Food and Agriculture Organization of the United Nations

ISSN 1810-0708

Rift Valley fever action framework

FAO ANIMAL PRODUCTION AND HEALTH / **GUIDELINES 29**

Financial support provided by

USAID FROM THE AMERICAN PEOPLE

FAO ANIMAL PRODUCTION AND HEALTH / **GUIDELINES 29**

Rift Valley fever action framework

Authors

Jeffrey C. Mariner, Eran Raizman, Claudia Pittiglio, Charles Bebay,
Fredrick Kivaria, Juan Lubroth, Yilma Makonnen

Food and Agriculture Organization of the United Nations
Rome, 2022

Required citation
Mariner, J.C., Raizman, E., Pittiglio, C., Bebay, C., Kivaria, F., Lubroth, J., Makonnen, Y.. 2022. *Rift Valley fever action framework*. FAO Animal Production and Health Guidelines, No. 29. Rome. https://doi.org/10.4060/cb8653en

ISBN 978-92-5-135775-0
ISSN 1810-0708

Photo cover: FAO/Eran Raizman

Contents

Acknowledgements

This Rift Valley Fever Action Framework is supported through the USAID-funded "Global Health Security Agenda (GHSA) – OSRO/GLO/507/USA" project. The authors are grateful to USAID for its continued support and partnerships with FAO. The content and views expressed in this work are solely those of the authors and do not necessarily represent those of USAID and FAO. The authors would like to thank Elisa Palamara and Wantanee Kalpravidh for their technical input on Text Box 1, Clarisse Ingabire for her contribution to Annex II and the information management and publishing team composed of Claudia Ciarlantini, Enrico Masci and Cecilia Murguia. The authors would also like to record special thanks to the reviewers of this document: Bouna Diop, Madhur Dhingra and Paolo Calistri.

Abbreviations and acronyms

Africa CDC	Africa Centres for Disease Control and Prevention
AUC	African Union Commission
AU-IBAR	African Union Interafrican Bureau for Animal Resources
AU-PANVAC	Pan-African Veterinary Vaccine Center of African Union
AYAM	Abortion and young animal mortality syndrome
BCR	Benefit–cost ratio
CAHW	Community animal health worker
CHW	Community health worker
CDC	United States Centers for Disease Control and Prevention
CEA	Cost-effectiveness analysis
CH	Community health (human and animal)
CVO	Chief veterinary officer
CMO	Chief medical officer
DMO	District medical officer
DMS	Director of medical services
DSF	Decision Support Framework
DST	Decision Support Tool
DVO	District veterinary officer
DVS	Director of veterinary services
EAC	East African Community
ECTAD	Emergency Centre for Transboundary Animal Disease
EFSA	European Food Safety Authority
ELISA	Enzyme-linked immunosorbent assay
ENSO	El Niño–Southern Oscillation
EWS	Early Warning System
FAO	Food and Agriculture Organization of the United Nations
FUO	Fever of unknown origin
GEE	Google Earth Engine
GLEWS	Global Livestock Early Warning System
GHA	Greater Horn of Africa
HIH	Hand-in-Hand
ICPAC	IGAD Climate Prediction and Applications Centre
IGAD	Intergovernmental Authority on Drought and Development
ILRI	International Livestock Research Institute
IO	International organization
MCM	Multisectoral Coordination Mechanism
MoA	Ministry of agriculture
MoH	Ministry of health
NASA	National Aeronautics and Space Administration
NDVI	Normalized difference vegetation index

NGO	Non-governmental organization
NOAA	National Oceanic and Atmospheric Administration
OH	One Health
OIE	World Organization for Animal Health
PCR	Polymerase chain reaction
PE	Participatory epidemiology
PPE	Personal protective equipment
PSS	Participatory syndromic surveillance
RA	Risk assessment
RECs	Regional Economic Communities
RNA	Ribonucleic acid
RVF	Rift Valley fever
RVFV	Rift Valley fever virus
SH	Sentinel herds
SST	Sea surface temperatures
TZG	Tripartite Zoonosis Guide
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
WHO	World Health Organization

Executive summary

Rift Valley fever (RVF) is an arboviral disease of mammals, including livestock, wildlife and people, transmitted by eight genera of mosquitoes, primarily by members of the *Aedes* and *Culex* genera. RVF frequently occurs in epidemics, often in five- to 15-year intervals, causing widespread abortion and neonatal mortality in sheep, goats and cattle. During epidemics, mild infection in people is common, with severe complications in a small but significant percentage of cases.

Endemic infection occurs widely in Africa, and in the Jizan border area between Saudi Arabia and Yemen. Endemic infection is characterized by periods of cryptic virus circulation in mammals and transovarial transmission in *Aedes* mosquitoes. Explosive epidemics may occur in endemic countries following periods of abnormal rainfall and are the direct impact of the disease. Although not all infected countries have detected epidemics, over the years the range of RVF epidemics has significantly expanded.

RVF is an excellent example of a One Health challenge that is best addressed as a veterinary public health threat (and an occupational hazard), and which requires a better understanding of the environment in which the disease may occur or spread. A transdisciplinary approach, which brings together diverse expertise to produce a single, coordinated institutional plan, is therefore needed. This Action Framework advocates for multi-partner, transdisciplinary and multisectoral approaches, using risk assessment and mapping tools, action planning, and coordinated risk-based surveillance and response.

The range of RVF is largely determined by the distribution of suitable vector habitat and rainfall. Transovarial transmission has been demonstrated in *Aedes* mosquitoes, and Rift Valley fever virus (RVFV) is believed to be capable of persisting for years in dormant *Aedes* mosquito eggs during dry periods. As a result, it is not possible to eradicate RVF from an endemically infected area using current technologies. The complete prevention of epidemics would require high levels of herd immunity in multiple species to be maintained indefinitely. This may be possible, but would require costly and open-ended control measures. As a result, the focus of action for most countries is on predicting, preventing and mitigating outbreaks using risk-based approaches.

Risk-based approaches recognize that the likelihood of adverse events varies over time. Surveillance, prevention and mitigation measures directed at these areas and times of high risk are more likely to be successful and have greater effect.

Epidemiological and climatic forces shape the patterns of RVF and determine the appropriate approaches for risk mitigation of the disease in Africa. A risk assessment that includes consideration of hydrology, climate and soils; viral presence and previous transmission patterns, or the means of introduction and diffusion of the disease; transport networks; the density of ruminants; vaccination patterns; and vectors is the tool recommended for systematically defining future patterns of disease.

This RVF Action Framework builds on previous general and RVF-specific guidance, such as:

- *Manual on livestock disease surveillance and information systems* (FAO Animal Health Manual No. 8);
- *Manual on Preparation of Rift Valley Fever Contingency Plans* (FAO Animal Health Manual No. 15);
- OIE *Guide to terrestrial animal health surveillance* (Cameron, *et al.*, 2015);
- RVF Decision Support Framework (DSF; Consultative Group for RVF Decision Support, 2010);
- Rift Valley Fever Surveillance (FAO Animal Health Manual No. 21; Mariner, 2018);
- FAO circulars on RVF vaccination and sentinel herds; and
- Recommendations of the RVF Technical Workshop held in 2018 (Annex I).

For infected countries that experience epidemics, the phased approach to response breaks down the epidemiological cycle into four phases:

- *Inter-epidemic period:* Infected countries without any specific warning of an approaching RVF epidemic or high-risk period.
- *Pre-epidemic period:* Infected countries that have received an RVF warning or warning of a high-risk period.
- *Epidemic period:* Infected countries that have detected a case of RVF disease in humans or animals.
- *Post-epidemic period:* Infected countries recovering from an epidemic that have not detected a case in six months.

Risk-based One Health surveillance and a phased approach to response based on the evolving level of risk is strongly recommended. When undertaking risk-based surveillance, risk assessment and mapping carried out during the inter-epidemic period can identify targets for surveillance activities both in terms of location and time. Of the surveillance options available, syndromic surveillance approaches that combines data on public and animal health are recommended as a cost-effective foundation for surveillance and helpful technique for the early detection of epidemics. Active participatory syndromic surveillance is the recommended approach needed to improve the sensitivity and timeliness of disease surveillance and environmental monitoring, especially in the pre-epidemic period. A One Health approach incorporating both public and animal health surveillance will increase the sense of shared ownership of information and allow prompt, integrated responses during an escalating outbreak situation. Investment in awareness and education efforts in rural and peri-urban communities improves all types of surveillance.

Infected countries that have not experienced epidemics, and countries that are free of infection but at risk of introduction, are discussed separately.

Given the long inter-epidemic period and explosive nature of outbreaks, there is debate over the best approach to targeting vaccinations. As a vector-borne disease, RVF has clear associations with specific locations that support suitable vector dynamics. However, the timing of outbreaks is difficult to predict in a manner that would allow vaccination to be implemented before an outbreak. There are several acceptable vaccines available, but as yet there is insufficient evidence to make a recommendation of a preferred vaccine. This Framework presents non-prescriptive, practical approaches to vaccination in emergencies (evolving outbreaks) and as a potential preventive measure before the occurrence of outbreaks.

Vaccination strategies and plans should be developed and the necessary vaccines sourced during the inter-epidemic period. The procurement and prepositioning of vaccine stocks takes three to four months, and is therefore difficult to achieve in the short time between forecasts indicating risk or RVF alerts and the onset of an outbreak.

This Framework provides guidance on how to build capacity over the medium term for implementing more effective risk-based surveillance and responses to RVF. This can be best achieved through an overall One Health multisectoral coordination mechanism (MCM) and planning process. Technical information on epidemiological patterns, early warning systems and intervention tools will undoubtedly evolve over the life of the Framework, and the intent is to avoid prescriptions that will become rapidly dated. Outbreaks of disease are explosive in nature; procedures, trained personnel and resources must therefore be established before risk forecasts and outbreak alerts are received. The Framework is not an action plan in itself, but rather a tool to help countries formulate multi-year action plans aimed at building their capacity for managing RVF risk.

Purpose and approach

The purpose of this One Health Action Framework is to provide risk-based guidance on appropriate preparations, risk monitoring and responses aimed at mitigating the impact of RVF on national economies and human health. Actions are recommended based on a country's epidemiological status and the epidemiological stage in the cycle of outbreaks in infected countries.

This manual is not intended as an exhaustive review of the technical information on RVF or the literature on this topic. It is intended as an action guide for decision-making, and for managers and One Health professionals responsible for planning and implementing RVF interventions. The aim is to present a clear framework for the formulation of national risk-based action plans.

The challenge

RIFT VALLEY FEVER

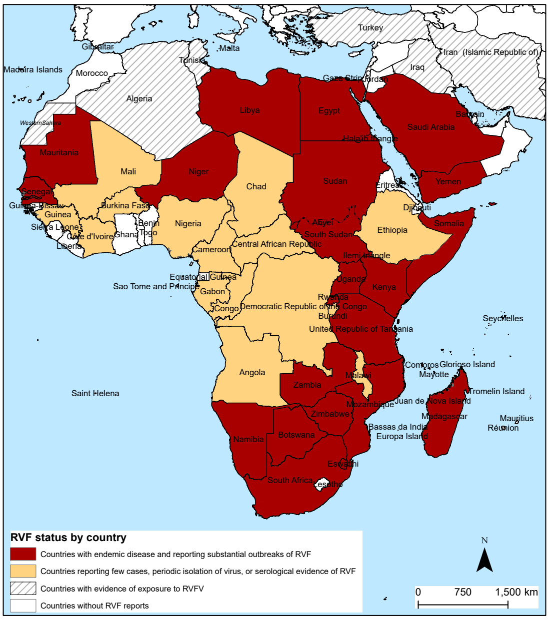
Rift Valley fever was first diagnosed in the Rift Valley in Kenya in 1931. It is caused by RVFV, an Ribonucleic acid (RNA) virus and member of the Phlebovirus genus. It is an arboviral disease that has been isolated from eight genera of mosquitos from the family Culicidae: *Aedes, Anopheles, Conquillettidia, Culex, Culiseta, Eretmepodites, Mansonia and Ochlerotatus* (Bouloy, 2001; Rolin, Berrang-Ford and Kulkarni, 2013; Tantely, Boyer and Fontenille, 2015; Linthicum, Britch and Anyamba, 2016). In addition to these, Sang *et al.*, (2017) has reported a ninth genus: *Aedeomyia*. Vertical transmission in *Aedes* spp. plays a key role in the persistence of infection in endemic areas. Rift Valley fever disease is generally an acute infection with viremia rarely lasting more than seven days. In livestock, it infects the liver and leads to widespread abortions and neonatal death. Infection in humans is common and characterized by a passing fever associated with head and eye pain. In less than one percent of human cases, the disease can lead to uncontrolled bleeding and death or blindness. Outbreaks are associated with unusual rainfall patterns or changes to local hydrology, such as the creation of dams and irrigation systems, and often explode rapidly across suitable landscapes, first affecting livestock and then humans, with significant economic consequences resulting from direct losses, the closure of markets and trade disruption.

GLOBAL EPIDEMIOLOGICAL SITUATION

Since it was first described in Kenya, RVF disease or infection has been identified across sub-Saharan Africa, wide areas of southern Africa, and in Madagascar, Egypt and the Jizan border area of Saudi Arabia and Yemen. The global extent of infection and history of outbreaks is presented in Figure 1. The global distribution and epidemiology of RVF is expected to change in the coming years, especially in the face of climate change, and decision makers should keep abreast of developments. Endemic infection is maintained by periods of limited, local virus circulation in mammals, and transovarial transmission in *Aedes* mosquitoes, whose infected eggs can lie dormant in dry breeding sites for years.

Explosive epidemics may occur in endemic countries following periods of abnormal rainfall or the construction of dams and irrigation systems. These outbreaks are caused by the hatching of infected *Aedes* mosquitos, leading to an initial round of amplification in livestock. Elevated soil humidity during relatively warm periods encourages hatching, a greater frequency of mosquito feeding (transmission) and egg production, and shortens the reproductive cycle of the vectors. If rains persist or environmental conditions that encourage mosquitos breeding are maintained over a longer period, additional waves of mosquitos, predominately *Culex* spp., result in the sudden onset of large epidemics. In a given location, the time from the first index case to the peak of the epidemic is measured in weeks, and the majority of the susceptible population may be affected in the brief

FIGURE 1
Geographical distribution of Rift Valley fever (left) and years in which there was an RVF notification for animals, humans or both, by country (right).



Country	Years of notification in animals, humansor both (since 2000*)	Additional documented outbreaks (before 2000)
Comoros		2008
Egypt	*2003*	1977/1978/1993/1997/ 1998
Eswatini	**2008**	1979/1990/1991
The Gambia	**2002/** *2018*	1999
Kenya	2006/2007/ *2014/2015/ 2018* /**2019/**2020	1997/1998
Libya	**2020**	
Madagascar	2008/2009	1979/1990/1991
Mali	**2016/2017**	
Mauritania	**2006/**2010**/2011/**2012**/ 2013/2014/ 2015/** 2020	1982—1985/1987/1998/ 1993/1994/1999/2002
Mayotte (Fr)	**2008/2018/** 2019	
Mozambique	**2007/2013/2014/2016/ 2018**	1969
Namibia	**2010/2011/2012**	1955/1974/1975
Niger	2016	
Nigeria	**2017**	
Rwanda	**2012/2013/2014/2016/ 2017/2018**	
Saudi Arabia	*2000* **/2010**	
Sudan	2007/*2008* /2019	1973
South Sudan	**2017/2018**	
Senegal	**2013/2014/2015/2016/ 2018/2020**	1999/2002
Somalia	*2006/2007*	
Tanzania	2007	1997/1998
Uganda	**2016/2017/2018** /*2019*	
South Africa	**2008/2009/** 2010/**2011/ 2018**	1950- 1953/1955—1959/1969— 1971/1974—1976/1981/1
Yemen	*2000* /**2005/2006/2007**	
Zambia		1973/1974/1978/1985
Zimbabwe		1955/1957/1969/1970/ 1978

*In animals (bold), humans (italic) or both (blue)

Disclaimer: The boundaries and names shown and the designations used on these map(s) do not imply the expression of any opinion whatsoever on the part of FAO concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers and boundaries. Dashed lines on maps represent approximate border lines for which there may not yet be full agreement. Final boundary between the Sudan and South Sudan has not yet been determined. Final status of the Abyei area is not yet determined.

Source: UN 2020, modified with the data from the United States Centers for Disease Control and Prevention (CDC) RVF Distribution Map with supplementary information (Munstermann, Delarocque and Formenty, 2012; Rolin, Berrang-Ford and Kulkarni, 2013; Paweska, 2015; Sumaye *et al.*, 2019; Nielsen *et al.*, 2020; CDC, 2021a, 2021b; EMPRES-i, 2021; OIE, 2021; WHO, 2021).

lifetime of the epidemic. Although many infected countries have not yet detected epidemics, over the years the range of infected countries affected by epidemic disease has progressively expanded.

Regionally, the interaction between rainfall and epidemics follows different patterns. In East Africa, El Niño is the major climate force driving the occurrence of epidemics. In West Africa, two patterns have been described: in the Senegal River Basin, similar to East Africa, prolonged rains are considered the driver, whereas in northern Senegal and Mauritania, two periods of rain with an intervening dry spell of around ten days are considered a causal pattern (Lacaux *et al.*, 2007; Soti *et al.*, 2012; Soti *et al.*, 2013; Caminade *et al.*, 2014). In Southern Africa, RVF outbreaks persisted over a four-year period from 2008 to 2011. During this period, outbreaks were mainly contained within specific areas, but in 2010, the disease was widely distributed across the region (Metras *et al.*, 2012). In South Africa there is evidence of significant virus circulation in the absence of outbreaks (van den Bergh *et al.*, 2019).

Given that many countries are infected with RVFV, and either have never experienced disease or do not experience disease for extended periods, the World Organization for Animal Health (OIE) defines three categories of national status:

- infected with RVFV but in an inter-epidemic period;
- infected with RVFV during an epidemic of RVF disease; and
- free of RVFV infection.

For infected countries that experience epidemics, the phased approach to response breaks down the epidemiological cycle into four phases:

- *Inter-epidemic period:* Infected countries without any specific warning of an approaching RVF epidemic or high-risk period.
- *Pre-epidemic period:* Infected countries that have received an RVF warning or warning of a high-risk period.
- *Epidemic period:* Infected countries that have detected a case of RVF disease in humans or animals.
- *Post-epidemic period:* Infected countries recovering from an epidemic that have not detected a human or livestock case in six months.

It should be noted that the post-epidemic period, defined here as six months, is for internal management purposes only. The current OIE Terrestrial Animal Health Code (OIE, 2019) does not define a waiting period for the resumption of trade after an epidemic.

IMPACT

The impact of RVF is diverse and wide-ranging. Not only are there direct effects of the disease on livestock and people, there are also major indirect social and economic effects brought about by the closures of abattoirs and markets, quarantine restrictions, import bans, the cost of surveillance and control interventions, and the collapse of demand for products due to public perceptions of risk. In addition to these, the disease has significant downstream economic effects on the economy, as rural communities and value chain stakeholders reduce their purchase of goods and services.

RVF is a major public relations challenge, and the actions of government are often designed to address public concerns while being of little epidemiological or health value. It is important that governments take action and show solidarity with and concern for affected or anxious groups of stakeholders. However, this has often resulted in ineffective regulatory actions that disrupt incomes and livelihoods in livestock production, or misguided interventions implemented only after the window of opportunity to change the course of the outbreak has passed.

During the 2006–2007 outbreak in Kenya which saw a market and slaughter ban, Garissa District officials reported their surprise at the number of families and wide range of livelihoods that were directly dependent on the local abattoir. It was estimated that 100 households with livelihoods that supported the slaughterhouse operation (food sales, transport, by-products, etc.) were affected (Rich and Wanyoike, 2010). District officials and families noted that the schools were in crisis, as the general public were unable to cover the normal fees and expenses due to the closure of markets (Mariner, unpublished data). The closures were timely and appropriate based on the public health requirements of that time, but the sale of livestock was the public's main means of generating cash to pay expenses. Current policy on markets, animal slaughter and value chains seeks to avoid closures and disruptions while assuring the safety of the workers, consumers and livestock products in these value chains.

During the same outbreak, red meat consumption collapsed across the country and the consumption of poultry products increased. Butchers' sales fell 95 percent, and around 28 percent of the butchers in Thika went bankrupt as they exhausted their savings and were unable to resume their enterprise (Rich and Wanyoike, 2010). The collapse in meat demand was a negative effect of poor risk communication, leading to panic. The lowering of the pH in aged meat inactivates the virus, and commercial meat procured from sites outside the outbreak area is not considered a significant risk for transmission. Most people are infected by direct contact with sick livestock at the outbreak site. This illustrates the importance and impact that risk communication can have.

Historically, RVF has been a major impediment to trade. Saudi Arabia implemented a ban on the importation of livestock from the Horn of Africa that lasted some six years as a result of the outbreak in Jizan in 2000. However, the Arabian Peninsula's environment supported suitable vectors and the disease remained endemic after 2000. The ban was continued during low-risk inter-epidemic periods, with serious economic consequences for exporting countries. The OIE has since revised the categories of national disease status for RVF to reflect the epidemiology of the disease, and this has helped to mitigate the negative impact on trade. As is described later in this document, developing a national RVF action framework is an additional measure that countries can take to build trading partners' confidence and mitigate the impact of RVF on trade.

CLIMATE CHANGE

The most recent reports on climate change indicate that the rate of change is greater than previously projected (IPCC, 2018). The effects of climate change on the epidemiology of RVF will be twofold: the direct impact of changing habitats (humidity and soil temperatures) on vector distribution and ecology will change risk profiles both geographically and across seasons and years, while there will also be an impact resulting from human responses to climate change (Ogden, 2017). Land use patterns will change as production activities adapt to new environmental conditions. Moreover, climate change results in human migration, which has significant effects on the epidemiology of disease (McMichael, C., 2015; Schwerdtle, Bowen and McMichael, 2017) and conflict (Bowles, Butler and Morisetti, 2015; Burrows and Kinney, 2016).

Temperature changes are predicted to be more severe in temperate regions than in tropical areas. Temperate regions are currently free of RVF, but the risk of spread is increasing. The spread of bluetongue through much of Europe is a prime example of the impact of climate change on arbovirus disease distribution (McMichael, A.J., 2015).

As climates are dynamic, the time at which modelling, early warning and risk assessment systems were developed should be taken into account. RVF risk will change over time, and ground truthing of vector distributions, predictive models and risk assessment will need to be constant features of RVF management. Environmental monitoring and field validation are an important component of RVF surveillance and applied research.

ONE HEALTH

The One Health transdisciplinary approach seeks to bring the human, animal and environmental sectors together in order to improve health and well-being and achieve a greater impact and better use of resources than could be achieved by each sector working separately. Rift Valley fever is an excellent example of a disease that is best addressed by a comprehensive One Health approach. As a vector-borne disease, the distribution of RVF is determined by environmental factors that create suitable habitats for the survival of *Aedes* mosquitoes, including their spread into new areas. Human outbreaks follow livestock outbreaks, and human infections primarily result from exposure to sick livestock or their tissues. Control of human infection is best achieved through environmental monitoring and timely interventions at the vector and livestock levels.

To be fully successful, the One Health approach needs to be coordinated at international, regional, national and sub-national levels, and across the relevant sectors (public health, animal health, forestry, fisheries, natural resources, land use planning, etc.). Excellent progress has been made in recent years in advancing One Health approaches, but much more needs to be done. Information sharing and consultation between disciplines is becoming much more common. However, dysfunctional competition between sectoral ministries and professions for resources and budgets is still a lingering constraint of the old approaches. The One Health coordination mechanism needs to be fully empowered to make decisions and allocate budgets in such a way as to maximize efficiency while working towards achieving health, economic and epidemiological results. By giving joint structures these powers, the competition between sectoral ministries and professions for budget resources should be rationalized.

Action frameworks

SITUATION ANALYSIS

Overview

There are essentially three strategic options for action frameworks:

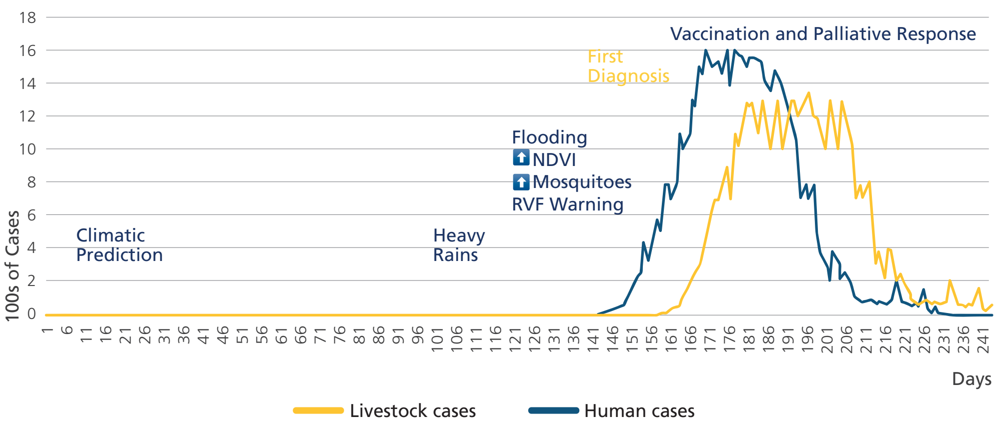
- **reactive** palliative or supportive actions implemented after the diagnosis of the first case;
- **pre-emptive** risk-based actions implemented in response to a climatic warning, designed to interrupt an evolving outbreak scenario; and
- **preventive** risk-based actions implemented during the inter-epidemic period to reduce the risk of an outbreak.

The **reactive** approach is the easiest to implement and, on the surface, appears to have the lowest control costs. However, it is also the least effective and undoubtedly the costliest of the three strategies when its impact on public health, livestock and trade is taken into consideration (Figure 2).

Figure 2. The epidemiological curves for livestock and humans are shown in blue and yellow, respectively. Events and reactive intervention options are described in blue. The first diagnosis in humans is noted in yellow.

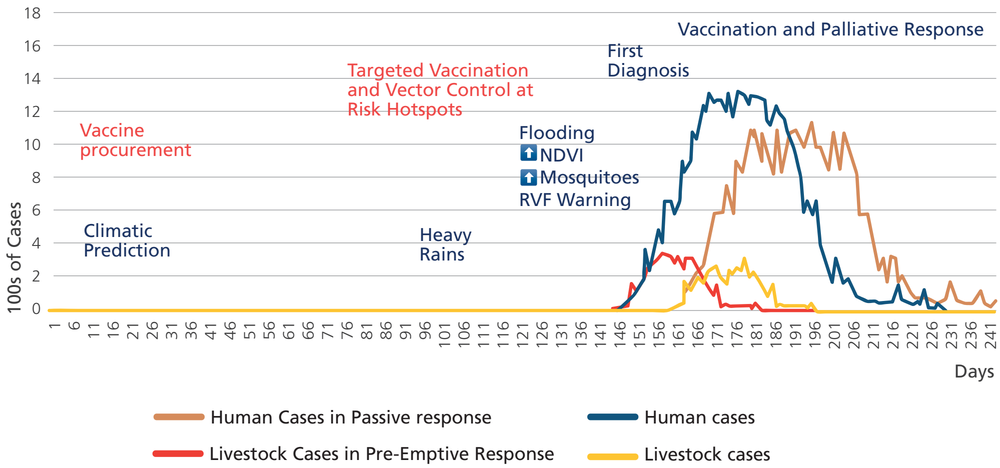
The **pre-emptive** approach, if carried out properly, has the potential to significantly reduce the incidence of the disease in livestock and humans in a cost-effective way.

FIGURE 2
RVF outbreak scenario following a passive response



Source: Jeff Mariner.

FIGURE 3
Potential impact of early warning and pre-emptive intervention compared to passive response after diagnosis



Source: Jeff Mariner.

It is without a doubt the most complex option and requires a high level of management to implement interventions in a timely manner. The investments pre-emptive control requires are significant, but the potential for a lesser impact on livestock, public health and trade can reduce the overall cost of the outbreak. Figure 3 compares the hypothetical impacts of the pre-emptive and reactive approaches. The pre-emptive approach, if well implemented, is believed to have the highest cost-effectiveness.

The **preventive** approach requires action – primarily in the form of vaccination and One Health risk communication – on a large scale during the inter-epidemic period. Large-scale interventions may continue for years at great cost. The level of management required is less than for the pre-emptive approach. This approach requires a serious open-ended commitment and resource prioritization, which may be justified when the minimizing the impact on public health is taken into account. It may result in less severe outbreaks or potentially prevent them altogether.

In Figure 3, events and interventions to mitigate on-going outbreaks are shown in blue. Pre-emptive actions are noted in red. The red and yellow epidemiological curves show the potential impact of pre-emptive interventions on livestock and human cases, respectively.

For pre-emptive strategies to be effective, early warning systems need to provide sufficient lead time to mobilize and implement interventions. Jost *et al.* (2010) collected detailed stakeholder observations on the actual timeline of the 2006–2007 outbreak in Kenya which have provided important lessons for the prediction of outbreaks and risk management. Table 1 shows the time intervals from the observed onset of rains to key events in the evolution of the risk of an outbreak. On average, the onset of the first cases as reported

TABLE 1
Elapsed time between milestones in the 2006–2007 RVF outbreak in Kenya

Event	Average elapsed days since previous event
Onset of heavy rains	0
Mosquito swarms	23.6
First case in livestock	16.8
First case in human	17.5

Source: Elaborated by author with data based on Jost ***et al.***, 2010.

by livestock owners was around only 17 days after mosquito swarms were observed and approximately 40 days after heavy rains. Human cases were observed around 18 days after the first livestock cases (Jost *et al.*, 2010).

The RVF early warnings based on factors including information on vegetation growth (the normalized difference vegetation index[1]) were issued in November 2006. In retrospective interviews, community members reported that the first observed cases of livestock and human disease occurred in November, before the first official livestock case was reported in December 2006. Although RVF alerts based on the normalized difference vegetation index (NDVI) are very valuable since they are based on indicators that develop simultaneously with vector populations, evidence suggests that they are unlikely to be issued before the onset of the first livestock cases on the ground (the beginning of the outbreak).

More recently, the early warning models have placed more emphasis on a broader range of indicators, including sea surface temperatures (SST), and on the application of more advanced remote sensing products and techniques than those used in 2006.

Over the past five years, the Food and Agriculture Organization of the United Nations (FAO) has developed a prototype RVF Early Warning System based on near real-time satellite images and modelling to provide decision makers with near real-time RVF risk maps for West, East and Southern Africa (See Box 1, page 23). The tool was successfully used to conduct rapid risk assessments of RVF outbreaks in Niger (2016), Uganda (2017/2018) and South Sudan (2018), and predict RVF occurrences in West Africa, South Africa and Kenya between 2017 and 2019, allowing preventive and control measures to be implemented in countries at risk of RVF occurrence up to two months before the recognition of the first signs of RVF infection. This prototype has substantially improved the model's ability to identify areas at risk of RVF vector amplification, and provided a proof of concept for the development of the web-based RVF Early Warning Decision Support Tool (RVF DST) that was piloted in three RVF-endemic countries in East Africa: Kenya, Tanzania and Uganda. It is now believed that warnings may precede the first signs of outbreaks by six to eight weeks, depending on the region in question (see Table 2), but more field validation how

[1] The normalized difference vegetation index (NDVI) is an indicator that uses remote sensing to detect visible red and infrared spectral reflectance and thus determine whether or not an area of land contains live green vegetation. Simply put, in the context of arthropod vector activity, whereever there is green growth after rainfall, there will also be mosquito vectors.

the actual onset of livestock cases compares to the official detection of outbreaks and early warnings is needed. Although the web-based RVF DST allows for some pre-emptive action to be taken, it may fall short of the four months needed to fully mobilize interventions such as vaccinations in the absence of prior procurement and preplacement of supplies. These points highlight the challenges of implementing pre-emptive approaches.

The desired outcome of the pre-emptive and preventive strategies is a reduction in the severity or frequency of outbreaks. It is difficult to make an evidence-based argument in favour of either strategy, as decades of experience and evaluation of well-implemented strategies would be required. The RVF Decision Support Framework highlighted the challenge to delivery of pre-emptive responses, while noting the high cost of open-ended preventive approaches lasting several years or decades (Consultative Group for RVF Decision Support, 2010). On the other hand, Saudi Arabia has been pursuing a preventive vaccination strategy since their first outbreak in 2000 and has not experienced an outbreak despite continued virus circulation. This suggests, but does not prove, that their approach has been successful. Moreover, a cost-effectiveness analysis by Kimani *et al.* (2016b) found that preventive vaccination was justified from a public health perspective, if not from the perspective of the disease's impact on livestock alone.

At present, most countries lack a clear action framework that identifies the strategic approach being used, and instead adopt a spontaneous mixture of all three approaches. Strategic planning should include a clear statement of approach with defined objectives, activities, performance indicators and expected outcomes. Post-outbreak analysis is essential to making evidence-based decisions on the strategic approaches and specific outbreak response actions needed.

The availability of an approved national action framework will help reassure trade partners that the country is aware of its RVF status and able to respond appropriately.

One Health coordination

At the conceptual level, the One Health approach is widely accepted, and significant change is taking place in the way human and animal health, and to some extent environmental services, are perceived, managed and delivered. However, reforming institutional approaches developed over centuries is not always an easy task that can be accomplished in a decade. The attitudes, expectations and biases of each sector's professional culture are formed over the lifetimes of the individuals who make up these professions. They are based on the history of these professions and the training or education that their members receive. Programmes promoting the full implementation of One Health are supporting structural change in many countries, as well as the development of new professional training curricula. International and regional organizations, national institutions (ministries, professional bodies and practitioners, etc.) and sub-national institutions are all involved.

As a model One Health disease, RVF is often at the forefront of the institutional adoption of One Health approaches. It is difficult to generalize across all affected countries, but most have created some form of joint RVF management office or joint zoonosis management office responsible for managing RVF. The most cost-efficient responses to the public health impacts of zoonoses involve prevention in animals and animal management to decrease the opportunities for pathogen spillover to humans or other new hosts. RVF and rabies are excellent examples of this. Historically, it was difficult for animal health departments to secure a large enough budget to implement veterinary public health actions. Ideally, RVF risk mitigation would be carried out as part of a One Health approach that applies to all zoonotic diseases, and the RVF management plan would be one part of a comprehensive One Health plan.

A study by Kimani *et al.* (2016a) looked at One Health in Kenya using RVF as a case example. Given the epidemiology of RVF, district veterinary officers (DVOs), district medical officers (DMOs) and pastoralists were considered key players in the response to the disease. The perception of these three key groups was that they themselves were falling short in their roles as far as managing the impact of RVF was concerned. They attributed this to a lack of resources and logistics, as well as a weak interface between the health services and pastoralists. The study noted that access to services, particularly animal health services, was an important constraint in RVF management.

Initiatives are underway to develop and test integrated service delivery models that combine the delivery of human, animal and environmental services into one visit. These range from mobile clinic approaches to integrated community health and community animal health networks. Local government and NGOs are pioneering these efforts.

International and regional organizations continue to innovate in One Health information sharing for RVF. FAO and partners such as the World Health Organization (WHO), OIE, the United States National Aeronautics and Space Administration (NASA), and recently, the Intergovernmental Authority on Drought and Development (IGAD) are at the forefront of this innovation. They have been collaborating over the years to issue and disseminate RVF alert messages (FAO, 2006, 2008, 2014, 2015, 2017, 2020), and subsequently deploy One Health country-level field missions (e.g. those conducted in Madagascar in 2008, Uganda in 2019 and Mauritania in 2020). National early warning systems have also been put in place following RVF outbreaks: Mauritania, for example, launched joint human, animal and vector investigations of the country's 2003 outbreak (Faye *et al.*, 2007). New RVF alert platforms resulting from multi-agency collaboration have issued more timely alerts for several of the recent outbreaks across Africa. What is more, the situation is continuously improving. One Health projects are now working on fully integrated national surveillance information systems. International agencies should take note of developments downstream in relation to the coordination of national decision making and interventions.

The effective management of RVF requires a One Health MCM with the authority to manage resources across sectors, report disease, issue alerts and declare outbreaks. Institutionally, those close to the ground are moving in this direction.

Research, targeted studies and analysis

Research and brief targeted studies and assessments have played an important role in expanding our understanding of RVF epidemiology and ability to assess and map the risk of RVF and diagnose and control the disease. Climate change means that aspects of RVF ecology such as vector distributions are not static and need to be periodically updated. An example of an integrated One Health assessment of the extent of the outbreaks in Senegal in 2013–2014 is provided by Sow *et al.* (2016). The sections that follow on risk assessment and mapping and early warning systems are examples of the state of science and RVF.

It would be a distraction from the main purpose of this document to review all the advances in RVF research over the last decade. Suffice it to say, that the volume of publications attests to the importance with which this disease is perceived by professional communities.

Major advances include:

- improved tools for forecasting climatic RVF risk factors that integrate expert knowledge (e.g. the web-based RVF DST);
- a better understanding of risk factors associated with the spread of RVF;
- the ability to produce accurate RVF alerts and risk maps;
- a better understanding of the endemic persistence and transmission of RVF; and
- improved knowledge of the risk factors associated with transmission to humans.

The challenges that remain are the following:

- the lack of a field diagnostic assay/platform to support surveillance;
- a lack of the capacity to convert RVF risk forecasts into actionable items at the national level;
- insufficient economic analysis comparing RVF prevention measures to other disease priorities;
- the absence of novel vaccine candidates representing a marked improvement in comparison with currently available vaccines;
- the national registration of available RVF vaccines; and
- the lack of an established approach to RVF risk assessment.

Beyond stressing its importance for building on successes and overcoming remaining challenges, this document will not discuss research. Instead, it will indicate where targeted studies and assessments could play a role in surveillance and control.

Risk assessment and mapping

Although there are a number of examples of risk assessments and risk mapping for RVF, there is currently no consensus on the methodology for RVF risk assessment. Appropriate methods need further development and their accuracy must be validated. This is essentially an applied research activity, where data from surveillance, targeted studies and sentinel herds will be used to move from the piloting of methods to making predictions built on strong foundation of evidential analysis. Some examples of the methods used in RVF risk assessment include multicriteria decision analysis, disease and risk modelling, vector modelling and regression analysis of risk factors.

With regard to qualitative methods, the FAO–OIE–WHO Tripartite Zoonoses Guide (WHO, OIE and FAO, 2019), the zoonotic risk assessment guide that is part of the guide (WHO, OIE and FAO, 2020), and GLEWS+ (Global Livestock Early Warning System) rapid risk assessment guidelines (FAO, 2021) present a multisectoral approach to conducting qualitative risk assessments aimed at addressing animal health and zoonotic disease threats at the national, regional and global levels. These documents provide good guidance on the principles of risk assessment but more work is needed to develop guidelines that fully address the unique environmental components of the risk of vector borne diseases such as RVF.

In the literature, considerable progress has been made in relation to identifying risk factors such as vector distributions, as well as the determinants of vector distribution, such as hydrology patterns and soil types, which are important for mapping risk (Munyua *et al.*, 2016).

Another example of this progress is provided by Clements *et al.* (2007), who carried out a sophisticated Bayesian spatial regression analysis of ecosystem variables, including distance to ponds, identified seasonal peak rainfall and the presence of pond ecosystems, which they took to be the principle risk factors in Senegal.

Most risk mapping methods combine quantitative, semi-quantitative and expert opinion methods. A mapping study of the Maghreb region analysed factors driving vector density and found that the northern regions of the Maghreb were moderately suitable for enzootic transmission and highly suitable for epizootics (Arsevska *et al.*, 2016). This should be contrasted with the European Food Safety Authority (EFSA) risk analysis discussed below, which concluded that there was insufficient data to analyse the risk of endemic establishment in an area which included the Maghreb. A study from Kenya reported methodologies for ranking indicators such as the frequency of outbreaks and severity of outcome. The authors noted that the final ranking of districts required direct adjustment by experts (Munyua *et al.*, 2016).

The OIE approach to risk assessment (RA) focuses on assessing the risk of new infectious agents being introduced to a location through the trade in animals or commodities. For the most part, however, RVF outbreaks emerge in areas where the virus has already been periodically circulating.

For virus-free countries with suitable vectors, the economic consequences of the disease becoming endemic to vector populations are the most significant concern. The European Food Safety Authority conducted a risk assessment of the introduction of RVF to virus-free areas in the southern Mediterranean Basin (EFSA, 2013), which was subsequently updated in 2020 (Nielsen *et al.*, 2020). In the original study, competent vector species were mapped and a risk model based on parameters expert opinion was created. The analysis indicated that areas of the southern Mediterranean Basin were at risk of spread from endemic countries, most likely due to the movement of animals. The updated analysis also considered the movement of animals to be the pathway that posed the greatest risk, but indicated that the risk of spread to the European Union was very low given the strict animal import controls in place. It noted that the European Union should maintain strong surveillance measures due to the risk of the spread of RVF to neighbouring countries and the risk posed by the spread of infected vectors.

Statements concerning the way in which RVFV is spread to new areas are often based on circumstantial evidence. The relative importance of the movement of animals compared to vector movements or climate change has been the subject of much debate and speculation. Statements concerning the sources and spread of RVF should be backed by genomic data that demonstrate the relationship between viruses and support the hypotheses proposed. For example, the undetected transmission of a virus may precede outbreaks by decades. In the case of the 2016 outbreak in Niger, high RVF seroprevalence levels were found as far back as the 1980s (Mariner, Morrill and Ksiazek, 1995), suggesting that the virus may not have been a recent introduction and had been present for more than 35 years before clinical cases were detected. Genomic analysis can provide solid evidence for understanding the source of the 2016 RVF outbreak in Niger.

The specific correlation between weather and the onset of outbreaks is regionally diverse. The risk relation between El Niño events and RVF outbreaks is well established for the Greater Horn of Africa (GHA). In West Africa, two scenarios have been described: in the more arid areas of northern Senegal and Mauritania, RVF outbreaks have been linked to patterns of two rainy periods separated by a dry period, whereas in the Senegal River Basin, a period of prolonged rainfall similar to the GHA scenario has been proposed as a risk factor. In Southern Africa, associations with rainfall and the NDVI have been reported, but these patterns are less clear than in the GHA. A pattern of annual outbreaks in the region was reported between 2010 and 2012, with the highest frequency of cases between January and April (Glancey, Anyamba and Linthicum, 2015). Detailed temporal-spatial analysis of outbreaks occurring between 2008 and 2011 has also been carried out for Southern Africa (Metras *et al.*, 2012). After a classic pattern of intermittent outbreaks with multi-year inter-epidemic periods, Mauritania experienced outbreaks in four of the five years between 2010 and 2015 (Faye *et al.*, 2014; Sow *et al.*, 2014; Boushab *et al.*, 2016; Sow *et al.*, 2016), as well as more recently in 2020.

Numerous examples of risk maps are available. It has been shown that suitable habitats and vectors exist outside the current range of RVFV, and if the virus were to spread to these populations, there is no known method of elimination.

Risk assessments and risk maps are not static. Climate change affects average temperatures, seasonality, the frequency of severe weather events (McMichael, A.J., 2015), precipitation distribution and humidity. Climate change can also alter the vector competence of species already present in an area. The range of RVFV vectors will thus expand into new areas, and in existing endemic areas, the frequency and patterns of outbreaks will change.

There is a clear need for applied research to review and validate the progress made in relation to RVF risk analysis. Risk analysis methods should be disaggregated into infected countries and those at risk of becoming infected. International investment should be mobilized to fund collaborations between expert risk assessment organizations such as EFSA, researchers and national stakeholders to validate risk analysis methods. As with prediction systems, future events are the evidence base for evaluating the accuracy of risk assessments. Data from surveillance systems, outbreak analyses and sentinel herd systems will be essential for validating both risk analysis and RVF prediction methods. Further, risk assessments should include an evaluation of the consequences of endemic and epidemic infection and mitigation responses on livelihoods, households and community institutions deemed at risk in the event of an outbreak, allowing policymakers to make informed decisions.

Early warning

Overview

Pre-emptive responses to RVF outbreaks require sufficient lead time. As vaccines are not typically stocked in sufficient quantities to mount a full response to an RVF warning, lead times of up to four months prior to the onset of transmission are required to allow procurement (Consultative Group for RVF Decision Support, 2010). Seasonal weather projection approaches provide valuable risk information but cannot provide definitive warnings of RVF outbreaks. The most accurate RVF alert systems use indicators based on current climatic and environmental conditions, such as the NDVI. These indicators are influenced by humidity and soil temperatures, and thus closely parallel favourable conditions for vectors. Such alerts are very valuable but problematic as a form of early warning, as in general they coincide with the onset of the outbreak: during the 2006–2007 outbreak in the GHA, livestock owners were already observing animal cases of RVF at the time the NDVI-based early warning was issued (Jost *et al.*, 2010). This can be explained by the fact that the warnings relied heavily on the presence of indicators such as NDVI that occur in conjunction with the vector blooms that initiate the outbreaks in livestock (Anyamba *et al.*, 2010).

Evaluation of how promptly past alerts were issued is problematic, as this depends on how sensitive the surveillance is. In prior decades, human cases were almost always detected first, suggesting that livestock outbreaks lasting several weeks had been missed. More recent outbreaks have for the most part been detected in livestock first, and this indicates a substantial improvement in surveillance. The current web-based RVF DST developed by FAO, which includes past, current and projected environmental and climatic indicators, appears to have improved the lead time from the issuing of warnings to the detection of outbreaks (Box 1, page 23 and Table 2, page 28). This may encourage more active surveillance in the lead-up to outbreaks, and at least in part explains the improvements in index case detection. The validation and improvement of predictions will require better One Health coordination and more data from environmental monitoring, active surveillance and sentinel herds.

Regional weather forecasts, El Niño predictions and information on rainfall anomalies and RVF risk maps are regularly updated at:

- National Weather Service. Climate Prediction Centre: NMME forecasts for the international regions (https://www.cpc.ncep.noaa.gov/products/international/nmme/nmme.shtml)
- Columbia Climate School. International Research Institute for Climate and Society (https://iri.columbia.edu/our-expertise/climate/forecasts/seasonal-climate-forecasts/)
- National Weather Service. Climate Prediction Centre: El Niño/Southern oscillation (ENSO) diagnostic discussion (http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_advisory/enso-disc.html)

The IGAD Climate Prediction and Applications Centre (ICPAC) monitors forecasts and remote sensing data for the GHA and provides summary projections by country for a number of agriculture and health issues, including RVF. In 2020 FAO and IGAD began working together to issue joint RVF alert messages and assessments:

- IGAD Climate Prediction and Applications Centre (ICPAC) (http://www.icpac.net)
- IGAD Centre for Pastoral Areas and Livestock Development: IGAD and FAO Join Forces Against Rift Valley Fever (https://icpald.org/igad-fao-join-forces-against-rvf/)
- IGAD Centre for Pastoral Areas and Livestock Development: RVF: IGAD and FAO Advise Countries to Remain Vigilant (https://icpald.org/rvf-countries-remain-vigilant/)
- FAO and IGAD alert countries in eastern Africa to enhance preparedness for Rift Valley fever (http://www.fao.org/3/cb5141en/cb5141en.pdf)

The GLEWS+ early warning system is a collaboration between FAO, WHO and OIE, and addresses disease risk in general:

- The Joint FAO-OIE-WHO Global Early Warning System for Health Threats and Emerging Risks at the Human-Animal-Ecosystems Interface (http://www.glews.net/)

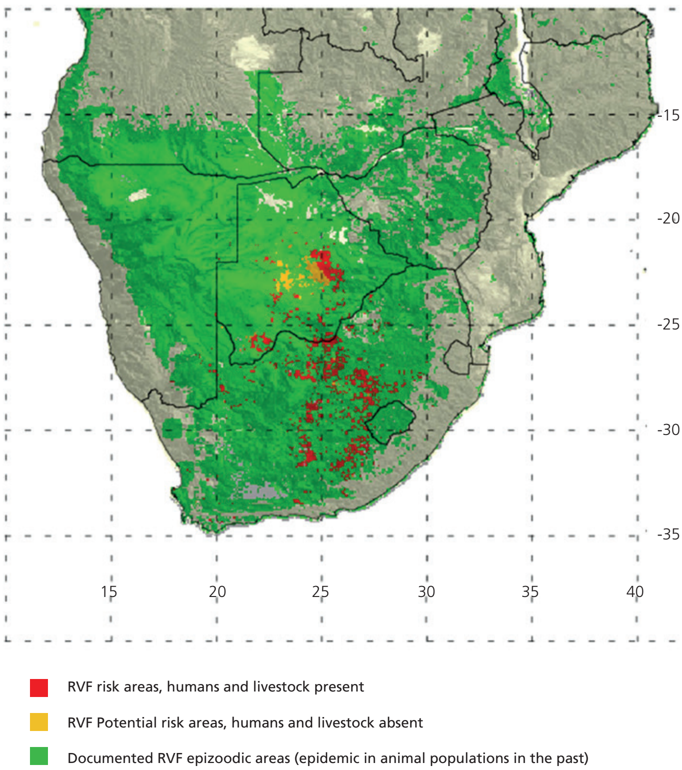
Good progress has been made in relation to forecasting high-risk conditions and the issuing of outbreak alerts. Although decision makers are showing more interest in forecasting and alerts, more needs to be done to increase ownership of the required response actions and the way in which alerts are translated into prompt action appropriate to the level of risk. Experts also note that it is important to continue to collect data on the ground to further validate and refine models.

Reports indicate climate change is accelerating and ecological systems will change over the coming decades (IPCC, 2018). Warming and increases or decreases in precipitation and humidity will likely produce changes in the ecosystems and in the geographic distribution of vectors. The frequency of weather anomalies will also change, and there may also be complex interactions or threshold effects that are difficult to assess. The one certainty, however, is change.

Agricultural Research Service risk maps

In Figure 4, an RVF risk map produced by the United States Department of Agriculture (USDA) Agricultural Research Service (ARS) forecasting at-risk areas for February 2019 is shown. Areas shown in green are potential epizootic areas identified from thresholding of climate variables (rainfall and NDVI) and occurrences of previous outbreaks. This includes the likely endemic area in the Republic of South Africa. Areas currently considered at risk (indicated in red) are based on rainfall information. These risk maps were updated and made available quarterly up until May 2019, and could be consulted to allow the early procurement of vaccines.

FIGURE 4
Agricultural Research Service risk map for RVF in Southern Africa for February 2019



Source: USDA ARS https://www.ars.usda.gov/ARSUserFiles/60360500/rvf/archives/0119.pdf downloaded from https://www.ars.usda.gov/southeast-area/gainesville-fl/center-for-medical-agricultural-and-veterinary-entomology/docs/rvf_archivereports/.

El Niño risk-mapping model

The El Niño–Southern Oscillation (ENSO) risk-mapping model produced by the United States of America's National Oceanic and Atmospheric Administration (NOAA) was the first approach to provide more accurate alerts of an RVF outbreak. It was able to issue alerts two to six weeks before the first official report of the major December 2006 outbreak in East Africa. However, retrospective analysis has indicated that the disease was already being observed in livestock in the field at the time of the alert (Jost *et al.*, 2010). The model produces RVF risk maps based on predictions of ENSO-related climate events using satellite data on sea-surface temperatures, rainfall and vegetation (NDVI) levels. It was able to accurately map and issue timely alerts of disease activity as RVF moved from southern Somalia through Kenya to northern Tanzania (Anyamba *et al.*, 2009). Alerts based on the NDVI are extremely valuable when it comes to taking action as they indicate that an outbreak is likely escalating. However, alerts based on current conditions alone are not triggered early enough to allow pre-emptive responses. This is probably due to the fact that sudden and massive increases in RVF vector numbers occur under the same NDVI conditions that trigger the alert.

BOX 1

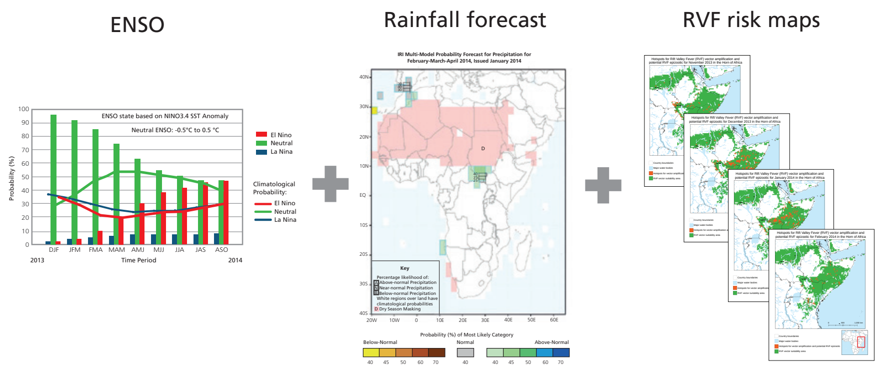
The FAO RVF Monitoring/Early Warning System and web-based RVF Decision Support Tool (RVF DST)

FAO takes an active role in RVF monitoring and forecasting in sub-Saharan Africa using (i) a near real-time climate-based model and an Early Warning System (EWS) developed by NASA's Goddard Space Flight Center (GSFC) and adjusted, calibrated and validated by FAO in East and West Africa, and (ii) a multi-criteria decision analysis (MCDA) model based on expert consultation (Tran *et al.*, 2016). The first model builds upon the work described in the previous paragraphs (Anyamba *et al.* 2009). It is dynamic and allows monthly forecasting of potential hotspots for vector amplification. The second model predicts the likelihood of RVF occurrence, in countries with scientific evidence of RVF virus circulation but without any reported cases. FAO was also involved in facilitating the consultation process in the formulation of the Decision Support Framework (DSF), which serves as a guide for appropriate responses to RVF in East Africa (Consultative Group for RVF Decision Support, 2010).

The FAO RVF Monitoring Tool and Early Warning System (EWS) produces monthly risk maps and risk assessments for Africa. The system makes use of three main sources of data (see Figure 5): long-term ENSO climate predictions, past and current rainfall estimates and forecasts, and past and current vegetation data and forecasts (NDVI). The model is dynamic and computes cumulative climatic anomalies across a time span of the last three consecutive months. If the algorithm predicts a warm event such as El Niño and persistently shows areas of unusually high levels of rain and vegetation, the risk of vector amplification is high. The co-occurrence of susceptible livestock species and humans in these high-risk areas then increases the likelihood of an RVF outbreak. The FAO RVF EWS's panel of experts verifies the at-risk areas with FAO officers on the ground and assesses if conditions warrant an RVF alert.

The RVF EWS was originally developed by NASA, FAO and WHO and was then calibrated and validated by FAO comparing model results to retrospective analysis of field observations and outbreaks. The vegetation indicator (the NDVI) is representative of several of the factors that determine when conditions are suitable for mosquito breeding and development: temperature, rainfall and soil humidity. Warm conditions increase vector feeding (biting) rates and egg production and decrease the length of the vector's reproductive cycle. Increased feeding rates also mean increased transmission rates.

FIGURE 5
Data used by the FAO RVF Early Warning System

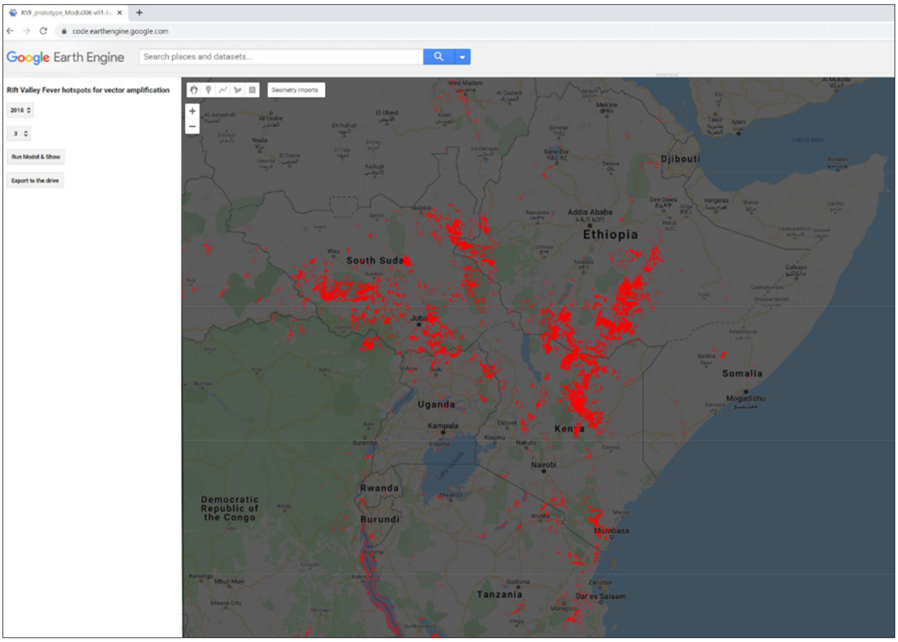


Sources: (a): IRI ENSO Forecast 2014 January Quick Look (https://iri.columbia.edu/our-expertise/climate/forecasts/enso/2014-January-quick-look/). (b): IRI Multi-Model Probability Forecast for Precipitation for Feb-Mar-Apr 2014, issued January 2014 (https://iri.columbia.edu/our-expertise/climate/forecasts/seasonal-climate-forecasts/). (c): FAO.

Figure 5 shows data used by the FAO RVF Early Warning System, which uses climatic predictions and rainfall and vegetation patterns to produce risk maps that inform decisions to issue RVF alerts.

In 2017, the FAO EWS was improved and implemented in Google Earth Engine (GGE), an internet-based platform for global environmental analysis. The transition from desktop to the GEE platform streamlined and optimized the preprocessing of the satellite images, allowing near real-time RVF risk mapping and thus increasing early warning capacity (Figure 6). It also provided easy access to near real-time climatic and environmental data from a range of different institutions, which allowed near immediate updates to predictions. The RVF GEE EWS provided decision makers with more up-to-date RVF risk maps for monitoring, preventing and controlling RVF outbreaks in livestock and humans. The tool represented a proof of concept, and demonstrated the successful use of information technology in animal health and early warning forecasting. The tool was successfully used to conduct rapid risk assessments of RVF outbreaks in Niger (2016), Uganda (2017/2018) and South Sudan (2018), as well as forecast RVF occurrences in the Gambia, Senegal, Mauritania, South Africa, Kenya, Rwanda and Sudan between 2017 and 2019 (Table 2, page 28).

FIGURE 6
The FAO RVF Monitoring and Early Warning Tool on the Google Earth Engine platform



Disclaimer: Final boundary between the Sudan and South Sudan has not yet been determined. Final status of the Abyei area is not yet determined.

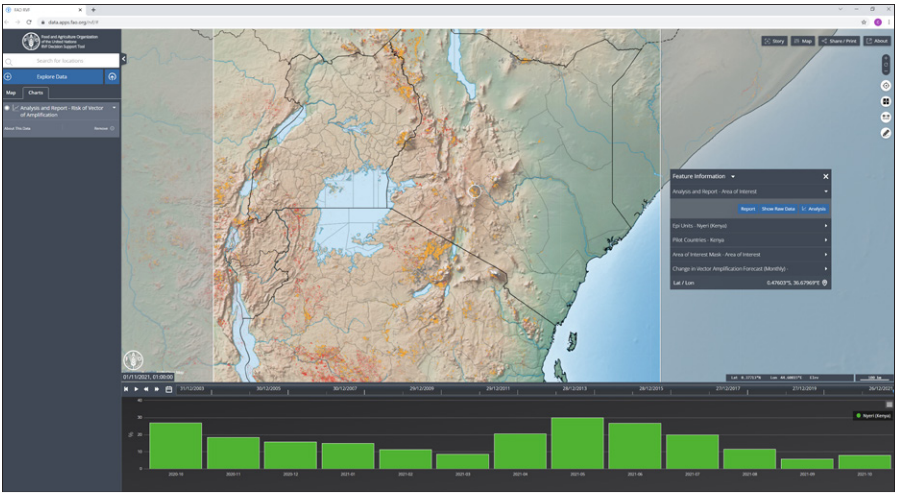
Source: UN 2021, modified with data from FAO RVF Monitoring and Early Warning Tool on the Google Earth Engine platform, March 2018.

In Figure 6, the FAO RVF Monitoring and Early Warning Tool on the Google Earth Engine platform shows the predicted hotspots for RVF vector amplification (red areas) for March 2018. The RVF outbreak (black star) was first observed in Kenya on 11 May 2018 and reported on 6 June 2018 (see Table 2, page 28).

The web-based RVF Early Warning Decision Support Tool (RVF DST)

More recently, to help guide appropriate national responses to RVF, FAO has developed a web-based RVF Early Warning Decision Support Tool (Figure 7) that combines near real-time RVF risk maps (based on RVF dynamic risk-mapping model) with relevant geospatial data (including observed and forecasted precipitation and NDVI anomalies, El Niño forecasts, past and current RVF occurrences, geographic distribution and estimates of the numbers of livestock species at risk of RVF and, human population, market places, road networks and available animal trade routes, irrigation areas) and expert knowledge in RVF eco-epidemiology (e.g. the Decision Support Framework produced by FAO and the International Livestock Research Institute [ILRI]), risk assessment and categorization, and recommended actions. In parallel, a One Health (OH) workshop on RVF preparedness, response and contingency plans was organized with a pool of international,

FIGURE 7
The FAO web-based RVF Early Warning Decision Support Tool



Source: FUN, 2022 modified with data from FAO web-based RVF Early Warning Decision Support Tool, 2021.

regional and national experts, as well as epidemiologists from veterinary services in the target countries. The RVF DST was developed in collaboration with the national veterinary services, FAO global, regional and national offices, and the FAO Information Technology Services Division in order to guarantee sustainability by creating ownership among the beneficiaries.

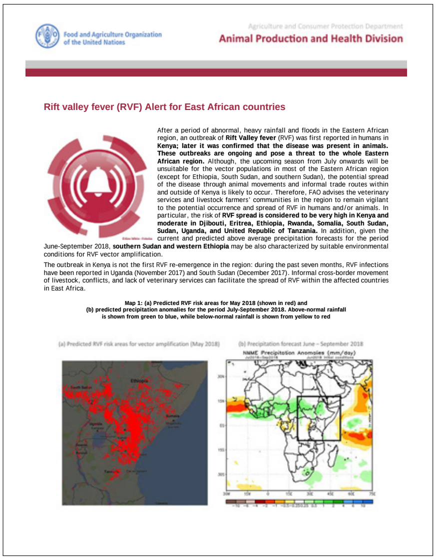
The web-based RVF DST has been incorporated into FAO's online Hand-in-Hand (HIH) geospatial data platform and piloted in three RVF-endemic countries in East Africa (Kenya, Uganda and Tanzania), providing decision makers with near real-time RVF risk maps and assessments, which are updated on a monthly basis at a spatial resolution of 250 m (FAO, 2019). The HIH geospatial platform is a web-based dashboard providing a suite of geospatial data from FAO and other agencies for use by all countries and partners, promoting transparency and collaboration. The platform has significantly increased the interoperability of FAO geospatial data, maintaining the different FAO geospatial applications more cost-effective, including the web-based RVF DST.

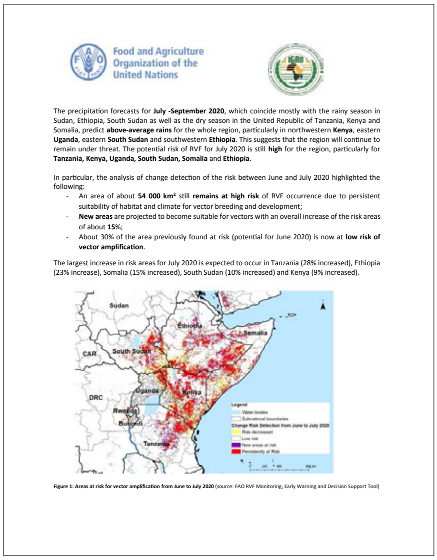
The web-based RVF DST has increased FAO's capacity to identify high-risk areas and issue alerts and early warning messages to allow prevention and control in countries at risk of RVF occurrence well before the first signs of RVF infection in the countries are reported (Figure 8 and Table 2, page 28). The tool's outputs can be used in combination with the results of other RVF monitoring and surveillance activities (e.g. sentinel herd monitoring) and expert knowledge to permit near real-time validation of potential RVF hotspots, thus informing decision makers and supporting early responses. The overall result is an increased state of vigilance and preparedness.

The web-based RVF DST is a good example of how near real-time modelling, risk forecasting and digital innovation can increase preparedness and improve pre-emptive measures. The tool is used to build countries' capacity in relation to early warning and forecasting (Figure 8).

FIGURE 8

Examples of RVF alert messages for East African countries





Source: Left: FAO RVF alert (June 2018). Right: Joint FAO–IGAD alert (July 2020)

Future developments in the system should include: (i) a dedicated ground truthing system to rapidly verify the at-risk areas and weather conditions on the ground; (ii) scaling-up of the tool to other regions such as western Africa, and/or other diseases; and (iii) capacity building to improve risk-based surveillance.

TABLE 2
Recent FAO RVF warnings and onset of disease. The observation date is the date a disease event was observed in the field. The reporting date is the date a disease event was reported.

Countries	Date of FAO risk assessment/alert	Reporting date (EMPRES-i)	Observation date (EMPRES-i)
The Gambia	15 Sept 2017	19 Jan 2018	10 Dec 2017
Senegal	15 Sept 2017	01 Mar 2018	28 Feb 2018
South Africa	5 Feb 2018	16 May 2018	28 Apr 2018
Kenya	Mar 2018	06 Jun 2018	11 May 2018
Rwanda	Mar 2018	18 May 2018	06 May 2018
Kenya	10 Oct 2018	14 Feb 2019	31 Dec 2018
Sudan	10 Oct 2018	21 Nov 2018	04 Oct 2018
Mauritania	10 Oct 2018	26 Nov 2018	04 Nov 2018
Sudan	9 Sept 2019	06 Oct 2019	19 Sep 2019
Horn of Africa	16 Oct 2019	02 Dec 2019 (in Uganda)	15 Nov 2019
Mauritania/Senegal	24 June 2020	16 Sept 2020	04 Sep 2020
Kenya	24 June 2020 15 Jan 2020 2 Apr 2020 15 May 2020 10 July 2020 7 Oct 2020	22 Dec 2020	15 Mar 2020 19 Aug 2020 19 Nov 2020

Source: EMPRES-i, 2020.

Trade measures

The OIE provides clear risk-based guidelines for the importation of animals that stipulate that livestock imports should be sourced from RVFV infection-free areas and have been either vaccinated against RVF 14 days prior to shipment or protected from exposure to RVFV infected vectors en route. When animals are sourced from RVFV-infected areas during an inter-epidemic period, they should be free from clinical signs of RVF and have been either vaccinated or kept in insect-free quarantine facilities for the 14 days before shipment. If animals are sourced from an infected country during an epidemic, they should be sourced from an area unaffected by the epidemic and have been both vaccinated and kept in insect-free quarantine facilities for 14 days before shipment. For a more complete description of this guidance, please refer to the chapter on RVF in the OIE's Manual of Diagnostic Tests and Vaccinations for Terrestrial Animals (2016). Any changes to this guidance are published annually on the OIE website (www.oie.int).

Required mitigation measures on meat and milk do not create undue barriers to trade. Meat and meat products can be exported provided that they are produced from animals

BOX 2
RVF national action plans

During the inter-epidemic period, countries should prepare five-year national action plans that define RVF mitigation objectives and the activities required in order to realize these objectives. The plans should define strategies and put in place all everything needed to respond to an outbreak prior to a new RVF outbreak alert being received. They should include:

- a One Health statement of objectives that includes the objective of RVF mitigation;
- a comprehensive One Health coordination and decision-making mechanism that covers RVF;
- a national risk assessment and risk map of RVF hotspots to inform risk-based surveillance and interventions;
- a risk-based environmental, livestock and vector surveillance plan that includes forecasting and early warning tools;
- an achievable vaccination policy that includes targets for preventive and/or pre-emptive vaccination and a realistic plan for procurement and deployment within the time frame of an epidemic;
- pre-registration of RVF vaccines to allow for rapid deployment;
- objectives and plans for vector monitoring and control;
- a communications plan for both national and international stakeholders;
- a social and economic impact mitigation plan to be implemented during the epidemic and post-epidemic phases; and
- a capacity-building plan to to support the above-specified measures.

This Action Framework suggests options for response measures and provides guidance on good practice which may assist in the preparation of a country's national action plan.

that showed no signs of RVF in the 24 hours before slaughter at a regulated slaughter facility. Meat should be matured at a temperature above 2°C for at least 24 hours. The pH change associated with the maturation of meat inactivates RVFV.

INTER-EPIDEMIC PERIOD

National action plan

The inter-epidemic period is the critical period for building the capacity to respond to new outbreaks. This section provides guidance on how a detailed RVF national action plan, to be fully implemented over a five-year period, might be prepared. The RVF action plan is best produced as part of a country's national One Health agenda, although this is beyond the scope of this document. Guidance on the optimal use of the range of tools available, as well as on the formulation of capacity-building plans to fully develop and ensure the capacity is in place, is also outlined.

RVF action plans should include:

- a statement of One Health RVF objectives;

- a One Health RVF MCM consisting of public health managers, veterinary authorities, livestock producers and traders, those participating in the livestock product value chain, meteorologists, entomologists and wildlife ecologists, financial managers, communication specialists and community representatives;
- a national risk assessment and risk map of RVF hotspots;
- a clear statement of preventive (inter-epidemic), pre-emptive (pre-epidemic) and palliative (epidemic) measures;
- targets, desired outcomes and time-bound performance indicators for all measures; and
- a review of action taken following its completion (carried out by the One Health RVF MCM).

One Health RVF objective

The first step in defining an RVF objective comes down to a choice between trying to fully prevent RVF outbreaks and accepting that future outbreaks will occur and thus seeking to mitigate their impact.

If an objective of preventing future outbreaks is decided on, countries will need to invest heavily in inter-epidemic vaccination, seromonitoring to measure herd immunity, and vector monitoring and control. This is an open-ended and costly commitment that may or may not be justified based on the public health impacts of RVF and political considerations. The support of financial and political decision makers would be needed.

Due to limited resources and competing health priorities, most countries seek to mitigate the impact of outbreaks rather than prevent them. An objective of mitigating the impact of outbreaks should define the impacts to be mitigated as a guide for intervention. These may include impacts on public health, the livelihoods of producers and other value chain stakeholders, the national economy and access to international trade.

One Health coordination

The most efficient and effective use of resources will be achieved through an integrated multisectoral response mechanism with the authority to make decisions. In the case of RVF, the most effective interventions for the protection of public health would be those in the livestock and environment sectors, including forecasting, surveillance in livestock, vector surveillance and control, measures to limit contact with livestock, and the vaccination of livestock where deemed appropriate. Such interventions to promote public health are the responsibility of veterinary services, local government and environmental services.

In endemic countries, a MCM should be created that includes human, animal and environmental (for vector control and weather forecasting) authorities, as well as representatives of communities and value chain stakeholders. It should be a standing body that works throughout the inter-epidemic period and intensifies its activities during pre-epidemic, epidemic and post-epidemic periods. During the inter-epidemic period, the MCM is mandated to develop and implement the detailed RVF action plan. The MCM should be empowered to:

- implement contingency and preventive measures and capacity-building activities during the inter-epidemic period;

- declare periods of pre-epidemic risk justifying increased expenditure in RVF pre-emptive measures;
- issue national RVF alerts based on international guidance;
- initiate disease investigations and declare RVF outbreaks based on confirmed RVF cases in livestock or humans; and
- build coordination, collaboration, communication mechanisms, including responsibilities and command structures.

The MCM should ensure that sufficient finance is available for all phases of RVF response and recovery. This includes setting up systems for allocating funds in the inter-epidemic period that can be rapidly released for pre-emptive measures in the pre-epidemic phase and palliative and recovery measures once the outbreak is confirmed.

In terms of its command structure, it is suggested that there be an oversight committee on which each of the concerned ministries is represented, and that this committee select one coordinator with the authority to make day-to-day decisions for a period of two years. The coordinator post should rotate between the different agencies involved to ensure balanced ownership.

The MCM should have appropriate sets of officers that include early warning and risk assessment, disease surveillance and control, vector monitoring and control, and communication.

In the event of an area being declared at risk of RVF, the head of the MCM should have the authority (delegated by the chief veterinary or chief medical officers) to directly instruct district authorities on matters related to RVF preparation, surveillance and response. Where the system of governance is decentralized, the MCM should be able to interact directly with local government following the same procedures and customary practice used by national ministries.

International and regional organizations have an important role to play in terms of promoting good practice and timely information exchange on the evolution of risk and outbreaks. They can also assist with the transparent management of trade issues to minimize the impact of outbreaks. Over the decades, organizations such as the OIE, FAO, the African Union Interafrican Bureau for Animal Resources (AU-IBAR) and Africa's Regional Economic Communities (RECs) have played a central role in increasing and sharing knowledge on RVF control.

Forecasting and early warning systems

The national action plan should specify who will monitor international forecasting and early warning systems (see the section on early warning starting on page 24) and who will be informed of indicators of increasing risk.

Trigger points for the following, with accompanying actions, should be specified in advance:

1. long-term projections of climatic conditions indicative of elevated risk of an RVF outbreak; and
2. RVF alerts based on indicators (i.e. vegetation anomalies) of conditions associated with outbreaks.

BOX 3

Abortion and young animal mortality (AYAM) syndrome

Outbreaks of:

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

Supporting evidence:

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

Surveillance

Syndromic surveillance

Syndromic surveillance refers to the use of descriptions of categories of disease as targets for surveillance rather than specific diseases defined by the agent responsible. The use of syndromes is more appropriate at the clinical level, as a definitive diagnosis in not usually available in the field at the time of suspected events being detected. Oyas *et al.* (2018) describe a recent example of the use of risk-based syndromic surveillance techniques for RVF using telephone interviews with famers enrolled in surveillance programme in high-risk areas following an RVF alert. Syndromic approaches in a One Health context were also used in Mauritania.

It is recommended that countries use a syndromic case definition for RVF. The RVF Surveillance (Mariner, 2018) suggests the Abortion and Young Animal Mortality (AYAM) syndromic case definition as a model for RVF surveillance (Box 2, page 28; Mariner, 2018). Syndromic definitions should be used in disease reporting systems and active surveillance activities.

In addition, investigations of fever of unknown origin (FUO) can result in the detection of unrecognized cases of RVF in humans. A recent publication reporting the results of tests on a sample of FUO in Madagascar found one human case of RVF during an inter-epizootic period (Guillebaud *et al.*, 2018).

Passive surveillance and disease reporting

Disease reporting is used to refer to generalized systems of routine reporting of detected disease events. The majority of reports are based on clinical detections made by livestock owners or service providers in the course of their daily work. In public health, disease reporting uses sets of definitions for the diseases or clinical syndromes covered by the reporting system. Reports must meet specific criteria laid out in the definition. These case definitions increase the clarity and usefulness of reporting data. The use of case definitions is now recommended in animal disease reporting, although most countries have yet to adopt the practice. Case definitions can describe a specific disease or a syndrome. For example, a syndromic case definition can be used for mycoplasmal pneumonias in small ruminants, and is more appropriate for general disease reporting, as data on the specific cause of mycoplasma are usually not available at the time of reporting.

Historically, the reporting of RVF in animals has suffered from delays and a lack of sensitivity for detecting cases. Often, outbreaks of RVF were first detected following the diagnosis of human cases in hospitals. The situation has improved in recent years, however, with several livestock outbreaks first detected and diagnosed in livestock during the 2018 round of outbreaks in the GHA.

A study by Kimani *et al.* (2016) suggests that stakeholders find disease reporting for RVF to be weak. Among the factors negatively affecting disease reporting identified by the study was poor communication between pastoralists and health services, and a lack of access to services, which created a negative incentive. It has been recognized for decades that community-based health and animal health programmes can improve communication between pastoralists and health service providers (WHO, 1989).

Public veterinary services are encouraged to embrace participatory and community-based approaches by engaging with and supporting partners that are highly active in the community. Training staff in participatory methods and increasing their awareness of community animal health knowledge systems will improve communication, ensure staff are more aware of the situation on the ground, and improve the data quality and completeness of passive disease reporting processes.

The use of paper-based systems to process large amounts of data is slow and at times has resulted in system failure due to the lack of human resources to carry out tasks such as data entry. Database systems have at least in part addressed this issue. Several electronic or digital approaches to expanding reporting systems to include more reporters have been tested. The geographic range of cell phone networks and cell phone ownership in Africa, even in remote pastoral areas, is remarkable. Some systems have also enabled community workers to report. Sustaining access costs after the pilot project's completion has been the main issue. New methods of reporting are continually being tested, and the One Health community is seeking to create integrated digital reporting systems that will be invaluable in RVF passive and active surveillance.

With regard to international reporting requirements, countries with a 'disease-free' status must report any occurrence of RVF in livestock. During an inter-epidemic period, RVF-infected countries must report any 'substantial' increase in RVF incidence above normal inter-epidemic rates, as this would mean that they have entered an epidemic period. They must then submit follow-up reports until the incidence of disease falls to normal inter-epidemic rates. The term 'substantial' is not currently defined.

Participatory syndromic surveillance and environmental monitoring

Forms of surveillance that actively reach out to livestock owners and the public can increase the number and timeliness of case detections. Active surveillance is more costly than passive disease reporting but often detects disease events and whole categories of disease that have been overlooked by disease reporting systems. The reason that active surveillance is more costly is that involves personnel leaving the office to seek out and engage with the public, thus generating transport costs and other expenses. Participatory syndromic surveillance (PSS), which uses a case definition based on a disease syndrome and involves actively searching for cases that meet that definition, is the technique recommended by the Rift Valley Fever Surveillance (Mariner, 2018).

Participatory methods are approaches that have evolved in development settings over the last 30 years. The methods rely on semi-structured interviews and interactive exercises that facilitate the exchange of knowledge on subjects of mutual interest. The use of this approach in epidemiology is known as epidemiology (PE) [Mariner *et al.*, 2011], and is now widely practised in Africa and Asia (Mariner and Paskin, 2000). Participatory surveillance (Fleeman *et al.*, 2000) evolved as a means of surveillance in rinderpest eradication, and allowed several of the last foci of the disease to be identified and targeted (Mariner and Roeder, 2003). At present, most countries affected by RVF have developed expertise in PE and PSS. The capacity to carry out PSS should be established during the inter-epidemic period and the surveillance itself carried out at a baseline level. This should include training or refreshing of core personnel, field assessments to learn local RVF knowledge and terminology (such as the names used for RVF and *Aedes* and *Culex* mosquitoes), piloting case definitions, the creation and testing of interview checklists, procedures for documenting environmental and vector status, and procedures for reporting information to surveillance and decision-making pathways. PSS should then be ramped up during the pre-outbreak period.

Sentinel surveillance

"Most importantly, [sentinel herds] are a systematic, risk-based method that provides objective evidence of the presence or absence of virus transmission, and which can anchor the overall RVF surveillance database for disease response and trade decision-making."

Sentinel herds (SHs) are an objective, evidence-based tool for the documentation of RVFV circulation within a population (Annex II) that complements active surveillance based on outreach such as PSS. They are essential in the post-outbreak analysis of RVF strategies and interventions.

To establish sentinel herds, RVF-naive herds or flocks must be selected at locations of interest, based on serological assays. If the herds are to be used as part of a risk-based surveillance system, these locations would be sites with a high risk of RVF transmission. Sentinels can also be used as a tool to provide evidence of the absence of virus circulation for reasons such as trade. For this objective, SHs might be identified in low-risk areas intended as a source of exports.

The function of sentinel herds is to delineate outbreaks and retrospectively document the onset of the outbreak. This is very valuable information for validating early warning systems and other surveillance activities.

Sentinel herds are not an early warning system. Detection of virus transmission using sentinels requires animals are infected at least seven to ten days with a detectable immune response and one to two weeks for sampling, transportation and testing to take place. Realistically, the earliest point at which detection can occur is three to four weeks after the onset of the outbreak at the sentinel herd's location.

Seroconversion may be indicative of outbreak or occur as a result of low-level endemic virus circulation during inter-epidemic periods. In the event that seroconversions are detected, active surveillance in the form of participatory syndromic surveillance should be immediately carried out in the area of the sentinel herd to determine the type of transmission detected. The results should be communicated quickly, and the One Health MCM should then also immediately conduct an evaluation of the risk and implement an appropriate response. Given how long seroconversion and its sampling and testing takes, if an outbreak is first detected in a sentinel herd, this suggests that the passive and active surveillance system failed to detect events in a timely manner. Analysis of the outbreak event should look at why early warning and syndromic surveillance activities did not detect RVF activity.

Not all herds will be infected during an outbreak; some will escape infection by chance. The choice of which herds and individual animals to include in sentinel systems requires epidemiological analysis. Studies on the clustering of infection indicate that there is greater variability in infection between different herds than there is between the individual animals within a herd (Bett, 2018). Including multiple herds from a single location may be required to provide certainty that an area where sentinels remained negative was truly not infected during an outbreak.

Vector surveillance

Vector surveillance as a tool for early warning is an area were the costs and benefits should be carefully weighed. It may be sufficient to monitor NDVI and have qualitative reporting of vector abundance. Up-to-date vector maps are essential for risk mapping. However, more detailed and cost-effective information is best obtained through well-designed periodic surveys rather than some form of continuous surveillance.

Where national strategies include vector monitoring, plans should be developed and documented with measurable indicators. Target sites should be high-risk areas identified using risk mapping. There is considerable merit to having one coordinated plan for both sentinel herds and vector sampling. This could reduce costs and provide inegrated data sets.

Countries that undertake vector monitoring usually monitor both adult and larval population numbers to track population data and associated risk.

Simple techniques for larval monitoring may involve using a dipper of a fixed volume and counting the larvae manually. Threshold counts triggering interventions would need to take into consideration local data and the presence of other indicators of a high-risk period for outbreaks.

The usual procedures for monitoring adult vectors are to place light traps in areas at risk for high vector density. A sampling plan and schedule with a standard operating procedure should be developed with the participation of local vector control personnel. A documented plan will facilitate performance monitoring and help target adult vector control activities as mosquito blooms occur.

Viral monitoring of vector populations was previously recommended by OIE norms, but it is *no longer recommended*. Surveillance based on random or systematic testing for the virus where there is no specific suspicion of disease is insensitive and not cost-effective. This is due to the fact that the actual prevalence of infected hosts or vectors in the population at large is very low, and thus large random sample sizes and extravagant amounts of testing would be required to detect the virus when it is present in the population.

Targeted studies

Surveillance budgets should take into account funding for specific small-scale studies or assessments, which can be a useful complement to surveillance and provide key information for risk assessment and mapping. There is no clear distinction between targeted studies and research, however targeted studies tend to be of short duration and take advantage of immediate opportunities that require a quick response. Examples are expanded outbreak investigations that go more deeply into delineating the time course and extent of the outbreak or serological surveys to validate risk maps.

Vector mapping is an example of a targeted study that provides information for risk mapping. Due to climate change, the distribution of competent vectors of arboviruses, and the subsequent distributions of arboviral disease, are changing. Vector maps should be periodically updated based on surveys designed in light of climate change.

Diagnosis of RVF

The diagnosis of an RVF index case while risk conditions are still evolving is part of effective RVF risk management and not an appropriate trigger for a national RVF response. Diagnosis is an important component of confirmation and documentation that should reinforce decisions and action already taken based on the evolving risk indicators. This can and should include keeping trade partners informed of evolving risk conditions and the interventions being made. It should be kept in mind that the diagnosis of a case in the absence of other outbreak risk factors may indicate low-level endemic circulation rather than an outbreak. However, given conditions consistent with an outbreak, the diagnosis of a clinically-affected index case is the trigger for international reporting to the OIE. The AYAM case definition provides guidance in relation to clinical presentation and conditions such as persistent rains or other hydrological events and an abundance of vegetation and vectors.

The appropriate diagnostic tests for RVF are defined, described and referenced in the OIE Terrestrial Animal Health Code in the chapter on RVF (OIE, 2016). The OIE Code emphasizes the tests that are the most reliable and safe for the rapid diagnosis of RVF. Working with live RVFV requires special facilities and skills. It is recommended that countries focus on recommended tests that do not require the handling of infectious material beyond the initial processing of field materials. Staff should be fully trained in biosecurity risks and practices associated with RVF diagnostics.

The tests recommended are:

- conventional or real-time polymerase chain reaction (PCR)
- IgG and IgM ELISA for seromonitoring and serosurveillance (Madani *et al.*, 2003; Munyua *et al.*, 2010).

Conventional PCR is currently the most appropriate test for confirming outbreaks (Sall *et al.*, 2001; Couacy-Hymann *et al.*, 2002) and all countries should ensure that they have the capacity to carry out these tests. This should be followed by virus sequencing (Garcia *et al.*, 2001; Drosten *et al.*, 2002; Bird *et al.*, 2007). Countries may request this service from reference laboratories if the capacity for this is not available locally. These tests can also be run on pooled samples of vectors (Jupp *et al.*, 2002). Sequence data demonstrate the relatedness of isolates and are an evidence-based approach to identifying outbreak sources and temporal–spatial trends.

The IgM ELISA is an especially valuable tool in RVF epidemiology as it allows recent events to be confirmed in the absence of antigen or genetic detection. It should be noted, however, that seromonitoring also refers to the validation of vaccination programmes and measurements of herd immunity following vaccination. Serosurveillance refers to studies that document transmission or general herd immunity resulting from either transmission or vaccination.

Disease control

Control in livestock

The RVF control options for livestock consist of vaccination, movement control and the direct use of insecticides on animals.

Countries should develop and implement a clear policy on vaccination against RVF for the inter-epizootic and pre-epidemic periods. There are several options in terms of timing and the choice of vaccine to use, and the decision of which approach to take is up to the individual country. Ultimately, a country's ministry of finance must be convinced of the return on investment and opportunity costs of any vaccination programme. The guidance provided here describes approaches that offer a reasonable prospect of positive effects and which are clearly unlikely to result in a negative impact. Some accepted observations are:

1. Vaccination undertaken after the detection and diagnosis of the first case is unlikely.
2. Due to a lack of market incentives, vaccine stocks available for purchase in the face of outbreaks are usually insufficient to meet demand, leading to long procurement delays.
3. To be effective, vaccination must either take place during the inter-epidemic period or before widespread flooding in the pre-epidemic period.
4. Due to the lack of political incentives, vaccination campaigns may be difficult to implement in a manner that will result in effective levels of herd immunity during the inter-epidemic period.
5. Possible public resistance to RVF vaccination campaigns and associated adverse reactions should be factored in when planning.

A study by Kimani *et al.* (2016) assessed current, as well as several proposed, control scenarios for RVF using a benefit–cost ratio (BCR) for livestock and a cost-effectiveness analysis (CEA) for public health impacts. They found that the current practice of limited vaccination during the inter-epidemic period (2-11 percent coverage) is not cost-effective from a public health perspective. This means that the amount spent on vaccination in these low-input scenarios did not result in a meaningful reduction in human life lost (disability-adjusted life years) during the following epidemic. However, scenarios involving increased livestock vaccination during the inter-epidemic years (up to 40-50 percent coverage two years before a hypothetical outbreak) reduced the extent of livestock outbreaks and transmission to humans. This increased vaccination had a low BCR of around one from a direct livestock perspective, but a highly favourable CEA in public health terms. In other words, wider vaccination resulted in an effective level of reduction in human life lost measured in disability-adjusted life years.

One limitation of this analysis is that increased vaccination was modelled to take place in the years immediately preceding the next outbreak. In practice, the timing of the next outbreak cannot be known, and vaccination during an inter-epidemic period may need to be continued for up to a decade before the next outbreak.

Investment in both human and animal health is limited and opportunity costs should be considered. The public health cost of RVF compared to other major human health risks (malaria, neonatal diarrhoea, etc.) needs to be determined. This requires comparative analysis of the numbers of human lives saved as a result of investment in RVF mitigation compared with investment to reduce other causes of human illness.

It is worth noting that increased vaccination of livestock was primarily of benefit to public health. This means that higher levels of inter-epizootic vaccination can be justified from a public health perspective and should therefore be financed from public health funds. Although the study by Kimani *et al.* (2016) did not consider trade and downstream economic effects, its findings highlight the central role public health plays in determining what impact the disease will have and how beneficial interventions will be.

Since its 2000 epidemic, Saudi Arabia has practised annual vaccination, with a goal of vaccinating all animals in the endemic zone at least once over the course of their lifetime. Important levels of adult and larval vector control are also practiced. The extent to which the country's goals for vaccination and vector control are being met is open to debate. Herd immunity is at around 50 percent, and yet Saudi Arabia has not experienced a second outbreak to this day, which could well be due to their control strategy.

Targeted pre-epidemic vaccination is a second approach to reducing the extent of outbreaks which is potentially cost-effective. It would require less vaccination and cost than high levels of vaccination during the inter-epidemic period, but very timely procurement, planning and management that would need to be established during the inter-epizootic period.This approach is discussed in more detail in the section on the pre-epidemic phase.

The pre-epidemic use of insecticides, particularly pour-ons, is a measure that can potentially reduce viral amplification during critical periods and protect against livestock losses. Protected livestock also reduce the risk of human exposure. Insecticides should continue to be used until the outbreak is over, as animals protected by insecticides are fully susceptible to infection once the chemicals wear off. Once herds have been exposed or have experienced abortions and young animal mortality, the benefits of insecticide treatment are debatable.

Capacity for the supervision of markets and livestock product value chains should be validated and upgraded if necessary to assure the national competence to mitigate RVF risk in livestock value chains. Countries should be in a position to ensure that products (primarily meat, milk and milk products) reaching consumers outside of outbreak areas pose no more than a negligible risk. Given that proper aging of meat eliminates viable virus, this is an achievable goal, and is required in order to protect the health and safety of the public and reassure trading partners that product exports are safe.

Official, regulated markets and abattoirs should remain open throughout the outbreak period as the best means of mitigating the risk of transmission from livestock and livestock products to humans. In addition to protecting the livelihoods of livestock owners and ensuring supplies of animal-source proteins, regulated markets and abattoirs continuing to operate will discourage high-risk slaughter practices and improve the monitoring of the movement of animals. Proper aging of meat inactivates the RVF virus, and thus consuming aged meat is not considered a risk factor. Slaughterhouse personnel and other workers participating in the livestock product value chain are at high risk, and special initiatives should be put in place to provide them with training and access to appropriate protective equipment. Inspection and regulations will be reinforced during the outbreak to ensure a high level of compliance with food safety and biosecurity measures.

Countries that have formulated action plans using this Action Framework will be in a better position to justify requests for the funding of response activities during each of the epidemiological phases. The scarcity of hard epidemiological and economic data on the impact of control measures makes justifying investment more difficult. A clear and comprehensive plan that continues to be updated based on the lessons learned from the activities already implemented will encourage investment from financial authorities.

Vector control

As part of their action plan, countries should include a clear policy statement and plan in relation to the recommended methods and products to be used for vector control, taking international standards, environmental concerns and virus activity into account. This vector control policy should address both health and environmental safety aspects of the use of insecticides. It should ensure that insecticides are only used where they will be effective. If resources or logistics do not permit sufficient coverage or an appropriate frequency of coverage, then it may be more appropriate to forgo mass vector control. The goal is to use safe products when and where they are needed, while limiting their unnecessary or ineffective use. The vector control policy should be prepared and reviewed with appropriate consideration for national regulations as part of a process involving the national authority responsible for the regulation of insecticides and their use. Given the fact that the compounds available, and our understanding and perceptions of their use and safety, change, this document will not attempt to prescribe specific control measures.

Factors to consider:

- the procurement, storage and distribution of the materials needed to carry out pre-emptive vector control;
- the threshold indicators that trigger the use of insecticides and determine the duration of this use, for example:
  - forecasts
  - alerts
  - vector counts;
- areas of insecticide use in relation to risk maps; and
- the products to be used, and appropriate application, frequency and rates.

If the need for aerial spraying is foreseen, sufficient funds and the aircraft required for this should be established in advance. For ground spraying, the preplacement of sprayers, personal protection equipment (PPE) and materials will be essential to success and protect spray operators.

As movement is difficult in flooded areas and biological control is relatively safe, community health workers (CHWs) and community animal health workers (CAHWs) are an important resource that should be incorporated into a country's response. In the inter-epidemic period, it would be best to develop and periodically test the plan using pilot groups of workers. Full scaling should wait until the pre-epidemic phase, as years might pass before community health personnel are called into action and personnel turnover could be significant.

Capacity building

Capacity-building activities to establish the above include:

National RVF action plan and related standard operating procedures

- the RVF action plan will be established with the participation of key stakeholders from the public health, animal health, environmental, finance and law enforcement authorities at various levels (from the staff at their main office to their field personnel), as well as the plan's beneficiaries from affected communities, value chains and international and non-governmental organizations. The final plan will be shared with implementation staff and stakeholders, such as livestock owners, community animal health workers and local community leaders, through presentations at seminars.

Surveillance

- the training of field staff, private veterinarians and community animal health workers to reinforce passive reporting based on case definitions and disease recognition;
- a ten-day training course on participatory syndromic surveillance and environmental monitoring, practice in the field, and a two-day refresher course for the public, private and community personnel selected to implement the syndromic surveillance the training of field personnel (in both public- and private-sectors) on how to recognize and report AYAM cases and take proper samples;
- the training of public, private and community surveillance personnel in how to monitor environmental variables such as rainfall anomalies, floods and mosquito blooms in at-risk areas in order to track the evolution of the outbreak and ground-truth risk maps and prediction systems;
- the training of sentinel herd system personnel in the operation of the system, environmental monitoring and the sampling regime; and
- the training of vector surveillance personnel in how to collect larval vectors and trap adult vectors, in accordance with the action plan.

Control

- the training of public, private and community vaccination personnel in RVF epidemiology, recognition, reporting and biosafety/biosecurity, and the designation of local teams;
- seminars for community leaders outlining response plans and their rationale;
- the training of abattoir and livestock product value chain workers and managers in the risks posed by RVF and the appropriate measures to mitigate risk during product handling and ensure the safety of products.
- the training of abattoir inspection and regulation personnel in RVF biosafety and food safety protocols; and
- the training of vector control personnel in the use of larvicides and spraying techniques, in accordance with the national action plan.

PRE-EPIDEMIC PERIOD

Various stages can be defined within the pre-epidemic period, and the Decision Support Framework (Consultative Group for RVF Decision Support, 2010) does an excellent job of breaking down this dynamic period, with specific actions for each sub-period.

Forecasting and on-the-ground indicators of evolving risk

Generally, the pre-epidemic period starts when forecasts of future weather conditions or, failing that, RVF alerts indicating the presence of conditions consistent with RVF, are made available. At the national level, the team member(s) delegated by the MCM to monitor forecast and alert systems each week should immediately inform their team of information suggesting an increasing risk of an outbreak.

Surveillance teams should undertake environmental monitoring at risk hotspots.

The MCM should initaite the activities described in the next sections while continuing to monitor international and national sources of information concerning RVF risk.

Logistics of risk management

The timeliness of logistics will determine the impact of mitigation measures. The action plan created during the inter-epidemic period sets the strategy, and thus the type and quantity of inputs to be purchased, as well as the timing of their purchase and delivery. The MCM should have established the core budget for the RVF response.

For items not already stockpiled, the MCM should place orders based on forecasts.

Vaccines are the most problematic input, as vaccine producers do not usually stock RVF vaccines in sufficient quantities to fully permit immediate risk-based vaccination, and it is doubtful that they could produce sufficient quantities to allow all countries in a region at risk of an epidemic to adopt a pre-emptive vaccination strategy.

The second area in which logistics is concerned is ensuring that sufficient funds for operating costs in the field are available where they are needed.

Hospitals and clinics should be resupplied with the appropriate medications to manage severe cases of RVF and haemorrhagic fever.

One Health coordination

The MCM should be meeting weekly from the time of the first forecasts of conditions indicating risk. Its members should then be working together on a daily basis from the time an RVF alert, or national environmental monitoring data indicating that flooding has occurred at high-risk locations, are received.

Risk communication

Messaging should take different target audiences into consideration and seek to inform but not alarm. The principal groups targeted are:

- producers, livestock workers and the rural public, especially women and young;
- industrial value chain holders;
- consumers of animal source foods; and
- trading and other international partners.

Messaging targeted at consumers and trading partners is a particularly sensitive area. Messages should describe the risks in practical language, as well as the actions being taken to mitigate risks.

Messaging should evolve over the pre-epidemic period in line with escalating risk factors, as laid out in the Decision Support Framework (Consultative Group for RVF Decision Support, 2010):

For producers and the rural public in outbreak areas:

- At the time of forecasts, messaging should provide general information on RVF and the preparations being made and action being taken in light of evolving events, as defined in the action plan. Pre-emptive measures should be emphasized, such as:

  - pre-emptive vaccination before flooding, provided that this is part of the action plan;
  - the pre-emptive treatment of livestock with insecticides; and
  - the use of bed nets and repellents.
- At the time of RVF alerts or widespread flooding consistent with RVF risk, messaging should focus more directly on:
  - the signs and symptoms of RVF, and what action to take if RVF is suspected;
  - protecting human health by providing information on the risks associated with exposure to sick animals and the slaughter of sick animals;
  - plans for ensuring food safety and biosafety in livestock product value chains;
  - the pre-emptive treatment of livestock with insecticides;
  - the use of bed nets and repellents; and
  - vaccination, where this is still possible and provided that this is part of the action plan.

Value chain stakeholders (slaughterhouse workers, butchers, retailers, by-product workers, etc.) are at high risk of RVF and merit special attention. Refresher training materials on the risk of exposure during slaughter and the handling of fresh animal source foods should be disseminated. Value chain stakeholders also face the risks to their livelihoods from the market collapse due to public perceptions about meat safety. Messaging should alert them to the fact that a challenging business climate may follow. Useful advice could include short-term defensive approaches, such as saving and avoiding new investments or loans that would expose them to even greater business risk.

With regard to urban consumers, the principal message should be that the meat on retailers' shelves that has come through official channels is one hundred percent safe. Outbreaks often, but not always, affect areas within a country (Metras *et al.*, 2012). The public should be advised that in the event of an outbreak, the movement of live animals outside infected areas will not be permitted other than for slaughter or due to animal welfare concerns. Slaughterhouses should be encouraged to continue to operate in order to encourage offtake and thus provide income in all areas and discourage unsupervised slaughter. Heightened food safety and biosecurity standards should be implemented as part of the plan.

Any meat available for purchase in the formal sector should have originated from regulated facilities and have been inspected at the time of slaughter and aged.

The best approach to managing trade relationships is for a country's director of veterinary services (DVS) to establish direct communication with counterparts and trading partners, and provide them with the full action plan for monitoring and responding to RVF. The key is to assure trading partners that exported animals will be certified as sourced from areas not experiencing an epidemic, that the systems are in place to detect an outbreak if it occurs, and that all measures to comply with OIE norms are in place.

Surveillance

Surveillance, including participatory disease, sentinel and environmental indicator surveillance, should be scaled out in line with the action plan. The supplies for sampling suspected AYAM cases and ensuring the safe transfer of these samples should be distributed and pre-positioned at the time of the first forecasts indicating RVF risk.

Passive surveillance

Passive surveillance for AYAM should be reinforced through the chain of command and using a circular/decree designed to refresh the knowledge of RVF and RVF surveillance and reporting practices.

Participatory syndromic surveillance

Previously trained teams should participate in a one-day refresher meeting to learn about the current environmental risk profile and review surveillance and reporting procedures.

PSS in high-risk areas should monitor rainfall, flooding, and larval and adult mosquito density, and search for RVF cases. During the pre-epidemic period, the PSS teams should reconfirm the local terms for RVF and *Aedes* and *Culex* mosquitoes. As rainfall, flooding and mosquitoes set in, the full focus should be on identifying cases in livestock. Conventional wisdom holds that the first wave of amplification occurs in livestock at vector hotspots, and that this precedes human cases by one to two weeks. Success at this stage would be detecting the index case in animals before an ill human being is diagnosed at hospital.

Sentinel herds

The sampling of sentinel herds should be carried out on a weekly basis, with samples then immediately transported and tested.

Vector surveillance

Vector surveillance activities should be carried out weekly at the predetermined sampling sites. As mentioned previously, vector monitoring and sentinel surveillance should ideally be carried out at the same sites.

Disease control

Livestock control

As has previously been mentioned in the section on logistics of risk management (see page 41), early and prompt procurement and deployment of vaccines is essential if vaccination is to be effective. Vaccination procedures, teams and targets should have been established during the inter-epidemic period as part of the formulation of the implementation plan. A good briefing should be sufficient to start off the vaccination programme.

The target for each location is the vaccination of 100 percent of livestock (cattle, sheep and goats) eligible for the type of vaccine in use. In practice, 80 to 90 percent coverage should be considered successful. While awaiting the delivery of vaccines, personnel can visit communities to raise awareness of the forthcoming programme and the importance of participating in it, verify communities' location and movement plans, and discuss their response to flooding and mosquito swarms. Communities often change their usual herding patterns in response to El Niño events and seek areas with fewer insects and better drained soils, both for comfort and to manage foot rot.

The window for operation in the field may be extremely short given procurement could take up to 120 days and flooding may make movement by vehicle impossible. Community animal health workers can contribute greatly in this regard, as they use foot and animal transport.

Monitoring the movement of animals from known hotspots is an important component of control. As noted above, movement patterns will change in an environmental emergency, perhaps dramatically. Understanding likely responses is an important part of ensuring preparedness, and may provide important information in terms of maintaining the integrity of communications with trading patterns.

Vector control

Larval and adult vector control should be carried out in accordance with the action plan at the correct intervals and using preset thresholds once flooding is underway.

Early procurement and preplacement of supplies is essential for ground applications of insecticides, as many sites will become difficult to access at the time of vector breeding.

Trade

This is a critical period for the mitigation of impact on trade. Historically, the knowledge that a country was carrying out RVF vaccination was sufficient to cause trade bans. In recent years, however, international understanding of RVF risk has evolved, to the extent that the OIE has created special national status categories that are unique to RVF.

It is strongly recommended that the chief veterinary officer (CVO) and chief medical officer (CMO) engage with trading partners and present them with their detailed RVF surveillance and action plans in order to build confidence in their country's ability to recognize its status and effectively manage risk. Ministries of health and public perceptions of health risk can be the driving force behind trade bans, so it is important that a One Health message of capable, confident and transparent risk management is conveyed.

Economic and social impact mitigation

Determining an outbreak's economic and social impact is an important part of consequence analysis in well-conducted risk assessments. Local authorities should update assessments of the livelihoods, households and community institutions at risk in the event of an outbreak.

It is much easier to assess livelihoods and businesses before they collapse, when the direct physical evidence of economic activity is present. As has been mentioned, livestock and livestock product value chains are complex. For example, there are livelihoods, such as the kiosks and informal restaurants that cater to slaughterhouse workers and meat traders, that on the surface may not appear to be part of the livestock product value chain, but which are integral to and entirely dependent on this value chain.

It is important that local authorities confirm risks and consequences immediately prior to the outbreak, as markets and livelihoods evolve, and an imminent hazard often brings issues into sharper focus.

EPIDEMIC PERIOD

Communities experiencing RVF outbreaks are deeply affected. In past outbreaks, human cases of RVF occurred in the context of a storm of livestock disease and severe environmental conditions that made daily survival a challenge: no dry place to stand for weeks, and waves of insects and other intercurrent infections such as malaria. Taking a loved one to a health post required tremendous effort. It is essential that governments and the professionals from the public health, animal health and environmental sectors act to show solidarity and concern.

Epidemiologists and health professionals may find that certain actions are unlikely to have an impact at the technical level. Despite being a common response measure, vaccination during the epidemic period is not going to change any outcomes in the affected community. However, doing nothing is not an option. A more effective course of action would be to carry out vaccinations at the appropriate time and then switch the focus to supportive and recovery interventions that will make a difference to people's health and livelihoods.

One Health coordination

During the epidemic period more than ever, the professionals from the public , animal and environmental health sectors need to work together. At this point, it is unlikely that the course of the local epidemic curve can be altered. With the exception of interventions to limit human exposure, the strategy should shift from prevention and pre-emption to palliative or supportive care and recovery responses aimed at the individuals and communities affected.

It is important to note that the epidemic does not usually occur everywhere simultaneously. There will be other hotspots where the disease has not yet started, and interventions should be tailored to the stage in the epidemiological cycle at that location. It is perhaps relevant to note that in many instances, the 'spread' of the disease is in fact the emergence of separate strains of the virus at different locations as the conditions for an outbreak mature.

Risk communication and social mobilization

At the time of an index case being confirmed, messaging targeting local communities should focus on:

- the signs and symptoms of RVF, and what action to take if RVF is suspected;
- the importance of seeking medical assistance for any fever in high-risk areas, and where to seek care;
- protecting human health by providing information on the risks associated with exposure to sick animals or animals suspected of being infected, as well as the slaughter of sick animals or animals suspected of being infected;
- the pre-emptive treatment of livestock with insecticides;
- the use of bed nets and repellents;
- what is permitted in terms of the movement of animals and their sale and slaughter; and
- the access to animal source foods through safe, formal, regulated channels.

For those involved in the livestock product value chain, food safety practices, biosecurity and the means of preserving their livelihoods are the priority.

With regard to trade, it is essential that the outbreak is promptly reported to the OIE and trading partners, and that information is made available on the action being taken to stop all animals and animal products originating from affected areas or areas at high risk of becoming affected from entering export value chains.

Surveillance and epidemiological investigation

Passive reporting

Passive reporting should continue as a standard procedure.

Participatory syndromic surveillance

Participatory syndromic surveillance should continue, but the geographic focus should be shifted to high-risk areas that have not yet experienced cases.

Sentinel herds

In herds that have not seroconverted, sampling should continue to be carried out once per week in order to accurately detect the first circulation of the virus. This information will help to assess the accuracy of early warning and RVF alert data, as well as the timeliness of interventions made on a pre-emptive basis.

Palliative and supportive care

RVF is a viral disease, and treatments that directly address the cause of the disease are not yet available. Clinical case management, infection prevention and control, and psychosocial support are all important in the management of this disease.

Good case management will reduce mortality in humans, and is the most important activity during this period. Given this is an RVF action plan, it is important to bear in mind that there will be other flood-associated health issues that deserve equal attention.

As the slaughter of animals during an ongoing outbreak is risky both for abattoir personnel and the public, alternative sources of animal-source proteins should be made available. In pastoral areas, bans on the sale and slaughter of livestock severely limit household purchasing power, meaning that the purchase of substitute animal proteins is not possible. Nutritional support delivered through schools and community institutions is appropriate during acute outbreaks.

During livestock emergencies, general health interventions such as deworming will be welcomed. During past El Niño events, extreme environmental conditions created other problems, including foot rot, bluetongue, pneumonia and stress due to the high numbers of insects. Supportive care in the form of minerals and access to treatment for foot rot, pneumonia and anaemia should be provided (LEGS, 2014; FAO, 2016).

Disease control

From a technical perspective, vaccination in communities where an outbreak has already occurred is not likely to have any impact on animal health, as the infection has already been and gone and most of the survivors are immune. The continued use of insecticides on animals, however, will have a positive supportive impact.

Movement out of affected areas for trade purposes should not be permitted until the epidemic is over. Evidence is building that the movement of animals has contributed to the spread of infection to new areas (Metras *et al.*, 2012; Napp *et al.*, 2018) and should be regulated if possible. However, the movement of pastoralists seeking more favourable sites with better soil drainage and lower insect burdens cannot be prohibited from a humanitarian and animal welfare perspective. There is no rationale for prohibiting movement within outbreak areas.

Trade in livestock and livestock products

Markets and abattoirs in outbreak areas should remain open throughout the outbreak period for domestic purposes.

Slaughterhouses should be encouraged to continue to operate in order to facilitate offtake – and thus provide income – in all areas and discourage unsupervised slaughter. Heightened food safety and biosecurity standards should be implemented in accordance with procedures set out during the inter-epidemic period. Employees should receive PPE and refresher training on biosecurity and the use of PPE. Ante-mortem and post-mortem inspections should be carried out on all animals, and compliance with biosecurity procedures should be rigorously monitored to protect the health and safety of employees and those participating in the value chain. Procedures for monitoring and certifying the aging of meat should be reinforced.

All these measures will rely on the country's capacity to ensure appropriate control of product flows in light of food safety and biosecurity issues established during the inter-epidemic period.

Markets and abattoirs can continue to operate in non-affected areas provided active surveillance is present in the area. Meat allowed to mature at 2 °C to 6 °C for at least 24 hours is of negligible risk to consumers.

It is important to stress the impact on livelihoods of closing markets and abattoirs. Recovery mechanisms to mitigate the impact of control measures on livelihoods should be provided. These need to be designed locally and adapted to suit the customary practices of local institutions and communities in order to maximize equity and limit market disruption. Interventions should strengthen resilience rather than encourage dependency. Free handouts are to be discouraged in favour of investment approaches that create responsibility and accountability.

POST-EPIDEMIC PERIOD

Surveillance

A serosurvey to measure herd immunity immediately after the outbreak will delineate exposure and provide useful information for the assessment of programme interventions. A serosurvey will contribute to an assessment of the risk of lingering outbreaks, as has been seen in some regions in recent years. For the most part, these annual outbreaks affect different areas within a country. Analysis needs to be local and action plans need to be tailored to local risk and population structures.

Vaccination programmes should be limited to situations where a risk of continuing RVF disease has been reasonably established based on serological evidence. Vaccination is not justified after major outbreaks where a third to half (or more) of the surviving population is immune.

Economic and social impact mitigation

The economic impact of RVF includes both direct and indirect effects.

Producers can be assisted with animal health care. In addition, civil society organizations should be supported to respond to individual cases of need based on the details of the personal or family situation.

At the industry level, the complexity of the abattoir system means that a range of livelihoods depend on them. It has been observed in previous outbreaks that meat consumption can collapse nationally, even at locations at great distance from the actual outbreak site. This was probably due to the fact that the public lacked confidence in the sanitary measures taken to ensure food safety. Communication activities should be area-specific and highlight the risk-management measures adopted at outbreak sites.

Measures to mitigate the economic impact of the outbreak should use a value chains approach and take all those involved in product and export value chains into consideration. Ideally, such programs should begin in the pre-epidemic phase, by registering potential beneficiaries, as it may be difficult to validate applicants' eligibility once markets are closed and livelihood activities cannot be observed.

Schools in outbreak areas can be hard hit, as families have no ready cash to cover school fees. Support for school programmes will show solidarity with the communities and are not unduly difficult to implement in an equitable manner.

Rather than invest in the vaccination of largely immune herds after the outbreak, it would be more appropriate to invest in stabilizing livelihoods and social services in pastoral areas and for those in animal industries that have been affected. Interventions to stabilize livelihoods should be prepared based on an assessment of the impact on value chains and dialogue with affected livelihood groups. Demand shifts, such as increased consumption of poultry and decreased red meat consumption, will probably still occur despite extensive communication efforts to stabilize markets. If demand declines, slaughterhouse activity, employment and value chain incomes will be hard hit. Previous value chain assessments have identified the categories of value chain stakeholders (such as butchers) affected during RVF outbreaks (Rich and Wanyoike, 2010). Post-epidemic assessments should identify those hardest hit and test credit or other options to restart or stabilize livelihoods.

The direct effects of RVF and the indirect effects on markets create financial stress and food and nutritional insecurity. Families lack the cash to meet their needs, such as the purchase of cereals and payment of school fees and health expenses. Schools struggle to meet the needs of students when parents are unable to make normal payments. In addition to supporting the health needs of communities, the public sector has a role to play in ensuring food and nutritional security and that social programmes including schools continue to operate.

Study and impact assessment

The study of past outbreaks has allowed more informed and effective action today. Many questions remain, however, and predictive models and mechanisms continue to need data for calibration and validation purposes. Impact assessments should look at both the epidemiological and socio-economic impact. The results of these assessments should be used to inform efforts to mitigate the outbreak's economic and social impact.

The events of the outbreak, from the time of first prediction of weather anomalies, through flooding, vector blooms, first case, full outbreak to last case should be outlined in a timeline. Data from environmental, vector and disease surveillance should be gathered and shared on a common platform. Intervention data on vaccination, the timing and extent of market and abattoir closures, vector control, public health interventions and communications should be collected and compared with the outbreak timeline.

Data from sentinel herds are especially useful during the post-epidemic period and should be analysed in relation to other surveillance data and the timing of response interventions. Some key questions include:

- How much time elapsed between early warnings and disease alerts and the first seroconversions? It is worth remembering in relation to this that infection probably precedes seroconversion by 10–14 days.
- Did disease reporting and PSS detect cases in a timely manner?
- How much time elapsed between pre-emptive measures being taken and the first sentinel herd seroconversions at the location?
- What were the environmental conditions and pre-emptive measures taken at sites where seroconversions were not detected in the sentinel herds?

This analysis should be shared in multisectoral consultations for the purposes of reflection, understanding and communicating lessons learned and allowing more effective future actions. International agencies should participate in this process, especially where the lessons learned could help to improve or validate early warning systems.

INFECTED COUNTRIES WITH NO HISTORY OF OUTBREAKS

This category includes a mix of countries with different situations. Suffice it to say that over the decades, several countries with serological evidence of virus circulation have eventually experienced outbreaks of clinical disease. Niger is probably the most recent example. RVF was first detected in a large serum set collected between 1984 and 1988. In Agadez, 47.5 percent of camels were found to be positive for RVF antibodies (Mariner, Morrill and Ksiazek, 1995). At the time, herders were aware of a zoonotic condition associated with mosquitoes and rainfall that was clinically consistent with RVF. This information pre-dates the outbreak in Senegal which lead to heightened awareness of RVF in West Africa, and RVF was not considered a risk in Niger at the time. The first recognized outbreak of RVF in Niger was not until 2016.

There is thus descriptive evidence to suggest that some countries in this category have had prior outbreaks. From this, it can be reasonably assumed that in those cases, authorities either did not detect them or chose not to act on the information available to them regarding outbreaks.

Infected countries with no history of outbreaks should undertake three integrated activities:

- a national serosurvey and vector survey;
- a national risk assessment and risk map; and
- participatory syndromic surveillance targeting high-risk locations and seasons, depending on the results of the risk assessment.

As an example, Botswana experienced limited cases during the Southern African outbreak in 2010. A post-epidemic serosurvey of northern Botswana (Okavanga Delta and Chobe National Park) found a seroprevalence of 5.7 percent and 12.7 percent in cattle and buffalos, respectively (Jori *et al.*, 2015). This suggested more intensive transmission than was previously known. A subsequent vector survey conducted using the same sampling methodology in 2011–2012 found an abundance of vectors (particularly *Culex* pipiens) but detected no virus in these vectors (Pachka *et al.*, 2016). The absence of virus detection is not informative, however, as virus surveillance in vector catches is an insensitive method of detection and no longer recommended. It is the serological and vector information that enables for evidence-based risk assessment.

Changing risks due to climate change are a reality. The distribution of rain, humidity, temperature, vectors and vector competence is changing and will continue to change for the foreseeable future.

Countries that take a transparent and aggressive approach to RVF detection and risk management will be rewarded with the public's confidence, as well as that of trade and other international partners.

NON-INFECTED AT-RISK COUNTRIES

Competent RVF vectors are widely distributed around the world (Linthicum, Britch and Anyamba, 2016). If RVF enters an ecosystem with vectors capable of transovarial transmission, disease eradication can only be achieved through vector eradication, involving drastic interventions likely to cause unacceptable damage to the wider ecosystem services and whose likelihood of success is low to nil.

RVF infection can spread as a result of the movement of infected vectors or hosts. Changing risks include climate change, globalization and demographic change. Climate change and the movement of animals (both legal and illegal) are the two greatest threats. The geographic distribution of vector competence has changed for other arboviruses, notably bluetongue in Europe. The capacity for human hosts to act as a pathway for the introduction of RVF to new environments is assumed to be negligible but our understanding of this is incomplete (Chevalier *et al.*, 2010; Rolin, Berrang-Ford and Kulkarni, 2013). At present, the movement of people is at record levels, but attempts to limit travel create shifting patterns of unregulated flows of people without the benefit of medical surveillance and support. Responsible, balanced medical surveillance will result in the best outcome.

Non-infected at-risk countries should:

- assess national vector competence with appropriate attention to global warming trends;
- complete a risk assessment, including a risk map for the introduction of RVF and develop a realistic risk management plan; and
- prepare a contingency plan for addressing an introduction of RVF.

Examples of published risk assessments include those by Rolins, Berrang-Ford and Kulkarni (2013) for the United States, Arsevska *et al.* (2016) for North Africa, and Chevalier *et al.* (2010) for Europe.

Global warming and migration trends suggest that the expansion of RVF's range is inevitable in the coming decades. In fact, each decade has seen RVF recognized in new areas. Rather than react in an unproductive manner, international and national health authorities should come together to manage environmental change in a responsible manner that minimizes the impact of the spread of RVF on human health and economic activity.

Summary of key action

INTER-EPIDEMIC PERIOD

Category	Area	Action
Management	One Health coordination	Formation of MCM with the authority to implement necessary measures
	Objectives	Establish statement of objectives
	Early warning	Establish personnel and procedures for the monitoring of early warning resources
	Risk assessment	Prepare a national risk assessment and risk map
	Action plan	Develop five-year action plan that sets out strategy and ensures the capacity to implement the plan is in place
	Funding	Use the plan to attract funding for a phased risk-based response to RVF
	Trade	Establish relationships with counterparts in trading partners and brief them on national risk management strategies
Communication	Preparation	Devise a communication strategy including prototype messages and vehicles for each epidemiological phase.
	Messages	Distribute general communication materials on RVF to surveillance stakeholders
Surveillance	Passive	Develop syndromic surveillance system based on case definitions
	Participatory	Develop participatory surveillance system using syndromic case definitions Implement environmental monitoring and ground truthing to inform risk assessment and decision-making
	Sentinel	Establish sentinel herd system based on risk assessment and map
Control	Livestock	Establish vaccination strategy as part of the five-year action plan. If the strategy includes preventive vaccination, implement in accordance with the RA and risk map.
	Vector	Identify triggers for control measures and procurement plan
Capacity building	Risk assessment	Ensure capacity for RA and risk mapping is in place if it is not already
	Action plan	Share national action plan through seminars with implementation staff and stakeholders such as livestock owners, community animal health workers, local community leaders and the ministries responsible for livestock, health and the trade in livestock
	Surveillance	Train field staff, private veterinarians and community animal health workers in order to reinforce passive reporting based on case definitions and disease recognition Provide a ten-day training course on participatory syndromic surveillance and environmental monitoring, field practice, and a two-day refresher course for the public, private and community personnel selected to implement the syndromic surveillance programme Train field personnel (public and private) on how to recognize and report AYAM cases and take proper samples

(cont.)

Category	Area	Action
Capacity building	Surveillance	Train public, private and community surveillance personnel in how to monitor environmental variables, such as rainfall anomalies, floods and mosquito blooms, in at-risk areas in order to track the evolution of the outbreak and ground truth risk maps and prediction systems
		Train sentinel herd system personnel in how the system works, environmental monitoring and the sampling regime
		Train vector surveillance personnel how to collect larval vectors and trap adult vectors, in accordance with the action plan
	Control	Train public, private and community vaccination personnel in RVF epidemiology, recognition, reporting and biosafety, and designate local teams
		Provide seminars for community leaders outlining response plans and their rationale
		Train abattoir and livestock product value chain workers and managers in the risks posed by RVF and appropriate measures to mitigate risk during product handling and to ensure the safety of products
		Train abattoir inspection and regulation personnel in RVF biosafety and food safety protocols
		Train vector control personnel in the use of larvicides and spraying techniques, in accordance with the national action plan

PRE-EPIDEMIC PERIOD

Category	Area	Action
Management	One Health coordination	Weekly meetings, increasing to daily as an international RVF alert is received or issued nationally
	Objectives	Review statement of objectives to ensure clarity of purpose
	Early warning	Early warning focal point alerts MCM to recognize increasing risk
	Risk assessment	Review national risk assessment and maps in light of emerging risks
	Action plan	Mobilize pre-epidemic action plan and procure and preplace supplies
	Funding	Mobilize pre-epidemic funding in accordance with action plan
	Trade	Brief trading partners on national risk management
Communication	Preparation	Review and update prototype materials and produce final versions
	Dissemination	Post materials, broadcast messages on rural radio and form discussion groups
Surveillance	Passive	Alert passive surveillance system to heightened risk
	Participatory	Activate participatory surveillance system using syndromic case definitions in accordance with action plan
		Environmental monitoring and ground truthing of risk assessment and decision-making
	Sentinel	Alert sentinel herd system and shift to weekly sampling
Control	Livestock	If the strategy includes pre-emptive vaccination, begin vaccinating immediately using stocks available in accordance with RA and risk map
	Vector	Initiate vector control as environmental and surveillance triggers for control measures emerge
Capacity building	Risk assessment	Review risk assessment in light of developments and share observations with MCM
	Surveillance	Brief PSS personnel
	Control	Brief vaccination personnel
		Brief vector control personnel
		Train CHWs and CAHWs in larval control

EPIDEMIC PERIOD

Category	Area	Action
Management	One Health coordination	Daily meetings to coordinate response to human and animal RVF
	International partners	OIE and trading partners informed of events
	Action Plan	Epidemic phase action plan implemented
	Funding	Funds allocated for humanitarian and ancillary support
	Trade	Trading partners are briefed on national risk management
Communication	Dissemination	Messaging on minimizing risk of exposure and how to seek assistance
Surveillance	Passive	Passive surveillance system alerted to diagnosis of outbreak
	Participatory	Participatory surveillance system using syndromic case definitions is repositioned to areas not yet affected
	Sentinel	Sentinel herd system alerted and continues weekly sampling until the outbreak is resolved or the majority of the herd has seroconverted
Control	Livestock	In infected areas, discontinue vaccination and shift focus to supportive interventions. Continue vaccination at sites not yet affected.
	Vector	Continue vector control
Capacity building	Risk assessment	N/A
	Surveillance	N/A
	Control	N/A

POST-EPIDEMIC PERIOD

Category	Area	Action
Management	One Health coordination	Weekly assessments of recovery
	Objectives	Lesson learned relating to objectives
	Impact assessment	Assess extent of area affected and specific epidemiological and socio-economic impacts
	Action plan	Review the action plan in light of lessons learned
	Funding	Produce reports on impact of funding, continue mitigation activities
	Trade	Brief trading partners and OIE on evidence of resolution of outbreak
Communication	Dissemination	Messaging on safety of livestock products and economic recovery
Surveillance	Passive	Continue passive surveillance
	Participatory	Develop lessons learned from participatory surveillance system
	Sentinel	Consolidate data from sentinel system and combine with data from PSS
Control	Livestock	Collate data on interventions
	Vector	Collate data on interventions
Impact mitigation	Economic	Programs to contribute to stabilizing production systems and livelihoods coping mechanisms
	Social	Support for schools and social mechanisms in the community
Capacity building	Reflection	Retrospective meeting to discuss efficacy of actions

References

Anyamba, A., Chretien, J.P., Small, J., Tucker, C.J., Formenty, P.B., Richardson, J.H., Britch, S.C., Schnabel, D.C., Erickson, R.L. & Linthicum K.J. 2009. Prediction of a Rift Valley fever outbreak. *Proceedings of the National Academy of Sciences of the United States of America*, 106(3): 955–959.

Anyamba, A., Linthicum, K.J., Small, J., Britch, S.C., Pak, E., de La Rocque, S., Formenty, P., Hightower, A.W., Breiman, R. F., Chretien, J.P., Tucker, C.J., Schnabel, D., Sang, R., Haagsma, K., Latham, M., Lewandowski, H.B., Magdi, S.O., Mohamed, M.A., Nguku, P.M., Reynes, J.M. & Swanepoel, R. 2010. Prediction, assessment of the Rift Valley fever activit in East and Southern Africa 2006-2008 and possible vector control strategies. *American Journal of Tropical Medicine and Hygiene*, 83(2 Suppl): 43–51.

Arsevska, E., Hellal, J., Mejri, S., Hammami, S., Marianneau, P., Calavas, D. & Henaux, V. 2016. Identifying Areas Suitable for the Occurrence of Rift Valley Fever in North Africa: Implications for Surveillance. *Transboundary and Emerging Diseases*, 63(6): 658–674.

Bett, B. 2018. Association between Rift Valley fever virus seroprevalences in livestock and humans and their respective intra-cluster correlation coefficients, Tana River County, Kenya. *PLoS One:* 1–9.

Bird, B.H., Bawiec, D.A., Ksiazek, T.G., Shoemaker, T.R. & Nichol, S.T. 2007. Highly sensitive and broadly reactive quantitative reverse transcription-PCR assay for high-throughput detection of Rift Valley fever virus. *Journal of Clinical Microbiology*, 45(11): 3506–3513.

Bouloy, M. 2001. Rift Valley fever virus. In M.W. Service, ed. *Encyclopedia of Arthropod-transmimtted Infections of Man and Domesticated Animals*, pp. 426–430. UK, CABI Publishing.

Boushab, B.M., Fall-Malick, F.Z., Ould Baba, S.E., Ould Salem, M.L., Belizaire, M.R., Ledib, H., Ould Baba Ahmed, M.M., Basco, L.K. & Ba, H. 2016. Severe Human Illness Caused by Rift Valley Fever Virus in Mauritania, 2015. *Open Forum Infectious Diseases*, 3(4): ofw200.

Bowles, D.C., Butler, C.D. & Morisetti, N. 2015. Climate change, conflict and health. *Journal of the Royal Society of Medicine*, 108(10): 390–395.

Burrows, K. & Kinney, P.L. 2016. Exploring the Climate Change, Migration and Conflict Nexus. *International Journal of Environmental Research and Public Health*, 13(4): 443.

Cameron, A., Mariner, J., Paisley, L., Parmley, J., Roger, F., Scott, A., Willenberg, P. & Wolhuter, M. 2015. *OIE Guide to Terrestial Animal Health Surveillance*. Paris, World Organization for Animal Health.

Caminade, C., Ndione, J.A., Diallo, M., MacLeod, D.A., Faye, O., Ba, Y., Dia, I. & Morse, A.P. 2014. Rift Valley Fever outbreaks in Mauritania and related environmental conditions. *International Journal of Environmental Research and Public Health*, 11(1): 903–918.

CDC. 2021. *RVF Distribution Map* [online]. [Cited 8 January 2021]. https://www.cdc.gov/vhf/rvf/outbreaks/distribution-map.html

CDC. 2021. *Outbreak Summaries* [online]. [Accessed 08 January 2021]. https://www.cdc.gov/vhf/rvf/outbreaks/summaries.html

Chevalier, V., Pepin, M., Plee, L., & Lancelot, R. 2010. Rift Valley fever – A threat for Europe? *Eurosurveillance*, 15(10): 19506.

Clements, A.C., Pfeiffer, D.U., Martin, V., Pittiglio, C., Best, N., Thiongane, Y., Tourre, Y.M., Lacaux, J.P., Vignolles, C., Ndione, J.A., Lafaye, M., Akakpo, A.J., Saluzzo, J.F., Bada, R., Bornarel, P. & Sarradin, P. 2007. *Spatial risk assessment of Rift Valley fever in Senegal Mapping of zones potentially occupied by Aedes vexans and Culex poicilipes mosquitoes, the main vectors of Rift Valley fever in Senegal* [Epidemiology of Rift Valley fever in West Africa. 1. Serological investigation of small ruminants in Niger]. *Vector-Borne and Zoonotic Diseases*, 7(2): 203–216.

Consultative Group for RVF Decision Support. 2010. Decision-support tool for prevention and control of Rift Valley fever epizootics in the Greater Horn of Africa. *American Journal of Tropical Medicine and Hygiene*, 83(2 Suppl): 75–85.

Couacy-Hymann, E., Roger, F., Hurard, C., Guillou, J.P., Libeau, G. & Diallo, A. 2002. Rapid and sensitive detection of peste des petits ruminants virus by a polymerase chain reaction assay. *Journal of Virological Methods*, 100(1–2): 17–25.

Drosten, C., Gottig, S., Schilling, S., Asper, M., Panning, M., Schmitz, H. & Gunther, S. 2002. Rapid detection and quantification of RNA of Ebola and Marburg viruses, Lassa virus, Crimean-Congo hemorrhagic fever virus, Rift Valley fever virus, dengue virus, and yellow fever virus by real-time reverse transcription-PCR. *Journal of Clinical Microbiology*, 40(7): 2323–2330.

EFSA. 2013. Scientific Opinion on Rift Valley fever. *EFSA Journal*, 11(4): 48.

EMPRES-i. 2021. *Global Animal Information System* [online]. [Cited 8 January 2021]. http//empres-i.fao.org/epiws3g/.

FAO. 2016. *Livestock-related interventions during emergencies – The how-to-do-it manual*. Rome.

FAO. 2019. Real-time monitoring and forecasting of Rift Valley fever in Africa. FCC-EMPRES Information Sheet. July 2019 http://www.fao.org/3/ca5511en/ca5511en.pdf

FAO. 2021. *Technical guidelines on rapid risk assessment (RRA) for animal health threats*. FAO Animal Production and Health Guidelines No. 24. Rome.

Faye, O., Ba, H., Ba, Y., Freire, C.C., Faye, O., Ndiaye, O., Elgady, I.O., Zanotto, P.M., Diallo, M. & Sall, A.A. 2014. Reemergence of Rift Valley fever, Mauritania, 2010. *Emerging Infectious Diseases*, 20(2): 300–303.

Faye, O., Diallo, M., Diop, D., Bezeid, O.E., Ba, H., Niang, M., Dia, I., Mohamed, S.A., Ndiaye, K., Diallo, D., Ly, P.O., Diallo, B., Nabeth, P., Simon, F., Lo, B. & Diop, O.M. 2007. Rift Valley fever outbreak with East-Central African virus lineage in Mauritania, 2003. *Emerging Infectious Diseases*, 13(7): 1016–1023.

Fleeman, L.M., Irwin, P.J., Phillips, P.A. & West, J. 2000. Effects of an oral vasopressin receptor antagonist (OPC-31260) in a dog with syndrome of inappropriate secretion of antidiuretic hormone. *Australian Veterinary Journal*, 78(12): 825–830.

Garcia, S., Crance, J.M., Billecocq, A., Peinnequin, A., Jouan, A., Bouloy, M. & Garin, D. 2001. Quantitative real-time PCR detection of Rift Valley fever virus and its application to evaluation of antiviral compounds. *Journal of Clinical Microbiology*, 39(12): 4456–4461.

Glancey, M.M., Anyamba, A. and Linthicum, K.J. 2015. Epidemiologic and Environmental Risk Factors of Rift Valley Fever in Southern Africa from 2008 to 2011. *Vector-Borne and Zoonotic Diseases*, 15(8): 502–511.

Guillebaud, J., Bernardson, B., Randriambolamanantsoa, T.H., Randrianasolo, L., Randriamampionona, J.L., Marino, C.A., Rasolofo, V., Randrianarivelojosia, M., Vigan-Womas, I., Stivaktas, V., Venter, M., Piola P. & Heraud J.M. 2018. Study on causes of fever in primary healthcare center uncovers pathogens of public health concern in Madagascar, **12**(7): e0006642.

IPCC. 2018. Summary for Policymakers. In V. Masson-Delmotte, H.O. Pörtner P. Zhai, *et al.*, eds. *Global Warming of 1.5°C: An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*. Geneva, Switzerland.

Jori, F., Alexander, K.A., Mokopasetso, M., Munstermann, S., Moagabo, K. & Paweska, J.T. 2015. Serological Evidence of Rift Valley Fever Virus Circulation in Domestic Cattle and African Buffalo in Northern Botswana (2010-2011). *Frontiers in Veterinary Science*, 2: 63.

Jost, C.C., Nzietchueng, S., Kihu, S. Bett, B., Njogu, G., Swai, E.S. & Mariner, J.C. 2010. Epidemiological assessment of the Rift Valley fever outbreak in Kenya and Tanzania in 2006 and 2007. *American Journal of Tropical Medicinge and Hygiene*, 83(2 Suppl): 65–72.

Jupp, P.G., Kemp, A., Grobbelaar, A., Lema, P., Burt, F.J., Alahmed, A.M., Al Mujalli, D., Al Khamees, M. & Swanepoel, R. 2002. The 2000 epidemic of Rift Valley fever in Saudi Arabia: mosquito vector studies. *Medical and Veterinary Entomology*, 16(3): 245–252.

Kimani, T., Ngigi, M., Schelling, E. & Randolph, T. 2016. One Health stakeholder and institutional analysis in Kenya. *Infection Ecology and Epidemiology*, 6: 31191.

Kimani, T., Schelling, E., Bett, B., Ngigi, M., Randolph, T. & Fuhrimann, S. 2016. Public Health Benefits from Livestock Rift Valley Fever Control: A Simulation of Two Epidemics in Kenya. *EcoHealth*, 13(4): 729–742.

Lacaux, J., Tourre, Y., Vignolles, C., Ndione, J. & Lafaye, M. 2007. Classification of ponds from high-spatial resolution remote sensing: Application to Rift Valley Fever epidemics in Senegal. *Remote Sensing of Environment*, 106: 66–74.

LEGS. 2014. *Livestock Emergency Guidelines and Standards*. Rugby, UK, Practical Action Publishing.

Linthicum, K.J., Britch, S.C. & Anyamba, A. 2016. Rift Valley Fever: An Emerging Mosquito-Borne Disease. *Annual Review of Entomology*, 61: 395–415.

Madani, T.A., Al-Mazrou, Y.Y., Al-Jeffri, M.H., Mishkhas, A.A., Al-Rabeah, A.M., Turkistani, A.M., Al-Sayed, M.O., Abodahish, A.A., Khan, A.S., Ksiazek, T.G. & Shobokshi, O. 2003. Rift Valley fever epidemic in Saudi Arabia: Epidemiological, clinical, and laboratory characteristics. *Clinical Infectious Diseases*, 37(8): 1084–1092.

Mariner, J.C. 2018. *Rift Valley Fever Surveillance.* FAO Animal Production and Health Manual No. 21. Rome. Food and Agriculture Organization of the United Nations (FAO).

Mariner, J.C., Hendrickx, S., Pfeiffer, D.U., Costard, S., Knopf, L., Okuthe, S., Chibeu, D., Parmley, J., Musenero, M., Pisang, C., Zingeser, J., Jones, B.A., Ali, S.N., Bett, B., McLaws, M., Unger, F., Araba, A., Mehta, P. & Jost, C.C. 2011. Integration of participatory approaches into surveillance systems. *Revue Scientifique et Technique*, 30(3): 653–659.

Mariner, J.C., Morrill, J. & Ksiazek, T.G. 1995. Antibodies to hemorrhagic fever viruses in domestic livestock in Niger: Rift Valley fever and Crimean-Congo hemorrhagic fever. *American Journal of Tropical Medicinge and Hygiene*, 53(3): 217–221.

Mariner, J.C. & Paskin, R. 2000. *Participatory Epidemiology: Methods for the Collection of Action-Oriented Epidemiological Intelligence*. FAO Manual No. 10. Rome, FAO. 81 pp.

Mariner, J.C. & Roeder, P.L. 2003. Use of participatory epidemiology in studies of the persistence of lineage 2 rinderpest virus in East Africa. *Veterinary Record*, 152(21): 641–647.

McMichael, A.J. 2015. Extreme weather events and infectious disease outbreaks. *Virulence*, 6(6): 543–547.

McMichael, C. 2015. Climate change-related migration and infectious disease. *Virulence*, 6(6): 548–553.

Metras, R., Porphyre, T., Pfeiffer, D.U., Kemp, A., Thompson, P.N., Collins, L.M. & White, R.G. 2012. Exploratory space-time analyses of Rift Valley Fever in South Africa in 2008-2011. *PLoS Neglected Tropical Diseases*, 6(8): e1808.

Munstermann, S., Delarocque, S. & Formenty, P. 2012. The disease epidemiology in animals and overview of its global spread. In *RVF: Challenges, prevention and control*. Global Framework for the Progressive Control of Transboundary Animal Diseases (GF-TADs) report for the OIE–FAO Inter-Regional Conference for the Middle East and Horn of Africa. 118 pp.

Munyua, P., Murithi, R.M., Wainwright, S., Githinji, J., Hightower, A., Mutonga, D., Macharia, J., Ithondeka, P.M., Musaa, J., Breiman, R.F., Bloland, P. & Njenga, M.K. 2010. Rift Valley fever outbreak in livestock in Kenya, 2006-2007. *American Journal of Tropical Medicinge and Hygiene*, 83(2 Suppl): 58–64.

Munyua, P.M., Murithi, R.M., Ithondeka, P., Hightower, A., Thumbi, S.M., Anyangu, S.A., Kiplimo, J., Bett, B., Vrieling, A., Breiman, R.F. & Njenga, M.K. 2016. Predictive Factors and Risk Mapping for Rift Valley Fever Epidemics in Kenya. *PLoS One*, 11(1): e0144570.

Napp, S., Chevalier, V., Busquets, N., Calistri, P., Casal, J., Attia, M., Elbassal, R., Hosni, H., Farrag, H., Hassan, N., Tawfik, R., Abd Elkader, S. & Bayomy, S. 2018. Understanding the legal trade of cattle and camels and the derived risk of Rift Valley Fever introduction into and transmission within Egypt. *PLoS Neglected Tropical Diseases*, 12(1): e0006143.

Nielsen, S.S., Alvarez, J., Bicout, D.J., Calistri, P., Depner, K., Drewe, J.A., Garin-Bastuji, B., Rojas, J.L.G., Schmidt, C.G., Michel, V., Chueca M.Á., M., Roberts, H.C., Sihvonen, L.H., Stahl, K., Calvo, A.V., Viltrop, A., Winckler, C., Bett, B., Cetre-Sossah, C., Chevalier, V., Devos, C., Gubbins, S., Monaco, F., Sotiria-Eleni, A., Broglia, A., Abrahantes, J.C., Dhollander, S., Stede, Y.V. & Zancanaro, G. 2020. Rift Valley Fever - epidemiological update and risk of introduction into Europe. *EFSA Journal*, 18(3): e06041.

Ogden, N.H. 2017. Climate change and vector-borne diseases of public health significance. *FEMS Microbiology Letters*, 364(19).

OIE. 2016. Chapter 2.1.18: Rift Valley fever (Infection with Rift Valley fever virus). In *OIE Manual of Diagnostic Tests and Vaccines for Terrestial Animals 2016* [online]. http://www.oie.int/fileadmin/Home/eng/Health_standards/tahm/2.01.14_RVF.pdf.

OIE. 2021. *WAHIS: The World Animal Health Information System* [online]. [Cited 8 January 2021]. https://www.oie.int/animal-health-in-the-world/the-world-animal-health-information-system/the-world-animal-health-information-system/

Oyas, H., Holmstrom, L., Kemunto, N.P., Muturi, M., Mwatondo, A., Osoro, E., Bitek, A., Bett, B., Githinji, J.W., Thumbi, S.M., Widdowson, M.A., Munyua, P.M. & Njenga, M.K. 2018. Enhanced surveillance for Rift Valley Fever in livestock during El Nino rains and threat of RVF outbreak, Kenya, 2015-2016. *PLoS Neglected Tropical Diseases*, 12(4): e0006353.

Pachka, H., Annelise, T., Alan, K., Power, T., Patrick, K., Veronique, C., Janusz, P. & Ferran, J. 2016. Rift Valley fever vector diversity and impact of meteorological and environmental factors on Culex pipiens dynamics in the Okavango Delta, Botswana. *Parasites & Vectors*, 9(1): 434.

Paweska, J.T. 2015. Rift Valley fever. *Revue Scientifique et Technique*, 34(2): 375–389.

Rich, K.M. & Wanyoike, F. 2010. An assessment of the regional and national socio-economic impacts of the 2007 Rift Valley fever outbreak in Kenya. *American Journal of Tropical Medicinge and Hygiene*, 83(2 Suppl): 52–57.

Rolin, A.I., Berrang-Ford, L. & Kulkarni, M.A. 2013. The risk of Rift Valley fever virus introduction and establishment in the United States and European Union." *Emerging Microbes & Infections*, 2(12): e81.

Sall, A.A., Thonnon, J., Sene, O.K., Fall, A., Ndiaye, M., Baudez, B., Mathiot, C. & Bouloy, M. 2001. Single-tube and nested reverse transcriptase-polymerase chain reaction for detection of Rift Valley fever virus in human and animal sera. *Journal of Virological Methods*, 91(1): 85–92.

Sang, R., Arum, S., Chepkorir, E., Mosomtai, G., Tigoi, C., Sigei, F., Lwande, O.W., Landmann, T., Affognon, H., Ahlm, C. & Evander, M. 2017. Distribution and abundance of key vectors of Rift Valley fever and other arboviruses in two ecologically distinct counties in Kenya: 1935–2735.

Schwerdtle, P., Bowen, K. & McMichael, C. 2017. The health impacts of climate-related migration. *BMC Medicine*, 16(1): 1.

Soti, V., Chevalier, V., Maura, J., Begue, A., Lelong, C., Lancelot, R., Thiongane, Y. & Tran, A. 2013. Identifying landscape features associated with Rift Valley fever virus transmission, Ferlo region, Senegal, using very high spatial resolution satellite imagery. *International Journal of Health Geographics*, 12: 10.

Soti, V., Tran, A., Degenne, P., Chevalier, V., Lo Seen, D., Thiongane, Y., Diallo, M., Guegan, J.F. & Fontenille, D. 2012. Combining hydrology and mosquito population models to identify the drivers of Rift Valley fever emergence in semi-arid regions of West Africa. *PLoS Neglected Tropical Diseases*, 6(8): e1795.

Sow, A., Faye, O., Ba, Y., Ba, H., Diallo, D., Faye, O., Loucoubar, C., Boushab, M., Barry, Y., Diallo, M. & Sall, A.A. 2014. Rift Valley fever outbreak, southern Mauritania, 2012. *Emerging Infectious Diseases*, 20(2): 296–299.

Sow, A., Faye, O., Ba, Y., Diallo, D., Fall, G., Faye, O., Bob, N.S., Loucoubar, C., Richard, V., Dia, A.T., Diallo, M., Malvy, D. & Sall, A.A. 2016. Widespread Rift Valley Fever Emergence in Senegal in 2013-2014. *Open Forum Infectious Diseases*, 3(3): ofw149.

Sumaye, R., Jansen, F., Berkvens, D., De Baets, B., Geubels, E., Thiry, E. & Krit, M. 2019. Rift Valley fever: An open-source transmission dynamics simulation model, 14(1): e0209929.

Tantely, L.M., Boyer, S. & Fontenille, D. 2015. A review of mosquitoes associated with Rift Valley fever virus in Madagascar. *American Journal of Tropical Medicinge and Hygiene*, 92(4): 722–729.

Tran, A., Trevennec, C., Lutwama, J., Sserugga, J., Gely, M., Pittiglio, C., Pinto, J. & Chevalier, V. 2016. Development and Assessment of a Geographic Knowledge-Based Model for Mapping Suitable Areas for Rift Valley Fever Transmission in Eastern Africa. *PLoS Neglected Tropical Diseases*, 10(9): e0004999.

van den Bergh, C., Venter, E.H., Swanepoel, R. & Thompson, P.N. 2019. High seroconversion rate to Rift Valley fever virus in cattle and goats in far northern KwaZulu-Natal, South Africa, in the absence of reported outbreaks. *PLoS Neglected Tropical Diseases*, 13(5): e0007296.

WHO. 1989. *Strengthening the performance of community health workers in primary health care*. 46 pp.

WHO. 2021. *Rift Valley fever* [online]. [Cited 8 January 2021]. https://www.who.int/csr/don/archive/disease/rift_valley_fever/en/

WHO, OIE & FAO. 2019. *Taking a Multisectoral, One Health Approach: A Tripartite Guide to Addressing Zoonotic Diseases in Countries*.

WHO, OIE and FAO. 2020. *Joint Risk Assessment Operational Tool (JRA OT): An Operational Tool of the Tripartite Zoonoses Guide – Taking a Multisectoral, One Health Approach: A Tripartite Guide to Addressing Zoonotic Diseases in Countries. Geneva.*

Annexes

Annex I
Regional RVF roadmap

The roadmap was developed during the Rift Valley Fever Regional Technical Workshop in East Africa, held in Dar es Salaam, United Republic of Tanzania in 2018.

The objectives of a regional RVF roadmap are:

- to leverage the potential and opportunities provided through a One Health approach to stimulate a coordinated and harmonized RVF prevention, detection and response in Eastern Africa;
- to provide a guide for governments, the private sector, communities, and livestock and public health stakeholders on the management of RVF; and
- to provide opportunities for the review and operationalization of enabling policies and a regulatory framework for RVF management in Eastern Africa.

The regional roadmap covers the following thematic areas: the One Health approach, risk assessment and communication, vaccine, surveillance and response.

There are three categories of priority action identified by the roadmap: short-term, short- and medium-term, and medium-term.

PRIORITY ACTIONS

Short-term priority actions

- Facilitate a regional discussion on the technical aspects of RVF vaccination, involving research institutions, governments, the private sector (vaccine producers) and organizations providing technical support (FAO, WHO, the OIE, AU-IBAR, the Pan-African Veterinary Vaccine Center of African Union [AU-PANVAC], the Africa Centres for Disease Control and Prevention [Africa CDC] and Africa's RECs)
- Establish and strengthen One Health coordination mechanisms at the national and sub-national levels (ministry of agriculture (MoA), ministry of health (MoH), Africa CDC and technical partners)

Short- and medium-term priority actions

- Institutionalize and strengthen the One Health framework at the national and regional levels (carried out by the DVS and DMS, IGAD and the East African Community (EAC), and technical partners)
- Develop or review RVF risk assessment guidelines at the national and regional levels (carried out by the MoA and MoH, RECs and technical partners)
- Develop a strategic risk-based RVF response involving surveillance, vaccination, awareness and communication
- Set up a regional One Health programme to consolidate and share lessons learned from member states and technical partners on an annual basis (carried out by FAO, WHO, the EAC, IGAD)

- Establish and strengthen the sentinel herd system used to carry out systematic RVF surveillance of livestock, and strengthen the capacity to carry out surveillance of RVF in humans (carried out by the MoA and MoH)
- Expedite the operationalization of regional reference labs, and strengthen their capacity for coordination with member states (carried out by the OIE)
- Develop and strengthen integrated One Health RVF preparedness and contingency plans at the national level (carried out by the MoA and MoH and technical partners)
- Increase the capacity for RVF diagnosis at the national level (carried out by the MoA, MoH and OIE/FAO Reference Centres)

Medium-term priority actions

- Develop a regional risk and crisis communication strategy to be adopted at the national level (carried out by IGAD, the EAC and technical partners)
- Establish a regional and national RVF (One Health) advisory group to advocate, mobilize resources and assess progress (carried out by the EAC, IGAD, AU-IBAR and technical partners)
- Develop guidelines showing core indicators broken down by thematic area (risk assessment and communication, vaccine, surveillance, response and One Health) to help monitor progress at the national and regional levels (carried out by FAO, WHO, the OIE, the EAC and IGAD)

Annex II
Establishing sentinel herds to improve Rift Valley fever surveillance

1. INTRODUCTION

Key facts about RVF

1. The RVF virus is transmitted from ruminant to ruminant by mosquitoes. Different climatic, environmental and socio-economic factors may influence the transmission of the virus.
2. In ruminants, RVF infection causes abortion storms in groups or flocks of pregnant females and acute deaths in newborns.
3. In the majority of human cases, RVF infection is asymptomatic or causes mild illness. However, severe forms, characterized by retinitis, encephalitis, or hemorrhagic fever and death, can occur.
4. Both health and economic impacts can be greatly reduced when control measures (e.g. such as vaccination, insecticide spraying) and, awareness creating in the affected community are quickly implemented

According to a study conducted by Lichoti *et al.* (2014), , Rift Valley fever (RVF) virus activity occurs even in the absence of clinical infections in herds. Therefore, active surveillance is needed between epidemics to be able to detect transmission among livestock, and possible human exposure that may go undetected among remote rural communities. The trade in livestock from infected countries is permitted during inter-epizootic periods when clinical disease is inapparent. Confidence among trading partners in the accuracy of surveillance information is essential to maintaining access to international livestock markets.

In order to prevent the virus spillover into the human population, minimize losses in the livestock population and promote the economic growth associated with access to international markets, improvements to evidence-based surveillance mechanisms are needed that increase the sensitivity of detection. The use of sentinel herds (SHs) as a risk-based approach to improving disease detection and response is an objective option based on the presence, or absence, of seroconversion being demonstrated in a laboratory. It is important to consider that due to the time it takes for seroconversion, the collection of samples, their shipment and processing, and the reporting of results, SHs cannot be seen as an early detection tool, but rather as an evidence-based tool that shows that infection and virus circulation has occurred

(FAO, 2018). However, if sampling is carried out frequently and molecular testing performed, SHs can serve as a safety net, speeding up detection when early detection methods fail. Most importantly, SHs are a systematic, risk-based method that provides objective evidence of the presence or absence of virus transmission, and which can anchor the overall RVF surveillance database for disease response and trade decision-making.

2. WHY USE SENTINEL HERDS?

Given the complex epidemiology of the disease, passive surveillance alone cannot lead to early detection. There is therefore a need to complement passive surveillance with an active search for virus circulation within at-risk populations. Sentinel herds established in high-risk areas offer a strong possibility of determining the local onset of virus circulation, with the location of these sentinel herds allowing the disease's potential distribution to be identified.

Thus, if an adequate and sustained budget is provided, sentinel herds can provide a systematic approach to monitor population status. In order to be effective, a comprehensive, risk-based number of sentinel herds need to be established and selected for periodic observation, serosampling and monitoring to detect the circulation of RVF viruses and the likelihood of RVF outbreaks.

3. ESSENTIAL ELEMENTS TO CONSIDER BEFORE ESTABLISHING SENTINEL HERD PROGRAMME

Key aspects of SH surveillance protocol

1. Sentinel herds are composed of naive animal populations.
2. Veterinary services must make regular visits to livestock owners.
3. A follow-up system, with skilled and trained field veterinarians, should be set up.
4. RVF can reasonably be suspected when abnormal and high levels of abortions and stillbirths are observed in an area infested with mosquitoes (under certain climatic and environmental conditions such as abundant rainfall or the presence of dams or irrigation systems, etc.).
5. Young females (12–18 months) with two teeth which are likely to remain longer within sentinel herds and which no longer have maternal antibodies should preferably be selected.
6. Animals with a positive IgG (indicating prior virus circulation) should always be removed from the sero-surveillance programme and replaced, since they would remain positive and thus cannot contribute to early detection.
7. The observation of animals with IgM+ shows recent virus circulation. In this case, veterinary services are required to follow the emergency preparedness and response plan for such cases (low viral circulation or beginning of an RVF outbreak).

To increase the efficacy of the programme, veterinary services should have a good understanding of RVFV activity within the country. They should mobilize partners to set up a One

Health advisory task force for emerging diseases, with a joint RVF task force to monitor and coordinate activities, which will:

- create and maintain a database of all evidence of RVF events;
- continuously build field veterinarians' capacity to carry out syndromic surveillance and investigate outbreaks, including through the provision of biosafety equipment (PPE) and sampling consumables;
- guide the animal health, public health, environment and wildlife sectors to increase information sharing and conduct joint outbreak investigations when necessary;
- build national laboratory capacity to detect and confirm RVFV, including the bio-safety measures;
- ensure that investigation teams have adequate material, equipment, vehicles and logistical support to move safely and rapidly to potential outbreak areas, since RVF outbreaks can occur under very challenging conditions, such as widespread flooding;
- secure adequate funding, and confirm that the materials and transport are available to immediately investigate all reports of RVF or abortion and neonatal mortality;
- adopt a comprehensive approach in which all essential components of disease control are in place; and
- interact to ensure the success of sentinel herd surveillance.

4. HOW SHOULD SUITABLE AREAS FOR THE PLACEMENT OF SENTINEL HERDS BE SELECTED?

Key principles in the management and monitoring of sentinel herds

1. Before heavy rains, baseline data should be collected.
2. All animals belonging to sentinel herds must be tested for RVFV antibodies (IgG and IgM) to provide baseline data.
3. Sero-surveillance should be carried out during high-risk periods
4. No insecticides should be used on the sentinel herd.
5. Sentinel animals should not be vaccinated against RVF.
6. Animals in the sentinel herds should be individually identified and the identification system should remain during the entire process.
7. Livestock owners should be made aware of the need to ensure suspected RVF cases (such as abortion in herds, or human cases), as well as flooding and mosquito swarms, are reported early.
8. Toll-free phone lines should be set up to encourage early reporting.

The purpose of surveillance is to mitigate the immediate direct and indirect impacts of infection and disease. It is important to remember that RVF viruses may occur in regions that have not reported a single case, and the choice of sites for establishing sentinel herds and carrying out sampling should thus be made based on the risk of an outbreak. Risk assessment will guide the placement of sentinel herds, and should take into consideration the following risk factors: (i) environmental suitability, such as prolonged rainfall leading to flooding; (ii) the presence and competence of vectors; (iii) the movement of animals, including transhumance; (iv) historical data on any past outbreaks; (v) the distribution and density of susceptible host species populations; (vi) the distribution of suitable mosquito habitat[2] (e.g. irrigated lands, dams); and vii) areas where animals are concentrated, such as markets, bore holes and water points, and abattoirs. In addition, the forest ecosystem may play a role in RVF's inter-epizootic perpetuation or amplification cycle. All these factors should be taken into consideration during risk assessment and the production of risk maps.

This information will ultimately contribute to the monitoring of the evolving risk of RVF occurrence and help identify risk areas. In addition, this information should be considered alongside veterinary and medical reports of past human cases. Ideally, provided that veterinary services have skilled personnel, RVF risk maps should be produced and updated accordingly.

Once the risk assessment has been completed and high-risk areas identified, a clear surveillance protocol for monitoring sentinel herds should be prepared and strictly followed. Livestock owners who join this programme should be regularly visited and informed of the risk of RVF occurrence and its symptoms. Incentives should be put in place to encourage farmers not only to collaborate with authorities in sampling these herds, but also to regularly report any abortion (in the early, mid or late stages of gestation) or stillbirth. Active surveillance is also carried out by regularly collecting serum samples and testing for RVFV.

5. HOW SHOULD SENTINEL HERDS BE MANAGED?

A sentinel herd can be composed of 10–40 animals, which have ideally been ear-tagged or otherwise individually identified for easy reference. When the rainy season starts, trained veterinary technicians should make weekly visits to collect blood for the purposes of monitoring virus circulation. Ideally, the herd should be visited again 30 days after the rainy season.

Sentinel herds must **not** be vaccinated against RVF in order to avoid confusion between vaccine-induced immunity and immunity resulting from a natural viral strain. Dedicated field veterinarians employed by a country's veterinary services should be assigned to monitor these herds. It is of paramount importance that a large enough budget is allocated for serosurveillance activities, as well as providing in-kind incentives for farmers enrolled in the programme, such as deworming products, seeds for forage production, advice on reproduction, etc. An agreement between the veterinary services and livestock owners shoud be reached on the minumum time period (1–2 years) that the sentinel animals should remain in the herd.

This will eventually ensure the continuity and sustainability of the program. Farmers should be regularly visited and encouraged to report any suspicion of disease occurance, particularly abortion or reproductive issues, to the veterinary services. Active serosurveillance should ideally be conducted once or twice a year, depending on the budget available. However, the frequency of and timeline for seromonitoring is subject to change depending on the above-mentioned risk factors, and specifically:

[2] Of particular interest in this regard is information on topographical features such as altitudes, watercourses, water holes in national parks and the infection of wildlife susceptible species. Likely flood areas can be used to map the extent of potential mosquito breeding habitats.

- seasonal weather forecasts[3] and weather tracking (e.g. predictions of above-average rainfall conditions). For example, during an El Niño event, weekly sampling may be justified.
- increased vector activity, e.g. higher numbers of mosquitoes; and
- reports of increased reproductive issues, abortions and stillbirths.

Participatory epidemiology to collect this information can greatly assist in building a comprehensive picture of the epidemiological situation and facilitate the long-term collaboration of livestock owners (FAO, 2018). Ideally, animals from the sentinel herd should not be removed from the herd, but since this is rather difficult to achieve under field conditions, it is recommended that sentinel animals be monitored as a herd rather than at the individual level to ensure sustainability. This is cost-effective and would avoid the regular replacement of animals, in the case of death or sales.

6. WHAT TO DO WHEN IGM IS DETECTED

The detection of IgM is direct evidence of recent virus circulation and an indicator of the potential onset of an outbreak. In this case, veterinary services should carry out active surveillance through joint investigations with public health services (whenever possible) to assess the epidemiology of the disease, review the risk situation and advise on response measures. In addition, awareness-raising campaigns targeting abattoir staff, animal health professionals and farm assistants should be immediately launched. Veterinary services may consider limiting the movement of animals and implementing quarantine and vaccination protocols, depending on the assessed risk.[4]

7. CONCLUSIONS

Sample collection

1. Random sampling of susceptible species should be carried out.
2. Frequency for sample collection: every 4–6 weeks during the dry season, and weekly throughout the short and long rains.
3. Collected blood on anticoagulant, organs (aborted, spleen and river) samples are used for virus isolation and PCR.
4. Samples should be kept at +4 °C for whole blood and organs and 0 °C–20 °C for serum.
5. Sampling forms should be completed including the name of the veterinarian; the race, age, sex and geographic location of the animals; and any clinical signs, abortion or mortality observed in the herd.

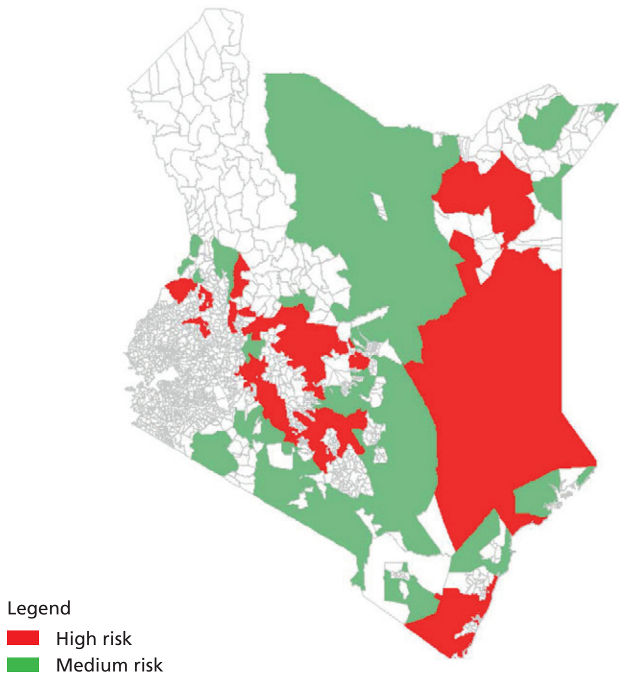
[3] For example, monitoring normalized difference vegetation index (NDVI) values in at-risk countries where there is a known history of the disease and the ecological conditions favourable to its spread could indicate a possible increase in the risk of RVF viral circulation or disease.

[4] Reference made to vaccination section- RVF response to outbreak

The use of sentinel herds distributed and monitored for both clinical signs and serological evidence of RVF infection is already established in East and West Africa (Kenya, Mauritania and Senegal); however, the continuation of this activity requires regular funding that varies widely depending on a country's animal health focus and priorities. It is important to ensure that local communities' capacity to recognize and report suspected cases of RVF is developed by focusing on identifying and reporting non-specific clinical signs such as higher than expected numbers of abortions or neonatal mortalities in ruminants, particularly when the area is experiencing abnormal climatic and environmental conditions. It should be noted that seromonitoring may be more difficult if sentinel animals are selected from within pastoralist herds. In this case, it would be necessary to establish a good relationship with pastoralist communities so that they are encouraged to remain in the sentinel herd monitoring programme and regularly report any unusual symptoms to the veterinary services.

EXAMPLES OF SENTINEL HERD PROGRAMMES

FIGURE A1
RVF risk map for Kenya (March 2018)



In Kenya, the RVF sentinel herd programme is run by the by the Veterinary Epidemiology and Economics Section in collaboration with the country's veterinary investigation laboratories. In recent years sentinel herds have been in Trans Nzoia, Naivasha, Nakuru, Machakos, Taita-Taveta and Maseno counties.

Source: Bett, B., Omolo, A., Notenbaert, A. and Kemp, S. 2012. Spatial-temporal analysis of the risk of Rift Valley fever in Kenya. Presentation at the 13th Conference of the International Society of Veterinary Epidemiology and Economics, Maastricht, The Netherlands, 20-24 August 2012. Nairobi, Kenya: ILRI. https://cgspace.cgiar.org/bitstream/handle/10568/21772/RVF%20spatial%20analysis.pdf?sequence=2&isAllowed=y

BIBLIOGRAPHY

Davies, F.G. & Highton, R.B. 1980. Possible vectors of Rift Valley fever in Kenya. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 74(6): 815–816.

FAO. 2015. *The last hurdles towards Rift Valley fever control.* FAO Animal Production and Health Report on the 5–7 March 2014 ad hoc workshop on the current state of Rift Valley fever vaccine and diagnostics development. Rome.

FAO. 2018. *Reports on sentinel herds monitoring in Kenya and Senegal.*

FAO. 2018. *Rift Valley Fever Surveillance.* FAO Animal Production and Health Manual.

FAO. *Surveillance active de la FVR: Protocole d'enquête.* FAO Senegal.

Lichoti, J.K., Kihara, A., Oriko, A.A., Okutoyi, L.A., Wauna, J.O., Tchouassi, D.P., Tigoi, C.C. *et al.* 2014. Detection of Rift Valley Fever Virus Interepidemic Activity in Some Hotspot Areas of Kenya by Sentinel Animal Surveillance, 2009–2012. *Veterinary Medicine International,* 2014: 379010. https://doi.org/10.1155/2014/379010

Plee, L. 2012. *Original Proposal for the establishment of sentinel herds in Mauritania*.

Tran, A., Trevennec, C., Lutwama, J., Sserugga, J., Gely, M., Pittiglio, C., Pinto, J. & Chevalier, V. 2016. Development and Assessment of a Geographic Knowledge-Based Model for Mapping Suitable Areas for Rift Valley Fever Transmission in Eastern Africa. PLoS *Neglected Tropical Diseases,* 10(9): e0004999. doi:10.1371/ journal.pntd.0004999

Trevennec, C., Pittiglio, C., Wainwright, S., Plee, L., Pinto, J., Lubroth, J. & Martin, V. 2012. Rift Valley Fever: Vigilance needed in the coming months. *EMPRES Watch,* No. 27.

FAO ANIMAL PRODUCTION AND HEALTH GUIDELINES

1. Collection of entomological baseline data for tsetse area-wide integrated pest management programmes, 2009 (En)
2. Preparation of national strategies and action plans for animal genetic resources, 2009 (En, Fr, Es, Ru, Zh)
3. Breeding strategies for sustainable management of animal genetic resources, 2010 (En, Fr, Es, Ru, Ar, Zh)
4. A value chain approach to animal diseases risk management – Technical foundations and practical framework for field application, 2011 (En, Zh, Fr**)
5. Guidelines for the preparation of livestock sector reviews, 2011 (En)
6. Developing the institutional framework for the management of animal genetic resources, 2011 (En, Fr, Es, Ru)
7. Surveying and monitoring of animal genetic resources, 2011 (En, Fr, Es)
8. Guide to good dairy farming practice, 2011 (En, Fr, Es, Ru, Ar, Zh, Pt[e])
9. Molecular genetic characterization of animal genetic resources, 2011 (En, Zh**)
10. Designing and implementing livestock value chain studies – A practical aid for Highly Pathogenic and Emerging Disease (HPED) control, 2012 (En)
11. Phenotypic characterization of animal genetic resources, 2012 (En, Fr[e], Zh[e])
12. Cryoconservation of animal genetic resources, 2012 (En)
13. Handbook on regulatory frameworks for the control and eradication of HPAI and other transboundary animal diseases – A guide to reviewing and developing the necessary policy, institutional and legal frameworks, 2013 (En)
14. *In vivo* conservation of animal genetic resources, 2013 (En, Zh**)
15. The feed analysis laboratory: establishment and quality control – Setting up a feed analysis laboratory, and implementing a quality assurance system compliant with ISO/IEC 17025:2005, 2013 (En)
16. Decision tools for family poultry development, 2014 (En)
17. Biosecurity guide for live poultry markets, 2015 (En, Fr[e], Zh[e], Vi)
18. Economic analysis of animal diseases, 2016 (En, Zh)
19. Development of integrated multipurpose animal recording systems, 2016 (En, Zh)
20. Farmer field schools for small-scale livestock producers – A guide for decision-makers on improving livelihoods, 2018 (En, Fr[e])
21. Developing sustainable value chains for small-scale livestock producers, 2019 (En, Zh**)
22. Estimation des bilans fourragers dans la région du Sahel d'Afrique de l'Ouest et Centrale, 2020 (Fr)
23. Carcass management guidelines – Effective disposal of animal carcasses and contaminated materials on small to medium-sized farms, 2020 (En, Fr, Es, Ru, Zh, Ar, Sq, Sr, Mk)
24. Technical guidelines on rapid risk assessment (RRA) for animal health threats, 2021 (En)
25. Good beekeeping practices for sustainable apiculture, 2021 (En, Es)
26. Responsible use of antimicrobials in beekeeping, 2021 (En)
27. Developing field epidemiology training for veterinarians – Technical guidelines and core competencies, 2021 (En)
28. Making way: developing national legal and policy frameworks for pastoral mobility, 2022 (En)

Availability: February 2022

Ar – Arabic
En – English
Es – Spanish
Fr – French
Mk – Macedonian
Pt – Portuguese
Ru – Russian
Sq – Albanian
Sr – Serbian
Vi – Vietnamese
Zh – Chinese

Multil – Multilingual
* Out of print
** In preparation
[e] E-publication

The *FAO Animal Production and Health Guidelines* are available through authorized FAO Sales Agents or directly from Sales and Marketing Group, FAO, Viale delle Terme di Caracalla, 00153 Rome, Italy.

Rift Valley fever (RVF) is an arboviral disease affecting humans and livestock transmitted by mosquitoes. It is endemic to large areas of Africa, resulting in widespread abortion and neonatal mortality in livestock, and severe complications in a small but significant percentage of human cases. The range of RVF is largely determined by the distribution of suitable vector habitat and rainfall, which changes over time and as a result of climate change. In addition to which, the movement of animals and animal products for trade may lead to the spread of RVF to previously non-infected areas.

This RVF Action Framework is intended to provide decision makers with guidance on the best course of action to take in response to an RVF outbreak or the risk of an outbreak, and help them develop a national action plan for this response. A coordinated One Health approach that brings together the public, animal and environmental health sectors is recommended, as is a risk-based approach that uses risk assessment and mapping to determine the appropriate measures to be taken and the locations where they are required. A country's RVF response can be best broken down into the four phases of the epidemiological cycle: the inter-epidemic, pre-epidemic, epidemic and post-epidemic periods. Surveillance, risk assessment and capacity building, for instance, are key during the inter-epidemic period, while the focus during the post-epidemic period shifts to mitigating the disease's impact.

ISBN 978-92-5-135775-0 ISSN 1810-0708

9 789251 357750

CB8653EN/1/03.22