The epizootiology of foot-and-mouth disease in high risk zones in Kenya

Kibore B[2], Gitao C. G[1*], Sangula A[2] and Kitala P[1]

[1]The University of Nairobi, Faculty of Veterinary Medicine, P.O. Box 30197, Nairobi, Kenya

[2]Foot-and-Mouth Disease Laboratory, Ministry of Livestock Development, P.O. Box 18021, Embakasi, Nairobi, Kenya.

***Corresponding** author: Tel: +254721846346 E-mail: cggitao@gmail.com

ABSTRACT

Foot-and-mouth disease remains a serious endemic disease in Kenya causing extensive production losses in the dairy industry. In order to understand the foot-and-mouth disease (FMD) situation in Kenya and related risk factors in high risk zones that include; the trade and stock routes, national parks and game reserves, proposed disease free zones and borderlands; a cross sectional sero-survey was conducted utilizing bovine serum samples at Embakasi foot-and-mouth disease laboratory. The samples were randomly collected throughout the country and screened using commercial non-structural protein antibody Elisa kit. The serology results were then extrapolated to determine the seroprevalence across several high risk zones. From the serology results, the FMD seroprevalence was higher in the Kenya/Uganda border at 95% compared to the Kenya/Somalia border (Somali ecosystem) which had 38.1%. The seroprevalence was also higher in non-pastoral areas at 58.6% compared to pastoral regions at 53% although the difference was not statistically significant ($p>0.05$, 95%CI). The seroprevalence was also found to be high in the proposed north rift disease free zone at

97.5% as well as areas bordering the Mt. Elgon national park at 100%. Similarly, the Turkana/Pokot/Trans Nzoia/ Uasin Gishu/Nakuru/Nairobi stock route in the northern corridor was also found to have high FMD seroprevalence at 80.5%. The study was carried out in order to assist in policy formulation and to help county governments understand the transboundary and trans-county nature of the foot-and-mouth disease.

Keywords: Foot-and-mouth disease, stock route, national parks, borderlands, seroprevalence

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INTRODUCTION

Foot-and-mouth disease (FMD) is a highly contagious acute viral infection of cloven hoofed animals including domesticated ruminants and pigs and more than 70 wildlife species and is one of the most important economic diseases of livestock (Coetzer *et al*., 1994, Broonsvoort *et al*., 2004). It is caused by a virus of genus *Aphthovirus*, in the family *Picornaviridae* (Belsham, 1993), of which seven distinct serotypes O, A, C, (South African Territories) SAT1, SAT2, and SAT 3 and Asia 1 are known (Murphy *et al*., 1999). The disease is characterized by fever, loss of appetite, salivation and vesicular eruptions in mucosa of the mouth, skin of the inter-digital spaces and coronary bands of the feet and teats. It is also characterized by high morbidity and low mortality (Coetzer *et al*., 1994). It is a major constraint to international trade in livestock and livestock products and acts as a barrier to accessing good markets in the world.

The disease is considered endemic in Kenya partly due to poor reporting of the disease with five of the serotypes shown to have been in circulation i.e., O, A, C, SAT1 and SAT2 (Vosloo *et al*., 2002, Sahle, 2004). The disease spreads rapidly by movement of infected animals or mechanically on formites such as clothing, shoes, vehicles, and veterinary instruments. The reasons for the rapidity of spread to fully susceptible populations is due to the highly infectious nature of the virus, the production of high titer in respiratory secretions and the large volumes of droplets and aerosols of virus shed by infected animals, the stability of virus in such droplets, the rapid replication cycle with very high virus yields and the short incubation period (Sellers, 1971). The extensive uncoordinated livestock movements within the East African region coupled with porous borderlands pose the greatest challenge to regional disease control. In addition, illegal livestock movement for marketing and cattle rustling within the region contribute to disease spread. The role of wildlife in the maintenance and transmission of FMD is recognized and therefore the intensive wildlife-livestock interaction enhances disease transmission through contact, sharing of water and pasture (Chepkwony *et al.*, 2012)

The government of Kenya, through the state department of livestock, is in the process of establishing disease-free-zones which is aimed at controlling diseases that have negative bearing on international trade including foot-and-mouth disease. In order to achieve sustainable disease control and/or eradication especially on high risky areas, a good understanding of disease epidemiology is important and this can only happen if the disease is traced and regular and effective surveillance is done together with vaccination regimes being put in place (Donaldson, 1994, Chepkwony *et al*, 2012). The nonstructural protein (NSP) ELISA test was used because

it is able to discriminate animals that have been infected by wild virus from those that have been vaccinated using either purified/semi-purified vaccines. The nonstructural proteins antibodies can only be induced by the wild virus. Such test would be able to detect continued viral circulation and would therefore be extremely useful for serological surveys with a view to eradication (Diego *et al.*,1997).

MATERIALS & METHODS

Samples

The sera samples were obtained from the collection at the Embakasi foot-and-mouth disease laboratory assembled from various activities including the Somali ecosystem rinderpest eradication coordination unit (SERECU) project. The sera were collected in the year 2010 from a total of ten randomly selected villages in each of the selected district with a total of 3709 bovine sera collected from 39 counties. All the samples were individually verified and entered into a data sheet with the details as follows; animal laboratory identification, location and coordinates of the source (district and county), species, sex (either male or female), age of the animal (<1 year, 1-2 years and >2 years) and vaccination history (either vaccinated, non-vaccinated or unknown).

Sera from counties bordering the east African countries, from counties bordering the national parks & game reserves, from counties within the proposed disease free zones as well those from counties that lie within several trade and stock routes were subjected to the

nonstructural protein Elisa screening test. In addition, a total of 739 samples that were positive on screening were subjected to the liquid phase blocking Elisa (LPBE) to titrate the serotypes.

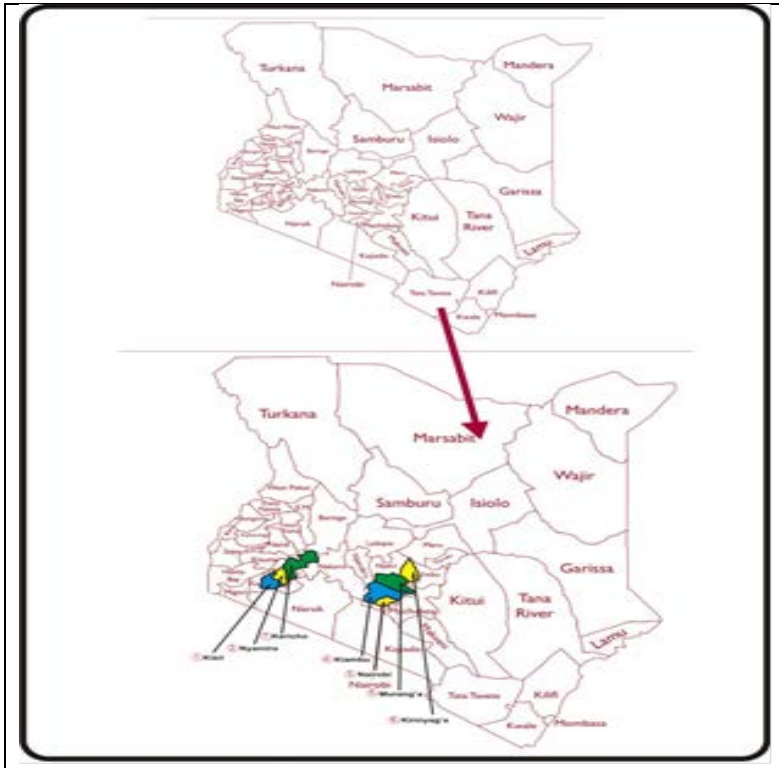

Figure 1: Map showing the 39 Counties sampled.

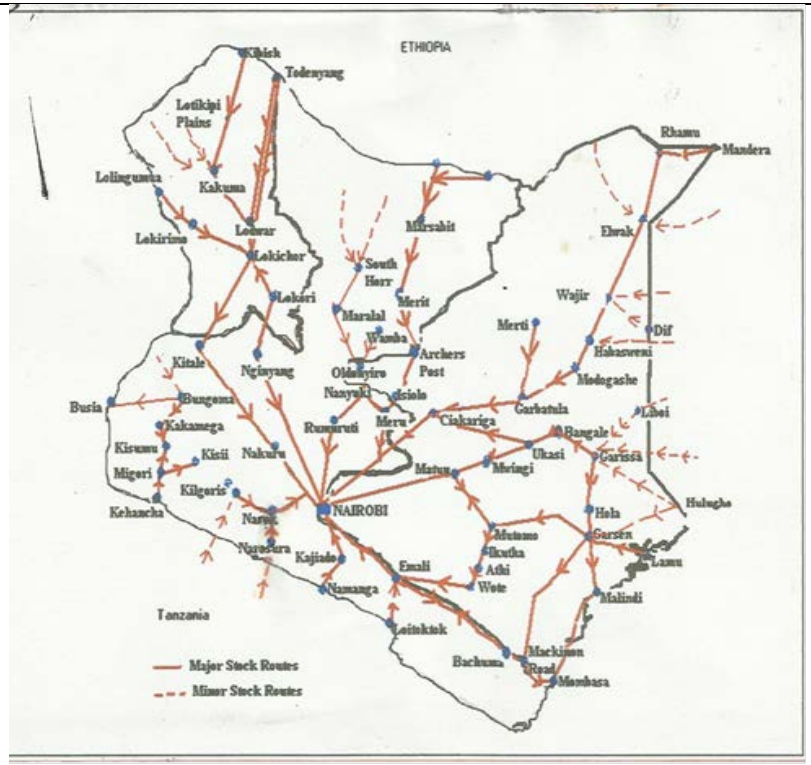

Figure 2: Map showing various trade and stock routes in Kenya.

Serological tests

All the 3709 bovine samples were subjected to foot-and-mouth disease virus screening test; non-structural protein-Elisa (AniGen® FMD NSP Ab ELISA). The AniGen® foot-and-mouth disease virus antibody Elisa kit was designed to detect FMDV specific antibodies in bovine serum. The test was useful because it was able to discriminate animals that had been infected (wild virus induced antibodies) from those that had been vaccinated with purified vaccine (vaccine induced antibodies) The test materials including AniGen® test kit, chemicals (washing & stopping solutions) and biological (negative & positive control, enzyme conjugate & substrate) reagents were availed by the FMD reference laboratory.

Briefly, the test sera, negative and positive reference sera were added to all the 96 well ELISA plate coated with 3ABC antigen. Following addition of the diluted enzyme conjugate and incubation for 90 minutes at 37^0C, the plates were washed three times with washing buffer. After the last washing, tetramethylbenzidine (TMD) ready to use substrate was added and plates were incubated at room temperature for another 15 minutes. The reaction was terminated by adding 1M Sulphuric acid stopping solution. The optical density of the samples were measured at 450nm and the result was expressed as an index derived by dividing the absorbance value of the test serum by that of the cut-off control (OIE 2004). A sample with a Percentage Inhibition (PI) value of above 50 (i.e. $\geq$ 50.0) on AniGen FMD NSP Ab Elisa was regarded as a positive result while a sample of PI value of less than 49 (i.e. <50.0) was regarded as a negative result (Diego *et al.,* 1997). The liquid phase blocking elisa (LPBE) test was performed according to the manual (Kenya, FMDV Elisa Kit, Bench protocol, 2009).

Data analysis

The results of both the NSP Elisa were then entered in an Excel spreadsheet (Microsoft Corp) with the following information; sampling location, age, sex, species, vaccination history, AniGen results. The data was imported to SPSS 20 version for analysis. Descriptive statistical analysis was then done to determine the proportion of positive samples and serotype distribution across the country and at county level. Graphs were drawn using Microsoft excel.

RESULTS

a). Foot-and-mouth disease seroprevalence in borderlands

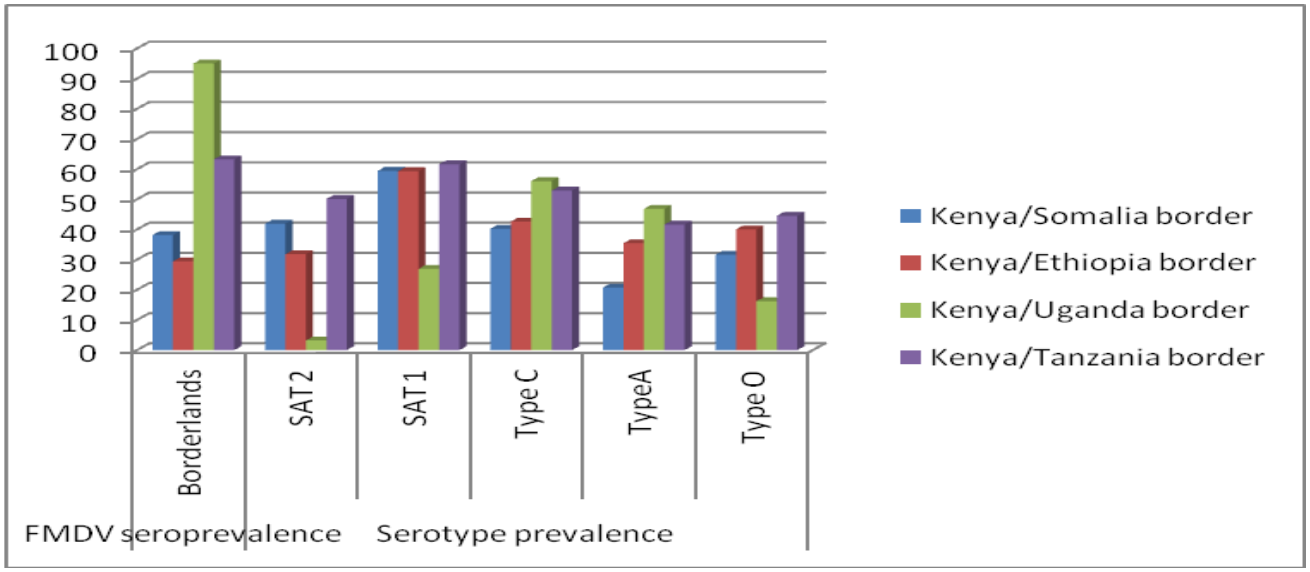

Figure 3: FMDV and serotype prevalence in borderlands.

The Kenya/Somalia borderland (Somali Ecosystem), Kenya/Ethiopia borderland and Kenya/Tanzania borderland (Maasai ecosystem) had mean foot-and-mouth disease virus seroprevalence of 38.1%, 29.4% and 63.2% respectively with SAT1 and serotype A being the most prevalent and least prevalent serotypes while the Kenya/Uganda borderland had the highest FMDV seroprevalence of 95% with serotype C (56%) and SAT2 (3.2%) being the most and the least prevalent respectively (Figure 3 and Table 1).

Table 1: FMDV and serotype prevalence in borderlands

		Kenya/Somalia border	Kenya/Ethiopia border	Kenya/Uganda border	Kenya/Tanzania border
FMDV seroprevalence	Borderlands	38.1	29.4	95	63.2
Serotype prevalence	SAT 2	41.9	31.8	3.2	50.1
	SAT 1	59.4	59.3	26.9	61.6
	Type C	40.2	42.6	56	52.9
	TypeA	20.7	35.4	46.8	41.6
	Type O	31.6	40	16.2	44.5

b).Foot-and-mouth disease seroprevalence in proposed disease free zones

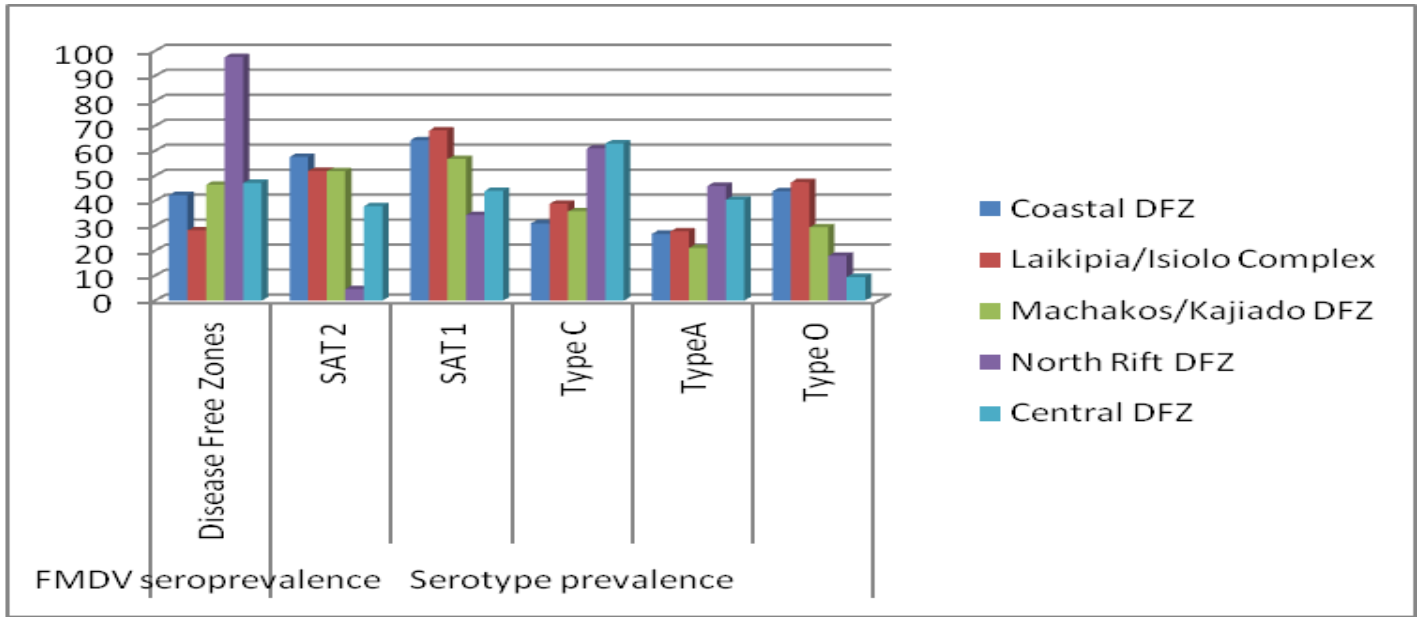

Figure 4: Foot-and-mouth disease virus seroprevalence in disease free zones.

The Coastal, Laikipia/Isiolo complex and Machakos/Kajiado disease free zones had a mean foot-and-mouth disease virus seroprevalence of 42.2%, 28.1% and 46.4% respectively with serotype SAT1 and serotype A being the most and the least prevalent serotypes.

Table 2: FMDV and serotype prevalence in disease free zones

		Coastal DFZ	Laikipia/Isiolo Complex	Machakos/Kajiado DFZ	North Rift DFZ	Central DFZ
FMDV seroprevalence	Disease Free Zones	42.2	28.1	46.4	97.5	47.1
Serotype prevalence	SAT 2	57.5	51.9	51.8	4.6	37.8
	SAT 1	64.2	68.1	56.7	34.3	43.9
	Type C	30.9	38.7	35.7	60.9	62.9
	TypeA	26.7	27.7	21	45.9	40.4
	Type O	43.8	47.4	29.3	17.9	9.4

The North Rift disease free zone had the highest FMDV seroprevalence at 97.5% with serotype C (60.5%) and SAT2 (4.6%) being the most and the least prevalent serotypes respectively. On the other hand, the Central DFZ had FMDV seroprevalence of 47.1% with serotype C (62.9%) showing the highest prevalence while serotype O (9.4%) being the least prevalent (Figure 4, table 2 and figure 5).

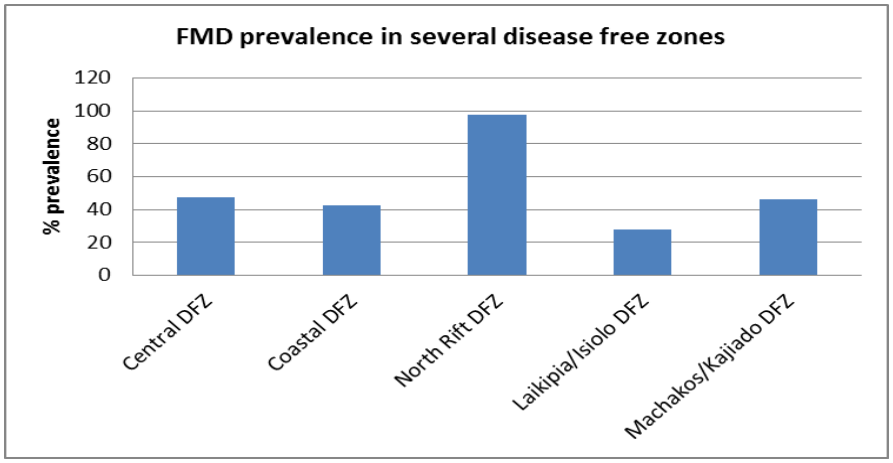

Figure 5: FMDV seroprevalence in several disease free zones.

c). Foot-and-mouth disease seroprevalence in regions surrounding the national parks and game reserves

Table 3: FMDV and serotype seroprevalence around national game parks and game reserves

		Sibiloi	South Turkana	Marsabit	Losai	Samburu	Meru	Mt Elgon	Mt Kenya &Abardare	Maasai Mara G.R.	L.Nakuru & Hells Gate	Amboseli	Tsavo
FMDV seroprevalence	National parks	49	93	19.5	28.3	43	38.2	100	30	64.1	61.2	66.1	42.3
Serotype prevalence	SAT 2	24.3	4.3	50.7	54.1	81.3	64.8	2.3	55	25.1	35.8	55	61.8
	SAT 1	57.6	40	68.8	79.9	87.5	68.4	17.8	54.8	44.4	46.9	60.2	63.4
	Type C	52.3	65.3	51.3	53	12.5	41.2	44.4	56.3	41.6	58.3	58.8	37.7
	TypeA	50	68.3	31.8	25.8	31.3	27.1	40	29.2	36.9	45.4	51.5	24.3
	Type O	54.2	19	53.8	57.2	50	39.8	6.7	24.2	20.7	22.3	50.2	44.6

The FMDV seroprevalence was high in Mt Elgon national park (100%) and South Turkana game reserve (93%) with serotype C and serotype A being the most prevalent serotypes at 44.4% and 68.3% respectively. On the other hand, Mt Kenya & Abardare national park and Losai game reserve had the least FMDV seroprevalence at 30% and 28.3% with serotype C and SAT1 being the most prevalent serotypes at 56.3% and 79.9% respectively (Table 3 and Figure 6).

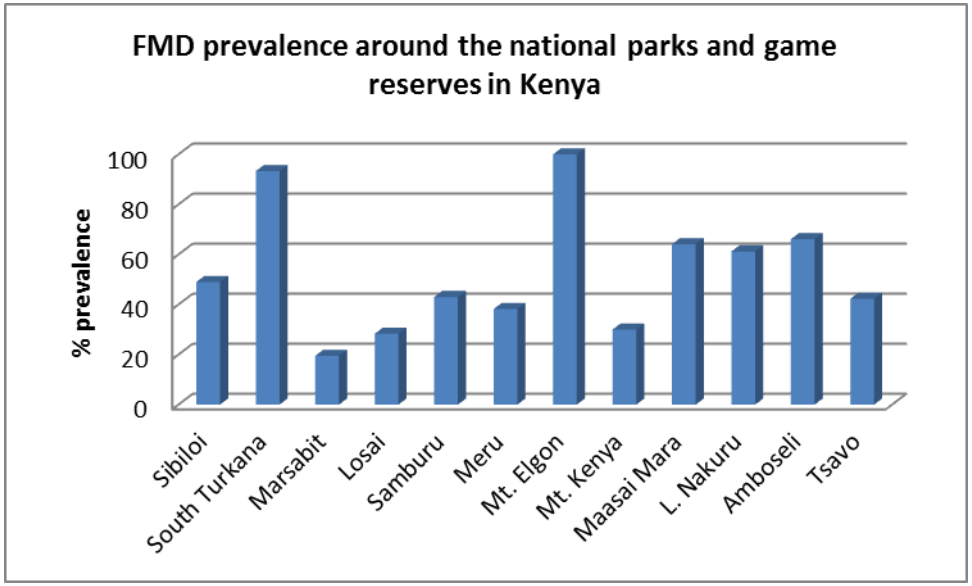

Figure 6: FMDV seroprevalence around the national parks and game reserves in Kenya.

d). Foot-and-mouth disease and serotype seroprevalence along several trade and stock routes in Kenya

Table 4: Foot-and-mouth disease seroprevalence along several trade and stock routes in Kenya

	North Eastern Corridor							Northern Corridor		Southern Corridor	
	Stock Routes	Route 1	Route 2	Route 3	Route 4	Route 5	Route 6	Route 1	Route 2	Route 1	Route 2
	FMDV seroprevalence	35.5	26.6	44.8	38.6	48.7	50.9	37.4	80.5	77.9	47.2
Serotype prevalence	SAT 2	57.3	69.9	53.4	49.5	62.9	62.3	53.1	8.1	30.1	52.1
	SAT 1	70.3	79.9	69	63.1	60.6	75	51.3	32.2	55.9	69.6
	Type C	40.3	61.3	29	43.2	44.9	33.9	37.6	54.4	52.1	53.5
	TypeA	35.4	12.6	25.8	28.5	27.2	30.1	28.7	40.5	42.5	44.9
	Type O	70.5	42.2	45	41.7	44.3	52.6	25.6	22.6	24.2	60.5

Key:

Northern Eastern Corridor

Route 1-Ethiopian border-Moyale-Marsabit-Isiolo-Meru-Embu-Nairobi

Route 2-Ethiopian border-Marsabit-Isiolo-Laikipia-Nyeri-Nairobi

Route 3-Ethiopia/Somalia/Mandera-Wajir-Garissa-Tana River-Lamu-Kilifi-Mombasa

Route 4-Mandera-Wajir-Isiolo-Meru-Embu-Nairobi

Route 5-Somalia/Wajir-Garissa-Tana River-Kitui-Machakos

Route 6-Wajir-Garissa-Tana River-Lamu-Kilifi-Mombasa

Northern Corridor

Route 1-Samburu (Baragoi/Maralal)-Laikipia-Nyandarua-Nakuru-Nairobi

Route 2-Turkana (Lokichogio/South Sudan/Lodwar)-Pokot-Trans Nzoia-Uasin Gishu-Nakuru-Nairobi

Southern Corridor

Route 1-Migori-Narok-Kajiado-Nairobi

Route 2-Narok-Kajiado-Taita Taveta-Kwale-Mombasa

In the Northern Eastern corridor, stock route 6 (Wajir-Garissa-Tana River-Lamu-Kilifi-Mombasa) had the highest seroprevalence at 50.9% while route 2 (Ethiopian border-Marsabit-Isiolo-Laikipia-Nyeri-Nairobi) had the least FMDV seroprevalence at 26.6% with serotypes SAT1 and SAT2 being the most prevalent serotypes and serotype A being the least prevalent respectively in all the routes. In the Northern corridor, stock route 2 (Turkana-West Pokot-Trans Nzoia-Uasin Gishu-Nakuru-Nairobi) had the highest FMDV seroprevalence at 80.5% with serotype C and SAT2 being the most and the least prevalent serotypes at 54.4% and 8.1% respectively. In the Southern corridor, stock route 1 (Migori-Narok-Kajiado-Nairobi) had the highest FMD seroprevalence at 77.9% with serotype SAT1 (55.9%) and serotype O (24.2%) being the most and the least prevalent serotypes respectively (Table 4, Figure 2 and Figure 7).

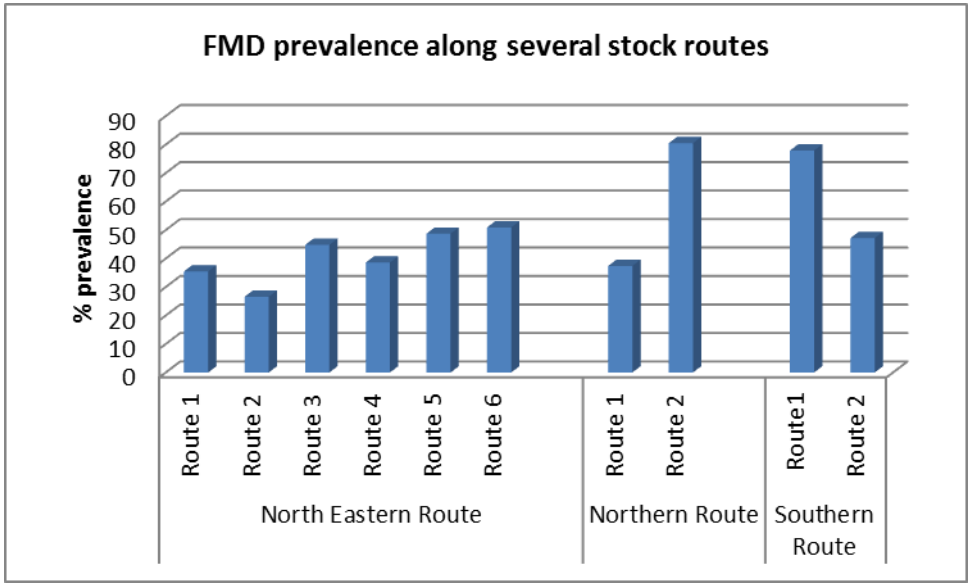

Figure 7: FMD seroprevalence along several trade and stock routes in Kenya.

e). FMD prevalence in pastoral (agro-ecological zone V-VII) and non-pastoral regions (AEZ I-IV)

The pastoral regions comprises areas occupying agro-ecological zones V-VII and include the following counties; Turkana, Samburu, Isiolo, West Pokot, Marsabit, Garissa, Mandera, Moyale, Wajir and Baringo that form the northern pastoral areas as well as Narok, Kajiado, Kitui, Laikipia, Tana River, Lamu and Taita Taveta that comprise the southern pastoral areas. The southern pastoral regions had a mean seroprevalence of 58.2% when compared with the northern one which had mean FMDV seroprevalence of 49.4%

although the difference was not statistically significant (p>0.05, 95%CI). The overall mean FMD seroprevalence in the pastoral region was 53%.

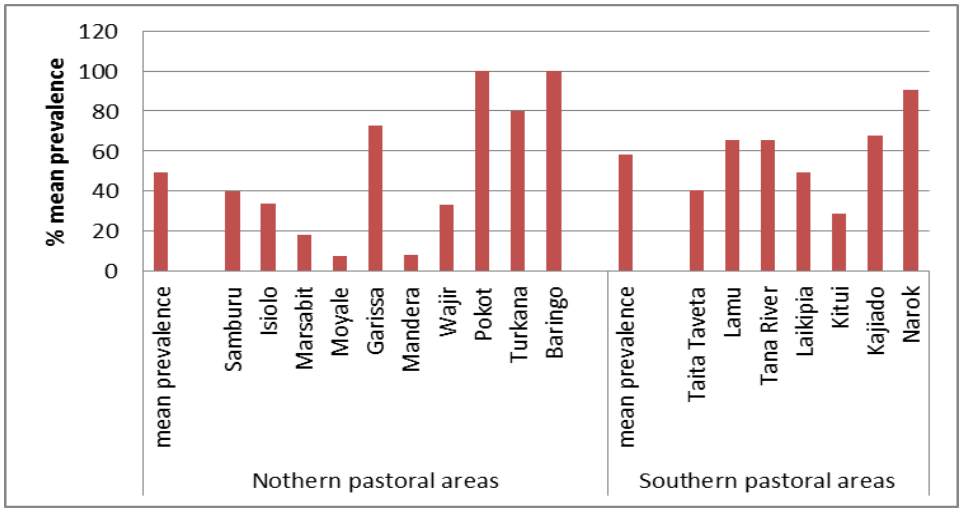

Figure 8: FMD seroprevalence in pastoral areas of Kenya.

The non-pastoral areas of Kenya fall under agro-ecological zone I-IV and made up of the following counties; Elgeyo Marakwet, Uasin Gishu Nandi, Trans Nzoia, Bungoma, Kakamega, Bomet, Migori, Nakuru, Siaya, Machakos, Makueni, Nyeri, Embu, Meru, Nyandarua, Tharaka Nithi, Kilifi, Malindi, Mombasa, Kwale and Kisumu. The seroprevalence of FMD was higher in non-pastoral regions at 58.6% compared to that of pastoral areas at 53% although the difference was not statistically significant (p=0.52, 95%CI) (Figure 8 & Figure 9).

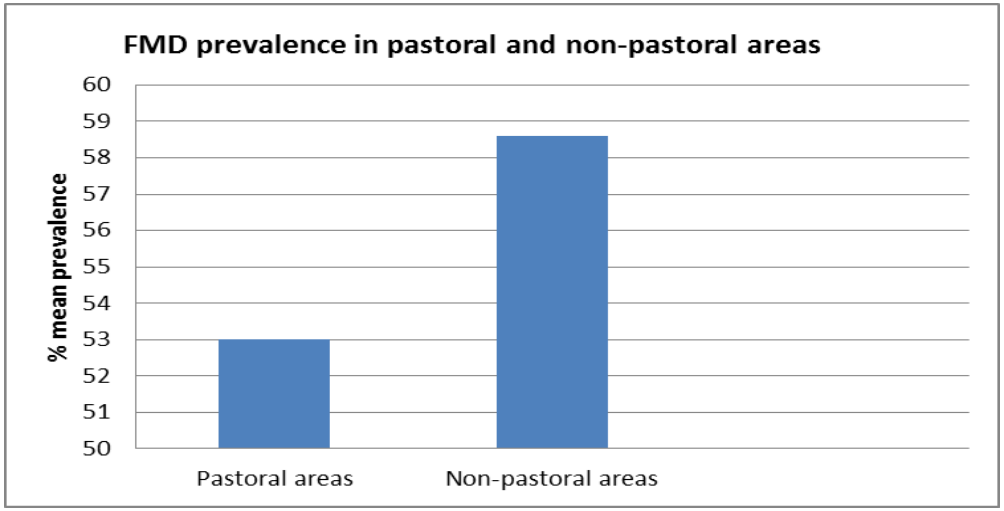

Figure 9: FMD seroprevalence in pastoral and non-pastoral regions.

DISCUSSION

The Kenyan borderlands remain predominantly inhabited by pastoral communities who are characterized by high mobility in search of water and pasture with strong cross border linkages with their counterparts on the other side of the border. Borderlands constitute a dynamic livestock trading zone that supports the livelihoods of thousands of people. Despite tension and numerous border closures that occasionally occur; community interactions, livestock migration and trade have continued unabated. Cross border livestock

migration and trade have kept relations at the community level vibrant, while national economies and local authorities have benefitted from taxes on the flourishing trade in livestock and livestock products. In the Kenya/Tanzania borderland for example, the Kenyan Maasai's who are the main inhabitants in these areas continuously crosses the border into Tanzania in search of water and pasture. The livestock also interact freely with roaming wild life in these areas therefore acting as virus maintenance zone. The FMDV seroprevalence in Kenya/Uganda (95%) and Kenya/Tanzania (63.2%) was higher compared to the FMDV national seroprevalence (52.5%). The presence of wildlife with continuous interaction with cattle acts as a key basis for the high seroprevalence (Kibore *et al.*, 2013).

In the Kenya-Somali border (Somali Ecosystem), the high prevalence of SAT1 and FMDV seroprevalence especially in Garissa county could be attributed to the interaction between local and market livestock sourced from as far as Ethiopia and Somalia. The border county harbors very vibrant livestock market with resultant high contact of cattle from different sources therefore acting as a key source of exposure. The high seroprevalence in non-pastoral regions as compared to pastoral regions may be associated with the difference in the type of breeds kept. The exotic animals are mostly kept in the non-pastoral areas and are susceptible to FMD infections more compared to the more resistant (indigenous) livestock kept in the pastoral areas. Additionally, the sub-optimal use of FMD vaccination in relation to the population size of livestock increases the risk of susceptible animal populations (FAO, 2005-2006).

In line with Vision 2030, the Ministry of Livestock Development is in the process of establishing disease free zones in coast region, Laikipia/Isiolo complex, North Rift, Machakos/Kajiado and central Kenya (Appendix 1). Disease free zones will serve as the last holding points for cattle that have been vaccinated and quarantined en-route. The DFZ's will be equipped with dips, water and feeding facilities and will be fully fenced. It also aims at building and rehabilitating quarantine centers (Mirtini and Bachuma in coast). The DFZ will target cattle coming from the North and North Eastern provinces of Kenya, Somalia and Ethiopia.

DFZ aims at creating a geographically compact area within which the frequency of vaccination can be safely reduced to once per annum. The zoo-sanitary measures applied will be cost-wise rather being prohibitive to both government and farmers and will be applied at ease. Benefits accrued from such venture will be immense ranging from free and regular movement of livestock to markets without undue quarantine restrictions, increase in exports earnings from sale of beef and pigs in international markets, improved export marketing possibilities for live animals, Kenya could act as source of disease free breeding stock, improved and regular deliveries of cattle and pigs to slaughterhouses, increased availability of cheaper disease free meat to improved turn over from livestock and livestock products. However, obtaining recognition of zones free from FMD will be 'logistically difficult', very expensive and socially disruptive with displacement and exclusion of local populations and livestock (Thomson, 2008). The alternative to this would be to upgrade and strengthen veterinary services and animal disease surveillance, reporting and control-key elements. These need to be addressed in the short to medium term with a view to perhaps establishing DFZs in the long term.

Thomson *et al*., (2003) made an observation that wherever in the world FMD has been eradicated from livestock, it has always disappeared from wildlife in those regions too. Similarly, outbreaks of FMD in zoological gardens have coincided with outbreaks of FMD in domestic animals. In Sub-Saharan Africa, wildlife is clearly involved in the maintenance of FMD. Wildlife in South Africa, particularly the Cape buffalo ((*Syncerus caffer)* has been identified as natural hosts for the SAT serotypes of FMDV, although they may be infected by all serotypes (Hedger, 1976). Most wildlife-protected areas are in confluence with livestock grazing areas and as such the interface constraints the control of diseases shared between wildlife and domestic animals. The role of wildlife in maintenance and transmission of FMD disease is recognized and the intensive wildlife-livestock interaction enhances disease transmission through contact, sharing of water and pasture.

The seroprevalence of FMD was highest 100% in areas around Mt. Elgon National Park. The park extends from Kenya into Uganda and bisected by the border. Elephants and buffaloes can be found on the lower slopes of the mountain. Cattle in many areas in Africa including Kenya are reared on open rangelands with communal grazing and potential contact with wildlife populations. This wildlife-livestock interface is critical for disease transmission particularly around common watering points and through contamination of pastures. Other factors include cattle straying into wildlife conservancies especially during the dry seasons in search of pasture and coming in contact with wildlife species. The disease has been reported in several species of wildlife, such as the African buffalo (*Syncerus caffer*), impala (*Aepyceros melampus*), Kudu (*Tragelaphus strepsiceros*) species, Warthog (*Phacochoerus aethiopicus*), and African savanna and forest elephants (*Loxodanta Africana/Loxodanta cyclotis* respectively) with an ability to both maintain and

transmit the disease. The mechanism facilitating SAT-type virus transmission from buffalo appears to occur readily when there is close contact between the two species during acute stage of infection and shedding large amounts of virus.

The seroprevalence was also high in South Turkana national game reserve at 93.3%. Livestock interact freely with wild life which include; elephants, buffalo, eland, oryx, impala, bushbuck, greater kudus, Grants and Thomson gazelle. The high number of herbivores known to harbor and transmit the disease may be the reason for the high FMD prevalence. Impala (*Aepyceros melampus*) is the most frequent infected species and act as an intermediary in disease transmission of the disease between livestock and buffalos (Vosloo *et al.,* 2002). Wildlife do not excrete virus to the level of domestic pigs and are not believed to play an important role in the epidemiology of FMD in Africa. Rare case of FMD has also been reported in Indian elephant (*Elephas maximus*) and in the African elephant (*Loxodo africana*) (Thomson, 1994). The Amboseli national park which spans across the Kenya/Tanzania border consists of African Elephant, Cape buffalo, impala, zebras and wildebeests which may be responsible for maintaining FMD virus in the Maasai ecosystem.

It is noted that stock routes extend to neighboring countries like Uganda, Sudan, Ethiopia, Somalia and Tanzania. Most of the stock routes terminate in Nairobi and Mombasa markets. Nairobi's Dagoretti market is served by southern corridor (including supplies from Tanzania), Northern corridor from North West Kenya (including supplies from Uganda, South Sudan and Ethiopia) and North Eastern corridor mostly from Garissa. Dandora is served by Northern route (Moyale, Marsabit), western and eastern (Garissa). Mombasa

receives most of its animals from North Eastern corridor. The supply chains are based on trekking (mostly from pastoral areas to primary and secondary markets) and trucking from secondary markets to terminal markets in Nairobi and Mombasa. In some cases trekking is also done from the secondary to the terminal market as in the case of Garissa-Tana River-Mombasa route (AU-IBAR, 2006). Livestock sale contribute directly or indirectly towards food security and therefore disruption of the stock routes (i.e. through insecurity) impact negatively on livelihood.

As animals (sick/carriers) are trekked, they disseminate the virus along their paths through saliva and other excretions. Kenyan borders remain porous and therefore disease surveillance by the veterinary personnel may not be effective or achieved. The contact between market and local animals at watering points or pastures act as an important avenue of transmission. As animals are trekked, they interact with wild life such impala, African buffalo, Kudu species, Warthog and African savanna or forest elephants, known to maintain or transmit the disease. Some of the trade routes cut cross game reserves and national parks. Illegal stock routes for trade and movement as a result of drought act a key cause of disease spread. In addition, Illegal livestock movement for marketing and cattle rustling together with forced movement of livestock due to cattle rustling within the region and in neighboring countries also contribute to disease spread. (Chepkwony *et al*., 2012). Thus, uncoordinated livestock movements pose the greatest challenge to disease control in the region.

CONCLUSION AND RECOMMENDATIONS

Foot-and mouth disease is endemic in Kenya. Various factors contribute to the maintenance and spread. Uncoordinated animal movements across counties and across porous borderlands, existence of wildlife-domestic animal interphase, existence of multiple serotypes with absence of cross protection as well as low vaccination coverage are some of the risk factors associated with the spread of foot-and-mouth disease. The FMD inactivated vaccines in use in Kenya confer short duration of immunity after vaccination. A repeated vaccination does result in an increase in levels and duration of immunity but a further complication is the ability of the virus to undergo antigenic variation when circulating in livestock. With these factors in mind, there is need to institute an elaborate and workable control measures against the disease. In addition, there is need to use the oil based vaccines that confers longer immunity, moderate the prices of vaccines, continuously perform vaccine matching with field strains as well as carry out continuous sero-monitoring in other susceptible species both domestic and wildlife.

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APPENDICES

Appendix 1: Proposed disease free zoning in Kenya