include keeping many livestock in confinement in night housings and communal grazing where livestock share watering points and grasslands (Provost *et al*., 1987). From one country to another, cattle movement for trading and social activities is responsible for the spread of the contagion (Roeder and Rweyemamu, 1995).

1.5.3 Hosts

Under the natural conditions prevailing in Africa, CBPP affects mainly cattle, both *Bos taurus* (European) and *Bos indicus* (zebu) types (The Centre for Food Security and Public Health, 2015).

Infections can also occur in the domestic Asian water buffalo (*Bubalus bubalis*), captive bison (*Bison bison*) and yak (*Poephagus grunnien*, formerly *Bos grunnien*) but the wild bovids such as the African wild buffalo (*Syncerus caffer*) and camels seem to be resistant and not affected by CBPP (Povasta *et al*., 1970) and hence do not play an important role in the transmission of the disease (Provost *et al*., 1987). A case was described of a Willems's phenomenon in a roan antelope (*Hippotragus equinus*) and serological responses may occur in other animal species, such as the gnu (*Gorgon taurinus*) (Povasta *et al*., 1970). Even though M. *mycoides* can be isolated from small stock such as sheep and goats, (Brandau, 1995; Lefevre *et al*., 1987; Leforban *et al*., 1993) their role in the transmission of CBPP has not been established. Humans are not susceptible to *Mycoplasma mycoides SC.* (The Centre for Food Security and Public Health, 2008).

1.5.4 Host Susceptibility

Species play a role in determining the susceptibility and species such as cattle and buffalo are affected under natural conditions. In the environmental conditions prevailing here in Africa, taurine cattle are more prone to CBPP than *Bos indicus* and some of the breeds that are resistant include the small zebu breed from Côte d'Ivoire and the Masai breed of Tanzania. N'Dama cattle of Guinea and imported cattle from Europe are more susceptible to the disease than the zebu (Provost *et al*., 1987).

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Old cattle develop more serious lesions compared to young ones. Adult cows tend to develop pulmonary lesions and calves develop joint lesions (Masiga *et al.*, 1978). It has been noted that vaccine reactions show a comparable severity on different individuals, group and breed hence before the vaccine can be used, it must be tested to avoid such incidences. There are breeds that have proven to be more susceptible to the vaccines and easily develop post-vaccinal reactions. Such breeds are the N'Dama cattle from Guinea or Côte (Provost *et al*., 1987) that have displayed vaccine reactions with the T1/44 strain. Dairy breeds have shown to be more susceptible than beef breeds as demonstrated by Hudson (Hudson *et al*., 1971; Masiga *et al*., 1978).

Old cattle develop more serious lesions compared to young ones. Adult cows tend to develop pulmonary lesions and calves develop joint lesions (Masiga *et al.*, 1978). The immune status of an animal determines its susceptibility to CBPP and recovered animals are resistant to further challenge (Windsor *et al*., 1977).

1.5.5 Predisposing factors

Uncontrolled movement of cattle is one of the most important risk factors that contributes to the spread of CBPP from one herd, region or country to another and its role in the epidemiology of the disease cannot be ignored (Domenech, 1988; Masiga *et al.*, 1995). In parts of Africa where there are dry climatic conditions, nomadism and transhumant pastoral practices are common making it very difficult not only to control livestock movements (Roeder and Rweyemamu, 1995), but also to conduct disease surveillance because the farmers and their animals move from one place to another in remote areas with few roads and no means of modern communication (de Leeuw et al., 1995; Catley, 2006). A lot of commitment is required both from the pastoralists and the government and pastoralists play a role when it comes to disease reporting and surveillance (Thrusfield, 2009).

Countries like Namibia, Zambia and Botswana where there is no nomadism, have managed to control cattle movement by setting up cordon fences separating the infected and CBPP-free zones in the country. Uncontrolled movement of trade of cattle by trekking remains one important risk factor for the

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spread of CBPP and favourable conditions for transmission of CBPP are created when animals mix at auction points, at common points drinking water and in the kraal when they are housed together.

CBPP outbreaks are precipitated when animals are moved, or new stock is introduced in an infected herd or within a susceptible cattle population. Cattle that are kept in the communal set up are continuously at risk of CBPP because different herds tend to mix during grazing and at common watering points, and during different socio-cultural practices (FAO, 2000; Mariner *et al*., 2006).

Human communities that live along the Namibia-Angola border and livestock move freely across the border in both directions. Immediate families stay across the border. Namibian livestock move to Angola and back in a transhumant pattern in search of grazing, while Angolan livestock are taken to water in Namibia. Animals are traded, given, lent and stolen across the border. Local cross-border movement is accepted by both countries; for those who choose to cross at official border points, a document known as a "border pass" is available to people who have no other travel documents and plan to remain within 30km of the border. There is a well-established customary movement across the border which is accepted by governments on both sides (GRN 2005).

The political situation of a country plays a role in the epidemiology of CBPP. There is a lot of unexpected movements of cattle which poses a risk of spreading the disease from one country to another when there are civil wars and political unrest. In many parts of Africa it is difficult to control cattle movements and up to now countries like Namibia still sit with a challenge when it comes to CBPP control and eradication because of the porous border that exist between Namibia and Angola (Provost *et al*., 1987).

Climate is another determinant that affects the spread of CBPP. It is known that infected aerosols can be inactivated by ultraviolet light and hence many outbreaks are experience more in humid conditions than in dry climates (Provost *et al*., 1987). Climate affects farming practices and as a result tends to play a role in the epidemiology of the disease.

Therefore, the epidemiology of CBPP in Africa has four factors that play a role:

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- The political situation of a country is also a predisposing factor
- Climate plays a role in the spread of CBPP
- Sick animals are the main source of infection and requires close contact between infected and uninfected cattle
- Uncontrolled movement of cattle remains a top risk factor for the spread and maintenance of CBPP.

1.6. Pathogenesis

There is need of further research to establish the pathogenesis of CBPP. It is believed that after infection with *M. mycoides*, conditions such as causes bronchiolitis and pneumonia set in and the causative agent attaches to the cell surface and mucosal secretions cannot the remove the organism. The lung lesions that occur in CBPP are as a result of hypersensitivity and auto-immune reactions .An acute lobar pneumonia is a common feature of this disease together with pleurisy developing after initial septicaemia. The development of thrombosis in the pulmonary vessels coupled with perivascular organisation and then necrosis are pathognomonic vascular lesions of CBPP resulting in death from anoxia and/or toxaemia (Martel *et al*., 1985).

1.7. Clinical Signs

CBPP is a respiratory disease that causes acute, subacute symptoms that usually progress to a chronic stage, death and or recovery. It is characterised by pneumonia and sero fibrinous pleurisy (Thiaucourt et al., 2004). In an outbreak situation it is important to do a thorough herd examination rather than in a single animal since it might be misleading to make a diagnosis of CBPP in a single animal.

1.7.1 Hyper acute form

CBPP infection may progress rapidly without pre monitory signs. The hyper acute form occurs at the initial stages of an outbreak and may result in high mortalities. In some cases an animal may die

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without any pre monitory signs after one to three days as a result of asphyxia, toxaemia or heart failure (Masiga *et al*., 1996)

1.7.2 Acute form

The acute form is common especially in the initial stages of an outbreak. In this acute phase, the infected animal presents with fever, unwillingness to eat and respiratory signs such as rapid painful breathing and irregular dry coughing. The mortality rate can reach up to 60% or higher in susceptible populations (Huebschle *et al*., 2006).

During post mortem, plenty of pleural fluid is usually found (Weldearegay *et al*. 2015). Animals present with a stiff posture and unwillingness to move. Affected animals stand with a characteristic posture extending their heads and dilated nostrils to improve in the breathing. The mouth sometimes stays open if the disease is severe with some foam on the mouth. If subjected to stress and exercises, the respiratory distress will be aggravated. Cows show a drop in milk yield and cessation of rumination is a common finding in affected cattle. In the acute stage of the disease, infected cattle may recover, become chronically infected, or die (Masiga *et al*., 1996).

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Figure 1-2 Animal showing respiratory due to acute CBPP. (http://www.fao.org/docrep/004/ac147e/ac147e00.htm)

In the acute stage, auscultation reveals pleuritic friction sounds with moist gurgling rales in the later stages. Consolidation of the lung may result in areas of silence and pleural effusion can be picked up during auscultation. Conditions such as arthritis, pericarditis, peritonitis and abortion are a common sequel to the infection (Masiga *et al*., 1996).

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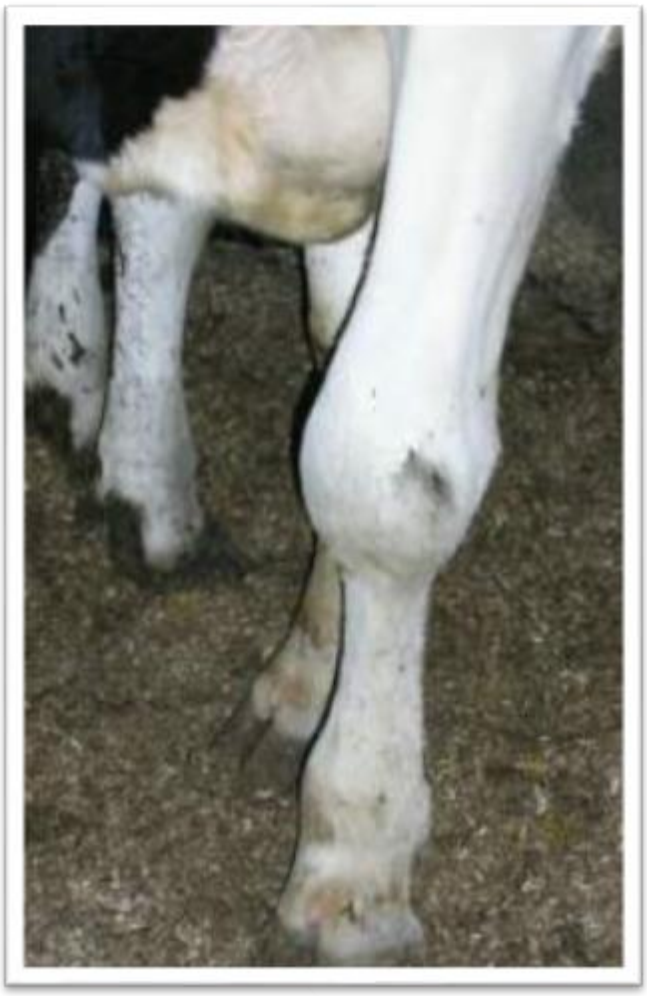

Figure 1-3 Complications such as arthritis are often seen as a sequele to CBPP

1.7.3 Subacute and symptomless forms

The subacute and subclinical infections are very common and may present just like the hyper acute form with little or no pre monitory signs. Animals at this stage are able to transmit the infection. (Masiga *et al*., 1996)

1.7.4 Chronic form

Animals that progress to this form may exhibit signs that are not typical, with mild respiratory signs that become evident when the animal is in distress due to exercise. Animals also present with intermittent low grade fever, loss of body condition and prolonged cough with lung lesions that may

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take time to heal. The chronic form of the disease is common towards the end of an epidemic (Masiga *et al*., 1996).

1.7.5 Courses of the various forms of the disease

Most of the animals that present with hyper acute form of CBPP usually die and those that thrive develop acute lesions. Mortality rate can reach up to 60% or higher in susceptible populations in the acute form (Huebschle *et al*., 2006). Many infected animals may progress into the chronic form but it is not known if they recover completely creating chronic lungers with lesions that become encapsulated.

Acute and chronic cases may recover from the disease with the formation of scar or normal tissue. (Masiga *et al*., 1996). The chronic carriers are suspected to be responsible for generating and maintaining infections in Africa (Curasson, 1942; Mahoney, 1954; Martel *et al*., 1985; Provost *et al*., 1987; Dedieu *et al*., 1996; Egwu *et al*., 1996). However it still remains debatable; Windsor and Masiga (1977) failed to observe CBPP transmission after mixing healthy animals with lungers. Hence these chronic carriers play might only an occasional role in the epidemiology of CBPP.

1.7.6 Willems's reaction

The name Willems's reaction comes from the veterinarian Belgian who first described the reaction. The reaction occurs in subcutaneous connective tissue due to local inoculation of virulent strains of *M. mycoides* or of some vaccine strains with residual pathogenicity, such as the T2 or V5 strains, or even the T1/44 strain (Figure 1-4). The painful reaction that occurs does not cause typical CBPP except the oedema that develops around the area of inoculation seven to ten days post. About 1% of the zebu cattle that were vaccinated in East Africa during the early vaccination campaigns developed reactions and subcutaneous inoculation behind the shoulder produced reactions in 3 to 4% of zebu cattle. These reactions are more common and severe in some breeds such as the Bos *taurus* than in *Bos indicus*. Treatment with antibiotics has proven helpful in curing the lesions. (Masiga *et al*., 1996)

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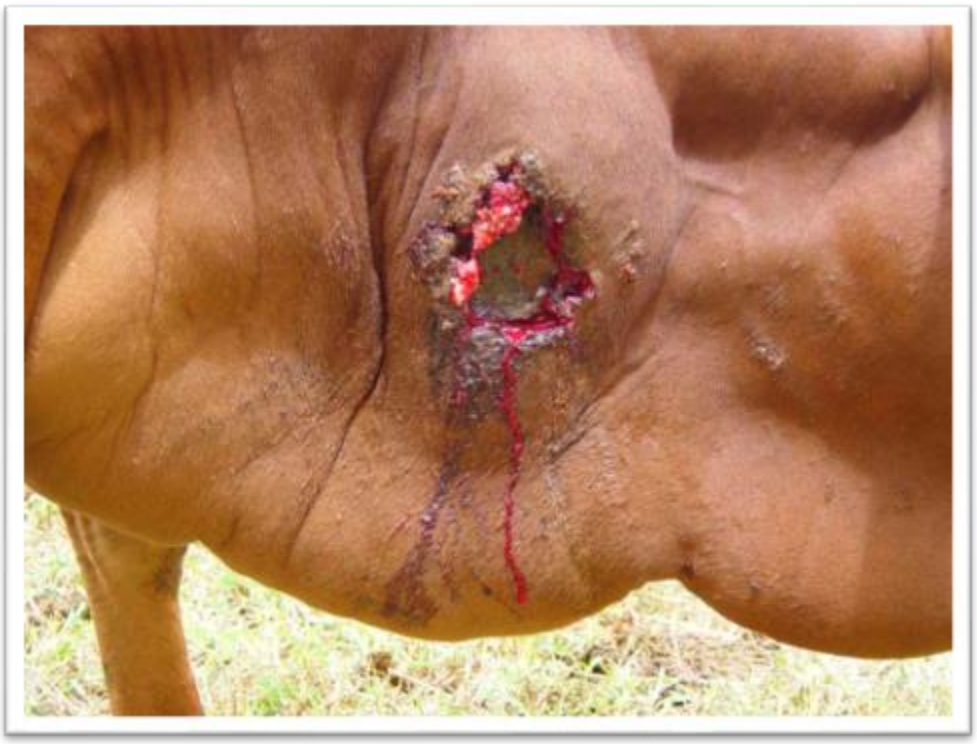

Figure 1-4 Animal with Willem's reaction on the shoulder. The reaction occurs in subcutaneous connective tissue due to local inoculation of virulent strains of M. mycoides or of some vaccine strains with residual pathogenicity.

1.8. Pathology

1.8.1 Gross pathology

An affected animals presents with fibrinous, lobar and lobular pneumonia that usually undergoes acute progression, and pleural exudation. Typically, CBPP has four stages. In the first stage, congestion takes place within the first 24 hours post infection and the lung looks very hyperaemic. In the second stage of red hepatisation or consolidation, the alveoli fills with exudate giving rise to the gross appearance of solidification, or consolidation, of the alveolar parenchyma (Caswell *et al*,. 2007). In this early acute phase of the disease, necrosis of the lung parenchyma is observed surrounded by a fibrous capsule and mycoplasmas can be isolated from the lesions in animals that recover from the disease (Masiga *et. al.*, 1996).

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In the third stage of grey hepatisation the alveoli looks paler in colour and drier on the cut surface (Fischer *et al*,. 2015). The lung tends to stick or adhere to the costal wall because of the yellow fibrin with typical 'omelette' look (Masiga, 1996).

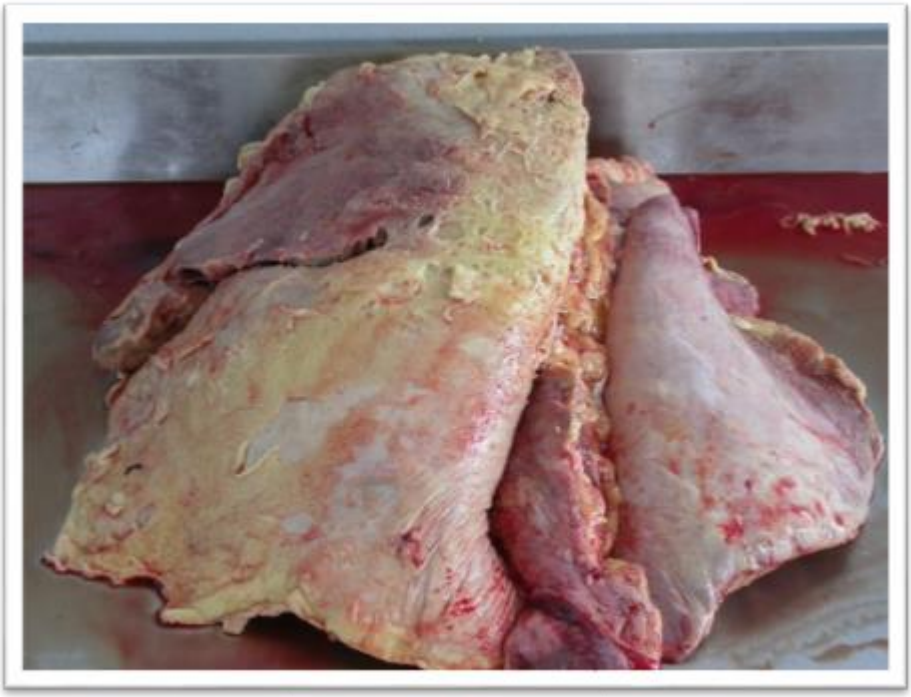

Figure 1-5 Lung froma an animal with advanced CBPP. The lung adheres to the costal wall, due to the presence of yellow fibrin up to 2-3 cm thick, with typical 'omelette' appearance.

There is complete pulmonary tissue recovery in the last stage of resolution. The first and second stage of congestion, red hepatisation describes ore acute pathological findings, whereas the third stage of grey hepatisation describes chronic pathological findings.

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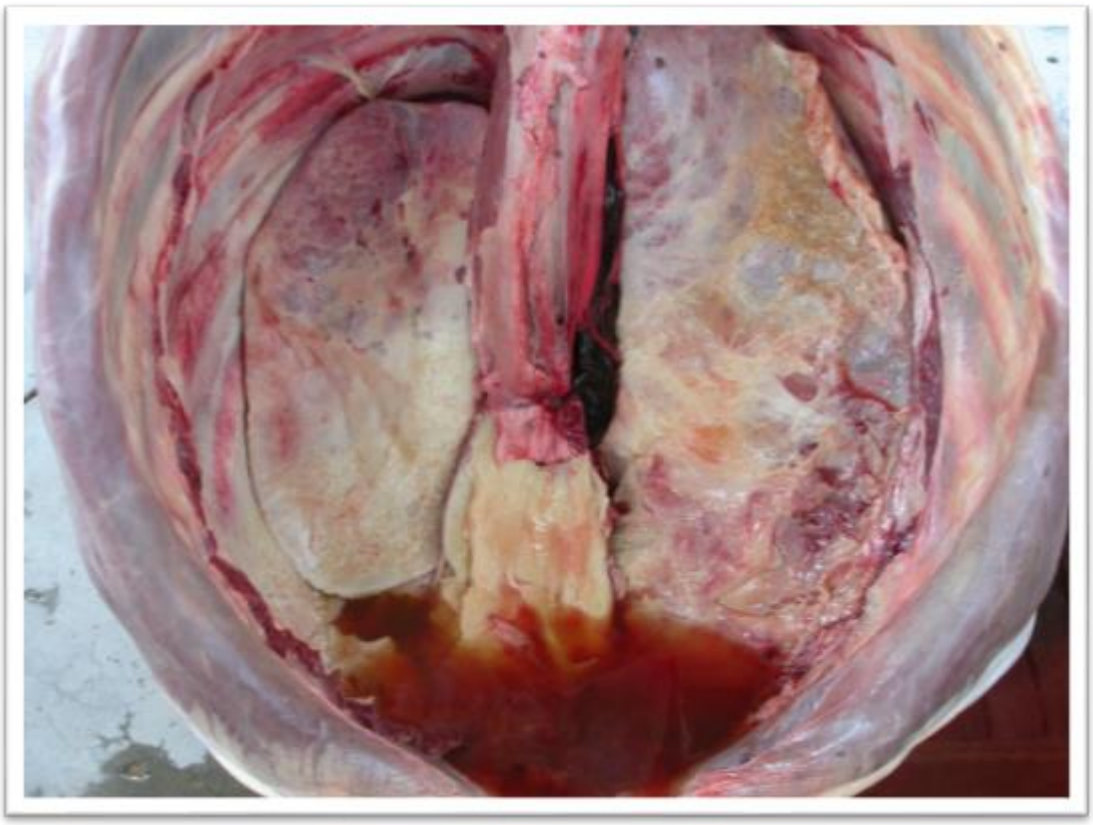

Figure 1-6 Thoracic cavity of an animal with CBPP indicating pleural exudate and adhesions.

Severe cases of CBPP may presents with infarcts in the kidneys (Masiga *et. al.*, 1996) and exudative pericarditis and peritonitis. Calves may be found with lesions in the carpal and tarsal joints and synovial membranes (Masiga *et. al.*, 1996).

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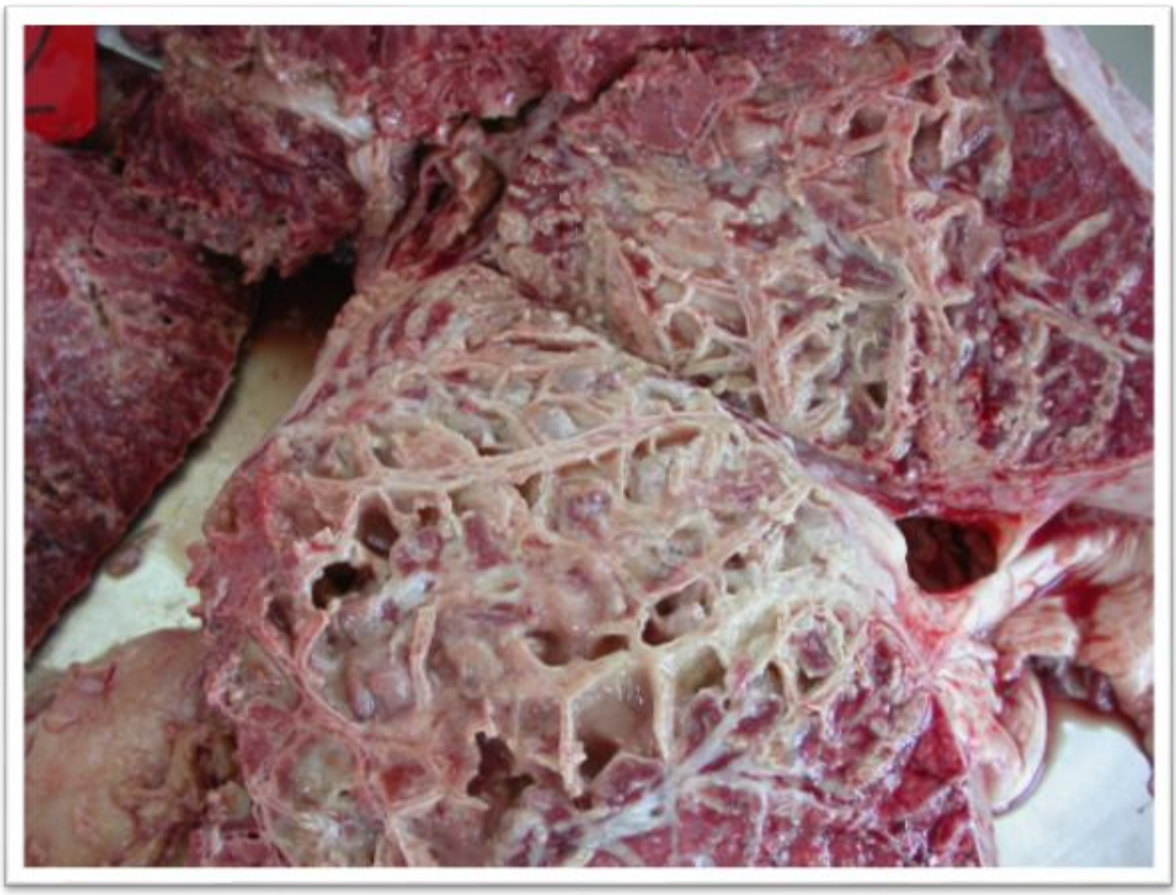

Figure 1-7 Marbled appearance of the lung with interlobular thickening

1.9. Diagnosis

Currently the techniques that are available for the diagnosis of CBPP demonstrate that there have been recent research and studies done on the molecular biology and immunology of CBPP and this will open up new ways for improved and effective ways of CBPP diagnosis (Amanfu, 2009).

There are several methods available for CBPP diagnosis and these include clinical signs, post mortem examination of lungs of affected animals that present with pathologic lesions. Other methods are isolation and identification of the causative agent which is fastidious and slow growing from the infected organs (Bashiruddin *et al*., 2005), immunoblotting, serology and the use of PCR techniques (Amanfu, 2009).

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1.9.1 Histology

Identifying typical or specific CBPP lesions is a vital tool in detecting sub-clinically infected cattle. "The so called "organising centres" in the interlobular septa of the affected lungs are pathognomonic for CBPP (Ferronha *et al*, 1990; Di Francesco *et al*, 1998).

1.9.2 Culture

1.9.2.1 Sample collection for culture

It should be noted that the proper authorities must be contacted before samples are collected and dispatched. Only authorised and accredited laboratories with secure conditions should be allowed to handle CBPP suspicious samples to prevent the spread of the disease (The Center for Food Security and Public Health, 2015).

The detection of *M. mycoides* SC in nasal swabs or secretions, bronchoalveolar washes or transtracheal wash fluid, pleural fluid and from blood, urine and synovial fluid from swollen joints in live animals can give a definitive diagnosis (The Center for Food Security and Public Health, 2015).

Samples such as pleural fluid can be collected at post mortem and affected organs such as lungs and lung-associated lymph nodes, and kidneys may be a good source of the contagion.

Secure and insulated containers are ideal for transporting tissue samples at temperatures between 0 and +4 °C and they should reach the laboratory within 48 hours of sampling. Samples could be kept frozen at –20 °C before dispatching but it should be noted that the causative agent may lose its viability. Swabs must be kept and sent to the laboratory within 48 hours in a suitable medium at temperatures between 0 and +4 °C. This is very important for the successful isolation of the causative agent especially in Africa where hot climatic conditions prevail.

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1.9.2.2 Isolation and transport media

Isolation and transport media for MmmSC are based on conventional growth media and inhibitors to stop the growth of cell-walled bacteria have been added. The concentrations of inhibitors such as ampicillin, 1.0 g/L; bacitracin, 0.2 g/L; penicillin G, 0.05 g/L; polymyxin B, 0.05 g/L; and thallium acetate 0.5 g/L., allow normal growth of MmmSC and may be mixed to produce a highly selective medium**.**

1.9.2.3 Growth media

MmmSC is easy to grow. It only requires special mycoplasma growth media and should be done in a secure, fully equipped and accredited bacteriological laboratory. A specifically formulated PRM medium (named after the developers) gives maximum growth rate and yield of SC strains .Apart from the normal glucose, pyruvate has been added as a supplementary energy source (Nicholas *et al*. (2000).

1.9.3 Immunohistochemistry

Immunohistochemistry (IHC) is important for CBPP diagnosis especially when the causative organism, MmmSC, cannot be recovered (e.g. following long transport distances), where an animal has died in the early stages of the outbreak and serology cannot be done or is giving inconclusive results (Ferronha *et al*., 1990; Scanziani *et al.*, 1997). Sensitivity of IHC using polyclonal serum has been reported to be low and non-specific results may be produced (Bashiruddin *et al.*, 1999). A monoclonal antibody, M92/20 was identified by Ayling *et al.*, (1998) and can be of use in IHC confirmation of suspected CBPP cases. With this antibody some cross reactivity with other mycoplasma from the "*M mycoides* cluster" has been demonstrated. Some affected lungs from Portuguese cattle were tested using IHC, PCR and culture. Out of the 11 lungs tested, IHC detected all 11 CBPP lungs whilst only 5 were picked up by PCR and 4 were detected by culture. Despite the sample size being small, IHC proved to be a very sensitive test for CBPP and hence should be regarded as the test of choice or the most preferable diagnostic test when there are highly suspicious carcasses of CBPP and the serum for serology and mycoplasma culture from lung is unreliable. For IHC samples can be collected from lung lymph nodes

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or lung tissue with suspected macroscopic lesions, fresh or already formalin fixed, and embedded in paraffin wax.

1.10. Prevention and Control

There are several methods available for effective control of CBPP and these are cattle movement control and quarantine, treatment and vaccination, test and slaughter and stamping out (Radostits *et al.*, 2000). With movement control alone, CBPP can be eradicated from a country (Newton and Norris, 2000), though it has proven very difficult and impractical to control due to factors such transhumance, trade, civil strife, socio-cultural practices, and shortage of veterinary personnel (Wanyoike, 1999; Windsor, 2000).

Many authorities believe that stamping out is one of the best ways to control and eradicate CBPP. The only drawback with stamping out is that it has some socio-economic implications (Le Gall, 2009). Hence it should be used as a last resort if outbreaks are to occur in the free or surveillance zones and if there are serious trade implications as a result of the outbreak. Stamping out could also be used to eradicate the disease when incidence is low and approaching zero (FAO, 1997).

Test- and -slaughter of animals can be an effective means of controlling CBPP if it is backed up with strict movement controls so that the disease cannot be reintroduced (Wanyoike *et al.*, 2004) but it is important to mention that it is difficult to carry out if there are no proper quarantine facilities (Scudamore, 1975). Disease investigation can start at slaughter houses and abattoirs during meat inspection and traced back to the place of origin where the herd is tested and decision made accordingly (Santini, 2008). This method may be an unpopular method of CBPP control and prevention especially in the absence of compensation (Thomson, 2005).

The use of antimicrobials to treat sick animals in an outbreak situation is not encouraged because it creates chronic carriers within the herd that will spread and maintain the infection (FAO, 1967) and emergence and persistence of resistant bacterial burden in the environment (Amanfu, 2007). However other researchers believe that the use of antimicrobials reduces death cases (Huebschle *et al.*, 2006).

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More research still needs to be done to establish if the sequestra from chronic carriers will not break down and causes outbreaks (FAO, 2007) although Huebschle *et al*., (2006) and Nicholas *et al*. (2007) showed some doubt on an outbreak that was reported to have emanated from such sequestra. Therefore vaccination has been adopted by many to be the most practical though expensive method for CBPP control (Tulasne *et al*., 1996

The OIE has recommended the use of T1 vaccine strain for vaccination against CBPP. Many countries in Africa opt to control CBPP via annual mass vaccinations using this recommended vaccine that has been described to have limited efficacy, requiring repeated yearly vaccinations (Sacchini *et al*., 2012). It is known and has been accepted that the protection offered by the T1 vaccine decreases after 12 months (Wesonga and Thiaucourt, 2000) and may last for a period longer than 12 months or a year (Nkando *et al*., 2011). To achieve good protection and reach a herd immunity level of 80% and above for adequate CBPP control, it is important to conduct at least two vaccinations per year as the first vaccinations may only achieves to 67% protection rate three months post inoculation while revaccination at six months brings up the immunity level to 95.5% (Wesonga and Thiaucourt, 2000). Even though the vaccine is regarded as avirulent, there have been reports of post-vaccinal adverse reactions in some breeds (Teshale, 2005).

1.11. Socioeconomic impact of CBPP

It is true that the economic impact of CBPP is high where the disease is endemic. Losses are mostly due to deaths recorded during the outbreak, emaciation, loss of draught power and poor fertility and growth rate in general. Other impacts are as a result of constraints from movement restrictions, quarantine, forced vaccination campaigns and bans in trading (Masiga et. al., 1996).

It is very difficult to evaluate the losses due to CBPP in many African countries where the disease is endemic because of the lack of proper reporting and economic evaluation (AU, 2013). Available data on the impact of the disease is however, limited to incidence rather than the effects on livelihoods. While such data may not be readily available, empirical evidence indicates that the disease occurrence in many sub-Saharan (SSA) countries comprising about 433.9 million people of whom 10% entirely

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depend on livestock for livelihoods may be significant. In countries where some data has been gathered, losses due to CBPP have been estimated to be very high especially when the disease enters a CBPP-free zone or country where cattle are susceptible (AU, 2013). For example, losses due to the reintroduction of CBPP in Tanzania may have caused more than $11 million dollars of direct losses in 1990. The reintroduction of CBPP in Botswana in 1995 led to the loss of about 320,000 cattle at a cost of US$ 100 million through slaughter in eradicating the disease. (AU, 2013).

Considering the diversity of apparently important cattle diseases in Africa and the need for donors and governments to prioritise investments, it is not surprising that CBPP has received little attention in most countries where it exists because of the enormous costs involved in its control.

The majority of the agro-pastoral societies in Namibia have an average heard size of 35 and if there is an outbreak of CBPP, The mortality rate can reach to 50% and that can be a huge blow on the livelihoods of the people affected. Due to the fact that there is a high dependency on livestock in these societies combined by the fact that there have relatively small herds, small holder farmers are vulnerable to the effects of an outbreak of CBPP in northern Namibia. Since the disease outbreaks occur in these communal areas, there is a need for examining the occurrence of the disease closely and identify possible risk factors that act as multipliers of infection or aid in introduction of the disease. Information of this kind is important in coming up with early warning signs and rapid response in case of an outbreak (Tambi *et al.*, 2006).

1.12. Contagious Bovine Pleura Pneumonia in Namibia

In Namibia, the first outbreak of CBPP was in 1856, in Warmbad which is in the southern part of Namibia and regular outbreaks were recorded in the Central parts of Namibia often mainly due to violence (Van Wolputte, 2015) in the second half of the nineteenth century. This outbreak was contained by quarantine measures adopted by missionaries in the area, but further cattle introductions from either South Africa or Botswana resulted in the infection reaching the central cattle-raising districts in 1859 (Penrith, 2014). Very high mortalities resulted and the Herero people referred to 1860

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as 'otjipunga', the year of the lung. In 1861 CBPP spread across the Limpopo River to cause heavy losses among the cattle of the Matabele in southern Zimbabwe (Provost *et al*., 1987).

By the year 1919 all commercial farms south of the VCF had been eradicated of CBPP and the disease was confined to the northern communal areas of the country (Schneider 1994, 127–140).

Between 1925 and 1975, there were repeated outbreaks of CBPP along the Namibian border with Angola (Van Wolputte, 2015). The northern region of Kunene was affected by CBPP in 1925 after two settlers came into Namibia from Angola with sick animals. Ever since, the occurrence of CBPP in north-west Namibia was characterised by successive major outbreaks of the disease (in 1931, 1938, 1954, 1963, 1968 and 1975) and these outbreaks coincided with periods of drought (Van Wolputte, 2015).

Kaoko was not really affected by CBPP and most of the outbreaks occurred in the north east (Schneider 1994, 133). There were no CBPP outbreaks after 1975 in the region, except in 1995 when a small outbreak occurred. This could be due to drought that affected the region from 1978 to 1982. Together with the political unrest, at least 80-95 % of the livestock in the region died (Van Wolputte, 2015).

The disease was contained briefly after the outbreak but reappeared after a few years (Huebschle *et. al.*, 2003). In the early 20th century, CBPP was successfully eradicated from the commercial farmlands after implementation of animal movement controls, vaccinations and destruction of infected animals (Huebschle *et. al*., 2003). However due to the nature of livestock rearing in the communal lands CBPP persisted until today despite many different vaccination campaigns during the last 80 years (Huebschle *et. al.*, 2003.). According to official documents that are available, the Directorate of Veterinary Services in Namibia tried at least 5 different vaccine formulations for disease control with varying degrees of success. Some of these vaccines that were tried included the Kabete vaccine, the KH3J strain vaccine, the V5strain vaccine, the T1 SR vaccine and presently the T1 44 vaccine. The latest vaccine change was done in 1997 and the number of outbreaks reduced dramatically.

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So currently the northern part of Namibia is affected by CBPP which is the area north of the Veterinary Cordon Fence, which separates the southern, foot and mouth disease free area from the NCA (Provost *et al*., 1987). The Kunene, Ohangwena, Omusati and Kavango districts that share borders with Angola are at high risk of outbreaks of the disease (Provost *et al*., 1987).

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Chapter 2

Research design and methodology

2.1. Research questions

Many of the farmers in the northern Namibia highly depend on livestock for their source of income. An outbreak of CBPP can have a significant impact on the livelihood of small holder farmers. Since the disease is endemic in these communal areas, there is a need for deeper investigation into the occurrence of the disease and to identify possible risk factors that act as multipliers of infection or aid in the introduction of the disease. There is a need for baseline information to assist with the formulation and evaluation of a proper surveillance system and the implementation of a rapid response program in the case of an outbreak.

Knowledge gained from this retrospective study on the prevalence of CBPP together with its temporal and spatial distribution in the NCA of Namibia (2001 to 2013) will provide evidence on whether the disease is contained to a specific area or if it has spread to previously uninfected areas. This information will be crucial in assessing and amending the disease preparedness and control program. It will also provide information that will aid in gaining political will for the implementation of control policies. This data can also assist in decision making on the feasibility of disease eradication.

2.2. Objectives of the study

In order to successfully carry out this study, at least five objectives had to be accomplished and these included to:

1 Compile a 12 year history of the temporal and spatial occurrences of CBPP in the NCA of Namibia during the period 2001 to 2013.

2 Identify areas that are at high risk of CBPP outbreaks in Namibia

3 Discuss the potential risk factors associated with the outbreaks of CBPP in the NCA of Namibia.

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4 To determine the vaccination coverage of CBPP in the infected areas (correlate vaccination doses used with animal numbers).

2.3. Materials and methods

2.3.1 Study Design

This was a retrospective study on the occurrence and control of CBPP in cattle in the NCA of Namibia spanning the period 2001 to 2013. For the purpose of this study, an outbreak of CBPP was defined as a laboratory confirmed case and a suspected outbreak as a clinically suspicious case for which no samples were submitted for laboratory confirmation. This data excludes all suspected cases that were confirmed negative following further investigation.

To identify areas that are at risk of CBPP in the NCA measures of risk such as the incidence and mortality rates were calculated for each year. Incidence rate can be defined as the proportion of an initially disease-free population that develops disease. For the purpose of this study all confirmed and suspected cases were considered for the calculation of the crude incidence rate.

$$\text{CBPP Incidence Rate} = \frac{\text{Number of new cases of disease during a specified year}}{\text{Average population at risk during a specified year}} \times 10^5$$

Incidence rates per 100 000 animals were used to identify the areas with the highest risk.

The crude mortality rate was calculated from all CBPP related deaths in the population and expressed per 100 000 animals.

$$\text{CBPP mortality rate} = \frac{Number\ of\ deaths\ over\ a\ specified\ year}{Average\ population\ \ at\ risk\ over\ a\ specified\ year} \times 10^5$$

For this study epidemiological units are represented by crush pens which are on average 5 km apart and they all have GPS coordinates data. The spatial distribution of CBPP in the NCA of Namibia was described by mapping outbreaks with a red triangle and suspected outbreaks with a blue dot. For temporal distribution of CBPP in the NCA, annual outbreaks consisting of confirmed and suspected

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cases were described from 2001 to 2013. Quantum GIS software was used to plot outbreaks per epidemiological unit for each year.

Analysis was made for the North central regions, Kavango, Kunene and Zambezi regions to describe the vaccination coverage and incidence and mortality rates from 2001 up to 2013.

2.3.2 Study area

The NCA of Namibia (NCA) comprise of areas north of the veterinary cordon fence (VCF) and include the following regions, Kavango East, Kavango West, Zambezi previously known as Caprivi, Ohangwena, northern parts of Oshikoto, Oshana, Omusati and Kunene North regions as well as Tsumkwe which forms the northern part of Otjozondjupa region. Most of them share a common border with Angola except for Oshikoto and Oshana as shown in Figure 2-1. The regions are controlled by different state veterinary districts: Kavango East and Kavango West fall under Rundu state veterinary district; Zambezi region falls under Katima Mulilo state veterinary district; Oshana region falls under, Ondangwa state veterinary district; Oshikoto region falls under Omuthiya state veterinary district; Ohangwena region falls under Eenhana state veterinary district; Omusati region falls under Outapi state veterinary district and Kunene North region falls under Opuwo state veterinary district.

Before 2006, Ohangwena, Oshikoto, Omusati and Oshana regions, ("O" regions) were all under the supervision on Ondangwa state veterinary district and were being referred to as the North Central Division.

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Figure 2-1 Map indicating the northern communal areas of Namibia. The red line indicates the Veterinary Cordon Fence and the study area included all regions north of this fence.

2.3.3 Data Collection

Data was sourced from the Epidemiology section of the Directorate of Veterinary Services in Namibia with the permission from the Chief Veterinary Officer. All the information regarding suspected and confirmed CBPP cases are recorded by the state veterinarian of the district on a disease report form (DRF). The DRF includes information such as name of the farmer, village of origin; crush pen, farming system, history of vaccinations and number of animals at risk. These forms are submitted to the Epidemiology section where the data are available in both paper and electronic formats. Departmental annual reports, disease reports to the OIE as well as reports from the Central Veterinary Laboratory were part of the source of the information in this study. A literature search was also done with guiding key words such as "CBPP" and "Namibia "on databases such as PubMed, Science Direct and CAB direct.

1.1.1 Data analysis

Data was captured in Microsoft® Excel which was also used to perform the calculations and to construct the graphs. Confidence intervals (CI) were also calculated because they provide a means of assessing and reporting the precision of a point estimate, such as a mortality rate or incidence rate. When CI is used to describe health data such as incidence or mortality rates, confidence levels of 95% are generally used (Brillinger, 1986). A Microsoft Excel template "Analytical tools for public health" available at http://www.apho.org.uk/resource/view.aspx?QN=TECH_BRIEFS was used to calculate the confidence intervals.

ArcGIS (Esri) was used to construct and plot the outbreaks on the maps.

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Chapter 3

Results

3.1. Temporal and spatial distribution of CBPP

For easy reference, a summary of annual laboratory confirmed and suspicious outbreaks in the study area between 2001 and 2013 is given below in

Table *3-1*. The geographical distribution of all the suspected and confirmed cases for the study period is presented in Figure 3-1.

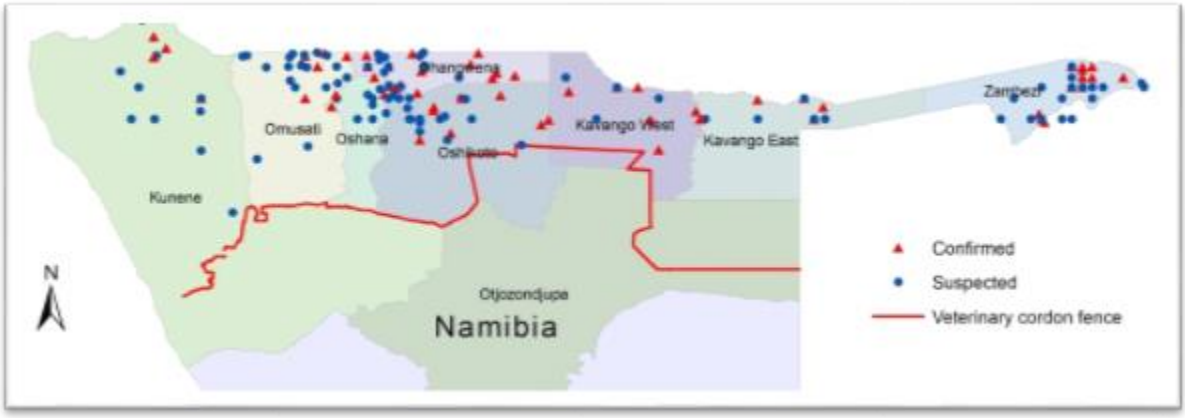

Figure 3-1 Map indicating all the confirmed (red triangles) and suspected (blue dots) outbreaks of contagious bovine pleuropneumonia in the different regions of the northern communal areas of Namibia between 2001 -2013.

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Table 3-1Summary of the number of confirmed and suspected outbreaks reported for contagious bovine pleuropneumonia in the different regions of the northern communal areas of Namibia between 2001 and 2013. Suspected cases are indicated in parenthesis. This data excludes all suspected cases that were confirmed negative following further investigation.

	Number of confirmed and (suspicious) outbreaks per year												
Region	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Zambezi			4(6)	4(4)	7(4)	4(5)	(1)		(2)	1(1)			
Kavango	4(7)	(2)	2(1)										(1)
Ohangwena*	*	*	*	*	*	*		1	1	1(3)	2(2)	1	(2)
Oshikoto*	*	*	*	*	*	*	1	1	1	(2)		(1)	6(2)
Oshana*	5*(55)	6*(10)	*(3)	2*(3)	1*(1)	4*(1)				(1)		(1)	
Omusati*	*	*	*	*	*	*			2	1(3)	(2)	(2)	1(6)
Kunene North	(1)	(2)	(2)		3(1)	(2)	(2)					2	2(2)
(Otjozoundjupa)Tsumkwe													
Total	9(63)	6(14)	6(12)	6(7)	11(8)	8(8)	1(3)	2	4(2)	3(10)	2(4)	3(4)	9(13)

*Indicates the north central regions that were managed under the Oshana State Veterinary District during the time 2001 to 2006 and represents the cumulative data for all four regions.
( ) indicates number of suspicious outbreaks.

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The highest numbers of outbreaks were recorded in 2005 with 11 laboratory confirmed outbreaks in the NCA. Zambezi and Kunene North regions were the most affected. In 2001 and 2013 Namibia experienced 9 laboratory confirmed outbreaks in each year mostly affecting Oshikoto, Kavango and Ohangwena regions. In 2006, 8 outbreaks were reported and this was a slightly less than the 11 outbreaks in 2005. From 2002-2004, 6 outbreaks were recorded for each year. It's important to note that from 2007 up to 2012; isolated outbreaks with less than 5 laboratory confirmed outbreaks were recorded. The annual frequency of suspected and confirmed outbreaks of contagious bovine pleuropneumonia during the study period 2001 to 2013 is shown in Figure 3-2.

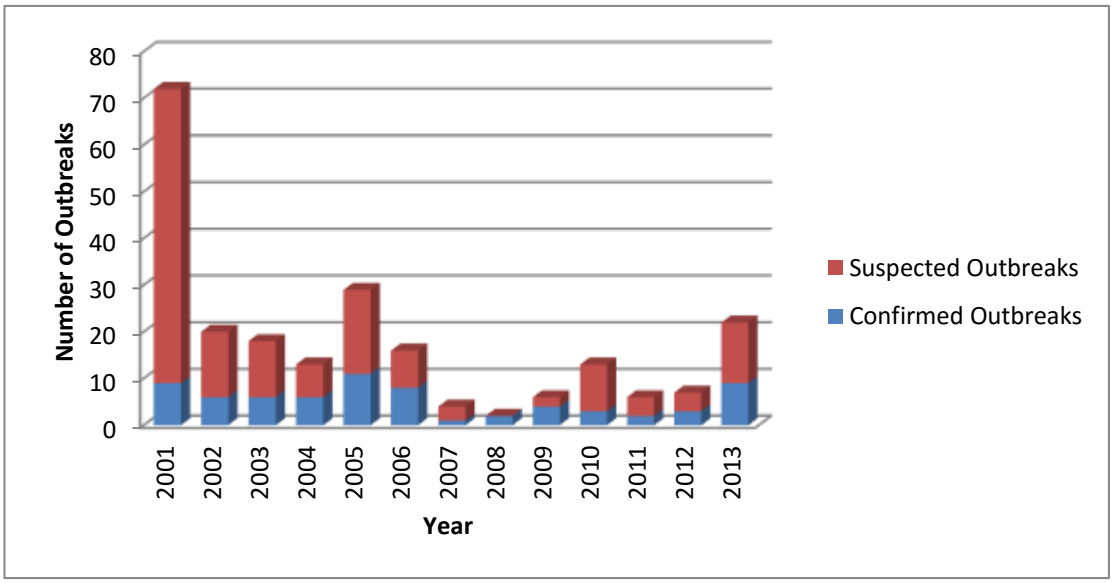

Figure 3-2 The annual frequency of suspected and confirmed outbreaks of contagious bovine pleuropneumonia during the study period 2001 to 2013

3.2. Vaccination coverage, incidence- and mortality rates

Zambezi

The vaccination coverage varied between 11 and 22 per 100 000 between 2001 and 2004, which was followed by a significant increase in both incidence- and mortality rates. It is important to mention that from 2001-2004, Zambezi region used to vaccinate only a small fraction of the cattle population in the region. It concentrated on areas along the Zambian border North of Katima road all the way to

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Kongola. Due to the outbreak of CBPP in Zambezi region in 2003, DVS decided to vaccinate the whole region. This explains why the vaccination coverage varied between 11 and 22 per 100 000 from 2001to 2004. Incidence- and mortality rates were calculated at 95% upper and lower confidence intervals (CI). The incidence rate peaked at 176 per 100 000 (156-199 CI) and the mortality rate reached 117 per 100 000 (101-136 CI) in 2004. Following a dramatic increase, to reach 85% vaccination coverage in 2005, the incidence and mortality rates dropped significantly to 43 (35-52 CI) and 15 per 100 000 (10-20 CI) respectively and remained at negligibly low levels from 2007 till 2013. Vaccination coverage was intermittently high with coverage above ≈ 90% during 2008, 2009, 2010 and 2012. Only 40% vaccination coverage was reached in 2013. The vaccination coverage as well as incidence and mortality rates for Zambezi region are given in figures Figure 3-3 and Figure 3-4.

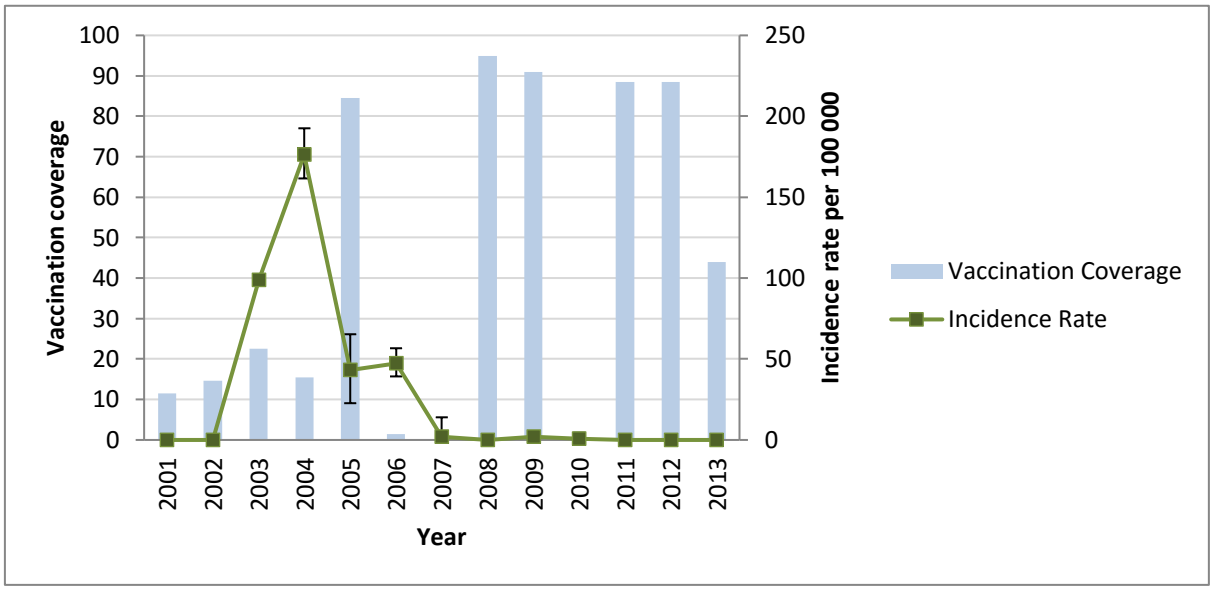

Figure 3-3 The vaccination coverage and crude incidence rates of CBPP in Zambezi region from 2001-2013. Incedence rates were calculated per 100 000 at a 95% confidence interval and the upper and lower intervals are indicated by the error bars.

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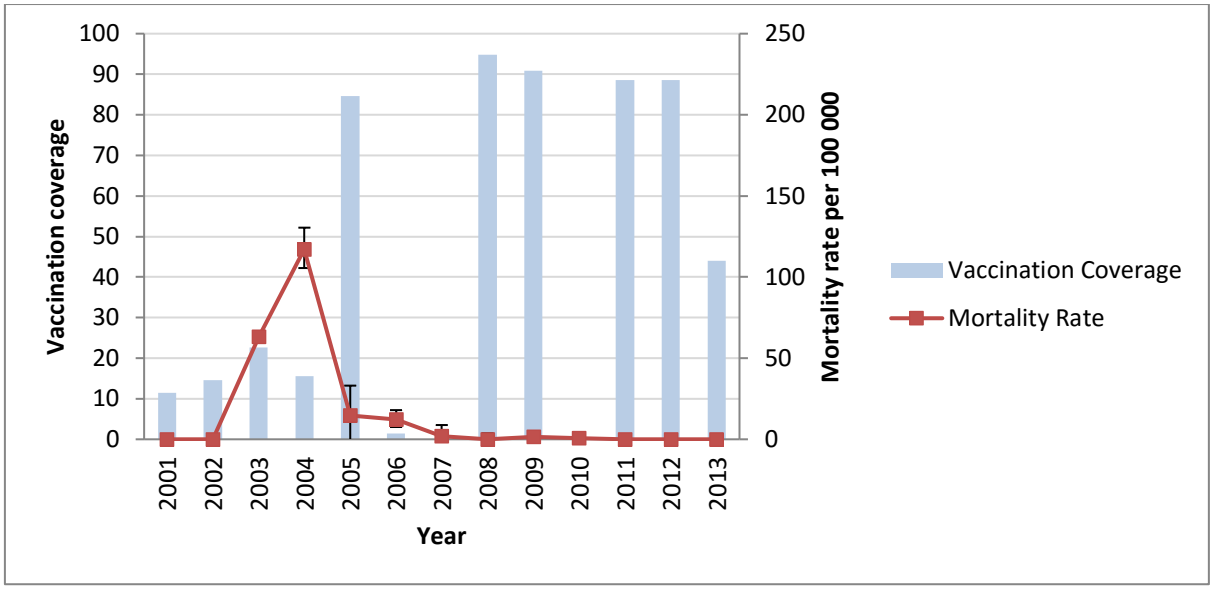

Figure 3-4 The vaccination coverage and mortality rates of CBPP in Zambezi region from 2001-2013. Mortality rates were calculated per 100 000 at a 95% confidence interval and the upper and lower intervals are indicated by the error bars.

Kunene

The vaccination coverage was below 50% in 2005, 2007 and 2013 and below 70% in 2008 and 2009. Otherwise Kunene region had vaccination coverage above 70% in 2001, 2002, 2003, 2004, 2006, 2011 and 2012.

Both the incidence- and mortality rates were never above 15 per 100 000 for the study period .The incidence rate peaked at 14 (9, 8-21, 4 CI) with mortality rate reaching 1 per 100 000 (0, 1-3, 8 CI) in 2005. In 2012 the incidence rate was 11,55 (7,2-17,7 CI) and a mortality rate of 4,95 per 100 000 (2,3-9,4 CI) .The vaccination coverage as well as incidence and mortality rates for Kunene region are given in Figure 3-5 and Figure 3-6.

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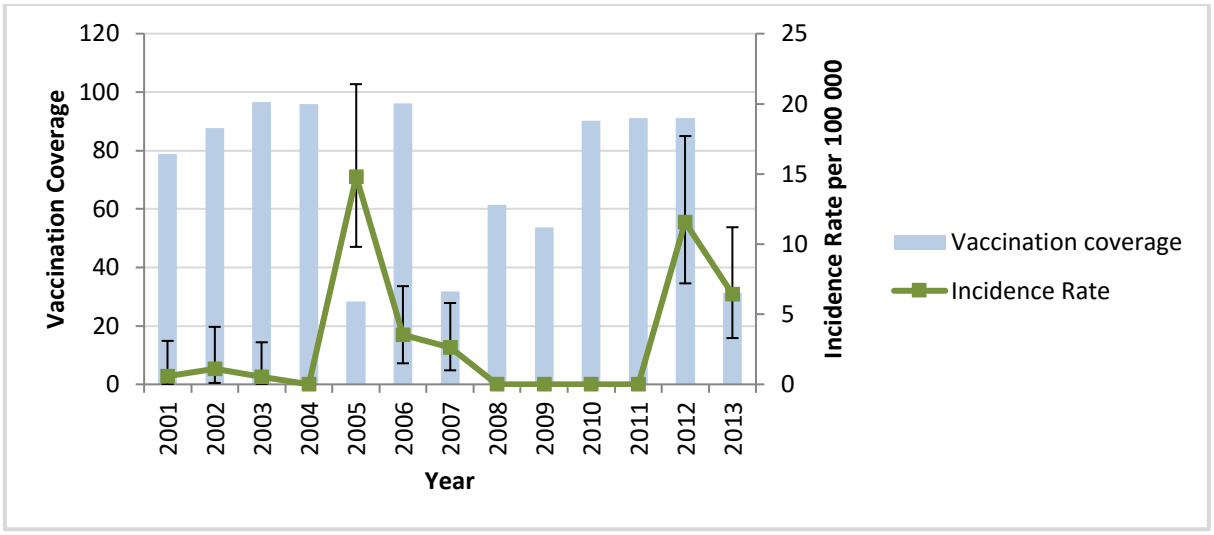

Figure 3-5 The vaccination coverage and crude incidence rates of CBPP in Kunene region from 2001-2013. Incedence rates were calculated per 100 000 at a 95% confidence interval and the upper and lower intervals are indicated by the error bars.

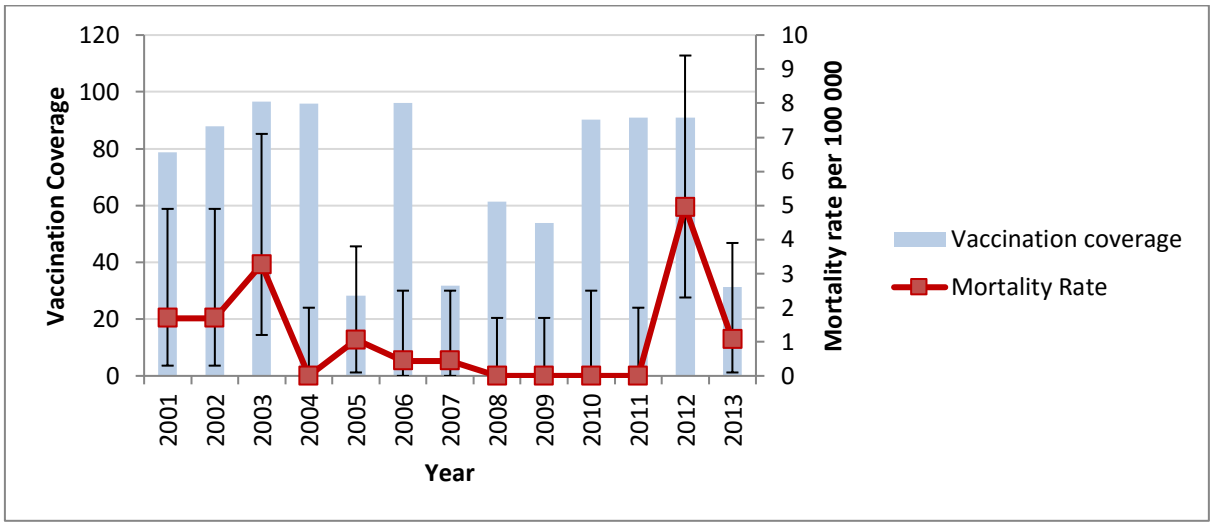

Figure 3-6 The vaccination coverage and mortality rates of CBPP in Kunene region from 2001-2013. Mortality rates were calculated per 100 000 at a 95% confidence interval and the upper and lower intervals are indicated by the error bars.

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Kavango

The region generally had good vaccination coverage throughout the study period with at least coverage of above 70% except in 2005 where the vaccination coverage was 43, 5% and in 2008 where there is no record of vaccination for that year.

Small peaks of the incidence rate and the mortality rate were recorded in 2001 where the incidence rate was 27, 73 (19, 3-38, 8 CI) and mortality rate of 32, 63 per 100 000 (23, 4-44, CI). In 2003 the incidence rate reached 26, 57 (18, 2-37, 5) and the mortality rate 21, 59 per 100 000 (14, 1-31, 6 CI).

The vaccination coverage as well as incidence and mortality rates for Kavango region are given in Figure 3-7 and Figure 3-8.

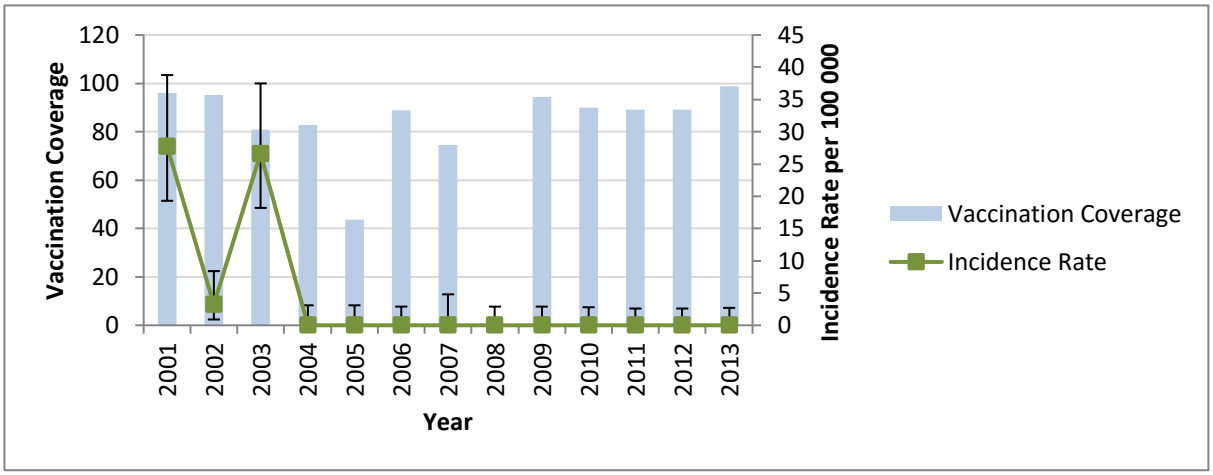

Figure 3-7 The vaccination coverage and crude incidence rates of CBPP in Kavango region from 2001-2013. Incedence rates were calculated per 100 000 at a 95% confidence interval and the upper and lower intervals are indicated by the error bars

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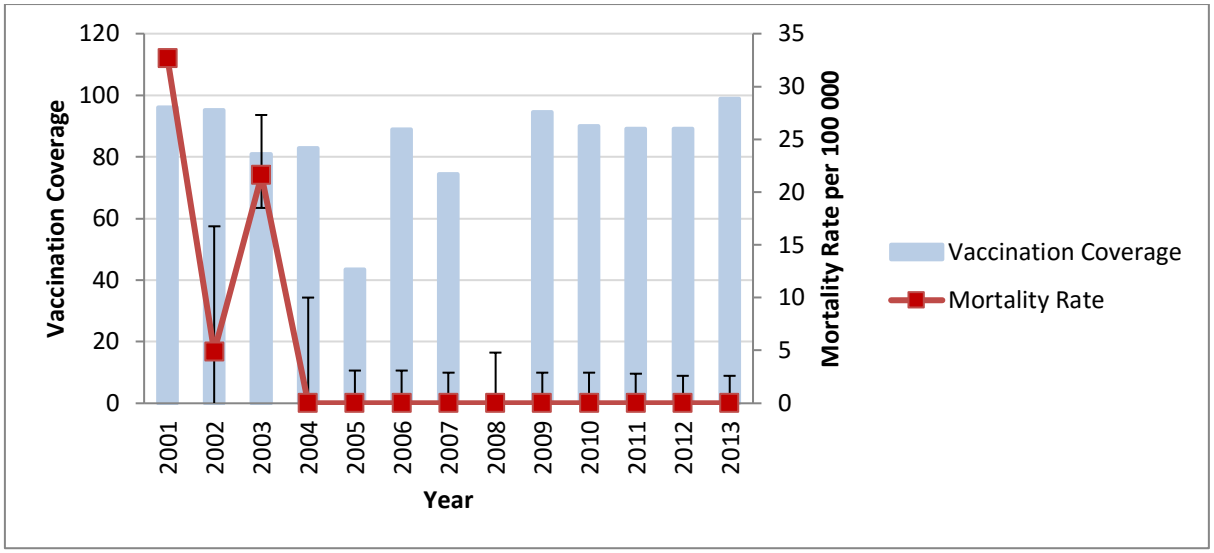

Figure 3-8 The vaccination coverage and mortalit rates of CBPP in Kavango region from 2001-2013. Mortality rates were calculated per 100 000 at a 95% confidence interval and the upper and lower intervals are indicated by the error bars.

Northern Communal Areas

The vaccination coverage for 2001 was 68.95 % and thereafter increased to at least 70 % coverage from 2002 up to 2006. A decrease is recorded for 2007 where the NCA only reached 50 % vaccination coverage. As from 2008 up to 2013 all the vaccinations recorded coverages above 70%. In 2001, the incidence rate was 36, 28 (31, 8-41, 2 CI) and the mortality rate was 7.8 per 100 000 (5, 8-10, 3 CI). In 2002, the incidence rate dropped to 18, 21 (15, 1-21, 8 CI) and the mortality rate was 5, 05 (3, 5-7, 1 CI). From 2003 up to 2011, there was a significant drop in both incidence and mortality rates in the NCA all below 5.

The vaccination coverage as well as incidence and mortality rates for the NCA are given in Figure 3-9 and Figure 3-10.

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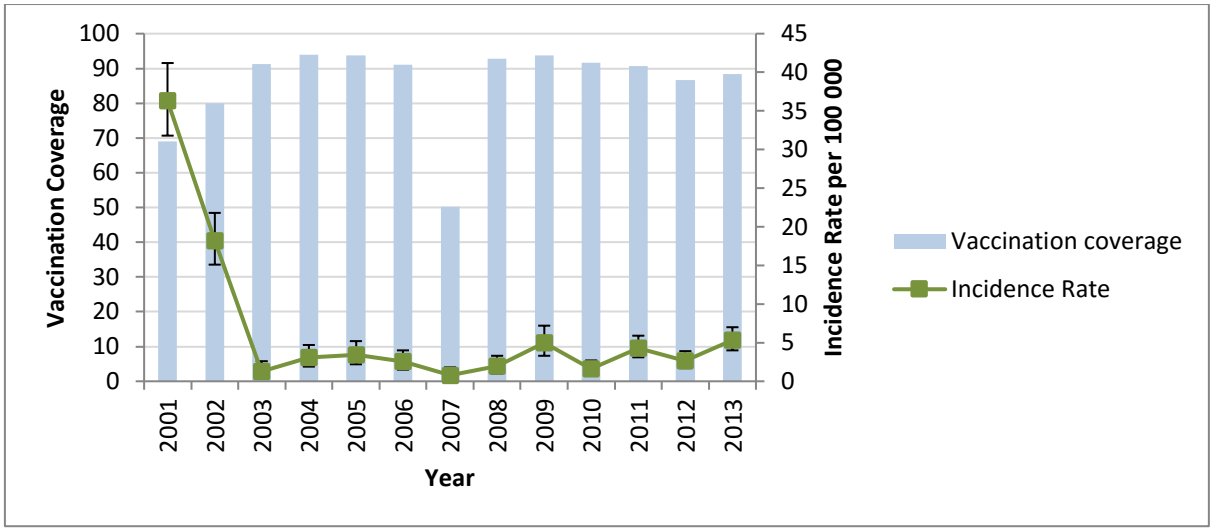

Figure 3-9 The vaccination coverage and crude incidence rates of CBPP in the NCA from 2001-2013. Incidence rates were calculated per 100 000 at a 95% confidence interval and the upper and lower intervals are indicated by the error bars

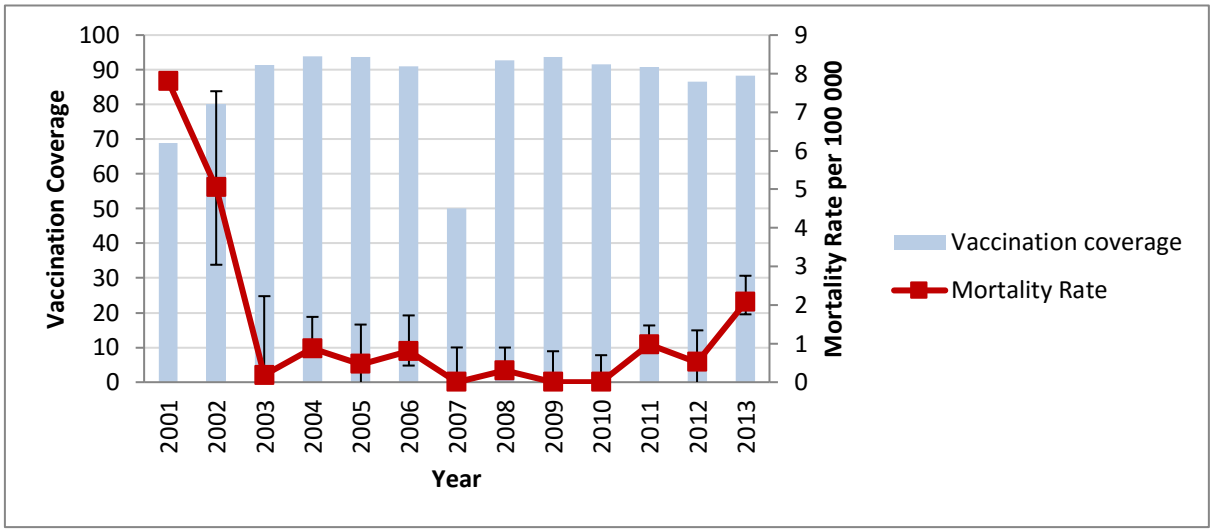

Figure 3-10 The vaccination coverage and mortality rates of CBPP in the NCA region from 2001-2013. Mortality rates were calculated per 100 000 at a 95% confidence interval and the upper and lower intervals are indicated by the error bars.

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3.3. CBPP outbreaks per year

2001

CBPP was reported in 6 regions: North Central (Ohangwena, Oshikoto, Oshana and Omusati), Kavango and Kunene North in the order of highest to lowest incidence rate. Nine outbreaks were laboratory-confirmed and involved a total of 27 diseased animals with 18 mortalities. A further 63 suspected (unconfirmed) outbreaks were reported which involved 245 diseased animals with 76 mortalities. Details of the outbreaks per region are given in Table 3-2. The geographical distribution of all the suspected and confirmed cases during 2001 is presented in Figure 3-11. Vaccination was performed in Kunene north, Kavango, Zambezi, Tsumkwe and in the NCA with a total of 727 612 doses being used and a 57, 97% coverage of the population at risk. Details of the cattle census and vaccine doses used are given in Table 3-3.

Table 3-2 Summary of confirmed and suspected outbreaks as well as the crude incidence- and mortality rates of CBPP in the northern communal areas of Namibia in 2001. Mortality and incidence rates were calculated at 95% confidence intervals and indicated in [ ]

Region	Number of outbreaks	Number Sick	Number dead	Incidence Rate (per 100 000)	Mortality rate (per 100 000)
Kunene North	(1)	(1)	(3)	0,56 [0-3,1]	1,69 [0,3-4,9]
*North Central	5(55)	15(222)	1(50)	36,28 [31,8-41,2]	7,81 [5,8-10,3]
Kavango	4(7)	12(22)	17(23)	27,73 [19,3-38,8]	32,63 [23,4-44,5]
Study Area	72	272	94	21,67 [19,2-24,4]	7,49 [6,1-9,2]

*Indicates the north central regions that were managed under the Oshana State Veterinary District during the time 2001 to 2006 and represents the cumulative data for all four regions.
( ) indicates number of suspicious outbreaks.

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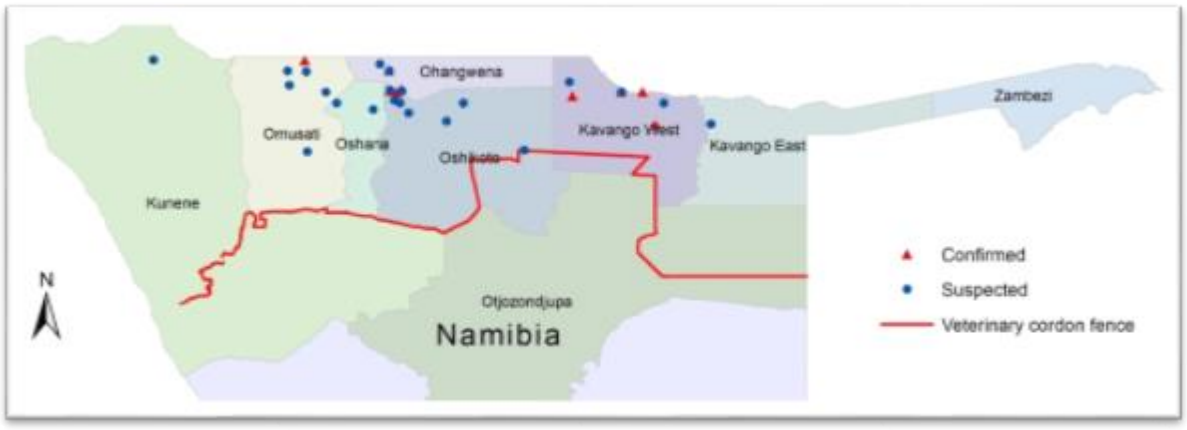

Figure 3-11 Map indicating all the confirmed (red triangles) and suspected (blue dots) outbreaks of contagious bovine pleuropneumonia in the different regions of the northern communal areas of Namibia during 2001

Table 3-3 Regions where cattle were vaccinated for CBPP during 2001 indicating the number of vaccine doses used and the percent covarage of the population at risk.

Region	Number vaccinated	Census	% coverage
Kunene North	139 523	177 215	78,73
*North Central	450 465	800 000	68,95
Kavango	117 781	122 301	96,04
Zambezi	17 307	152 325	11,45
Tsumkwe (Otjozoundjupa)	2 536	3387	74,87
Total	727 612	1 255 228	57,97

*Consists of Ohangwena, Oshikoto, Oshana and Omusati regions prior to 2007

It is important to note that although Zambezi has a cattle census of 152 325, only animals along the border with Zambia were vaccinated against CBPP.

2002

CBPP was confirmed at 6 foci in the NCA (Ohangwena, Oshikoto, Oshana and Omusati) with 73 diseased animals and 25 mortalities being reported. There were also 14 suspected outbreaks in Kavango, Kunene north and the NCA regions combined where 52 animals were diseased with 17

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deaths being reported. Details of the outbreaks per region are given in Table 3-4. The geographical distribution of all the suspected and confirmed cases during 2002 is presented in Figure 3-12. The annual vaccination campaign was performed using T_1-44 vaccine in Kunene north, Kavango, Zambezi, Tsumkwe and in the NCA. A total of 816 500 cattle were vaccinated yielding a 73, 85 % coverage of the population at risk. Details of the cattle census and vaccine doses used are given in Table 3-5. There are several designated crossing points along the Namibian Angolan border and 11 268 cattle were vaccinated in 2002 from Angola entering Namibia.

Table 3-4 Summary of confirmed and suspected outbreaks as well as the crude incidence- and mortality rates of CBPP in the northern communal areas of Namibia in 2002. Mortality and incidence rates were calculated at 95% confidence intervals and indicated in [ ]

Region	Number outbreaks	Number Sick	Number dead	Incidence Rate (per 100 000)	Mortality rate (per 100 000)
Kunene North	(2)	(2)	(3)	1,13 [0,1-4,1]	1,69 [0,3-4,9]
*North Central	6(10)	73(46)	25(8)	18,21 [15,1-21,8]	5,05 [3,5-7,1]
Kavango	(2)	(4)	(6)	3,26 [0,9-8,4]	4,89 [1,8-10,6]
Study Area	20	125	42	11,31 [9,4-13,5]	3,80 [2,7-5,1]

*Indicates the north central regions that were managed under the Oshana State Veterinary District during the time 2001 to 2006 and represents the cumulative data for all four regions.
( ) indicates number of suspicious outbreaks.

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Figure 3-12 Map indicating all the confirmed (red triangles) and suspected (blue dots) outbreaks of contagious bovine pleuropneumonia in the different regions of the northern communal areas of Namibia during 2002

Table 3-5 Regions where cattle were vaccinated for CBPP during 2002 indicating the number of vaccine doses used and the percent covarage of the population at risk.

Region	Number vaccinated	Census	% coverage
Kunene North	155 585	177 216	87,79
*North Central	522 427	653 332	79,96
Kavango	116 735	122 633	95,19
Zambezi	21 753	149 030	14,59
Tsumkwe (Otjozoundjupa)	0	3387	0
Total	816 500	1 105 598	73,85

*Consists of Ohangwena, Oshikoto, Oshana and Omusati regions prior to 2007

2003

CBPP was reported in Zambezi, Kavango, Kunene north and the NCA. It was only confirmed in Zambezi and Kavango with 6 and 4 outbreaks respectively. A total of 182 diseased animals with 124 mortalities were recorded from confirmed outbreaks in the regions. A further 12 suspected

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(unconfirmed) outbreaks were reported in Kunene north, NCA, Kavango and Zambezi regions which involved 21 diseased animals with 13 mortalities. Details of the outbreaks per region are given inTable 3-6. The geographical distribution of all the suspected and confirmed cases during 2003 is presented in Figure 3-13. Vaccination was performed in Kunene north, Kavango, Zambezi, Tsumkwe and in the NCA with a total of 817 049 doses being used and a 79, 93% coverage of the population at risk. Details of the cattle census and vaccine doses used are given in Table 3-7. At the entry point along the Namibia-Angolan border, 733 cattle were recorded to have entered Namibia from Angola during the period under review. DVS made sure that all these animals were vaccinated against CBPP and branded with an "A" to permanently identify them as imported animals.

Table 3-6 Summary of confirmed and suspected outbreaks as well as the crude incidence- and mortality rates of CBPP in the northern communal areas of Namibia in 2003. Mortality and incidence rates were calculated at 95% confidence intervals and indicated in [ ]Region

	Number of outbreaks	Number sick	Number dead	Incidence rate (per 100 000)	Mortality rate (per 100 000)
Kunene North	(2)	(1)	(6)	0,54 [0-3]	3,27 [1,2-7,1]
*North Central	(3)	(7)	(1)	1,27 [0,5-2,6]	0,18 [0-1,0]
Kavango	2(1)	30(2)	26	26,57 [18,2-37,5]	21,59 [14,1-31,6]
Zambezi	4(6)	152(11)	98(6)	98,93 [84,3-115,3]	63,12 [51,6-76,5]
Study Area	18	203	137	19,86 [17,2-22,8]	13,40 [11,3-15,8]

*Indicates the north central regions that were managed under the Oshana State Veterinary District during the time 2001 to 2006 and represents the cumulative data for all four regions.
( ) indicates number of suspicious outbreaks.

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Figure 3-13 Map indicating all the confirmed (red triangles) and suspected (blue dots) outbreaks of contagious bovine pleuropneumonia in the different regions of the northern communal areas of Namibia during 2003

Table 3-7 Regions where cattle were vaccinated for CBPP during 2003 indicating the number of vaccine doses used and the percent covarage of the population at risk.

Region	Vaccinated	Census	% Coverage
Zambezi	37 181	164 771	22,56 %
Kavango	97 435	120 454	80,89 %
Tsumkwe (Otjozoundjupa)	2879	3379	85,20 %
*North Central	502 338	550 090	91,32 %
Kunene North	177 216	183 512	96,57%
Total	817049	1 022 206	79,93

*Consists of Ohangwena, Oshikoto, Oshana and Omusati regions prior to 2007

It is important to note that the cattle census for Zambezi region is 164 771 but the CBPP vaccinations were only done along the border with Zambia and the targeted census was 37 181cattle at high risk.

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2004

After the initial outbreak of CBPP in 2003, Zambezi region was struck again with another outbreak in 2004 together with the NCA. Six outbreaks were laboratory-confirmed with a total of 136 diseased animals and 103 mortalities. Only 7suspected (unconfirmed) outbreaks were reported which involved 156 diseased animals with 83 mortalities. Details of the outbreaks per region are given in Table 3-8. The geographical distribution of all the suspected and confirmed cases during 2004 is presented in Figure 3-14. CBPP annual vaccination campaign was conducted as usual in all regions including Kunene North, Kavango, Zambezi, Tsumkwe and the NCA with a total of 952 000 cattle being vaccinated and 82.62% coverage of the population at risk. Details of the cattle census and vaccine doses used are given in Table 3-9.

Table 3-8 Summary of confirmed and suspected outbreaks as well as the crude incidence- and mortality rates of CBPP in the northern communal areas of Namibia in 2004. Mortality and incidence rates were calculated at 95% confidence intervals and indicated in [ ]

Region	Number of outbreaks	Number Sick	Number Dead	Incidence rate (per 100 000)	Mortality rate (per 100 000)
*North Central	2(3)	12(9)	(6)	3,06 [1,9-4,7]	0,88 [0,3-1,9]
Zambezi	4(4)	124(147)	103(77)	176,23 [155,9-198,5]	117,06 [100,6-135,5]
Study Area	13	292	186	25,34 [22,5-28,4]	16,14 [13,9-18,6]

*Indicates the north central regions that were managed under the Oshana State Veterinary District during the time 2001 to 2006 and represents the cumulative data for all four regions.
( ) indicates number of suspicious outbreaks

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Figure 3-14 Map indicating all the confirmed (red triangles) and suspected (blue dots) outbreaks of contagious bovine pleuropneumonia in the different regions of the northern communal areas of Namibia during 2004

Table 3-9 Regions where cattle were vaccinated for CBPP during 2004 indicating the number of vaccine doses used and the percent covarage of the population at risk.

Region	Vaccination	Census	% Coverage
Zambezi	23 850	153772	15,51
Kavango	99 690	120 168	82,95
(Otjozoundjupa) Tsumkwe	3 091	3 654	84,59
Ohangwena	153 960	163 783	94,00
Kunene North	181 278	189 052	95,89
Oshikoto	174 161	191 412	90,99
Omusati	242 176	249 546	97,05
Oshana	73 794	80 906	91,21
Total	952 000	1152293	82.62

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2005

In 2005, CBPP was reported in 3 regions: Zambezi, Kunene North and North Central (Ohangwena, Oshikoto, Oshana and Omusati) in the order of highest to lowest incidence rate. Eleven outbreaks were laboratory-confirmed and involved a total of 101 diseased animals with 25 mortalities. Eight suspected (unconfirmed) outbreaks were also reported which involved 49 diseased animals with 14 mortalities. Details of the outbreaks per region are given in Table 3-10. The geographical distribution of all the suspected and confirmed cases during 2005 is presented in Figure 3-15. Vaccination was performed in all the regions in the NCA: Kunene North, Kavango, Zambezi, and Tsumkwe and in the NCA with a total of 906 083 doses being used and 76.40 % coverage of the population at risk. Details of the cattle census and vaccine doses used are given in Table 3-11.

Table 3-10 Summary of confirmed and suspected outbreaks as well as the crude incidence- and mortality rates of CBPP in the northern communal areas of Namibia in 2005. Mortality and incidence rates were calculated at 95% confidence intervals and indicated in [ ]

Region	Number of outbreaks	Number of Sick	Number Dead	Incidence rate (per 100 000)	Mortality rate (per 100 000)
Zambezi	7(4)	76(24)	22(12)	43,05 [35,0-52,4]	14,64 [10,1-20,5]
*North Central	1(1)	4(18)	2(1)	3,44 [2,2-5,2]	0,47 [0,1-1,4]
Kunene North	3(3)	21(7)	1(1)	14,81 [9,8-21,4]	1,06 [0,1-3,8]
Study Area	19	150	39	12,65 [10,7-14,8]	3,29 [2,3-4,5]

*Indicates the north central regions that were managed under the Oshana State Veterinary District during the time 2001 to 2006 and represents the cumulative data for all four regions.
( ) indicates number of suspicious outbreaks

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Figure 3-15 Map indicating all the confirmed (red triangles) and suspected (blue dots) outbreaks of contagious bovine pleuropneumonia in the different regions of the northern communal areas of Namibia during 2005

Table 3-11 Regions where cattle were vaccinated for CBPP during 2005 indicating the number of vaccine doses used and the percent covarage of the population at risk.

Region	Vaccination	Census	% Coverage
Zambezi	196394	232 314	84,54
Kavango	52 472	120 496	43,55
Tsumkwe (Otjozoundjupa)	3 587	4 077	87,98
Oshikoto	191 034	207 722	91,97
Kunene North	53 500	189 052	28,30
Omusati	242 176	249 546	97,05
Oshana	101 696	106 091	95,86
Ohangwena	65 224	76 669	85,07
Total	906 083	1 185 967	76,40

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2006

CBPP was confirmed in Zambezi and North Central (Ohangwena, Oshikoto, Oshana and Omusati) in the order of highest to lowest incidence rate. A total of 8 outbreaks were laboratory-confirmed and involved 41 diseased animals with 19 mortalities. A further 8 suspected (unconfirmed) outbreaks were reported which involved 60 diseased animals with 7 mortalities. Details of the outbreaks per region are given in Table 3-12. The geographical distribution of all the suspected and confirmed cases during 2006 is presented in Figure 3-16. Vaccination was performed in most regions in the NCA except in Tsumkwe. The turnout was good with a total of 1 015 111 doses being used and 80, 36% coverage of the population at risk. Details of the cattle census and vaccine doses used are given in Table 3-13.

Table 3-12 Summary of confirmed and suspected outbreaks as well as the crude incidence- and mortality rates of CBPP in the northern communal areas of Namibia in 2006. Mortality and incidence rates were calculated at 95% confidence intervals and indicated in [ ]

Region	Number of outbreaks	Number of Sick	Number Dead	Incidence rate (per 100 000)	Mortality rate (per 100 000)
Zambezi	4(5)	23(51)	13(6)	47,32 [37,2-59,4]	12,15 [7,3-19,0]
*North Central	4(1)	18(1)	6	2,53 [1,5-4,0]	0,80 [0,3-1,7]
Kunene North	(2)	(8)	(1)	3,53 [1,5-7,0]	0,44 [0-2,5]
Study Area	16	101	26	8,00 [6,5-9,7]	2,06 [1,3-3,0]

*Indicates the north central regions that were managed under the Oshana State Veterinary District during the time 2001 to 2006 and represents the cumulative data for all four regions.
( ) indicates number of suspicious outbreaks

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Figure 3-16 Map indicating all the confirmed (red triangles) and suspected (blue dots) outbreaks of contagious bovine pleuropneumonia in the different regions of the northern communal areas of Namibia during 2006

Table 3-13 Regions where cattle were vaccinated for CBPP during 2006 indicating the number of vaccine doses used and the percent covarage of the population at risk.

Region/District	Vaccination	Census	% Coverage
Zambezi	2 289	156379	1,46
Kavango	111 879	125 927	88,84
Tsumkwe (Otjozoundjupa)	0	4 077	0
Oshikoto	187 021	213 112	87,76
Kunene North	217 879	226 537	96,18
Omusati	229 830	247 941	92,70
Oshana	101 206	105 943	95,53
Ohangwena	165 007	183 287	90,03
Total	1 015 111	1 263 203	80,36

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2007

Only one region recorded a confirmed case of CBPP in 2007. One outbreak was laboratory confirmed and reported in Oshikoto region and involved 5 diseased animals with no mortalities. Three suspected (unconfirmed) outbreaks were reported in Zambezi and Kunene with 9 diseased animals and 4 mortalities. Details of the outbreaks per region are given in Table 3-14. The geographical distribution of all the suspected and confirmed cases during 2007 is presented in Figure 3-17. CBPP vaccination was performed in most regions in the NCA except for Zambezi region and Tsumkwe constituency with no data available for this year. The total number of cattle vaccinated was 447 704 and a 41, 73 % coverage of the population at risk. Details of the cattle census and vaccine doses used are given in Table 3-15.

Table 3-14 Summary of confirmed and suspected outbreaks as well as the crude incidence- and mortality rates of CBPP in the northern communal areas of Namibia in 2007. Mortality and incidence rates were calculated at 95% confidence intervals and indicated in [ ]

Region	Number of Outbreaks	Number of Sick	Number Dead	Incidence rate (per 100 000)	Mortality rate (per 100 000)
Oshikoto	1	5	0	3,65 [0,7-5,3]	0 [0-0]
Zambezi	(1)	(3)	(3)	1,92 [0,4-5,6]	1,92 [0,4-5,6]
Kunene North	(2)	(6)	(1)	2,65 [1,0-5,8]	0,44 [0-2,5]
Study Area	4	14	4	1,27 [0,7-2,1]	0,36 [0,1-0,9]

( ) indicates number of suspicious outbreaks

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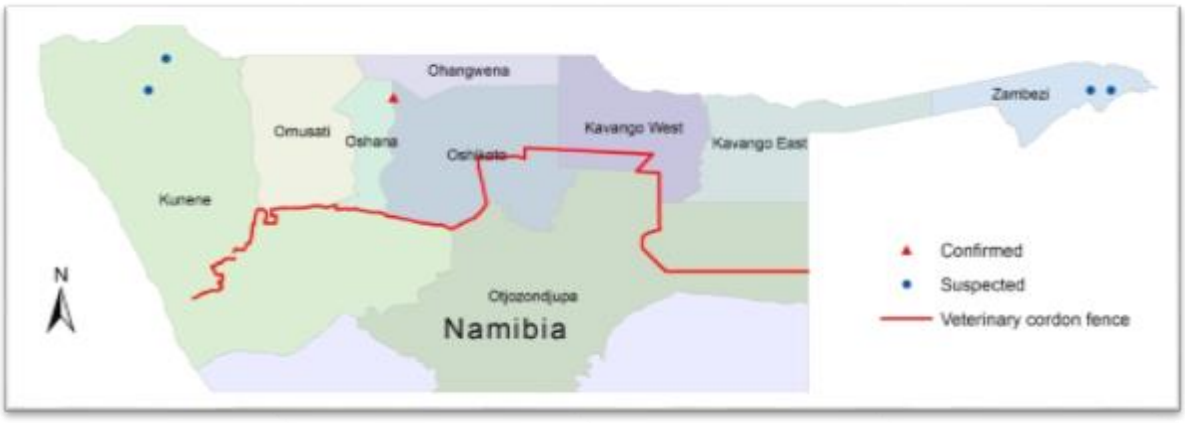

Figure 3-17 Map indicating all the confirmed (red triangles) and suspected (blue dots) outbreaks of contagious bovine pleuropneumonia in the different regions of the northern communal areas of Namibia during 2007

Table 3-15 Regions where cattle were vaccinated for CBPP during 2007 indicating the number of vaccine doses used and the percent covarage of the population at risk.

Region	Vaccination	Census	% Coverage
Zambezi	0	156 379	0
Kavango	57 285	76 938	74,46
Tsumkwe (Otjozoundjupa)	0	4 077	0
Oshikoto	11 800	218 882	5,39
Kunene North	71 746	226 537	31,67
Omusati	151 352	157 339	96,19
Oshana	17 881	107 959	16,56
Ohangwena	137 640	151 186	91,04
Total	447 704	1 099 297	41,73

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2008

CBPP was reported in 2 regions: Ohangwena and Oshikoto in the order of highest to lowest incidence rate. There were only 2 outbreaks that were laboratory-confirmed and involved a total of 13 diseased animals with 2 mortalities. Details of the outbreaks per region are given in

Table 3-16. The geographical distribution of all the suspected and confirmed cases during 2008 is presented in Table 3-16. The CBPP annual vaccination campaign was conducted in most regions in the NCA except in Kavango and Tsumkwe constituency where data is not available for this particular year. A total of 891 447 cattle were vaccinated with 76, 74% coverage of the population at risk. Details of the cattle census and vaccine doses used are given in Table 3-17.

Table 3-16 Summary of confirmed and suspected outbreaks as well as the crude incidence- and mortality rates of CBPP in the northern communal areas of Namibia in 2008. Mortality and incidence rates were calculated at 95% confidence intervals and indicated in [ ]

Region	Number of outbreaks	Number of Sick	Number Dead	Incidence rate (per 100 000)	Mortality rate (per 100 000)
Oshikoto	1	3	0	1,47 [0,3-4,3]	0 [0-0]
Ohangwena	1	10	2	6,45 [3,1-11,9]	1,29 [0,2-4,7]
Study Area	4	13	2	1,12 [0,6-1,9]	0,17 [0-0,6]

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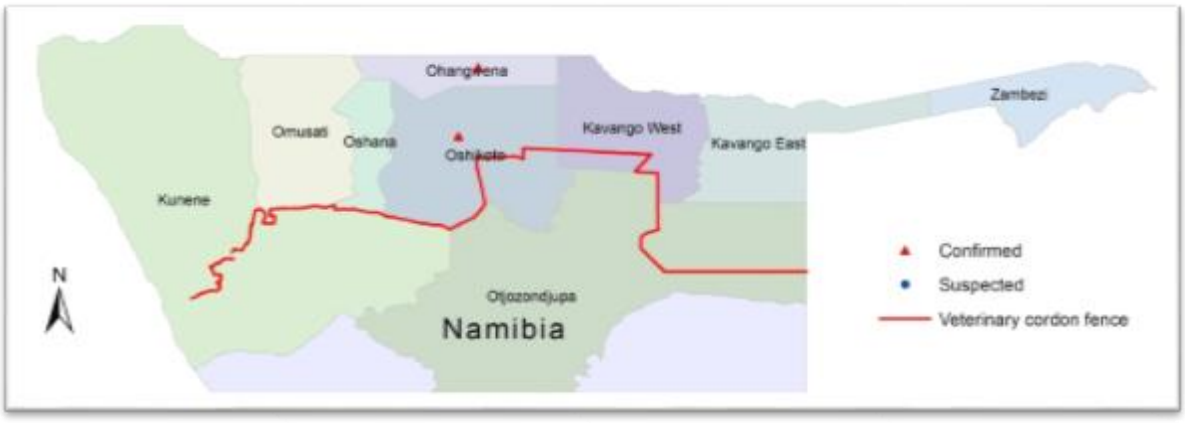

Figure 3-18 Map indicating all the confirmed (red triangles) and suspected (blue dots) outbreaks of contagious bovine pleuropneumonia in the different regions of the northern communal areas of Namibia during 2008

Table 3-17 Regions where cattle were vaccinated for CBPP during 2008 indicating the number of vaccine doses used and the percent covarage of the population at risk.

Region	Vaccination	Census	% Coverage
Zambezi	134 451	141 765	94,84
Kavango	0	125927	0
Tsumkwe (Otjozoundjupa)	0	4077	0
Oshikoto	177 132	203 726	86,95
Kunene North	133 683	217 879	61,36
Omusati	213 801	219 668	97,33
Oshana	90 887	93 427	97,2813
Ohangwena	141 493	155 078	91,24
Total	891 447	1161547	76,74

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2009

In 2009, the disease was confirmed in 3 regions: Omusati, Oshikoto and Ohangwena in the order of highest to lowest incidence rate. Four outbreaks were laboratory-confirmed with 27 diseased animals with no mortalities. There were only 2 suspected (unconfirmed) outbreaks in Zambezi region which involved 3 diseased animals and 2 mortalities. Details of the outbreaks per region are given in Table 3-18. The geographical distribution of all the suspected and confirmed cases during 2009 is presented in Figure 3-19. Vaccination was performed in Kunene north, Kavango, Zambezi and in the NCA except in Tsumkwe with a total of 888 105 doses being used and an 84, 77% coverage of the population at risk. Details of the cattle census and vaccine doses used are given inTable 3-19.

Table 3-18 Summary of confirmed and suspected outbreaks as well as the crude incidence- and mortality rates of CBPP in the northern communal areas of Namibia in 2009. Mortality and incidence rates were calculated at 95% confidence intervals and indicated in [ ]

Region	Number of outbreaks	Number of Sick	Number of Deaths	Incidence rate (per 100 000)	Mortality rate (per 100 000)
Zambezi	(2)	(3)	(2)	1,99 [0,4-5,8]	1,33 [0,2-8,8]
Ohangwena	1	3	0	2,88 [0,6-8.4]	0 [0-0]
Omusati	2	14	0	6,56 [3,6-11]	0 [0-0]
Oshikoto	1	10	0	7,36 [3,5-13,5]	0 [0-0]
Study Area	6	30	2	2,86 [1,9-4,1]	0,19 [0-0,7]

( ) indicates number of suspicious outbreaks

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Figure 3-19 Map indicating all the confirmed (red triangles) and suspected (blue dots) outbreaks of contagious bovine pleuropneumonia in the different regions of the northern communal areas of Namibia during 2009

Table 3-19 Regions where cattle were vaccinated for CBPP during 2009 indicating the number of vaccine doses used and the percent covarage of the population at risk.

Region	Vaccination	Census	% Coverage
Zambezi	137 129	150 853	90,90
Kavango	120 845	127 960	94,44
Tsumkwe (Otjozoundjupa)	0	4077	0
Oshikoto	124 275	135 845	91,48
Kunene North	117 219	217 879	53,80
Omusati	206 251	213 447	96,63
Oshana	86 901	93 427	93,02
Ohangwena	95 485	104 199	91,64
Total	888 105	1 047 687	84,77

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2010

CBPP was confirmed in 3 regions: Omusati, Ohangwena and Zambezi with a total of 14 diseased animals and 1 mortality. Ten suspected (unconfirmed) outbreaks were reported with no morbidity or mortalities being reported. Details of the outbreaks per region are given in

Table 3-20. The geographical distribution of all the suspected and confirmed cases during 2010 is presented in Figure 3-20. The annual vaccination campaigns were performed in Kunene north, Kavango and in the NCA and there is no record for Zambezi and Tsumkwe. A total of 997 713 cattle were vaccinated with a 79, 87% coverage of the population at risk. Details of the cattle census and vaccine doses used are given in Table 3-21.

Table 3-20 Summary of confirmed and suspected outbreaks as well as the crude incidence- and mortality rates of CBPP in the northern communal areas of Namibia in 2010. Mortality and incidence rates were calculated at 95% confidence intervals and indicated in [ ]

Region	Number of Outbreaks	Number of Sick	Number of Deaths	Incidence rate (per 100 000)	Mortality rate (per 100 000)
Zambezi	1(1)	1	1	0,66 [0-3,7]	0,66 [0-3,7]
Omusati	1(3)	5	0	1,80 [0,6-4,2]	0 [0-0]
Ohangwena	1(3)	8	0	4,11 [1,8-8,1]	0 [0-0]
Oshana	(1)	0	0	0 [0-0]	0 [0-0]
Oshikoto	(2)	0	0	0 [0-0]	0 [0-0]
Study Area	13	14	1	1,12 [0,6-1,9]	0,08 [0-0,4]

( ) indicates number of suspicious outbreaks

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Figure 3-20 Map indicating all the confirmed (red triangles) and suspected (blue dots) outbreaks of contagious bovine pleuropneumonia in the different regions of the northern communal areas of Namibia during 2010

Table 3-21 Regions where cattle were vaccinated for CBPP during 2010 indicating the number of vaccine doses used and the percent covarage of the population at risk.

Region	Vaccination	Census	% Coverage
Zambezi	0	151765	0
Kavango	116 889	130 000	89,91
Tsumkwe (Otjozoundjupa)	0	4077	0
Oshikoto	211 391	236 829	89,26
Kunene North	133 567	148 083	90,20
Omusati	259 791	277 016	93,78
Oshana	103 048	106 919	96,38
Ohangwena	173 027	194 418	90,00
Total	997 713	1 249 107	79,87

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2011

In 2007, only Ohangwena region was confirmed CBPP with twenty cattle were reported sick and 5 mortalities during the outbreak. A further 4 suspected (unconfirmed) outbreaks were reported which involved 20 diseased animals with 4 mortalities. Details of the outbreaks per region are given in

Table 3-22. The geographical distribution of all the suspected and confirmed cases during 2011 is presented in Figure 3-21. Vaccination was performed in Kunene north, Kavango, Zambezi and in the NCA with a total of 1 253 390 doses being used and a 90, 14 % coverage of the population at risk. Details of the cattle census and vaccine doses used are given in Table 3-23.

Table 3-22 Summary of confirmed and suspected outbreaks as well as the crude incidence- and mortality rates of CBPP in the northern communal areas of Namibia in 2011. Mortality and incidence rates were calculated at 95% confidence intervals and indicated in [ ]

Region	Number of outbreaks	Number of sick	Number Dead	Incidence rate (per 100 000)	Mortality rate (per 100 000)
Ohangwena	2(2)	20(16)	5(4)	18,43 [12,9-25,5]	4,61 [2,1-8,7]
Omusati	(2)	(4)	0	1,25 [0,3-3,3]	0 [0-0]
Study Area	6	40	9	2,88 [2,1-3,9]	0,65 [0,3-1,2]

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Figure 3-21 Map indicating all the confirmed (red triangles) and suspected (blue dots) outbreaks of contagious bovine pleuropneumonia in the different regions of the northern communal areas of Namibia during 2011

Table 3-23 Regions where cattle were vaccinated for CBPP during 2011 indicating the number of vaccine doses used and the percent covarage of the population at risk.

Region	Vaccination	Census	% Coverage
Zambezi	120 240	135 861	88,50
Kavango	126 569	142 172	89,03
Tsumkwe (Otjozoundjupa)	0	4077	0
Oshikoto	230 115	272 680	84,39
Kunene North	165 445	181 742	91,03
Omusati	284 411	320 000	88,88
Oshana	119 391	138 701	86,08
Ohangwena	207 219	195 302	106,10
Total	1 253 390	1 390 535	90,14

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2012

Three CBPP outbreaks were laboratory confirmed in Kunene and Ohangwena regions with twenty four diseased cattle and 10 deaths reported during these three outbreaks. There were 4 suspected (unconfirmed) which involved 23 diseased animals and 4 mortalities. Details of the outbreaks per region are given in

Table 3-24. The geographical distribution of all the suspected and confirmed cases during 2012 is presented in Figure 3-22. Vaccination was performed in Kunene north, Kavango, Zambezi and in the NCA with a total of 1 253 380 doses being used and a 90, 13% coverage of the population at risk. Details of the cattle census and vaccine doses used are given in Table 3-25.

Table 3-24 Summary of confirmed and suspected outbreaks as well as the crude incidence- and mortality rates of CBPP in the northern communal areas of Namibia in 2012. Mortality and incidence rates were calculated at 95% confidence intervals and indicated in [ ]

Region	Number of Outbreaks	Number of Sick	Number dead	Incidence rate (per 100 000)	Mortality rate (per 100 000)
Oshikoto	(1)	(3)	(1)	1,10 [0,2-3,2]	0,37 [0-2]
Oshana	(1)	(11)	0	7,93 [4-14,2]	0 [0-0]
Ohangwena	1	3	1	1,54 [0,3-3,7]	0,51 [0-2,3]
Omusati	(2)	(9)	(3)	2,81 [1,3-5,3]	0,94 [0,2-2,7]
Kunene North	2	21	9	11,55 [7,2-17,7]	4,95 [2,3-9,4]
Study Area	7	47	14	3,38 [2,5-4,5]	1,01 [0,6-1,7]

( ) indicates number of suspicious outbreaks

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Figure 3-22 Map indicating all the confirmed (red triangles) and suspected (blue dots) outbreaks of contagious bovine pleuropneumonia in the different regions of the northern communal areas of Namibia during 2012

Table 3-25 Regions where cattle were vaccinated for CBPP during 2012 indicating the number of vaccine doses used and the percent covarage of the population at risk.

Region	Vaccination	Census	% Coverage
Zambezi	120 240	135 861	88,50
Kavango	126 569	142 172	89,03
Tsumkwe (Otjozoundjupa)	0	4077	0
Oshikoto	230 115	272 680	84,39
Kunene North	165 445	181 742	91,03
Omusati	284 411	320 000	88,88
Oshana	119 381	138 701	86,07
Ohangwena	207 219	240 000	86,34
Total	1 253 380	1 390 535	90,13

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2013

CBPP was confirmed in 3 regions: Oshikoto, Kunene North and Omusati in the order of highest to lowest incidence rate. A total of nine outbreaks were laboratory-confirmed and involved 66 diseased animals with 23 mortalities. Details of the outbreaks per region are given in

Table 3-26 . The geographical distribution of all the suspected and confirmed cases during 2013 is presented in Figure 3-23. Vaccination was performed in Kunene north, Kavango, Zambezi, Tsumkwe and in the NCA with a total of 1 162 614 doses being used and a 77, 37 % coverage of the population at risk. Details of the cattle census and vaccine doses used are given in Table 3-26.

Table 3-26 Summary of confirmed and suspected outbreaks as well as the crude incidence- and mortality rates of CBPP in the northern communal areas of Namibia in 2013. Mortality and incidence rates were calculated at 95% confidence intervals and indicated in [ ]

Region	Number of outbreaks	Number of Sick	Number Dead	Incidence rate (per 100 000)	Mortality rate (per 100 000)
Oshikoto	6(2)	53	21	18.72 [14-24,5]	7,42 [4,6-11,3]
Omusati	1(6)	1	0	0,30 [0-1,7]	0 [0-1,1]
Kunene North	2(2)	12	2	6,41 [3,3-11,2]	1,07 [0,1-3,9]
Ohangwena	(2)	0	0	0 [0-0]	0 [0-0]
Kavango East	(1)	0	0	0 [0-0]	0 [0-0]
Study Area	22	66	23	4,39 [3,4-5,6]	1,53 [1-2,3]

( ) indicates number of suspicious outbreaks

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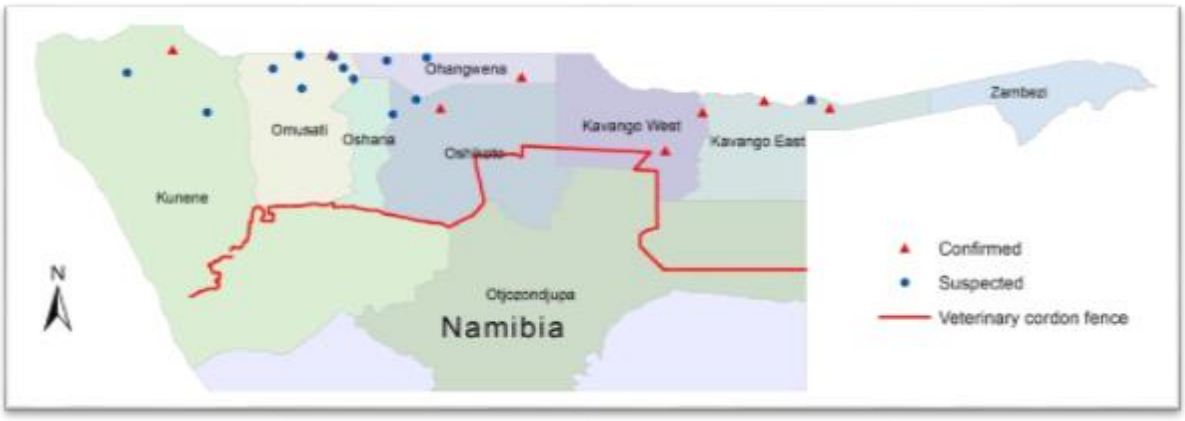

Figure 3-23 Map indicating all the confirmed (red triangles) and suspected (blue dots) outbreaks of contagious bovine pleuropneumonia in the different regions of the northern communal areas of Namibia during 2013

Table 3-27 Regions where cattle were vaccinated for CBPP during 2013 indicating the number of vaccine doses used and the percent covarage of the population at risk.

Region	Vaccination	Census	% Coverage
Zambezi	70 074	159 259	44,00
Kavango	135 008	136 623	98,82
Tsumkwe (Otjozoundjupa)	4 954	7 005	70,72
Oshikoto	274 449	283 088	96,95
Kunene North	58 549	187 226	31,27
Omusati	278 110	332 584	83,62
Oshana	147 164	156 798	93,86
Ohangwena	194 306	240 000	80,96
Total	1 162 614	1 502 583	77,37

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Chapter 4

Discussions

The retrospective analysis of the CBPP outbreaks from 2001 to 2013 brought up very interesting results. It is clear that CBPP is confined to the NCA especially in regions that share open border with Angola. Zambezi, Oshikoto, Ohangwena, Omusati, Kunene and Kavango are the hot spots in order of number of outbreaks recorded during the period under study. The DVS has been conducting CBPP annual vaccination campaign to reduce the risk of outbreaks.

The highest numbers of outbreaks were recorded in 2005 with 11 laboratory confirmed outbreaks in the NCA. Zambezi and Kunene North regions were the most affected. In 2001 and 2013 Namibia experienced 9 laboratory confirmed outbreaks in each year affecting Oshikoto, Kavango and Ohangwena regions. In 2006, 8 outbreaks were reported and this was a slight reduction after 2005 when Namibia had 11 reported outbreaks in the NCA. From 2002-2004, 6 outbreaks were recorded for each year. It's important to note that from 2007 up to 2012; isolated outbreaks with less than 5 laboratory confirmed outbreaks were recorded.

Zambezi region, previously known as Caprivi region had a cumulative total of 20 outbreaks within the period under study. This could be due to the fact that the vaccination only targeted areas along the border with Zambia were the risk was highest neglecting other parts of the region. The census for Zambezi region is about 151 100 cattle and the targeted census along the Zambian border was 17 307.

Most of the outbreaks occurred in the four "O" regions that is Ohangwena, Oshikoto, Oshana and Omusati. A total of 37 outbreaks were recorded in the NCA.

It is evident that despite good vaccination coverage, outbreaks still occurred. From the above data it is clear that even if good vaccination coverage, there can still be outbreaks of CBPP. The disease cannot be eradicated alone with annual vaccinations. Other factor such as the open border between Namibia

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and Angola that facilitates free movement of animals between the two countries has to be addressed first.

The source of CBPP has not been established in this study but several possibilities exist: The open border between Namibia and Angola will forever pose a challenge to the Namibian herd with transboundary animal diseases. Namibian animals freely cross into Angola in search of grazing.

4.1. The potential risk factors associated with the outbreaks of CBPP in the northern communal areas of Namibia

The cattle population in the NCA almost doubled over the past years. This is thought to be due to reduced marketing opportunities and partly to a preference to keep animals as a store of wealth gained from other income-earning activities (Bishi and Kamwi 2008). There has been growth in the human population which might also contribute to the increase in cattle population. Since 2001 the human population in the NCA, where many of the communal cattle are located, has grown by 11% (GRN 2005), while the cattle population has fluctuated but overall grew by around 20% during the same period (GRN 2005).

The livestock population in the NCA would be unable to survive at current levels and with existing grazing resources without access to Angolan grazing. Close to 148 000 cattle raised within 10 km of the border are dependent on Angolan rangelands for sustenance for most of the year.

Human communities that live along the Namibia-Angola border together with their livestock move freely across the border in both directions. Immediate families stay across the border. Namibian livestock move to Angola and back in a transhumant pattern in search of grazing, while Angolan livestock are taken to water in Namibia. Animals are traded, given, lent and stolen across the border. Local cross-border movement is accepted by both countries, for those who choose to cross at official border points, a document known as a "border pass" is available if they remain within 30km of the border. This is accepted by governments on both sides.

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Currently, a live attenuated culture of the causative organism strain T1/44 is used as a vaccine of choice. Although it confers some level of immunity, the T1/44 vaccine has certain drawbacks that include low efficacy (Thiaucourt *et al.,* 2000) and a short duration of immunity. Further, the vaccine causes adverse post-vicinal reactions at the site of inoculation leading to poor acceptance by farmers (Kusiluka and Sudi, 2003; Sori, 2005). It has been reported that the vaccine has poor stability (short shelf life), hence the requirement for a cold chain during delivery (Rweyemamu *et al*., 1995) and there is the possibility of reversion to virulence (Mbulu *et al*., 2004).

4.2. Limitations

There was a difference in the reporting format for different years. Before 2007, all the four "O regions" were being managed as one under the supervision of Ondangwa Veterinary Office. Regions such as Ohangwena, Oshikoto, Oshana and Omusati were being reported as one. Some full details were missed along the way.

Ideally livestock and livestock products are imported into Namibia through specified entry points and imports are controlled centrally through a permit system. The import permits specify the conditions under which the animals or animal product may be imported. All imported cattle are required to be branded by a clearly recognisable brand on the left cheek before arrival. The movement of imported animals will be traced and will not be allowed to enter the export abattoirs. However, these controls are not fully enforced when it comes to animals from Angola. Despite the fact that these cattle are clinically examined by veterinary staff to rule out presence of CBPP and FMD signs and vaccinated against CBPP upon entry through official crossing points; and hot iron branded with an "A" brand to indicate their origin as Angola, there is no quarantine of these animals before they are allowed to mingle with local livestock. Namibian livestock also graze in Angola within the allowed 30km zone where they may mingle with potentially infected cattle where on the other side of the border.

With the open border situation between Namibia and Angola, there is free movement of animals to and from Angola and NamLITS only works here in Namibia and will not be able to trace movement and any health events to animals that have crossed into Angola.

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Another limitation is the inability of DVS to establish the attack rate following an outbreak. DVS is not there to record all subsequent clinical cases and deaths to the end of each outbreak focus.

4.3. Further research

This study tried to bring together all the information regarding CBPP outbreaks in the NCA of Namibia from 2001 to 2013. Despite the efforts by the DVS to conduct annual vaccinations, these repeated outbreaks pose questions that require answers as to what triggers them. There might be need for further research into the efficacy of the vaccine that is being used.

Studies were done to compare the protective capacity of the live T1/44 vaccine with two inactivated preparations of Mmm strain Afadé, inoculated with an adjuvant. The Protection was measured after a challenge with Afadé and the protection levels were 31%, 80.8% and 74.1% for the formalin-inactivated, heat-inactivated and live attenuated preparations, respectively. These findings indicate that low doses of heat-inactivated Mmm can offer protection to a level similar to the current live attenuated (T1/44) vaccine formulation (Mwirigi *et al*, 2015). It will be beneficial if such trials are to be done here in Namibia as well to try and have a substitute for the live T1/44 vaccine that has been reported to have poor stability (short shelf life), hence the requirement for a cold chain during delivery (Rweyemamu *et al*., 1995) and there is the possibility of reversion to virulence (Mbulu *et al*., 2004).

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Chapter 5

Conclusions and Recommendations

5.1. Conclusions

The study described the temporal and spatial distribution of CBPP in the NCA of Namibia, from 2001 to 2013. There are still significant outbreaks in these regions under the current control measures. The regions that are at higher risk of being affected by CBPP are Omusati, Ohangwena, Kavango, Kunene and Zambezi. The role of the open-border policy between Namibia and Angola was not investigated in this study but could play an important role. It is important to maintain high herd immunity by conducting annual vaccination campaigns as before so that future outbreaks are minimized.

Other activities such as FMD vaccinations may disrupt the CBPP vaccinations especially if priority is being given to FMD because of its trade implications, but it is important to equally consider CBPP and continue with all measures that can be put in place to prevent future outbreaks.

5.2. Recommendations

All regions in the NCA should continue with CBPP vaccinations as long as the Namibian-Angolan border is porous and there is free movement of animals across. Namibia should erect the border fence along the Namibia-Angolan border for disease control purposes as outlined in the FMD and CBPP freedom project.

It has been shown that low doses of heat-inactivated Mmm can offer protection to a level similar to the current live attenuated (T1/44) vaccine formulation. It will be beneficial if such trials are to be done here in Namibia as well to try and have a substitute for the live T1/44 vaccine) that has been reported to have has poor stability (short shelf life), hence the requirement for a cold chain during delivery and there is the possibility of reversion to virulence

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Appendix

Animal Ethics Approval

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Animal Ethics Committee

PROJECT TITLE	**A retrospective analysis of the epidemiology and control measures of contagious bovine pleuropneumonia in the northern communal areas of Namibia from 2001-2013**
PROJECT NUMBER	**V068-16**
RESEARCHER/PRINCIPAL INVESTIGATOR	**P Mbiri**

STUDENT NUMBER (where applicable)	**UP_14447534**
DISSERTATION/THESIS SUBMITTED FOR	**MSc**

ANIMAL SPECIES	n/a	
NUMBER OF ANIMALS	n/a	
Approval period to use animals for research/testing purposes		**June 2016 –June 2017**
SUPERVISOR	**Dr. J Crafford**	

KINDLY NOTE:

Should there be a change in the species or number of animal/s required, or the experimental procedure/s - please submit an amendment form to the UP Animal Ethics Committee for approval before commencing with the experiment

APPROVED	Date	27 June 2016
CHAIRMAN: UP Animal Ethics Committee	Signature	

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