# Zoonotic diseases: who gets sick, and why? Explorations from Africa

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# Zoonotic diseases: who gets sick, and why? Explorations from Africa

Vupenyu Dzingirai[a], Bernard Bett[b], Sally Bukachi[b], Elaine Lawson[c], Lindiwe Mangwanya[a], Ian Scoones[d], Linda Waldman[d], Annie Wilkinson[d], Melissa Leach[d] and Tom Winnebah[e]

[a]Centre for Applied Social Sciences, University of Zimbabwe, Harare, Zimbabwe; [b]Department of Epidemiology, International Livestock Research Institute, Nairobi, Kenya; [c]Institute for Environment and Sanitation Studies (IESS), University of Ghana, Legon Accra, Ghana; [d]Institute of Development Studies, University of Sussex, Brighton, UK; [e]Institute of Geography and Development Studies, Njala University, Freetown, Sierra Leone



**ABSTRACT**
Global risks of zoonotic disease are high on policy agendas. Increasingly, Africa is seen as a 'hotspot', with likely disease spillovers from animals to humans. This paper explores the social dynamics of disease exposure, demonstrating how risks are not generalised, but are related to occupation, gender, class and other dimensions of social difference. Through case studies of Lassa Fever in Sierra Leone, Henipah virus in Ghana, Rift Valley Fever in Kenya and Trypanosomiasis in Zimbabwe, the paper proposes a social difference space–time framework to assist the understanding of and response to zoonotic diseases within a 'One Health' approach.

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## Introduction

Global risks of zoonotic disease are currently high on policy agendas, especially in the wake of Ebola (Galaz, Leach, Scoones, & Stein, 2015). Africa is seen as a key hotspot where spillovers are likely to occur from animals to humans (Karesh et al., 2012). But are the spillover and spread of such diseases and the subsequent mapping of potential risks, as often projected through risk maps with certain areas marked 'red for danger', fully understood? Such risk maps are often generated from models, where limited socio-economic information at a finer scale is included (Anyamba, Mahoney, Tucker, & Kelley, 2002). Our understandings of spillover and spread are dominated by biophysical understandings at a broad scale (Brierley, Vonhof, Olival, Daszak, & Jones, 2016), with major interventions constructed in response. But would a complementary understanding of social dynamics, differentiated by location and time, allow a more nuanced and targeted response? Combining disciplines across sectors is central to the 'One Health' approach, advocated by many as an integrated, holistic perspective (Green, 2012; Waltner-Toews, 2007; Zinsstag, Schelling, & Waltner-Toews, 2011). But too often there is a lack of detailed social, cultural and political insight informing such perspectives (Bardosh, 2016).

This paper offers a simple framework, focusing on the intersection of social difference, space and time, and applies it to four disease case studies in Africa. We argue that it offers a way of operationalising a One Health approach, bringing local perspectives on disease risk and response to the fore. Our framework draws on a long tradition of work in public health that recognises the importance of the social and political dimensions of disease risk and public health responses (Wilkinson & Marmot, 2003; CSDH, 2008), and the importance of a wider livelihoods perspective in disease management (Few, Lake, Hunter,

**CONTACT** Vupenyu Dzingirai vdzingi@gmail.com

& Tran, 2013). In this work, understandings of disease and daily activity patterns, seasonality, as well as interannual variations in disease incidence are seen as important (Altizer et al., 2006). Equally, spatial patterns of exposure due to patterns of mobility, agricultural practices and geographies of settlement are highlighted (Hawkes & Ruel, 2006; Kelly & Beisel, 2011). In turn, these dimensions all intersect with patterns of social difference, including across class, gender, age, ethnicity or occupation (Farmer, 1996).

In this paper, we bring three key aspects of this literature together – social difference, space and time – in a single framework. Making use of this, we explore, through case studies of Lassa Fever in Sierra Leone, Henipah virus in Ghana, Rift Valley Fever (RVF) in Kenya and Trypanosomiasis in Zimbabwe, who is at risk, where and when, offering a more variegated and focused perspective on disease risk. We argue that this will help with the focusing and targeting of responses to zoonoses within a One Health approach in the future.

## Methods and approach

This paper is based on studies carried out under the auspices of the Dynamic Drivers of Disease in Africa programme (DDDAC) that has looked at the ecological, social, economic and political drivers of disease with fieldwork focused on Lassa fever in Sierra Leone, Henipah virus in Ghana, RVF in Kenya and Trypanosomiasis in Zambia and Zimbabwe. The cases were chosen to represent different ecological contexts: dryland/savannah/forest areas in east, west and southern Africa. Each case represents a zoonosis with existing or potential human health impacts, often with an intermediate host. All affect poor people and their livestock in marginal places and so affect poverty and livelihoods.

In each case, the team involved a mix of natural and social scientists, working on a mix of disease epidemiology, modelling and social aspects. For the field-level social science work, a combination of methods was used (cf. Craddock & Hinchliffe, 2015). In each case, we used a household survey, allowing for a quantitative analysis of differential perceptions and responses across a differentiated community[1]. Surveys were complemented by in-depth qualitative discussions in focus groups, as well as with individuals. Focus groups allowed gender, occupation and age specific discussions to take place. These revealed the deeper, cultural dimensions of social responses to disease risk, exposing different sources of knowledge than those conventionally used for disease risk models. For spatial and temporal exposure to disease, we employed transect walks, social mapping and seasonal calendar techniques, all at the core of Participatory Rural Appraisal (Chambers, 1994), again highlight local insights and perspectives based on local knowledges. Based on these methods, the following sections offer insights from four cases, and the paper concludes with the implications for policy and practice.

## Lassa fever in Sierra Leone

A study of Lassa fever, a haemorrhagic viral fever with a rodent host (*Mastomys natalensis*) was conducted in rural and peri-urban communities in the forest zone of Eastern Region of Sierra Leone. This region has the highest reported incidence in the world, although this may be an artefact of intensive surveillance work (Peterson, Moses, & Bausch, 2014). Humans become infected with the virus through contact with rodent excreta. Transmission to humans is not well characterised, but is thought to occur when food and water is contaminated with rodent urine or droppings, or because rodents are consumed, when rodents are hunted, butchered and prepared for food. Evidence of infection in humans or rodents is confined to West Africa. Seasonal fluctuations may be due to the stability of the virus in different temperatures and humidity linked to rainfall, and changes in infected rodent population (Fichet-Calvet & Rogers, 2009). Existing risk maps based on large-scale models give only a very coarse picture of possible exposure (Fichet-Calvet & Rogers, 2009). To get a more detailed understanding of exposure patterns and socially differentiated risks, we have to move to a finer-grained analysis.

Lassa–rodent–human–land use dynamics revolve around agriculture and the relationships between fields and settlements. In the forest zone, the staple crop is rice, grown either on upland fields on a rotational fallow cycle, or in swamps in lower wetland areas. Urban and rural residents describe a mix of rodents in their rice fields, swamps and houses. Although people know that Lassa fever is caused by rodents, there is a common misconception about which rodent carries the virus. *Tuile* is the local name for a foul-smelling, rice-eating rodent, most likely a shrew, which is usually blamed locally. The difficult –to–identify *M. natalensis*, the confirmed host is locally said to be found primarily in swamps, although it has also been trapped in homes.

Rodents are eaten in rural areas. Young boys hunt them, and on occasion they are cooked as part of sacrificial ceremonies, but as a food source they are associated with poor people and consumption is increasingly stigmatised. People avoid *Tuile*, a shrew, due to its unappealing smell and the fact that it is widely and wrongly thought to be the 'Lassa rat'. No such restrictions apply to *M. natalensis.* In general poor people reported a preference for eating rodents found in the fields or swamps instead of those around houses. Whether in the swamp or home, *M. natalensis* is not considered a Lassa risk and is not subject to special caution besides routine pest control.

Exposure to Lassa fever relates to farming patterns. Because *M. natalensis* is a burrowing rodent, mounds constructed in fields are favoured sites. Those working in mounded fields and gardens, notably women, are therefore most likely to be exposed to disease. Exposure also relates to housing infrastructure. L. Moses (unpublished data) found houses with mud walls were nine times more likely to have rodent infestation than houses with concrete walls. This finding relates strongly to socio-economic differences. Homes with concrete or tiled floors and tin roofs are mostly inhabited by richer people, while homes made of mud brick and sticks, with thatched roofs, are inhabited by poorer people, including recent immigrants and 'strangers', making the inhabitants more vulnerable to sickness.

The prevalence of *M. natalensis* in homes is highest in the dry season (Fichet-Calvet & Rogers, 2009), which may be related to rodent migration to homes when food in fields and gardens is scarce. This pattern was also reported in focus group discussions. Rodents' seasonal bush to home migration may well contribute to the dry season spike in cases. In homes, exposure may be age and gender specific. Women and young children are present in and around homes and kitchens, carrying out domestic work such as cooking and sweeping. Gendered divisions of farming labour may also lead to differential exposures. Focus groups revealed that the mounds of earth created in swampland for vegetable planting during the dry season are preferred rodent habitats. Although men build these mounds initially it is women, accompanied by children, who spend time in direct contact with the mounded soil, crouching, weeding, watering and harvesting plants. For women, the gardens are an important source of 'own account' cash income (Leach, 1994). Yet, women's work in gardens may unwittingly put them at greatest risk of disease exposure. By contrast, men's garden work is of far shorter duration, conducted standing, with hoes, and so more likely to chase rodents away.

Thus, in relation to our framework, our research reveals how it is certain people at certain times and in certain places are potentially exposed to Lassa fever. It is these intimate connections between highly differentiated human practices and rodent ecology that must be understood if a more sophisticated understanding of who gets sick and why is to be grasped, and more focused control responses implemented.

## Henipah in Ghana

The natural reservoir hosts for Henipah (Hendra and Nipah viruses) – causing encephalitic diseases with human-to-human transmission and which usually has death rates of between 40 and 75%, but can be as much as 100% – are pteropid fruit bats (De Wit & Munster, 2015). Ghana is not usually identified as a place of risk, having not to date identified any human cases. Several factors may explain the absence of confirmed human cases, including the lack of diagnostic resources and surveillance, as well as ecological factors and human sociocultural practices (Kamins et al., 2015; Waldman, Gadzekpo, & MacGregor, 2016). However, given the close proximity of bats and human populations, concerns have been raised, particularly following the West African Ebola outbreak (Baker et al., 2013; Plowright, Hudson, Smith, Westcott, & Bryden, 2015; Olivier & Hayman, 2014). This makes a focus on the relationship between humans and bats essential.

The straw-coloured fruit bat (*Eidolon helvum*) and the Gambian epauletted fruit bat (*Epomophorus gambianus)* are widespread in south-west Ghana. Both act as disease reservoirs. *E. gambianus* demonstrates high seroprevalence of anti-Ebola virus antibodies, while *E. helvum* has high seroprevalence for the Lagos Bat virus, Henipah virus and Ebola virus (O'Shea et al., 2014).

In Ghana, bat–human interactions with both bat species are common, resulting in potential exposure. Henipah infection occurs through animal bites or consumption of and/or contact with: fresh blood, faeces, urine and other bodily fluids. Other possible routes of transmission include eating contaminated animal products, insect vectors and intermediate host species (Clayton, Wang, & Marsh, 2013). In Ghana, there is currently no evidence of spillover from bats to other domestic animals (Kamins et al., 2015; Waldman et al., 2016).

We examined bat–human interactions in three sites, including two rural sites near large bat colonies, Tanoboase in the Brong Ahafo Region, and Ve-Golokuati, in the Volta region and one urban site in Accra, namely the Military 37 Hospital and neighbouring parks and gardens (the 'Accra Complex'). In Ve-Golokuati, three types of bat are present including *E. gambianus* and *E. helvum* along with an insectivorous bat species. *E. gambianus* is the most common and roosts in trees scattered throughout the village. Although it is non-migratory (Olivier & Hayman, 2014), residents say that the bats are more prevalent during the dry season. This may reflect their increased interaction with the bats during this time, as it is also when fruit ripens and the bats feed on the mango, guava, graviol and pawpaw growing in their gardens. In contrast, *E. helvum* has no established roosting site in Ve-Golokuati and is only present in small numbers. In Tanoboase, four types of bats were identified: the Rosetta fruit bat (*Rousettus aegyptiacus*); the Hammer-headed fruit bat (*Hypsignathus monstrosus*), *E. helvum* and insectivorous bats. Most roost in a sacred grove, an area of thick semi-deciduous forest where hunting is forbidden by traditional leadership. In ways that explain wider Henipah exposure to humans, bats also roost in the many small but scattered tree colonies left by humans as they expand for settlement and agriculture. The residential areas of Tanoboase are far from the sacred grove which is located close to some of the fruit farms. The bats roost in the sacred grove all year, but increase between September and December. At the Accra Complex, *E. helvum* predominates. The bats roost in the neem and other trees that line the roads and are scattered across the area. These bats are again most common in the dry season. Across the sites, a number of different people are potentially exposed.

First, farmers in Tanoboase grow fruit – notably mango and cashew – that are favoured by bats. Fruit tree growing, and especially cashew production, has become popular as cocoa sales have declined. Urban demand for fruit has also increased. Bats are attracted to these orchards, owned by small-scale farmers, mostly managed by women. There are also bat roosts dispersed across the landscape, especially in the sacred grove. Farmers complain of partially eaten fruit left by the bats and that their crops are urinated upon near roosting sites. Consuming this fruit is a potential transmission pathway, with women and children particularly at risk.

Bat hunters are a second category. These are mostly young men or children, who are frequently poor. At Ve-Golokuati, very little bat hunting occurs because the smaller *E. gambianus* do not appeal to consumers. Also, the bats roost in areas heavily populated by humans making the use of catapults or guns difficult and because there is a conscious effort by some people in the town to promote bat conservation. Bat hunting was similarly not approved at the Accra Complex, and the military policed banned the use of weapons at the hospital. In the neighbouring parks and gardens hunting took place more openly. At Tanoboase, where bats had both sacred and conservation significance, traditional leadership declared hunting illegal. Although this made using guns difficult at both sites, bat hunting continued. At Tanoboase, this often took place at night using nets, sticks, baskets and catapults. At the Accra Complex, catapults were favoured. At both sites, the majority of hunters were men, with hunting seen to be a masculine activity carried out by 'strong and technical' men. Technique is required because catapults seldom kill bats outright. As a result, considerable dexterity is required to deal with the injured bats. Bat hunters get scratched and bitten, and come into contact with fresh bat blood and other bodily fluids. Although women do not traditionally hunt bats, they clean and prepare the meat, potentially exposing them.

The third category is bat meat traders. In Tanoboase, bat meat trading is a 'secret affair' as bat hunting is banned. Bat meat is an important economic activity in both Ve-Golokuati and in Accra. In both sites, traders' stalls are often below the trees where bats roost, and so are exposed to bat excrement and urine. As one trader from Ve-Golokuati explained, 'I was once eating under this mango and a bat dropped its excreta right on my lower lip'.

The fourth category is those people living and working in close proximity to bat roosts. At the Accra Complex, this includes medical, military and conservation staff. In Ve-Golokuati, this includes market traders and some residents, as the bats are concentrated in the centre of town. They roost mainly in mature mango trees and remaining indigenous trees between houses and within compounds. Many of the houses close by have bat droppings on their roofs. As the residents also practise rainwater-harvesting, bat excreta are potentially washed down into their drinking water containers.

Applying the framework, we clearly see that social difference matters. Poor people who depend on bats for meat; young men and children involved in hunting; women who prepare the meat; men trading in bat meat; and those living or working next to forests patches and orchards where bats roost or feed, risk exposure to Henipah. In terms of temporal dimensions, exposure is mostly in the dry season when bat populations and interaction with humans is high. In terms of spatial factors, neighbourhoods where bat roosts are located and farms with fruit orchards have higher likelihoods of exposure. Thus, bat contact varies by season, location and social group. If the conditions for Henipah emergence and spread arise in Ghana, responses need to be focused with this in mind.



## RVF in Kenya

We have also examined the impact of RVF virus in contrasting sites in eastern Kenya. This is a region where RVF outbreaks have occurred with devastating results. Maps of RVF risk are derived from looking at the spatial distribution of water bodies and land use (Britch, Binepal, Ruder, Kariithi, & Linthicum, 2013). RVF is transmitted by a wide diversity of arthropods; it has been isolated from more than 40 species of mosquito from eight genera (Britch et al., 2013). At least six mosquito genera (*Aedes*, *Anopheles*, *Coquillettida*, *Culex*, *Eretmapodites* and *Mansonia*) have been proven to be capable of being infected with RVF virus in the lab, or have been found to be infected in the wild (Chevalier et al., 2011). Some of these mosquitoes – including *Aedes mcintoshi*, *Aedes ochraceus* are considered as being primary vectors of RVF virus since they maintain the virus from one generation to the next through trans-ovarial transmission, while the rest are secondary vectors (Sang et al., 2010). During dry periods, the virus lies dormant in eggs, flourishing after heavy floods (Britch et al., 2013).

Preferred breeding sites for mosquitoes occur in low-lying wetland patches (*dambos*) in dry land pastoral areas, as well as in canals and other water bodies in the irrigated areas. Alternate periods of dry and wet spells are particularly important for the embryonation and drying of eggs before hatching (Lutomiah, 2015). The secondary vectors breed well in turbid waters and in areas with thick vegetation. In addition, high humidity enhances adult survival and water of neutral pH of 6.8–7.2 provides optimum conditions for larvae development (Pelizza, Lopez-Lastra, Becnel, Bisaro, & Garcia, 2007).

We contrasted dryland pastoral areas and irrigated areas within the same region. These were Ijara sub-County, Garissa County and Bura and Hola irrigation schemes, and Tana River County. A cross-sectional survey was carried out involving 728 people from the pastoral area and 303 from the irrigated areas, while 81 lived in a riverine environment. Serum sampling showed that 21.8% of the people had antibodies (immunoglobulin G) against the RVF virus. This percentage did not vary significantly ($\chi^2 = 1.43$; $p = 0.49$) by site. Conversely, there was a significant variation in the seroprevalance of RVF virus by gender, age and occupation (Table 1). Men as well as older people had higher seroprevalence compared to females and young people. Similarly, pastoralists had higher seroprevalence compared to farmers and other occupations.

In the 2006–2007 outbreak, the pattern of disease exposure and mortality among humans showed that during the initial phases of the outbreak, male pastoralists were mostly affected but in the later stages, people from various occupations, ages and genders got affected. In general, 61% of those

**Table 1.** Sero-prevalence of RVF virus.

| Factor | Levels | RVF seroprevalence $N$ | % positive (95% CI) | Chi |
|---|---|---|---|---|
| Gender | Male | 445 | 26.23 (22.21–30.58) | $\chi^2 = 8.41$, $p = 0.00$ |
| | Female | 665 | 18.95 (15.20–22.14) | |
| Age (years) | <9 | 145 | 2.07 (0.43–5.93) | $\chi^2 = 129.45$, $p = 0.00$ |
| | 9 to ≤18 | 239 | 5.44 (2.93–9.12) | |
| | >18 to ≤30 | 264 | 21.97 (17.13–27.45) | |
| | >30 | 462 | 36.58 (32.18–41.16) | |
| Occupation | Farmer | 202 | 29.70 (23.49–36.52) | $\chi^2 = 56.56$, $p = 0.00$ |
| | Pastoralist | 295 | 38.31 (32.73–44.12) | |
| | Student | 126 | 2.31 (0.48–6.60) | |
| | Other | 75 | 28.00 (18.24–39.56) | |

affected were males and their ages ranged between 4 and 85 years (Centre for Disease Control, 2007). Livestock, particularly sheep, are seriously affected by RVF (Walter & Barr, 2011). RVF epidemics occur following periods of excessive and persistent rainfall that facilitate the amplification of the secondary vectors, which in turn boost the transmission processes initiated by the primary vectors. RVF epidemics often disrupt pastoralists' traditional food sources as consumption of meat, milk and blood from livestock is banned. During the 2006–2007 epidemic, RVF caused losses of over USD$32 m (Rich & Wanyoike, 2010).

There is an increasing pattern of RVF endemism beyond the wetter forest areas. Improving water storage and utilisation in the drylands – such as through the development of dams and irrigation systems – enlarges areas that are suitable for mosquito development, increasing the presence of primary and secondary vectors. This results in a potential pattern of RVF endemism, with major consequences for risk and exposure for both livestock and humans (Walter & Barr, 2011).

Participatory social science studies in both sites showed how livelihood activities influence the risk of exposure to RVF and other mosquito-borne infections. In the pastoral sites, livestock grazing, especially in the dry season, is often located in riverine, swampy or forested habitats, bringing herders into close proximity with mosquito breeding sites. During such periods, domestic animals and wildlife share the few sources of water, resulting in closer interaction between vectors, hosts and pathogens. Among the practices with high risk, herding, slaughtering and birthing are mostly done by men, while milking and caring for sick animals are done by women. In irrigated areas, crop farming is carried out by both men and women. Practices that predispose people to mosquito-borne diseases include guarding crops in the farms against birds and wildlife, harvesting, charcoal burning and fetching of water. However, it is often poorer households, with plots at the end of canals where water flows are more sporadic, that are most exposed to mosquitoes, as these breed in these sites where water is stagnant, rather than in free-flowing canals. Poorer people and in-migrants are also employed as labourers across the irrigation area, and so are also exposed.

Across our sites, the highest densities of mosquitoes are found on irrigated farms, and then (in order) in permanent settlements, near water canals, around temporary settlements and in pastoral rangelands (Figure 1). Conditions that favour the development of large populations of mosquitoes in irrigated farms include: high humidity given the presence of standing water and high temperatures; presence of feed, especially pollen grains from maize plantations; and use of ammonia-based fertilizers that serve as an attractant. The permanent settlements used by the majority of the people in the area are constructed using local materials such as mud and grass that are often preferred by mosquitoes. Most of the permanent settlements in irrigated areas also have enclosures for sheep and goats.

In the pastoral rangelands, mosquito population density changes with climate (mainly precipitation). A mathematical model, developed as part of the broader project, was used to predict these populations based on rainfall levels indicates that peaks in mosquito densities lag those of rainfall by a period of about four weeks (Figure 2). However, for RVF epidemics to occur, rainfall has to persist to maintain

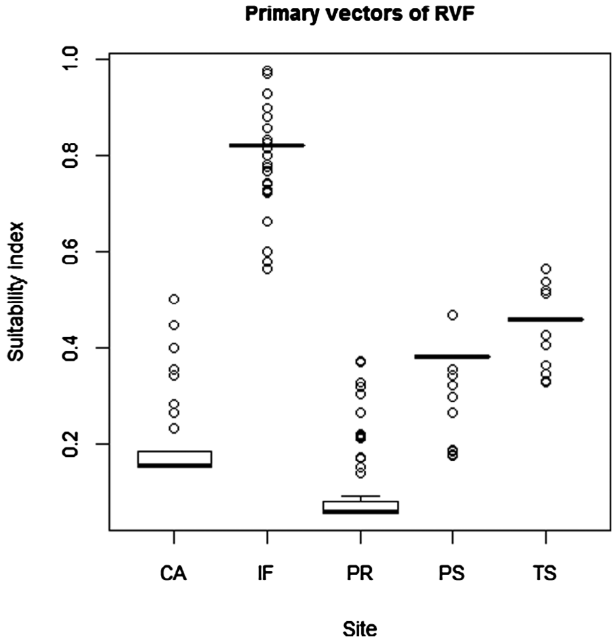


**Figure 1.** Boxplot illustrating the suitability of various sites for the development of the primary vectors of RVF (*Aedes macintoshi* and *Aedes ochraceous*) (CA – water canals, IF – irrigated farms, PR – pastoral rangelands, PS – permanent settlements, TS – temporary settlements); the suitability index represents ecological niche values for various species of mosquitoes sampled from the study sites.

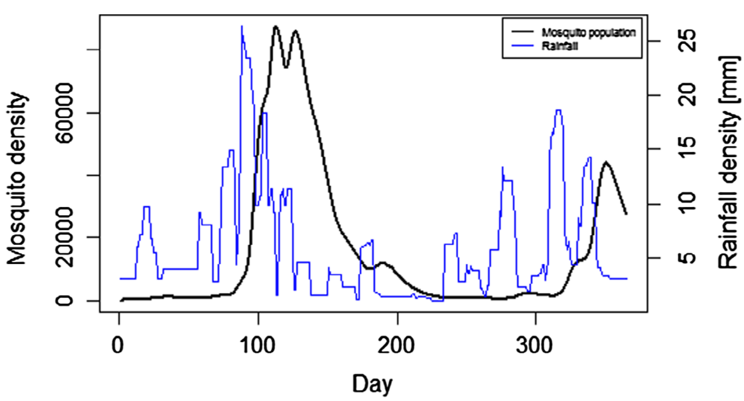


**Figure 2.** Predicted changes in the density of Culex mosquitoes in Ijara, a pastoral rangeland in the north-eastern Kenya.

flooding in dambos for a period of at least six weeks. The persistence of floods for a period of 10–15 days is necessary to allow emergence of infected *Aedes* floodwater species, while flooding for a further period of 4–6 weeks and the colonisation of the waters by secondary vectors allows for the amplification of virus transmission (Linthicum, Davies, Bailey, & Kairo, 1983). The presence of mosquitoes in irrigated areas is sensitive to water management systems. In our study sites, water is allowed to persist in the drainage canals, even when irrigation is not active, allowing persistence of mosquito populations.

Thus, by applying the framework, we can get a better idea of how and when different people are exposed. In the pastoral areas, exposure occurs when mosquitoes emerge from low-lying *dambo* areas following extended rainfall. This is the time when animals and people are concentrated in such 'key

**Table 2.** Respondents' perceptions of areas with high tsetse exposure.

| Village category | % |
|---|---|
| Core village | 1.3 |
| Frontier villages | 63.4 |
| Mushangishe gorge villages | 16.4 |
| All villages | 2.4 |
| Near rivers | 1.5 |
| Missing | 13.1 |
| Total | 100 |

resources' areas for end-of-dry-season grazing (Scoones, 1994). In terms of social difference, herders, mostly from poor households, are especially exposed, followed by women who manage young and sick animals. In the irrigated areas, those living in poorly maintained, grass-thatched houses made with earth walls and floors are especially exposed to the mosquito attracted by these conditions. Poorer households, located for example at the end of a canal, where water flow is not continuous are also exposed, along with labourers, who work on clearing canals and in the fields with surface water.



## Trypanosomiasis in Zimbabwe

In Zimbabwe, we examined the impact of trypanosomiasis – both bovine and human – in Hurungwe district in the Zambezi valley. Trypanosomiasis is transmitted by tsetse flies that are present in areas below 1000 m altitude. Cattle, pigs and goats, as well as wildlife, are affected. These act as reservoir hosts, but where tsetse flies are present there is a chance that humans too can be infected. While recorded incidence is low, there is a strong expectation that actual exposure is higher. As a neglected disease, trypanosomiasis is a major killer in Africa, with many mortalities and much morbidity going unreported (Welburn & Maudlin, 2009). The most important bovine trypanosomes are *Trypanosoma congolense*, *T. vivax* and *T. brucei brucei*, which do not cause sleeping sickness in humans. Human African Trypanosomiasis (sleeping sickness) is caused by *T. brucei rhodesiense* in the study area. Despite extensive tsetse control activities over many decades, the problem of both human and bovine (HAT) trypanosomiasis remains (Simarro, Cecchi, Franco, Paone, & Diarra, 2012).

In our study, we combined satellite image analysis of vegetation and land use to identify areas of habitat suitability for two tsetse fly species, *Glossina morsitans morsitans* and *G. pallidipes*. We also trapped tsetse flies along transects and in particular habitat patches identified by local people. This was related to an analysis of bovine blood samples across the area for trypanosome presence, as well as social science analysis looking at how people's livelihoods, tsetse flies and disease interact.

Our survey looked at perceptions of tsetse exposure in relation to different land uses (Table 2). Through participatory mapping and transect walks, a number of different patches were identified, with the 'frontier villages' and the 'Mushangishe villages' (on the edge of a major gorge) seen as the most exposed.

We identified four population groups who are potentially affected by trypanosomiasis. The first group are internal migrants. Hurungwe has been a site of internal immigration for many decades. Land is plentiful, and local leaders have in the past been welcoming. In our surveys, we identified several different groups of immigrants. Some had come from southern Zimbabwe in the 1980–1990s, and had established homes on the edge of villages, but over time had cleared land and reduced forest areas, so reducing tsetse challenge. Other migrants are more recent, and they did not get access to village land, and had to establish homes in the wildlife areas, beyond the village reserved for concession hunting by local government. These illegal settlements are carved out of forest areas. This means tsetse challenge is high, especially given the density of wildlife populations in these areas. People refer to these areas as the 'maternity wards' for the tsetse fly. Such new settlers include farm workers, expelled by powerful groups aligned to the state from the former large-scale farms in the Karoi area following land reform in 2000, and those retrenched from nearby mines in the economic crisis of the 2000s. They have few

**Table 3.** Confirmed HAT cases in Hurungwe.

| Year | Number of cases | Deaths |
|---|---|---|
| 2005 | 2 | 0 |
| 2009 | 1 | 1 |
| 2011 | 2 | 0 |
| 2012 | 11 | 0 |
| 2013 | 1 | 1 |
| 2014 | 3 | 1 |

livestock but those they have often get sick, and while human trypanosomiasis is rarely reported, the risks are substantial.

Second, foragers also get exposed to tsetse flies, as they move in the forested areas. This group includes poorer women in the villages, as well as the illegal settlements. The peak of foraging happens in the dry season, when wildlife is also concentrated in these areas. Women collect a range of non-timber forest products, such as edible worms, insects, honey, fruits, wild vegetables, mushrooms, eggs and small birds. Foragers follow river tributaries whose banks and beds host these wild resources. They also penetrate into gorges where the popular 'mazhanje' (*Uapacca kirkiana*) fruit is found. These are all patches where both wildlife and tsetse flies are found.

Third, livestock herders, including young boys and immigrant workers, must accompany cattle to search out grazing and water, especially in the dry season. In our study area, the Mushangishe gorge marks out the route of a water course that drains into the Zambezi River to the north. This gorge is an important dry season grazing refuge and source of water – both for livestock and wild animals who migrate up the gorge from the wildlife areas. This temporal and spatial conjuncture means people and animals are exposed in the period from around September to the start of the rains in November, where excellent tsetse habitat exists along with 'key resource' grazing.

The last group is hunters, both subsistence and commercial. Subsistence hunting is concentrated in the dry season, when wild animals are concentrated, and people do not have farm work to attend to. Hunting in the wildlife areas is common, and is associated with younger men. Young men work closely with 'Mare'– medicine men that in addition to providing skills for hunting provide protection from the state and its anti-poaching units. Very often hunting, as a specialised skill, runs in families, meaning that certain kinship groups get especially exposed. But it is not only poorer, male villagers who are involved in hunting. The Hurungwe area attracts some commercial hunting too, whereby foreign clients pay considerable sums to come and shoot big game in the safari areas, accompanied by professional hunters and other workers working for hunting safari companies. These hunters, and perhaps especially the workers and the government officials from the National Parks department who oversee these operations, are regularly exposed to tsetse flies, as these areas are sites where habitat is especially suitable.

In terms of recorded deaths from trypanosomiasis, Table 3 shows confirmed cases of sleeping sickness in Zimbabwe since 2005. While data on human incidence is incomplete, and we did not undertake blood sampling within the human population in our sample, interviews with commercial hunters and National Parks personnel suggests that prevalence is much higher than is formally reported. The 11 cases reported in 2012 were all in the Zambezi Valley, with three of them in November alone. Two of the 11 were tourists and one a professional hunter. The reported case in 2011 was a ranger, who eventually succumbed to the disease (Katsidzira & Fana, 2010).

Thus, again following our framework, we can see how social difference, space and time affects who potentially gets sick and why (including in this case whose cattle). Our data show that social difference is important, but in diverse ways, depending on occupation. It may be men, women or young people, indigenes or migrants, rich or poor depending on what you do and where it takes you. Spatially and temporally there are certain places and times where exposure is heightened. In most of the landscape, tsetse is absent. The land is cleared for cropping and settlement, and tsetse habitat and wildlife presence is minimal. Most people live only in this area, and probably never see a tsetse fly. But for others, who are forced to live in the wildlife areas, who must move down into the deep gorges, or travel in the forested areas and along the river banks for hunting and foraging, it is different. These patches are biophysical features, but they are also social and political components of landscapes. They are constructed through histories of migration, exclusion and livelihood poverty, or alternatively by privilege, wealth and access (for rich commercial hunters and tourists, e.g.), and are reinforced by structurally unequal conditions and social institutions.

## Understanding zoonotic risks: the 'social difference, space and time' framework

Disease risk is as much as social, institutional and political phenomenon, as it is a biological one. Across the four cases, we can see that generalised risk assessments, generated by the type of models or surveillance data that often guide interventions, are insufficient. They are often too coarse in their spatial resolution; they rarely have a seasonal or daily temporal dimension to them; and they do not account for various dimensions of social difference as key factors in influencing exposure and risk. The cases illustrate how it makes a big difference who you are, what you do and what resources you have access to. Gender, age, wealth status, housing quality, occupation, ethnicity, location of fields and homes all influence disease incidence, among other factors.

In basic understandings of epidemiology it is of course recognised that 'social factors' influence transmission rates, but in most models, just as with the risk maps, these factors remain in a 'black box' and are rarely discussed. The result is that surveillance systems, as well as disease prevention and outbreak responses, are often poorly targeted, offering only a generalised response within a broad area, without focusing on particular locations, times and people. This occurs even in so-called integrated approaches such as 'One Health', where the ideal of linking human, animal and ecosystem health is rarely realised (Bardosh, 2016).

In our case studies, we have identified how important it is to understand differential patterns of human health impact, as well as animal disease dynamics. Setting this understanding of disease dynamics within ecological understandings is equally important – whether in relation to land use change, climate patterns or vector ecology and behaviour. But still this is not enough. In each of our cases, we highlighted how social difference was important across a range of axes, and this required a detailed understanding of how different people use environments, and how this affects exposure to disease.

This is why we recommend our 'social difference-space-time' framework as a route to complementing more generalised pleas for a One Health approach, and as a way of operationalising these concerns in particular settings. Table 4 offers a summary of the key findings across the four disease cases, and in relation to the three dimensions of the framework.

As a complement to modelling efforts, such insights may assist with model design and 'downscaling' of results, allowing models to be more specific in their parameterisation, and more realistic and finely tuned in their outputs. In relation to surveillance efforts, improvements in sample design and survey focus may help improve results. And in relation to disease response interventions, a more effective targeting of risky areas, times, people, occupations and practices may improve results.

Social difference has a major impact on disease risk, and different axes of difference intersect and interact. It is not always obvious who will be at risk most. Very often it is the poorest and most marginalised, as they farm, herd, hunt, trade or work in places that are most exposed, have housing infrastructure that is least protected, or they are too poor to afford protective and preventive measures. However, this is not always the case. Sometimes it is richer, more powerful individuals and groups who are vulnerable. Large herd owners in Kenya, for example, must manage grazing routines that result in exposure to RVFV-carrying mosquitoes at certain times, as do those living in permanent homes near irrigated areas. In Zimbabwe, rich commercial hunters and tourists may be especially exposed, as tsetse flies retreat to particular forest patches. They have similar risk profiles therefore to poorer herders, women foragers/gatherers and young male hunters.

Drivers of disease and their social determinants are not a constant, however. Across the cases, we see how changes in land use, agricultural practice and habitat distribution affect disease spillover

**Table 4.** The 'social difference-space-time' framework, as applied to the four case studies: key findings.

| | Social difference | Space | Time |
|---|---|---|---|
| Lassa Fever | Women and children exposed in field mounts and homes with lower quality housing infrastructure | Gardens where burrow in mounds (for yam/cassava), plus edges of rice fields near swamps | Dry season movement from swamps/gardens to homes, and also dry-season cultivation in mounded gardens in or near swamps |
| Henipah | Small-scale farmers growing fruit; bat hunters (mostly men and boys); bat meat traders (mostly poorer women); those living/working near bat roosts | Orchards that are feeding grounds for bats and areas near bat roosts, especially if these are in villages/towns | Year round, but dependent on roosting and migration behaviour of bats |
| RVF | Pastoralists and hired herders taking animals to dambo areas for grazing/watering; cultivators on irrigation schemes, especially those with end of canal plots and stagnant water, poor villages near irrigation schemes | Dambo wetland patches in dryland pastoral areas and irrigation schemes, particularly certain canals and holding ponds | In pastoral areas, rainy season, especially after sustained rainfall and in irrigated areas year-round – rainy season peaks in villages/fields when standing water, and dry season incidence when canal flows reduced |
| Trypanosomiasis | Recent immigrants establishing settlements in wildlife/buffer areas, herders taking animals to gorge, and foragers (mostly women and children); hunters (men) and sport hunters | Forested areas, including gorges and 'frontier' and 'buffer' wildlife areas. Key resource grazing (and watering) areas, where forest/grass available, and suitable habitat for tsetse still exists | Dry season peaks, as wildlife, cattle, people and tsetse flies are pushed together in one place |

opportunities, along with changes in settlement patterns. Equally, changes in the climate, and especially the distribution and level of precipitation, can have a major influence on vectors; for example mosquitoes carrying RVF virus. Drivers also interact over time, affecting how current socio-ecologies influence disease.

But to understand these changes means asking the right questions at the right scale. Large-scale risk assessments are often too generic to get a sense of how often very small habitat patches are the locations of key hosts and vectors at particular times of the year. Understanding how mounded dry season gardens in swamplands link with rodent ecologies and movement and so disease exposure is crucial in understanding the Lassa Fever case, for example. In Zimbabwe, the patches that still have tsetse within the study area are now very small – a few metres across in some instances – and exist at a level of granularity that is difficult to ascertain, except from local knowledge and site-specific understanding of patch ecology and its dynamic relationship with disease.

This has methodological implications for how the framework proposed here can be operationalised. The gaze from space using satellite imagery and linking this to large-scale spatial-ecological disease models is often seen as a cost-effective and quick route to assessing potential risks, but this may not be enough without ground-truthing, and iterating between local contexts and understandings and wider patterns and models. In our work, a participatory mixed methods approach was central, linking models to ground realities (Leach & Scoones, 2013). To get a picture that engages with social difference of course means asking many different people: men, women, old, young, migrants, indigenes, hunters, farmers, labourers, traders and so on. In our work, interviews and ethnographic observation were combined to get a rich picture. Such field-level data in turn must be triangulated with more standard data sources, including climate data, satellite imagery of land-use, blood sampling of humans and animals, vector/intermediate host (bat, rat or insect) population surveys, as well as standard epidemiological data and models on all aspects of disease transmission.

This triangulation can help produce sometimes unexpected, surprising results – such as the disease exposure to Lassa fever in Sierra Leonean villages and gardens – as well as confirm more well-known findings – such as the dynamics of trypanosomiasis in the Zambezi valley. But in all instances, by focusing on the triad of social difference, space and time, we now have a better idea of how to target interventions to reduce spill over and spread of sometimes devastating diseases.

## Conclusion

This paper suggests a simple framework for understanding zoonotic disease risk that takes account of social difference, and spatial and temporal dynamics at appropriate scales. In the context of integrated One Health responses to diseases, this can allow for interventions to be targeted more effectively; rather than blanket responses, it may be possible to design highly specific interventions. For example, in relation to Lassa fever, protection of farmers working in mounded fields and gardens and improvements in housing infrastructure may act to reduce disease transmission from *Mastomys* populations. Only certain people need be targeted, making the interventions cheaper, and much more likely to have an impact. By involving local people in both the investigation of risk and the design of responses, One Health interventions will have more legitimacy and ultimately will be more effective. However, by identifying certain groups as 'at risk' care must be taken to avoid stigmatisation or exposure of precarious, sometimes illegal, livelihoods (whether hunting or settlement in wildlife areas). Targeting needs also to be time-sensitive. In each of our cases, there was a clear seasonal dimension to risk exposure, as well as frequently some inter-annual patterns relevant to changing drivers of disease. The framework will also assist with the design and implementation of monitoring and surveillance systems, making sampling approaches appropriate to the social, temporal and spatial patterns and so more focused, cost-effective and locally legitimate.

One Health approaches have often been accused of being narrowly conceived, and reliant on limited perspectives, dominated by technical veterinary and public health knowledge and excluding ecological and social science (Galaz et al., 2015). We argue that to make the slogans of One Health useful and truly empower those affected to determine forms of intervention, the approach has to be extended further to root diagnosis and analysis in local settings, and to start from these understandings to ask who gets sick and why. Through a focused approach, based on field-based participatory analysis, a cost-effective and targeted response may result. As these four cases have shown, simply alerting the world to disease risk through generalised assessments is not enough; we have to ask the next questions of who gets sick, when and where, as a next step to practical solutions for zoonotic disease challenges.



## Note

1. Sample sizes were Zimbabwe ($N = 527$); Kenya ($N = 1012$); Sierra Leone ($N = 200$); Ghana ($N = 340$).

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## References

Altizer, S., Dobson, A., Hosseini, P., Hudson, P., Pascual, M., & Rohani, P. (2006). Seasonality and the dynamics of infectious diseases. *Ecology Letters, 9*, 467–484.

Anyamba, L., Mahoney, K., Tucker, R. C., & Kelley, P. (2002). A mapping potential risk of Rift Valley Fever outbreaks in Africa Savannah using Vegetation Index Time Series Data. *Programmatic Engineering and Remote Sensing, 68*, 137–145.

Baker, K. S., Todd, S., Marsh, G. A., Crameri, G., Barr, J., Kamins, A. O., … Peel, A. J. (2013). Novel, potentially zoonotic paramyxoviruses from the African straw-colored fruit bat Eidolon helvum. *Journal of Virology, 87*, 1348–1358. doi:10.1128/JVI.01202-12

Bardosh, K. (2016). *One health: Science, politics and zoonotic disease in Africa*. New York: Routledge.

Brierley, L., Vonhof, M. J., Olival, K. J., Daszak, P., & Jones, K. E. (2016). Quantifying global drivers of zonotic bat viruses: A process-based perspective. *The American Naturalist, 187*, E53–E64. doi:10.1086/684391

Britch, S. C., Binepal, Y. S., Ruder, M. G., Kariithi, H. M., & Linthicum, K. J. (2013). Rift Valley Fever risk map model and seroprevalence in selected wild ungulates and camels from Kenya. *PLoS One, 8*, e66626. doi:10.1371/journal.pone.0066626

Centre for Disease Control. (2007). Rift Valley Fever outbreak – Kenya, November 2006 –January 2007. *Morbidity and Mortality Weekly Report (MMWR), 56*, 73–76.

Chambers, R. (1994). The origins and practice of participatory rural appraisal. *World Development, 22*, 953–969.

Chevalier, V., Rakotondrafara, T., Jourdan, M., Heraud, J. M., Andriamanivo, H. R., Durand, B., & Rakotondravao, R. (2011). An unexpected recurrent transmission of Rift Valley Fever virus in cattle in a temperate and mountainous area of Madagascar. *PLoS Neglected Tropical Diseases, 5*, e1423. doi:10.1371/journal.pntd.000142

Clayton, B. A., Wang, L. F., & Marsh, G. A. (2013). Henipaviruses: An updated review focusing on the Pteropid reservoir and features of transmission: Henipaviruses: The Pteropid reservoir and features of transmission. *Zoonoses and Public Health, 60*, 69–83. doi:10.1111/j.1863-2378.2012.01501.x

Craddock, S., & Hinchliffe, S. (2015). One world, one health? Social Science engagement with the one health agenda. *Social Science and Medicine, 129*, 1–4.

CSDH. (2008). *Closing the gap in a generation: Health equity through action on the social determinants of health*. Final report of the commission on social determinants of health. Geneva: World Health Organization. Retreived from http://apps.who.int/iris/bitstream/10665/43943/1/9789241563703_eng.pdf

De Wit, E., & Munster, V. J. (2015). Animal models of disease shed light on Nipah virus pathogenesis and transmission: Nipah virus pathogenesis and transmission. *The Journal of Pathology, 235*, 196–205. doi:10.1002/path.4444

Farmer, P. (1996). Social inequalities and emerging infectious diseases. *Emerging Infectious Diseases, 2*, 259–269.

Few, R., Lake, I., Hunter, P. R., & Tran, P. G. (2013). Seasonality, disease and behavior: Using multiple methods to explore socio-environmental health risks in the Mekong Delta. *Social Science & Medicine, 80*, 1–9. doi:10.1016/j.socscimed.2012.12.027

Fichet-Calvet, E., & Rogers, D. D. (2009). Risk maps of Lassa Fever in West Africa. *PLoS Neglected Tropical Diseases, 3*, e388. doi:10.1371/journal.pntd.0000388

Galaz, V., Leach, M., Scoones, I., & Stein, C. (2015). *The political economy of One Health research and policy* (STEPS Working Paper 81). Brighton: STEPS Centre.

Green, J. (2012). One health, one medicine and critical public health. *Critical Public Health, 22*, 377–381.

Hawkes, C., & Ruel, M. (2006). The links between agriculture and health: An intersectoral opportunity to improve the health and livelihoods of the poor. *Bulletin of the World Health Organization, 84*, 984–990.

Kamins, A. O., Rowcliffe, J. M., Ntiamoa-Baidu, Y., Cunningham, A. A., Wood, J. L. N., & Restif, O. (2015). Characteristics and risk perceptions of Ghanaians potentially exposed to bat-borne zoonoses through bushmeat. *EcoHealth, 12*, 104–120. doi:10.1007/s10393-014-0977-0

Karesh, W., Dobson, B., Lyodd-Smith, A., Lubrth, J., Dixon, M., Bennett, M., … Aldritch, S. (2012). Ecology of zoonoses, natural and unnatural histories, Public Health Resources, Paper 296*, Lancet , 380,* 1936–1945.

Katsidzira, L., & Fana, G.T. (2010). Pitfalls in the diagnosis of trypanosomiasis in low endemic countries: A case report. *PLoS Neglected Tropical Diseases, 4*, e823. doi:10.1371/journal.pntd.0000823

Kelly, A. H., & Beisel, U. (2011). Neglected malarias: The frontlines and back alleys of global health. *BioSocieties, 6*, 71–87.

Leach, M. (1994). *Rainforest relation: Gender and resource use among the Mende of Cola Sierra Leone*. Edinburgh: Edinburg University Press.

Leach, M., & Scoones, I. (2013). The social and political lives of zoonotic diseases models: Narrative, science and policy. *Social Science and Medicine, 88*, 10–17. doi:10.1016/j.socscimed.2013.03.017

Linthicum, K. J., Davies, F. G., Bailey, C. L., & Kairo, A. (1983). Mosquito species succession in a dambo in an East African forest. *Mosquito News, 43*, 464–470.

Lutomiah, J. L. (2015). *Environmental drivers of densities of key Rift Valley Fever virus vectors and the role of host vector interaction in virus maintenance in epidemic regions* (PhD thesis). Jommo Kenyatta University of Agriculture and Technology, Nairobi.

O'Shea, T., Cryan, P. M., Cunningham, A. A., Fooks, A. R., Hayman, D. T. S., Luis, & Wood, J. L. N. (2014). Bat flight and zoonotic viruses. *Emerging Infectious Diseases, 20*, 741–745.

Olivier, K. J., & Hayman, D. T. S. (2014). Filoviruses in bats: Current knowledge and future directions. *Viruses, 6*, 1759–1788. doi:10.3390/v6041759

Pelizza, S. A., Lopez-Lastra, C. C., Becnel, J. J., Bisaro, V., & Garcia, J. J. (2007, October). Effects of temperature, pH and salinity on the infection of Leptolegnia chapmanii Seymour (Peronosporomycetes) in mosquito larvae. *Journal of Invertebrate Pathology, 96*, 133–137.

Peterson, A. A., Moses, L. M., & Bausch, D. G. (2014). Mapping transmutation risks of lassa fever in West Africa: The importance of quality control, sampling bias, and error weighting. *PLoS One, 9*, e100711. doi:10.1371/journal.pone.0100711

Plowright, R. K., Hudson, P. J., Smith, I. L., Westcott, D., & Bryden, W. L. (2015). Ecological dynamics of emerging bat virus spill over. *Proceedings of the Royal Society B: Biological Sciences, 282*, 20142124. doi:10.1098/rspb.2014.2124

Rich, K. M., & Wanyoike, F. (2010). An assessment of the regional and national socio-economic impacts of the 2007 Rift Valley Fever outbreak in Kenya. *American Journal of Tropical Medicine and Hygiene, 83*, 52–57. doi:10.4269/ajtmh.2010.09-0291
Sang, R., Kioko, E., Lutomiah, J., Warigia, M., Ochieng, C., & O'Guinn, M. (2010). RiftValley fever virus epidemic in Kenya, 2006/2007: The entomologic investigations. *The American Journal of Tropical Medicine and Hygiene, 83*, 28–37. doi:10.4269/ajtmh.2010.09-0319
Scoones, I. (1994). *Living with uncertainity: New directions in pastoral development in Africa*. London: Intermediate Technology Publications.
Simarro, P., Cecchi, G., Franco, J. R., Paone, M., & Diarra, A. (2012). Estimating and mapping the population at risk of sleeping sickness. *PLoS Neglected Tropical Diseases, 6*, e1859. doi:101371/journal.pntd0001859
Waldman, L., Gadzekpo, A., & MacGregor, H. (2016). Responding to uncertainty: Bats and the construction of disease risk in Ghana. In K. Bardosh (Ed.), *One Health: Science, politics and zoonotic disease in Africa* (pp. 139–155). London: Routledge.
Walter, C. T., & Barr, J. N. (2011). Recent advances in the molecular and cellular biology of unyaviruses. *Journal of General Virology*, *92*, 2467–2484. doi:10.1099/vir.0.035105-0
Waltner-Toews, D. (2007). *The chickens fight back: Pandemic disease that jump from animals to humans*. Vancouver: Greysrone Books.
Welburn, S., & Maudlin, M. C. (2009). Neglected and endemic zooneses. *Philosophical Transaction of the Royal Society of Biological Sciences, 264*, 2777–2787.
Wilkinson, R. G., & Marmot, M. G. (2003). *Social determinants of health: The solid facts*. Copenhagen: World Health Organization.
Zinsstag, J., Schelling, E., & Waltner-Toews, D. (2011). From "one medicine" to "one health" and systemic approaches to health and well-being. *Preventive Veterinary Medicine, 101*, 148–156.