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Social network analysis provides insights into African swine fever epidemiology

Jacqueline Kasiiti Lichoti[a,c,*], Jocelyn Davies[b], Philip M. Kitala[c], Samuel M. Githigia[d], Edward Okoth[e], Yiheyis Maru[b,e], Salome A. Bukachi[f], Richard P. Bishop[b,e]

[a] Ministry of Agriculture, Livestock and Fisheries, State Department of Veterinary Services, Private Bag-00625, Nairobi, Kenya
[b] Commonwealth Scientific and Industrial Research Organization, Land and Water Flagship, Business & Innovation Centre, Desert Knowledge Precinct, Alice Springs 0870, NT, Australia
[c] University of Nairobi, Department of Public Health, Pharmacology and Toxicology, P.O. Box 29053, Nairobi 00625, Kenya
[d] University of Nairobi, Department of Veterinary Pathology, Microbiology and Parasitology, P.O. Box 29053, Nairobi 00625, Kenya
[e] International Livestock Research Institute and Biosciences Eastern and Central Africa, P.O. Box 30709, Nairobi 00100, Kenya
[f] University of Nairobi, Institute of Anthropology, Gender & African Studies, P.O. Box 30197, Nairobi 00100, Kenya

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ABSTRACT

Pig movements play a significant role in the spread of economically important infectious diseases such as the African swine fever. Characterization of movement networks between pig farms and through other types of farm and household enterprises that are involved in pig value chains can provide useful information on the role that different participants in the networks play in pathogen transmission. Analysis of social networks that underpin these pig movements can reveal pathways that are important in the transmission of disease, trade in commodities, the dissemination of information and the influence of behavioural norms. We assessed pig movements among pig keeping households within West Kenya and East Uganda and across the shared Kenya–Uganda border in the study region, to gain insight into within-country and trans-boundary pig movements. Villages were sampled using a randomized cluster design. Data were collected through interviews in 2012 and 2013 from 683 smallholder pig-keeping households in 34 villages. NodeXL software was used to describe pig movement networks at village level. The pig movement and trade networks were localized and based on close social networks involving family ties, friendships and relationships with neighbours. Pig movement network modularity ranged from 0.2 to 0.5 and exhibited good community structure within the network implying an easy flow of knowledge and adoption of new attitudes and beliefs, but also promoting an enhanced rate of disease transmission. The average path length of 5 defined using NodeXL, indicated that disease could easily reach every node in a cluster. Cross-border boar service between Uganda and Kenya was also recorded. Unmonitored trade in both directions was prevalent. While most pig transactions in the absence of disease, were at a small scale (<5 km) and characterized by regular agistment, most pig sales during ASF outbreaks were to traders or other farmers from outside the sellers' village at a range of >10 km. The close social relationships between actors in pig movement networks indicate the potential for possible interventions to develop shared norms and mutually accepted protocols amongst smallholder pig keepers to better manage the risk of ASF introduction and transmission.

1. Introduction and background

Pork production is increasing in certain African countries, particularly Uganda with a pig population of 3.7 million. Western Kenya's recent annual growth rate in pig meat production was 7.4%, higher than that of other types of meat in the country (Kagira et al., 2010). Pig rearing has a considerable potential for raising incomes of resource poor farmers (Swai and Lyimo, 2014) and can also improve direct consumption of white meat increasing access to high levels

* Corresponding author at: Ministry of Agriculture, Livestock and Fisheries, State Department of Veterinary Services, Private Bag-00625, Nairobi, Kenya.
E-mail addresses: kasiiti.orengo@gmail.com, lichoti@yahoo.com (J.K. Lichoti), s.jocelyn.davies@gmail.com (J. Davies), pkitala@uonbi.ac.ke (P.M. Kitala), sgithigia@uonbi.ac.ke (S.M. Githigia), e.okoth@cgiar.org (E. Okoth), yiheyis.maru@csiro.au (Y. Maru), sallybukachi@yahoo.com (S.A. Bukachi), r.bishop@cgiar.org (R.P. Bishop).

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of protein. The current major motivations for pig-keeping, especially for the small-scale and backyard farming systems, include pork production and income generation (Swai and Lyimo, 2014). Pigs are an asset representing a store of wealth or safety net in times of crisis. Smallholder farmers prefer pig keeping compared to other livestock because pigs are easy to sell, have a short reproductive cycle, grow faster and require minimal rearing space (FAO, 2012; Mutua et al., 2010). Short-cycle livestock species like pigs that are prolific can easily be used for poverty alleviation and food security

African swine fever is widely regarded as representing the major disease constraint to pig production and enhancement of pork value chains in Africa (Costard et al., 2009). AU-IBAR statistics estimated 260,000 pig deaths in sub-Saharan Africa in 2009 (0.65% of pig populations), but this is certainly a minimum figure due to under-reporting of disease outbreaks. African swine fever causes serious socio-economic losses to pig value chain actors and has threatened their livelihoods. African swine fever outbreaks have threatened export of pig products thus lowering foreign exchange earnings (DVS, 1994–2012). Although new approaches to vaccine development have been initiated, these are still some way from commercialisation. Several control measures have been instituted including public awareness regarding the most appropriate husbandry methods and pig and pig products movement control. These measures have frequently not been successful in reducing outbreaks and spread of ASF in the past as evidenced by continued outbreaks in Kenya and Uganda owing to non-compliance by actors in the pig value chain (DVS, 1994–2012; OIE, 1996–2014).

African swine fever was first reported in Kenya in 1921 as an entity distinct from classical swine fever (Penrith and Vosloo, 2009). Kenya did not experience ASF outbreaks for three decades since 1963 until an outbreak occurred in 1994 in small scale pig farms in Central Kenya (DVS, 1994). The next outbreak occurred in 2001 in medium to large scale pig farms in city of Nairobi and adjacent towns. This outbreak was traced to infective swill derived from pork imported from Uganda illegally into Kenya (DVS, 2001). Another outbreak occurred in November 2006–2007 with much wider spread in central, rift valley and western regions of the country. Since December 2010, the country has been experiencing shorter inter-epidemic periods of ASF (DVS, 2012). Uganda has reported ASF outbreaks since 1996. There were 7 cases reported to the OIE in 1997 and the number of outbreaks increased each subsequent year with the highest number of outbreaks (57 outbreaks) reported in 2002. The outbreak number reduced from 45 in 2003 to 1 in 2010. In 2011, there was a rise the number of outbreaks to 10. There was no available information about ASF disease situation from 2012 to 2014 though it is presumed that some areas experienced outbreaks but did not report thus were not documented. Most outbreaks occurred in the central and eastern regions of Uganda (OIE, 1996–2014).

The causal agent for ASF is a large DNA virus classified in the monotypic family Asfaviridae, genus *Asfivirus* (Dixon et al., 2005). African swine fever is contagious amongst pigs and is easily spread over broad geographical areas through the movement of infected pigs or contaminated pork and pork products. In endemic areas, spread at local level is often associated with free-ranging pig production, local pig movements and lack of basic biosecurity measures (Costard et al., 2009). The specific causes of persistent and transient ASF outbreaks in endemic areas are frequently difficult to ascertain because of the multiple factors that affect transmission. The virus can cause 100% mortality when introduced into a naïve pig population, such as occurred when the pig population of Cameroon was decimated in 1982 (Penrith et al., 2009). Later there may be sporadic recurrence of smaller scale outbreaks on regular basis, as is the case of Busia on the Kenya/Uganda border. There is currently no vaccine or chemotherapeutics and ASF control is by diagnosis and slaughter to eradicate infected animals. Biosecurity is the main option for prevention of outbreaks, and is absent in almost all small holder farms (Nantima et al., 2015b)

Ties in value chains that link production systems, markets and consumers constitute a contact network for contagious diseases and provide opportunities for transmission of disease within and between sectors (FAO, 2011). Networks provide a conceptual framework that can express relationships between constituent elements (Birgas-Poulin et al., 2006). Epidemiological research was initially interfaced with social network analysis (SNA) in order to address recognized inadequacies, highlighted by the HIV-AIDS pandemic, in representing the social structure of populations and patterns of social interaction which contribute to pathogen spread. Social network analysis is now being incorporated in epidemiological research to develop better predictive models of disease transmission and inform effective strategies for intervention and control (Klovdahl et al., 1994; Martíınez-Loípez et al., 2009; Rothenberg et al., 1998; Woodhouse et al., 1994). Social network analysis is therefore emerging as an important tool for identifying pathways for transmission of infectious diseases amongst livestock (Guillaume et al., 2013). The first major application of SNA in an animal disease context was ex-post investigation of the dynamics of the spread of 2001 UK Foot and Mouth Disease outbreak (Shirley and Rushton, 2005; Ortiz-Pelaez et al., 2006). Social network analysis has since been used in Denmark where cattle movements over a 179-day period and swine movements over a 232-day period in Denmark in 2002–2003 were studied (Birgas-Poulin et al., 2006, 2007). Use of SNA in preventive veterinary medicine is being used to identify populations and specific areas at risk of disease introduction and dissemination (Martíınez-Loípez et al., 2009). Social networks that are important in livestock disease control are not only those related to livestock movements but also those that influence people's adoption of practices and behaviours that could reduce the risk of disease transmission (Alvergne et al., 2013).

The social network research reported here is part of a wider study conducted by BecA-ILRI in partnership with CSIRO as part of an AusAID programme directed at sustainable improvement in food security in sub-Saharan Africa. The broader study aims to understand the epidemiology of African Swine Fever (ASF) as a basis for improving prevention and control of ASF outbreaks and for reducing the social and economic impact of the disease on pig value chain actors. This research was conducted in the border region of Kenya and Uganda because this area has been identified by the Department of Veterinary Services Kenya as a priority region for understanding the ASF transmission dynamics due to frequent recent outbreaks of ASF and risks of transboundary transmission.

The aim of this study was to characterise the structure of networks through which pigs are traded in the study region in order to identify (1) potential pathways for transmission of ASF virus, and (2) network structural characteristics that might be exploited to develop better targeted interventions aimed at reducing the risk of ASF transmission and enhancing pork production. We describe networks of pig movements associated with trade, boar service and agistment (an arrangement for taking in another person's livestock into one's own home to feed and care for in kind or cash payment by the owner) along the Kenya–Uganda border in Busia, Teso and Tororo districts.

2. Materials and methods

Data were collected through a structured questionnaire administered by interview to pig keepers between July and December 2012 with respondents from 683 smallholder pig-keeping households in 34 villages in Tororo and Busia Districts of Uganda and Teso and Busia Districts in Kenya. Villages were the primary sampling

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