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ORIGINAL RESEARCH

Patterns, risk factors and characteristics of reported and perceived foot-and-mouth disease (FMD) in Uganda

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Abstract Patterns of outbreaks of foot-and-mouth disease (FMD) in Uganda were elucidated from spatial and temporal retrospective data retrieved from monthly reports from District Veterinary Officers (DVOs) to the central administration for the years spanning 2001–2008. An assessment of perceived FMD occurrence, risk factors and the associated characteristics was made based on semi-structured questionnaires administered to the DVOs. During this period, a total of 311 FMD outbreaks were reported in 56 (70%) out of Uganda's 80 districts. The number of reported FMD outbreaks changed over time and by geographical regions. Occurrence of FMD was significantly associated with the dry season months (p = 0.0346), the time when animals movements are more frequent. The average number of FMD outbreaks was higher for some sub-counties adjacent to national parks than for other sub-counties, whilst proximity to international border only seemed to play a role at the southern border. DVOs believed that the major risk factor for FMD outbreaks was animal movements (odds ratio OR 50.8, confidence interval CI 17.8–144.6) and that most outbreaks were caused by introduction of sick animals.

Keywords Foot-and-mouth disease outbreaks · Occurrence · Sub-counties · Uganda

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Introduction

Foot-and-mouth disease (FMD) is one of the major diseases globally affecting livestock production and marketing (James and Rushton 2002; Perry 2007). The causative virus (FMDV) belongs to the genus *Aphthovirus* and family *Picornaviridae* with seven different serotypes, including O, A, C, Asia 1, SAT 1, SAT 2 and SAT 3 (Belsham 1993). In Uganda, the first outbreak was recorded in 1953, and since then, outbreaks have regularly occurred in cattle with all FMDV serotypes except for Asia 1. However, serotype C was last diagnosed in the early 1990s, whilst serotype Southern African Territories (SAT) 3, though isolated in Ugandan African buffalos in 1970 and 1997 (Vosloo et al. 2002a; Kalema-Zikusoka et al. 2005), has never been confirmed in outbreaks in domesticated animals.

FMD is known to affect all cloven-hoofed animals including cattle, goats, sheep, pigs and wild ungulates (Thomson 1994). The disease may occur sporadically or endemically and is highly contagious in nature with the

possibility of transmission by direct contact with infective material or fomites, animal products, contaminated surfaces including vehicles, people, water, feeds and air (Alexandersen and Mowat 2005). Wind-borne spread is recognised in temperate climatic conditions and has been shown to occur over long distances (Donaldson et al. 1982; Gloster et al. 1982; Christensen et al. 2005). Generally, outbreaks of FMD in Africa are believed to arise from preexisting foci of infection in sick animals, persistent infections in African buffalos (*Syncerus caffer*) and infective materials or environment harbouring the virus. The factors responsible for initiation and spread of FMD epidemics vary considerably amongst others depending on the source of infection, animal species, animal density, viral strains, previous exposure, geographical conditions and the control methods in place (Alexandersen et al. 2003).

The epidemiology of FMD in East Africa is not yet well known (Vosloo et al. 2002a). In Uganda in particular, there is not much data on the epidemiology of FMD, yet outbreaks are very frequent and difficult to control. Uganda's livestock population is composed of 11.4 M cattle, 12.5 M goats, 3.4 M sheep and 3.2 M pigs (UBOS/MAAIF 2009), and animals frequently cross Uganda's five international borders to other countries. Moreover, 4.6% of the country (about 11,150 km^2) is occupied by ten national parks inhabited by a vast number of ungulates, including impalas and buffalos freely roaming across national parks and international borders. The contribution of domestic and wildlife species to the introduction and maintenance in FMD outbreaks is not known.

The aim of this study was to elucidate possible patterns, risk factors and characteristics of occurrence of outbreaks of FMD in Uganda based on retrospective data and a questionnaire regarding the risk factors and characteristics of FMD in Uganda administered to the District Veterinary Officers (DVOs).

Materials and methods

Retrospective data on FMD outbreaks in Uganda during 2001–2008 were kindly provided by the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), Uganda. The information was based on the monthly outbreak reports from the DVOs. For the period considered under this study, Uganda had 80 districts, divided into 958 sub-counties. The lowest administrative units reporting FMD outbreaks in Uganda are sub-counties, and in this work, these were used as epidemiological units for FMD outbreaks and classified as adjacent to the national park(s) and international border(s) or not based on cartographic data available at National Diagnostics and Epidemiology Centre (NADDEC), MAAIF.

The national parks considered in this study are: Queen Elizabeth National Park (QENP), Lake Mburo National Park (LMNP), Murchison Falls National Park (MFNP), Kidepo Valley National Park (KVNP), Rwenzori Mountains National Park (RMNP), Kibale National Park (KINP), Mount Elgon National Park (MENP), Bwindi Impenetrable National Park (BINP), Mgahinga Gorilla National Park (MGNP) and Semliki National Park (SNP).

Rainfall values and the seasons for the different months, districts and years were obtained from the Meteorological department, Ministry of Energy Water and Mineral Resources, Uganda. For convenience of data handling and presentation, seven geographical regions, which in most cases vary by rainfall (Basalirwa 2007), agro-ecology and farming production systems, were considered (MAAIF 1995; Fig. 1). The months of the year were categorised as having below average rainfall (dry season), above average rainfall (wet season) and average rainfall (neither wet nor dry season) based on long-term mean monthly rainfall over the period 1978–2008. Analysis of variance (Kruskal–Wallis rank test) was used to assess the effect of the season (Intercooled Stata 9.0).

Semi-structured questionnaires on the occurrence of FMD outbreaks and the perception of risk factors and characteristics of these outbreaks were administered to the DVOs at a national annual meeting to report and discuss the animal disease situation in their respective districts. General subject introductions and clarifications were made immediately after the distribution of the questionnaires. Questions included the probable number of animals involved, livestock/wildlife species involved, the frequency of FMD outbreaks, period of the year when the outbreaks occur and the source and actions to control outbreaks of FMD at local level. Questions were answered by ticking pre-written choices, whilst additional information could be supplied in the extra spaces provided. Opinions and data were collected, entered into Excel 2007, summarised, coded and analysed. Perceived risk factors were scored on a Likert scale (Likert 1932) and categorised as less or not important (below 25%), important (26–100%) or not applicable so as to estimate the corresponding odds ratios (ORs) as described by Bland and Altman (2000).

Results

Temporal patterns for the occurrence of FMD

Annual and monthly occurrence of FMD

Regional summary of monthly reports of FMD outbreaks from sub-counties during the years 2001–2008 are summarised in Table 1. The total number of districts which reported FMD was 56 (70%), with 311 outbreaks in 225 out of the 958 sub-counties. The number of FMD-affected sub-counties was highest (57) in 2008 and lowest (4) in 2007. More sub-counties were affected by FMD during the months of February (33), June (53) and July (36) than during the rest

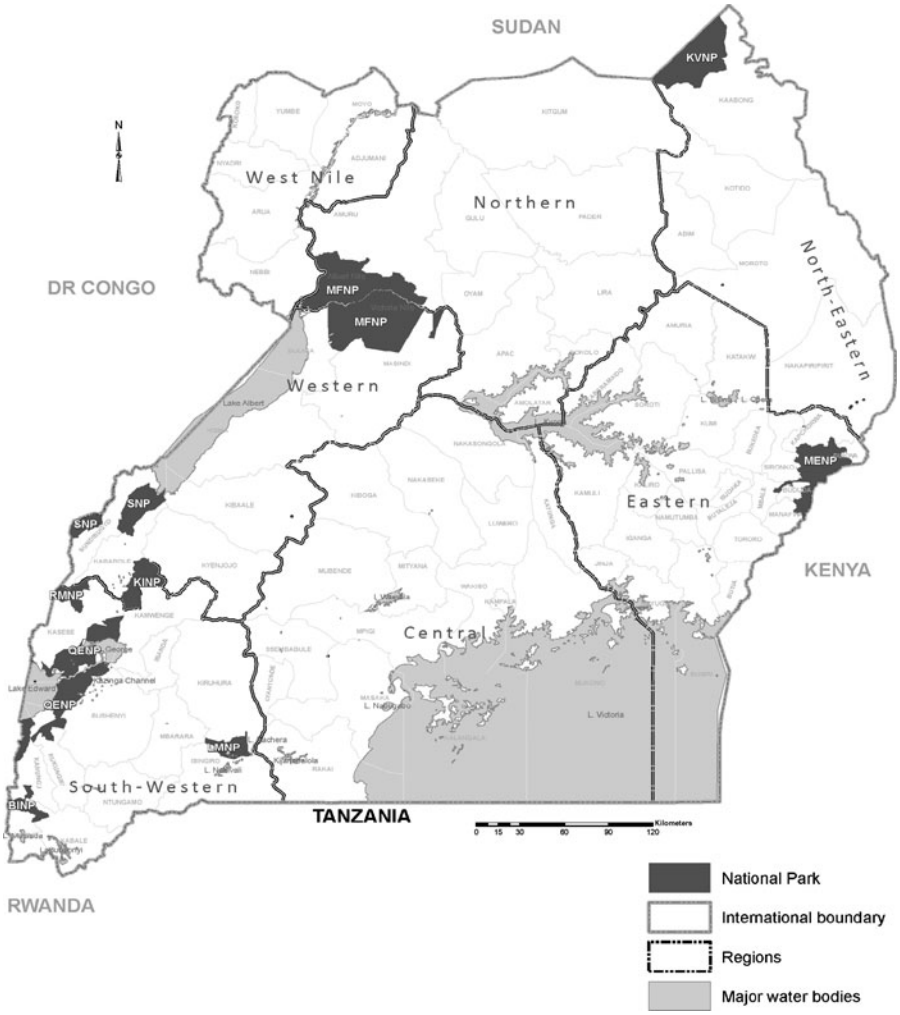

Fig. 1 Map of Uganda showing the different national parks, national borders and the regions used in this study

of the year. The months of August (13) and November (11) had the lowest numbers of sub-counties reporting FMD outbreaks. With some exceptions (September–December 2001, October–December 2005, October–December 2006, June–December 2007, July–September 2008), FMD outbreaks were reported almost every month during the entire study period.

Seasonal differences in the occurrence of FMD outbreaks

In the districts and regions where rainfall data were available, it was apparent that the number of outbreaks was significantly higher ($p = 0.0346$) when mean monthly rainfall (mm) was below average (dry season; mean number of outbreaks/district, 5.7±1.6) than when rainfall was above average (wet season mean of outbreaks/district, 1.2±0.8; Table 2). The same pattern was evident when looking at regional data (Fig. 2) where the peak period for the occurrence of FMD outbreaks was June–July, coinciding with rainfall levels below average (dry season) in most regions, and a second peak was observed for the dry season month of February. A slight change was observed during the wet season in the month of October, with an increase up to 26 reported FMD outbreaks.

Spatial patterns for the occurrence of FMD

Regional occurrence of FMD outbreaks

The Central region reported by far the highest number of FMD outbreaks (116) followed by the Eastern (55), Western (46), Southwestern (42) and Northern regions (34), whilst reporting of FMD outbreaks was sporadic in the Northeastern (10) and West Nile (1) regions (Table 1). The occurrence of FMD did not seem to follow distinct spatial patterns apart from the cumulative clustering of most outbreaks along the Southwestern–Northeastern stretch when plotted on a map (Fig. 3). However, in four out of eight years, a FMD-free period of at least 3 months in the last part of the year was followed by reports of reemergence in January or February of the consecutive year. Thus, this pattern was observed in the Western region in January 2002, in the Eastern region in

Table 1 Reported FMD outbreaks by year, month and region in Uganda (2001–2008)

	Region	Reported FMD outbreaks by month[a]												Total	
		J	F	M	A	M	J	J	A	S	O	N	D		
2001	N	–	–	–	–	–	–	–	–	–	–	–	–	0	
	W	–	1	–	–	–	–	–	–	–	–	–	–	1	
	SW	–	–	1	1	–	–	1	4	–	–	–	–	7	
	C	4	–	–	–	–	–	1	1	–	–	–	–	6	(15)
	E	1	–	–	–	–	–	–	–	–	–	–	–	1	
	NE	–	–	–	–	–	–	–	–	–	–	–	–	0	
	WN	–	–	–	–	–	–	–	–	–	–	–	–	0	
2002	N	–	–	1	–	–	–	–	–	–	–	–	1	2	
	W	2	–	1	1	–	1	–	3	1	1	–	–	10	
	SW	–	1	–	–	–	1	–	1	1	–	–	1	5	
	C	–	6	–	1	–	1	–	2	–	2	1	–	13	(51)
	E	–	1	1	1	–	–	7	–	7	1	2	–	20	
	NE	–	–	–	–	–	–	–	–	–	–	1	–	1	
	WN	–	–	–	–	–	–	–	–	–	–	–	–	0	
2003	N	–	–	–	–	–	–	3	–	–	–	–	1	4	
	W	–	6	1	–	–	1	3	1	1	–	–	–	13	
	SW	–	1	–	–	–	1	2	–	–	1	1	–	6	
	C	–	1	1	2	–	1	–	–	1	2	4	11	23	(50)
	E	2	–	–	–	1	–	–	–	–	–	–	1	4	
	NE	–	–	–	–	–	–	–	–	–	–	–	–	0	
	WN	–	–	–	–	–	–	–	–	–	–	–	–	0	
2004	N	–	–	–	–	–	–	–	1	–	–	–	–	1	
	W	–	–	2	1	–	–	–	–	2	1	–	–	6	
	SW	–	1	1	–	–	–	–	–	–	–	–	1	3	
	C	5	2	1	6	1	4	–	–	5	–	1	3	28	(53)
	E	1	3	1	3	–	–	–	–	–	–	–	–	8	
	NE	–	–	–	–	–	5	–	–	–	–	1	–	6	
	WN	–	–	–	–	–	–	–	–	1	–	–	–	1	
2005	N	–	–	–	4	–	4	1	–	–	–	–	–	9	
	W	–	2	–	–	1	–	–	–	–	–	–	–	3	
	SW	–	3	–	–	–	–	–	–	–	–	–	–	3	
	C	–	1	–	–	–	4	3	–	1	–	–	–	9	(27)
	E	–	1	–	–	–	–	1	–	–	–	–	–	2	
	NE	1	–	–	–	–	–	–	–	–	–	–	–	1	
	WN	–	–	–	–	–	–	–	–	–	–	–	–	0	
2006	N	–	–	1	–	–	–	–	–	–	–	–	–	1	
	W	–	–	–	2	–	–	7	–	–	–	–	–	9	
	SW	–	–	1	–	1	5	4	–	1	–	–	–	12	
	C	–	–	8	2	2	4	3	–	2	–	–	–	21	(47)
	E	2	1	–	–	1	–	–	–	–	–	–	–	4	
	NE	–	–	–	–	–	–	–	–	–	–	–	–	0	
	WN	–	–	–	–	–	–	–	–	–	–	–	–	0	
2007	N	–	–	–	–	–	–	–	–	–	–	–	–	0	
	W	–	1	–	–	1	–	–	–	–	–	–	–	2	
	SW	–	1	–	–	–	–	–	–	–	–	–	–	1	
	C	–	–	–	–	–	–	–	–	–	–	–	–	0	(4)
	E	–	–	–	1	–	–	–	–	–	–	–	–	1	

Table 1 (continued)

	Region	Reported FMD outbreaks by month[a]												Total	
		J	F	M	A	M	J	J	A	S	O	N	D		
	NE	–	–	–	–	–	–	–	–	–	–	–	–	0	
	WN	–	–	–	–	–	–	–	–	–	–	–	–	0	
2008	N	–	–	–	–	–	3	–	–	–	12	–	2	17	
	W	–	–	–	–	2	–	–	–	–	–	–	–	2	
	SW	1	–	–	–	–	4	–	–	–	–	–	–	5	
	C	–	–	5	–	6	4	–	–	–	–	–	1	16	(57)
	E	–	–	–	–	–	10	–	–	–	4	–	1	15	
	NE	–	–	–	–	–	–	–	–	–	2	–	–	2	
	WN	–	–	–	–	–	–	–	–	–	–	–	–	0	
	Total	19	33	26	25	16	53	36	13	23	26	11	23		(304)[b]

Regional summary of the number of sub-counties reporting FMD outbreaks

W Western, *E* Eastern, *SW* Southwestern, *C* Central, *NE* Northeastern, *WN* West Nile, *N* Northern

[a] Dashes (-) represent periods when there were no newly reported FMD outbreaks

[b] Seven reported FMD outbreaks did not have the specific months of occurrence and therefore not included (three in 2002, one in 2003, one in 2004, one in 2005 and one in 2006)

January 2006 and in the South Western region in February 2007 and January 2008, respectively.

Occurrence of FMD outbreaks adjacent to national parks

A total of 100 out of 958 sub-counties in Uganda lie adjacent to the different national parks. Occurrence of FMD outbreaks in sub-counties bordering the national parks is summarised in Table 3. A total of 84 out of 311 FMD outbreaks were reported in 53 sub-counties adjacent to the national parks. FMD outbreaks occurred more than once in 16 of these sub-counties. The average number of outbreaks per sub-county adjacent to a national park was 0.84 (84/100), whilst the average number of outbreaks per

Table 2 Assessment of patterns of occurrence of FMD outbreaks and the distribution of rainfall in selected districts in Uganda

Region	District	Mean annual rainfall (mm)	FMD outbreaks by rainfall (mm)[a]			Total number of outbreaks
			Above Average[b]	Average[c]	Below average[d]	
W	Kasese	884	0	4	10	14
W	Masindi	1317	0	7	6	13
SW	Mbarara	936	4	3	14	21
SW	Bushenyi	1,235	0	1	0	1
C	Masaka	1,023	7	0	1	8
C	Luwero	1,216	0	4	9	13
C	Rakai	987	1	4	9	14
N	Kitgum	1,343	0	8	0	8
NE	Kotido	703	0	1	7	8
WN	Arua	1,443	0	0	1	1
Total			12	32	57	101

Monthly rainfall (mm) was evaluated as average (normal season), below average (wet season) or above average (dry season) based on long-term mean. Mean annual rainfall values (mm) represent the distribution across selected weather stations and regions

[a] Dashes (-) represent periods when there were no newly reported FMD outbreaks

[b] Wet season

[c] Neither dry nor wet season

[d] Dry season

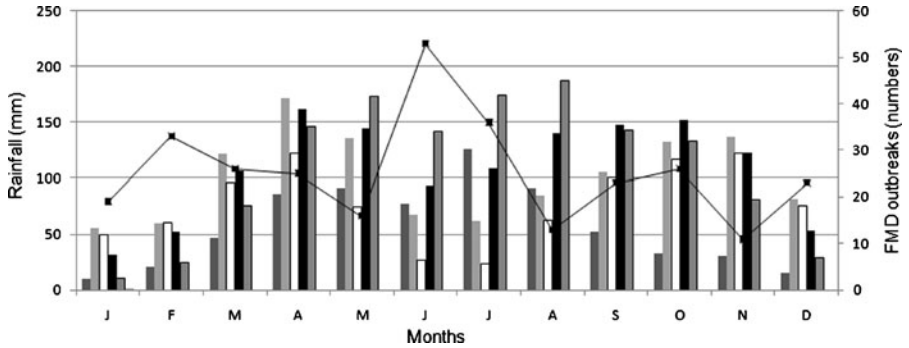

Fig. 2 Graph showing the variation in seasonal rainfall and the monthly distribution of FMD outbreaks in different regions of Uganda. Rainfall values (*RF*) were generalised for the Northeastern (*NE*), Northern (*N*), Central (*C*), Southwestern (*SW*) and Western (*W*) regions. Key: RF (NE); RF (N); RF (C); RF (SW); RF (W) FMD (Outbreaks)

sub-county not adjacent to a national park was 0.26 (227/858). The highest number of sub-counties affected by FMD were those adjacent to LMNP (23 outbreaks in seven sub-counties), MFNP (17 in 10 sub-counties) and MENP (16 in 28 sub-counties) where outbreaks occurred during at least five out of the eight years included in this study. A total of 17 FMD outbreaks occurred in sub-counties adjacent to more than one national park, including QENP, BINP, RMNP, SNP and KINP. There were no reports of FMD outbreaks inside any of the ten national parks and in the sub-counties adjacent to KVNP.

Occurrence of FMD outbreaks adjacent to the international borders

Uganda is landlocked and shares borders with Sudan (435 km) on the northern side, Democratic Republic of Congo (DRC, 765 km) on the western side, Tanzania (396 km) and Rwanda (169 km) on the southern side and Kenya (933 km) on the eastern side (Fig. 1). Table 4 shows the numbers of sub-counties adjacent to the international borders and the occurrence of FMD. The total number of sub-counties adjacent to the international border is 110 out of the total 958 sub-counties in Uganda. Thirty-one FMD outbreaks occurred in 22 out of the 110 sub-counties along the international border (average number of outbreaks/sub-county, 0.28) compared to 280 outbreaks that occurred in sub-counties that are distant from the border (average number of outbreaks/sub-county, 0.33). The number of FMD outbreaks varied between the different international borders, the highest being adjacent with Tanzania (nine outbreaks in three of eight sub-counties) and DRC borders (ten outbreaks in 9 of 43 sub-counties). The lowest number of FMD outbreaks were reported among the sub-counties bordering Rwanda (three outbreaks in 3 of 13 sub-counties) and Kenya (four outbreaks in 4 of 27 sub-counties).

Perceived risk factors for the occurrence of FMD in Uganda

The questionnaire response rate was 89% of the 80 DVOs in Uganda at that time (71/80). The DVO opinions of risk factors for outbreaks of FMD in Uganda are summarised in Table 5. Animal movements (OR 50.8, 95% CI 17.8–144.6) were perceived as the most important risk factor for the occurrence of FMD in Uganda. Feeding on contaminated pastures was perceived as a risk factor of low significance (OR 1.0, 95% CI 0.4–2.4). Other risk factors including contact with wildlife or people, by wind and through sharing of drinking water, were perceived as not important. The odds ratio for DVO perception of other risk factors as being important (OR 1.8, 95% CI 0.2–14.8) is deceptive since only 7 of 71 DVOs had answered this question, and they all proposed different risk factors including milk handling utensils, hides and skins, ghee (clarified butter), straw on cattle transport trucks, civil wars, communal farming and cattle rustling.

Perceived characteristics of occurrence of FMD outbreaks in Uganda

Opinions among the DVOs about the characteristics of occurrence and control of FMD in Uganda are summarised in Table 6.

Forty-four of the 47 DVOs answering a question about significance of FMD perceived it to be as important in relation to other livestock diseases in Uganda as per the following rating: “very important” by 25 DVOs, “fairly important” by six DVOs and “important” by 13 DVOs, whilst three DVOs found it “not important”.

Wild animals involved in the spread of FMD

Twenty-six DVOs gave opinions on the role of wild animals in the transmission of FMD in Uganda. Buffalos (15 DVOs) and warthogs (12 DVOs) were perceived to be more important than Uganda kobs (five DVOs) and Impala (three DVOs).

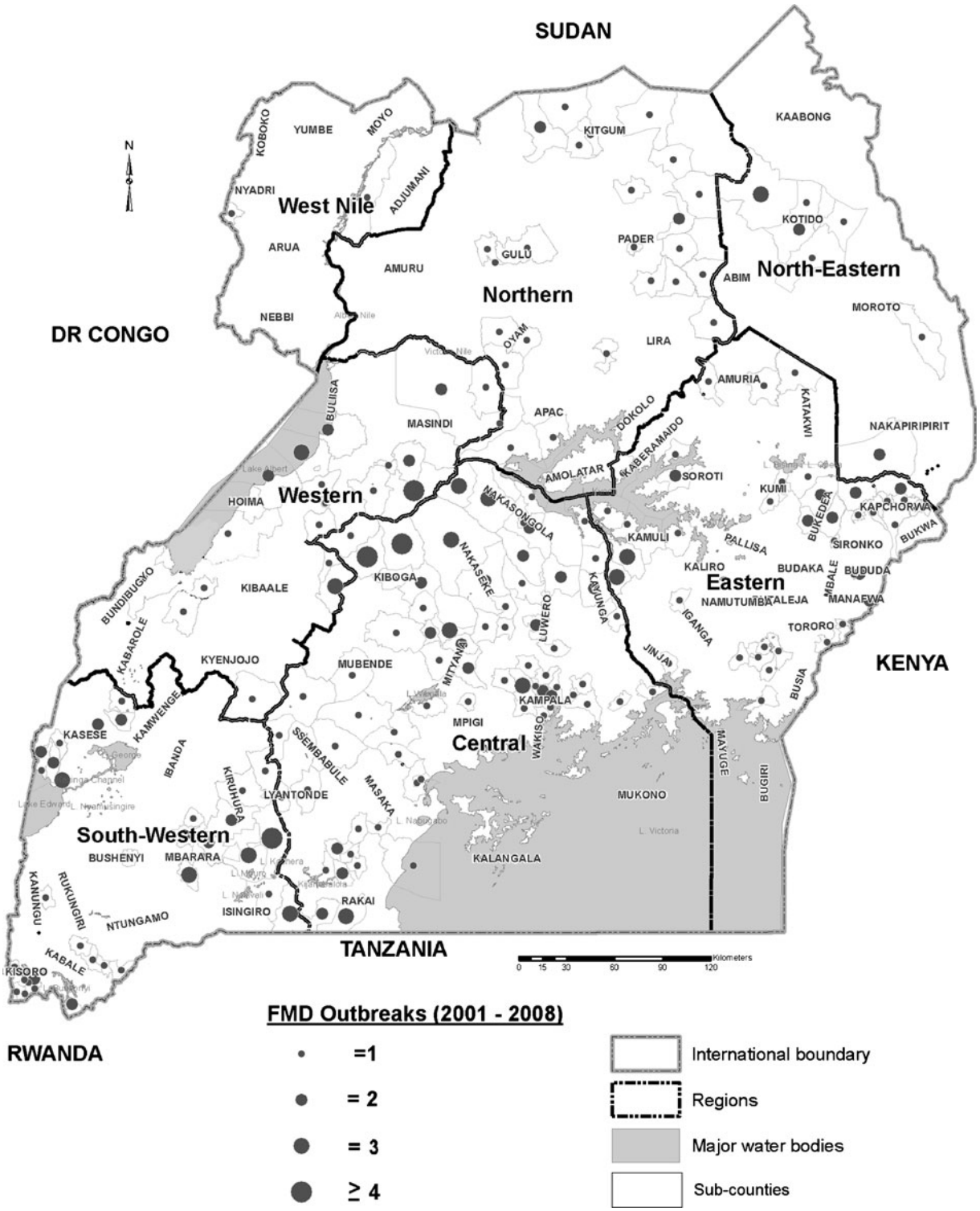

Fig. 3 Map of Uganda showing the cumulative sub-county distribution of FMD outbreaks (2001–2008). FMD outbreaks were reported from the marked sub-counties. Names by location of all the districts in Uganda are indicated

Table 3 Occurrence of FMD outbreaks within the districts adjacent to the national parks

National parks	Year of FMD occurrence in different sub-counties								Total
	2001	2002	2003	2004	2005	2006	2007	2008	
LMNP	2	5	6	3	3	2	–	2	23
MFNP	1	5	5	2	1	–	–	3	17
KVNP	–	–	–	–	–	–	–	–	0
QENP	–	–	–	–	–	1	–	–	1
KINP	–	–	–	1	1	–	–	–	2
SNP	–	–	–	–	–	–	–	–	0
RMNP	–	–	–	–	–	–	–	–	0
MGNP	4	–	–	–	–	4	–	–	8
BINP	–	–	–	–	–	–	–	–	0
MENP	–	9	3	2	1	1	–	–	16
BINP and QENP[a]	–	–	–	–	–	1	–	–	1
RMNP and QENP[a]	–	–	1	–	–	1	–	–	2
QENP, SNP and KINP[a]	–	2	1	–	–	9	2	–	14
Total	7	21	16	8	6	19	2	5	84

[a] Outbreaks occurred in sub-counties sharing borders with more than one national park

Livestock species suspected to be responsible for the spread of FMD

Four livestock species were suspected to be responsible for the spread of FMD, namely: cattle, sheep, goats and pigs. The majority of 28 DVOs answering this question believed that cattle (n = 25) were the major livestock species responsible for spread of FMD compared to pigs (n = 8) and sheep and goats (n = 7).

Number of animals affected by FMD outbreaks

The number of domesticated animals believed to be affected by FMD during an outbreak varied from <25 to over 100 animals per outbreak. The opinions about this question varied as 15 of the 50 respondents indicated that FMD may affect over 100 animals, whilst 13 and 11 DVOs thought that outbreaks involve 1–25 and 26–50 animals, respectively.

Table 4 Occurrence of FMD in sub-counties adjacent to the international borders

Border country	Number of adjacent sub-counties	Number of affected sub-counties	Number of FMD outbreaks
Tanzania	8	3	9
Rwanda	13	3	3
Kenya	27	4	4
DRC	43	9	10
Sudan	19	3	5
Total	110	22	31

FMD outbreak duration

The perception of 51 DVOs on the duration of FMD outbreaks in Uganda varied as follows: 1–3 months (n = 32), 4–6 months (n = 14), 7–9 months (n = 2), 10–12 months (n = 2) and above 12 months (n = 1).

Source of FMD outbreaks

Most DVOs perceived that introduction of sick animals was the most important source of FMD outbreaks (50/54 DVOs). One respondent believed that cattle trucks were possible sources of FMD outbreaks.

Actions taken to contain FMD outbreaks

The perceived predominant actions to contain FMD outbreaks included animal movement restrictions (n = 49/52) and vaccination (n = 47/52). A few DVOs (n = 6) believed that in addition, actions like awareness creation (n = 1), closure of markets (n = 2) and symptomatic treatment of the sick animals (n = 1) were useful.

Frequency of FMD outbreaks

The majority of the 54 responding DVOs believed that FMD outbreaks occur less frequently than once a year (n = 43). However, others believed that outbreaks occur once a year (n = 7), twice a year (n = 1), thrice a year (n = 1) or four times a year (n = 2) in their districts.

Table 5 Opinions of DVOs on the importance of risk factors for the occurrence of FMD in Uganda

Perceived risk factors for occurrence of FMD	Response			Odds	95% CI	
	Important	Not important	NA[a]	Ratio	Lower	Upper
Animal movements	57	8	6	50.8	17.8	144.6
Contact between livestock and wildlife	18	27	26	0.4	0.2	1.0
Wind	6	30	35	0.0	0.0	0.1
People	16	22	33	0.5	0.2	1.3
Water	19	24	28	0.6	0.3	1.5
Pastures	21	21	29	1.0	0.4	2.4
Others[b]	4	3	64	1.8	0.2	14.8

[a] Not applicable: number of DVOs not answering this question

[b] Milk handling utensils, hides and skins, ghee, straw on cattle transport trucks, civil wars, communal farming and cattle rustling

Seasonal occurrence of FMD outbreaks

In most of the districts, FMD outbreaks were most frequently encountered during the months January to March (n =15/34) and July to September (n =14/34), co-incident with the two dry seasons in Uganda. However, other DVOs perceived that in a few cases, FMD occurs during the months of October–December (n = 10/34) and April–June (n = 4/34).

Reasons for livestock and wildlife getting into close contact

The DVO opinions on this question varied. Livestock and wildlife were believed to get into close contact in search of pastures (n =040/50), water (n =032/50) and sometimes due to free interaction or lack of a barriers (n = 26/50). Other reasons given were incidental (n = 2/50) and rabid animals leaving the parks (n = 1/50).

Discussion

FMD outbreaks occurred during the entire study period (2001–2008). Our findings show that reported FMD outbreaks occurred more frequently in some years than in others and varied between the regions of the country. It is believed that FMD outbreaks in endemic countries are greatly underreported, depending on the level of economic and political development of the country (Sumption et al. 2008). This is also believed to be true in Uganda since clinical signs may not always be noticed or reported and laboratory confirmation is not always achieved in a timely manner (WRLFMD 2009). Accordingly, the exact true duration of the individual FMD outbreaks or epidemics in this study could not be definitively established. However, the presented high frequency of reports of FMD outbreaks suggests that FMD is generally endemic in Uganda.

Occurrence of reported FMD outbreaks differed between regions with most outbreaks reported in the Central region (116) than any other region where moderately fewer reports (34–55) were received, including Eastern, Western, and Southwestern, whilst very few reports (≤10) were received from the Northeast and West Nile regions. This variation could be caused by a number of factors including animal husbandry practices, season, prevailing animal breeds, level of immunity, vigilance in disease control, animal movements and other factors related to virus transmission (Alexandersen and Mowat 2005; Rweyemamu et al. 2008). The observed cumulative clustering of FMD outbreaks along the Southwestern–Northeastern stretch exactly matches the area termed as the cattle corridor (MAAIF 2006), an area believed to have the highest livestock numbers and extending diagonally across Uganda, from the pastoralist Ankole area in the Southwest, touching Rwanda and Tanzania, to the Karamoja region bordering Sudan and Kenya in the Northeast. This area often experiences lower rainfall and has increasingly become prone to frequent droughts leading to depletion of both pasture and water resources (NEMA 2006), resulting in massive seasonal movements of livestock along the Southwestern–Northeastern stretch to alternative grazing areas hence the increased risk for FMD outbreaks.

In the reported study, there was a tendency to a seasonal pattern with higher frequency of reported FMD outbreaks during the months with lower rainfall. Rainfall distribution in Uganda has been shown to follow 14 distinct climate zones, which often span beyond the administrative partitions (Basalirwa 2007). An exact analysis of time-specific rainfall data from a smaller number of districts confirmed that outbreaks were more common during the dry season compared to the parts of the year with average and above average rainfall (normal and wet season). However, due to the limited dataset, it was not possible to draw firm conclusions regarding the impact of climatic zones and annual rainfall.

Table 6 Perceived characteristics of FMD occurrence and control in Uganda

Perceived variables	Parameters	Response (numbers/proportion)		
		Yes	No	NA[e]
Rating of FMD as an important disease	Very important	25 (0.35)	21 (0.30)	25 (0.35)
	Fairly important	6 (0.08)	40 (0.56)	25 (0.35)
	Important	13 (0.18)	33 (0.46)	25 (0.35)
	Not important	3 (0.04)	43 (0.61)	25 (0.35)
Wildlife species involved in the spread of FMD	Buffalos	15 (0.21)	11 (0.15)	45 (0.63)
	Impalas	3 (0.04)	23 (0.32)	45 (0.63)
	Uganda kobs	5 (0.07)	21 (0.30)	45 (0.63)
	Warthogs	12 (0.17)	14 (0.20)	45 (0.63)
Livestock species involved in the spread of FMD	Cattle	25 (0.35)	3 (0.04)	43 (0.61)
	Sheep and goats	7 (0.10)	21 (0.30)	43 (0.61)
	Pigs	8 (0.11)	20 (0.28)	43 (0.61)
	Others	0 (0.0)	28 (0.39)	43 (0.61)
Number of animals affected during FMD outbreak	1–25	13 (0.18)	38 (0.54)	20 (0.28)
	26–50	11 (0.15)	40 (0.56)	20 (0.28)
	51–75	7 (0.10)	44 (0.62)	20 (0.28)
	76–100	4 (0.06)	47 (0.66)	20 (0.28)
	>100	15 (0.21)	36 (0.51)	20 (0.28)
Duration of FMD outbreaks	1–3 months	32 (0.45)	19 (0.27)	20 (0.28)
	4–6 months	14 (0.20)	37 (0.52)	20 (0.28)
	7–9 months	2 (0.03)	49 (0.69)	20 (0.28)
	10–12 months	2 (0.03)	49 (0.69)	20 (0.28)
	Above 12 months	1 (0.01)	50 (0.70)	20 (0.28)
Sources of FMD outbreaks	Introduction of sick animal(s)	50 (0.70)	2 (0.03)	19 (0.27)
	Migration to a new area	1 (0.01)	51 (0.72)	19 (0.27)
	Livestock–wildlife close contact	2 (0.03)	50 (0.70)	19 (0.27)
	Others[a]	1 (0.01)	51(0.72)	19 (0.27)
Actions taken to control FMD	Animal movement restrictions	49 (0.69)	3 (0.04)	19 (0.27)
	Vaccination	47 (0.66)	5 (0.07)	19 (0.27)
	Other actions[b]	6 (0.08)	46 (0.65)	19 (0.27)
Frequency of FMD outbreaks	Once a year	7 (0.10)	47 (0.66)	17 (0.24)
	Twice a year	1 (0.01)	53 (0.75)	17 (0.24)
	Thrice a year	1 (0.01)	53 (0.75)	17 (0.24)
	Four times a year	2 (0.03)	52 (0.73)	17 (0.24)
	More than once per year[c]	43 (0.61)	11 (0.15)	17 (0.24)
Months when FMD is frequent	January–March	15 (0.21)	19 (0.27)	37 (0.52)
	April–June	4 (0.06)	30 (0.42)	37 (0.52)
	July–September	14 (0.20)	20 (0.28)	37 (0.52)
	October–December	10 (0.14)	24 (0.34)	37 (0.52)
Reasons for close contact between livestock and wildlife	Search for water	32 (0.45)	18 (0.25)	21 (0.30)
	Search for pasture	40 (0.56)	10 (0.14)	21 (0.30)
	Proximity/lack of a barrier	26 (0.37)	24 (0.34)	21 (0.30)
	Others[d]	3 (0.04)	47 (0.66)	21 (0.30)

[a] Cattle trucks (1)

[b] Sensitization (1), closure of markets (2) and symptomatic treatment (1)

[c] Above 1 year (2), very rare (38)

[d] Rabid (1) and incidental cases (2)

[e] Not applicable: number of DVOs not answering this question

The spatial and temporal patterns of FMD outbreaks indicate that the virus may survive during periods without reports of FMD outbreaks; however, as pointed out above, this could be a result of underreporting of FMD outbreaks. Another option is that the virus may truly disappear from the livestock and is reintroduced through contact with infected animals either in the form of infected newly moved livestock or contacts with

persistently infected buffalos. The role played by the African buffalos in the persistence of FMDV and subsequent initiation of outbreaks in livestock and wildlife populations has not been fully studied in Uganda, apart from the evidence that they, under natural conditions, are persistently infected with the SAT serotypes (Kalema-Zikusoka et al. 2005; Ayebazibwe et al., accepted). Apparently, transmission of FMDV from domestic animal carriers to other animals has not been confirmed, but there is evidence that the virus may be recovered from oesophageal–pharyngeal fluid samples of persistently infected ruminants (Van Bekkum et al. 1959), thereby posing an unquantified potential threat for new outbreaks and complicating the disease control strategies (Alexandersen et al. 2002; Sutmoller and Casas 2002). It has been established that FMDV can persist for up to 3.5 years in cattle and for up to 24 years in African buffalo herds (Condy et al. 1985; Alexandersen et al. 2002; Thomson et al. 2003), and buffalos are known to play a unique role as reservoirs for FMD virus among wildlife species (Anderson et al. 1993; Bastos et al. 2000). Moreover, it has been demonstrated that FMDV transmission can occur from African buffalos to cattle (Dawe et al. 1994a, b; Sutmoller et al. 2000; Vosloo et al. 2002b). Thus, since FMDV and antibodies towards FMD virus have previously (Hedger et al. 1973; Kalema-Zikusoka et al. 2005) and recently (Ayebazibwe et al., accepted) been demonstrated in Ugandan African buffalos, and cattle are routinely grazed in some of the national parks in Uganda, then transfer from buffalo to cattle is not an unlikely scenario in the epidemiology of FMD in Uganda.

In this study, 84 out 311 FMD outbreaks were reported in 53 of the 100 sub-counties adjacent to the national parks, with some national parks being more involved than others. However, most of the outbreaks of FMD (227) were reported in the sub-counties that are not adjacent to the national parks (858). It is therefore clear that much as the frequency of FMD outbreaks were in some cases higher around the national parks, the results of this study cannot succinctly conclude on the dynamics of transfer of FMDV between livestock and wildlife in Uganda. The overall number of FMD outbreak reports per sub-county adjacent to the international borders did not exceed the overall number of FMD outbreak reports per sub-county not adjacent to an international border (31/110 and 280/848, respectively). However, there was an overrepresentation of outbreaks along the Tanzanian border (average 1.1 outbreaks per sub-county). Hence, though the occurrence of FMD does not entirely depend on proximity to international borders, it is, as suggested for Cameroon by Bronsvoort et al. (2004b), important to consider control of cross-border movements in the animal disease control programme in Uganda.

The perceptions of the DVOs on risk factors were highly suggestive that livestock movements are the most important risk factors for the occurrence of FMD outbreaks (OR 50.8%, 95% CI 17.8–144.6). This is an important finding that could not be easily obtained through analysis of spatial and temporal data. A combination of findings from the spatial and temporal studies and DVO-based analysis of risk factors and characteristics of FMD outbreaks in Uganda indicates that the risk is highest during the dry season when livestock movements are more pronounced in search of pasture and water. Similar findings were obtained in other studies in other African countries including Tanzania (Kivaria 2003), Ethiopia (Rufael et al. 2008; Megersa et al. 2008), Cameroon (Bronsvoort et al. 2003; Bronsvoort et al. 2004a) and most of sub-Saharan Africa (Vosloo et al. 2002a). Moreover, previous reports indicate that the spread of FMD in Uganda is associated with, among others, cattle movements, cattle markets, cattle rustling, communal farming and concealment of epidemics by some farmers (Nkuranga 2002). This is supported by Bronsvoort et al. (2003) who stated that livestock husbandry practices like the communal grazing under the pastoral production systems could play an important role in enhancing the spread of FMD.

Most FMD outbreaks close to Uganda's international borders have been suspected to originate in neighbouring countries due to the porous nature of the border and lack of vigilance to enforce animal movement control (Nkuranga 2002). However, except for the Tanzanian border, our analysis shows that the sub-counties adjacent to international borders do not have a higher risk of experiencing an outbreak of FMD. It is possible that some sub-counties are favoured as cross-border cattle migratory routes due to a number of reasons beyond the scope of this study, including the availability of water, pastures, good terrain, less inconvenience from other farmers or area authorities, as well as other local perspectives (Rugalema et al. 2009).

Fifty of the 71 responding DVOs (70%) perceived FMD outbreaks to be due to the introduction of sick animal(s). The majority of responding DVOs (25/28) indicated that cattle were much more affected by FMD, whilst much fewer believed that goats, sheep and pigs were affected. This may be explained by the lack of regular and informative reports on FMD outbreaks in domestic animals other than cattle. With regard to wildlife, though a number of responding DVOs indicated that African buffalos (15/26) and warthogs (12/26) play a role in the spread of this disease, contact with wildlife was generally perceived as not being a very important risk factor (OR = 0.4, 95% CI = 0.2–1.0). For non-buffalo wildlife species including warthogs, this accords with the findings by Bronsvoort et al. (2008) and by Ayebazibwe et al. (under revision). However, though sick buffalos have not been sighted and reported by the Ugandan veterinary authorities, it has been

shown that the Ugandan buffalos are infected with FMDV (Hedger et al. 1973; Kalema-Zikusoka et al. 2005; Ayebazibwe et al., accepted), and since national parks in Uganda are not fenced, livestock and wildlife readily mix on rangelands and at water sources, thereby increasing the likelihood of spread of FMD.

With regard to the validity of the data presented in this paper, the DVOs are well trained and experienced in animal disease surveillance and control activities, and it is highly likely that the information obtained through extracts from the regular reports to the central government and through the questionnaire is reliable.

This study supports that movement of infected animals is the most important factor for consideration in the transmission of FMD within endemic regions as reviewed by Rweyemamu et al. 2008. Lack of geo-reference data and non-adherence to standardised outbreak reporting formats and schedules were seen as major challenges for this kind of study.

It is recommended that strategies for control of FMD in Uganda should at least include consideration of the season and animal movements. More detailed and systematic studies should be undertaken to investigate further the specific risk factors and patterns of occurrence of FMD in Uganda.

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