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manual

RIFT VALLEY FEVER SURVEILLANCE

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Contents

Preface

Rift Valley fever (RVF) is an epizootic disease. Even in regions where the RVF virus is always present, outbreaks do not necessarily occur. Several years can separate outbreaks, with no evidence of disease in the interim.

What is out of sight is all too often out of mind. With RVF, extended interepizootic periods lull us into inaction and opportunities for disease prevention are lost. Once an outbreak takes hold, it is too late to prevent the toll on animals, livelihoods and even human life.

It is difficult to convince health leaders of how crucial emergency preparedness, particularly for animal diseases - even zoonotic ones. The international community, including development organizations like FAO, need to scan the horizon constantly to recognize evolving risk. We must remind countries and stakeholders of the importance of being prepared for disease emergencies. We must build effective national or regional response capabilities to minimize the risk of outbreaks and socio-economic impact of disease.

Disease surveillance is the main pillar of early detection and response. FAO has long advocated its importance to national decision-makers – sadly, often with limited success. Nevertheless, even a long journey starts with a single step.

FAO works consistently with countries to improve surveillance capacity, so they can detect and respond to transboundary animal diseases like RVF.

This surveillance manual is for countries at risk of RVF - and those where RVF is endemic. It is a guide to conducting effective surveillance, reducing the socio-economic consequences of outbreaks, and preventing them where possible. It is addressed to veterinarians and other animal health professionals and uses plain language supported with practical examples. We hope that our readers will implement these strategies and build effective surveillance capacity to prevent and control RVF.

Acknowledgements

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Acronyms

AGID	agar gel immunodiffusion
AYAM	abortion and young animal mortality
BSL	biosecurity level
CBPP	contagious bovine pleuropneumonia
CVO	chief veterinary officer
DSF	decision support framework
EDTA	ethylene diamine tetra-acetic acid
ELISA	enzyme-linked immunosorbent assay
EMPRES	Emergency Prevention System for Transboundary Animal and Plant Pests and Diseases
ENSO	El Niño–southern oscillation
FAO	Food and Agriculture Organization of the United Nations
FVO	field veterinary officer
GIEWS	Global Information and Early Warning System on Food and Agriculture
GLEWS	FAO OIE WHO Global Early Warning System
GIS	geographic information system
IATA	International Air Transport Association
ITCZ	intertropical convergence zone
IGAD	Intergovernmental Authority on Development
OH	One Health
OIE	World Organisation for Animal Health
NGO	non-governmental organization
PE	participatory epidemiology
PENAPH	Participatory Epidemiology Network for Animal and Public Health
PS	participatory surveillance
PPE	personal protective equipment
NDVI	normalized difference vegetation index
PCR	polymerase chain reaction
REC	regional economic community
RSSD	remote sensing satellite data
RVF	Rift Valley fever
SEIR	Susceptible, exposed, infectious and recovered
SNT	serum neutralization test
SST	sea surface temperatures
TRMM	Tropical Rainfall Measuring Mission
WAHIS	World Animal Health Information System
WHO	World Health Organization

Definitions

Basic reproductive number (R_0): Measure of the transmission capacity of the strain of an agent in a population of hosts. It is defined as the average number of secondary cases that would result from the introduction of one infected animal into a fully susceptible host population.

Infection-free countries: Countries where infection is not present in animals or competent vector populations.

Infected countries during an interepizootic period: Countries where RVF infection is present but circulates undectably at very low levels, and where environmental conditions for the foreseeable future indicate that a disease outbreak of clinical concern is unlikely.

Infected countries during an epizootic: Endemic countries experiencing, or at significant risk of experiencing, a significant increase in RVF transmission leading to an overt disease outbreak.

Institutions: Societal mechanisms that carry out specific social functions and include the organizations, stakeholders, and formal and informal rules or customs that guide their interactions.

Transdisciplinarity: A principle or approach that goes beyond traditional disciplinary boundaries to integrate the natural, social and health sciences in a shared analytical framework.

Zero reporting: A requirement in disease reporting procedures where each reporting office must report the number of events detected in each reporting period, or report zero in the absence of cases.

Introduction

Health professionals detect, prevent and control disease in the population. Disease surveillance is about collecting practical information on the occurrence and patterns of disease. This enables health professionals to fulfil their roles, make timely decisions and take action. Disease surveillance may safeguard the national economy and livestock production, as well as people's livelihoods and health.

This manual follows a risk-based approach to surveillance. It uses the principles outlined in the OIE *Guide to Terrestrial Animal Health Surveillance* (Cameron *et al.,* 2015) for designing and implementing surveillance programmes. The statements in this manual are for guidance and should not be treated as prescriptions. Appropriate surveillance at the national level depends on local epidemiological conditions, production systems, culture and institutional arrangements.

RVF is a vector-borne zoonosis that severely impacts livelihoods, national and international markets, and human health. Within Africa and the Middle East, there are conditions that favour vector populations that are capable of transmitting the disease. This is how RVF becomes anchored in local environments. Competent vectors are known to exist even beyond the current range of RVF and there is a recognized risk of global spread.

RVF is a One Health issue with significant potential to emerge as a global concern.

RVF outbreaks in humans are preceded by epizootics in livestock. However, most of the major outbreaks have first been recognized in the human population. This manual supports the development of more effective veterinary surveillance for RVF in a One Health context.

In the past, the impact of RVF on international trade (Antoine-Moussiaux *et al.*, 2012) and domestic livestock economies has been aggravated by a lack of effective communication strategies and a lack of confidence between trade partners. Animal health decision-makers were often reluctant to discuss the emerging risk of an RVF outbreak for fear of upsetting markets. Little mention has been made until the outbreak is well under way and human cases have been diagnosed. At that point, it is too late to take effective mitigating action. The eventual declaration of an outbreak results in mistrust and public alarm, and trading partners generally assumed the worst case scenario.

Today, risk-based approaches are widely accepted and the conditions leading to an epidemic and risk factors for the disease spreading are all better known. This makes it possible to manage the health and economic impacts of RVF with an evidence-based approach.

Revisions to the *OIE Terrestrial Animal Health Code* include the option to recognize three distinct risk categories for countries. This has improved our ability to forecast outbreaks. Developing the RVF Decision Support Framework (DSF) has opened the way to transparency in managing risk and mitigating impacts - reassuring trade partners and the public.

Holistic animal heath surveillance plays an important role in mitigating the health and economic impacts of RVF. This includes long-term weather forecasting and environmental monitoring. International trading partners are reassured by accurate information on risk

and are more confident that both the risk and actual occurrence of RVF will be openly communicated in a timely and way.

USING THIS MANUAL

This manual provides animal health professionals and paraprofessionals with the information they need to design and implement effective animal health surveillance for RVF. Our approach is guided by a One Health approach.

As a contextual foundation for surveillance, the manual provides general information on RVF and the agent that causes it, the RVF virus (RVFV). The background data focus on the epidemiology and main determinants of risk.

The manual suggests a range of surveillance objectives and activities for countries in line with their epidemiological status. The goal is to help countries to develop risk-based surveillance systems that are fit for purpose and cost effective.

The One Health approach to surveillance is ideal for tackling the zoonotic and vector-borne nature of RVF. Surveillance systems need to cover a range of human, animal and environmental issues. The risk of an RVF outbreak can only be assessed in a transdisciplinary manner. This manual focuses on animal health surveillance in the context of an integrated surveillance and response system.

Nature of the disease

DEFINITION AND IMPORTANCE

RVF has a direct impact on livestock and human health as well as on trade. It is currently limited to Africa and parts of the Middle East but has the recognized potential to spread globally.

RVF is an acute, vector-borne, viral disease of mammals. It is caused by Rift Valley fever virus of the genus *Phlebovirus*, family Bunyaviridae. Outbreaks are characterized by high levels of mortality in lambs, kids, calves and adult sheep. Abortion is a common outcome in adult sheep, cattle and goats. In fatal cases and aborted foetuses, hepatitis with focal hepatic necrosis is a principal lesion. You can find the clinical presentations and clinical case definitions for recognizing the disease in Annex I.

RVF is zoonotic. It can result in widespread febrile illness in humans, associated with severe and sometimes fatal sequelae in under one percent of cases.

Although epizootics in livestock generally precede human epidemics, several major outbreaks have first been detected in humans, with livestock epidemics only retrospectively diagnosed. The close relationship between humans, animals and the environment in the epidemiology of RVF warrants a One Health approach to surveillance and response.

The principal vectors of RVF are mosquitos: over 30 species from 12 genera have been implicated. The disease is cyclical in nature. Massive outbreaks in naïve populations result in high levels of immunity; populations regain susceptibility only after extended interepidemic periods. Prolonged rains or changes in water management systems which lead to favourable conditions for vector multiplication trigger the epidemic cycle (Swanepoel and Coetzer, 2005).

AETIOLOGY

The RVF virus (RVFV) is an arthropod-borne virus or arbovirus. It is a single-stranded RNA virus with three segments. The Zinga and Lunya viruses are identical to RVF. The Lunya virus was first isolated in 1955, in Uganda. The Zinga virus was first isolated in 1969, in the Central African Republic.

RVFV is serologically related to other phleboviruses but can be differentiated by (virus) serum neutralization tests. There is only one RVFV serotype. The virus is rendered inactive by lipid solvents (such as ether) and by strong solutions of sodium or calcium hypochlorite (residual chlorine should exceed 5,000 ppm).

HISTORY AND GLOBAL DISTRIBUTION

RVF was first identified in an outbreak of abortions and deaths in exotic wool sheep, along with illness in humans. The outbreak occurred in 1930-31 in the Rift Valley of Kenya after heavy rainfall (Daubney *et al.*, 1931). Outbreaks have since occurred in the highlands of Kenya at irregular intervals of 3–15 years.

The major epizootic in the East African region occurred in 1997–1998. This took place in the drier areas of northeast Kenya and southwest Somalia after heavy rains associated with El Niño. This caused human deaths as well aslivestock losses, particularly of camels. Arguably more significant was the disruption to livestock exports from the Horn of Africa to the Middle East.

The most recent outbreak in East Africa was in 2006–2007. Despite forecasts and widespread disease in livestock, it was first identified by diagnosing hospitalized human cases.

In southern Africa, the disease was first recorded in 1950, when a major epizootic in the Republic of South Africa caused an estimated 100 000 deaths and 500 000 abortions in sheep. A second extensive epizootic occurred in Namibia and South Africa in 1974–1975. Periodic severe outbreaks continue to occur and have also been experienced in Mozambique, Zambia and Zimbabwe.

In 1973, RVF outbreaks occurred in irrigation areas of Sudan. In 1977, the disease was recognized in humans in Egypt and caused an estimated 600 human deaths. After that, ongoing heavy losses in sheep, goats, cattle, buffaloes and camels were recognized in the Nile valley and delta. Further outbreaks again occurred in Egypt in 1993.

A serious outbreak of RVF occurred in the Senegal river basin of southern Mauritania and northern Senegal in 1987. This outbreak first came to attention through severe illness and deaths of people in the area, but there was also a high abortion rate in sheep and goats. There was another outbreak of RVF here in 1998.

The virus occurs across sub-Saharan Africa as a cryptic infection. Until recently, RVF was thought to be restricted to Africa. However, it was reported in the Tihama region, in Saudi Arabia and Yemen, in September 2000. There were extensive abortions in sheep and goats, and some 855 severe human cases with 118 deaths. The virus was similar to the one circulating in Kenya and Somalia in 1997–1998. The Tihama plain, about 50 km wide, is in the west of Saudi Arabia and Yemen between the mountains and the Red Sea, east of the Great Rift Valley. This is a semi-arid zone with alluvial fanning from the mountains that form the escarpment of the Rift. Its ecological characteristics are similar to those on the western side of the Rift Valley in Africa, where RVF occurs.

An extensive outbreak of RVF occurred in Southern Africa between 2008 and 2011, and in Madagascar in 2008 and 2012 (Linthicum *et al.,* 2016). The Union of the Comoros experienced human cases in 2007, with evidence of circulation in subsequent years (Lernout *et al.,* 2013).

RVF has not been known to occur in North Africa, west of Egypt. However, seropositive camels have been documented in Morocco (El-Harrak *et al.*, 2011). A recent extension of the epizootic range of RVF into Northern Mauritania in 2010 has been observed (El Mamy *et al.*, 2011). This suggests that the Mediterranean ecosystem is at risk, especially in light of climate change.

At the time of writing, a clinical outbreak of human and animal RVF has been recognized in the Niger's Tahoua region (WHO, 2016). There has long been serological evidence of RVF circulation in this region of the Sahel (Mariner *et al.*, 1995). However, is the first time that a clinical epizootic in the centre of the Sahel has been detected. The outbreak is associated with nomadic cattle, and seasonal festivals and migrations may constitute a risk for further spread (WHO, 2016).

HYDROLOGY, CLIMATE AND DISEASE RISK

Outbreaks of RVF occur in populations with low immunity levels and in association with events in local hydrology like prolonged rains. More rarely, outbreaks occur in association with the building of dams and irrigation schemes, such as in Senegal and Egypt. As herd immunity is high just after an outbreak, in most endemic areas there are periods of years between reports of RVF.

In East Africa and Southern Africa, outbreaks are associated with prolonged heavy rains that characterize 'El Niño' or ENSO events. These are periodic changes in sea surface temperatures (SST) and associated winds in the eastern Pacific Ocean. These changes shape the weather in much of the tropics and subtropics. In East Africa these changes are associated with heavy and often prolonged rains. Where and when SST are increasing, the event is termed El Niño. Such prolonged rains favour successive waves of *Aedes* and *Culex spp.* mosquitoes and a dramatic increase in transmission. This results in an intense epidemic that exhausts the susceptible host population within weeks.

In West African Sahelian areas, studies suggest that outbreaks are not necessarily linked to excess precipitation and that the pattern of rainfall is an important determinant. Even in years with normal precipitation levels, prolonged rains with a brief dry interval favour a double cycle of local *Aedes* vectors. These lead to simultaneous waves of *Aedes* and *Culex* vectors (Soti *et al*., 2012; Caminade *et al*., 2014).

With climate change, the frequency and severity of extreme weather events, including 'El Niño,' is projected to increase (Patz *et al*., 2005; Cai *et al*., 2014; Lwande *et al*., 2015). This is expected to alter the spatial distribution of disease with significant impacts on human mortality (Patz *et al*., 2005). The expected evolution in environmental conditions and density of vector populations conducive to RVF outbreaks will cause changes in the spatial patterns of the disease. High-risk receptive areas include the Tigris / Euphrates delta in Iraq, the Islamic Republic of Iran, and southern Europe.

HOST RANGE

Many species of mammals, including humans, are susceptible to RVF infection. Among domestic livestock, sheep are the most susceptible, followed in decreasing order by goats, cattle, camels and water buffaloes., Young animals are generally more severely affected than adults. Other susceptible species include antelopes, African buffaloes, monkeys, cats, dogs and rodents. Infection in humans results in a transient febrile illness, with more severe effects observed in less than one percent of cases. See Annex I for more information on how RVF presents.

TRANSMISSION

The virus is biologically transmitted to animals by mosquitoes. Many mosquitoes are known to be efficient vectors, notably species of the *Culex*, *Aedes*, *Anopheles*, *Eretmapodites* and *Mansonia* genera. Under certain conditions, other biting insects may transmit the virus mechanically.

Non-vector-borne transmission is not considered a major means of transmission in animals.

Animals are infectious for mosquitoes during the viremic period. Viremia may be brief (6–18 hours) or persist for six to eight days. There is no carrier state in animals.

Large numbers of infected mosquitoes may be carried long distances on wind or air currents. This may lead to the rapid spread of the virus from region to region or even internationally. This may have been a factor in the spread to and within Egypt in 1977 and

1993. Smaller numbers of infected mosquitoes can also be transported in vehicles and aircraft over long distances.

While humans can become infected from mosquito bites, the majority of human cases are thought to result from handling the blood, tissues, secretions or excretions of infected animals, notably after abortion (Mohamed *et al.*, 2010). This may be through handling, milking, slaughtering, butchering or necropsying such animals. Exposure to aerosols during slaughter of infected animals is thought to be a major risk factor. Consuming infected animal products like fresh meat, milk and urine is also a source of infection.

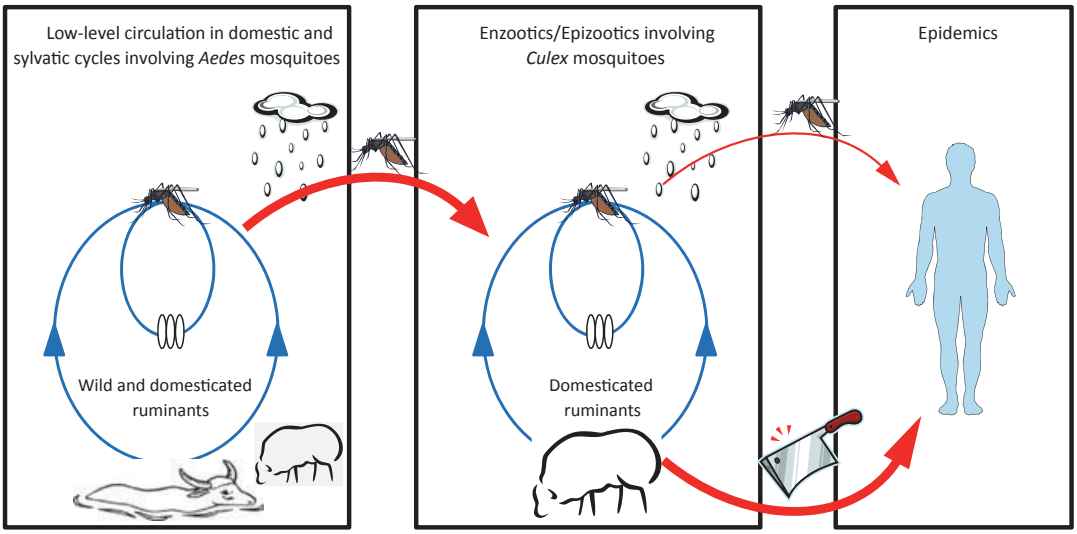
The virus is pH sensitive and the aging process used in commercial meat processing is believed to significantly reduce, if not eliminate, the risk of transmission.

Laboratory-acquired infections also occur. Work with the virus and suspect materials should be conducted only with recommended personal protective equipment (PPE) and biocontainment consistent with biosecurity level 3 (BSL 3) (CDC 2009).

ECOLOGY

How RVF remains endemic, has been a subject of scientific interest for some time. We know it remains endemic where no known epizootics have occurred as well as in areas prone to epizootics. The current understanding of the endemic and epidemic transmission cycles is summarized in Figure 1.

FIGURE 1
RVF endemic and epidemic transmission cycles



In endemic areas, the virus is maintained in a sylvatic cycle involving wild ruminants, possibly other mammalian hosts and mosquitoes. An explosion of the mosquito population can result in spillover to domesticated ruminants, resulting in epizootics and, potentially, an enzootic situation. Human epidemics result from contact with animal fluids released during slaughtering of viremic animals or, less frequently, via mosquito bites.

Source: Adapted from FAO 2014

FIGURE 2
A flooded dambo (wetland pool) in Kenya

Source: http://www.fao.org/docrep/006/y4611e/y4611e04.htm

There is limited but significant evidence that the virus is transmitted transovarially in *Aedes* mosquitos of the *neomelaniconium* group. These are floodwater breeding species that emerge in enormous numbers in floodplains and other habitats, where they oviposit. This is now widely accepted as a key component of the endemic mechanism. These mosquito eggs and the virus they carry, remain viable for long periods in the mud of dried-up surface pools or shallow depressions (locally known as *dambos* or pans and *vlei*), or in floodplains (Figure 2). Infected mosquitoes hatch from these when they flood again. This is how the virus persists during prolonged interepidemic periods in grasslands and semi-arid regions of eastern, western and southern Africa.

There is also evidence of sporadic but clinically undetected circulation in wildlife that is not associated with recognized outbreaks in livestock (Beechler *et al*., 2015; Lwande *et al.,* 2015, Manore and Beechler, 2015). Modelling studies suggest that both transovarial transmission in *Aedes* mosquitoes and silent, or cryptic, transmission in mammalian hosts play a role in the endemic maintenance of the virus.

Aedes are believed to be responsible for the maintenance of the virus in nature (Figure 3). They are responsible for endemic cycling and the initial infection of mammalian hosts, during the amplification of the virus, in the lead-up to an epizootic. The presence of Aedes alone is insufficient for a major outbreak, though. They are not an efficient species for transmitting the virus between mammalian hosts.

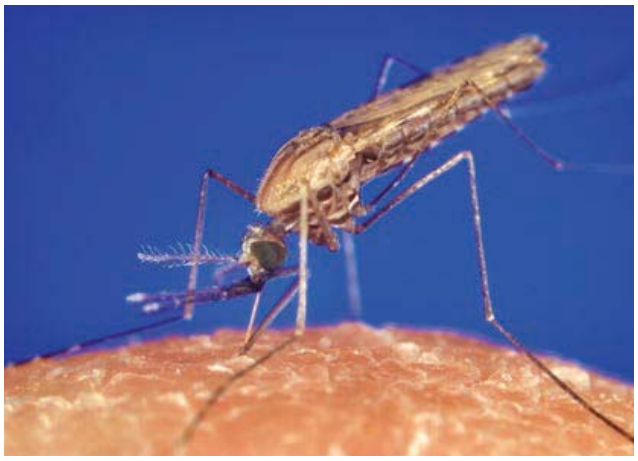
For a major epidemic to occur, other species that are efficient at transmitting disease between mammalian hosts need to be present. These include members of the genus Culex (Figure 4). Although movement of animals has not been implicated in transboundary spread, the movement of infected animals *within* affected countries to sites experiencing *Culex* blooms is believed to have occasionally resulted in secondary outbreaks in the absence of a local primary, *Aedes*-driven endemic cycle (Anyamba *et al*., 2010). It is suspected that this was a contributing factor in Niger's 2016 outbreak (WHO, 2016).

FIGURE 3
An example of *Aedes* spp (*A. albopictus*)

Note the striped legs that help identification

Source: http://www.futura-sciences.com

FIGURE 4
An example of *Culex* spp.



Source: James Gathany, US Centers for Disease Control and Prevention

Secondary waves of *Culex* vector populations are responsible for animal-to-animal transmission and increase in clinical disease associated with major RVF outbreaks.

The local ecology and population dynamics of *Aedes* and *Culex* shape the ecology of RVF. In the Horn of Africa, prolonged rains believed to be necessary for a major epizootic. These can support two sequential waves of primary and secondary vectors - *Aedes* followed by *Culex*. It has been suggested that, in West Africa, prolonged rains interspersed with dry periods favour repeated waves of *Aedes* mosquitoes, leading to simultaneous populations of infected *Aedes* and *Culex* and major RVF outbreaks.

FIGURE 5
An endemic habitat in West Africa that is not prone to overt epizootics

©Jeffrey Mariner

This area is near the site of the first outbreak recorded in Niger, in 2016

FIGURE 6
Representative hosts and habitat in Tanzania during an interepizootic period

©Jeffrey Mariner

EPIDEMIOLOGY AND EPIDEMIOLOGICAL STATUS

The ecology of the virus is such that approximately 16 of the 32 countries in its endemic range never or rarely experience overt infection. The predominant level of virus circulation presents a negligible risk of human infection and of spread through trade (Figure 5). In Africa, the interepidemic infectious cycle among indigenous, domestic and wild vertebrate animals (including people) and mosquitoes is not apparent (Figure 6). In the rainforest and wetter wooded areas, the virus circulates silently between wild and domestic species and insect vectors. This cryptic RVF circulation is extremely difficult to identify and occurs in most countries in sub-Saharan Africa (Geering and Davies, 2002).

The OIE defines three epidemiological statuses for live animals in countries or zones:

- free of infection
- infected during an interepizootic period
- infected during an epizootic (OIE, 2016).

In addition, there is a specific "infected" status for animal products (e.g. meat, milk, semen).

Note that many of the countries classified as "infected during an interepizootic period" have never been known to experience an epizootic.

In a subset of infected countries that have experienced epizootics, major epidemics occur at irregular intervals of 3–15 years or longer. The frequency depends on the ecological characteristics of the country. The periodicity of RVF epizootics may be greatly changed by increases in the temperature of the Pacific and Indian Oceans. These temperatures strongly influence precipitation in Africa and elsewhere. There is evidence of greater amplitude changing frequency of these oscillations in the recent past, with dramatic effects on flooding and drought conditions worldwide.

For epidemics to occur, three factors must be present:

- the pre-existence or introduction of the virus in the area;
- large antibody-negative populations of susceptible ruminants;
- climatic or environmental conditions that encourage a massive build-up in vector mosquito populations.

The last of these usually occurs when there are warm conditions and unusually heavy and persistent rainfall that causes surface flooding. This leads to the hatching of infected *Aedes* spp. mosquito eggs and large numbers of secondary vector mosquitoes. Alternatively, it may occur in the absence of rainfall, but where there is a great quantity of surface water. For example, an outbreak can occur in a river floodplain after heavy rainfall in river basins hundreds of kilometres away. This condition may also occur as a result of irrigation, as in the Gezira area of Sudan and in Egypt.

During RVF epidemics, the highest levels of virus amplification occur when the secondary vector populations are at their greatest. These periods of intense virus activity usually persist for 6–12 weeks, infecting the vast majority of susceptible mammalian hosts.

During the long interepidemic periods, low levels of virus activity may occur in certain foci within the epidemic and enzootic areas. These will remain undetected unless intensive surveillance activities are carried out. Virus activity may be revealed by random isolations from mosquitoes or by occasional human disease. Small local RVF outbreaks may occur, when and where the micro-environmental conditions are favourable and susceptible livestock are present (Murithi *et al.*, 2011). However, the incidence of infection is usually too low to detect. Clinical disease in humans or animals is generally missed without specific, well-focused and active surveillance.

Institutional framework for surveillance and control

OIE INTERNATIONAL STANDARDS

The World Organisation for Animal Health (OIE) provides basic but binding standards on animal disease surveillance in general, and RVF specifically.

The most relevant chapters of the *OIE Terrestrial Animal Health Code* (2016) are:

Chapter 1.4. Animal health surveillance

Chapter 1.5. Surveillance for arthropod vectors of animal diseases

Chapter 5.10. Model veterinary certificates for international trade in live animals, hatching eggs and products of animal origin

Chapter 8.14. Infection with Rift Valley fever virus.

In addition, standards for the diagnosis of RVF and production of RVFV vaccines are provided in the OIE *Manual of Diagnostic Tests and Vaccines for Terrestrial Animals* (2016):

Chapter 2.1.18. Rift Valley fever (infection with Rift Valley fever virus).

ONE HEALTH

RVF is best addressed through a One Health approach. This is partly because of the environmental, animal and human determinants of its epidemiology and impact, as well as its diverse effects on livelihood, the general economy and human wellbeing. Only a few other agents fit the One Health model this well.

Although major livestock outbreaks precede human epidemics, most of the pronounced RVF events in history were first diagnosed in humans. The amplifying livestock epizootics were recognized only after the disease was noticed in the human population.

In livestock, the impact of RVF on domestic markets and international trade is probably greater than the direct mortality and production impacts of the disease. In the past, a country's declaration of even one case could be a threshold event with major economic consequences. Official reporting of a case of RVF often led trading partners to impose import bans for livestock and livestock products. Today, importing countries are more likely to take a nuanced, risk-based approach to trade restrictions. Trade impacts still remain one of RVF's major economic effects, creating a significant disincentive to declaring a first case of RVF or reporting an outbreak (or even the risk of one). This can lead to delays in declarations until the evidence is undeniable, which heightens the risk of international spread and reduces the effectiveness of mitigation.

The institutional arrangements for reporting disease differ for human and animal health.

In the veterinary world, livestock disease is treated largely as an economic issue. Only national governments can make international reports to the OIE.

For human health, although national health ministries are responsible for formal disease reporting, the WHO has a mandate to verify informal reports of incidents that have a potentially international impact. This is in line with the International Health Regulations (IHR 2005).

Better control of epidemics and more effective mitigation of impacts can be achieved by coordinated actions to detect and control human and animal epidemics, as well as infected vector populations. Monitoring the environment for conditions that indicate an increasing risk of outbreak, combined with early detection in livestock, is the best way to safeguard human health.

Regardless of government policy, the urgent nature of RVF outbreaks has often resulted in admirable examples of impromptu interministerial cooperation. This approach helps to address the complexities of an epidemic and its associated impacts. This guide makes no assumptions about government structures or policies in regard to One Health. Given the nature of the disease, though, creating a joint task force is highly recommended. This should have appropriate participation from agencies with responsibility for human and animal health and the environment. The task force, which can also deal with other One Health diseases, should:

- share and jointly interpret risks based on forecast data;
- integrate surveillance plans to ensure synergy and timeliness;
- share surveillance data and produce integrated risk assessments and risk maps;
- promote consistent communication messages across disciplines;
- coordinate preparedness and response to outbreaks.

Such a task force should not prevent individual authorities from acting in a timely manner, nor exempt them from their responsibility to do so.

Authorities recognize that predicting outbreaks and early detection in livestock are useful tools to mitigate economic and human health impacts. At the same time, the appropriate resources to ensure adequate animal health surveillance and preparedness are often unavailable during interepizootic periods. Using integrated approaches to RVF within a One Health context should result in a more balanced allocation of resources between the professions. If this can be achieved during interepizootic periods, it should in turn lead to earlier detection and better mitigation of outbreaks.

Surveillance and preparedness are best implemented in an interdisciplinary way that fully integrates veterinary, public health, entomological, landscape and climatological data. A holistic approach that transcends disciplines is required to adequately assess risk and build risk-targeted surveillance and response capacity. Regions should be encouraged to think in terms of cross-border ecosystems. The zoonotic and vector-borne nature of RVF means that standard phytosanitary precautions at national borders will not prevent its spread, especially in light of predominant climate change scenarios.

RVF DECISION SUPPORT FRAMEWORK (DSF)

The 2006–2007 RVF outbreaks in East Africa provided many lessons that contributed to developing a holistic planning tool to guide all aspects of preparedness, surveillance and response. Ten years had elapsed since the 1996 outbreak in East Africa and many of the personnel in the government services had transitioned to new roles by 2006. Despite predictions of heavy rainfall and the increased risk of RVF, the outbreak was not recognized until it was well under way, by the confirmation of a human case in hospital. Animal health decision-makers were especially aware of the missed opportunity for early detection in livestock and wanted to prevent future surveillance failures.

It was widely recognized that the institutional memory of the 1996–1997 had largely faded, taking with it much useful awareness of how RVF erupts across the landscape and

The RVF DSF was developed by decision-makers in East Africa as a road map to risk-based management of the threat of evolving RVF outbreaks in their region. The framework provides guidance on appropriate surveillance, preparedness and response in light of the regional epidemiology of the disease. Decision-makers from other RVF affected regions (e.g. West Africa and Southern Africa) should develop a region-specific DSF based on the local history and epidemiology of the disease as a basis for surveillance and control planning.

poses unique challenges for control and mitigation. Decision-makers resolved to record their lessons from the 2006–2007 outbreak in a simple framework to aid appropriate and timely action in future (Anonymous, 2010). The framework is a retrospective timeline of the actions decision-makers should have taken in response to the outbreak. As the decision-makers built the framework, they had a clear sense of ownership of the result. The framework is a living document produced in the spirit of One Health, and has been updated on several occasions to better reflect trade and public health dimensions (Anonymous, 2015). It was first published anonymously to safeguard the sense of collective ownership that evolved while developing the framework.

The retrospective study revealed a clear timeline of recognizable events leading up to the outbreak. Each event was an indicator of an increasing level of risk. The sequence of events started six months before the first human case was recognized (Jost *et al.*, 2010) and set out what could be used as decision points for incrementally implementing phased responses appropriate to the risk level. These were:

- early warning of weather events consistent with an outbreak;
- onset of heavy, prolonged rains;
- onset of widespread flooding;
- onset of increased mosquito populations;
- livestock disease consistent with the RVF clinical case definition and the community's case definition;
- outbreaks of human febrile illness;
- confirmation of a human case in hospital.

It was proposed that the decision-makers use this as the basis for a table or matrix of events. This indicated the appropriate actions to be considered at each step, justified in relation to the evolving risk of an outbreak. They identified the following events and list of response categories to be considered at the time of each event:

Timeline events

- Normal situation between outbreaks
- Early warning of RVF or heavy rains
- Localized, prolonged heavy rains reported by eyewitnesses
- Localized flooding
- Localized increases in mosquito populations
- First detection of suspected RVF in livestock by active searching

- Laboratory confirmation in livestock
- First rumour or field report of human RVF case
- Laboratory confirmation of first human RVF case
- No new human cases for six months
- No clinical livestock cases for six months
- Post-outbreak recovery and reflection.

Action categories

- Capacity building and training for effective surveillance and response
- Communication plan and messages
- Coordination in a One Health context
- Forecasting and early warning systems
- Vector control
- Environmental, vector and disease surveillance
- Disease control
- Quarantine and movement control
- Mitigation actions to protect trade and markets
- Funding
- Post-outbreak recovery and reflection
- Institutions and policies
- Research, impact assessment and risk assessment.

The RVF DSF interprets events in relation to existing risk maps and risk analysis. These may be quantitative or qualitative. Although the tool was developed for East Africa, it can be adapted. Using local risk maps and risk analysis, the tool could include the weather events that drive outbreaks in western and southern Africa. Specific forecasting methods for West Africa have been suggested (Caminade *et al*., 2014).

The RVF DSF highlights preparedness, surveillance and response activities in relation to the timeline for the emergence of an RVF outbreak in an endemic country. As such, the DSF is an excellent tool for outlining risk-based surveillance needs in the context of an evolving outbreak.

Prevention and control

All countries at high risk should establish an RVF task force that includes, at a minimum, participation from veterinary, medical, entomological and meteorological departments. The task force should have the mandate to conduct integrated risk assessments, coordinate surveillance activities, and coordinate preparedness, prevention and response activities in the event of a warning or emergence of an outbreak. The task force's level of activity will depend on the country's risk status. This surveillance guide does not prescribe the appropriate level of coordination but, at a minimum, all departments should share plans and data and be responsive to requests for support across ministries.

INFECTION-FREE COUNTRIES AT RISK

Countries at risk should take whatever steps they can to prevent the entry or occurrence of the disease.

As with all serious livestock diseases, a comprehensive quarantine programme should be seen as the first line of defence.

Although international animal movement is of concerning, it has not yet been shown to be a source of infection in incursions. The movement of animals has not been associated with new foci of disease in Africa, as has been the case with lumpy skin disease and many other animal diseases. However, it is believed that infected animal movement to areas with high epidemic vector concentrations (*Culex* spp.) has resulted in satellite outbreaks in ongoing outbreaks (Anyamba *et al*., 2010).

It has been suggested that RVF entered Egypt via camels or small ruminants. While this cannot be disproved, it is called into question by the brief period of viremia, the typical length of transport in live animal trade in Africa, and the predominantly vector-borne transmission among animals. Vector movement in air currents is a well-documented phenomenon and a proven means for the spread of plant insect pests. Examples include *Cuilicoides* vectors of bluetongue (Sellers, Gibbs *et al*., 1979; Sellers, Pedgley *et al*., 1982) and malaria. Animal movement should be closely monitored if animals are being imported from known epizootic areas, and should only take place during demonstrated interepizootic periods. Insect vector movement in low-level air currents is uncontrollable and vigilance is necessary to monitor for possible RVF introduction in receptive areas that are deemed to be of high risk.

INFECTED COUNTRIES DURING AN INTEREPIZOOTIC PERIOD

In theory it is impossible to prevent RVF from recurring in regions of Africa where outbreaks have already happened. This is because of the presence of the vector and the likely circulation of the RVFV at undetectable levels.

Livestock movement controls are unlikely to play a major role in reducing the propagation of RVF in the enzootic/epizootic areas of Africa.

Continuing mass livestock vaccination programmes during interepidemic periods are unlikely to be economically justifiable, especially when using existing monovalent vaccines. However, the routine vaccination of high-value animals should be considered.

Given the length of time between major epizootic episodes, it is uneconomic for vaccine suppliers to stockpile vaccines in quantities that would enable mass vaccination in the face of an RVF outbreak or even an early warning. The majority of stockpiled vaccines would expire before sale. So manufacturers only need to stock limited supplies to meet the modest and occasional demands between outbreaks.

It has been suggested that multivalent vaccines that include antigens against other endemic diseases, such as brucellosis or sheep-and-goat pox, could change this economic constraint to vaccination. However, there are unanswered questions about the most appropriate combinations of antigens and the possible strategies for their use. Multivalent vaccines limit the flexibility to adjust control strategies to the epidemiological needs of individual diseases targeted by the vaccine. For example, the use of bivalent rinderpest-contagious bovine pleuropneumonia (CBPP) vaccine became a constraint on completing the eradication of rinderpest. Its use had to be discontinued in the 1990s, much to the detriment of the CBPP situation. Combining antigens that require indefinite application, like RVF, with antigens against diseases targeted in active eradication programmes would probably be inappropriate.

This does not mean that nothing can be done. On the contrary, the emphasis must be on early warning programmes to detect and track emerging epidemics, and on maintaining early reaction capacity to mitigate the impact of outbreaks on livelihoods, markets and human health. The RVF DSF is a useful guide to timely actions in surveillance and control.

Early warning data should be continuously reviewed because predictions often change as the weather events actually unfold (Anyamba *et al*., 2010).

INFECTED COUNTRIES DURING AN EPIZOOTIC PERIOD

Vaccination

Both live attenuated and inactivated vaccines are available for RVF. Several candidate vaccines are also in the final stages of validation. As new information is continuously becoming available, the relative merits of the range of vaccines will not be reviewed here (Heath and Smit, 2012; FAO, 2014; Goovaerts, 2015).

Mass vaccination in the face of an outbreak has never been successfully applied. This is because of the hyperacute nature of the outbreaks and the difficult environmental conditions often prevailing at onset. Without subsidized vaccine banks, the quantities available at the time of an outbreak – whether predicted or not – are often insufficient for mass vaccination. It has been estimated that the best-case scenario for procuring and positioning vaccines in the face of an expected epizootic episode, when vaccine production needs to be re-activated, is 147 days (Anonymous, 2010). This is prohibitively long, even if decision-makers were able to commit funds at the first indication of an early warning.

National experts suggest that targeted vaccination of critical populations believed to be involved in the initial amplification of the virus can pre-empt outbreaks – or has the potential to do so (source: personal communications).

Irrespective of the above considerations, it makes sense to focus vaccination on the hotspots for emergence (as indicated by risk maps). This approach warrants further

consideration and piloting. However, given the long interval between outbreaks it has been impossible to test, let alone validate, the hypothesis. In any event, protecting animals at hotspots would reduce the impact of the outbreak on the livelihoods of affected communities.

Vector control

The first stage of an RVF outbreak is the emergence of infected mosquitoes. Subsequent waves of mosquitoes contribute to the amplification in livestock. In theory, the control of mosquitoes can reduce the amplification and contribute to the mitigation or prevention of outbreaks. However, the same issues already raised for vaccination should be considered: timing, cost, practical access to sites, and the cost of delivery on a scale large enough to have an impact.

Although adult mosquitoes and larvae can be controlled, applying larvicides to breeding areas can have a longer-term impact. The breeding sites for the primary foci need to be well defined if the approach is to have maximum effect. During widespread flooding, breeding sites may be so extensive that larvicides are no longer practical (WHO, 2017). The choice and use of insecticides should follow national and international regulations, with proper attention to environmental considerations. Current policies ban the use of insecticides that persist in the environment. These were used in disease control historically but should not be considered now. Insects are an important part of the ecosystem: they are active in the recycling of nutrients and pollination of plants, and are an important link in the food chain. Detailed guidance on vector strategies and the choice of insecticides is available (Anyamba *et al.*, 2010) and current expert advice should be solicited as part of implementing a programme.

Treating animals with pour-on insecticidal or repellent products reduces the risk of infection as well as the risk for humans. Insect-proof housing could be considered as a way of protecting high-value livestock.

Mitigating risk of human exposure

People are primarily infected through contact with infected livestock, including sick and dead animals and aborted foetuses. Slaughtering livestock and exposure to fresh meat is also a major risk. Proper aging of meat renders the virus inactive. Human health can be protected through provision of information to promote appropriate actions to limit exposure.

Individuals at outbreak sites should avoid unprotected contact with sick and deceased animals, and with fluids and tissues from abortions. Use of personal protective equipment (PPE) is advised for professionals when attending disease events where RVF is part of the differential diagnosis. Advice on precautions for livestock owners is discussed below in the **Communication as part of control** section.

The slaughter of animals should be postponed at outbreak sites and at slaughter facilities serving communities affected by outbreaks. The size of RVF outbreaks and public concern generated can have a profound negative effect on meat value chains (Antoine-Moussiaux *et al.*, 2012). Consumer panic resulted in a collapse of urban meat consumption in Kenya during the 2006–2007 outbreak. It was estimated that approximately 50 percent of the butchers in Kenya went bankrupt as a result (Rich and Wanyoike, 2010).

An important measure in preventing and mitigating the economic impact of RVF outbreaks is to develop of modern slaughter and inspection systems. These can reassure consumers of the safety of meat in urban centres, distant from outbreak sites.

During high-risk periods, the use of treated bed nets and repellents for personal protection, is recommended. Avoiding locations and times of high vector activity is also advised.

Communication as part of control

Effective communication is one of the best methods for safeguarding human health and mitigating the economic impacts of RVF. Messaging should be transparent, as well as risk- and evidence-based. Communications should be intensified during the early warning phase and provide guidance on appropriate actions to safeguard public and animal health alongside the economy and trade. Target audiences include animal health personnel, livestock producers, those who process and sell livestock products, urban consumers, and trading partners. Messages should be tailored to the needs of each group.

Recommended actions must be realistic in the context of prevailing socio-economic conditions. For example, producers in intensive systems may have access to basic items of PPE, like rubber gloves and protective masks. Messaging can appropriately recommend that they use these when disposing of aborted material. More usually, though, major outbreaks involve remote pastoral populations with no access to basic PPE. Recommendations that focus on using unavailable materials are a disservice to the public and should be avoided. Ideally, basic messages should be prepared and PPE materials distributed before areas are cut off by flooding and the first cases appear. This requires pre-emptive action, using a DSF tailored to the local epidemiology of RVF.

Messaging needs to accurately reflect the level of risk in an evolving outbreak. A general communication strategy should be prepared during the interepidemic period to be updated and refined when an outbreak occurs. Rapid assessments should check that messages meet the needs of the public and are delivered through the most effective channels.

Urban consumers and trading partners are important stakeholders. They may be unaware of measures in place to mitigate risk or lack an accurate understanding of the risk involved. The response of urban consumers and trading partners is an important determinant of the overall economic damage that an outbreak or perceived risk of an outbreak can cause. Public health communication may be risk-averse to the point of inducing undue alarm in urban populations actually at low risk. This can contribute to market collapse and significant economic harm. The communication strategy should avoid causing scares that can exacerbate the economic and trade impacts of the disease. It is important that the authorities responsible for animal health, livestock marketing and public health all collaborate on messages that are appropriate to their target audience. For example, if demonstrable safeguards exist for managing risk in traded animals and the urban meat supply, this should be part of the messaging. Waiting until the first confirmed (human) case before initiating communication activities with the public and trading partners is not advised. It is a recipe for widespread panic and severe economic consequences.

The human populations at risk are mainly rural, and the route of human infection is through direct contact with animals, fresh fluids or aborted foetuses - largely an occupational hazard. Participating in slaughter, and in the post-mortem examination and processing of

fresh products also carries a high risk. The meat aging process results in pH changes that inactivate the virus and reduce risk.

Given that the geographic extent of outbreaks has varied over the years and new areas are affected almost every year, individuals in high-risk professions (e.g. health, livestock production and marketing) throughout the region should take precautions during years when virus activity is suspected. Communications should remind high-risk personnel to limit exposure to aborted material as well as fluids and aerosols during livestock slaughter or post-mortem procedures.

Surveillance concepts and techniques

Surveillance is the ongoing collection of information and intelligence to inform decision-making and action. Generally, surveillance differs from research as its primary purpose is collecting timely information, rather than producing unbiased parameter estimates. Many forms of surveillance are risk-based and designed to find disease.

Three useful surveillance techniques or concepts are introduced here. These approaches are not mutually exclusive and subsequent sections will present activities that integrate all three. In the section on surveillance systems, a suggested activity – participatory syndromic surveillance (PS) – will be described in detail.

SYNDROMIC SURVEILLANCE

'Syndromic surveillance' detects clinical cases or outbreaks of illness consistent with a defined clinical syndrome rather than a specific disease. Syndromic surveillance is defined by the OIE (Cameron *et al*., 2015) as "the process of actively looking for groups of symptoms, signs or patterns of diseases, rather than specific diseases". It is intended to capture most events that exhibit the principal clinical or epidemiological features of the target disease. Syndromic surveillance uses a case definition based on a constellation of symptoms that are representative of a clinical syndrome rather than one disease.

The syndromic case definition for RVF should capture all events that may indicate the disease in light of diagnostic processing. At field level, the syndromic case definition is often not specific, pulling cases of other diseases into the diagnostic process. The emphasis at the grassroots level is on ensuring that possible cases of the target disease are not missed.

RVF's syndromic definition includes abortion, death in young stock associated with presence of vectors, and environmental conditions conducive to transmission. The title 'abortion and young animal mortality' syndrome is suggested (see text box on page 22).

RVF epidemics should always be strongly suspected when there is a sudden onset of large numbers of abortions in ruminant herds. These include sheep, goats, cattle or camels, and deaths in lambs, kids or calves. This is especially the case if there is surface flooding in savannah or semi-arid areas following prolonged rains (or in irrigated areas), if the mosquito populations are high, and if there is concurrent illness in human populations. RVF in domestic animals is often recognized only after the illness in people has been diagnosed.

Detailed clinical descriptions for the majority of domestic host species and humans are provided in Annex II. Clinical case definitions for livestock and humans are suggested in a text box in Annex II.

Each report that meets the syndromic case definition requires investigation and sample collection by trained personnel using PPE - see Annex II.

An example of a syndromic case definition

"Abortion and young animal mortality syndrome"

Core definition

Outbreaks of:

- abortion in ruminant livestock, combined with
- mortality in young ruminant livestock.

Optional supporting evidence:

- The presence of vectors and environmental conditions conducive to transmission, such as flooding or other significant changes in local hydrology.

The syndromic approach is a strategy that should be used across surveillance activities. The syndromic case definition should form the criteria for reporting systems, outbreak investigation and participatory surveillance. Once cases are pulled into the investigatory chain, a more specific RVF case definition should be applied to confirm cases. Using the syndromic case definition involves field veterinary officers (FVOs), veterinary auxiliary staff, agricultural extension officers, local authorities and livestock owners. All have a role in the clinical recognition of RVF.

One advantage of syndromic surveillance is that the use of syndromes reduces some disincentives to reporting major transboundary disease events. For diseases, such as RVF, their prominent role in trade makes reporting suspect cases stressful and perhaps hazardous for staff. If a suspect RVF event turns out *not* to be RVF, they may face criticism for having caused undue alarm. Reporting 'abortion and neonatal mortality associated with mosquitos' does not require field agents to infer any suspect diagnosis.

Implementation of active syndromic surveillance is justified where and when a threat of an epidemic exists. However, conducting good syndromic surveillance requires tested protocols, trained teams and clear reporting procedures. These should be established during the inter-epidemic period and tested annually.

PARTICIPATORY SURVEILLANCE

Participatory epidemiology (PE) began as the application of participatory rural appraisal methodologies to animal health challenges (Mariner and Paskin, 2000). It has recently been defined as follows:

Participatory epidemiology is the systematic use of approaches and methods that facilitate the empowerment of people to identify and solve their health needs. It should promote the participation of people leading to a shared learning environment that improves the understanding of their risk perception, health risks and options for surveillance, control, and health evaluation in populations. It should be conducted by professionals on equal partnership among all involved in the activity and with mutual respect and trust, ensuring acceptability and a sense of ownership.

(Modified from Catley *et al.*, 2012 by Allepuz *et al.*, 2017, Allepuz *et al.*, submitted for publication, based on input from stakeholders in an FAO electronic consultation)

Participatory surveillance refers to the application of PE to surveillance and is defined by the OIE (Cameron *et al.*, 2015) as:

an active form of risk-based disease surveillance… based on participatory methods. In the past this approach was termed participatory disease surveillance. The approach taps into community knowledge systems and leads to more effective engagement of livestock owners in surveillance.

PE practitioners gather people's perceptions of disease patterns and the impacts of those diseases on livelihoods. These methods are used in:

- disease surveillance, impact assessment and control;
- disease recovery and prevention of reinfection;
- project development;
- epidemiological research.

The methods require training and mentored fieldwork not included in conventional academic programmes. Participatory surveillance was developed within the Global Rinderpest Eradication Programme to improve the targeting of surveillance and to validate eradication of the disease from given areas. It is now being used to improve the professional-client interface in disease control programmes. It also brings the voice of the beneficiaries of disease control into decision-making processes.

At the technical level, participatory approaches complement quantitative epidemiological and economic methods as well as surveillance systems. They give communities a direct voice in their health programmes and provide researchers with contextual information. This enhances the design and interpretation of expensive and logistically complex quantitative studies. Data obtained in a participatory manner can also help identify sources of bias and confounding factors in statistical analyses. Participatory approaches suit broad-based livelihood analyses by helping to distinguish the impacts of diseases and their control on community assets (e.g. social and environmental). Participatory epidemiology does not replace quantitative studies but rather adds value to those studies. This makes possible a stronger and more representative surveillance system than traditional epidemiological methods can achieve alone. (PENAPH 2011)

PE uses a toolkit of methods originally developed as 'participatory rural appraisal' (Mariner and Paskin, 2000). It uses semi-structured interviews based on a checklist of topics for discussion, rather than structured questionnaires. The interviewer begins each topic with an open-ended question, which allows the participants to influence the direction of the interview. The toolkit includes techniques for ranking and scoring information, as well as visualization tools like mapping and diagramming. Participatory methods also use direct observation: the interview is an opportunity to observe behaviour and interactions alongside recording verbal messages. PE also uses transect walks, during which the team walks through the area with community members making observations on conditions, risk factors, practices and behaviours. During the transect walk, the team engages members of the community in discussion to clarify observations. Information from a variety of respondents, collected by multiple methods, is synthesized through a process called 'triangulation'. This refers to looking for patterns in the information and oral testimony

shared by participants. Details of how to organize a PS programme are included in the participatory syndromic surveillance section, including a sample checklist. A sample training agenda is attached as Annex IV.

This flexible approach benefits from the ability and knowledge of stakeholders to recognize and describe issues that affect their health and livelihoods and that are of an epidemiological nature. Many traditional livestock-keeping cultures give names to local diseases and can describe their clinical, pathological and epidemiological characteristics. Often, they have accurately associated specific species of insect vectors and environmental conditions.

In the case of RVF in 2006–2007, Somali pastoralists described a disease with the clinical and epidemiological characteristics of RVF. They named this *hardik* ('blood from the nose'). This disease was reported to be mosquito borne, associated with flooding, causing abortion, death of young animals and human febrile illness (Jost *et al*., 2010). When asked if they had seen the disease before, they reported it had last occurred in the floods of 1996–1997. Thus, traditional terminology and descriptions can be used to build a clinical case definition.

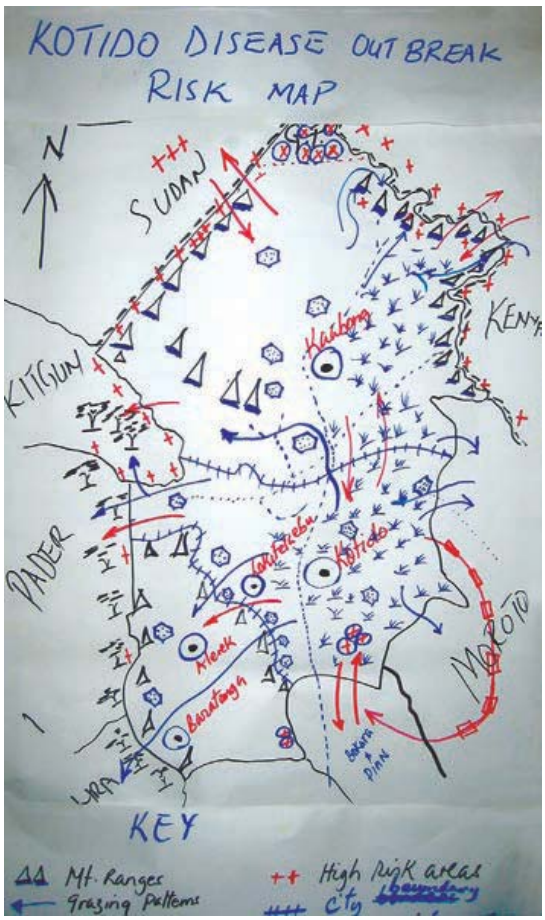
FIGURE 7
Somali elder describing *hardik* (RVF)

©Jeffrey Mariner

Participatory surveillance is a risk-targeted, active surveillance methodology that can use specific or syndromic case definitions derived from stakeholder perceptions. For diseases whose outbreaks have a distinctive signature, such as RVF, PS can be used as a case-finding methodology and often increases the number of outbreaks and cases detected. The sites for implementation of PS are those most likely to experience outbreaks. The sites are usually selected using qualitative or quantitative risk maps. Used retrospectively in 2007, the approach allowed the construction of detailed timelines and spatial diagrams. These illustrated the local time course and heterogeneity of outbreak onset.

Combined with disease reporting (page 37) and sentinel systems (page 39), PS using syndromic case definitions based on livestock owner information could lead to earlier detection of outbreaks. In the event of RVF forecast information, active participatory surveillance should be implemented to map the evolution of environmental events, and should be on the spot to detect the early livestock outbreaks. It offers the advantage over sentinel approaches that it is fully flexible and not a fixed-point system.

FIGURE 8
A qualitative risk map drawn by field veterinarians in Karamoja



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Risk Map Drawn by Members of the Participatory Epidemiology Course Held in Moroto in October 2003.

Case definitions should be developed with local communities to ensure that the criteria are appropriate in light of local knowledge regarding the disease.

RISK-BASED SURVEILLANCE

Risk-based surveillance targets surveillance to locations, populations or periods with the greatest threat of disease impact. The aim of risk targeting is to increase the probability and promptness of disease detection and better use limited resources.

Risk-based surveillance can use quantitative or qualitative information. The section on risk mapping in this manual provides excellent examples of the development of maps from quantitative information. Qualitative risk maps based on the knowledge of key informants are also very useful and can be developed within hours. Many formal mapping studies now integrate both quantitative and qualitative approaches in an effort to capture the benefits of both.

Temporal forecasting based on weather and climatic factors is also a form of risk targeting over time. The level and type of RVF surveillance should be adjusted over time in light of the evolving risk situation.

Participatory epidemiology uses the concept of risk targeting to select appraisal sites. The PE team reviews risk factors and develops qualitative risk maps (Figure 8) as one of the first steps in implementing appraisals.

The RVF DSF is a risk-based framework capturing spatial (risk maps) and temporal (forecasts and early warnings) information for RVF surveillance and mitigation.

Surveillance systems

PURPOSE, OBJECTIVES AND APPROPRIATE ACTIVITIES

We define surveillance objectives as the technical goals that will contribute to achieving the purpose of surveillance (Cameron *et al.*, 2015). Once the purpose and objectives of surveillance are articulated, it is easier to identify the stakeholders to involve and inform, the data needed, and the most appropriate surveillance activities to obtain the data. Debates about data needs, surveillance activities and products often arise from differing but unstated assumptions about the objective of surveillance.

Surveillance "information for action"

The overall purpose of surveillance is to inform decision-makers. This enables cost-effective reduction of the impacts of infection or disease (or the risk of an infection or disease) on a country's economy, and its people's livelihoods and health. This has been termed 'information for action' (Orenstein and Bernier, 1990), as opposed to research to understand the epidemiology of a disease.

For RVF, the specific impacts to be mitigated and technical objectives of surveillance will depend on the country's epidemiological status and the RVF risk factors present. For the most part, these risk factors will be natural or associated with trade, transport, and human culture and movement. Given the consequences of RVF's introduction into disease-free countries that host competent vectors, many authorities also acknowledge the potential of the RVF virus as a biological warfare/bioterrorism threat. This suggests that risk factors other than those associated with the natural epidemiology of the disease or economic activities may be of interest in targeting surveillance activities, particularly in infection-free countries.

Trade partners are important stakeholders in surveillance. Trade decision-makers are greatly influences by the level of confidence they have on the surveillance information provided by the exporting country (accuracy, timeliness and transparency). Downstream, the producing and consuming public have the right to know current levels of RVF risk associated with their activities.

All countries should conduct RVF animal health surveillance in the context of the national RVF task force. At a minimum, this should include participation from veterinary, medical, entomological and meteorological departments.

This manual looks at four epidemiological risk categories or situations for a country:

- Infection-free countries at risk (Table 1)
- Infection-free countries at high risk (Table 2)
- Infected countries during an interepizootic period (Table 3)
- Infected countries during an epizootic (Table 4)

The purpose, objectives, indicators and activities depend on the country's epidemiological risk category and are different for each category. Tables 1–4 define each category and

TABLE 1
Infection-free countries at risk

Definition	Countries with ecological conditions and vector populations that would provide endemic habitats for RVFV, were it to enter the country.
Purpose	The *purpose of surveillance* is to mitigate the risk of RVF being introduced and established in competent domestic vector populations.
Objective	Technical objectives include detecting events associated with high risk of introduction (illegal importation, migrations, etc.) and early detection of infected vectors or mammalian hosts.
Indicators	*Principal indicators* of interest will be data on human, animal and vector movement, numbers of detections of exotic vectors or disease associated with exotic vectors (e.g. airport malaria), and clinical events consistent with an RVF case definition.
Activities	*Appropriate activities* include surveillance of imports, surveillance for vector introductions at ports and airports, routine disease reporting, prompt reporting of suspect or confirmed human and animal cases, and early outbreak detection and containment. This is best achieved by raising awareness among people working in the country's import control, vector control and public health systems. They need to understand the epidemiology of the disease and the consequences of its introduction into the country.

suggest the purpose, objectives, indicators and activities appropriate to their risk situation. Each country's surveillance task force should carefully assess its epidemiological risk category and make use of the tables as the first step in designing or reviewing their surveillance system. Going through this simple process will speed up the selection of activities and help build a strong consensus among stakeholders.

Building RVF surveillance – step by step:

1. Convene an RVF One Health task force.
2. Determine your country's epidemiological risk category.
3. Review the suggested surveillance purpose, objectives, indicators and activities and adapt these to the national context.
4. Reach consensus on the purpose and objectives of surveillance!
5. Proceed to the detailed design and planning of individual surveillance activities.

Infection-free countries at risk are those where there are environments conducive to vector survival. We have split the infection-free category into two risk categories (regular and high risk). It is up to countries to self-assess their risk level, based on ecological, climatic, trade and human migration criteria. For example, recent publications suggest that Mediterranean Europe is at risk of an introduction leading to endemic infection, given ecological relationships with North Africa and the proximity of endemic infection south of the Sahara. A recent survey of six countries in Mediterranean Europe found variable capacity for RVF surveillance. Several countries had not mapped vector distributions; and while three of four countries had case definitions for human disease, only one had a case definition for RVF in animals (Cito *et al*., 2013).

Discussions around the design of surveillance are often challenging. Participants have different visions of the purpose and objects of surveillance and are actually trying to achieve

TABLE 2
Infection-free countries at high risk

Definition	Countries with ecological conditions and vector populations that would be likely to be suitable endemic habitats for RVFV, were it to enter the country, and that have recognized risk pathways for introduction through animal movement, trade or movement of infected vectors. Climate change scenarios are a notable consideration for this category. The existence of high-risk pathways warrants greater investment and intensity of surveillance.
Purpose	The *purpose of surveillance* is to mitigate the risk of infection being introduced or established in competent domestic vector populations.
Objective	Technical objectives include monitoring risk trends as they evolve in relation to climate and population movement patterns (human, animal and vector); detecting events that are associated with a high risk of introduction (illegal importation, migrations, etc.); and early detection of the introduction of infected vectors or mammalian hosts and early detection of the introduction of infection.
Indicators	*Principal indicators* of interest will be data on human, animal and vector movement, numbers of detections of exotic vectors or disease associated with exotic vectors (e.g. airport malaria), and clinical events consistent with an RVF case definition.
Activities	*Appropriate activities* include establishing an RVF task force, vector and risk mapping, monitoring ong-term climate and weather projections and population demographics, surveillance of imports, surveillance for vector introductions at ports and airports, routine disease reporting, prompt reporting of suspect or confirmed human and animal cases, and early outbreak detection and containment. This can best be accomplished by raising awareness of the epidemiology of the disease and the significance of an introduction into the country among people working in the country's import control, vector control and public health systems.

very different outcomes. If the discussion begins with a frank review of the country's status and establishes a consensus on the purpose and objectives of the national surveillance programme, the selection of indicators and activities can proceed smoothly.

SURVEILLANCE ACTIVITIES

This section provides guidance and information on surveillance activities as they relate to RVF surveillance. This is not intended to be prescriptive and countries are encouraged to adapt methods to suit their local context and institutions.

It cannot be overemphasized that multidisciplinary approaches and integration of surveillance design and analysis are essential. Joint implementation of activities on the ground with public health, entomological and meteorological involvement may result in significant synergy.

For more information, refer to the *Manual on livestock disease surveillance and information systems* (FAO Animal Health Manual No. 8), the *Manual on preparation of Rift Valley Fever contingency plans* (FAO Animal Health Manual No. 15) and the OIE *Guide to terrestrial animal health surveillance* (Cameron *et al*., 2015).

Forecasting, early warning and risk indicators

Forecasting and early warning enable rapid detection of the appearance of serious livestock diseases – or sudden increased incidence – before they reach epidemic proportions. Forecasting embraces all the initiatives, that lead to improved awareness and knowledge of distribution and behaviour of infection and of disease outbreaks. These include disease surveillance, reporting and epidemiological analyses.

Effective mitigation of RVF outbreaks is only possible if authorities make use of early warning systems and a decision support framework.

The response **must start before the onset of cases** or it will be too late to change the outbreak's 's course!

In regions where RVFV is present it is possible to mount more effective responses to RVF. This includes forecasting the probability of epidemics at least three months (and possibly up to six months) before they start. It also involves using a suitable decision support framework.

The capacity of animal and human health authorities to mount an effective disease control campaign will be severely limited. This is especially the case if an RVF outbreak does not come to official attention until it is under way.

The three prerequisites for an epidemic are a susceptible livestock population, a massive build-up of mosquito vectors and the presence of a virus. For endemic areas with known infection and susceptible host populations, environmental conditions that favour large vector populations are the main predictors of an outbreak.

In the Horn of Africa, all of the past seven major RVF outbreaks have been preceded by heavy widespread rainfall (Anyamba *et al.*, 2009). These increased rains in Eastern Africa were caused by a weather pattern known as El Niño. This is associated with increased sea surface temperatures (SST) in the Pacific and Indian Oceans (Linthicum *et al.*, 2016). Rains must be both prolonged and higher than average to support sequential emergence of large populations of *Aedes* and *Culex* mosquitoes.

Long-term weather forecasting as a tool to predict risk of outbreaks associated with El Niño has been available for several decades. Sophisticated forecasting models provide information about future rainfall patterns and El Niño events. These models use data like SST for the Indian and Pacific Oceans. Forecasts provide information about the risk of events and conditions conducive to large vector populations up to four months before

TABLE 3
Infected countries during an interepizootic period

Definition	Endemic countries where RVFV is circulating at very low levels and where weather conditions for the foreseeable future are not considered predisposing for an outbreak.
Purpose	The *purpose of surveillance* is to mitigate the impacts of the presence of RVF infection on the national economy and livelihoods of households.
Objective	The *objective of surveillance* is to detect (or document the absence of) disease in susceptible mammalian hosts or transmission of infection in insect and mammalian hosts. Establishing and operating effective surveillance contributes to risk reduction in the context of international trade. It may well contribute to safeguarding and enhancing access to markets.
Indicators	*Appropriate indicators* will be the temporal and spatial distribution of cases and/or seroconversions, long-term weather forecasts and climate change scenarios.
Activities	*Activities* should include routine disease reporting systems with clear case definitions, zero reporting procedures, and the use of sentinel herds. Activities to maintain high levels of awareness and positive interactions between livestock owners, field staff and disease-reporting systems are essential. The capacity for active, targeted surveillance approaches based on risk maps, like participatory syndromic surveillance, should be established and made ready for mobilization in case of a warning. Medical surveillance and case reporting data should be monitored. Authorities should monitor long-term weather forecasts (ENSO warnings) and local risk indicators like rainfall, flooding and normalized difference vegetation index (NDVI). Weather data combined with herd immunity levels and historic data could be combined as a risk score for probability of an RVF outbreak. Managers of surveillance systems (human, veterinary, vector and environmental) should form a joint task force for sharing and analysing the evolving risk or progression of an outbreak.

detecting human cases. However, the longer the temporal range of the forecast, the greater the uncertainty that it will be accurate.

As conditions develop, the use of data on cloudiness, rainfall and vegetation, like NDVI data, enhances the accuracy of remote-sensing analysis but decreases the lead time to outbreaks. Proliferation of vegetation in response to rainfall occurs concurrently with the proliferation of vectors and amplification of the virus, rather than preceding outbreaks. Outbreaks in Somalia and northeast Kenya in 1997–98 and 2006–07 showed that the foci of RVF virus activity in these countries could be correlated with high NDVI values. Although not a true predictor in a temporal sense, vegetation (NDVI) is a very useful indicator or warning of heightened risk. Remote-sensing indicators are an invaluable source of information for guiding RVF surveillance and response.

For example, the 2006–2007 outbreak was first predicted in East Africa in September 2006 based on SST. This was more than two months before the first human case and about the time of the onset of rains. More precise warnings in November 'predicted' outbreaks two to six weeks before the first report of human cases (Anyamba *et al*., 2009). Retrospective investigation revealed that livestock cases were actually occurring prior to the 'early warning' announcement (Jost *et al.*, 2010).

More recently, climatic modelling based on SST, rainfall and remote sensing data on NDVI highlighted the probability of other outbreaks. These included the 2006–2007 outbreak in East Africa, the 2007 outbreak in Sudan (Anyamba *et al*., 2010) and the 2008–2010 outbreaks in Southern Africa and Madagascar (Linthicum *et al*., 2016).

In West Africa, retrospective modelling has been used to analyse rainfall patterns associated with outbreaks. Findings here are that prolonged intermittent rains combined with flooding of small ponds resulted in two waves of *Aedes* vectors. The second wave was reported to coincide with the proliferation of *Culex* sp. and epidemic amplification of the virus.

International agencies are best placed to analyse satellite and other data and to provide countries with early warning about likely weather patterns associated with increased RVF activity. FAO, through its GIEWS and EMPRES/Animal Health, plays a central role in generating these data on a ongoing basis to provide an early warning/risk assessment service.

Weather forecasts and information about RVF risk are regularly updated at:
http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_advisory/ensodisc.html
http://www.ars.usda.gov/Business/Docs.htm?docid=23464
General sites for transboundary disease information and reports including RVF are:
http://www.glews.net/

Points for action – Forecasts and warnings – Endemic countries

The national RVF task force should:

1. Monitor weather forecasts and early warning sites.
2. Inform national stakeholders of changes in outbreak risk.
3. Initiate activities in line with the level of risk, using the Decision Support Framework as a guide where applicable.

TABLE 4
Infected countries during an epizootic

Definition	Endemic countries experiencing or at risk of experiencing a significant increase in RVF transmission.
Purpose	The *purpose of surveillance* is to mitigate the immediate, direct and indirect impacts of the epizootic.
Objective	The *objectives of surveillance* are to track the evolving risk situation (weather forecasts, rainfall, flooding, vector populations) and document the temporal and spatial distribution of cases if an outbreak occurs.
Indicators	*Appropriate indicators* are weather forecasts, rainfall data, NDVI maps, flooding, observations on vector density, RVF seroconversions in sentinel herds, the temporal and spatial distribution of clinical reports consistent with a recognized RVF case definition, and confirmation of representative cases with PCR and genomic analysis of isolates. Medical surveillance and case-reporting data should be monitored.
Activities	Activities should include routine disease-reporting systems with clear case definitions and zero reporting procedures, use of active, targeted surveillance approaches based on risk maps like participatory syndromic surveillance and the use of sentinel herds. Activities to monitor vector density should be in place. Managers of surveillance systems (human, veterinary, vector and environmental) should form a joint task force for sharing and analysing the evolving risk or progression of an outbreak.

http://www.fao.org/ag/againfo/programmemes/en/empres/home.asp
http://www.oie.int/wahis_2/public/wahid.php/Diseaseinformation/WI

Awareness-raising

In RVF-free countries at risk of an introduction, and in countries where an interepizootic period is ongoing, staff need to be kept aware of the epidemiology and clinical recognition of RVF. One of the best tools for this is to create a clinical case definition (see text box opposite). The definition could also be integrated into national reporting systems. Surprisingly, many countries with identifiable risk pathways for introduction of RVFV do not have veterinary case definitions for RVF (Cito *et al.*, 2013).

In endemic countries, the development of awareness-raising and communication materials should be based on assessments of stakeholders' existing knowledge levels. They should build on local terminology and methods of disease recognition. Local knowledge is often related to culture and usually varies across ethnic groups. Local veterinarians are often not fully aware of the complexity of traditional knowledge. It is best to involve personnel who have experience in participatory methods or medical anthropology. Awareness materials should target specific stakeholder groups.

Participatory surveillance using syndromic case definitions

In most RVF outbreaks to date, widespread clinical disease in domestic livestock preceded the outbreak's official detection by weeks or months. Livestock owners were usually aware of the disease well before health systems. The objective of participatory surveillance (PS) is to search for clinical disease and confirm outbreak as early as possible in its evolution. PS should start as soon as weather events consistent with an RVF outbreak are predicted.

Examples of RVF clinical case definitions

RVF livestock clinical outbreak definition (herd or community level):

- Widespread abortion and mortality in lambs and calves.
- May be associated with outbreaks of human febrile illness.
- Persistent rains leading to flooding or significant changes to local water retention and management schemes.
- Above-average vector densities.

Differential diagnosis: Nairobi sheep disease, ovine enzootic abortion, brucellosis and leptospirosis

RVF human clinical outbreak definition (village or community level):

- Widespread and sudden onset of flu-like fever, muscle and joint pain and headache.
- Occasionally (less than 1%) associated with severe jaundice and haemorrhage.
- Ocular (up to 2%) or encephalitic (less that 1%) forms are also characteristic, but onset is delayed for up to one to four weeks after fever begins.
- Persistent rains leading to flooding or significant changes to local water retention and management schemes.
- Above-average vector densities.

Note: Epidemics in livestock are believed to always precede human disease. Despite this, many major outbreaks of RVF were first diagnosed in humans and only retrospectively detected in animals.

Historically, most epizootics of RVF were first recognized in humans despite widespread undetected livestock disease. To be effective, PS should start as soon as an early warning is received.

PS personnel must be well trained and the system field-tested during the interepizootic period.

Do not wait for an RVF warning to start building PS capacity.

PS has been applied to a number of diseases, including RVF, with good results. This section outlines activities required to implement a PS programme using the Abortion and Young Animal Mortality (AYAM) syndromic case definition. Figure 9 shows a flow chart that integrates PS, outbreak investigation and use of the AYAM syndromic case definition.

The following points should guide the establishment of PS programmes:

- All countries at risk of RVF outbreaks should use the interepizootic period to establish and maintain the capacity to carry out PS. *Do not wait for an RVF warning to start building PS capacity.* Once a warning is issued, PS should start within weeks.
- Governments are encouraged to involve trainers experienced in PS at the outset of the design of the programme to help with developing methodologies, checklists, selecting personnel and designing training programmes.

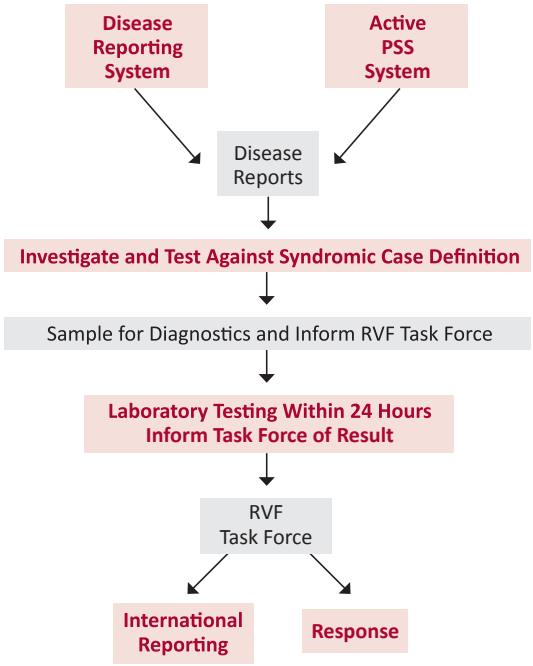
RVF Participatory Syndromic Surveillance Checklist

1. Introduction (do not mention RVF or AYAM in the introduction to avoid biasing the interview)
2. Recent weather (rainfall patterns, grazing and flooding, etc.)
   - A timeline may be useful
   - Maps of flooding/mosquitoes.
3. List and probe disease problems in general
   - Build a dictionary of local disease terms
   - If a disease problem meeting the AYAM case definition is mentioned, probe it.
4. Insects and disease
5. Flooding and disease
6. Ask about disease problems in the region
7. If AYAM has not been described up to now, the topic can now be introduced
8. History of AYAM in the area
   - A timeline may be useful.
9. Do the participants have any questions?
10. View the herd and sick animals.

Proportional piling or matrix scoring could be used to explore disease problems and the community's perceptions of the relationship between risk factors (rain, flooding, vectors, etc.) and disease.

- PS is an expert approach and practitioners need to be well trained and experienced in the method to be fully effective. Experienced PS trainers, who should preferably have completed a certification process, should deliver the training.
- Trainers and surveillance personnel should conduct a field assessment to develop the design of the PS programme and its content. An example of a suitable introductory training programme plan is attached as Annex IV.
- PS is implemented by small teams of two to four individuals, usually with complementary backgrounds. An ideal team for RVF includes expertise on human and animal health as well as disease vectors and their ecology. The next step in establishing PS is to select appropriate personnel for training as PS team members.
- PS training is a three-step process consisting of an introductory training course for practitioners, completion of a practical field assignment, and refresher training where participants share the results of their fieldwork and lessons learned. In the case of RVF PS, the field assignment should be to conduct two weeks of RVF PS. In this manner, trainees gain experience in the method while field-testing the surveillance methodology. The outcome will be practitioners certified in the practice of RVF PS.
- PS teams should have strong links to local services, diagnostic services and decision-makers. Diagnostic services should be on the alert for the reception and immediate testing of samples when PS teams are active. A rapid reporting

FIGURE 9
Flow diagram for surveillance illustrating principal sources of outbreak reports, investigation, diagnosis and action



mechanism should be in place so that first-hand information on early outbreaks meeting the AYAM syndromic case definition is available to the Director of Veterinary Services within hours, with samples presented to the diagnostic laboratory within 24 hours.

- PS requires few materials. Teams should be equipped for sampling (including PPE) and field-based diagnostics, if they exist. The primary costs are allowances and transport; these should be adequately budgeted at the outset of the programme. Nothing is more demoralizing than participating in a training process and then waiting months or years for funds to carry out field practice. If this happens, it is recommended that the introductory training course is repeated once the programme is ready to start.
- PS teams should meet in the field annually to refresh their skills during interepizootic periods.

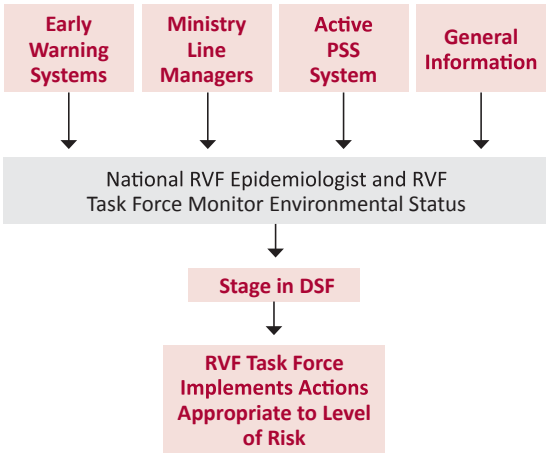
PS should include the following elements:

- *Reviewing secondary sources*: The starting point for PS is for practitioners to review available information on the disease issue and communities of interest. PS practitioners should be well grounded in local knowledge and customs and appropriate behaviours when interacting with communities. Many communities have previous experience with RVF and have local names for the disease. In PS, this is termed reviewing secondary sources.

- *Developing an interview checklist*: PS does not use questionnaires. Interviews are semi-structured; they are guided by a checklist of topics and exercises to be explored in the interview. This flexible approach enables respondents to provide direction to the interview, and allows for the discovery of new, unanticipated information. An example of a checklist as a starting point is provided in the text box on page 34. The checklist can be developed during the assessment mission of the trainers and finalized by the practitioner training programme.
- *Developing a qualitative risk map*: Based on the nature of the RVF warning, the PS teams should develop a qualitative risk map to help site field interviews. This is one of the principal activities in the risk-targeting process. The teams should use input from secondary sources, such as pre-existing studies, in this process. Note that the sampling plan will be continuously updated in light of the results of ongoing interviews.
- *Implementing semi-structured interviews:* The teams will conduct interviews and examine suspect cases. All PS interviews should include transect walks (interactive walks through the community). All cases that meet the AYAM definition will be sampled, and samples will be immediately dispatched for testing.
- *Observing ecological conditions*: PS teams should evaluate conditions in terms of the risk of an outbreak, and note the rainfall and its duration to date, location and status (flooding) of vector breeding sites, prevalent vectors and their density. This information should be promptly shared with decision-makers so that they are aware of the stage that conditions have reached relative to the DSF.
- *Introductions that do not bias the work:* The teams will want to introduce themselves accurately to communities. However, they should not mention RVF or AYAM in the introduction, as this will bias the interview. The team should present themselves as interested in animal health.

FIGURE 10

Flow diagram illustrating environmental surveillance in response to an RVF warning



Source of data are indicated, along with the process for monitoring the evolution of risk conditions to inform decision-making.

- *Look at animals:* The teams should take every opportunity to examine herds and sick animals.

Reporting systems

National disease-reporting systems are the foundation of all surveillance and depend on active public and professional participation. Well-developed systems use clinical case definitions to help classify events. Examples of syndromic and clinical case defintions are provided in the sections on Syndromic surveillance and Awareness-raising on pages 21 and 32.

Public health reporting systems usually have well-developed case definitions, but animal health systems are continuously raising their standards of operation. Countries are encouraged to establish mobile phone and digital reporting systems. A syndromic approach to disease reporting is recommended for RVF so as to encourage reporting. An RVF-specific case definition is appropriate for outbreak confirmation purposes in the later stages of outbreak investigation but grassroots reporting should focus on a syndromic approach first.

In areas anticipating an outbreak based on an early warning, an immediate investigation and interim response plan is warranted to protect human health because of the zoonotic nature of the disease. The reporting system should include an expedited reporting channel for 'abortion and young animal mortality events'. This should include clear communication messages to reduce human exposure, like how to safely dispose of carcasses and abortion material. Messaging should recommend suspending all home slaughter, and give guidance on marketing animals and animal products from affected populations (see Communication as part of control and Awareness-raising sections).

Disease-reporting activities from abattoirs are an important contributor to surveillance. Suppliers should be interviewed and the animal intake should be clinically evaluated using the syndromic definition. Slaughtering RVF infected animals is a major risk to abattoir workers and inspection personnel, so both need training on principal lesions (hepatitis) and appropriate action to limit exposure.

Points for action – disease reporting systems – all countries

1. Develop and use case definitions as the criteria for reporting events.
2. Establish reporting of the absence (zero reporting) of disease.
3. Investigate all reports that meet the RVF clinical case definition or abortion and neonatal mortality syndromic case definition.
4. Train reporting officers on the use of case definitions.

In countries anticipating an outbreak, prompt reporting and suspension of the abbatoir's operations can be warranted. This should happen wherever cases meet the syndromic definition or exhibit pathology consistent with RVF. Decontamination and disposal of contaminated clothes is advised. Samples for diagnosis and dispatching to the national diagnostic laboratory should be taken immediately. Local and national links with public health reporting systems should be established and data on risk and cases fitting the syndromic case definition, as well as zero reporting, should be shared.

Outbreak investigation

Reports of significant mortality in young stock or abortion should always be investigated. Disease investigations in endemic or at-risk countries should always have the capacity to collect appropriate clinical information and biological samples. However, general disease-reporting and investigation systems have tended not to detect RVF in livestock prior to its recognition in humans.

Reports of events that fit the syndromic case definition for RVF should immediately be investigated by a fully equipped team who are trained for RVF investigation and have adequate PPE. RVF outbreaks typically occur under very challenging conditions, like widespread flooding. Investigative teams should have adequate material, equipment, vehicles and logistical support to move safely and rapidly under typical outbreak conditions.

In the event of an RVF warning, it is suggested that veterinary personnel work closely with public health authorities to proactively respond to events, as livestock disease precedes human outbreaks.

The outbreak investigation team takes the first steps towards moving beyond the syndromic definition and confirming the diagnosis. The team should be fully trained in the clinical appearance, outbreak progression, entomology and pathology of RVF. They should be able to make all relevant observations on the cases and the outbreak context to finalize the diagnosis.

Where the results of investigations are consistent with the syndromic or clinical case definition, the national epidemiologist, national laboratory and director of veterinary services should be notified without delay. In line with Annex II, samples should be transmitted for confirmation and the results reported to the director of veterinary services for international notification to the OIE.

Points for action – outbreak investigation – all countries

1. Establish abortion and neonatal mortality outbreak investigation teams. Ideally, these teams will be the same teams responsible for participatory, syndromic surveillance activities in endemic countries.
2. Provide training on participatory epidemiology, RVF epidemiology, recognition and diagnosis of RVF and biosecurity measures.
3. Assure adequate budget, materials and transport for immediate investigation of all reports of RVF or abortion and neonatal mortality.
4. Establish and maintain links between investigation teams, reporting systems, diagnostic systems and management to enable immediate action.

Environmental surveillance

The Decision Support Framework and associated risk maps should guide surveillance and outbreak response decision-making. Several of the decision points in the framework are largely defined by environmental events. This is because landscape, climate and weather drive the outbreak timelines. Disease management personnel must actively monitor evolving environmental conditions in the event that an outbreak is predicted.

To be effective, surveillance requires good relations with livestock owners built on mutual respect. The best way to achieve respect is to give respect. Livestock owners in many regions recognize RVF and its vectors using traditional names. Livestock owner information is invaluable for early detection of disease in livestock.

Communications messaging should build on local knowledge.

Soils, production systems and movements of livestock should be mapped using both available resources and primary data collection. Often, qualitative maps offer significant advantages in terms of the amount of information provided in an easy and accessible manner for all users. Where resources and skills exist, geographic information systems can enhance detail and, if used and interpreted well, add quantitative rigor. A selection of links to digital resources is provided in Annex III. Long-term forecasts, regular monitoring of weather and weather-driven conditions on the ground should be collected by the appropriate agencies. These should be monitored by animal health authorities through their participation in an integrated surveillance system. The veterinary personnel responsible for coordinating surveillance should be proficient in the climatic and meteorological dimensions of RVF. PS and sentinel herd surveillance can contribute to environmental monitoring. Figure 10 presents a flow chart integrating sources of environmental information and decision-making in the event of an RVF prediction. The approach is based on the use of the DSF and incremental risk-based responses to evolving conditions.

Vector surveillance

Surveillance of vector species and infection in vectors has an important role to play. It is used in interepizootic surveillance, predicting outbreaks and guiding vector control programmes in efforts to mitigate outbreaks. National and regional ecozone maps of vector distribution, (including seasonal fluctuations) should form a baseline for real-time surveillance.

Vector surveillance can be integrated into sentinel programmes at high-risk locations as part of monitoring for vector and viral activity. In the interepizootic periods, *Aedes* species will be of principal interest. As conditions progress towards a potential epizootic phase, *Culex* spp. will be of interest as well. These two genera have different habits and periods of activity. *Aedes* are active during the day and at evening and dawn (the 'crepuscular period'). *Culex* prefer crepuscular and night-time activity.

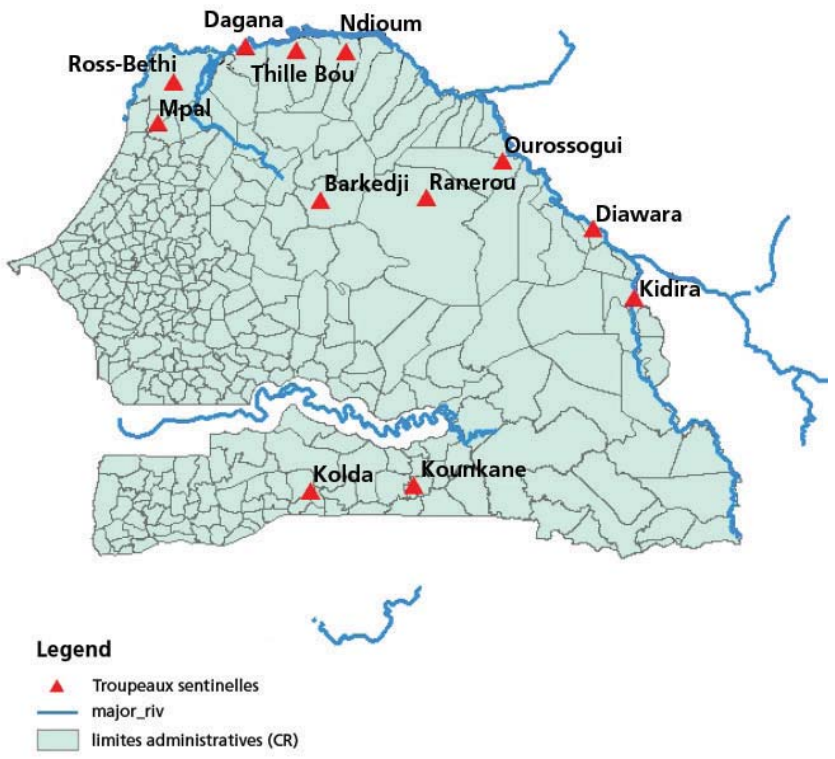
Pre- and post-vector control surveillance is recommended to guide control efforts and judge the efficacy of interventions (Anyamba *et al*., 2010). Timing of control interventions relative to the life cycle of specific species is important for impact.

Vector monitoring should be included in PS and sentinel herd surveillance systems. The involvement of entomologists is recommended. If sentinel herds are used, this may offer an excellent opportunity for vector trapping and monitoring.

Sentinel herds

Risk-based identification of herds for periodic serosampling and observation is an established form of surveillance for RVF. It has provided valuable information in the past, as passive livestock surveillance is poor at detecting outbreaks or demonstrating interepidemic transmission. Provided that a sustained budget is secured, sentinel herds provide a systematic approach to profiling population status. Sentinel systems are in place in Kenya, Senegal (see figure 11) and Mauritania. They have been used to document interepidemic transmission and

FIGURE 11
Location of sentinel herds in Senegal



Source: Direction des Services Vétérinaires Senegal.

the extent of outbreaks. Given the time lag between infection, seroconversion, sampling and the availability of test results, they are not an early warning tool. They provide an evidence-based method for documenting transmission.

Sentinel systems provide an evidence-based method for documenting transmission. There is time lag between infection, seroconversion, sampling and the availability of test results. For this reason, sentinel systems are not an early warning tool.

Siting of sentinel herds and sampling strategies should be carried out in relation to the risk of an outbreak. Risk maps and historical data on outbreaks provide excellent guidance for siting. Seasonal weather forecasts and weather tracking should guide the timing and frequency of sampling. For example, in the midst of an El Niño event, weekly sampling may be justified.

Activities at sentinel sites should be integrated with other data sources at the same site. Observations on rainfall, flooding and entomological sampling would increase information that contributes to the monitoring of the evolving risk of the outbreak in line with the DSF. They will assist decision-makers in taking appropriate phased action prior to detection of the first animal (or human) cases.

Targeted studies and assessments

In the interests of disease control, specific practical or strategic questions can often be answered through small, focused studies. The sampling method in risk-based surveillance, as information for action, is biased to maximize detection of disease. On the other hand, general disease reporting often suffers from an under-reporting bias.

Targeted studies can make use of sampling frames and random or systematic sampling methods to conduct biological sampling or collect information from respondents for the purposes of measuring parameters in the study sample and making inferences about the larger source population. Targeted studies can test hypotheses and estimate parameters such as prevalence or the transmission potential of a strain of an infectious agent in a specific population by measuring the basic reproductive number or R_0. Study design will depend on the study question. For example, the study objective could be understanding spatial distribution of antibody-positive livestock at district level immediately following an outbreak. To properly answer this question, the sample from each district would need to be large enough to make inferences for the whole district level, and sampling within the district would need to be randomized at the herd level. To ensure that targeted studies are appropriately designed to answer the study question, formally trained epidemiologists should be involved.

A qualitative approach could be to conduct district-level participatory assessments using PE methodologies. This could profile high-risk districts in terms of levels of disease experienced, stakeholder knowledge and practices, and disease impacts. This approach, while being less quantitative, could give a much broader understanding of the epidemiology, impact and potential methods for mitigating the disease's future impact.

Demonstrating that a population is free from infection is an example of a specialized study. In a strict sense, it is not statistically possible to prove complete freedom. Instead, this is inferred from the failure to detect disease down to a specificied minimum prevelance and confidence level. There are several feasible approaches (Cameron *et al.*, 2015). The classic method is to conduct testing on a radomized sample that is representative of the population. Methods based on risk-based sampling that target high-risk populations for sampling are also available. There is no single prescribed method. The usual approach involves presenting an evidence-based argument appropriate to the population under study that includes information from complementary approaches.

Timelines for implementing surveillance

For any RVF surveillance programme to be reliable, it needs to be established and tested during the interepidemic period. This includes selecting and training personnel as well as piloting methods. PS personnel should also receive annual field-based refresher training.

CAPACITY-BUILDING PLANS

Surveillance training plans should be defined on the basis of the national surveillance strategy. As outlined on page 27, once objectives, indicators and surveillance activities are identified, appropriate training plans are relatively straightforward to design and justify. Examples of table-top training exercises for surveillance personnel are presented in Annex V.

The following training programmes should be considered:

Rift Valley fever surveillance and management

In endemic and disease-free countries at high risk, a workshop for relevant decision-makers and line managers should be held every three years. This ensures that surveillance and preparedness systems are fully understood, in place and operational in the event of a warning. Current forecasting systems, review of the region's DSF and surveillance activities should be the main items on the agenda.

Over a ten-year interval, capacities degrade, technologies change, institutions evolve and individuals change roles. New opportunities arise and resources that were once taken for granted may disappear. For example, between the last two outbreaks in East Africa, cellphone and email became the standard means of communication. Additionally, almost everyone who managed the 1996 outbreak had retired by 2006. Refresher training for managers is a must, both for surveillance and response capacity.

Rift Valley fever recognition and reporting

Field staff should be trained in the epidemiology and recognition of RVF and principles of zero reporting (see definitions on page 3). They also need training in the use of clinical and syndromic case definitions. The suggested format is short training courses designed to reinforce disease reporting in general and highlight RVF disease reporting.

Participatory syndromic surveillance and outbreak investigation

For participatory syndromic epidemiology, core staff entrusted with active surveillance should receive training through recognized training formats. These training programmes are based on three steps:

- a ten-day introductory course that focuses on practical experience;
- a short field assignment;

- refresher training where participants report back on their field assignment and share lessons learned.

The trainees are only certified as PS practitioners after completing all three steps. In the introductory training course, participants receive four days of classroom training in concepts, tools and techniques. This part emphasizes in-class practice and role-playing. The remainder of the course is dedicated to guided field practice where trainees conduct surveillance with the support of training staff. The Participatory Epidemiology Network for Animal and Public Health (PENAPH) (www.penaph.net) can provide referrals to certified trainers in most regions worldwide. The course should be tailored to RVF surveillance using the abortion and neonatal mortality syndromic definition. An outline of a training programme is presented in Annex IV.

RVF early response refresher

In the event of an early warning being declared, refresher training should be implemented on epidemiology and probable course of outbreaks, recognition, disease investigation, safety precautions and advice to livestock owners. The timeline in the DSF can serve as a useful framework for planning and delivering the course. The training should be delivered to veterinary services line management immediately upon receipt of information indicating increased risk of an outbreak.

The objective of the refresher will be to orient and mobilize response.

MOBILIZING RESOURCES

Appropriate surveillance requires adequate resources. In the event of an outbreak or early warning, documentation of the prediction and guidelines for response, like the RVF DSF, have been used successfully to mobilize resources at the national level.

Given the human health impacts of RVF, One Health approaches, and integrated surveillance and response plans may assist in mobilizing resources.

Three funding phases should be considered:

- Specific allocation – Design and initial implementation with associated capacity-building needs.
- Routine – Baseline activities (disease reporting, forecasting, etc.) and maintaining preparedness during interepidemic periods.
- Emergency – Scaling-up of surveillance activities, including active surveillance in the face of outbreaks (or outbreak predictions).

A budget is a plan expressed in financial terms. Once the surveillance system plan is established, all elements should be budgeted for. The challenge is to secure resources in order to maintain preparedness for scaling up surveillance in the event of a warning. Documented plans and information from the forecasting websites mentioned in the section on forecasting can help. The actual scaling-up of surveillance will need to happen within about one month from the date of the early warning, as will many other response activities. For implementation to be timely, a pre-established process for mobilizing emergency funds is needed.

Analysing surveillance data

Analyzing surveillance transforms accesible information for data into readily accesible information for decision-makers and other stakeholders to act promptly to mitigate risk. Animal health information systems organize and standardize data to permit statistical analysis and enhance this accessibility. The unique aspect of surveillance data is that it can inform decision-makers about the current conditions on the ground.

Modelling, risk analysis and risk mapping are analytical tools that allow diverse types of data to be combined in one analysis. Surveillance data are an important input and can also be used to validate risk and disease transmission models. These types of analyses may include information on the environment and the biology of the disease, as well as demographic, production and trade data. All these techniques are aimed at providing decision-makers with enhanced knowledge to guide their decisions.

One of the challenges of doing useful analysis is involving those on the front lines of disease surveillance and control in the design of analytical systems. Unfortunately, analysts often embark on analysis without consulting stakeholders. Every system sets out to provide information to help answer a set of questions about disease risk and control. It is essential that decision-makers and other stakeholders share in the definition of the questions. This enhances the usefulness, relevance and ownership of the output.

Surveillance and animal health information systems

RVF surveillance is a transdisciplinary activity that requires participation of veterinary, medical, entomological and meteorological experts, at a minimum. There are different ways to achieve this.

One approach is for veterinary authorities to participate in the established animal health information systems and, at the same time, maintain an RVF surveillance group within the national RVF task force. The goal should be to build and maintain a common RVF risk assessment and use this common assessment to guide the activities of the authorities concerned. In addition, the RVF DSF can provide guidance on the sequence of activities that should be considered in response to an RVF warning or to evolving conditions suggesting that an outbreak may be imminent.

National surveillance programmes require strong international links with:

- OIE (WAHIS) and RECs for disease reporting
- FAO EMPRES Animal Health, GLEWS, and international forecasting services for early warning
- OIE/FAO Reference Laboratories for prompt confirmation of diagnosis
- Veterinary authorities in neighbouring countries at a national level, and at a local level near shared borders.

THE ROLE OF MODELLING

There is a considerable body of literature on modelling approaches to analysing RVF risk (Metras *et al.*, 2011). The majority of models relate to the recurrence of outbreaks in endemic areas or the risk of introduction to disease-free countries. The suitability of models for RVF is partly because it is a vector-borne disease with strong environmental and climatological determinants and predictors.

Three forms of modelling have been applied.

The first are different types of statistical models (regression and time series analysis) that relate exposures to the risk of disease outbreaks. These statistical models are often developed in relation to geographical information systems (GIS) with the ultimate objective of producing vector (Conley *et al.*, 2014) and risk maps or forecasting models to predict the timing of outbreaks. Good examples are presented in the next section on risk assessment and risk mapping.

The second type of model is knowledge based. It converts expert opinion into scalable indicators using multi-criteria approaches, and then analyses the results as inputs into models (Tran *et al.*, 2013). Widely used in risk assessment and risk mapping, these integrate the opinions of multiple experts where data may be lacking. The second example shown below in the section on risk assessment and risk mapping combines statistical models of risk factors with expert opinion (Munyua *et al.*, 2016).

The third major form of modelling is disease-transmission modelling that uses mathematical equations - like compartmental SEIR models. There are many examples in the literature for RVF (Niu *et al.*, 2012; Chitnis *et al.*, 2013; Cavalerie *et al.*, 2015). One interesting example integrated climate change parameters to predict changes in transmission patterns (Mpeshe *et al.*, 2014). Transmission models for vector-borne disease are more complex than for directly transmitted diseases, as they must model mammalian host and vector population dynamics and behaviour. Only then can they model the multiplication of the infectious agent in mammalian hosts and the vectors.

Insights from mathematical analysis can also assist with risk analysis and mapping that does not require the construction of models. The ability of a vector to support the multiplication of a pathogenic agent is termed 'vector competence'. However, the role of a potential vector in supporting outbreaks is determined by more than just vector competence. The potential vector must also feed on competent mammalian hosts that are capable of infecting other vectors or hosts. Mathematical relations based on biting rates and competence indices, like the vector amplification fraction, can be calculated and compared for candidate vectors when preparing risk maps or analyses (Golnar *et al.*, 2014).

Modelling work in East Africa has highlighted the importance of excess rainfall. The association with excess rainfall is less clear in southern Africa and not present in West Africa. In West Africa, the outbreaks are smaller in scale and linked to the temporal and spatial distribution of rainfall and animal populations using systems of small ponds (Metras *et al.*, 2011). Modelling suggests that individual ponds would be unable to sustain endemic transmission, so animal movement between ponds is a necessary component of the causal mechanism (Favier *et al.*, 2006). In addition, outbreaks are confined to years of simultaneous occurrence of populations of *Aedes* and *Culex* (Soti *et al.*, 2012).

Thus, modelling is very useful in helping to understand the mechanisms behind endemic maintenance and the periodic emergence of outbreaks. Models have also been valuable in mapping risk and helping to target risk-based surveillance and response.

There is limited empirical data on the threat of introduction into new regions. Risk models tend to work with expert assumptions regarding the relative roles of animal movement, product movement, infected human and vector movement through transport systems, vector movement in the environment and climate change. Although risk analysis is the preferred approach to modelling, transparency is essential where input assumptions (and therefore outputs) are speculative.

RISK ASSESSMENT AND RISK MAPPING

Risk assessment and risk mapping are practical analytical activities that support decision-making on surveillance, prevention and control strategies. A risk map is an integral part of the DSF and defines the geographic range which the framework addresses. This guide will only introduce the concept. For a more detailed discussion of RVF risk analysis, see the *FAO Manual on Preparation of RVF Contingency Plans* (Geering and Davies, 2002). A useful example of a recent risk analysis for the introduction of RVF to the European Union is available (EFSA, 2013).

Sketching risk maps is an important starting point for all surveillance discussions. An hour with a group of key informants gathered around a table can be invaluable.

These activities, even when informal and qualitative, can be very informative. They can be as simple as a group of experts meeting to list risk factors or hazards and sketching their spatial distribution within a region (risk mapping) or establishing priorities through estimation of probabilities and impacts (risk assessment) (see Figure 8). In either case, these simple activities can contribute greatly to the prioritization and targeting of risk-based surveillance activities. Qualitative risk mapping is one of the first steps in participatory surveillance.

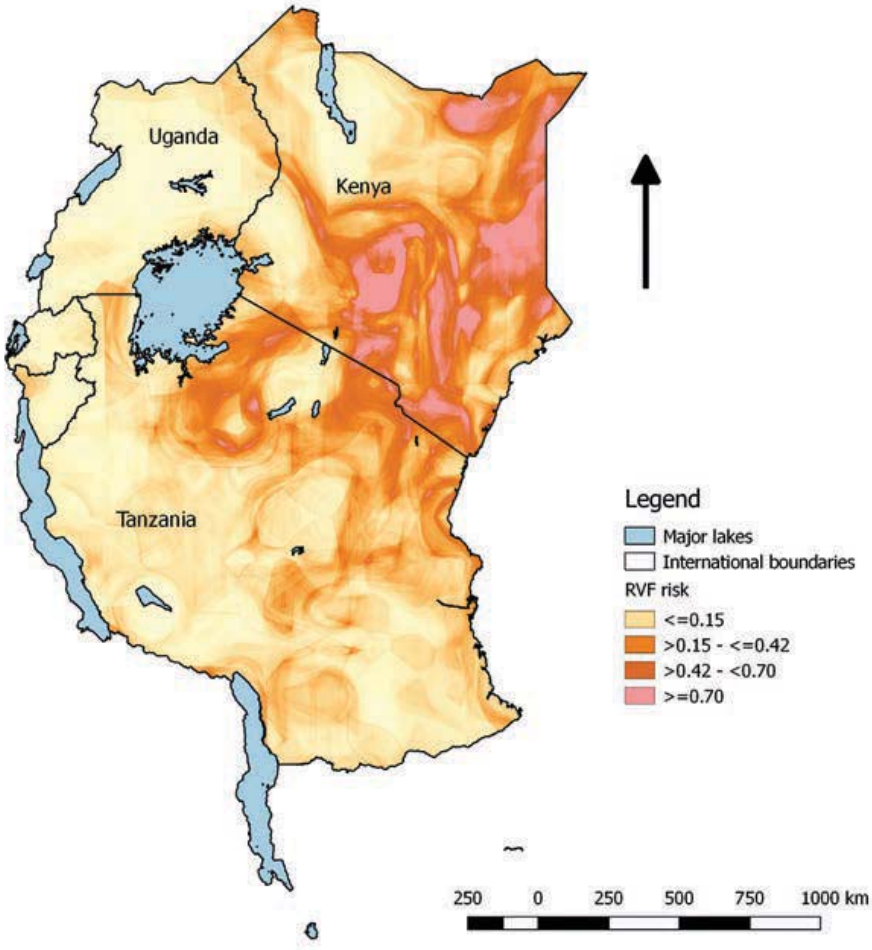
In its quantitative form, risk analysis involves the building of models to simulate potential pathways for the introduction of RVF. Then the risk of each step of the pathway is quantified, leading to an overall estimate of the likelihood of an outcome. Placing values on the negative economic costs of the outcome can help to justify investments in surveillance and mitigation measures.

As a hypothesis, a country with competent RVF vectors that is currently free of infection could look at the risk of importing sheep from an infected country during an interepizootic period. The risk model would look at all steps in the pathway and assess the overall risk of the import. For example, it would consider how likely it is that the sheep would be infected in the country of origin, how likely it is that the sheep would still be infected when they arrived in the importing country, and how likely it is that the competent vectors would become infected from the imported sheep in the importing country. After systematically assessing the situation, the importing country is in a much better position to make an informed decision. Potential mitigating measures that would reduce risk might be surveillance activities on the sheep being traded or a simple quarantine in a mosquito-free environment where transmission is unlikely to occur.

With quantitative risk mapping, the predictive value of various risk factors draws on where outbreaks of RVF have previously occurred. Usually, this involves statistical modelling in regression analysis. The predictions of statistical models can be displayed in a GIS as a map, where the value of the model is calculated at each point or block on the map.

Two examples of RVF quantitative risk maps have been reproduced here with permission. One focuses on the East Africa region (Figure 12) and the other on Kenya (Figure 13).

FIGURE 12
Predicting RVF risk areas in East Africa

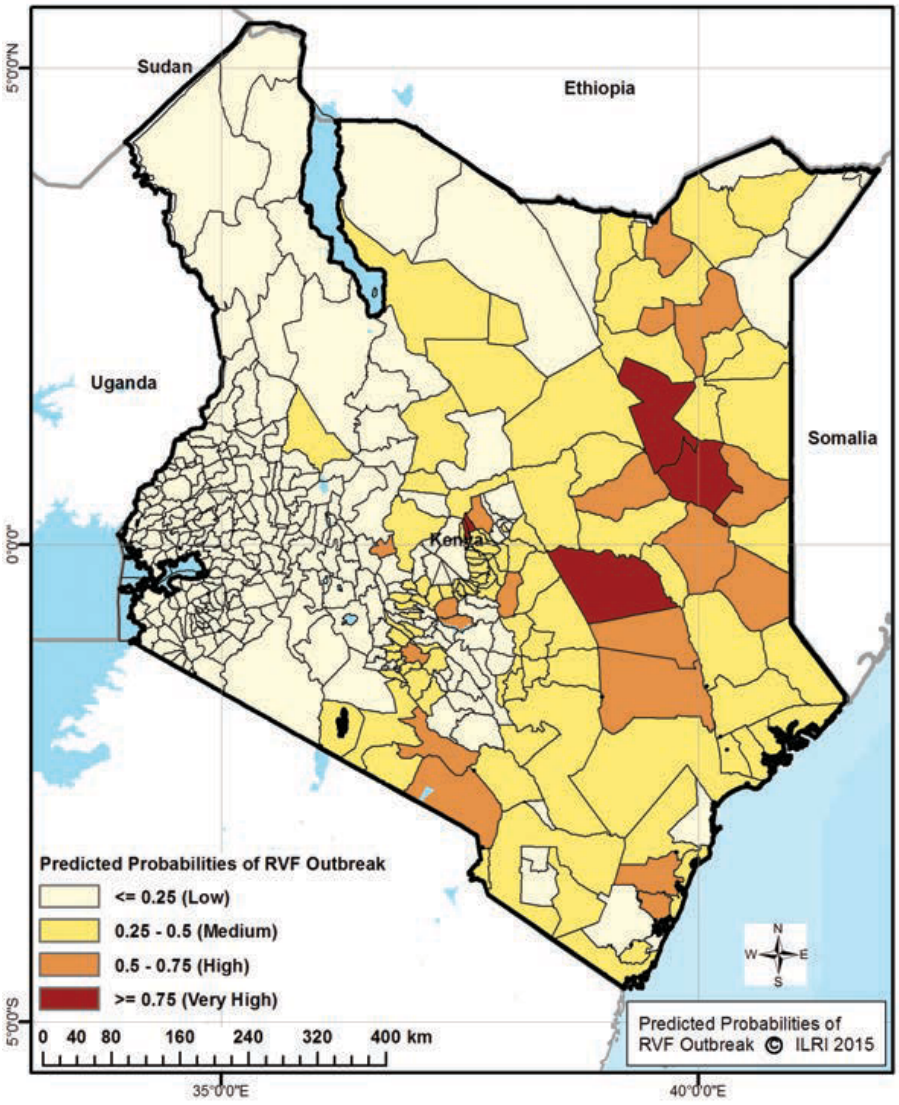


Generated using the Random Forest (RF) algorithm in R (version 3.1.1) by combining data on known occurrence of the disease and environmental (rainfall and normalized difference vegetation index), geologic (soil types) and topographic (altitude and land cover) spatial layers. Occurrence data included centroids of divisions (in Kenya) or districts (in Tanzania) that were affected in the recent 2006–2007 outbreak based on the data published by Munyua *et al*., 2010) and Sindato *et al*., 2014. Monthly values of rainfall and NDVI were extracted from online databases for the period January 1998 to December 2012, but data for the period October 2006 to March 2007 when the RVF outbreaks occurred were used in the analysis. This period was chosen in line with surveys conducted just after the outbreak, which showed that the epidemic started in mid-October 2006 (Jost *et al*., 2010) and had ended by June 2007. Rainfall data were obtained from Tropical Rainfall Measuring Mission (TRMM) at a resolution of 25km while land surface temperature and NDVI data were obtained from MODIS satellite at resolutions of 250m. Altitude, land cover (Global land cover data [GLC2000], FAO) and soil type (FAO Harmonized World Soil Database [HWSD], 2008) were the other spatial data used as predictors. The model fitted to the data was then used to generate a hazard map as predicted probability of RVF occurrence in 1km pixels.

It is important to recall that RVFV is thought to occur in many other areas across the region. Yet some of these locations have never had outbreaks. The outbreak data sets used to generate the maps were themselves generated from known outbreak locations. It can therefore be argued that these maps are biased towards identifying areas likely to experience El Niño-associated RVF outbreaks.

These maps identify areas that are prone to RVF outbreaks and so should be targeted for surveillance, prevention and control activities. For example, posts could be set up for monitoring of pre-outbreak events (rainfall, flooding, vector emergence) and sentinel herds could be established to detect symptoms or seroconversion.

FIGURE 13
RVF risk by administrative division in Kenya



This map (presented in Munyua *et al*., 2016) used a multi-variable logistic regression model with the same predictors as presented above, but with a division as the unit of analysis. Predicted probabilities were then mapped out using ArcGIS software.

Annex I
Clinical signs, pathology and differential diagnoses

CLINICAL SIGNS

Below are descriptions of the main clinical signs in domestic livestock and in humans. Examples of appropriate clinical case definitions that include both clinical and epidemiological criteria are provided in the awareness-raising section on page 32.

Sheep and goats

Clinical disease occurs in susceptible sheep of all ages, but is most severe in young lambs. The morbidity rate in infected flocks is close to 100 percent. The mortality rate may be as high as 95 percent in lambs less than one week old, about 40–60 percent in weaner lambs, and 5–30 percent in adult sheep. The abortion rate may be close to 100 percent.

In peracute cases, sheep are either found dead or suddenly weaken and collapse when driven. In acute cases, there is a very short incubation period – less than 24 hours – followed by fever, rapid pulse, weakness, unsteady gait, vomiting, mucopurulent nasal discharge and death in 24–72 hours. Other signs often observed are lymphadenitis, colic, haemorrhagic diarrhoea and petechial or ecchymotic haemorrhages in visible mucous membranes.

Subacute disease is more likely in adult sheep. Diphasic fever is accompanied by anorexia and weakness. There may be some vomiting and evidence of abdominal pain, with or without haemorrhagic gastroenteritis. Hepatitis with jaundice develops in most cases. Abortion is an almost inevitable consequence of infection in pregnant ewes, occurring in acute or convalescent stages of the disease.

RVF in goats is similar to that in sheep, but is usually not quite so severe.

Cattle and water buffalo

In cattle, as in sheep, the most severe disease is seen in young animals. Mortality rates in exotic calves of *Bos taurus* breeds, like Friesians, may be up to 30 percent, or even higher in neonates. Animals up to 6 and even 12 months may be severely ill and debilitated with hepatitis and jaundice for some months. The acute disease is similar to that in sheep. In adult cattle, the mortality rate is less than 2–5 percent. The majority of affected cows abort. They may show fever, a sharp drop in milk production, with lymphadenitis, anorexia and malaise. Haemorrhage from the mouth and nares often occur, with colic and haemorrhagic diarrhoea. In extensively ranched cattle, abortions may not be observed and a drop in calving rates may be the only sign recognized.

Camels

Although infection is generally subclinical in mature animals, pregnant camels may abort at any stage of pregnancy and neonatal deaths can occur. Abortion rates of 70 percent of pregnancies have occurred with many deaths in foals up to three to four months of age.

Humans

After an incubation period of two to six days, patients experience an influenza-like disease with a sudden onset of fever, debility, headache, backache and other muscle pains, and often photophobia and vomiting. There is usually a degree of liver damage with jaundice. In uncomplicated cases, the illness generally resolves itself within four to seven days. Many cases are mild. However, RVF in people who have pre-existing diseases such as shistosomiasis or malnutrition may be severe or even fatal.

Complications of RVF that occur in a small percentage of human infections include (WHO 2017):

- *Eye involvement (retinitis)*: Onset one to three weeks after the initial fever. Patients report blurring or reduced vision and permanent vision deficits occur in up to 50 percent of patients
- *Neurologic form (meningo-encephalitis)*: Onset one to four weeks after the first symptoms of RVF appear. Symptoms include severe headache, lethargy, dizziness, confusion, memory loss, hallucinations, convulsions and coma. Neurological complications can appear after several months. Mortality in the encephalitic form is low, yet permanent neurological deficits are a common outcome.
- *Bleeding form with jaundice (haemorrhagic form):* Onset two to four days after the initial fever, beginning with severe hepatitis and jaundice. Signs of bleeding include vomiting blood, passing blood in the stool, bleeding in the skin (rashes or ecchymosis) bleeding from the nose or gums, menorrhagia and bleeding after drawing of blood. The case-fatality proportion of the haemorrhagic form is up to 50 percent. Death usually occurs three to six days after the onset of symptoms.

There may also be sporadic cases or small outbreaks in non-epidemic circumstances, which are more difficult to diagnose in the field and may therefore be missed.

PATHOLOGY IN ANIMALS

The most characteristic lesions are of various degrees of necrosis of the liver. There are also petechial and ecchymotic haemorrhages on all serous surfaces, lymph nodes, subcutis, kidneys and in various other tissues.

When severely affected – for example, in young lambs – the liver is swollen and capsule tense, giving an external impression of firmness. However, on section the organ is quite friable, congested and contains many haemorrhages. When not masked by blood, the colour of the liver ranges from pale grey-brown to yellow-brown. Numerous grey-white foci, 1–2 mm in diameter, are scattered throughout the parenchyma. The gall bladder may be oedematous and contain petechial or ecchymotic haemorrhages. All the carcass lymph nodes are likely to be enlarged, oedematous and haemorrhagic.

The gastrointestinal tract exhibits varying degrees of inflammation, from catarrhal to haemorrhagic and necrotic. Petechial or ecchymotic haemorrhages are present in most

internal organs. Ascites, hydropericardium, hydrothorax and pulmonary oedema may be present. The fluid in the body cavities is frequently bloodstained and the carcass jaundiced.

DIFFERENTIAL DIAGNOSES

There are a number of diseases that may be confused clinically with RVF. RVF outbreak conditions might also be favourable for other insect-borne diseases like bluetongue, Nairobi sheep disease and Wesselsbron disease. Other livestock diseases - such as *peste des petits ruminants* (PPR), contagious caprine and bovine pleuropneumonia, and foot-and-mouth disease (FMD) – may also occur through dislocation of farming communities and movement of animals as a result of flooding. The simultaneous occurrence of other diseases may compound diagnostic difficulties.

Together with all causes of abortion in ruminant animals, diseases to be taken into consideration in the differential diagnosis of RVF include:

- Wesselsbron disease
- Bluetongue
- Enterotoxaemia
- Ovine enzootic abortion
- Nairobi sheep disease
- Hepatotoxins
- Brucellosis
- Bacterial septicaemias
- Peste des petits ruminants.

Annex II
Laboratory diagnosis

Laboratory diagnosis is an essential component of surveillance systems. For the most current recommendations and technical details on diagnostic tests, see the RVF chapter of the *OIE Manual* (OIE, 2016).

It is not sustainable or an appropriate use of funds for every country to attempt to maintain the full range of tests or the facilities to contain highly infectious animal and human pathogens. As a result, a system has evolved of international reference laboratories combined with national laboratories with a set of core competencies.

The rapid and certain diagnosis of diseases can only be assured in fully equipped laboratories. These require a range of standardized diagnostic reagents, experienced staff and a sufficient throughput of diagnostic specimens to maintain expertise. For RVF, the relatively simple facilities required for testing serums by ELISA are a realistic possibility for most countries with biosecurity BSL 2 facilities. Developing diagnostic expertise for diseases exotic to the host country, or that require handling a live, highly infectious zoonotic virus such as RVFV (e.g. SN tests), should only be attempted in laboratories with appropriate BSL 3 facilities and higher.

All countries with significant livestock populations should have a veterinary diagnostic laboratory. This must be equipped to competently undertake a broad range of standard techniques in pathology, virology, bacteriology and serology. This should be to the level where initial identification of aetiological agents for most, if not all, emergency livestock

Safety precautions

Many RVF cases occur in veterinarians, laboratory workers, farmers and others through handling infected blood, tissues or other virus-contaminated materials. Vaccination of high-risk personnel is recommended (CDC 2009).

Appropriate care should be taken with autopsies on animals suspected of dying from the disease, and in handling aborted foetuses. Full PPE including rubber gloves, disposable coveralls and face masks should be worn. Personal disinfection should be thorough. Autopsied carcasses should be disposed of by burial, burning or incineration by personnel in PPE trained to handle human pathogens. A high level of biocontainment, biosafety level 3, is recommended for laboratories outside endemic areas. CDC 2009 is also required in laboratories handling infectious materials associated with the RVF virus.

People at high occupational risk of contracting RVF should consider being immunized. An experimental inactivated tissue human culture vaccine manufactured in the United States may be made available for this purpose.

diseases can be attempted. It would be impractical and excessively costly for most countries to maintain a national veterinary diagnostic laboratory with full capacity to confirm diagnoses for all transboundary and other emergency diseases, many of which will be exotic to the host country. If RVF is deemed to be a high-threat disease, consideration should be given to developing capabilities for some primary key diagnostic tests for the RVF antigen (formolized tissue and immunohistochemistry or PCR) and antibody detection (ELISA tests).

Specimen transport containers should be kept at central and state or provincial veterinary laboratories and should be made readily available for FVOs and specialist diagnostic teams. Containers should ideally consist of primary leak-proof glass universal bottles with metal screw top and rubber washer, or good-quality plastic screw-top jars. These are then packed into a leak-proof secondary container (e.g. a steel paint tin or a plastic or Styrofoam™ cool box) with absorbent material and an ice pack, and finally put into a well-labelled robust outer container. Specimen advice notes should also be provided.

DIAGNOSTIC SERVICES

A network of FAO and OIE reference laboratories for RVF exists around the world. These are available to provide advice and assistance to countries. Their names, full contact details, subjects and geographic areas of responsibility are given in Appendix III.

As part of their RVF surveillance planning, countries should establish a dialogue with the appropriate reference laboratories and collaborating centres. Countries should determine the nature and range of diagnostic specimens or isolated agents to be sent for confirmatory diagnosis or further characterization. The specific means of transport, method of packaging and refrigeration, and labelling of package should all be decided on. This includes checking the correct address and any necessary customs or IATA declaration. This information should be documented in country plans.

Potential or confirmed aetiological agents from emergency disease outbreaks must be sent to the appropriate International Reference Laboratory for further characterization. It is recommended that several isolates from different geographic locations and at different phases of the outbreak be forwarded. Submitting samples to any laboratory outside the country of origin should always be subject to prior agreement with the recipient. Transportation must be in containers meeting IATA regulation standards.

Examples of what reference laboratories and collaborating centres can provide include training opportunities, specialized planning advice and standardized diagnostic reagents.

POST MORTEM

It is not advisable to conduct a post mortem on a subject that meets the clinical case definition for RVF, or is suspected of having been infected by RVFV for any other reason, unless appropriate conditions and supplies are available to protect those conducting the post mortem, and the public.

BIOLOGICAL SAMPLES

Notification

The national epidemiologist and national laboratory should be notified at the earliest opportunity. They need to know that a case meeting the syndromic case definition and sampling

for RVF diagnostics has been recognized. The national reporting system should have a focal person (or office) for all such events clearly designated and communicated to all field offices. Establishment of reporting by cellphone, SMS or other digital means is encouraged. Ideally, the laboratory should be notified of sampling prior to or immediately after this takes place.

Sample collection

Whole blood, liver, lymph nodes and spleen are the tissues of choice for isolating the virus (OIE, 2016). Blood samples of 5 ml should be collected from febrile animals into ethylene-diamine-tetra-acetic acid (preferred) or heparin to which antibiotics have been added as preservatives (penicillin 200 units and streptomycin 200 µg/ml, final concentration). Samples of liver and spleen (1 cm^3) should be collected aseptically from freshly dead animals at autopsy and from aborted foetuses, if available. These should be placed in sterile containers, and stored at 0–4^0 C (refrigerated or on ice). Duplicate tissue specimens should be collected in neutral buffered formalin for histopathology. These can be stored at room temperature. Blood samples, about 20 ml each, should be collected from animals in the acute and convalescent phases of the disease, for serum.

Packaging, transport and storage

Samples should be triple packed: primary (sample tubes), secondary (sealed in plastic) and tertiary containers (appropriate insulated boxes with coolant). They should be labelled with biohazard markings indicating they are diagnostic materials. Ideally, the materials should be stored and transported at 0–4^0C when short delays of up to 24 hours are anticipated before testing. If longer delays are anticipated, the material should be frozen and shipped on dry ice.

DIAGNOSTIC TESTS

Virus isolation. The RVF virus can be isolated from whole blood or homogenates of fresh tissues by intracerebral injection of suckling mice or intraperitoneal injection of adult mice or hamsters. It can also be readily isolated in various primary cell cultures (e.g. primary lamb and calf kidney or testis) or cell lines (e.g. BHK-21 and Vero). The identity of the isolated virus is confirmed by polymerase chain reaction (PCR), enzyme-linked immunosorbent assay (ELISA), fluorescent antibody staining or virus-serum neutralization tests.

Interpreting results

- Detecting RVF virus, antigen or genetic material is evidence of active infection and diagnostic of an event.
- Detecting RVF IgM is evidence of recent infection or vaccination and can be diagnostic of a recent disease event (within the past nine months), provided clinical and epidemiological information are also indicative of RVF.
- Detection of RVF IgG is indicative of previous exposure to RVF at some point in the life of the host. Demonstration of a raising titre in paired serum samples together with supportive clinical and epidemiological evidence can be diagnostic.

Antigen detection. RVF antigen is detected by direct or indirect immunofluorescence tests on impressions smears or cryostat sections of liver, spleen and brain (OIE, 2016). A rapid diagnosis can sometimes be made by AGID tests on fresh tissues. Immunocapture-ELISA and histochemical staining of cryostat sections or formalin-fixed tissues and PCR are now much more widely used for RVF.

Antibody detection. The ELISA test has now replaced the older inhibition of haemagglutination (IHA), immunofluorescence assay (IFA) and SNT as the test of choice in routine diagnostics. The SNT is still the test prescribed by the OIE for trade-related decision-making, though. ELISA systems are available to test for the presence of IgM and IgG, which are extremely valuable in epidemiological investigations. The virus serum neutralization test in microtitre tissue culture systems remains the definitive test system. It is highly specific with little or no cross-neutralization with other phleboviruses. It can be used to detect antibodies in all animal species. However, as it requires the use of live virus, it is not recommended for use outside endemic countries unless a high level of biocontainment is available in laboratories.

Other serological tests are less specific, but still have a very useful role.

The indirect ELISA test is a reliable and sensitive test and can provide results within hours. There are tests for both IgM and IgG antibodies. In an outbreak situation index case, the low-level serological cross-reactions with other members of the *Phlebovirus* genus may cause problems. For this reason, doubtful results should be interpreted with caution and may need to be confirmed by serum neutralization (SN) tests at a reference laboratory.

Detection of viral genetic material. A reverse transcriptase and real-time PCR tests are available for detecting viral genetic material.

Histopathology. In the livers of young animals, there are well-defined primary foci of severe coagulative necrosis, which may be centrilobular. These are accompanied by diffuse and massive pan-necrosis involving most (or all) of the rest of the parenchyma. Some livers also show mineralization of scattered (or small groups of) necrotic hepatocytes. The primary necrotic foci are later infiltrated by histiocytes, lymphocytes and neutrophils, many with marked pyknosis and karyorrhexis. Intracytoplasmic Councilman-like bodies may be present in degenerate hepatocytes or free in sinusoids. Eosinophilic inclusion bodies are often found in the nuclei of cells that are still recognizable as hepatocytes.

Characteristic histological lesions with pan-necrosis in the livers of young animals or foetuses suggest a diagnosis of RVF. However, the are not sufficient to confirm it. The OIE Manual indicates that histopathology is useful for samples from remote areas as formalin-fixed tissues do not require a cold chain.

Annex III
Reference laboratories and resources

REFERENCE LABORATORIES

Dr Noël Tordo
Institut Pasteur
Unité des Stratégies Antivirales
Départment de Virologie
25 rue du Dr Roux
75724 Paris Cedex 15
FRANCE
Tel: +33-1 40.61.31.34
Fax: +33-1 40.61.32.56
Email: ntordo@pasteur.fr

Dr Baratang Alison Lubisi
Onderstepoort Veterinary Institute
Agricultural Research Council
Private Bag X05
Onderstepoort 0110
SOUTH AFRICA
Tel: +27-12 529 91 17
Fax: +27-12 529 94 18
Email: lubisia@arc.agric.za

The contacts for reference centers change with time. You are encouraged to consult the OIE website for the most recent contacts. http://www.oie.int/our-scientific-expertise/reference-laboratories/list-of-laboratories/

WEB-BASED RESOURCES

CDC Biosafety in Microbiological and Biomedical Laboratories
https://www.cdc.gov/biosafety/publications/bmbl5/BMBL.pdf

European Space Agency Globcover Portal:
http://due.esrin.esa.int/page_globcover.php

USGS AVHRR Normalized Difference Vegetation Index (NDVI) Composites:
https://lta.cr.usgs.gov/NDVI

SPOT Vegetation time series
http://www.vgt.vito.be/index.html and
http://www.vito-eodata.be/PDF/portal/Application.html#Home

FAO Digital soil map of the world:
http://www.fao.org/geonetwork/srv/en/metadata.show?id=14116

Global livestock production systems (FAO and ILRI)
http://www.fao.org/docrep/014/i2414e/i2414e.pdf

Annex IV
PS practitioners' training programme

INTRODUCTION

This ten-day training workshop provides an introduction to participatory methods and the participatory syndromic surveillance (PS) programme for RVF. The training workshop is followed by a two-week field assignment where trainees practice RVF PS. After that, three days of refresher training are held, where participants report on their fieldwork and share their experiences with colleagues to identify lessons learned. Participants receive RVF PS practitioner certificates when they complete the refresher training.

The first day focuses on principles and concepts. The next three days consist of training in the toolkit of participatory methods and role-playing to practice techniques with colleagues. The five days after that consist of guided field practice where trainees take turn leading semi-structured interviews and using the tools with livestock owners in the field.

TRAINING OBJECTIVES

On completing the three-step training programme, participants will be able to:

- explain the principle of participatory epidemiology and its application to surveillance;
- develop a checklist and conduct a semi-structured interview;
- use the techniques of proportional piling and other scoring techniques, participatory mapping and timelines;
- explain the epidemiology and ecology of RVF in the region;
- apply clinical and syndromic case definitions for RVF; and
- implement participatory syndromic surveillance for RVF.

OUTLINE OF THE INTRODUCTORY TRAINING WORKSHOP

	Topics
Day 1	Introductions and expectations Introduction to Participatory Epidemiology (PE) Attitudes and assumptions Synergies between qualitative and quantitative inquiry Applications of PE Local or existing knowledge Source of bias Key informants and risk target Basic epidemiology concepts Syndromic surveillance
Days 2–4	The PE toolkit: scoring, visualization and observation Semi-structured interviews: open-ended questions and probing Non-verbal communication Role-playing an interview The techniques demonstrated and practiced in role-playing exercises are: proportional piling matrix scoring cluster piling participatory mapping transect walks and participant observation venn diagramming time lines and seasonal calendars Data validation: probing and triangulation Data analysis Preparation for field practice
Day 5-9	Field practice in the morning Discussion in the afternoon
Day 10	Lessons learned Preparation of RVF PS checklist Planning for field assignment Closing

Annex V
Information for action: Using surveillance

This section presents three scenarios for training and discussion. Each describes an epidemiological situation and asks how surveillance and surveillance outputs could be used to mitigate it.

These are intended as tabletop exercises once you've read the manual. For each scenario, you need to make a plan to address the problem. Your proposals need to be realistic in terms of cost, and logistically feasible within the time available.

There is no single correct answer for each of the scenarios.

SCENARIO 1: AN ENDEMIC COUNTRY THAT EXPORTS LIVE ANIMALS TO INFECTION-FREE COUNTRIES

In this scenario, your team makes the animal health decisions for a country with endemic RVF. Your country has not had an outbreak in over 10 years, but your trading partners and the animal health industry have expressed concerns about your ability to detect and respond to the risk of an RVF outbreak.

Reviewing the information provided in this manual and from other available sources, what surveillance actions would you propose and why? Please state your objective, surveillance indicators and activities, and the reasons behind your choices.

SCENARIO 2: AN ENDEMIC COUNTRY WHERE A POSSIBLE EL NIÑO EVENT HAS BEEN PREDICTED IN SIX MONTHS' TIME

Here you are the head of the epidemiological service and you've just received a prediction that an El Niño event may occur in five or six months' time. Fortunately, last year you established an RVF PS programme and have an emergency allocation of US$50 000 that you can draw on. It's not much, but it's something. What actions would you prioritize?

Reviewing the information provided in this manual and from other sources that may be available, what surveillance actions would you propose and why? Please state your objective, surveillance indicators and activities, and the reasons behind your choices.

SCENARIO 3: AN INFECTION-FREE COUNTRY WITH LINKS TO ENDEMIC COUNTRIES

You are the director of veterinary services in an RVF infection-free country that has trade and transport links to endemic countries that have a history of outbreaks. Your country has food deficits and imports live animals and livestock products. Your consumers benefit from lower prices for animal source food resulting from the trade. In the context of a changing climate, while recognizing the benefit of this trade, you wish to mitigate risk.

Reviewing the information provided in this manual and from other available sources, what surveillance actions would you propose and why? Please state your objective, surveillance indicators and activities, and the reasons behind your choices.

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Rift Valley fever (RVF) virus, a mosquito-borne zoonotic agent, causes hemorrhagic fever in humans, and abortion and neonatal death in livestock. Outbreaks have caused national meat markets to collapse and have in the past caused regional trade embargoes.

The geography of infection and clinical disease is expanding. Climate change is expected to accelerate this spread. The known geographic range of the virus is already larger than the areas where clinical disease has been observed. Effective surveillance is essential to mitigate the impact of RVF on lives, livelihoods and national economies.

The RVF Surveillance Manual provides risk-based guidance for designing, planning and implementing effective participatory and syndromic surveillance. It builds on approaches outlined in the OIE Guide to Terrestrial Animal Health Surveillance and the RVF Decision Support Framework. It shows you how to tailor this guidance to the epidemiological needs of individual countries, starting with setting appropriate objectives. RVF surveillance objectives need to be in line with the country's risk category and economic goals. Selecting the most appropriate indicators and methods for the situation follows easily from these goals and objectives. The manual is not prescriptive. Instead, it suggests questions to help you build a timely and sensitive surveillance system suited to national objectives and resources.

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