



Incidence of Contagious Bovine Pleuropneumonia in the Northern Regions of Namibia

Pricilla Mbiri¹, Erick Kandiwa¹, Borden Mushonga¹, Alaster Samkange^{1*}, Alec S. Bishi¹, Oscar Madzingira¹, Frank Chitate¹

¹School of Veterinary Medicine, Faculty of Agriculture and Natural Resources, University of Namibia, Private Bag 13301, Pionierspark, Windhoek, Namibia

ABSTRACT

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*Correspondence to:

alastersamkange@gmail.com

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A 25-year retrospective study investigated the incidence of contagious bovine pleuropneumonia (CBPP) in the northern communal areas of Namibia. Throughout the study period, the proportion of bovine animals that clinically recovered following treatment of suspected CBPP infection were greater than those that died from suspected CBPP infection (71.6% and 28.4%, respectively, $N=4743$; $z=42.16$, $p<.001$). The proportion of unconfirmed CBPP diagnoses was greater than that of confirmed cases (65.4% and 34.6%, respectively, $z=30.04$, $p<.001$). More animals died from confirmed CBPP infection in the North Central Regions (NCR) and Zambezi region (5.4% and 4.1%, respectively) than in Kavango (East and West) and Kunene regions (2.1% and 0.5%, respectively; $p<.05$). Kavango regions had the greatest proportion of animals (7.9%; $p<.05$) that clinically recovered following treatment of confirmed CBPP infection whilst more animals in NCR and Kunene region recovered following treatment of unconfirmed CBPP (41.6% and 1.0%, respectively; $p<.05$). The NCR and Kunene region had greater proportions of animals that died from unconfirmed CBPP infections (9.1% and 1.0%, respectively; $p<.05$). More animals than expected died of confirmed CBPP in 1990, 1995, 2000, 2002, 2003 and 2004 ($p<.05$) whereas more animals than expected died of suspected CBPP in 1990, 1991, 1993 and 2004 ($p<.05$). Overall, the majority of animals died of confirmed CBPP in April, August and December (2.8%, 1.9% and 0.7%, respectively, $p<.05$). The highest CBPP vaccination coverage was achieved in 2003, 2004, 2009, 2011 and 2012 (96.6%, 82.6%, 84.8%, 90.1% and 90.1%; respectively). The greatest CBPP incidence rates (per 100 000) occurred in 1995, 1996, 1997, 1998 and 2003 (54.1, 43.4, 75.3, 106.2 and 25.5, respectively). The highest CBPP-related mortalities (per 100 000) occurred in 1995, 1996, 1997, 1998 and 2004 (25.3, 11.1, 17.2, 11.9 and 15.6, respectively). Although the incidence of CBPP cases has decreased, control of the disease remains a challenge because of cross-border livestock movements between northern Namibia and southern Angola.

1. INTRODUCTION

Contagious bovine pleuropneumonia (CBPP) is an OIE-Listed transboundary, pneumonic disease of cattle, now considered the most important disease since the eradication of rinderpest (Francis et al., 2015; Mamo et al., 2018). The disease is a major challenge to cattle production in sub-Saharan Africa (Amanfu, 2009; Muuka, 2013; Tambi et al., 2006) through its impact on livestock health, loss of revenue by farmers (stock losses) and treatment costs

(Jores et al., 2013; Otte et al., 2004). Affected countries experience revenue losses due to costly disease control and prevention programs, farmer compensation, international trade embargoes and medium to long-term reduction in livestock investment (Abdela and Yune, 2017; Demil, 2017; Nkando et al., 2012).

CBPP is caused by *Mycoplasma mycoides* subspecies *mycoides* (Mmm) (Teodoro et al., 2018). The disease is endemic in sub-Saharan Africa (Francis et al.,

2015) where it causes significant morbidity and mortality (Malicha et al., 2017; Muuka, 2013). Age, sex, vicinity to game parks, breed, poor body condition, dry seasons, purpose of rearing (draft power), uncontrolled animal movements and mixed grazing predispose animals to CBPP (Alhaji et al., 2016; Séry et al., 2015). Transmission occurs through aerosols and by direct contact (Lesnoff et al., 2004; Radostits et al., 2007). Lung lesions (sequestra) in subclinical cases are a source of infection for several months to years, especially under stressful conditions (Spickler, 2015). Diagnosis of CBPP, based on clinical signs (fever, anorexia, dyspnoea, polypnea, nasal discharge, coughing, abortion and arthritis), is less reliable due to inconsistency and non-specificity of these signs (Daniel et al., 2017; Hübschle et al., 2006; Schnee et al., 2011). Post mortem findings (pericarditis, peritonitis, lung consolidation, serofibrinous pleuropneumonia and pleural effusions) are more reliable for diagnosis, although, OIE-recommended serological tests (ELISA, complement fixation test and immunoblotting) are commonly used for screening and confirmation (Daniel et al., 2017; Thiaucourt, 2018). Culture and PCR of *M. mycoides* var *mycoides* are also important for confirmation of CBPP infections (Amanfu, 2009; Schnee et al., 2011).

Treatment with long acting tetracyclines, fluoroquinolones and macrolides has been attempted, both, *in vivo* and *in vitro* with varying degrees of success (Amanfu, 2009; Hübschle et al., 2004; Mitchell et al., 2012; Niang et al., 2010). Treatment is known to create carriers which tend to harbour infections in affected herds (Niang et al., 2010; Yaya et al., 2003). Control of CBPP is achieved through quarantine, movement control, culling, treatment and vaccination; strategies which are very expensive and impractical for farmers in most African countries (Abdela and Yune, 2017; Kairu-Wanyoike et al., 2014; Mwirigi et al., 2016). The role of surveillance, which is backed by strong field and laboratory services, as well as disease control through mass vaccinations, cannot be overemphasised (Demil, 2017). The disease has been eradicated from much of southern Africa including South Africa, Botswana, Zimbabwe (Amanfu, 2009) and much of Zambia and Namibia. The disease has remained endemic in southern Angola (Daniel et al., 2017; Jores et al., 2013) and the northern communal areas of Namibia.

Since the first outbreak of CBPP in Namibia at Warmbad in 1856 (Thiaucourt et al., 2004), sporadic outbreaks have been associated with climatically and politically instigated human movements across the Namibia-Angola border (Van Wolputte, 2015). By 1919 CBPP had been eradicated

from all commercial farms south of the Veterinary Cordon Fence (VCF), thus confining the disease to the northern communal areas of Namibia (Schneider, 1994). Vaccination campaigns within communal farmlands in the last 95 years, however, have failed to eradicate CBPP from these areas (Hübschle et al., 2004). In an attempt to control CBPP, the Directorate of Veterinary Services (DVS) in Namibia has used different vaccines and different formulations (Kabete, KH3J strain, V5 strain, T1/SR and T1/44), with varying degrees of success (Schieck et al., 2014). The use of T1/44 since 1997 led to dramatic reduction in the number of CBPP outbreaks. The Kunene, Ohangwena, Omusati and Kavango regions lying north of the VCF and along the border with Angola are at high risk of CBPP outbreaks (Provost et al., 1987).

Several studies have separately reported on Namibian CBPP outbreaks and history in the last three decades (Hübschle et al., 2004; Huebschle et al., 2006; Mbulu et al., 2004; Scacchia et al., 2011; Schneider, 1994; Van Wolputte, 2015). Given the vast economic significance of CBPP, the aim of this study was to investigate and characterize the longitudinal pattern of this disease in Namibia in order to provide critical information for its future control and, possibly, eradication. A similar study over a 20-year duration was undertaken in Ethiopia (Abdela and Yune, 2017).

2. MATERIALS AND METHODS

2.1 Study area

This study was based on data gathered from 1990 to 2014 by state veterinarians in the North Central Regions (Omusati, Ohangwena, Oshikoto and Oshana), Kunene, Kavango (later Kavango East and Kavango West) and Caprivi (later Zambezi). Of these regions, Kunene and Oshikoto straddle the Veterinary Cordon Fence (VCF/Red line) which separates the northern regions from the central and southern regions of Namibia. Most farm land in the northern regions is communal and therefore lacks fences to control livestock movements. Mixed grazing and shared watering points are the norm in these communal farm lands. Most farm land in the central and southern regions which are south of the VCF is commercial, with fences that separate livestock from different farms. The vegetation in Kavango East, Kavango West and Zambezi regions is mostly savanna woodlands with annual precipitation ranging from 500-700mm. The vegetation in the NCR is Mopane Savanna with annual precipitation of not more than 500mm.

2.2 Study animals

The bovine population in the eight regions (Oshana, Oshikoto, Omusati, Ohangwena, Kavango East, Kavango West, Zambezi and the northern part of Kunene) under study between 1990 and 2014 constituted the animals at risk of contracting CBPP infection during the study period. The annual bovine census figures by the Directorate of Veterinary Services (DVS) in these areas were used as the denominator population at risk.

2.3 Diagnosis of CBPP

Preliminary diagnosis of CBPP by DVS was based on clinical signs (fever, anorexia, dyspnoea, polypnea, nasal discharge, coughing, abortion and arthritis) and the epidemiological picture. In some cases, the latex agglutination test was used to confirm diagnosis in the field. In this test, whole blood or serum was mixed with a suspension of killed and stained *M. mycoides* organisms for the detection of agglutinating antibodies. Laboratory confirmation was carried out, whenever possible, at the Central Veterinary Laboratory (CVL) using the complement fixation test (CFT) to detect antibodies against *M. mycoides* in serum samples. The peroxidase-antiperoxidase (PAP) test was used for histopathological confirmation of CBPP on formalin-fixed lung tissues from suspected CBPP cases. Pathological diagnosis of CBPP was based on the accumulation of yellow fluid around uncollapsed lungs and on marbled lungs and pleuritis. Pleural

fluid and diseased lungs from suspected CBPP cases were also sent to the CVL for culture, isolation and identification of *M. mycoides* in Mycoplasma Experience (ME) broth and agar medium (Mycoplasma Experience, Reigate, Surrey, United Kingdom). All cattle suspected of CBPP infection were treated with oxytetracycline or tylosin until clinical recovery.

2.4 Data Collection

Data was sourced from the Epidemiology section of the Directorate of Veterinary Services in Namibia with the permission of the Chief Veterinary Officer. All the information regarding suspected and confirmed CBPP cases were 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 the number of animals at risk. These forms were submitted to the Epidemiology section where the data was captured and made available in both paper and electronic formats (Fig.1). 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 conducted with guiding key words such as “CBPP” and “Namibia” on databases such as PubMed, Science Direct and CAB direct.

B	C	D	E	F	G	H	I	J	K	L
Date	Year	Months	Farm ID	Mag Dist	Species	Number Sick	Number Dead	Tentative Diag	Longitude	Latitude
26/06/01	2001	6	1	4NCD	BO	1	1	CBPP	16.15	-17.82
12/03/01	2001	3	2	KAVA	BO	5	4	CBPP	19.21	-18.20
25/06/01	2001	6	3	4NCD	BO	5	0	CBPP	15.06	-17.44
26/03/01	2001	3	4	KAVA	BO	3	4	CBPP	18.23	-17.86
01/03/01	2001	3	5	KAVA	BO	2	6	CBPP	18.81	-17.81
21/09/01	2001	9	6	4NCD	BO	5	0	CBPP	16.07	-17.80
11/05/01	2001	5	7	4NCD	BO	2	0	CBPP	16.20	-17.78
27/09/01	2001	9	8	4NCD	BO	2	0	CBPP	16.06	-17.56
09/05/01	2001	5	9	KAVA	BO	2	3	CBPP	19.06	-17.81
28/03/01	2001	3	10	KAVA	BO	3	4	CBPP?	19.87	-18.19
11/05/01	2001	5	11	4NCD	BO	4	0	CBPP?	17.66	-18.50
22/01/01	2001	1	12	KAVA	BO	1	1	CBPP?	18.81	-17.81
23/04/01	2001	4	13	KAVA	BO	3	8	CBPP?	18.19	-17.69
02/03/01	2001	3	14	KAVA	BO	4	8	CBPP?	18.81	-17.81
15/02/01	2001	2	15	4NCD	BO	0	10	CBPP?	15.87	-18.02
17/05/01	2001	5	16	4NCD	BO	7	0	CBPP?	16.94	-17.94
10/07/01	2001	7	17	4NCD	BO	4	1	CBPP?	15.08	-17.57
04/06/01	2001	6	18	4NCD	BO	4	0	CBPP?	16.29	-18.06
24/01/01	2001	1	19	KUNE	BO	1	3	CBPP?	13.27	-17.43

Fig. 1. Example of Data Sheet from an area

2.5 Statistical analysis

The Shapiro-Wilk test confirmed that the study population, over the 25-year study period, had a normal distribution ($W=0.95$). The Chi-square test

and post hoc adjusted residuals was then performed to test the dependence of four categories (sick animals with confirmed CBPP infection, dead animals with confirmed CBPP infection, sick animals

with unconfirmed CBPP infection and dead animals with unconfirmed CBPP infections) on the year, month and region. In 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. The analysed data excludes all suspected cases that were confirmed negative following further investigation. The annual CBPP incidence and mortality rates for the overall study area and for the four regions were separately determined at 95% confidence level. The Z-test for comparison of proportions was also used at 95% confidence level. The Statistical Package for Social Sciences (SPSS) version 25 was used for Chi-square analysis and Microsoft Excel 2013 was used for determination of CBPP incidence and mortality rates.

3. RESULTS

The results of this study are reported in four parts; z-scores and significance of the comparison of proportions of unconfirmed and confirmed cases, the Chi-square test results (with post hoc adjusted residuals) from tests for independence/dependence of sick and dead cases according to months, years and regions, the annual incident rates of CBPP and resulting mortality rates and the spatial distribution of foci of CBPP cases throughout the study period.

As shown in Table 1, a greater proportion of CBPP cases were not confirmed (65.4%, N=4743; $z=30.04$, $p<0.001$), whilst a greater proportion of CBPP confirmed were successfully treated (71.6%, N=4743; $z=42.16$, $p<0.001$). The overall proportion of CBPP suspected cases with confirmed disease that died (12.1%) and that of sick bovines with unconfirmed CBPP infection (49.1%) were greater than expected [$X^2(1, N=4743) = 52.46$, $p<0.05$].

As shown in Table 2, the distribution of animal sickness and death due to confirmed/unconfirmed CBPP were dependent on the region; $X^2(9, N=4743) = 964.57$, $p<0.001$. The proportion of animals that died from confirmed CBPP were greater in the NCR and Zambezi (5.4% and 4.1%, respectively; $p<0.05$) than in Kavango (East and West combined) and Kunene, whilst those that died from unconfirmed CBPP infections were greater in the NCR and Kunene (9.1% and 1.0%, respectively; $p<0.05$). Animals that got sick and recovered from confirmed CBPP infections were greatest in Kavango (East & West) (7.9%; $p<0.05$) whilst those that got sick and recovered from unconfirmed CBPP infections were greater in the NCR and northern Kunene (41.6% and 1.0%, respectively; $p<0.05$) than in the rest of the regions under study.

Table 1: The number and proportion of cattle that died or became sick from confirmed or unconfirmed CBPP infections.

Diagnostic status	Condition of animals		
	Number of sick animals (%)	Number of dead animals (%)	Total (%)
Confirmed CBPP	1068 (22.5)	572 (12.1)*	1640 (34.6)
Unconfirmed CBPP	2330 (49.1)*	773 (16.3)	3103 (65.4)
Total	3398 (71.6)	1345 (28.4)	4743 (100.0)

*These values were significantly greater than expected since $p<0.05$

Table 2: The 25-year categorical distribution of CBPP cases according to region

Region	CBPP confirmed sick (%)	CBPP confirmed dead (%)	CBPP suspected sick (%)	CBPP suspected dead (%)	Total (%)
NCR	438 (9.2)	257 (5.4)*	1971 (41.6)*	433 (9.1)*	3099 (65.3)
Zambezi	199 (4.2)	193 (4.1)*	130 (2.7)	93 (2.0)	615 (13.0)
Kavango	375 (7.9)*	98 (2.1)	181 (3.8)	198 (4.2)	852 (18.0)
Kunene	56 (1.2)	24 (.5)	48 (1.0)*	49 (1.0)*	177 (3.7)
Total	1068 (22.5)	572 (12.1)	2330 (49.1)	773 (16.3)	4743 (100.0)

*These values were significantly greater than expected since $p<0.05$

As shown in Table 3, the distribution of bovine sickness and death due to confirmed/unconfirmed CBPP were dependent on the year; $X^2(72, N=4743) = 2973.82$, $p<0.0001$. The overall annual proportions

of sick animals with confirmed CBPP infections were greater than in 1992, 2000, 2002, 2003, 2005, 2008 and 2009, ($p<0.05$) than in the other years. The overall proportion of dead animals with confirmed

CBPP infections were greater in 1990, 1995, 2000, 2002, 2003 and 2004 ($p < 0.05$) than in the other years. The overall annual proportions of sick animals with unconfirmed CBPP infections were greater than expected in 1996, 1997 and 1998 ($p < 0.05$). The overall annual proportions of dead animals with unconfirmed CBPP infections were greater than expected in 1990, 1991, 1993 and 2004 ($p < 0.05$). As shown in Table 4, the distribution of animal sickness and death due to confirmed/unconfirmed CBPP were varied with the month; $X^2 (33, N=4743) = 920.05$, $p < 0.001$.

Throughout the study period, the proportion of animals that recovered from confirmed CBPP infections were more than expected in the months of January, August, October and December (6.3%, 3.4%, 1.0% and .8%; respectively) whilst those that died from confirmed CBPP infections were more than expected in April, August and December (2.8%,

1.9% and .7%; respectively). The proportion of animals that recovered from unconfirmed CBPP infections were more than expected in the months of February, June and September (8%, 6.9% and 1.6%; respectively) whilst those that died from unconfirmed CBPP infections were more than expected in the months of March, July and November (4%, 2% and 1.5%; respectively). As shown in Table 5, the highest levels of overall vaccine coverage were achieved in 2003, 2004, 2009, 2011 and 2012 (96.6%, 82.6%, 84.8%, 90.1% and 90.1%; respectively). The highest CBPP incidence rates (per 100 000) occurred in 1995, 1996, 1997, 1998 and 2003 (54.1, 43.4, 75.3, 106.2 and 25.5; respectively). The highest CBPP-related mortality (per 100 000) occurred in 1995, 1996, 1997, 1998 and 2004 (25.3, 11.1, 17.2, 11.9 and 15.6; respectively).

Table 3: The 25-year categorical distribution of CBPP cases according to year

Year	Confirmed CBPP sick (%)	Confirmed CBPP dead (%)	Suspected CBPP sick (%)	Suspected CBPP dead (%)	Total (%)
1990	1 (0.02)	13 (0.27)*	3 (0.06)	15 (0.32)*	32 (0.67)
1991	18 (0.38)	8 (0.17)	9 (0.19)	34 (0.72)*	69 (1.45)
1992	233 (4.91)*	10 (0.21)	16 (0.34)	4 (0.08)	263 (5.55)
1993	33 (0.70)	8 (0.17)	30 (0.63)	49 (1.03)*	120 (2.53)
1994	15 (0.32)	4 (0.08)	25 (0.53)	1 (0.02)	45 (0.95)
1995	103 (2.17)	103 (2.17)*	124 (2.61)	96 (2.02)	426 (8.98)
1996	10 (0.21)	5 (0.11)	276 (5.82)*	93 (1.96)	384 (8.10)
1997	104 (2.19)	24 (0.51)	423 (8.92)*	132 (2.78)	683 (14.40)
1998	7 (0.15)	12 (0.25)	931 (19.63)*	106 (2.23)	1056 (22.26)
1999	1 (0.02)	0 (0.00)	27 (0.57)	7 (0.15)	35 (0.74)
2000	75 (1.58)*	69 (1.45)*	56 (1.18)	23 (0.48)	223 (4.70)
2001	22 (0.46)	18 (0.38)	102 (2.15)	45 (0.95)	187 (3.94)
2002	60 (1.27)*	36 (0.76)*	10 (0.21)	8 (0.17)	114 (2.40)
2003	152 (3.20)*	92 (1.94)*	11 (0.23)	6 (0.13)	261 (5.50)
2004	34 (0.72)	104 (2.19)*	72 (1.52)	76 (1.60)*	286 (6.03)
2005	77 (1.62)*	25 (0.53)	58 (1.22)	14 (0.30)	174 (3.67)
2006	12 (0.25)	6 (0.13)	53 (1.12)	7 (0.15)	78 (1.64)
2007	5 (0.11)	0 (0.00)	5 (0.11)	4 (0.08)	14 (0.30)
2008	11 (0.23)*	2 (0.04)	0 (0.00)	0 (0.00)	13 (0.27)
2009	27 (0.57)*	0 (0.00)	3 (0.06)	2 (0.04)	32 (0.67)
2010	13 (0.27)	1 (0.02)	20 (0.42)	11 (0.23)	45 (0.95)
2011	15 (0.32)	5 (0.11)	18 (0.38)	2 (0.04)	40 (0.84)
2012	14 (0.30)	6 (0.13)	12 (0.25)	1 (0.02)	33 (0.70)
2013	26 (0.55)	21 (0.44)	43 (0.91)	33 (0.70)	123 (2.59)
2014	0 (0.00)	0 (0.00)	3 (0.06)	4 (0.08)	7 (0.15)
Total	1068 (22.52)	572 (12.06)	2330 (49.13)	773 (16.30)	4743 (100.00)

*values were significantly greater than expected since $p < 0.05$

Table 4: The 25-year categorical distribution of CBPP cases according to month

Month	Confirmed CBPP sick (%)	Confirmed CBPP dead (%)	Suspected CBPP sick (%)	Suspected CBPP dead (%)	Total (%)
January	301 (6.3)*	77 (1.6)	167 (3.5)	48 (1.0)	593 (12.5)
February	67 (1.4)	54 (1.1)	380 (8.0)*	55 (1.2)	556 (11.7)
March	143 (3.0)	23 (0.5)	375 (7.9)	189 (4.0)	730 (15.4)
April	93 (2.0)	134 (2.8)*	286 (6.0)	106 (2.2)	619 (13.1)
May	76 (1.6)	65 (1.4)	216 (4.6)	72 (1.5)	429 (9.0)
June	61 (1.3)	38 (0.8)	325 (6.9)*	58 (1.2)	482 (10.2)
July	45 (0.9)	18 (0.4)	123 (2.6)	93 (2.0)	279 (5.9)
August	159 (3.4)*	88 (1.9)*	180 (3.8)	40 (0.8)	467 (9.8)
September	10 (0.2)	9 (0.2)	76 (1.6)*	21 (0.4)	116 (2.4)
October	47 (1.0)*	21 (0.4)	40 (0.8)	12 (0.3)	120 (2.5)
November	28 (0.6)	12 (0.3)	150 (3.2)	70 (1.5)	260 (5.5)
December	38 (0.8)*	33 (0.7)*	12 (0.3)	9 (0.2)	92 (1.9)
Total	1068 (22.5)	572 (12.1)	2330 (49.1)	773 (16.3)	4743 (100.0)

*values were significantly greater than expected since $p < 0.05$.

4. DISCUSSION

As shown in Table 1, the overall annual proportions of sick animals with unconfirmed CBPP infections were greater than expected in 1996, 1997 and 1998 ($p < 0.05$) and the overall annual proportions of dead animals with unconfirmed CBPP infections were greater than expected in 1990, 1991, 1993 and 2004 ($p < 0.05$). Many samples were not confirmed in the laboratory and diagnosis was thus primarily based on clinical signs. This may be attributed to a low veterinary service coverage and a lack of awareness of the disease among farmers. Prior to, and soon after Namibia's independence in 1990, the veterinary service in the northern parts of the country was very low due to limited numbers of DVS personnel. The Northern Central Regions (NCR) which included Oshana, Oshikoto, Ohangwena and Omusati were serviced by state veterinarians based in distant regions. Coupled with inadequate resources, few samples were therefore collected for laboratory diagnosis. In addition, the veterinary pharmaceutical supply chain (Yansambou et al., 2018) was not efficient. With time, the DVS capacity improved

greatly and each region in the NCR had two veterinarians with para-veterinary supporting staff which improved CBPP and other livestock disease diagnoses and reporting. The improvement of veterinary services capacity as well as better CBPP mass vaccination coverage could explain the decrease in overall annual proportions and incidence of animals with confirmed CBPP infections observed in the years 2000, 2002, 2003, 2005, 2008 and 2009 up to 2014. A number of studies have pointed out the importance of awareness of the disease among farmers for disease control. The effect of the availability of improved veterinary infrastructure, adequate veterinary personnel, increased vaccination coverage and treatment have been emphasized by other studies as the keys for the control of the disease (Alemayehu et al., 2015; Kairu-Wanyoike et al., 2014). A strong surveillance system can only be achieved with the backing of a strong veterinary field and laboratory service (Demil, 2017). In any case, other studies have reported a positive link between region of origin and the risk of infection with CBPP (Mohamed, 2016).

Table 5: The 25-year CBPP incidence and mortality rates according to year

Year	Census	Vaccine coverage (%)	Total CBPP cases	CBPP Incidence rate/100 000	95% C. I.	CBPP-related mortality/100 000
1990	639223	-	32	5	3.4-7.1	4.38
1991	702075	-	69	9.8	7.6-12.4	5.98
1992	711635	-	263	37	32.6-41.7	1.97
1993	627305	-	120	19.1	15.9-22.9	9.09
1994	659532	-	45	6.8	5-9.1	0.76
1995	787780	-	426	54.1*	49.1-59.5	25.3*
1996	885279	-	384	43.4*	39.1-47.9	11.1*
1997	906634	-	683	75.3*	69.8-81.2	17.2*
1998	994235	-	1056	106.2*	99.9-112.8	11.9*
1999	1080099	-	35	3.2	2.3-4.5	0.65
2000	1263598	-	223	17.6	15.4-20.1	7.28
2001	1255228	58.0	187	14.9	12.8-17.2	5.02
2002	1105598	73.9	114	10.3	8.5-12.4	3.98
2003	1022206	96.6*	261	25.5*	22.5-28.8	9.59
2004	1152293	82.6*	286	24.8	22-27.9	15.6*
2005	1185967	76.4	174	14.7	12.6-17	3.29
2006	1263203	80.4	78	6.2	4.9-7.7	1.03
2007	1099297	41.7	14	1.3	.7-2.1	0.36
2008	1161547	76.7	13	1.1	.6-1.9	0.17
2009	1047687	84.8*	32	3.1	2.1-4.3	0.19
2010	1249107	79.87	45	13.6	2.6-4.8	0.96
2011	1233994	90.1*	40	3.2	2.3-4.4	0.57
2012	1342804	90.1*	33	2.5	1.7-3.5	0.52
2013	1502583	77.4	123	8.2	6.8-9.8	3.59
2014	1525603	-	7	0.5	.2-0.9	0.26

*The greatest five values within each column; - data not available

The proportions of animals that died from confirmed CBPP were greater than expected in the NCR and Zambezi (5.4% and 4.1%, respectively) than in Kavango and Kunene (Table 2). The high proportion of animals that died in the NCR could be attributed to low veterinary service capacity at the time. The launch of the Namibian Livestock Identification and Traceability System (NamLITS) and its enforcement after 2011 enabled individual cattle identification and facilitated effective disease outbreak management. Movement restriction enforcement thus became easier since NamLITS was implemented and the NCR was no longer being treated as one epidemiological unit (Nicholas et al., 2006).

In 2003 (Table 3) an outbreak of CBPP occurred in the Zambezi region after 60 years of relative “silence”. This outbreak caught DVS unprepared and resulted in massive losses of cattle in the region. The outbreak was caused by an introduction of cattle from

Zambia (Huebschle et al., 2004; Nicholas et al., 2006). A similar situation of a sudden upsurge of CBPP after a long lull was reported elsewhere (Masiga et al., 1996) whilst other authors have recommended that effective disease surveillance was essential to avoid re-introduction of CBPP (Alemayehu et al., 2015).

Animals that got sick and recovered from confirmed CBPP infections were greatest in Kavango (7.9%) (Table 2). In this region, the Namibia-Angola border has a physical barrier in the form of the Kavango River, unlike in other regions bordering Angola. This makes it difficult for cattle to freely cross between the two countries during the rainy season. Imposing movement control as a strategy in trying to control an outbreak is feasible in this region. Together with antibiotic treatment, these could be the reasons why Kavango had the higher observed overall recovery rate following treatment of CBPP. In a study

conducted in the Zambezi region, it was discovered that the off-label use of some antimicrobials such as danofloxacin could greatly reduce the transmission of *M. mycoides* subsp. *mycoides* to in-contact animals (Hübschle et al., 2004). It is possible that danofloxacin was effective against *M. mycoides* subsp. *mycoides* or, alternatively, it cleared the animals of concurrent infections rendering the animals less susceptible to CBPP.

The distribution of animal sickness and death due to confirmed/unconfirmed CBPP were dependent on the month (Table 4). Throughout the study period, the proportion of animals that recovered from confirmed CBPP infections were more than expected in the months of January (6.3%.) Around this time there is plenty of grazing in the NCR, animals are in a good condition to fight infection, and also increasing their likelihood of recovering from concurrent illnesses. Studies have confirmed the negative link between body condition score and susceptibility to CBPP (Atnafie et al., 2015; Geresu et al., 2017).

The proportion of animals that died from confirmed CBPP infections were more than expected in April, August and December (2.8%, 1.9% and .7%; respectively). Most regions in the NCR are generally dry with little to no grazing from August to December. The dry season has been identified as a risk factor in a number of studies (Geresu et al., 2017; Kassaye and Molla, 2013; Mamo et al., 2018). The lack of good grazing and water forces animals to move long distances, in search of better grazing and water, sometimes deep into Angola where CBPP is endemic (Daniel et al., 2017; Jores et al., 2013). The mixing of cattle with other herds increases the risk of infection with CBPP (Alhaji, 2011; Alhaji et al., 2016). In addition, trekking of cattle on hoof in groups would have increased chances of infection, probably through increased stress (Spickler, 2015). The presence of concurrent diseases on the northern side of the VCF can predispose cattle to CBPP infection (Thomson, 2005). In addition to this, animals in these areas were more confined to 'favourite' grazing areas and watering points and thus facilitating the transmission of CBPP in these crowded pastures (Thiaucourt, 2018). Humans and their livestock living along the Namibia-Angola border, for example, often freely move across the border for socio-political reasons, trade, grazing and water in both directions (Mbiri, 2017). Local cross-border movement is accepted by both countries thus further exacerbating the risk of spreading CBPP (Mbiri, 2017; Provost et al., 1987).

The proportion of animals that recovered from unconfirmed CBPP infections were more than expected in the months of February, June and

September (8%, 6.9% and 1.6%, respectively) whilst those that died from confirmed CBPP infections were more than expected in the months of March, July and November (4%, 2% and 1.5%, respectively). This may have been due to the fact that the climate may weaken the host and thus increase its susceptibility to infection or provide host conditions favourable for the survival of the infectious agent (Thrusfield and Christley, 2018).

It has been reported that vaccination is the most realistic option for CBPP control in Namibia at the moment (Muinde, 2014; Nicholas et al., 2006). However, the live-attenuated *M. mycoides* subsp. *mycoides* (T1/44) strain, which confers only short term immunity of about 8 months to 1 year, has low efficacy and may result in adverse reactions (Mwirigi et al., 2016). Another challenge is that the T1/44 vaccine strain from the Botswana Vaccine Institute (BVI), which was used in Namibia, must be used within one hour after reconstitution. It is manufactured as 100-dose vials which might not be finished within the prescribed one hour, especially in situations of low cattle turnout during mass vaccination campaigns leading to the inevitable use of non-viable vaccine. Despite the good vaccination coverage of 80–90% that has been achieved by the DVS in these regions, CBPP vaccines used have been known to achieve only 30–60% protection after primary vaccination (Wesonga and Thiaucourt, 2000). It has been speculated that the low vaccine titres result from the poor vaccine manufacturing standards in African countries, improper management of the cold chain (especially in hot climates like Namibia) and pH changes that occur between reconstitution and administration of the vaccine (March, 2004).

Namibia tried at least five different vaccine formulations (the Kabete vaccine, the KH3J strain vaccine, the V5 strain vaccine, the T1/SR vaccine and the T1/44 vaccine) for CBPP control with varying degrees of success. The last switch to the T1/44 vaccine which was implemented in 1997 drastically reduced the number of outbreaks. This may explain why the highest CBPP incidence rates and related mortalities were recorded before 1997. From our results, the years that received the best vaccine coverage were 2003, 2004, 2009, 2011 and 2012 (Table 5). It has been demonstrated in previous studies that adverse post-vaccination reactions (Thiaucourt et al., 2004) and even residual pathogenic infections arising from vaccination has discouraged farmers from participating in vaccination programmes (Mbulu et al., 2004; Scacchia et al., 2011; Teshale, 2005). Despite the effort from the DVS to conduct intensive vaccination

campaigns, the attitude from the farmers contributed to the low turnout during such campaigns before 2003.

A question still remains as to why there are isolated outbreaks despite good vaccination coverage. Apart from the loss of viability of the current vaccine that occurs in the time between reconstitution and administration of the vaccine, accompanied by the lower levels of protection, there is a need to look at the inconsistencies surrounding the selection of animals for vaccination. According to the CBPP vaccine manufacturer (BVI), calves less than two months old should not be vaccinated. One study showed that unvaccinated calves, between the ages of 2 and 8 months in vaccinated herds, are equally susceptible to CBPP infection (Muuka, 2013). Thus the probability of calves getting the infection from adult cattle within the herd is very high (Muuka, 2013). Unlike other traditional set-ups in sub-Saharan Africa where calves are usually tethered within the homestead whilst adult cattle are taken for grazing to save them from exhaustion suffered by older animals walking long distances in search of grazing and water as well as interacting with herds from other households, Namibian cattle generally graze together with their calves. This continuously exposes these calves to CBPP which often enough is facilitated by the lack of solid immunity (Muuka, 2013).

Another reason for isolated outbreaks despite good vaccination coverage is uncontrolled movements of cattle between northern Namibia and southern Angola where CBPP is endemic. These livestock movements result in mixing of some recently vaccinated but not yet protected animals with infected animals. In the Zambezi region where there is no uncontrolled livestock movement across the borders, isolated outbreaks of CBPP have not been reported since the last major outbreaks of 2003 and 2004.

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