The occurrence of selected disease syndromes of livestock detected through a passive surveillance system in western Kenya

By

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List of Abbreviations

A	Adult
ADSARS	Animal Disease Surveillance and Reporting System
AFI	Acute Febrile Illness
AHA	Animal Health Assistants
AHR	Animal Health Reporters
AIDS	Acquired Immunodeficiency Syndrome
BOSSS	Bovine Syndromic Surveillance System
BOVID	Bayesian Cattle Disease Diagnostic Program
CAB	Community Advisory Board
CCK	Communication Commission of Kenya
CDC	Centre for Disease Control and Prevention
CNS	Central Nervous System
ECF	East Coast Fever
EMS	Event Management System
EPIMED	EPIdemiology and Detection of Emerging Diseases
F	Female
FAO	Food and Agriculture Organization
GAO	Government Accountability Office
GSM	Global Systems for Mobile
HIV	Human Immunodeficiency Virus
HDSS	Human Demographics Surveillance System
HMS	Household Morbidity Study
IEIP	International Emerging Infectious Program
IDSR	Integrated Disease Surveillance and Response
IHAHP	Integrated Human-Animal Health Program
ILRI	International Livestock Research Institute
IOM	International Organization for Migration
ITU	International Telecommunication Union
KEMRI	Kenya Medical Research Institute
L	Local
M	Male
OIG	Office of Inspector General
RSVP	Rapid Syndromic Validation Project-Animals
RVF	Rift Valley Fever
SARS	Severe Acute Respiratory Syndrome
SAS	Statistical Analysis System
SMS	Short Message System
SVO	Sub-County Veterinary Officer
VET-PAD	Vet Practitioner-Aided Disease Surveillance System
VR	Village Reporter
WHO	World Health Organization

Summary

The occurrence of selected disease syndromes of livestock detected through a passive surveillance system in Western Kenya

By

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Animal disease surveillance has been integral in improving early warnings and predicting disease emergence and spread in humans as well as in animal hosts. Syndromic surveillance is an emerging approach to monitoring populations for change in disease levels, based on the distribution of clinical signs that occur in sick individuals. A number of disease syndromes in livestock may be associated with increased likelihood of endemic, emerging, re-emerging and zoonotic diseases. The overall aim of the current study was to implement a passive animal disease surveillance and response system with a capability of detecting emerging zoonotic diseases in domestic and peridomestic animals, in a trial site where active human disease surveillance is ongoing. The project was intended as a demonstration of the system on a short-term basis, with the intention of conducting an evaluation of its performance later. The specific objective was to evaluate and investigate four selected disease syndromes (abortions/stillbirths, sudden death, neurologic signs, red urine) affecting cattle, sheep and goats using a mobile phone-based rapid short message system (SMS) reporting system within the study site, to allow animal owners to report cases of animal disease. SMS reports were logged in a central database and generated a response from a veterinary team to investigate cases. The study was conducted in Asembo division of Rarieda Sub-county of Siaya County, Nyanza Province in western Kenya, from July 2011 through June 2012. A total of 185 events were reported during the study period. Of these, 46 (24.9%) were considered invalid on investigation. The 139 valid events comprised 75 cases of abortions, 43 cases of sudden death, 12 cases of red urine, and 9 cases of nervous signs. Goats were the most frequently affected species at 47% (n=64), cattle at 34% (n=47) and sheep at 19% (n=26). The incidence rate of events by species (per 1,000 population per year) was 7.3 in sheep, 6.5 in goats and 4.1 in cattle. The incidence rate of abortions by species per 1,000 population per year was 5.1 in sheep, 4.0 in goats and 1.5 in cattle. The incidence rate of sudden deaths by species per 1,000 population per year was 2.1 in goats, 2.0 in sheep and 1.3 in cattle. The incidence rate of neurological signs by species per 1,000 population per year was 0.6 in cattle, 0.3 in sheep and 0.2 in goats. The incidence rate of red urine by species per 1,000 population per year was 1.1 in cattle, 0.1 in goats and 0 in sheep. Presumptive diagnoses implicated haemoparasites infections; including theileriosis, babesiosis, anaplasmosis and heartwater and bacterial infections (septicaemia, clostridial infections and anthrax). This project demonstrated that passive animal surveillance using mobile technology is feasible in a resource-constrained setting, although it is likely that cases were underreported.

CHAPTER 1: Literature Review

1.1 Disease Surveillance

Disease surveillance has been defined as "the continual scrutiny of all aspects of occurrence and spread of a disease that are pertinent to effective control" (IOM, 2003; Last, 1995; WHO, 2000), usually involving "systematic collection, analysis, interpretation, and dissemination of health data" (WHO, 2000). Although the purposes and objectives of disease surveillance may vary between different health sectors, it is generally agreed that surveillance is useful for rapid detection of foreign diseases, provision of evidence of freedom from diseases within a defined geographic area or population, accurate delineation of distribution and occurrence of diseases relevant to disease control, and provision of evidence required to assess progress and success of disease control or eradication (FAO, 2004). Disease surveillance has played a role in early disease detection, essential for the control of emerging, reemerging, and novel infectious diseases, whether naturally occurring or intentionally introduced. Containing the spread of such diseases in an interconnected world requires active vigilance for signs of an outbreak, rapid recognition of its presence and diagnosis of its microbial cause, in addition to strategies and resources for an appropriate and efficient response. Although these actions are often viewed in terms of human public health, they are also challenges in plant and animal health communities.

Disease surveillance and detection relies heavily on the astute individual: the clinician, veterinarian, plant pathologist, farmer, livestock manager or agricultural extension agent who notices something unusual, atypical, or suspicious and brings this to the attention of an appropriate representative of human public health, veterinary medicine, or agricultural agencies in a timely way. In comparison to the developing world, most developed countries have the resources to detect and diagnose human, animal, and plant diseases relatively rapidly (Stanley *et al.,* 2007). Some surveillance systems are designed to provide early warning of a disease threat by detecting the presence of potentially infectious microorganisms. For example, in the U.S.A, the federal BioWatch program uses a network of aerosol sampling stations to monitor major population centers for a range of potential biological agents such as anthrax, plague, and tularemia (Shea and Lister, 2003), within 36 hours of release, thereby allowing federal, state, and local officials to organize a timely response (OIG, 2005). Surveillance approaches have also been used to monitor the progress and outcome of interventions to mitigate the progression of a communicable disease e.g. during the SARS pandemic (IOM, 2004; Heymann and Rodier, 2004) and in the campaigns to eradicate smallpox (Henderson, 1999) and polio (WHO, 2006).

Infectious diseases are responsible for a quarter of all human deaths worldwide, and the majority of these deaths occur in developing countries (King *et al.,* 2006). Africa has the highest burden of infectious diseases in the world and yet the least capacity for their risk management (Esron *et al.,* 2011). On the early warning system of the World Health Organization's Regional Office for Africa through the Event Management System (EMS), it was reported that between January and October 2013 alone, there were 59 public health events reported, of which 88`% were due to infectious diseases (WHO/AFRO, 2013). The Democratic Republic of Congo reported over 14,000 cholera cases during this period. South Sudan has recently faced outbreaks of polio, meningitis and Rift Valley fever. Uganda has had four outbreaks of Ebola hemorrhagic fever since 2000 that have claimed nearly 300 lives. It was observed that weak surveillance systems resulted in under-reporting of epidemics, with many epidemics fading out undetected. Effective control and prevention of outbreaks require reliable public health systems, and therefore there is a need for improved surveillance systems that provide relevant and accurate epidemiologic and laboratory information. Most African countries have adopted the Integrated Disease Surveillance and Response (IDSR) strategy (www.cdc.gov/globalhealth/dphswd/idsr) with a major goal of strengthening district-level surveillance capacity for detecting, confirming and responding to priority diseases that affect African communities. For example, the disease surveillance system in Uganda follows the IDSR approach, which is integrated within the existing health system structures right from the communities, lower health facilities and laboratories to the regional and central level laboratories and the Ministry of Health (http://crofsblogs.typepad.com/h5n1/2012/08/uganda-are-we-doing-enough-to-prevent-ebola-outbreaks.html). Lack of necessary resources i.e. inadequate numbers of skilled officers at district and regional levels to affect various work plans has been cited as one of the major hindrances to surveillance success (WHO-ROA, 2012*)*. Following the outbreak of chikungunya in the Indian Ocean, Madagascar's Ministry of Health directed the development of an early outbreak detection system and established a sentinel syndrome-based surveillance system which identified five outbreaks. Of the 218,849 visits, 12.2% were related to fever syndromes. Of these 26,669 fever cases, 12.3% were related to dengue-like fever, 11.1% to influenza-like illness and 9.7% to malaria cases confirmed by a specific rapid diagnostic test (Randrianasolo *et al.*, 2010).

1.2 Animal Disease Surveillance

Disease monitoring and surveillance systems have become one of the major components of veterinary activity. Such systems are used to assess the existing levels of disease, the effectiveness of control programmes, and after disease eradication, to document the continued absence of disease from a given region or zone (Doherr and Audige, 2001). Despite these efforts, weaknesses in veterinary surveillance systems in Africa have been highlighted during recent outbreaks of infectious diseases such as Rift Valley fever (RVF) and highly-pathogenic avian influenza (HPAI). Conventional passive surveillance systems have proven largely ineffective due to poor capacity and compliance. Furthermore, many countries do not have the capacity to initiate and sustain active surveillance systems. As a result, public veterinary services and the commercial livestock sector are neither able to detect and respond in a timely fashion to outbreaks of new disease threats, nor to successfully manage the control of transboundary diseases, many of which remain endemic in many parts of the continent. This situation not only compromises the development of livestock trade but also poses a continuing threat to human public health, since the majority of emerging infectious diseases are zoonotic;

(Morens and Fauci, 2013). Strategies are therefore needed to ensure that surveillance systems are able to meet the challenges posed by emerging infectious diseases while recognizing the context of resource limitations. It is therefore critical to identify appropriate tools and incentives that encourage the full participation of both public and private actors in disease surveillance (ILRI, 2011).

Animal disease surveillance has been integral in improving early warnings and predicting disease emergence and spread in humans (Morse *et al.*, 2012). As a preventive measure, disease surveillance aims to reduce animal health-related risks and major consequences of disease outbreaks on food production and livelihoods. Early warning systems are dependent on the quality of animal disease information collected at all levels via effective surveillance. Data gathering and sharing is essential to understand the dynamics of animal diseases in diverse agro-ecological settings to support effective decision-making to prevent disease and for emergency response. Animal disease surveillance systems may track zoonotic diseases and identify emerging diseases and as such, are recognized as a global public good to support improved animal and human health (FAO, 2011).

The World Health Organization (WHO) defines zoonoses as those diseases and infections that are naturally transmitted between vertebrate animals and humans. There are approximately 1415 pathogens known to affect humans, of which approximately 61% are zoonotic (Taylor *et al.*, 2001). Zoonotic diseases are common worldwide and constitute an important threat to human health in developing countries. Almost half of the zoonoses known to occur today are classified as emerging, and about 75% of emerging diseases are caused by zoonotic pathogens (Woolhouse and Gowtage-Sequeria, 2005). Zoonotic diseases have both direct and indirect effects on livestock health and production. Directly, they cause illness, death and financial loss. Indirect effects occur as a result of the risk of human infection, barriers to livestock trade, the added costs associated with control programs, marketing produce to ensure it is safe for human consumption and the loss of markets owing to reduced consumer confidence (Brown, 2004; Meslin *et al.*, 2000; Meslin, 2006; Schlundt, 2004).

As Collins and Carlos (2003) explain, early identification of zoonotic disease occurrence through simultaneous monitoring of human and animal disease surveillance systems is critical to protect health in both populations. Developing systems that link human and animal disease reporting can help in timely identification and facilitation of responses to known and emerging zoonotic diseases. According to Diane *et al*., (2008), the threat of bioterrorism and emerging infectious diseases has prompted various public health agencies to recommend enhanced surveillance activities to supplement existing surveillance plans. Co-analysis of animal and human diseases may facilitate the response to infectious disease events and limit morbidity and mortality in both animal and human populations. The U.S. General Accounting Office Report, *West Nile Virus Outbreak, Lessons for Preparedness*, indicated that the analysis of the West Nile virus (WNV) outbreak began as two separate investigations: one of sick people and the other of dying birds (GAO USA, 2000).

1.3 Syndromic Surveillance

Surveillance also extends to symptoms indicative of infectious disease. Syndromic disease surveillance is the real-time monitoring of non-specific, prediagnostic indicators for disease outbreaks (Stanley et al., 2007). According to Sosin (2003) and Stoto (2005), syndromic disease surveillance provides early warnings of infectious disease outbreaks and has been widely adopted by cities, states, and the federal government in the U.S.A. A syndrome can be considered as a collection of signs that occur in a sick individual. Syndromic surveillance is an emerging approach to monitoring populations for change in disease levels, based on monitoring of the distribution of signs and associations between health variables in a population (Shephard, 2006). The Centers for Disease Control and Prevention, define 'syndromic surveillance' as "surveillance using health-related data that precede definitive diagnosis and signals a sufficient probability of a case or an outbreak to warrant further public health response". In general, this refers to the provision of information available at the time of a patient's first clinical encounter with a healthcare provider or an emergency department of public health authorities. Information incorporates patient identifiers, triage information including temperature and the provider's clinical impression, but is most likely incomplete in terms of laboratory testing. The benefit to public health agencies is that this information is much timelier and avoids a potentially lengthy delay required for definitive, laboratory-confirmed diagnoses. Many laboratory studies for example, bacterial enteric pathogen serologic testing, stool culture, or pulsed field gel electrophoresis on potential food borne illnesses can take 2-3 weeks to be completed and reported to the provider. Once these syndromic reports exceed a predefined threshold of detection (defined differently for each specific syndrome), disease control and response efforts can be initiated without need for definitive laboratory confirmation. Early recognition of and responses to outbreaks can help get them under control earlier and prevent subsequent morbidity or mortality.

With the need for sensitive disease surveillance systems for the early detection and monitoring of outbreaks, syndromic surveillance, or the use of near "real-time" data and automated tools to detect and characterize unusual activity for further public health investigation has been crucial. The use of data on pre-diagnostic clinical syndromes (including atypical presentations of severe disease) and statistical algorithms rather than confirmed cases of specific diseases can detect epidemics earlier than traditional surveillance based on reporting from laboratories and healthcare facilities (Chretien *et al.*, 2008). Several countries have used syndromic surveillance for the early detection of and response to diseases of public health importance. Syndromes are usually clinical signs, symptoms, and possibly other abnormalities indicative of a diseased state detected at the time of presentation, which may be grouped according to common organ systems (e.g. respiratory, neurological), common clinical presentation (e.g. acute febrile illness) or a common putative cause (e.g. influenza like illness (Robertson *et al.*, 1994*;* Guasticchi *et al.*, 2009; Osemek *et al.*, 2009). In western Kenya for example, Feikin *et al*. (2011) used population-based surveillance to determine the burden of common infectious disease syndromes including acute lower respiratory tract illness (ALRI), diarrhea and acute febrile illness (AFI). Also in Kenya, a study on malaria in three districts applied a syndromic approach to fever in children and acute illness in adults (Abuya *et al.*, 2007). In Burkina Faso, between 1990 and 2000 a syndromic approach to sexually-transmitted infections (STIs) was used in the management and ecology of HIV infections; this resulted in improved health seeking behavior from the population (Nagot *et al.*, 2004).

1.4 Animal Disease Syndromic Surveillance

Although several advances have been made in the field of human syndromic surveillance (Kawana *et al.*, 2006*;* Joseran *et al.*, 2006*;* Cooper *et al.*, 2009), literature on the same topic in the veterinary field is sparse. Interestingly, those studies that have been done focused not only on primary veterinary syndromic surveillance for animal health, but also on the use of animals as sentinels for public health, representing a further application of the One Health approach (Dorea *et al.*, 2011). The syndromic surveillance studies applied primarily to animal health include the EPIMED (EPIdemiology and Detection of Emergences) system (Vourc'h *et al.*, 2006), the Veterinary Practitioner-Aided Disease Surveillance System (VetPAD) from New Zealand (McIntyre *et al.*, 2003), the Rapid Syndrome Validation Project – Animal (RSVP-A; De Groot, 2010), and the Bovine Syndromic Surveillance System (BOSSS; Shepherd, 2006). The EPIMED system applied epidemiological methodology to study emerging animal diseases with a strong link to clinical observations in bovine herds in France. The system targets atypical disease cases, as well as specific, known diseases hypothesized to be emerging (Vourc'h *et al.*, 2006). The program consists of two components: the farmer via routine surveys in farms, and the veterinarian via clinical case notification on the "emergences". VetPAD applies software for recording clinical cases, herd investigations, and therapeutic product information relevant to the practitioner and client on a handheld device. It has the advantage of providing information and advice in the field on animal disease treatment (McIntyre *et al.*, 2003). The RSVP-A approach was applied in the USA and patterned on a similar approach as human syndromic surveillance. It is a system that gathers clinical observations made by practicing veterinarians as they go about case management of cattle diseases. The clinical signs were grouped into syndromes to exclude common diseases and production problems, but did include signs of less common endemic disease presentations with which an exotic disease outbreak would bear initial similarity. The six syndromes (non-neonatal diarrhea outbreaks, neurologic dysfunction or inability to rise, abortion or birth defect outbreak, unexpected deaths, erosive or ulcerative lesions of the mucosa or skin, feed refusal or weight-loss outbreak without clear explanation) are mutually exclusive and oriented towards conditions that would affect multiple animals. Finally, BOSSS was developed as a web-based reporting system incorporating the Bayesian cattle disease diagnostic program (BOVID). It allows observers to receive immediate information from interpretation of their observation, providing a differential list of diseases, a list of questions that may help further differentiate cause, access to information and other expertise, and opportunity to benchmark disease control performance.

Improved diagnosis is a prerequisite for effective management of endemic cattle diseases in sub-Saharan Africa. This is currently constrained by the limited availability of suitably trained professional staff, field-level diagnostic tests and a general lack of knowledge about disease among livestock owners (Machila *et al.*, 2003). Moreover, under field conditions clinical diagnosis of these diseases is complicated by the lack of sophisticated laboratory tests which are required when there are co-infections which are a common feature in sub-Saharan Africa. Most diagnoses therefore rely only on epidemiological and clinical examinations (Dwinger *et al.*, 1994; Goossens *et al.*, 1997). Where multiple similar diseases occur, decision support tools might facilitate differential diagnosis (Magona *et al.*, 2004). Current thinking in terms of veterinary service provision favors pen-side diagnostic tests, whereas decision support technology is suitable for use by farmers, extension workers and agro-veterinary traders; i.e. those who most often make the diagnosis and treatment decisions in rural African settings (Machila *et al.*, 2003). In Uganda, a low-cost decision support tool was recently developed to aid the diagnosis of anaplasmosis, babesiosis, ehrlichiosis, fasciolosis, parasitic gastroenteritis, schistosomosis, theileriosis, and trypanosomosis (Eisler *et al.*, 2012). Combining such decision support tools with syndromic surveillance may enhance the value of surveillance systems.

There is a strong interest in developing reliable disease surveillance programs to provide "early-warning" systems, due to the growing concern about emerging and re-emerging animal and zoonotic diseases and their negative impacts on animal and public health, the environment and economy (Brown, 2004). Practicing veterinarians and producers are in close contact with livestock and consequently play an important role in the detection of initial cases of novel infectious diseases or changes in the incidence of specific syndromes (such as respiratory disease or mortality) critical for providing the first warning of a disease outbreak. This allows more rapid and efficient collection of diagnostic samples and implementation of disease control strategies (McIntyre *et al.*, 2003). Sick animals have signaled other environmental toxic health risks to humans including asbestos, mercury and lead exposure (Halliday *et al.*, 2007; Rabinowitz *et al.*, 2008; Stephen and Ribble, 2001). In many instances, observable morbidity or mortality in animals has preceded or coincided closely with the recognition of disease in humans following direct or indirect contacts. The outbreak of West Nile virus encephalitis in humans in the New York City metropolitan area in 1999, which was the first documented occurrence of the virus in the Western Hemisphere, was preceded by the death of a substantial number of birds in the area (Nash *et al.*, 2001), and the virus was first identified in tissue specimens obtained from affected crows (Steele *et al.*, 2000). In 1999, novel paramyxoviruses (later named Nipah virus) was identified as the cause of an outbreak of fatal encephalitis among pig farmers in Malaysia (Chua *et al.*, 1999). Outbreaks of Ebola virus in people and nonhuman primates are characterized by severe hemorrhagic fever and high case-fatality rates. Many of the recent outbreaks in people have resulted from handling infected wild animal carcasses (Leroy *et al.*, 2004). After the first outbreak of Ebola virus during 2001 between Gabon and the Republic of Congo, the Animal Mortality Monitoring Network was created with the aim to predict and prevent human Ebola outbreaks (Rouquet *et al.*, 2005).

A number of disease syndromes in livestock may be associated with increased likelihood of endemic, emerging, re-emerging and zoonotic diseases. Rift Valley Fever (RVF) is associated with sudden deaths and abortions/stillbirths in livestock, and hemorrhagic fevers and encephalitis in humans (Weaver and Barret, 2004); babesiosis with haematuria/nervous signs (Guerrant *et al.*, 2006); anthrax with sudden death (Dixon *et al.*, 1999); brucellosis with late-term abortions (Swai *et al.*, 2005); and rabies with central nervous signs in both animals and humans (Kariuki, 1988).

Although syndromic surveillance can provide useful early warnings of outbreaks, there exists no infrastructure in place to enforce guidelines for what to do with the information provided. As with any surveillance system, investigation of cases and implementation of an effective control program requires a robust public health infrastructure. Financial and technical support could be leveraged through collaborations with existing systems (e.g. integrated human and animal health surveillance systems). Simple monitoring tools can facilitate effective epidemic control, but require the translation of this early warning information into timely public health action. Resource constraints in many countries, compounded by high rates of staff turnover and difficulties with internet access and other communication tools require that systems be simple and built on existing works. Although WHO open-source systems for surveillance are accessible to countries and technological assistance can be provided, no funding allocation is currently available for implementation (Baker and Fidler, 2006; Larissa et al., 2009).

1.5 Use of Mobile Phones in Health

Mobile devices can play a role in improving the coverage and timeliness of data collected through surveillance systems (Alexander *et. al.*, 2013). Access and use of mobile telephony in sub-Saharan Africa has increased dramatically over the past decade. There are ten times as many mobile phones as landlines in sub-Saharan Africa (ITU, 2009) and 60 percent of the population has mobile phone coverage. Mobile phone subscription has increased by 49 percent annually between 2002 and 2009, as compared to 17 percent per year in Europe (ITU, 2008). Mobile telephony has brought possibilities to the continent. Across urban-rural and rich-poor divides, mobile phones connect individuals, information, markets and services. These effects can be particularly dramatic in rural Africa where in many places, mobile phones represent the first modern telecommunication infrastructure of any kind. Mobile phones have greatly reduced communication costs, thereby allowing individuals and companies to send and obtain information quickly and cheaply on a variety of economic, social and political topics. An emerging body of research shows that the reduction in communication costs associated with mobile phones has tangible economic benefits, including improved agricultural and labor market efficiency and producer and consumer welfare in specific circumstances and countries (Aker, 2008; Aker, 2010; Jensen, 2007; Klonner and Nolem, 2008). As prices of both handsets and airtime continue to fall, the mobile phone will complete its transformation from an elite status symbol to a necessity in all income levels (Aker and Mbiti, 2010).

In many human health projects in resource-challenged areas, mobile technologies have emerged as a promising solution for obtaining, transmitting and analyzing human health information in a timely fashion (Bernabe *et al.*, 2008*;* Diero *et al.*, 2006*;* Missinou *et al.*, 2005*;* Shirima *et al.*, 2007). In Peru, a mobile phone–based surveillance system has been used for early detection of infectious disease outbreaks in the Peruvian Navy (Soto *et al.*, 2008). In Africa, the Satellite project has been using mobile data collection devices for more than two decades in human health surveys, and a project is under way that uses mobile phones and wireless technology for disease surveillance in Uganda (Berhane, 2008). Many United Nations health and development projects in Africa now use mobile phones for obtaining field data (Vital Wave Consulting, 2009). In Malawi for example, those affected by HIV and AIDS can receive text messages daily reminding them to take their medicines on schedule (Aker and Mbiti, 2010).

For animal disease surveillance; a mobile phone–based infectious disease surveillance system was developed and implemented in Sri Lanka, involving field veterinarians reporting animal health information (Colin *et al.*, 2010). This demonstrated the possibility for early warnings of emerging infectious diseases and changing disease patterns, as it led to the establishment of baseline patterns of presumptive diagnoses and syndromes in cattle, water buffaloes and chickens. Development of human resource and increased communication between local stakeholders were instrumental for successful implementation. Lessons learnt were that mobile-phone-based surveillance in animal population is acceptable and feasible in resource-limited settings, and that the use of existing infrastructures and social networks help to reduce barriers to reporting and improve sustainability (Colin *et al.*, 2010). In Africa, the use of digital pens to monitor transboundary diseases has been utilized in Malawi, Namibia and Zambia for data gathering on potential outbreaks from remote field locations, to allow timely decisions in case quarantine needs to be imposed (Fred, 2010).

The penetration of mobile service in Kenya has reached 64.2 per 100 inhabitants. At the end of June 2011, Kenya had 25.27 million mobile subscribers, while mobile networks covered 86% of the population and 35% of Kenya's land area (CCK 2011) **(Figure 1).** The high mobile penetration rate and subscription numbers indicate that mobile technology can be useful in the livestock sector, even in rural and poor areas. A majority of Kenyans (78.4 per cent) live in rural areas (CountrySTAT Kenya 2009) and largely depend on agriculture as their main means of sustenance. At Kshs.1 (US $ 0.012) per SMS (short message service, or text message), sending an SMS is a cheap and easy way to communicate with farmers. It also allows details to be recorded and referred to later.

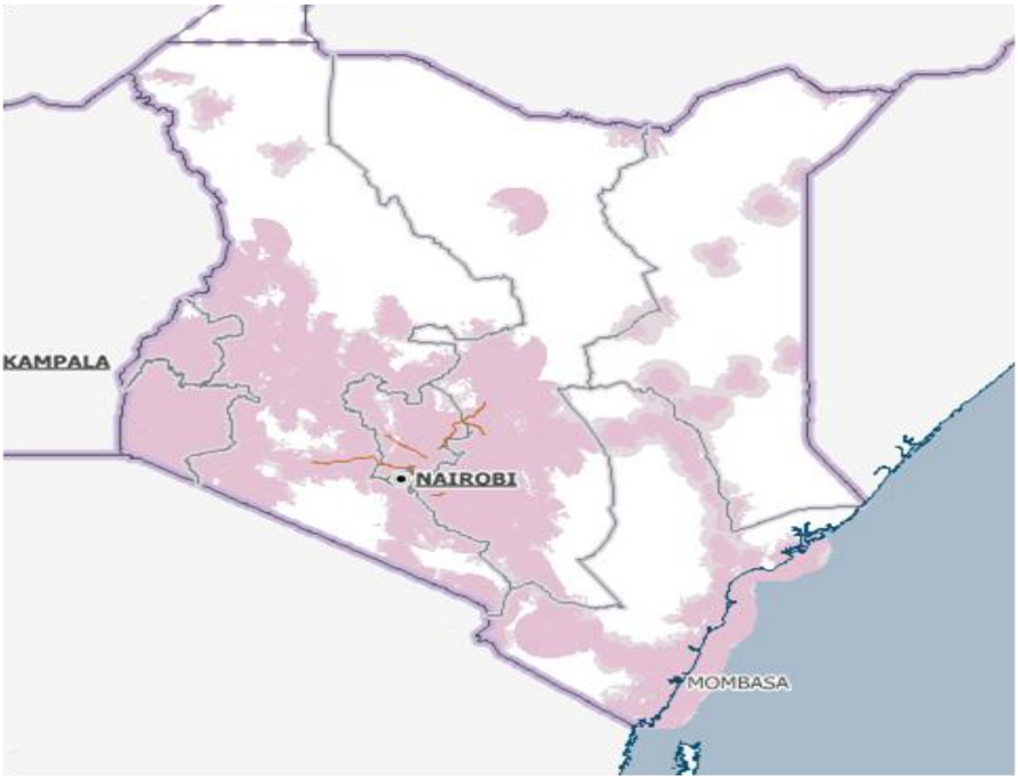

Figure 1. Mobile phone network coverage of Kenya in 2010 (©Europa Technologies & GSM Association).

1.6 Livestock Importance

According to Thornton *et al*. (2002), livestock production provides livelihood support to an estimated 400-600 million people worldwide, most of who live in poverty. Livestock are vital to subsistence and economic development in sub-Saharan Africa. They provide a flow of essential food products throughout the year and are a major source of government revenue and export earnings. Livestock sustain millions of people in rural areas, provide draught power and manure for crop production, and are the only food and cash security available to many Africans (Hans, 1982).

By 2009, Kenya had a human population of 38 million and a livestock (cattle, sheep, goats, camels) population of 65.3 million, with most of the livestock located in the arid and semi-arid areas of the country (Kenya Census Data, 2009). Livestock are the main source of food and livelihoods for the majority of people living in poverty in Kenya, whether it is the nomadic pastoralists living in the arid and semi-arid lands or the subsistence livestock farmers who keeps livestock on small pieces of land. Nevertheless, animals are also reservoirs of multiple pathogens including viruses, bacteria, helminthes and protozoa, some of which are zoonotic (Cleaveland *et al.,* 2001). Persons at risk of infection with zoonotic pathogens include household members, farm visitors, veterinarians, and those working in livestock processing and marketing chains, including abattoir workers, live animal traders and handlers, transporters and those in meat processing plants (Le Jeune and Kersting, 2010). However, there is a lack of effective health and productivity data on livestock in communal and small scale farm settings, with most available data in the country coming from large scale commercial livestock production systems (Behnke, 1985). Coupled with this are challenges in detecting, monitoring, documenting and responding to infectious conditions of livestock, particularly because veterinary services and resources are a constraint in Kenya. Obstacles include a lack of disease reporting and diagnosis, as well as systematic surveillance of their zoonotic impact on humans (Doherr and Audige, 2011).

1.7 Objectives of the study

The overall aim was to implement a passive animal disease surveillance and response system (ADSARS) with a capability of detecting emerging zoonotic diseases in domestic and peridomestic animals, in a trial site where active human disease surveillance is ongoing. The project was intended as a demonstration of the system on a short-term basis, with the intention of conducting an evaluation of its performance later.

The specific objectives were:

a) To evaluate and investigate four selected disease syndromes affecting cattle, sheep and goats using a mobile phone-based rapid SMS reporting system within the site, to allow animal owners to report cases of animal disease and the SMS reports logged in a central database generating a response from the veterinary team.

b) To train and equip a veterinary team of animal health assistants to respond to cases of animal disease.

CHAPTER 2: Materials and Methods

2.1 Study Site

The study was conducted in Asembo division of Rarieda Sub-county of Siaya County, Nyanza Province in western Kenya **(Figure 2),** between 2010 and 2012. The study area falls within a health and demographic surveillance system (HDSS) site run by the Kenya Medical Research Institute (KEMRI) and U.S. Centers for Disease Control and Prevention (CDC). The HDSS has been in operation since 2001, and by 2009 was covering approximately 220,000 inhabitants in 55,000 households in Asembo, Gem and Karemo divisions of Siaya County. It has served as a foundation for various health related research studies, whether at individual, household/compound or community level (Odhiambo *et al.*, 2012). Baseline socioeconomic (including animal ownership), educational and demographic data are collected on all the households in the demographic surveillance area. All households in the HDSS are marked at the door with a unique identification number. Routinely, households are visited every four months and information collected that includes documentation of births, deaths, pregnancies and migrations. Verbal and real autopsies are also completed for deaths occurring among residents of the HDSS area. The sites are each catered for by well-established referral health facilities for human health surveillance and clinical trials (Odhiambo *et al.*, 2012*;* Oria *et al.*, 2013).

The study site consisted of the 33 villages with a 5.5 km radius of St. Elizabeth Lwak Mission Hospital, which is the central health facility for population-based infectious disease surveillance conducted by the Kenyan International Emerging Infections Programme (IEIP) of KEMRI/CDC (Feikin *et al*., 2011). The population in these villages comprises about 25,000-27,000 people, largely sedentary smallholder agro-pastoralists and fishermen of the Luo ethnic group. The area is one of the most impoverished in Kenya: 60-70% of people in Siaya County live below the poverty line (Kenyan Central Bureau of Statistics, 1997). The area has perennial, high-level malaria transmission (Beier *et al.*, 1994) and a high rate of HIV infection (in 2003, >10% men and >20% women aged 13-34 years (Amornkul *et al.*, 2009). Other infectious diseases are also common in the area. Consequently, the area has mortality figures that reflect this burden of infectious diseases (Bigogo *et al.*, 2010). The infant mortality rate is 110 per 1,000 live births and the life expectancy at birth is 51.2 years (Bondo District Strategic Development plan 2005 – 2010).

Animal ownership is common in this catchment area. Analysis of the HDSS data revealed that 89% of compounds own livestock. In terms of individual species breakdown, between 42%-48% of the households own any of these three ruminant species (cattle, sheep, goats) with a mean ownership of 1 to 2 animals per household. Animal ownership data from a subset of 300 animal-owning households participating in a longitudinal surveillance for various zoonotic pathogens revealed mean numbers of animals per compound of 2.6 cattle and 3.3 small ruminants (goats and sheep). Of the livestock-owning compounds, 88.8% own between 1-10 cattle and 83.5% 1-10 small ruminants (KEMRI/CDC HDSS data 2010, unpublished)

Access to animal health services is currently limited for residents within the area. Prior to the study start, several attempts were made to identify qualified private animal health workers present in the area, whose livelihoods might be adversely affected by the clinical interventions associated with the project. Attempts included liaison with the District Veterinary Officer and the private veterinarian covering the area (animal health assistants or veterinary technicians would legally be required to work under the supervision of one of these individuals), meetings with all identified private animal health practitioners from surrounding areas, and engagement of the community in a participatory exercise to identify existing options for animal care and treatment. No full-time active private animal health assistants operating for the most part within the area were identified.

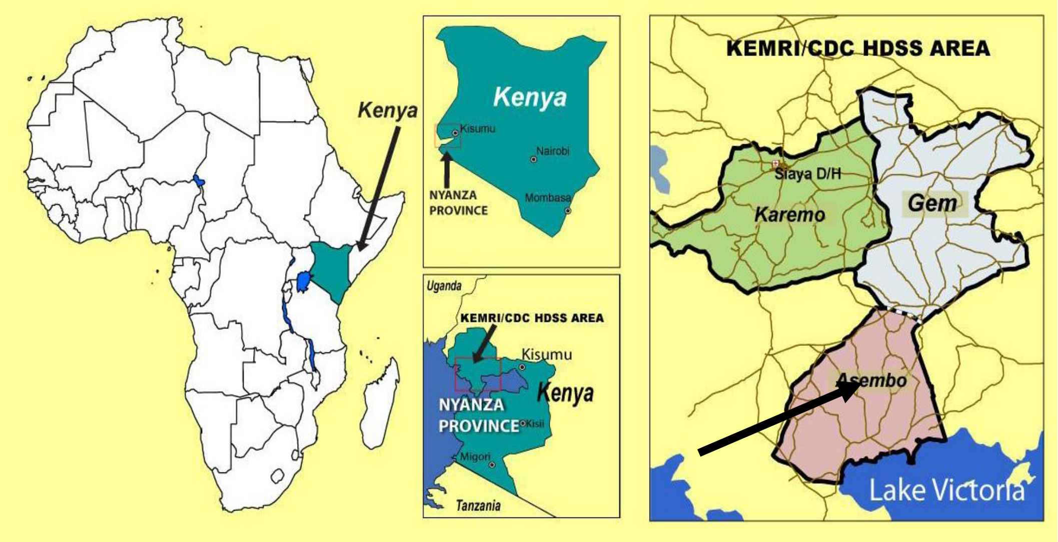

Figure 2. A map of the study site

2.2 Data Collection

This was a passive population-based disease syndrome surveillance system targeting the population of domestic ruminants within the 33 villages in the study site. Four disease syndromes were targeted by the surveillance system: abortions/still births, sudden deaths, central nervous signs (circling, incordination, head pressing, increased aggression) and red discoloration of urine (haematuria/hemoglobinurea/myoglobinuria). The selection of these syndromes in ruminants were due to their associations with zoonoses and their potential as early warning signs for emerging infections (Fernanda *et al.*, 2011, Kylius *et al.*, 2012, Glickman *et al.*, 2006, Celine et al., 2012 and Shaffer et al., 2007). Live births were also included to control for reporting bias.

These syndromes were selected for the following reasons:

I. Visibility and ease of detection by farmers.

II. Association with zoonotic diseases (e.g. abortions/still births: brucellosis, Q fever, leptospirosis, Rift Valley fever; sudden deaths: anthrax; central nervous signs: rabies).
III. Association with livestock diseases with potential for emergence in the study site (e.g. Asiatic babesiosis, which may cause sudden death, central nervous signs, or red urine).

Table 1 shows the zoonotic infections that may occur in the study area, and which might be amenable to detection through the syndromic surveillance system as piloted in this study.

The study was piloted in 10 villages from September through December, 2010, using a paper-based system. Various adjustments were made in the data collection tool and transition to a mobile phone data collection platform took effect from January, 2011. Presumptive diagnoses were assigned from June 2011. The study continued through to September 2012. This dissertation will present results from 12 months, from July 2011 through June 2012.

2.3 Disease Reporting

A short message service (SMS) disease notification system was developed for use on conventional hand-held mobile phones (Nokia 2730) by programmers at KEMRI/CDC, adapting available JavaRosa source code. JavaRosa is an open-source software programming platform developed by the OpenRosa consortium (http://www.dimagi.com/javarosa/) which allows individual programmers to tailor the system to their needs. The SMS system was designed to capture the following information in a central database, using a menu-driven system on users' mobile phones:

I. Event/case number (automatically generated).
II. Date & time reported (automatically generated).
III. Date of the event.
IV. Name of the village in which the event occurred.
V. The unique HDSS identification number of the compound in which the event occurred.
VI. The contact person in the compound in which the event occurred
VII. List of the species affected (cattle/sheep/goats).
VIII. Number of animals affected in each species.
IX. The nature of the event (abortion/stillbirth/haematuria/sudden death/central nervous signs or live birth).
X. Identity of reporter.

The SMS system was also designed to capture information on suspect OIE Notifiable diseases. After upload to the central database, these were forwarded to the local Sub-County Veterinary Officer (SVO) for further action.

Table 1. Possible zoonotic infections in the study site, and associated syndrome in ruminants

Disease	**Causative organism**	**Associated syndrome in ruminants**	**Means of spread to humans**	**Clinical manifestation in humans**
Bacterial Diseases				
Anthrax	*Bacillus anthracis*	Sudden death	Occupational exposure, Foodborne, wounds and insect bites. Rarely airborne	Ulcerative skin lesions, pneumonia and/or sepsis
Brucellosis	*Brucella abortus* *Brucella mellitensis* *Brucella canis* *Brucella suis*	Abortion	Occupational and recreational exposure, Foodborne Contact, rarely airborne	Fever (sub-acute and undulant), Sepsis, arthritis and endocarditis
Campylobacteriosis	*Campylobacter jejuni*	Abortion	Foodborne, milk, waterborne, occupational	Enteritis, arthritis, sepsis
Clostridial diseases	*Clostridia perfringens* type A *Clostridia septicum* *Clostridia novyi*	Sudden death	Foodborne; occasionally wound contaminant	Enteritis, gas gangrene, sepsis
Leptospirosis	*Leptospira interrogans* in 23 serogroups	Red urine/ Sudden death	Occupational and recreational; water- and Foodborne	Fever, rash, pneumonia, meningitis, hepatic and renal failure
Listeriosis	*Listeria monocytogenes*	Neurological/ Sudden death	Foodborne, raw contaminated milk, cheese, mud, water Vegetable; nosocomial infections	Enteritis, meningitis, sepsis, fetal infections
Salmonellosis	*Salmonella enterica* serovars	Abortion	Foodborne, occupational and recreational exposures	Enteritis to sepsis

Disease	**Causative organism**	**Associated syndrome in ruminants**	**Means of spread to humans**	**Clinical manifestation in humans**
Rickettsial Diseases				
Q-fever	*Coxiella burnetii*	Abortion	Airborne, contact, Foodborne and vectoborne	Fever, pneumonia, hepatitis, endocarditis
Fungal Diseases				
Aspergilosis	*Aspergillus* species	Abortion	Environmental exposure	Pneumonia, pulmonary disease with/out fungal ball
Parasitic Diseases				
Babesiosis	*Babesia divergence*	Red urine/Neurological	Bites of infected *Ixodes* ticks	Fever and hemolytic anemia
Toxoplasmosis	*Toxoplasma gondii*	Abortion	Foodborne (oocysts in feces of cats)	Fever, adenopathy, brain abscess and damage to CNS
Trypanosomosis	*Trypanosoma brucei* *Trypanosoma rhodesiense* *Trypanosoma gambiense*	Neurological/Red urine	Bites of infected tsetse fly (*Glossina spp)*	Painful chancre at bite site, fever, headache rash, somnolence, adenopathy
Viral Diseases				
Rift Valley fever	Rift Valley fever virus	Abortion/Sudden death	Mosquitoes (*Aedes spp)*, contact on autopsy or handling fresh meat.	Biphasic illness, brachycardia, petechiae, haemorrhages
Rabies and related infections	Lyssaviruses (Rabies, Duvenhage, Mokola)	Neurological	Bites/contact with infected animal via saliva	Paresthesia/pain at bite site, fever, myalgia, mood changes, hypersalivation, paresis, seizures, hydrophobia

A network of animal health reporters (AHRs) was trained and equipped with mobile phones. One or two AHRs were assigned per village. Communities were consulted to identify suitable candidates in each village. Ideal candidates were mostly older (possibly retired) individuals who were well-known, settled and still active within the community, particularly in matters of animal husbandry and disease. Those who were inactive in case reporting were replaced during the study period with a more active AHR identified through further community participation.

Animal owners verbally notified the AHRs of cases of any of the four syndromes of interest in 33 villages and live births in 10 villages, and the AHRs submitted the report using the SMS system. Once reports were confirmed as valid, the AHRs were compensated each time they were involved in an event investigation, through the reimbursement of mobile phone prepaid airtime vouchers.

2.4 Data Capture on Episurveyor

The SMS notification prompted a response from an animal health team comprising a veterinarian and four animal health assistants (AHAs) based at a facility adjacent to the Lwak Mission Hospital. Contact with the animal owner was made through the reporting AHR. Once this information was submitted, it was captured in a central database and forwarded to an Android smart phone held by the response team. Information on the cases was captured using Episurveyor open-source software (http://www.episurveyor.org), using a modified version of the Bovine Syndromic Surveillance System (BOSSS). BOSSS was developed by Ausvet Animal Health Services as a cattle disease surveillance tool for application in remote areas of northern Australia (http://www.ausvet.com.au/bosss), and was adapted for use the current context. The primary function of BOSSS was to capture all information on animal attributes, clinical signs and epidemiological information associated with the syndromes, and to upload these to a centralized database. Recorded information was useful for arriving at presumptive diagnoses which were also fed into the database. BOSSS was originally established as a web-based system, but part of the adaptation was modified for use with smart phones running on Windows Mobile. Each response team was provided with one such smart phone containing the modified BOSSS system. The forms within the smart phones were structured to cover information on the event identification, nature of the syndrome, samples collected and a presumptive diagnosis.

2.5 Case Validation, Presumptive Diagnoses and Case Management

Cases were investigated by the field veterinary team and evaluated for validity. Reports were considered invalid for any of the following reasons:

I. Absence of relevant clinical signs on investigation.
II. Clinical signs not within any of the syndromes of interest.
III. All episode present for more than 24 hours before reporting; due to setting in of pathological changes, decomposition and contamination.

IV. Butchered or absent carcasses.
V. Duplicate reports.
VI. Inability to trace compound (incorrect identification).
VII. Inability to trace contact person in compound (absence).
VIII. In the case of sudden death syndrome:
   a) Death > 6 hours after onset of clinical signs (to limit cases to per acute and acute death).
   b) Death as a result of obvious trauma.
   c) Neonatal deaths.

Our definition of sudden death was death with no observed clinical signs (e.g. animal observed to have been normal in the evening, but found dead in the morning), or an animal that expresses clinical disease and dies shortly after. By these, we worked with 6 hours as an allowable time for peracute and acute deaths; anything above 6 hours was considered subacute.

Presumptive diagnoses were arrived at based on epidemiological evidence, obtained history, clinical examination, gross pathological findings at necropsy and microscopic examination of blood and lymph node smears for hemoparasites and bacteria. The veterinary team met weekly to review cases and arrive at the presumptive diagnoses.

Cases were managed according to accepted treatment guidelines and based on the clinical judgment of the response team, all of whom were qualified and operating under the supervision of a registered veterinarian (the study veterinarian), in accordance with Kenyan national legislation. A treatment guideline was followed and this ensured proper and stipulated drug use.

2.6 Data Management

Data was managed using a dedicated web-accessible computer with a Linux-related open-source operating system, located in at the KEMRI/CDC field station. The computer offered the following services:

- a GSM modem to receive all SMS messages with the software to decode, parse and insert the contents into a database
- an open-source industry-strength database server (Oracle MySQL™) for the storage of all syndromic surveillance reports

All data were submitted to and stored in the central database using an appropriate relational structure. Data were checked for errors and corrected on a monthly basis. Events to the SVO for forwarding to the National disease index were also stored in the database.

2.7 Livestock Data

HDSS data were used to determine the animal population at risk. HDSS routinely carries out a socioeconomic survey of all households in the study are, which includes information of livestock ownership. In the 2010 livestock census there were 11,409 cattle, 3,558 sheep and 9,891 goats within the 3,800 study compounds in the 33 villages of the study site (KEMRI/CDC HDSS Data 2010, unpublished).

2.8 Statistical Analysis

The data was downloaded to Microsoft Access from the original database (Oracle MySQL™); at analysis it was exported to Microsoft Excel and analysed in SAS® (www.sas.com/technologies/analytics/statistics/). Variables were subjected to tests on account of all events; valid and invalid per species in comparison to time of the year, and events distribution by species and time.

Incidence rate is the number of new cases of disease during the specified time interval, divided by the average population during the interval. To calculate the incidence rate of events for each species, the 2010 livestock census data was used as an estimate of the average size of each population during the study period.

CHAPTER 3: Results

A total of 185 events were reported during the period July 2011 – June 2012. Of these, 46 (24.9%) were considered invalid on investigation. The reasons for exclusion are presented in Table 2. More than a quarter (12/46) of invalid reports were received in the first month of the study **(Figure 3).**

Table 2. Reasons for exclusions of event reports

	REPORTS	
Reasons for exclusion	Number	Percent
Wrong syndrome	16	34.8
Late report	11	23.9
Chronic illness	6	13.0
Compound incorrectly identified	4	8.7
Carcass interference	3	6.5
Submitted in error	3	6.5
Duplicate report	1	2.2
Participant absent	1	2.2
Neonatal death	1	2.2

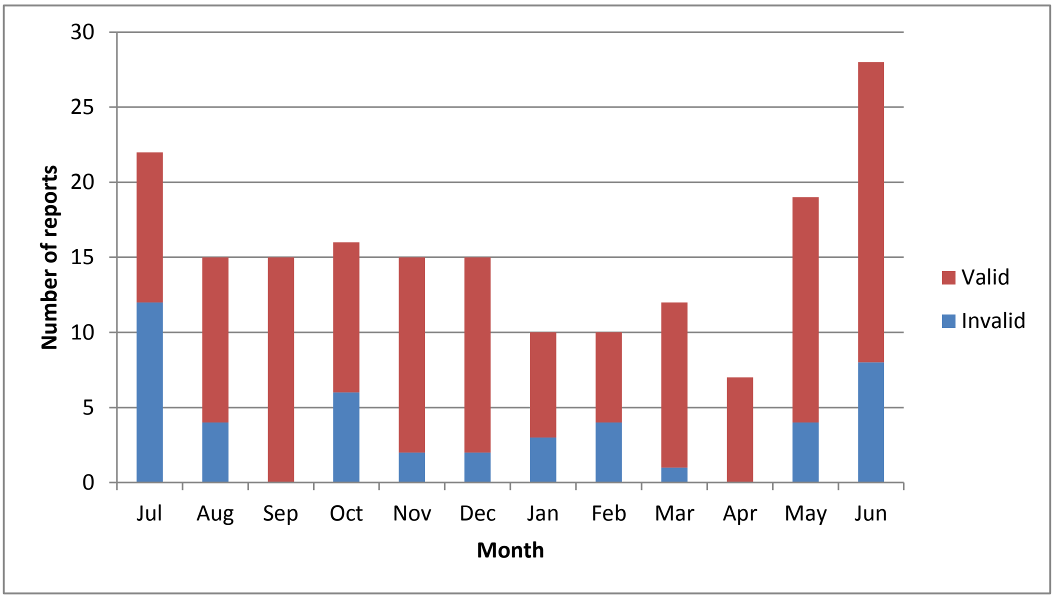

Figure 3. Validity of reports received by month, July 2011 – June 2012

One hundred and thirty-nine (139) valid events were reported during the study period. These comprised 75 cases of abortions, 43 cases of sudden death, 12 cases of red urine, and 9 cases of nervous signs (**Figure 4**). The distribution of syndromes by month is shown in **Figure 5**. The average number of events reported per month was 11.5 (range 6-20). The lowest number of events was reported in February, and the highest in June.

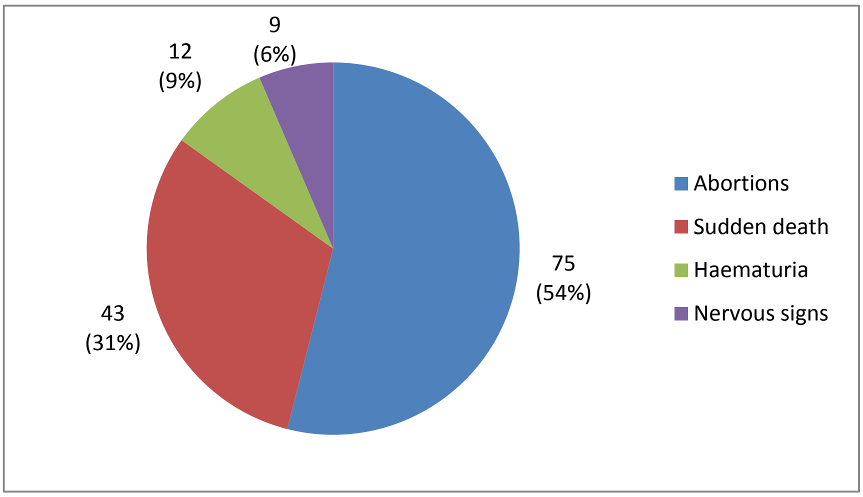

Figure 4. Number of events reported by syndrome, July 2011 – June 2012

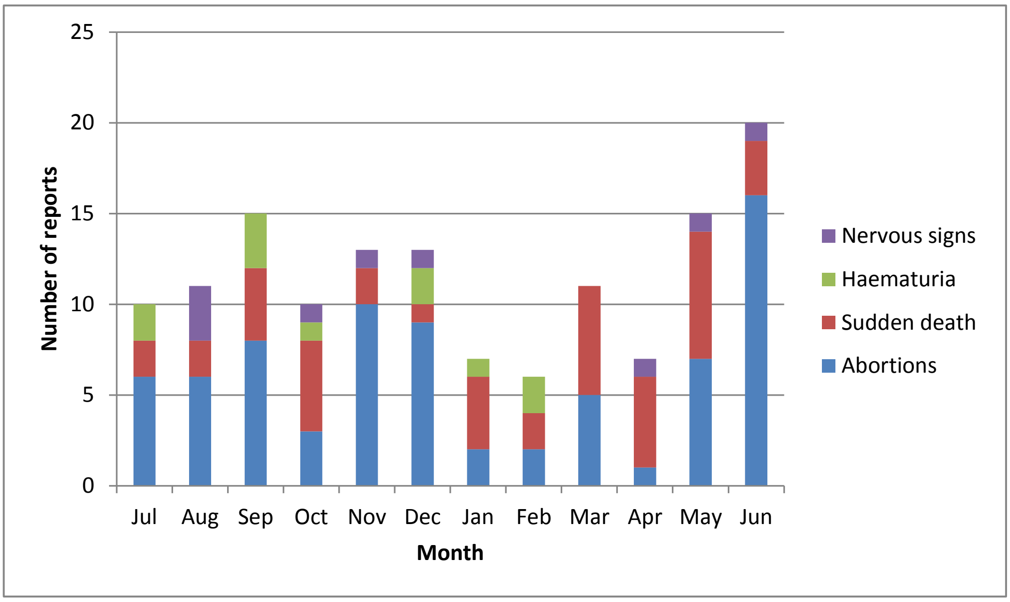

Figure 5. Reported events by month and by syndrome, July 2011 – June 2012

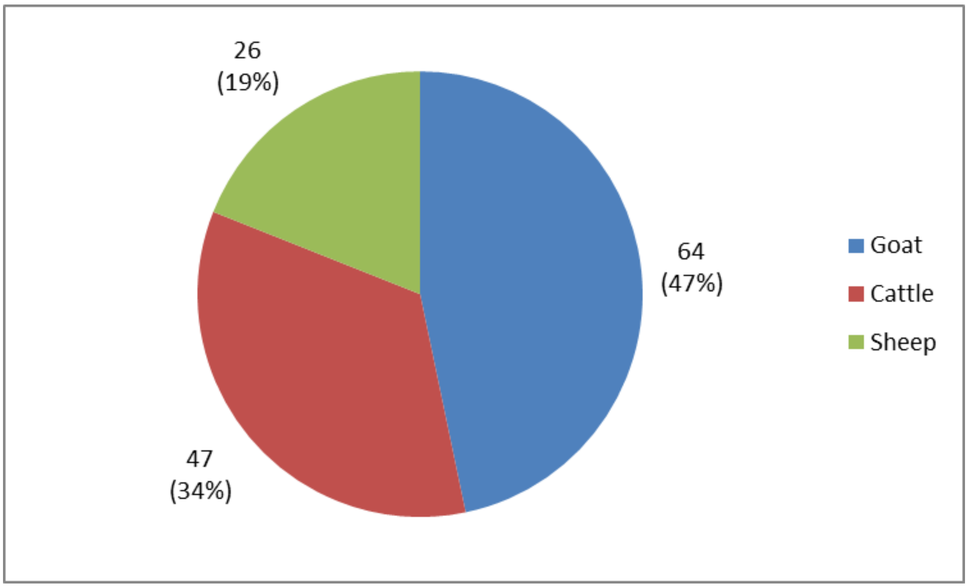

Figure 6. Number of events reported by species, July 2011 – June 2012

The distribution of events by species is shown in **Figure 6**. Goats were the most frequently affected at 47% (n=64), cattle at 34% (n=47) and sheep at 19% (n=26). The incidence rate of events by species (per 1,000 population per year) was 7.3 in sheep, 6.5 in goats and 4.1 in cattle.

In total, 37 AHRs were used across the 33 villages. Frequency of reports differed between AHRs. **Table 3** shows the average frequency of reports per month for the study period. This ranged from 0.08 to 1 report per month.

Table 3. Number of reports per month from each animal health reporter (AHR) over the period during which they were active in the study.

AHR no.	Village no.	No. months active	No. reports	Reports per month (mean)
1	2	9	2	0.22
2	9	8	5	0.63
3	10	12	4	0.33
4	11	12	12	1.00
5	11	12	6	0.50
6	12	12	8	0.67
7	13	12	2	0.17
8	13	12	6	0.50
9	14	12	2	0.17
10	15	12	1	0.08
11	15	12	2	0.17
12	19	12	1	0.08
13	24	12	3	0.25
14	26	12	4	0.33
15	28	12	4	0.33
16	35	8	3	0.38
17	36	12	3	0.25
18	46	12	3	0.25
19	47	12	2	0.17
20	47	12	1	0.08
21	48	12	3	0.25
22	49	6	1	0.17
23	49	6	1	0.17
24	50	12	5	0.42
25	50	12	8	0.67
26	51	12	2	0.17
27	52	12	2	0.17
28	53	12	3	0.25
29	54	12	6	0.50
30	55	12	12	1.00
31	55	12	3	0.25
32	57	12	6	0.50
33	58	12	6	0.50
34	59	4	1	0.25
35	60	9	3	0.33
36	68	7	1	0.14
37	68	4	2	0.50
TOTAL		**397**	**139**	**0.35**

3.1 Abortion Syndrome

Seventy-five (75) abortions were reported during the study period: 40 in goats (53%), 18 in sheep (24%) and 17 in cattle (23%). The frequency distribution of abortions by month and by species is shown in **Figure 7**. The incidence rate of abortions by species per 1,000 population per year was 5.1 in sheep, 4.0 in goats and 1.5 in cattle. No presumptive diagnoses were arrived at for these cases. To attempt to control for seasonal variation in breeding, we included reports of live births from 10 of the 33 villages (**Figure 8**).

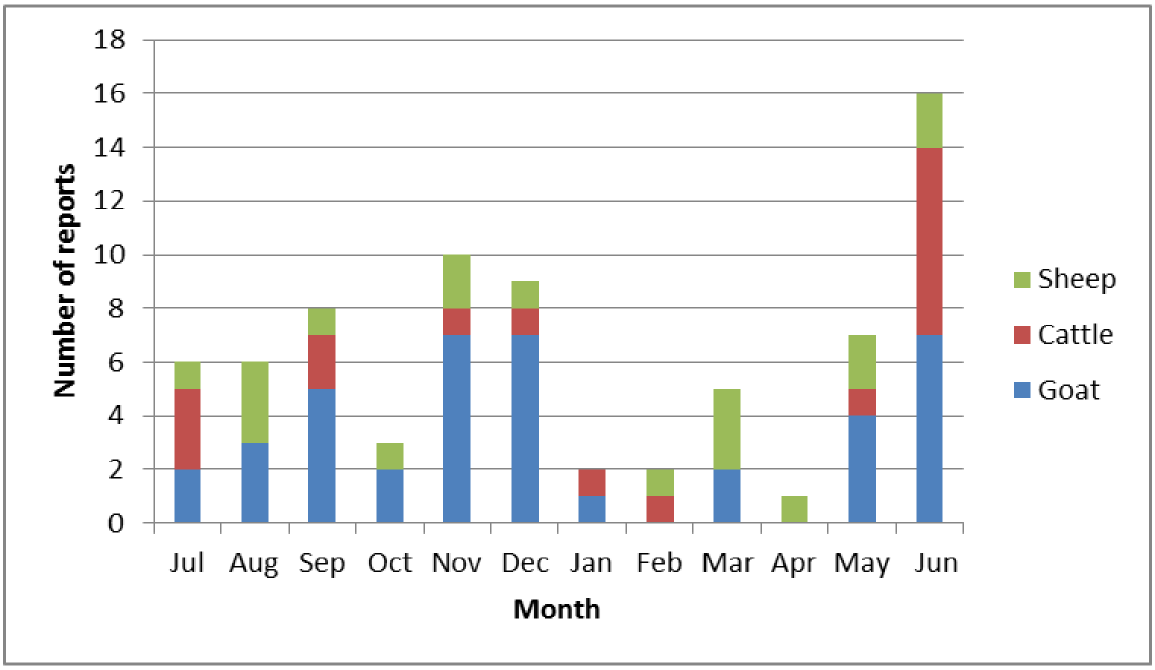

Figure 7. Reported cases of abortions in ruminants by month and by species, July 2011 - June 2012

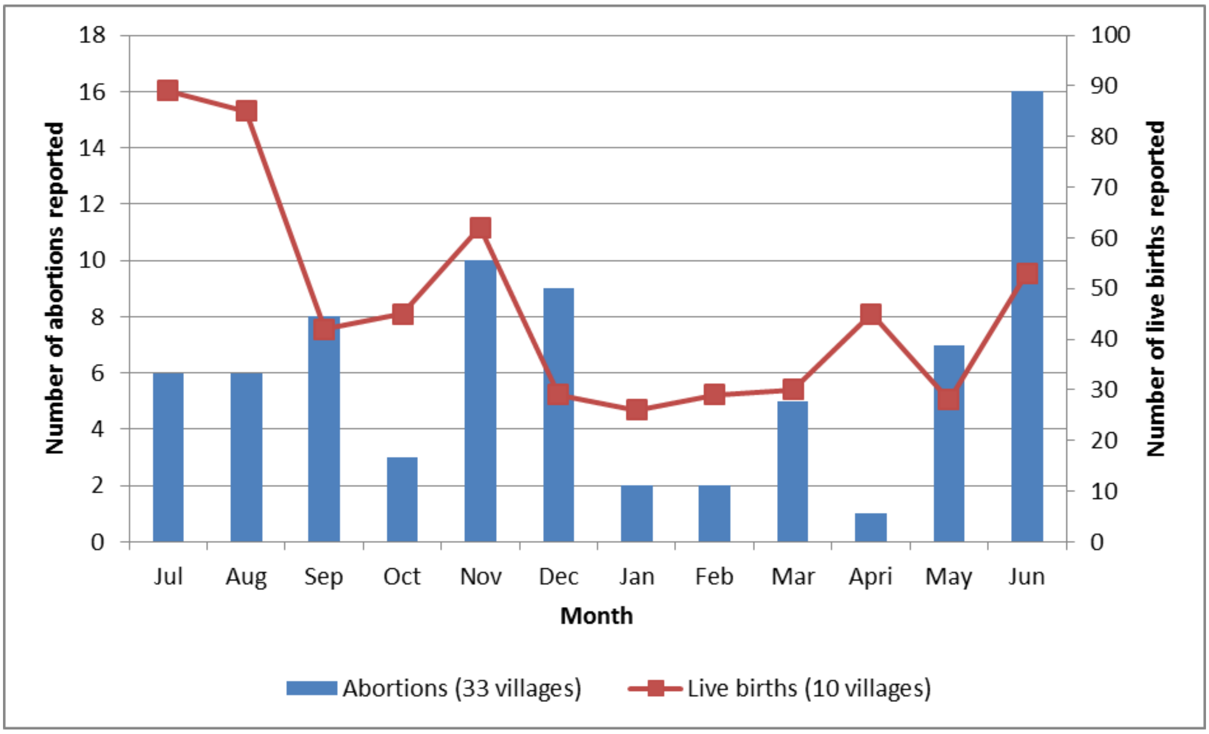

Figure 8. Reported cases of abortions (from 33 villages) and live births (from 10 villages) in ruminants by month, July 2011 - June 2012

3.2 Sudden Death Syndrome

Forty-three (43) sudden deaths were reported during the study period: 21 in goats (49%), 15 in cattle (35%) and seven in sheep (16%). History, clinical signs, necropsy findings and presumptive diagnoses for these cases by species are shown in Table 4a-c. The frequency distribution of sudden deaths by month and by species is shown in **Figure 9**. The incidence rate of sudden deaths by species per 1,000 population per year was 2.1 in goats, 2.0 in sheep and 1.3 in cattle.

Anthrax, a notifiable disease condition, was diagnosed in several cases of sudden death. Clinical findings and microscopy aided the diagnoses. At post mortem, the carcasses of suspected anthrax cases were not opened. For the response team, antibiotic therapy for the in-contact herds was the first course of action and as soon as the diagnoses was made, the local authority in-change of veterinary services (sub-county veterinary officer) was informed via Java-Rosa enabled Nokia 2730 phone with the message getting encoded on his hand set. Control of the disease was initiated by the SVO within 24 hours of reporting and included imposing quarantine, public education and vaccination campaigns for anthrax cases. The surrounding environment would be disinfected and the carcasses buried.

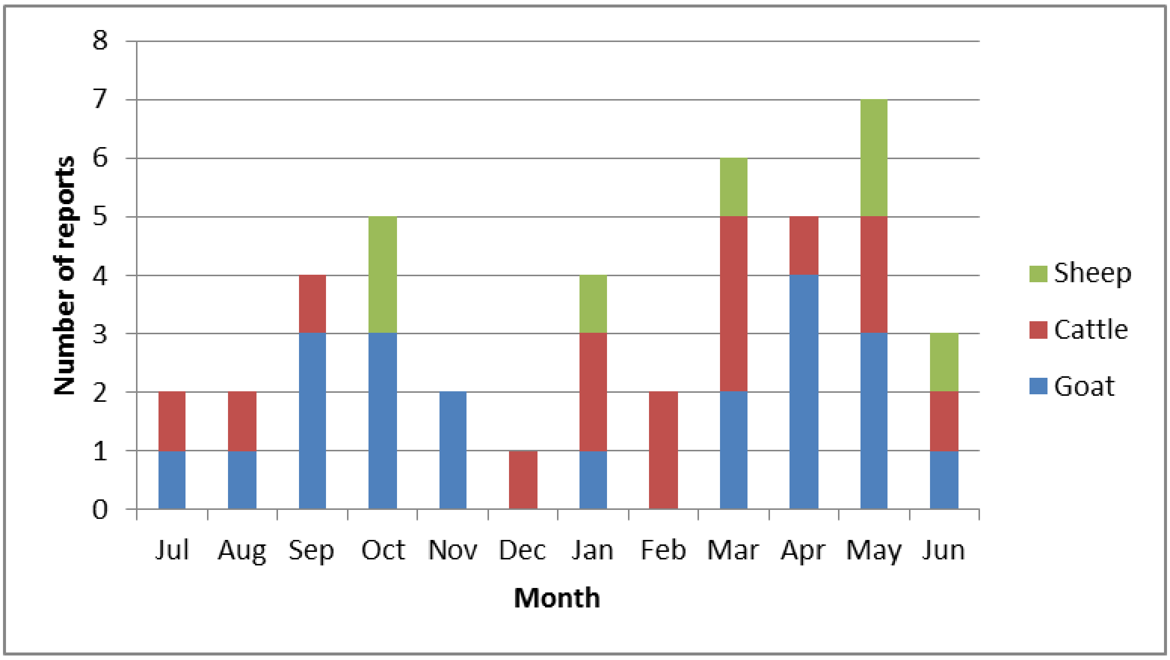

Figure 9. Reported cases of sudden death in ruminants by month and by species, July 2011 - June 2012

Table 4a. History, clinical signs, necropsy findings and presumptive diagnoses for reports of sudden death in cattle, July 2011 – June 2012

Cases	Age	Sex	Breed	History	Clinical signs	Necropsy	Microscopy	Presumptive diagnosis
1	3m	M	L	Not available	None seen	Respiratory lesions, haemorrhages of the omasal mucosa, intestinal serosa, pericardium, kidneys, spleenic congestion, large intestines ulcerations	No findings	Respiratory failure with mild bacterial systemic infection
2	1w	M	L	Not available	Rough hair coat	Respiratory lesions, Rigor mortis, bloat, bilateral corneal opacity, cyanosis of liver, small intestinal serosal haemorrhages, kidney and hardened faecal material	No findings	Acute tick-borne infection
3	A	F	L	Not available	None seen	Bloat, decomposition, thin blood from nostrils, parts of skin turning dark green	B.anthrax positive	Anthrax
4	120m	F	L	Not available	Dullness, weakness	Fluid accumulation on the lungs, same with a mixture of ingesta in the abdominal cavity, haemorrhages on serosa of large intestines and omentum, puncture of the small intestines with corresponding inner layer of skin	No findings	Puncture wound of small intestines predisposing to acute peritonitis

Cases	Age	Sex	Breed	History	Clinical signs	Necropsy	Microscopy	Presumptive diagnosis
5	8m	F	L	Not available	None seen	Emaciation, anaemia, yellow soiling of the perineum, bloody abomasal contents with heavy worm infestation, congestion of abomasal epithelia, duodenal worms, Kidney gelatinization	No findings	Helminthiais
6	12m	F	L	Not available	None seen	Presence of ticks, respiratory signs, pale liver, discoloured spleen, hydrothorax, hydropericardium, heart necrosis	Intraerythrotic marginal bodies and schizonts	Mixed infection of ECF, Heartwater and anaplasmosis
7	6m	F	L	History of similar death in similar species	Respiratory distress	Bloat, respiratory lesions ,haemorrhages on duodenum, hydropericardium, cassava roots in rumen	No findings	Bloat and cassava tubes/root poisoning
8	8m	F	L	Not available	None seen	Presence of ticks, respiratory distress, gall bladder distension, heavy worm infestation in rumen and reticulum, constipated reticulum, hydroperitoneum,	High numbers of Intraerythrocitic marginal bodies	Anaplasmosis
9	12m	M	L	Not available	None seen	Greenish froth from nostrils and buccal cavity, bloated stomach, respiratory lesions, left ventricle puncture, massive haemorrhages of tissue/organs, laughing of the epithelia of the 4 stomachs.	No findings	Acute bloat/Poisoning

Cases	Age	Sex	Breed	History	Clinical signs	Necropsy	Microscopy	Presumptive diagnosis
10	36m	F	L	Not available	Hard faeces	Presence of ticks, enlarged parotid lymph nodes, respiratory lesions, congestion of brain, lungs, spleen, heart and kidney, icterus of hepatic tissue, haemorrhages of duodenum, hepatomegally and slenomegaly, hydropericardium, hydrothorax,	No findings	Heartwater/babesiosis/anaplasmosis
11	72m	F	L	History of feeding on amaranths	None seen	Respiratory lesions, blood around the anal region, bloat, hydrothorax, hydropericardium	No findings	Acute bloat
12	2w	M	L	Not available	None seen	Respiratory distress, haemorrhages on the serosa of rumen, duodenum and intestines, necrotic kidney medulla	No findings	Pneumonia with possible septicaemia
13	2w	F	L	Indication of poor management	None seen	Presence of fleas and ticks, swollen bladder and liver, empty duodenum, grass present in rumen and abomasum	No findings	Starvation
14	4m	F	L	Presence of different tick species	Bloody diarrhoea	Sunken eye balls, corneal opacity, swollen lymph nodes, large numbers of cestodes and nematodes, necrosis and congestion of large intestines and abomasum.	Scanty schizonts seen on lymph node smear	Helminthiais/Clostridial infection/ ECF.

Cases	Age	Sex	Breed	History	Clinical signs	Necropsy	Microscopy	Presumptive diagnosis
15	1.2m	F	L	Presence of different tick species	None seen	Swollen prescapular and parotid lymph nodes, congestion of liver, lungs, kidneys cortex and spleen. Epicardium had petechiations. Nematodes and cestodes on the abomasum and small intestines, ulceration of large intestines.	Piroplasms and microschizonts seen on blood smears	Helminthiais/babesiosis/theileriosis.

Table 4b. History, clinical signs, necropsy findings and presumptive diagnoses for reports of sudden death in goats, July 2011 – June 2012

Cases	Age	Sex	Breed	History	Clinical signs	Necropsy	Microscopy	Presumptive diagnosis
1	48m	F	L	Earlier similar case in the same compound	None seen	Rumen extremely distended,	B. anthracis	Anthrax
2	8m	F	L	History of death of sheep and goats presenting diarrhoea	None seen	Respiratory lesions, lympadenopathy, liver flukes migratory routes, wire worms in abomasum, ulcerations, frank blood, white worms and haemorrhages on the large intestines, internal organs are covered by gel like piece	Intraerythrocitic marginal bodies	Helminthiais/anaplasmosis
3	2m	M	L	Not available	Abdominal pain evident	Presence of rigor mortis and ticks ,bloat, remedy to alleviate abdominal pain found in the lungs	No finding	Acute bloat/ Immediate cause of death: Asphyxiation
4	12m	M	L	Not available	None seen	Rigor mortis present, abdominal distension, haemorrhages on respiratory system, mild crepitus on thigh muscles	No findings	Clostridia infection
5	2m	M	L	Not available	None seen	Rigor present, bloat, faeces had sorghum and finger millet remnants, haemorrhages on the respiratory and digestive system	No finding	Ruminal impaction(Lactic acidosis)
6	4m	F	L	Not available	None seen	Respiratory lesions, liver necrosis, kidney and pericardium petechiations		Bacillary hemoglobinurea
7	60m	F	L	Not available	None seen	Bloat, haemorrhages on the lungs, foamy feedstuff on the reticulum and rumen	No findings	Acute bloat
8	6m	F	L	Not available	None seen	Digestive and respiratory lesions, hydropericardium	Intraerythrocitic marginal bodies	Clostridia infection/ Coccidiosis/anaplasmosis

Cases	Age	Sex	Breed	History	Clinical signs	Necropsy	Microscopy	Presumptive diagnosis
9	12m	M	L	Not available	Lameness, nervous signs	Presence of ticks, pustular lesions on nose bridge, abscess at fetlock, worm in abomasum, small intestines, haemorrhages in pericardium and intestinal mucosa, foam in the stiff joint	No findings	Septicaemia/Helminthiais
10	12m	M	L	Not available	None seen	Pediculosis, bloat, rigor mortis, respiratory and digestive lesions(large foreign body on the rumen causing blockage)	Not done	Foreign body in rumen causing blockage
11	4m	F	L	Not available	None seen	Presence of ectoparasites, respiratory lesions, rigor mortis present, congestion of heart, haemorrhages of the kidney's cortex,	No findings	Septicaemia caused by clostridia infection
12	72m	F	L	Not available	None seen	Enlarged lymph nodes, kidneys, liver, spleen, respiratory lesions, gelatinization of sub-mandible lymph nodes and fatty tissues	No findings	Caprine theileriosis/clostridia infection
13	2.5m	F	L	Not available	None seen	Presence ticks, respiratory lesions, worms on abomasum and small intestines, ulcerations of large intestines, enlarged mesenteric lymph nodes	No findings	Helminthiais
14	6m	F	L	History of diarrhoea noted	None noted	Presence of ticks, presence of rigor mortis, respiratory lesions, liver congestion, hydropericardium, hydroperitoneum, haemorrhages of kidney, uterus and urethra	No findings	Septicaemia associated with clostridia infection

Cases	Age	Sex	Breed	History	Clinical signs	Necropsy	Microscopy	Presumptive diagnosis
15	16m	F	L	Not available	None seen	Bloody discharge from vulva, respiratory lesions, skin and musculature around thoracic cavity were haemorrhaged	Intraerythrotic inclusion marginal bodies	Traumatic and acute anaplasmosis
16	8m	F	L	Not available	None seen	Presence of ticks, respiratory lesions, torticollis, bloat, hydropericardium,	Intraerythrotic inclusion bodies	Anaplasmosis/Heartwater
17	8m	F	L	Not available	None seen	Presence of ticks, blood clots appearing as a traumatised site at the junction of the tongue and trachea, dry omasal content, hard faecal materials.	Intraerythrocitic inclusion bodies	Acute anaplasmosis complicated by dehydration
18	6m	M	L	Dead snake found in the compound	None seen	Bloat, rigor mortis, respiratory and digestive lesions	No findings	Acute bloat/snake bite
19	2.5m	F	L	Evidence of feeding on *Lantana camara*	None seen	Respiratory and digestive lesions, haemorrhages on the muscles,	No findings	Plant poisoning/Clostridia infection
20	30m	F	L	Not available	Weakness	Presence of fleas, respiratory lesions, ,hydrothorax, peritonitis, presence of polythene material in the rumen, splenomegaly	No findings	Foreign material in the rumen and bloat
21	24m	F	L	Abortion two months ago	None seen	Respiratory and digestive lesions, scar in the kidney’s cortex	No findings	Clostridial infection

Table 4c. History, clinical signs, necropsy findings and presumptive diagnoses for reports of sudden death in sheep, July 2011 – June 2012.

Cases	Age	Sex	Breed	History	Clinical signs	Necropsy	Microscopy	Presumptive diagnosis
1	12m	F	L	Not available	None seen	Blood oozing from openings, rigor mortis absent, ruminal distension	B. anthracis	Anthrax
2	2m	M	L	Not available	None seen	Poor body condition, anaemia, alopecia, soiling of perineum, mesenteric lympadenopathy, abomasal haemorrhages with lots of wire worms, compaction and obstruction of intestines by tape worms,	No findings	Helminthiais
3	48m	F	L	Previous sudden death, evidence of poisonous plant	Lateral recumbency, inability to stand	Presence of ticks, absence of rigor mortis, haemorrhages of large intestines, hydropericardium,	No findings	Enterotoxaemia
4	8m	F	L	Not available	None seen	Anaemia evident, heavy flea infestation	No findings	Severe anaemia with a possibility of shock following flea bite and hypersensitivity
5	36m	F	L	History of anthrax infection in the farm two months ago	None seen	Dark non-clotting blood from openings, rigor mortis absent,	No finding	Clostridial infection
6	2m	M	L	Not available	None seen	Mange and tick infestation, mucoid nasal exudates, tape worms along the small intestines, hydropericardium, slight enlargement of mesenteric lymph nodes	Incidental finding of morulla-like bodies on brain smear	Luminal blockage following heavy tape worm infestation and shock

7	60m	M	L	History of lush pasture	None seen	Respiratory distress, massive worm infestation in the intestines, liver and rumen, congestion of the intestines, diaphragm, gum and below the skin, punctured omentum, intestines, bloat, haemorrhages of liver, heart, presence of ingesta within the peritoneum, soiling of the perineum, adhesion of diaphragm to liver, worms in the large intestines and bile duct as well as calcification of bile ducts.	No findings	Traumatic injury/bloat/Helminthiais

3.3 Red Urine Syndrome

Twelve cases of red urine were reported during the study period: 11 in cattle (92%) and one (8%) in a goat. History, clinical signs, necropsy findings and presumptive diagnoses for these cases by species are shown in Table 5a & b. The frequency distribution of red urine cases by month and by species is shown in **Figure 10**. The incidence rate of red urine by species per 1,000 population per year was 1.1 in cattle, 0.1 in goats and 0 in sheep.

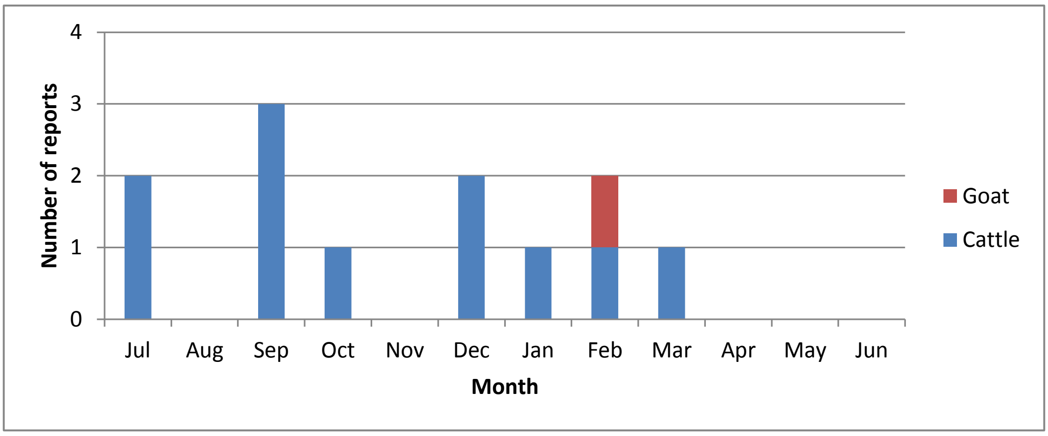

Figure 10. Reported cases of red urine in ruminants by month and by species, July 2011 - June 2012

Table 5a. History, clinical signs and presumptive diagnoses for reports of red urine in cattle, July 2011 – June 2012.

Cases	Age	Sex	Breed	History	Clinical signs 1	Clinical signs 2	Microscopy	Presumptive diagnosis
1	24m	M	L	Attempt treatment with tetracycline following hemoglobinurea	Sub-normal temperature (36.6)	Weakness,	Mild Intraerythrocitic piroplasms	Babesiosis
2	84m	F	L	Two day sickness, with anorexia with no treatment attempt	Rough hair coat with various tick species, Sub-normal temperature,	Diarrhea, emaciation	Intraerythrocitic marginal bodies and piroplasms	Babesiosis/anaplasmosis
3	72m	M	L	Two day sickness, anorexia,	Rough hair coat, weakness, fever, hemoglobinurea/ dark bloody urine	Blood stained feces,	No findings	Babesiosis
4	96m	M	L	Two day sickness, blood in feces, anorexia, grazing around the lake	Rough hair coat with different tick species, hemoglobinurea	Soiling of the perineal area, weakness/ dullness,	Extensive erythrolysis of red blood cells	Babesiosis
5	104m	M	L	Red urine seen, anorexia	Depression/dullness, ticks presence, prescapular lympadenopathy,	Unilateral otitis interna (pus and maggots)	Intraerythrocitic marginal bodies	Anaplasmosis
6	48m	M	L	Red urine, with increased frequencies of urination	Weakness/dullness, anemia, sub-normal temperature	Recumbency	Intraerythrotic marginal bodies and piroplasms	Babesiosis
7	18m	F	L	Bloody urine reported, anorexia	Blood tinted urine, weakness, starry coat, fever, jaundice, anemia,	Weakness, sunken eye balls,	Intraerythrotic piroplasms	Babesiosis

Cases	Age	Sex	Breed	History	Clinical signs 1	Clinical signs 2	Microscopy	Presumptive diagnosis
8	40m	F	L	Bloody urine for one day, presence of cats and dogs, no deworming, practiced communal grazing,	Bloody urine	Bloody loose fecal at the perineum,	Intraerythrocitic inclusion bodies and piroplasms	Babesiosis/anaplasmosis
9	60m	M	L	One day sickness, red urine, anorexia,	Hemoglobinurea, fever	Weakness/dullness,	Intraerythrocitic inclusion bodies and piroplasms	Babesiosis/anaplasmosis
10	100m	F	L	Third trimester abortion a day before, bloody urine, communal grazing,	Ticks present, fever, hemoglobinurea	No findings	Intraerythrocitic inclusion bodies and mild piroplasms	Babesiosis/anaplasmosis/leptospirosis
11	60m	M	`L	Blood in urine, no routine tick control	Ticks present, lympadenopathy, running nose, hemoglobinurea	Weakness, pale mucous membranes	Schizonts on lymph node smear	ECF/babesiosis/clostridial infection

Table 5b. History, clinical signs and presumptive diagnoses for reports of red urine in goats, July 2011 – June 2012.

Cases	Age	Sex	Breed	History	Clinical signs 1	Clinical signs 2	Microscopy	Presumptive diagnosis
1	48m	F	L	Communally served, and conceived, abortion suspected	Blood from vulva and hemoglobinurea seen one day ago, fever	No finding	Intraerythrotic inclusion bodies and piroplasms	Babesiosis/anaplasmosis/with urinary tract infection caused by clostridia

3.4 Neurologic Syndrome

Nine cases with neurological signs were reported during the study period: six in cattle (67%), two in goats (22%) and one in a sheep (11%). History, clinical signs, necropsy findings and presumptive diagnoses for these cases by species are shown in Table 6a, b & c. The frequency distribution of neurologic cases by month and by species is shown in **Figure 11**. The incidence rate of neurological signs by species per 1,000 population per year was 0.6 in cattle, 0.3 in sheep and 0.2 in goats.

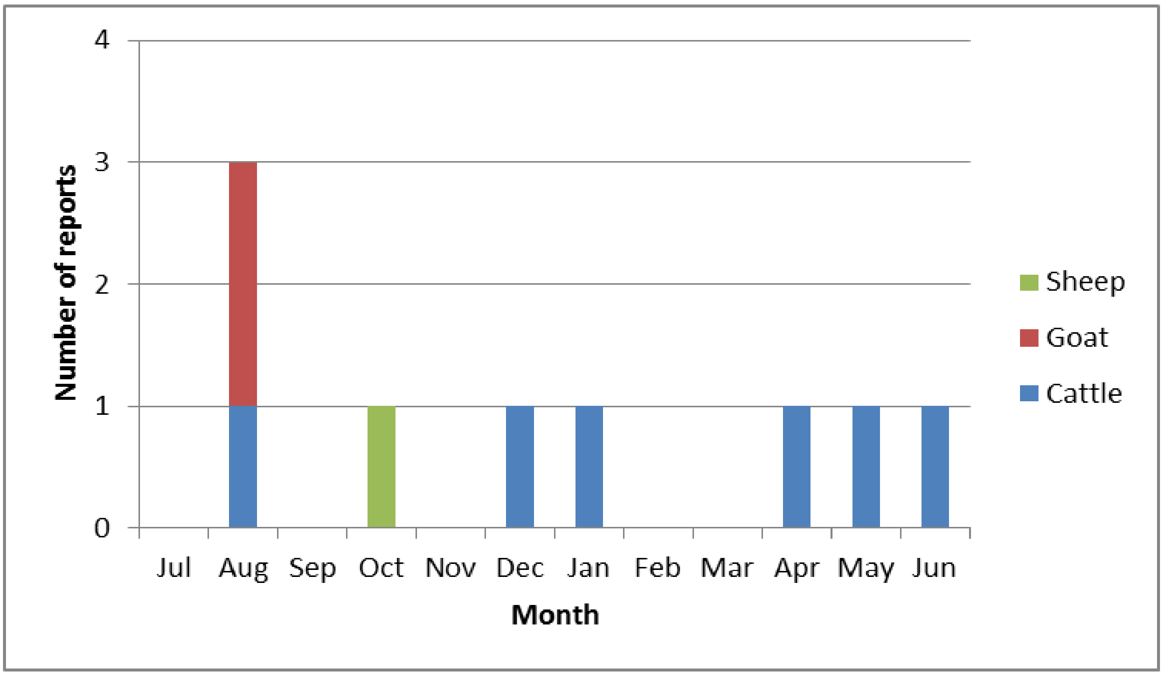

Figure 11. Reported cases of neurological syndrome in ruminants by month and by species, July 2011 - June 2012

Table 6a. History, clinical signs and presumptive diagnoses for reports of neurologic signs in cattle, July 2011 – June 2012.

Cases	Age	Sex	Breed	History	Clinical signs 1	Clinical signs 2	Microscopy	Presumptive diagnosis
1	36m	M	L	Sickness seen for a while, blood stained feces, treatment with anti-tryps attempted	Ticks present, stepping-staggering gait, jaundice, fever,	Purulent nasal discharge	Intraerythrocitic inclusion bodies and piroplasms	Heartwater/babesiosis
2	30m	F	L	Sick for more than one day, naturally served and is first trimester pregnant, aspiration pneumonia,	Ticks present, downer/laterally recumbent, muscle tremors, lympadenopathy, mild reflexes, sub-normal temperature,	Hemorrhages on tongue, gingivitis,	Intraerythrocitic piroplasms, schizonts	Terminal ECF/babesiosis
3	36m	F	L	Anorexia, intermittent ataxia, circling, stupor	Foamy mouth, recumbency, limb stiffness, hypersensitivity, increased respiratory rate, lympadenopathy, slow tongue reflex	Evident of diarrhea, wasting, weakness/dullness,	Intraerythrocitic piroplasms	Cerebral ECF and babesiosis
4	48m	M	L	Anorexia	Larval tick stages seen, circling, lacrimation, hypersalivation, staggering gait, , head bending, prescapular lympadenopathy, incoordination,	Constipation	Schizonts seen on lymph node smear	Cerebral ECF
5	84m	M	L	10 day sickness, circling, oxytetracycline and anti-tryps attempted by farmer	Ticks present, aggression, appears blind, mouth foaming, teeth grinding,	No findings	No findings	Tick paralysis

Cases	Age	Sex	Breed	History	Clinical signs 1	Clinical signs 2	Microscopy	Presumptive diagnosis
6	36m	M	L	Circling seen by farmer a day before, anorexia, constipation	Recumbency, fever	Weakness/lethargy	Intraerythrocitic piroplasms	Cerebral babesiosis

Table 6b. History, clinical signs and presumptive diagnoses for reports of neurologic signs in goats, July 2011 – June 2012.

Cases	Age	Sex	Breed	History	Clinical signs 1	Clinical signs 2	Microscopy	Presumptive diagnosis
1	24m	F	L	Circling and falling, head pressing, convulsions, five hours later the animal died with no treatment attempted,	Not examined	No findings	No findings	Acute listeriosis
2	36m	F	L	Three day sickness, treatment with oxytetracycline done	Recumbency, twisted neck, fever, ascending stiffness, incoordination	No findings	Intraerythrocitic marginal bodies	Anaplasmosis/tick paralysis

Table 6c. History, clinical signs 1 and 2 and presumptive diagnoses for reports of neurologic signs in sheep, July 2011 – June 2012

Cases	Age	Sex	Breed	History	Clinical signs 1	Clinical signs 2	Microscopy	Presumptive diagnosis
1	36m	F	L	Sudden circling onset	Muscle contraction, abdominal breathing, nasal discharge, open mouth breathing, hypersalivation, fever, increased pulse rate	N/A	No findings	Cerebral listeriosis/Clostridia infection

CHAPTER 4: Discussion

The key to success in controlling outbreaks of animal diseases and zoonoses is early detection. This requires that effective surveillance systems are in place, that allow for early detection and reaction. The basis for adopting this system was that disease episodes in animals can be used as indicators for outbreaks in humans. Through monitoring animal health information, early warnings of emerging zoonotic infections or of changing disease patterns can be detected (Morse *et al.*, 2012). Implementing an animal health surveillance system alongside ongoing human health surveillance is a step towards integrated surveillance for zoonotic diseases, through a One Health approach. Besides zoonoses, animal health can be linked to human health through two other pathways: (1) a socio-economic pathway, where improved livestock production is associated with healthy livestock, leading to improved household incomes, wealth and livelihood security (access to education and health care), and (2) a nutritional pathway, where owning healthy livestock increases access to animal source foods that in turn reduces the risk of malnutrition and associated morbidity/mortality.

In this population, livestock are an important asset. Even though the study area was limited in provision of animal health services, identifying community members who were well-known, settled and still active within the community (particularly in matters of animal husbandry and disease), to work as AHRs, and training and equipping them with mobile phones as a reporting tool, presented an opportunity to enhance animal disease reporting in this rural community. From our experience, we found that individuals with even a relatively low level of education could become conversant and confident in the use of the system and the submission of reports, but that continuous training is needed to maintain this. This approach was enabled by the relatively advanced technological infrastructure of mobile telephony, thereby enabling timely case submission. Just as in human health, mobile phones can be applied to animal disease surveillance. With mobile phone ownership and access in the study area standing at 70%, it is a potentially useful tool for surveillance.

Mobile phones have eased information sharing and provide a recipe for advancement of animal disease reporting; however, optimal use of these tools is still dependent on human nature. We observed substantial differences in reporting between individuals. This was due to factors such as distribution of network bandwidth; access to phone battery charging and airtime scratch card availability. Villages with poor network coverage had low number of reports recorded (e.g. village numbers 19, 47, 49 and 59). Sites nearer to market shops with access to airtime scratch cards and electricity supply necessary for phone charging reported a relatively higher number of reports (e.g. 11 and 55). According to AHRs, the incentive offered was not sufficient to warrant a report submission in itself. AHRs engaged themselves in other income generating activities which offered better economic gains. During farm months; August, September, November, January, February, March, April and May following long and short rains (ploughing, digging, planting, weeding, harvesting), lower cases were recorded as a more viable economic activity, farming out weighed this project's work. With a higher compensation, an improvement in reporting would have been seen, but questions of sustainability would arise. A roll-out involving livestock worker, the use of a toll-free reporting line or active case detection of livestock health events would have been a more dramatic venture in harnessing the potential of mobile phone technology to improve surveillance of animal diseases and improve livelihoods in general.

With sensitization and awareness, the community participated enthusiastically in reporting episodes of illness and death in animals through the AHRs. Participation may be improved by following a programme of hierarchical enrolment, e.g. at the level of village/location, house/school and person. One must enroll a village before enrolling a house/school in that village, and enroll a house/school before enrolling a person associated with that school or house. Reporting was likely encouraged by the free veterinary intervention offered by the animal health response team. Out of all the reports investigated within the study period, 25% were invalid, and of these, more than a quarter occurred in the first month of investigation. The majority of cases were invalid because they did not involve one of the study syndromes, an indication of the eagerness of participants to contact the AHRs in cases of animal diseases and death. In addition, participants may have had difficulties in differentiating the four syndromes - for example cases of animal slaughter were reported as death. These issues appear to have been resolved as the study progressed, through further training of AHRs and improved awareness among the participants of the appearances of these clinical syndromes. Desire for free animal health assistance may also have led to over-reporting – for example, chronic illnesses were reported as recent cases. Efforts were made to address this through sensitization during the study period.

Under-reporting of syndromes was the one of the biggest obstacles in the realization of the objectives of this program. Often, carcasses from cases of sudden death were butchered and consumed, an indication that public health education is lacking in the community. This may have led to under-reporting of sudden death cases due to fear of denial of a favorable delicacy. As households in the study area are far apart, unwillingness to follow up cases might also have resulted in under-reporting. Furthermore, this being a less well-resourced community and the compensation for aiding in reporting being only a few shillings, AHRs would engage in other income-generating activities, often making them unavailable when sought to relay reports. The main economic activity in the study area is subsistence farming and so peak crop farming seasons (January to April) received the lowest reports as AHRs as participants engaged in crop farming activities at the expense of livestock husbandry. Farming-free months (especially June and July) had higher numbers of reports (both valid and invalid), an indication that the AHRs and farmers had spare time and therefore improved observation of animal health issues. Increased levels of community sensitization and public health education could increase compliance both from the community and the AHRs in future surveillance efforts.

Active as opposed to passive surveillance might improve reporting. An ideal system might involve study staff scheduling household visits to obtain information on animal illness and death (similar to that used for human health surveillance through the IEIP platform – the household morbidity study or HMS), or perhaps providing a toll-free number for farmers to call whenever a situation arises. Although these might improve reporting, the sustainability of such systems for animal health surveillance is questionable (Feikin *et al.*, 2010; Thumbi *et al.*, under review). With proper and consistent community engagement, in small community forums, accurate reporting of valid episodes through passive surveillance can hopefully be improved. This will further enhance the use of animal disease reporting, and its utility for zoonoses detection.

Generally, sheep and goats form the largest number of domestic ruminants found in the tropics, especially in Africa. In Nigeria for example, the sheep and goat population is about 53 million (FAOSTAT, 2009). In Rarieda sub-county, western Kenya where this surveillance was conducted, the total livestock population is estimated at 19,807 sheep, 44,399 goats and 60,000 cattle (https://www.opendata.go.ke). In the study area, a livestock census revealed a population of 3,558 sheep, 9,891 goats and 11,409 cattle, thus the combined population of sheep and goats surpassed that of cattle. Out of the 139 valid reported syndromes 66% were observed to have occurred in goats and sheep with only 34% observations in cattle. Sheep suffered the highest incidence rate of disease events over the twelve months (per 1,000 population) at 7.3, followed by goats (6.5) and cattle (4.1). Abortions made up over half (54%) of the syndrome events reported. Sheep suffered the highest rate of abortions (5.1 per 1,000), followed by goats (4.0), with a relatively low incidence in cattle (1.5). Sheep and goats also suffered higher rates of sudden death (the second most common syndrome) than cattle. The situation was different in red urine and neurological syndromes, which had higher incidences in cattle. This can be attributed to the fact that these syndromes are not easily observed in small ruminants but are more pronounced in cattle, or to the fact that the main causes are more specific to cattle.

The consequences of animal diseases can be complex, and generally go well beyond the immediate effects on production. Impacts include productivity losses for the livestock sector (e.g. production losses, cost of treatment, market disturbances), loss of income from activities using animal resources (e.g. draft power for crop farming), reduction in human health and well-being (morbidity and even mortality, food safety and quality), prevention or control costs, and suboptimal use of production potential (animal species, genetics, livestock practices). For example, in Africa abortions caused by Rift Valley fever virus not only affect birth rates, but also, owing to lower levels of milk production, push human consumption of milk downward in the year following an outbreak. By far abortions and sudden deaths were the highest recorded syndromes, indicating their relative significance to livestock production in this area. Relatively high numbers of abortion cases were recorded in the last month of the study (June 2012); this was as a result of enhanced training, a few inactive AHRs being replaced and constant calls on the AHRs to submit the reports. By persistent reminder calls to the AHRs, more reports would be realized.

The choice for these four animal disease syndromes was because of their possible association with endemic, emerging, re-emerging and/or zoonotic diseases. The study area has a high incidence of human infectious diseases; including HIV, tuberculosis and malaria. There may also be a high burden of other, underdiagnosed causes of illness, considering the presence of disease vectors (mosquitoes, ticks, fleas, tsetse flies and sand flies), improper hygiene standards and immunocompromised individuals (Bigogo *et al.*, 2010 & 2011). In this study, endemic zoonotic infections were presumptively diagnosed, including anthrax and listeriosis. Economically important livestock diseases were also diagnosed, conditions which could result in severe losses to the livestock industry, hurt the economies of households and compromise animal source foods access. These included babesiosis, East Coast fever, heartwater, anaplasmosis and clostridial infections. Some of the diagnosed disease conditions were vector-borne. Tick-borne diseases were frequently diagnosed, an indication that tick control was wanting and that the vectors freely existed in that environment.

Presumptive diagnoses were based on the case history, clinical examination of ill animals and postmortem examination of dead animals. For the syndromes under observation, a presumptive aetiological diagnosis was made in almost all reported events. However, in the absence of laboratory confirmation, presumptive diagnoses may be inaccurate. In resource-constrained settings such as the study area, reliance on presumptive diagnoses may mean than underlying causes are misdiagnosed, with the result that appropriate interventions are not provided. As an example, misuse of antibiotics may lead to antimicrobial resistance, a serious concern in public health. Presumptive diagnoses should therefore ideally be supported through laboratory confirmation. However, due to limited diagnostic capabilities in the tropics, the extensive nature of animal husbandry in many areas (pastoralism), poverty and inaccessibility of rural communities, diagnoses and initiation of therapies rely on the judgment of the attending animal health provider, whose diagnoses are usually presumptive. Due to the lack of suitable trained personnel, field-level diagnostic tests and laboratory diagnostic capacity, diagnoses by animal health providers are often unconfirmed. Notwithstanding, presumptive diagnoses are important in making decisions about disease management, prognosis, control and prevention, and therefore remain the most practical option of animal disease control and treatment decisions in rural African settings (Machila *et al.*, 2003). For abortion cases, lack of specific clinical signs, necropsy findings and a wide range of potential etiologies made it difficult to arrive at presumptive diagnoses. Usually there is a wide range of associated etiological agents presenting similar clinical signs, thus making it difficult to pin point only one or a few organisms presumptively.

The study area was selected because it is also the site of household morbidity study conducted by the Kenyan International Emerging Infections Programme (IEIP) of KEMRI/CDC. That system also uses a syndromic approach, investigating four syndromes (respiratory illness, febrile illness, gastro-intestinal illness and jaundice). For the period from February 2013 to February 2014, a total of 38,208 human illness cases were reported. The frequency distribution of these cases among the four syndromes is shown in **Figure 12**.

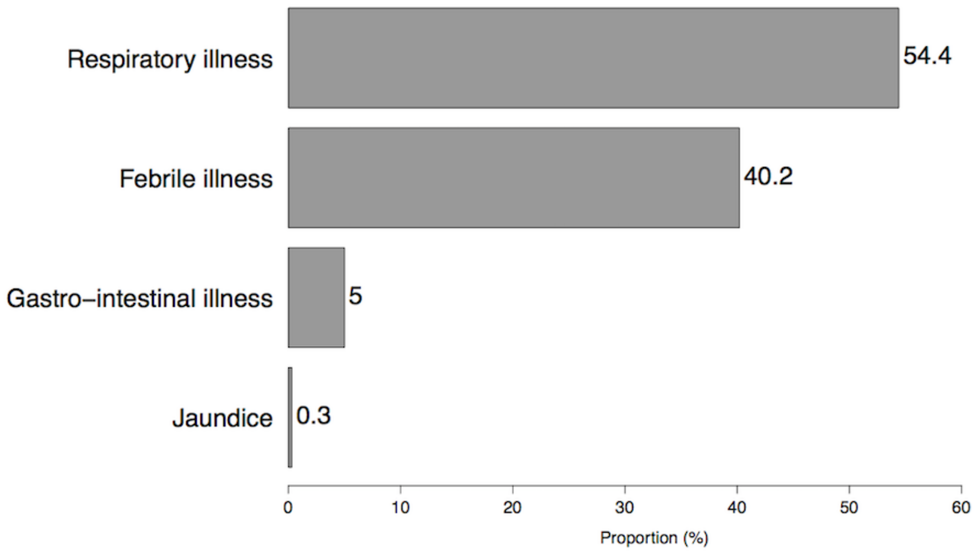

Figure 12. Frequency distribution of 38,208 cases of human illness among the four syndromes under investigation in the KEMRI/CDC household morbidity study, February 2013 to February 2014

Parallel population-based human and animal disease surveillance provides opportunity to correlate animal and human disease at the household level, and to test hypotheses whether the health of humans is related to animal sickness or death. For example, it can be hypothesized that relationships between households with high numbers of human illnesses and those with high numbers of animal illnesses may be driven by either the zoonotic pathway, with pathogens shared between humans and the animals they keep, or driven by factors that increase the household illness index. In the latter case, illnesses may be related to the environment in which the humans and animals co-reside, with hosts living in the same environment more readily exposed to a variety of pathogens, or practices that facilitate transmission and/or maintenance of pathogens, whether zoonotic or not.

CHAPTER 5: Conclusion

Livestock keeping provides significant socio-economic benefits, as a source of income/wealth, or a source of nutrition; however, these benefits may be offset by the risk of zoonoses and food-borne diseases. Surveillance, along with public health education, can be applied to limit the spread of these infections to humans, noting that the onset of zoonoses in humans is preceded by the appearance of the same pathogens in animals (wildlife and domestic). Proper livestock management practices were found to be lacking in the study area. Vector control and vaccinations ought to be encouraged, along with the practice of proper hygiene standards at farm and household levels, all of which can be incorporated in public health education. Lack of infrastructure for animal disease diagnosis is a serious concern that needs to be addressed, as basing animal treatments on tentative diagnoses is deemed to be one of the factors contributing to widespread antimicrobial resistance through the food chain. Both personnel and equipment needs to be sought to aid in this. As a start, existing veterinary investigation laboratories should have the capacity to assist practicing animal health providers with real-time and accurate diagnoses. Monitoring and documenting disease occurrences in both animals and humans should be a continuous exercise, to allow early detection and response to abnormal patterns, to mitigate any impacts on public health. Systems need to be in place at the lowest administrative levels to continuously monitor and detect public health episodes that may presage health disasters. Activities such as surveillance for vectors of major zoonotic and livestock diseases (ticks, fleas, tsetse flies, mosquitoes and sand flies) to determine their presence/distribution and the factors influencing their distribution (environmental, climate) need to be in place at sub-county and lower levels of governance to help predict probable epidemic occurrences, for example, relating mosquitoes numbers, distribution and weather patterns to the occurrence of RVF. An integrated, One Health approach to surveillance and research in human and animal health is needed. For this, a co-ordinated approach among all stakeholders is required. Doctors, veterinarians, epidemiologists, statisticians, environmentalists, sociologists and those from other related disciplines need to participate in One Health approaches. Incorporating One Health approaches in the training of these professions will be important to improve co-operation and co-ordination when a joint effort is needed. More training programs are needed to encourage joint training and capacity building of human doctors, nurses, laboratory staff, and veterinarians, to prepare them to jointly respond to public health issues through a collective effort.

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