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Foreword

Foot and mouth disease (FMD) still occurs in large parts of the world. Its transboundary nature is becoming increasingly important because of the rapid development of international trade in animals and animal products and the increase in people movements worldwide.

Countries and regions that are free from FMD are continuously threatened by the presence of FMD elsewhere. This makes FMD a major obstacle to regional and global trade in animals and animal products. However, FMD is more than a disease affecting global trade and threatening FMD-free countries. The consequences of FMD in developing countries are often underestimated. In regions where FMD is still endemic, the disease has a strong negative impact on animal production caused by mortality in newborn animals, reduced milk and meat production from cows, buffalo, goats, sheep and swine and preventing draught animals from preparing fields for crops or harvesting or use as a means of transport. The overall goals of the Global FMD Control Strategy are therefore to protect FMD-free countries from re-introduction of the virus and to improve animal production in FMD-endemic countries, which are very often developing countries, thereby contributing to the alleviation of poverty and improving the livelihoods of small-scale farmers.

The Food and Agriculture Organization of the United Nations (FAO) and the World Organisation for Animal Health (OIE) consider that FMD control activities should be seen as for a global public good, as they benefit all countries, all populations and future generations. Moreover, countries strongly depend on each other to achieve sustainable progress. The FMD Control Strategy recognises that improved FMD control will go hand in hand with the strengthening of veterinary systems, in particular the national Veterinary Services on the basis of the OIE Performance of Veterinary Services (PVS) Pathway. Therefore, the FMD Control Strategy has the subtitle 'Strengthening Veterinary Systems'. This in turn will result in improved control of other major animal diseases, while costs of activities may be shared.

The first global conference on FMD, 'The way towards global FMD control', was organised by OIE and FAO in Asunción, Paraguay, in June 2009. The participants of the conference formulated a set of recommendations and reiterated their strong support for a globally coordinated approach to FMD control.

Recommendation 14 called for a pledging conference with the participation of free and affected countries, relevant organisations and donors to support a global FMD control programme.

FAO and the OIE jointly prepared the Global FMD Control Strategy, assisted by regional organisations and experts and under the umbrella of the Global Framework for the Progressive Control of Transboundary Animal Diseases. The FMD Control Strategy is to be presented during the second international conference on FMD control in Bangkok, Thailand, from 27 June to 29 June 2012. This conference is organised by FAO and the OIE, together with the Thai Ministry of Agriculture and Cooperatives, and is supported by several sponsors.

We are proud to present these Proceedings. It will give conference attendees a quick overview of what was presented by the speakers at this event.

We would like to thank the many distinguished speakers who were kind enough to accept our invitation to present the FMD situation globally and in various parts of the world according to virus pools, the lessons learned in the different regions where FMD has been eliminated or where good progress has been made, and of course the major tools of the Global FMD Control Strategy and the cornerstones on which the strategy is built.

We would also like to thank the joint FAO/OIE FMD Working Group, the consultants who worked with them and everyone who has assisted and advised the working group while developing the FMD Control Strategy, the financial partners; and, last but not least, the experts from the World Bank, who took the lead in making an assessment of the budget necessary to roll out the Global FMD Control Strategy.

This successful meeting will be an important milestone in the global fight against FMD, and we sincerely hope that the necessary political and financial support will be generated.

Rome, June 2012
Juan Lubroth
Chief Animal Health Service
Chief Veterinary Officer of FAO

Paris, June 2012
Bernard Vallat
Director General of the OIE

Preface

Diseases are among the most significant limiting factors for sustainable livestock production, and, among them, foot and mouth disease (FMD) is an eminent transboundary animal disease that severely affects the production of livestock and disrupts regional and international trade in animals and animal products and the livelihoods of millions of people. In developing countries the adverse effects of FMD are often underestimated. The disease directly undermines food security and economic development at the level of both village smallholders or more organised value and market chains supplying urban and export markets, and indirectly the allied industries of feed, transport, and at times even tourism.

As recommended by the first World Organisation for Animal Health (OIE)/Food and Agriculture Organization of the United Nations (FAO) Global Conference on Foot and Mouth Disease in Asunción, Paraguay, in June 2009, the Global FMD Control Strategy was prepared under the umbrella of the FAO/OIE Global Framework for the Progressive Control of Transboundary Animal Diseases (GF-TADs). A first outline was presented during the 79th General Session of the World Assembly of Delegates of the OIE in May 2011 and it was further developed in consultation with experts, national and regional authorities and policy-makers, financial partners and private industry. The experiences of a number of countries and regions, especially Europe, South America and South-East Asia, also served as the basis for developing the strategy.

This second international conference on FMD control, held in Bangkok, Thailand, from 27 June to 29 June 2012, was organised by FAO and OIE, together with the Thai Ministry of Agriculture and Cooperatives, and was supported by several sponsors, partners, and OIE and FAO reference centres.

The three days of the meeting were divided into nine sessions, which provided ample time to address successively the global and regional situations, the tools to be used to control FMD, the key elements to control and eradicate the disease and to maintain free status. The Global FMD Control Strategy was described, including its rationale and objectives, the underlying strategic principles, the expected results, the activities, the governance and the limiting factors. The action plan and milestones, as well as the portfolio for the FMD control component, are included in a document entitled 'The global foot and mouth disease control strategy. Strengthening animal health systems through improved control of major diseases', which was distributed at the conference and was made available on the OIE and FAO websites.

The participants discussed the three components of the strategy, namely:

1. improving global FMD control

2. strengthening Veterinary Services and

3. improving the prevention and control of other major diseases of livestock.

By the end of the meeting, the global strategy was strongly supported, as attested in the recommendations of the conference.

The Global FMD Control Strategy is not seen as a 'standalone activity', aimed solely at FMD control, but as a carrier mechanism to simultaneously progress in other fields, with the strengthening of veterinary systems as a linchpin that will create a more sustainable environment to control other priority diseases as well as cost-effective combinations of activities to be promoted.

The FAO and the OIE consider that FMD and other high impact animal disease control programmes should be seen as a global public good, as they benefit all countries, all populations and future generations.

Juan Lubroth
Chief Animal Health Service
Chief Veterinary Officer of FAO

Bernard Vallat
Director General of the OIE

Session 1

Review of global FMD situation: introduction to the Progressive Control Pathway

Chair: W. Thitisak (Thailand)

Setting the scene

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This paper is a product of close co-operation between the World Bank (WB) Team and the Food and Agriculture Organization of the United Nations (FAO)/World Organisation for Animal Health (OIE) Global Framework of Transboundary Animal Diseases (GF-TADs) Foot and Mouth Disease (FMD) Working Group. The longer version of the paper (3) is available as a supporting document of the global strategy (2). The paper relies heavily on discussions with and data provided by the members of GF-TADs FMD Working Group consulted between November 2011 and May 2012. We are deeply grateful to Joseph Domenech (OIE) and Peter DeLeeuw (FAO) for overall guidance and inputs, including during our meetings at OIE Headquarters in Paris on 21–22 November 2011 and at FAO Headquarters in Rome on 19–21 December 2011, and to Giancarlo Ferrari (FAO), Samia Metwally (FAO), Nadège Leboucq (OIE) and Bernardo Todeschini (OIE) for generously sharing their time, data and expertise. We also would like to thank Brian Bedard (WB), Cyril Gay (United States Department of Agriculture [USDA]), Alex Donaldson (FAO/OIE consultant), Stephane Forman (WB), Mimako Kobayashi (WB), Caroline Planté (WB), Jonathan Rushton of Royal Veterinary College, University of London and Juergen Voegele (WB) for very useful inputs, comments and discussions.

Summary

Retrospectively, the success in the eradication of rinderpest was in large part because of the commitment from national, regional and international organisations coordinating the vision to remove the threat to cattle production in large swathes of Asia, the Middle East and Africa. As with the establishment of the World Organisation for Animal Health (OIE), the creation of the Food and Agriculture Organization of the United Nations (FAO) not only recognised the paramount importance of rinderpest but also emphasised the significance of foot and mouth disease (FMD). Over the past 30 years, the regional FMD campaigns in western Europe and parts of South America and the country programmes in East and Southeast Asia and southern Africa have been largely successful. However, in endemic settings, owing to multiple disease burdens, differing health and developmental priorities and resource-poor veterinary systems have not been successful in tackling the eroding production efficiencies caused by FMD. With an expected global population of over nine billion people by 2050 and the need to produce more food, as well as the forecasted demand for more animal products in people's diets, efficiencies in production parameters are required, as is the management of natural resources and sound policies for a vibrant livestock sector – including safe trade. The ever increasing disease threats in a globalising world place all countries at risk of incursions of FMD and other pathogens, as recently seen in East Asia, North Africa, Western Europe and the southern cone of the Americas.

While existing tools in FMD diagnostics and vaccines have proven successful for some regions, improved methods in risk management, understanding drivers in the emergence of virus variants, and insight into production and marketing practices can be used to improve FMD management. A progressive control pathway (PCP), which guides the public veterinary authorities and livestock holders to intervene at critical stages of convergence of risks, would be advantageous in terms of maximising epidemiological knowledge and would be cost effective especially in resource-poor environments. The developed PCP for FMD provides this framework and fully complements existing regional programmes on FMD control. Furthermore, this approach can be modified to address other high-impact diseases, including some zoonoses. In this regard, it is important that Veterinary Services meet their public good obligations to conform or reform to attain the international standards as prescribed by the OIE. Thus, investments into this aspect of agricultural and livestock development would have a major impact on overall human health, nutrition and food safety, and contribute to local and national economic and social growth.

In this context, it is for the global public good to tackle FMD control at source, and it is of vital interest of both developed (usually FMD free) and developing (usually endemically infected) countries. An international global concerted effort with strong regional coordination is necessary, as is global joint financing to further leverage public–private partnerships. There is a need for a global FMD strategy that opens opportunities to address other diseases *that impact efficiencies and food security and develops robust veterinary systems in developing countries.*

Keywords

Coordination – Foot and mouth disease – Foot and mouth disease virus – Progressive control – Regional roadmap.

Analysis of the worldwide foot and mouth disease situation, trends and regional differences

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Summary

Foot and mouth disease (FMD) is highly contagious, infects a wide variety of domestic and wildlife hosts and occurs as seven virus serotypes with multiple subtypes known as topotypes. Its presence reduces production and restricts trade opportunities for endemic countries and poses a constant threat to those countries free from the disease. The World Reference Laboratory for FMD (WRLFMD®) at the Pirbright Institute is part of the World Organisation for Animal Health (OIE)/Food and Agriculture Organization of the United Nations (FAO) FMD Reference Laboratory Network that regularly receives samples for FMD diagnosis from many parts of the world. FMD virus (FMDV) isolates are identified and nucleotide sequencing is carried out to provide precise characterisation and tracing of their origin by comparison with viruses held in the extensive WRLFMD® collection. To support vaccination-based control strategies in endemic situations and to provide vaccine strain information to FMD-free countries, vaccine matching of selected isolates is carried out.

The FMDV continues to evolve, giving rise to new strains that cause periodic upsurges in the number of cases and increase the risk of spread into new areas. To enable a targeted approach to FMD control, the global spread of FMD has been clustered into seven FMDV pools, comprising three pools covering Europe, the Middle East and Asia, three pools covering Africa and one pool covering the Americas. Globally, the most common FMDV serotype reported is type O; however, in recent times there has been a marked increase in the number of reports of serotypes Asia 1 in Pool 3 and, most recently, a rapid spread of the Southern African Territories serotype (SAT) 2 through Egypt and the Middle East.

The global surveillance provided by the OIE/FAO FMD Reference Laboratory Network highlights the regional differences in virus populations and enables the monitoring of emergence and spread of FMDV globally, providing critical intelligence for FMD control initiatives.

Keywords
Control – Diagnosis – Foot and mouth disease – FMD Reference Laboratory Network – FMD virus – FMDV pools – Ruminants – Serotype – Surveillance – Topotype – Vaccine matching.

Introduction

Foot and mouth disease (FMD) is highly contagious, infects a wide variety of domestic and wildlife hosts and occurs as seven virus serotypes with multiple subtypes known as topotypes. Its presence reduces production and restricts trade opportunities for endemic countries and poses a constant threat to those countries free from the disease. FMD viruses (FMDVs) are not randomly dispersed throughout the world but are associated with particular ecological niches. The distribution is affected by recurring upsurges in the prevalence of particular strains that may be associated with viral evolution, waning population immunity and/or opportunities presented by the increasing and more frequent movements of animals and their products. This can give rise to pandemic spread affecting new regions. Current global surveillance for FMD aims to identify the current hazards and to predict heightened risk so that appropriate diagnostics and vaccines can be made available for their detection and control.

The World Reference Laboratory for FMD (WRLFMD®) at the Pirbright Institute, United Kingdom (UK), is the centre of an OIE/FAO FMD Reference Laboratory Network that regularly receives samples for FMD diagnosis from many

parts of the world. FMDV isolates are identified by serotyping, vaccine matching with a range of current FMD vaccine strains and nucleotide sequencing to provide precise characterisation of new isolates and tracing of their origin by comparison with viruses held in the extensive WRLFMD® and other collections. This analysis assists the monitoring of the 'real-time' emergence and spread of FMDV globally.

Studies on FMDV occurrence over many years have provided the information to suggest the clustering or grouping of FMD viruses into seven virus pools, with three pools covering Europe, the Middle East and Asia, three pools covering Africa and one pool covering the Americas. It is then not such a great leap to suggest that each pool of viruses may need particular control measures such as pool-specific diagnostics and vaccines. This concept has provided the platform to enable a targeted approach to progressive FMD control at the national, regional and global level.

It can be considered that this network of FMD reference laboratories is the engine room of the progressive control effort and the vital diagnostic outputs greatly assist in the monitoring of emergence and spread of FMDV globally and provide critical intelligence for FMD control initiatives. However, such extensive efforts require a wider team approach encompassing national and international disease control services and their laboratories along with the commercial vaccine and diagnostic providers. The gathering of this information then also anticipates that decisions and actions enabling FMD control will be made by those with the power and influence to do so.

Foot and mouth disease

Foot and mouth disease virus is highly contagious and infects a variety of cloven hoofed animals, including cattle, sheep, goats, swine, wild ruminants and suidae. The morbidity of FMD is high in infected adult livestock but the disease is rarely fatal in adult animals. In contrast, high mortality can be observed in young animals due to myocarditis. Following infection, the incubation period can be from two to 21 days (average three to eight) and large amounts of virus are excreted by infected animals before clinical signs are evident. Infected animals exhibit blisters and ulcers on the mouth, tongue, lips, feet and udder. Clinically, animals salivate excessively, have a fever and sore feet, lose weight and stop producing milk. On recovery from FMD, at least 50% of ruminants become 'carriers' with persistent sub-clinical infection. These animals present a critically important risk to susceptible animals as reservoirs of the infection.

Movement of live animals still constitutes by far the greatest risk for the spread of FMD, followed by trade in animal products. In parts of Africa, the Cape buffalo provides an important reservoir for the maintenance of certain FMDV serotypes. FMDV continues to evolve, giving rise to new strains that cause periodic upsurges in the number of cases and increase the risk of spread into new areas. An OIE/FAO network of FMD Reference Laboratories has been established to help track the emergence and distribution of different FMDV variants, to make recommendations on vaccine strains needed in different parts of the world and to raise standards of laboratory testing. In many parts of the world, the main barriers to FMDV spread operate at a regional rather than a national level, consistent with attempts to establish regional disease control programmes.

Global and regional foot and mouth disease situation

Global surveillance for FMD aims to identify the current hazards and to predict heightened risk so that appropriate diagnostics and vaccines are available for their detection and control. This requires sustained effort directed towards the monitoring of FMD outbreaks and ideally also of FMDV circulation and persistence, along with collection and characterisation of FMDVs and integration of findings with associated epidemiological intelligence. Such an extensive effort requires a team approach encompassing national and international disease control services and their laboratories along with commercial vaccine and diagnostic providers. The OIE/FAO FMD Reference Laboratory Network is a vital contributor to the global control of FMD and provides opportunities and expertise for developing and sustaining laboratory capacity and capability, exchange of materials and technologies, harmonising approaches to diagnosis and supporting complementary research.

Foot and mouth disease is endemic in Africa, most of Asia, the Middle East and parts of South America (Fig 1). Recently, we have determined the global clustering of FMDVs and identified seven virus pools, where multiple serotypes occur but within which are topotypes that remain mostly confined to that pool. We have defined three pools covering Europe, the Middle East and Asia, three pools covering Africa and one pool covering the Americas

(Fig. 2) (1, 2). This enables a regional approach to be taken to assist global control of FMD. An increased regional knowledge of FMD outbreaks and identification of these within particular reservoirs or pools of FMD activity can greatly assist globally informed regional FMD control programmes. It also follows that, if vaccination is to be a major tool for control, each pool could benefit from investigation into the use of tailored or more specific vaccines relevant to the topotypes present in that pool, rather than a continued reliance on the currently more widely available vaccines.

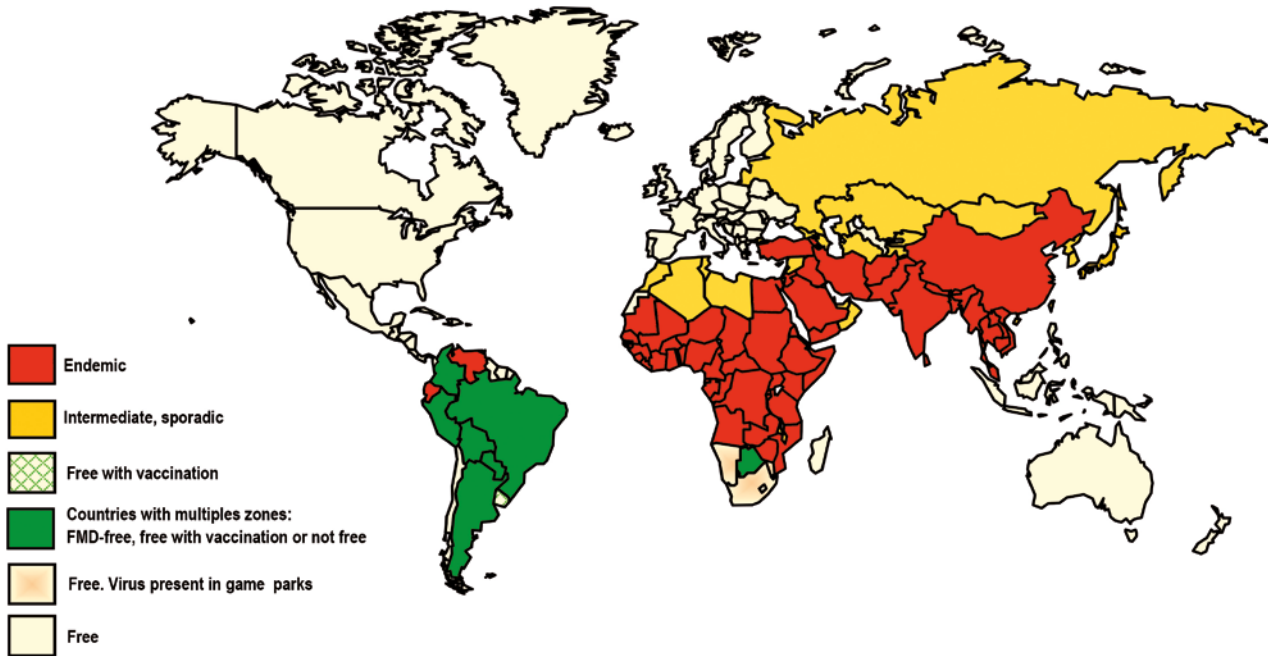

Fig. 1
The conjectured status of foot and mouth disease

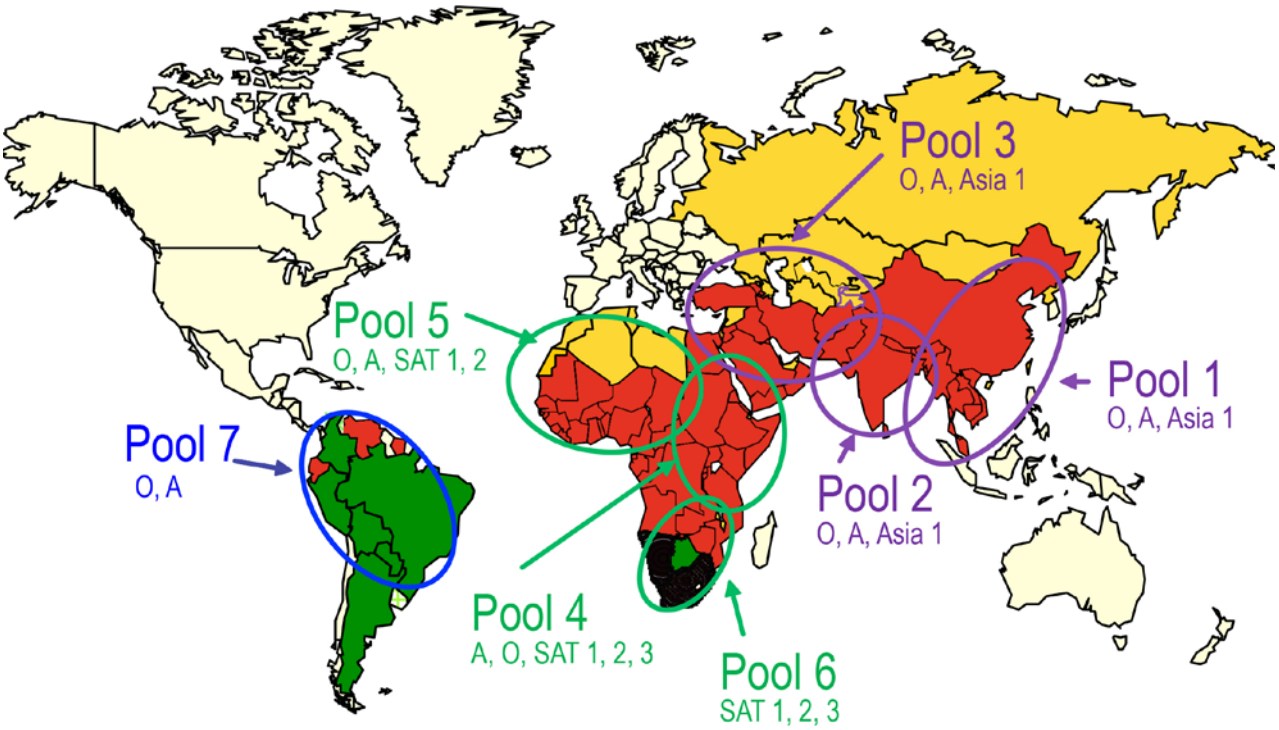

Fig. 2
The conjectured status of foot and mouth disease showing approximate distribution of regional virus pools

Over recent years there has been a notable increase in the incidence of FMD outbreaks reported in Asia and the Middle East and a concurrent spread of the serotypes O (Pan-Asia 2) and A (Iran 05) strains. In 2010–2011, Japan, the Republic of Korea and Bulgaria all suffered type O FMD outbreaks, losing their status as countries listed by the OIE as FMD free without vaccination.

Current trends show that globally the most common serotype identified is type O, with more than 80% of isolates characterised by the network laboratories in 2010–2011 being of this serotype (Fig. 3). However, in 2011–2012 there has been a marked increase in the number of reports of serotype Asia 1 in Pool 3 and, most recently, a rapid spread of the Southern African Territories serotype (SAT) 2 through North Africa into Libya and Egypt and on into the Middle East to the Palestine Autonomous Territories. In 2012, so far WRLFMD® has observed that, from over 500 samples tested, 25% of those were found to be type Asia 1 and 14% to be SAT 2. This rise in SAT 2 detection is due to increased sample submission from North Africa associated with the rapid spread of disease through Egypt in the first quarter of 2012 (Figs 4 and 5).

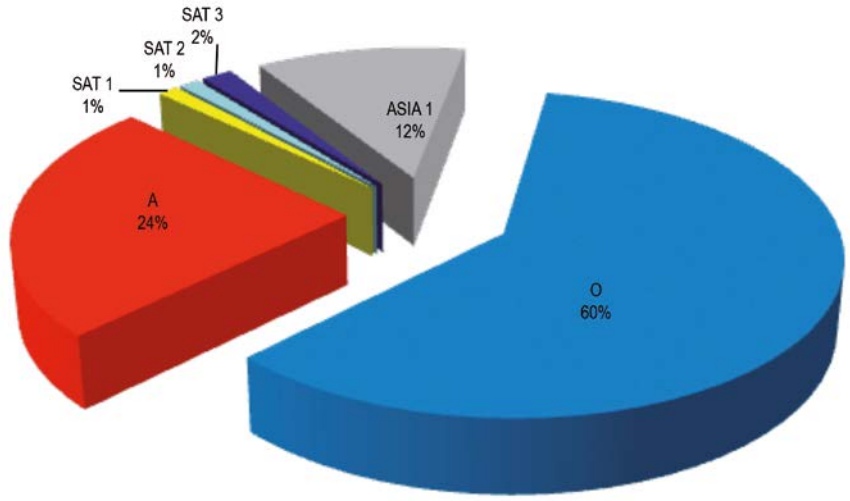

Fig. 3
Foot and mouth disease serotypes isolated in 2011

The network labs received >2,400 samples in 2011 from 34 countries; 60% were serotype O and no type C was detected

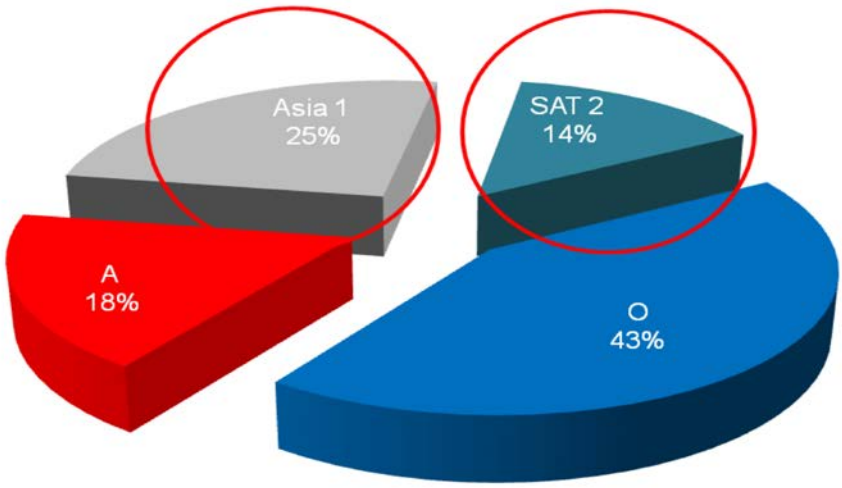

Fig. 4
World Reference Laboratory for FMD data only: serotypes isolated in first half of 2012

From > 500 samples in 2012; 43% were serotype O and there was no serotype C (not reported since 2004). Large increase in Asia 1 and SAT 2

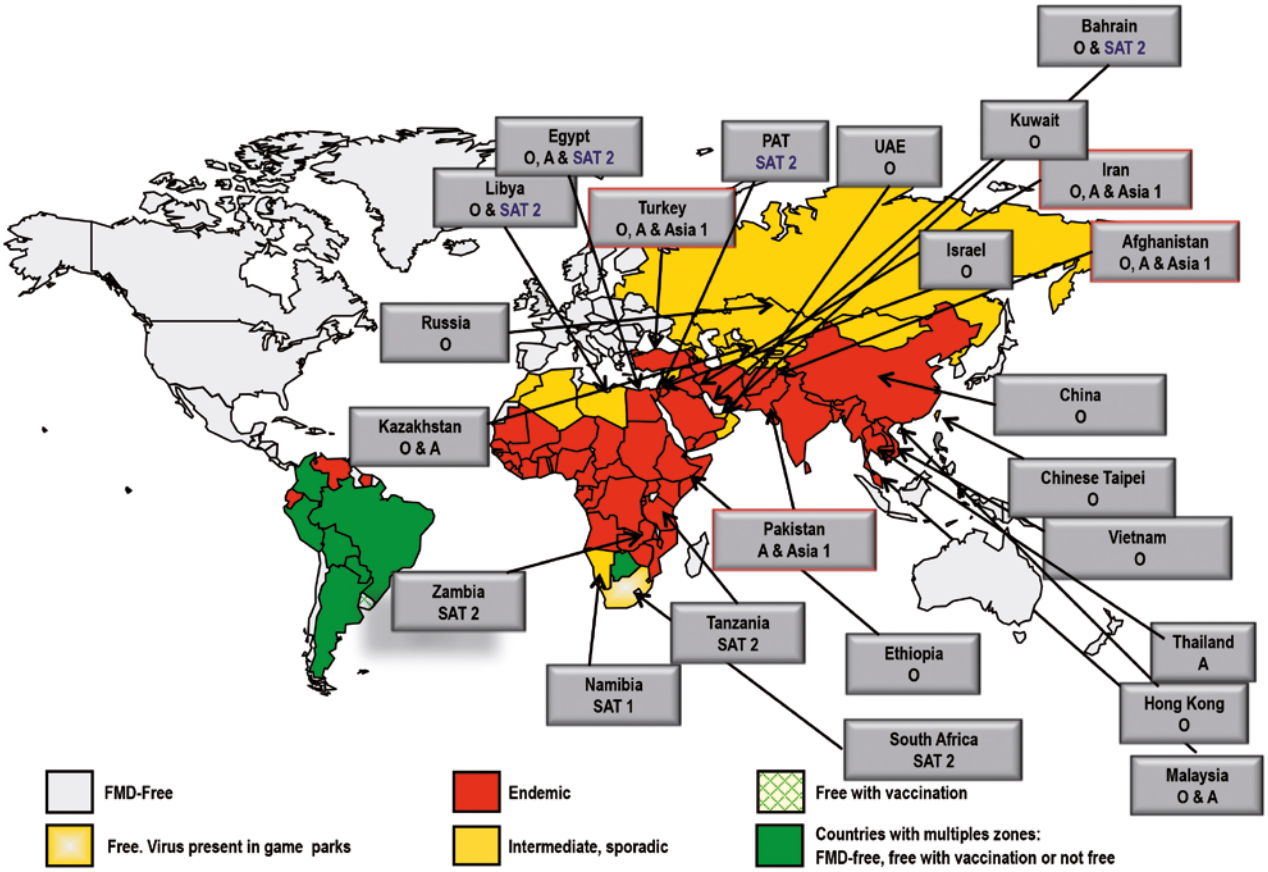

Fig. 5
Global incidence of foot and mouth disease: serotypes identified in first half of 2012

Characterisation of FMDVs isolated from Egypt, including serotypes O, A and, most recently, SAT 2, have highlighted the complexity of the disease situation common to many regions where a number of serotypes and topotypes are circulating concurrently. As a consequence, this situation necessitates the availability of accurate and timely diagnostics including serotyping and vaccine matching to be carried out to enable informed use of suitable multivalent vaccines to bring the spread of disease under control.

Reassuringly, vaccine matching studies carried out by WRLFMD® have shown that currently available vaccines should provide protection against the majority of these field isolates; however, it should be considered that vaccine supplies are limited due to production constraints and that obtaining the quantities of vaccine required for extensive control measures needs very careful planning and consultation with vaccine manufacturers.

Current vaccines for foot and mouth disease

Vaccines currently available for FMD control and eradication are based on preparations of whole virus that are derived from cell culture, chemically inactivated and blended with suitable adjuvant, and as such are far from ideal. As the disease is caused by seven different serotypes of virus, it is often necessary to include a combination of strains in the vaccine used to ensure protection. This is further complicated by the evolution of new subtypes of virus. The more virus serotypes in a vaccine, the more expensive it becomes, restricting use in many developing countries.

Moreover, the immunity offered by current vaccines is short lived, so revaccination is necessary, again limiting the role of vaccines in developing effective herd immunity levels. There is also an absolute requirement for a cold chain, making widespread vaccination in developing countries a particular problem.

It should also be noted that currently there are varying degrees of effort to identify improved vaccines in different regions. There are relatively few for use in Africa, while the developed world's vaccine banks have a good stock of vaccines destined for emergency use. A global approach to progressive control will require that each region or pool receive adequate laboratory support for rapid and accurate typing and vaccine matching work. Obviously regional Reference Laboratories and WRLFMD® can provide major support, but certain regions will need development of their own regional laboratory, utilising support from both FAO and OIE through the global strategy.

Threat analysis and vaccine matching

A threat analysis has been carried out utilising data collected over the last three years by WRLFMD® based upon current known FMDV circulation, risk of spread outside their current distribution and vaccine recommendations for control.

This analysis indicates that serotypes O and A still present the greatest threat for spread into FMD-free areas with the lineages/genotypes A-Iran-05 and O *PanAsia* 2 still presenting the greatest risk of further spread. Through continued analysis WRLFMD® previously demonstrated gaps in cover with emerging A-Iran-05 field isolates and the A22 Iraq vaccine strain. However, new vaccines released in 2009 by both Intervet and Merial specifically for A-Iran-05 appear to provide much better protection, but limited information is available on the ability of these vaccines to cross-protect against other A field strains as A22 Iraq has been shown to do. Antigenic variability of serotype O viruses is less than the A serotype and O1 Manisa has been recommended for many years as a suitable vaccine for viruses of the ME-SA topotype. However, a number of recent O isolates have shown poor vaccine matching by laboratory testing. This situation has been closely monitored and a newly available vaccine from Intervet (MSD) 'O *PanAsia* 2' has shown consistently higher r-values against recent field isolates of the *PanAsia* 2 genotype within this topotype and has now been included in the high-priority vaccine recommendations. A vaccine strain 'O4625' from Merial also matches well with a number of these isolates.

Asia 1 Shamir vaccine has given a good antigenic match to most strains within the Asia 1 serotype for many years. Again, more recent isolates from Afghanistan, Bahrain, Pakistan, Turkey and Iran, isolated in 2011 and 2012, have failed to match with Asia 1 Shamir vaccine. The situation is also being carefully monitored and the need for a new Asia 1 vaccine is being investigated by several manufacturers.

The SAT serotypes have never become established outside of Africa but there is need to maintain a close watch on the incidence and variation within the SAT 1 and SAT 2 serotypes, especially with the increased recent activity with SAT 2 in North Africa at present, but there is confusion over which vaccine strains to recommend as these are limited and there is very little information on the protection that they could offer against current field strains. The recent matching of the SAT 2 Eritrea vaccine strain with the field isolates from Egypt was reassuring and also slightly fortunate as there are only two SAT 2 vaccines available for use through commercial vaccine bank operations. The likelihood of spread is slightly different with SAT 3 viruses as they appear to be mainly associated with African buffalo and are not considered a real threat for broader spread.

It is intriguing to note that serotype C has not been reported since 2004.

WRLFMD® vaccine recommendations

The recommendations made by the WRLFMD® are drawn principally from a list of vaccine strains for which master seed vaccine viruses are believed to be available within the portfolios of vaccine suppliers able to fulfil the quality requirements for use in Europe (Table I). The ranking of the utility of the viruses is based on the results obtained by the WRLFMD® from *in vitro* serological tests to match these vaccine viruses to recent field isolates. As such, the WRLFMD® can only recommend vaccine virus strains for which it has received supplies of both the vaccine virus and the homologous antiserum. Since these vaccine strains are chosen to protect against threats from outside of Europe, it can be anticipated that the vaccines should also be useful to counter such threats at source. However, other vaccine strains are being produced by vaccine manufacturers located in the specific regions from which the threats are arising, using local isolates, and these may also provide an equivalent or even better antigenic match

to the field isolates that pose the threat. However, the quality and potency of these vaccines must be assured for success to be achieved by the global strategy.

Table I
World Reference Laboratory for foot and mouth disease® vaccine recommendations for antigen banks

High priority	Medium priority	Low priority
O Manisa	A Eritrea	A15 Bangkok related strain
PanAsia 2*	A Iran 96	A87 Argentina related strain
O BFS or O Campos	SAT 2 Zimbabwe	C Noville
A24 Cruzeiro	A Iran 87 or A Saudi 23/86	SAT 2 Kenya
Asia 1 Shamir	SAT 1 South Africa	SAT 1 Kenya
A Iran 05	A Malaysia 97	SAT 3 Zimbabwe
A22 Iraq	A Argentina 2001	A Kenya
SAT 2 Saudi Arabia or equivalent – Sat 2 Eritrea	O Taiwan 97 (or equivalent pig-adapted strain)	
	A Iran 99	

NB. Strains are not listed in order of importance within each priority grouping.

*Recent introduction: *PanAsia* 2 vaccine use will be monitored carefully during 2012.

Conclusions

Foot and mouth disease is present in many regions of the world and the highest risk of spread is through the movement of live animals and animal products. The presence of FMD has a significant effect on the livelihoods of livestock keepers and associated industries, placing it firmly in the 'one health' arena for consideration for control. The need to work together as an FMD information network is absolute and the WRLFMD® at the centre of the OIE/FAO FMD Reference Laboratory Network strives to provide a global 'real-time virus map' for the implementation of better-informed control measures for FMD. Laboratories within the network regularly receive samples for FMD diagnosis from many parts of the world. This network then provides a vital contribution to the global control of FMD and provides opportunities and expertise for developing and sustaining laboratory capacity and capability, exchange of materials and technologies, harmonising approaches to diagnosis and supporting complementary research.

It must be stressed that the use of vaccination alone is not enough for the successful implementation of the global control strategy; essential components that must also be included are public and livestock keeper education on disease spread and benefits of control and also the necessity for good biosecurity measures to be maintained on and between farms.

The clustering of FMD viruses into seven virus pools, with three pools covering Europe, the Middle East and Asia, three pools covering Africa and one pool covering the Americas, is now enabling a targeted approach to progressive FMD control through the combined activities of the OIE, FAO and the regional authorities. However, we must do more to increase surveillance by empowering regional and national laboratories to carry out their own testing and analysis.

The situation is highly complex and the task ahead is substantial and, therefore, it is of great importance to recognise that a major combined effort at the national, regional and global level is needed for the global control strategy to be successful.

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Foot and mouth disease: a look from the wild side

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Summary

*There are over 100 species of wild, feral, laboratory or semi-domesticated animals that have been infected naturally or experimentally with foot and mouth disease virus (FMDV). Apart from the African buffalo (*Syncerus caffer*) in sub-Saharan Africa, wildlife does not play a significant role in the maintenance of FMD infections. More often, wildlife are passively infected when outbreaks of FMD occur in domestic livestock, and in some wild ungulates infection results in severe disease. Efforts directed to control wildlife may not have the intended consequences of eliminating FMD when the disease is endemic in livestock and perhaps cause more harm to wildlife, human livelihoods, and domestic animals. Feral animals warrant a special concern and are not considered truly native wildlife.*

Keywords
Foot and mouth disease – FMD – Wild animals – Wildlife.

Introduction

Despite a number of review articles on foot and mouth disease (FMD) in wildlife (3, 31, 34, 39), important, science-backed information is still lacking (32). Key to understanding the epidemiological role of wildlife in the maintenance of FMD infections at population levels is the understanding of the cycles of infection and/or persistence of infection for the various species. Unfortunately, beyond the valuable experimental infection work performed in a quite a number of wildlife species, much of the published literature on the subject fails to distinguish between evidence of infection and the ability to effectively maintain infections at population levels that could result in either persistence or frequent transmission to other species. Both Thomson *et al.* (39) and Roeder (32) have discussed this issue. As a result, erroneous statements and conclusions regarding the role of wildlife in either the maintenance and/or the transmission of FMD are widespread.

Adding to confusion regarding FMD in wildlife is the lack of consistency in terminology used to indicate wildlife, wild animals, feral animals, zoo animals, species, etc. For the purposes of this discussion, we use the World Organisation for Animal Health (OIE) definitions for wild and feral animals:

– wild animals are those animals that do not live under human supervision or control and do not have their phenotype selected by humans;

– captive wild animals are those animals that live under human supervision or control but their phenotype is not selected by humans;

– feral animals are those animals that do not live under human supervision or control but their phenotype is selected by humans.

Clinical disease and transmission

The clinical picture of FMD in wildlife has been reviewed in Thomson *et al.* (39) and Arzt *et al.* (3). In general, the clinical signs seen in wildlife are similar to what is seen in domestic animals, although the pathogenesis of foot and mouth disease virus (FMDV) in many susceptible wildlife species has not been studied extensively. There is clear variation in the susceptibility to FMD based on the species and serotype involved. There is a wide range of clinical symptoms including subclinical, unapparent infection, as is seen typically in African buffalo (*Syncerus caffer*) (42), to a more severe, acutely fatal infection with extensive pathology to the pancreas, as is seen in mountain gazelles (*Gazella gazella*) (30, 35).

The serotypes

All seven of the serotypes (O, A, C, Asia 1, Southern African Territories [SAT] 1, SAT 2, and SAT 3) of FMDV have been found in wildlife. Within each serotype there are regional differences in the virus, known as topotypes, which can be sometimes used to determine the origin of the strain involved in an outbreak (40). Within the SAT viruses, there are at least eight topotypes within SAT 1, 14 in SAT 2 and six within SAT 3 (40). Apart from the SAT-type viruses found within the African buffalo populations, the other serotypes are all endemic to livestock. There is no evidence for any reservoir of other FMDV serotypes in wildlife around the world. FMDV appears to behave differently according to serotype and host factors. Therefore, the exact mechanism of pathogenesis for each serotype in each possible host species has not been completely defined (3). Animals can be impacted by more than one serotype of FMD (46). This may account for the differences in the reaction of wildlife to different strains.

The controversial carrier state

The importance of carriers or persistently infected animals is controversial. A carrier is defined as an animal with an unapparent infection and where a virus can be isolated beyond 28 days of virus infection. Cattle have been found to carry the virus for 3.5 years after infection and goats and sheep up to nine months after infection (33). Swine do not appear to be able to carry the virus; however, there may be some evidence indicating that this is not entirely true (26). African buffalo have been shown to carry the virus for at least five years, and virus may persist in a herd for 24 years or perhaps longer (9). It appears difficult under experimental conditions for persistently infected animals or carriers to transmit the virus to susceptible individuals (2, 6, 8, 15). In experimental studies of carriers, the levels of virus that have been obtained from probang samples have found the virus at a level 500 times lower than what is seen during an acute infection (17, 46). Other species have been found to be capable of persistent infection, although not every susceptible wild species has been examined. Water buffalo (*Bubalus bubalis*) may carry the virus for one to two years (4, 28). Kudu (*Tragelaphus strepsiceros*) become carriers for up to 160 days (19). Eland (*Taurotragus oryx*) can carry the virus for 32 days, wildebeest (*Connochaetes taurinus*) can carry the virus up to 45 days (19) and sable antelope (*Hippotragus niger*) remain viremic for up to 28 days (11). Fallow deer (*Dama dama*), sika deer (*Cervus nippon*) and white-tailed deer (*Odocoileus virginianus*) can become carriers for up to 11 weeks (13, 16, 25). With the exception of African buffalo, for which carrier transmission to other buffalo and cattle has been demonstrated, transmission by persistently infected livestock or wildlife to susceptible individuals has not been proven despite many decades of research (38).

Global status of foot and mouth disease in wildlife

Foot and mouth disease in sub-Saharan African wildlife has been studied since the early 20th Century. Both natural and experimental infections have been demonstrated in many species. Antibodies to FMD and/or clinical disease have been found in numerous species including the African buffalo (*Syncerus caffer*), impala (*Aepyceros melampus*), eland (*Taurotragus oryx*) and many others (Table I). Bush pigs (*Potamochoerus porcus*) and warthogs (*Phacochoerus aethiopicus*) develop severe clinical disease after experimental infection but do not excrete the virus as heavily as domestic pigs (19). African elephants can exhibit severe clinical disease when infected experimentally (20); however, only one natural case of FMD infection has ever been reported (39). Severe outbreaks in impala have been reported in Kruger National Park (KNP) for decades (43). Despite all the wildlife species that have been infected with FMDV, only African buffalo and impala, at least in South Africa, have been implicated in the transmission of FMD to cattle, particularly the SAT-type FMD viruses (41, 43).

Table I

Species documented with either natural (Nat) or experimental (Exp) infection with various serotypes of foot and mouth disease virus with indication of proven transmission to other animals or species (documented failure of transmission indicated in some reports), observation of clinical signs of infection and test methods used (antibody or virus isolation)

Species	Confirmed transmission to species	Exposure and serotype	Clinical signs	Antibody tested positive	Virus positive
Agouti (*Dasyprocta agouti*)	Agouti	Exp (C)	Y		Y
Alpaca (*Vicugna pacos*)		Nat (A)	Mild	N	N
Armadillo, Big Hairy (*Chaetophracius villosus*)	Armadillo Swine	Exp	Y	Y	Y
Armadillo, Nine-Banded (*Dasypus novemcinctus*)		Exp (A)	Y	Y	Y
Bat, Vampire (*Desmodus rotundus*)		Exp (A, O)	Y		Y
Bear, Brown (*Ursus arctos*)		Nat	Y		
Bear, Grizzly (*Ursus arctos horribilis*)		Nat	Y		
Bear, Tibetan/Asiatic Black (*Ursus thibetanus*)		Nat	Y		
Babirusa (*Babyrousa babyrussa*)		Nat	Y		
Bennett's wallaby (*Wallabia rufrogrisea frutica*)		Exp (A, SAT-1)	N		Y
Bison, European (*Bison bonasus*)		Nat	Y		
Bison, North American (*Bison bison*)	Cattle	Nat Exp (O)	Y Y	 Y	 Y
Black buck (*Antilope cervicapra*)		Nat (O)	Severe		Y
Brocket deer, Brown (*Mazama gouzoubira*)		Nat			
Brocket deer, Red (*Mazama americana*)		Exp			
Brown marsupial mouse (*Antechinus stuartii*)		Exp (A, SAT-1)	N	Y	Y
Buffalo, African (*Syncerus caffer*)	African Buffalo Cattle Impala Kudu	Nat (SAT-1, 2, 3) Nat (SAT-1) Exp (SAT-2) Exp (SAT-1, 2)	Mild N Mild	Y Y Y Y	 Y Y Y
Buffalo, Water (*Bubalus bubalis*)	Water Buffalo Cattle	Nat (A) Exp (O) Exp (Asia-1)	N Y Y	Y Y Y	Y Y Y
Bushbuck (*Tragelaphus scriptus*)		Nat Nat (SAT-1, 2, 3)	Y	 Y	
Bush pig (*Potamochoerus porcus*)		Nat Exp (SAT-2)	Y Severe	 Y	 Y
Camel, Bactrian (*Camelus bactrianus*)	No transmission	Nat (O) Exp (A)	Y Y	 Y	N Y

Y: Yes N: No

Species	Confirmed transmission to species	Exposure and serotype	Clinical signs	Antibody tested positive	Virus positive
Camel, Dromedary (*Camelus dromedaries*)	No transmission	Nat (A, Asia-1, C, O, SAT-1, 2) Exp (A, O)	Mild Mild/N	Y Y	Y Y
Capybara (*Hydrochoerus hydrochaeris*)	Cattle	Exp (O)	Y	Y	Y
Cattle (*Bos primigenius*)		Nat/Exp	Y	Y	Y
Caucasian tur/wild goat (*Capra aegagrus*)		Nat	Y		
Chamois (*Rupicapra rupicapra*)		Nat	Y		
Chinchilla (*Chinchilla lanigera*)		Exp (A)	Severe	Y	Y
Columbian deer (*Odocoileus virginianus leucurus*)		Nat	Y		
Coypu/nutria (*Myocaster coypus*)		Exp (A, C, O)	Y	Y	Y
Dorcas gazelle (*Gazella dorcas*)			Y		
Duiker (*Sylvicapra grimmia*)		Nat (SAT-1, 2, 3)		Y	
Echidna (*Tachyglossus aculeatus*)		Exp (A, O, SAT-1)	Mild	Y	Y
Eland (*Taurotragus oryx*)	Eland	Nat Nat (SAT- 1, 2, 3) Exp (SAT-1)	Y Mild	 Y Y	 Y
Eld's deer (*Rucervus eldii*)		Nat	Y		
Elephant, African (*Loxodonta africana*)	No transmission	Nat (A) Exp (SAT-2) Exp (SAT-2)	Y N Y	 N Y	 N Y
Elephant, Asian (*Elephas maximus*)		Nat (O) Nat (A, O)	Y	 Y	Y
Elk (*Cervus elaphus nelsonii*)	No transmission	Nat Exp (O)	Y Mild	 Y	 Y
Fallow deer (*Dama dama*)	Fallow deer	Nat Exp (C, O)	Y Mild	 Y	 Y
Gaur/Indian Bison (*Bos gaurus*)		Nat (A, Asia-1, O)	Severe	Y	Y
Gemsbok (*Oryx oryx gazelle*)		Nat (SAT-1, 2, 3)		Y	
Giraffe (*Giraffa camelopardalis*)	No transmission	Nat Exp (SAT-1, 2)	Y Y	 Y	 Y
Goat (*Capra aegagrus hircus*)		Nat/Exp	Y	Y	Y
Grant's gazelle (*Gazella granti*)		Nat (A, O)		Y	

Species	Confirmed transmission to species	Exposure and serotype	Clinical signs	Antibody tested positive	Virus positive
Grysbuck (*Raphicerus sharpei*)		Nat (SAT- 1, 2, 3)		Y	
Guanaco (*Lama guanicoe*)		Exp			
Guinea pig (*Cavia porcellus*)		Exp	Y	Y	Y
Hamster, Syrian/Golden (*Mesocricetus auratus*)		Exp	Y		Y
Hartebeest (*Alcelaphus buselaphus*)		Nat (SAT- 1, 2, 3)		Y	
Hedgehog, East African (*Atelerix prurei hindu*)		Exp	Y	Y	Y
Hedgehog, European (*Erinaceus europaeus*)	Guinea pig	Nat (O)	Y		Y
	Cattle	Exp (A)	Y		Y
Human (*Homo sapiens*)		Nat (A, C, O)	Y	Y	Y
Hyrax, Eastern tree (*Dendrohyrax arboreus*)		Exp	Y	Y	Y
Ibex (*Capra sp.*)		Nat	Y		
Impala (*Aepyceros melampus*)		Nat (SAT- 1, 2, 3)	Y	Y	Y
		Exp (SAT-2)	Y	Y	Y
Kangaroo, Eastern Grey (*Macropus giganteus*)		Nat (O)	Y		Y
		Exp (A, SAT-1)	N	Y	Y
Kangaroo, Red (*Megaleia rufa)*	Cattle	Exp (A, Asia-1, O, SAT-1)	Mild	Y	Y
Kangaroo, Tree (*Dendrolagus matschiei*)		Exp (A, SAT-1)	Mild	Y	Y
Kouprey (*Bos sauveli*)		Nat	Y		
Kudu, Greater (*Tragelaphus strepsiceros*)		Nat (SAT-1, 2, 3)		Y	
		Nat (SAT-1)	Y	Y	N
		Exp (SAT-2)	Severe	Y	Y
Kudu, Lesser (*Tragelaphus imberbis*)		Nat		Y	
Llama (*Lama glama*)	No transmission	Nat		Y	
		Exp (A, C, O)	Y	Y	Y
Long-nosed bandicoot *(Perameles nasuta)*		Exp (SAT-1)	N	Y	Y
Marsh deer (*Blastocerus dichotomus*)		Nat (A, C, O)		Y	
		Exp			
Mink (*Mustela vison*)		Exp (A, O)	N	Y	Y
Mithun/Gayal (*Bos frontalis*)		Nat (A, Asia-1, C, O)	Severe		Y
Mole, European/Common (*Talpa europaea*)		Exp (A, C, O)	Y	Y	Y
Mole rat, East African (*Tachyoryctes splendens*)		Exp	Y	Y	Y
Moose, European (*Alces alces*)		Nat	Y		
Mouflon (*Ovis musimon*)		Nat	Y		

Species	Confirmed transmission to species	Exposure and serotype	Clinical signs	Antibody tested positive	Virus positive
Mountain gazelle (*Gazella gazella*)		Nat (O) Exp (O)	Severe Severe		Y Y
Mouse (*Mus musculus*)		Exp (O)	Y		Y
Mule deer (*Odocoileus hemionus*)		Nat Exp (O)	Severe Y		
Muntjac/Barking Deer (*Muntiacus muntjak*)	Cattle Sheep	Nat Exp (C)	Y Severe	Y	N Y
Nilgai (*Boselaphus tragocamelus*)		Nat (O)	Severe		Y
Nyala antelope (*Tragelaphus angasi*)		Nat	Y		
Peccary, Collared/Javelina (*Pecari tajacu*)	Peccary	Nat Exp (O)	Y Y	 Y	
Peccary, White-lipped (*Tayassu pecari*)		Nat			
Porcupine, African (*Hystrix galeata*)		Exp (O)	Mild		Y
Potoroo *(Potorous tridactylus)*		Exp (A, SAT-1)	N	Y	Y
Possum, Brush tail (*Trichosurus vulpecula*)		Exp (A, SAT-1)	N	Y	Y
Pronghorn antelope (*Antilocapra americana*)		Exp	Severe		
Pudu, Southern (*Pudu pudu*)		Nat	Y		
Rabbit (*Oryctolagus cuniculus*)	Rabbit	Exp Exp (A, Asia-1)	Y N	Y Y	Y Y
Rat, African grass (*Arvicanthis niloticus*)		Exp	Y	Y	Y
Rat, Brown (*Rattus norvegicus*)	Rat	Exp (O)	Y	Y	Y
Red deer (*Cervus elaphus*)	Red deer	Nat Exp (C, O)	Y Mild	 Y	 Y
Reedbuck (*Redunca arundinum*)		Nat (SAT-1, 2, 3)		Y	
Reindeer (*Rangifer tarandus*)		Nat Exp	Severe Y		
Roan antelope (*Hippotragus equinus*)		Nat (SAT-1, 2, 3)		Y	
Roe deer (*Capreolus capreolus*)	Roe deer	Nat Nat (O)Exp (C, O)	Y Severe	 Y Y	 Y
Sable antelope (*Hippotragus niger*)	Sable antelope	Nat Nat(SAT-1, 2, 3) Exp (SAT-1)	Y Mild	 Y Y	 Y
Saiga antelope (*Saiga tatarica*)		Nat (A)	Severe		Y

Species	Confirmed transmission to species	Exposure and serotype	Clinical signs	Antibody tested positive	Virus positive
Sambar deer (*Rusa unicolor*)		Nat (O)	Y		Y
Sheep (*Ovis aries*)		Nat/Exp	Y	Y	Y
Sika deer (*Cervus nippon)*	Cattle Sheep	Exp (C)	Mild	Y	Y
Spotted deer (*Axis axis*)		Nat (O)	Y		Y
Springbok (*Antidorcas marsupialis*)		Nat (SAT-1, 2, 3)		Y	N
Squirrel, Grey (*Sciurus carolinensis*)		Exp (A, C, O)	Y	Y	
Squirrel, Indian (*Funambulus pennanti*)	No transmission	Exp (A, Asia-1, C, O)	Severe		Y
Steenbok (*Rhaphicerus campestris*)		Nat	Y		
Swine *(Sus scrofa domesticus)*		Nat/Exp	Y	Y	Y
Tapir, Asian (*Tapirus indicus*)		Nat	Y		
Tapir, South American (*Tapirus terrestris*)		Nat	Y		
Thomson's gazelle (*Eudorcas thomsonii*)		Nat (A, C, O)		Y	
Topi (*Damaliscus korrigum*)		Nat (O)		Y	
Tsessebe (*Damaliscus lunatus*)		Nat (SAT-1, 2, 3)		Y	
Vicugna (*Vicugna vicugna)*		Exp			
Vole, European water (*Arvicola amphibius amphibius*)	Water Vole	Exp (A, C, O)	Y	Y	Y
Vole, Field/Short-tailed (*Microtus agrestis*)	No transmission	Exp	Y		Y
Warthog (*Phacochoerus aethiopicus)*		Nat (SAT-1, 2, 3) Exp (SAT-2)	 Severe	Y Y	 Y
Waterbuck (*Kobus ellipsiprymnus*)		Nat (SAT-1, 2, 3)		Y	
Water rat (*Hydromys chrysogaster)*		Exp (A, SAT-1)	Mild	Y	Y
Watussi/Wild buffalo (*Bos taurus*)		Nat Nat (A)	Y Y		 Y
White-tailed deer (*Odocoilleus virginianus)*	Cattle	Exp (O) Exp (O)	Y Y	 Y	Y Y
Wildebeest, Black (*Connochaetes gnou*)		Nat (O) Nat	Y Y		Y
Wildebeest, Common (*Connochaetes taurinus*)		Nat (A, SAT-1, 2) Nat (O, SAT-1, 2) Exp (O)	 Y Mild	Y Y	 Y Y

Species	Confirmed transmission to species	Exposure and serotype	Clinical signs	Antibody tested positive	Virus positive
Wild boar (*Sus scrofa*)		Nat	Y		
		Nat (O)	Y	Y	Y
		Exp (A)	Y	Y	Y
		Exp (O)	Y		
Wombat (*Vanitatus hirsutas*)	No transmission	Exp (A, O, SAT-1)	N	Y	Y
Yak, Domestic (*Bos grunniens/ Poephagus grunniens*)		Nat (O)	Y		Y
Yak, Wild (*Bos mutus*)		Nat (O)	Y		Y

Antelope species may serve to propagate FMD. Impala, particularly in the KNP and possibly elsewhere in sub-Saharan Africa, have been associated with outbreaks in cattle (43). Ninety per cent of infections in impala occur from June to November. This is the same time in which buffalo calves are losing their maternal antibodies and becoming infected with FMDV (5). Since impala have not been shown to become carriers, it is suspected that impala are an intermediary species and become acutely infected and spread the virus to cattle outside KNP by jumping over fences (43).

Foot and mouth disease outbreaks are seen regularly in the countries of Central Asia. There are several important wildlife species that are impacted by FMD. Mongolian gazelles (*Procapra gutturosa*) from the Eastern Steppe of Mongolia have been infected by FMDV; however, several studies indicate that it is the continued circulation of FMDV in the domestic livestock of the Mongolian Eastern Steppe that results in the virus entering the susceptible gazelle population (7, 29). Furthermore, there is no evidence for the persistence of the virus in the gazelle population between outbreaks (38), and actions such as culling of Mongolian gazelles and fencing do not appear to have any impact on the disease in livestock (7).

In Kazakhstan, Saiga antelope (*Saiga tatarica*) are susceptible to FMD and suffer from more severe disease than what is seen in domestic ruminants. Saiga populations have declined dramatically due to excessive hunting in the 1990s. Mortality can be high (as much as 75% in experimentally infected animals) and past outbreaks have resulted in a loss of 10% of a population (27).

Foot and mouth disease has been found in wildlife in the Middle East. FMD has infected captive populations of Arabian oryx (*Oryx leucoryx*) in Bahrain and the United Arab Emirates (UAE) with high mortality, and seropositivity has been found in at least two captive individuals in Saudi Arabia. However, FMDV has not been detected in wild Arabian oryx populations in Saudi Arabia (14). Antibodies to all seven serotypes of FMDV have been found in dromedary camels (*Camelus dromedaries*) (47). They are believed to be mostly resistant to clinical FMD and virus isolation is sometimes difficult; however, natural and experimental infections have occurred. They are not believed to play a significant role in the transmission to livestock (45). Outbreaks among mountain gazelles in Israel have resulted in about 10% to 15% of the population becoming acutely infected with a 50% mortality rate (35).

Domestic water buffalo (*Bubalus bubalis*) are common throughout Asia and are susceptible to FMD. In India, water buffalo are frequently kept with both cattle and sheep (23). Maroudam *et al.* demonstrated that water buffalo can transmit FMDV to cattle and to each other (24). Clinical signs in water buffalo tend to be more covert than the clinical signs in cattle. In addition, water buffalo appear to have a longer incubation period and are infective prior to exhibiting any lesions. Water buffalo can become acutely infected as well as become a carrier for the virus (23, 24). Persistence of infection was found from one to two years after exposure to the virus (4).

Feral swine, wild boar (*Sus scrofa*) and feral water buffalo (*B. bubalis*) are often found in proximity to livestock and could play an important role in the epidemiology of FMD. In Sri Lanka, FMD outbreaks frequently occur in areas in close proximity to national parks where there are significant populations of feral water buffalo and wild boar (32).

Severe FMD has been reported in mithun (*Bos frontalis*), yak (*Bos grunniens*) and gaur (*Bos gaurus*). Frequently, migratory cattle come into contact with these species and transmission occurs. Asian elephants suffer a moderately severe disease particularly in the younger animals, and a serosurvey at an Indian zoo found positive antibodies

to FMD despite no history of clinical disease in many elephants (18). Other species documented to be infected are provided in Table I.

We found only one published experimental study conducted on the susceptibility of various Australian fauna (36). Clinical disease was not apparent for most of the infected animals, and only the red kangaroo (*Megaleia rufa*), tree kangaroo (*Dendrolagus matschiei*), water rat (*Hydromys chrysogaster*) and echidna exhibited mild clinical symptoms. Others are listed in Table I.

Despite experimental infections of several European cervids (13, 16), reports of natural infection in captive animals at European zoos (34), and the recent report of infected roe deer (*Capreolus capreolus*) and wild boar (*Sus scrofa*) in Bulgaria, there is no evidence for the maintenance of FMDV in wildlife in Europe (10). Severe natural and experimental infections have been reported in reindeer (*Rangifer tarandus*) (39). Experimental infections have been demonstrated in many species (Table I).

A survey during and after the 2011 outbreak of FMD serotype O among livestock in Bulgaria found a low seroprevalence and clustered distribution of positive roe deer and wild boar, indicating that FMD failed to become established in the wild populations. This suggests that wildlife populations are not able to maintain FMDV in the absence of FMD infection in livestock (10).

The first and only known outbreak of FMD in North American wildlife occurred in mule deer (*Odocoileus hemionus*) after an outbreak among cattle in California in 1924. Ten per cent of a population of mule deer exhibited clinical FMD. A mathematical model created by Ward *et al.* (44) found that wild deer and feral pigs have the potential to amplify disease spread and form a possible reservoir of FMD virus infection in Texas, but this has never been found in real outbreaks anywhere.

Experimental data indicate that there are many North American species that are susceptible to FMD and are capable of transmitting the disease to cattle. North American bison (*Bison bison*) and elk (*Cervus elaphus nelsonii*) have been infected with FMDV experimentally. Others are listed in Table I.

There has been no evidence of transmission from wildlife to livestock in South America and no history of outbreaks of disease despite the fact that many South American wild animal species are susceptible to FMDV (31). New World camelids can become infected with FMDV; however, they are not highly susceptible and appear to be unable to transmit the disease (32). Llamas were difficult to infect under experimental conditions and, when infected, they developed only very mild disease (12). Other reports of susceptible species in South America are presented in Table I. Despite conjecture on the role of South American wildlife as a possible reservoir for FMDV, there is no evidence to date to support that claim.

Efforts to manage wildlife and feral domestic animals

The feral animal situation should be considered separately from what is occurring with native wildlife. Feral animals are more similar to domestic animals than truly wild, native animals. They technically derive from domesticated genetic stock and so retain many of the physiological and behavioural qualities of domesticated animals. They are also more likely to be in contact with domestic livestock and humans. Although there has not been any sufficient evidence for the propagation of FMDV within feral populations (32), there does exist a greater risk than the risk presented from native wildlife. A wild boar found near the Turkish border was found with FMD lesions just prior to an outbreak among domestic livestock in Bulgaria (10). Feral animals have not been studied extensively with regard to FMD; however, several studies suggest that there is the possibility that feral swine have the ability to become carriers of the virus in their pharynx at least 33–35 days post inoculation (10, 26). Another report from an FMD outbreak in Israel suggested aerosol transmission from feral swine in Jordan.

Mongolian gazelles, as mentioned previously, have not been found to be a reservoir of FMD but are passively infected with FMDV when outbreaks occur among livestock (7, 29, 38). Modified stamping out, as was conducted in 2010 in Mongolia for Mongolian gazelles and livestock, involved the culling of clinically diseased animals. This method does not further decrease the spread of FMD, as not all infected animals will demonstrate clinical illness and often FMD is infectious prior to any lesions. The controlled movement of people and livestock as well as vaccinating before and during outbreaks are more effective means of handling an outbreak of FMD (38).

Veterinary cordon fences are commonly used to separate livestock from wildlife in southern Africa. This method is accepted by the OIE as one of the methods of establishing FMD disease-free zones in southern Africa (22,

39). However, the reliance of FMD exclusion provided by fences is problematic. The high cost of construction, maintenance and patrolling of the fences may be cost prohibitive in certain countries (37). Fences are frequently subject to various environmental and human pressures, including flooding, breaks due to wildlife movement, particularly elephants, and damage due to theft (22). The sheer magnitude of fencing that exists in some parts of southern Africa (for example, the perimeter fence surrounding the Kruger National Park is 750 km long) makes it difficult for fences to be maintained in a timely manner (21). Compromised fences allow cattle to move into reserves and wildlife areas.

The additional impact to wildlife populations and local people cannot be ignored. Fences interfere with normal migration patterns and in times of water scarcity block wildlife from critical water sources. Fences also prevent genetic exchange among populations of various wild species, thus potentially resulting in inbreeding and loss of genetic diversity. Fenced wildlife populations may remain small and capped, which could have significant effects on long-term survival or can exceed the carrying capacity of the land available, resulting in overcrowding, malnutrition, increased infectious disease problems and the need for population control efforts.

Recommendations

The diversity of this virus and its behaviour make it problematic to generalise any one strategy. The actual method used to control FMD will ultimately be regionally specific. Eradication is not feasible and may not be needed everywhere. Sub-Saharan Africa has the unique consideration of a significant reservoir of FMD with a wild species that may never truly result in disease freedom defined geographically. Efforts should be directed at finding opportunities for Africa to participate in international trade and to improve the economic situation that do not require complete eradication of FMD. Mechanisms such as commodity-based trading, where there is a negligible risk for transmission of FMD, provide one such opportunity. Vaccine programmes should be adapted to improve efficacy through the incorporation of appropriate strains based on the circulating viruses, increasing the frequency of vaccination using currently available vaccines, ensuring proper vaccine handling and conducting post-vaccination monitoring. Improved vaccines are needed. In addition, mixed land-use scenarios, such as those envisioned for the Transfrontier Conservation Areas (TCFAs), where there is added utilisation of wildlife resources, could be highly beneficial both economically and politically.

Conclusion

To date, the scientific evidence indicates that outside the sub-Saharan Africa situation, with SAT types of FMD adapted to African buffalo, effective control of FMD among domestic livestock will result in the protection of both livestock and wildlife without requiring direct management or interventional activities directed at wildlife. Control of feral domestic animals may be required. In parts of southern Africa, revenues from tourism now exceed the total revenues of agriculture, fisheries and forestry combined (1), and thus strategies selected for FMD control need to ensure that the costs of controlling the disease are put into context with the revenues that are or could be generated by other land-use choices, selection of species managed for meat, trophies, hides or tourism, or other means of ensuring safe and FMD-free meat such as that provided by compartmentalisation and commodity-based trade mechanisms. This broader view of animal health and human livelihoods and well-being provides an opportunity for the veterinary profession to make a significant contribution to the global good. The protection of wildlife should be a priority in the Global FMD Control Strategy.

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The Progressive Control Pathway for FMD (PCP-FMD): a tool for developing sustainable long-term national and regional FMD control

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Summary

The Progressive Control Pathway for FMD (PCP-FMD) was designed to assist countries where foot and mouth disease (FMD) is endemic to develop sustainable national FMD control policies appropriate to their livestock sectors, and medium- to long-term national strategies for progressive reduction of the disease impact. First developed by the European Commission for the Control of Foot-and-Mouth Disease (EuFMD) and Food and Agriculture Organization of the United Nations (FAO), further development of the PCP was recommended by the World Organisation for Animal Health (OIE)/FAO Global Conference in 2009 in Paraguay and, since 2011, adopted by both FAO and the OIE as a joint tool. The PCP-FMD is composed of five stages of increasing level of control, to the point where an application to the OIE for official recognition of freedom from FMD (with or without vaccination) may be successful and sustainable. The first stage, appropriate for all countries not officially free of from FMD, involves a low cost but comprehensive assessment of FMD risk and control options, considering the capacity and drivers for public and private investment and the benefits to sectors, culminating in a revised national policy and longer term strategy. The PCP processes assist the identification of gaps to be addressed and the development of national or regional support projects. National PCP progress underpins regional progress, and 10- to 15-year regional roadmaps have been developed in Asia and Africa, complementing those existing in South-East Asia and China and in South America. The PCP is thus an important tool in the global strategy for FMD, based on self-sustaining national investments backed by regional efforts to address transboundary issues.

Keywords
Europe – Foot and mouth disease – Global Strategy – Progressive Control Pathway (PCP) – Regional Roadmap – Vaccination – Virus pools – West Eurasia.

Introduction

Foot and mouth disease (FMD) is recognised as one of the most important, if not the most important, diseases of animals. In endemic countries, it is among the most common diseases of livestock, and recent surveys have indicated that exposure in the first year of life may approach 50% of ruminants (and pigs), and multiple episodes of FMD occur during the productive life of an animal. FMD distribution roughly mirrors economic development; wealthy countries have, through enormous effort, mostly eradicated FMD and the setback of an incursion can cost millions or billions of dollars to control, whereas many less developed countries have continuous circulation of FMD infection and experience major epidemics every 2–4 years. Sustained FMD freedom has been achieved in

over 60 countries and, possibly, one of the seven FMD serotypes (serotype C) has disappeared from circulation, in part resulting from the general control efforts in Europe and South America.

Given the burden of infection and frequency of epidemics, and the number of less developed countries that do not have publicly funded vaccination programmes, the prospects for achieving the national or zonal freedom from FMD in most cases appear so far out of reach that they cannot realistically be considered within the near future. The scale of investment and competencies required are daunting for any country. In countries already applying preventive vaccination, the high recurrent cost of such programmes and unclear or unrealistic expectations of these programmes have raised questions about the extent of stakeholder support, responsibilities and benefits, and sustainability. For these reasons, the Progressive Control Pathway for FMD (PCP-FMD) was developed as a framework for the development of sustainable FMD management, and regionally co-ordinated 'roadmaps' have been developed for countries in most of Eurasia and Africa using the PCP-FMD approach and assessment tools. The initial take-up of the approach at national level has been encouraging, but sustained support will be needed to ensure that the benefits of the approach are translated into national policy and practice, and a mature capacity to evaluate progress is achieved at national level.

PCP-FMD principles and application

The PCP-FMD has been developed by the European Commission for the Control of Foot-and-Mouth Disease (EuFMD) and the Food and Agriculture Organization of the United Nations (FAO) in 2008 (2) to assist countries where FMD is still endemic to progressively reduce the impact of FMD and the load of FMD virus. The PCP-FMD was adopted by FAO, EuFMD and the World Organisation for Animal Health (OIE) in 2011 as a joint tool, creating for the first time a 'single framework' that includes all possible levels of FMD control, from uncontrolled virus circulation to rigorously maintained freedom from infection without vaccination. The development of this single and comprehensive framework is an important step in international FMD management, enabling the possibility of setting national, regional and even global targets for progression.

The PCP-FMD is composed of five stages that guide the planning and management of efforts to increase the level of control to the point where an application to the OIE for endorsement of the national control programme or, at higher levels, official recognition of freedom from FMD (with or without vaccination) may be successful and sustainable (Fig. 1). The stages and requirements have been published in detail (1).

Stage 1 assists identifying appropriate control options, and Stage 2 involves the implementation of the chosen policy. It is not expected in Stage 2 that control measures will reduce FMD incidence across the entire population; measures might be largely privately financed, or a balance of public funding (e.g. in border regions) and private funding (e.g livestock keeper-supported vaccination programmes). Stage 2 therefore does not imply large investments at the national level, but if the producer is to pay for preventive measures, he/she will expect adequate information and access to effective vaccines, and this in itself will create demand for information and results to guide vaccine selection.

However, Stage 3, when progressive elimination of virus circulation is the objective, normally requires very significant national capacity and ongoing investment, including the ability to regulate internal trade and ensure sufficient immunity is maintained in critical populations to prevent virus circulation; evidence of progress within Stage 3 is important precursor for endorsement by the OIE (6) of the FMD control programme. Stages 4 and 5 involve the development of capacity and evidence needed for compliance with the official OIE status for freedom of FMD with or without vaccination, respectively.

The PCP approach is based on the following four principles:

1. Active monitoring for FMD virus circulation and understanding the epidemiology of FMD virus transmission. This underpins the foundation of any control programme, and therefore activities to meet these requirements are common in all stages. The improved information generated is of benefit nationally and regionally.
2. Activities in each PCP stage are appropriate to the required reduction in virus circulation and mitigation of disease risk to be achieved.
3. The optimisation of resource use for FMD control is achieved through the targeting of measures to the husbandry systems and critical risk points where the impact on disease control and/or virus circulation will be greatest.

4. Activities and their impacts are measurable at each stage, comparable between countries, and generate information and potential benefits to national as well as international stakeholders. The monitoring of outcomes (indicators of control effectiveness), within a national FMD management system, is included at the higher PCP stages.

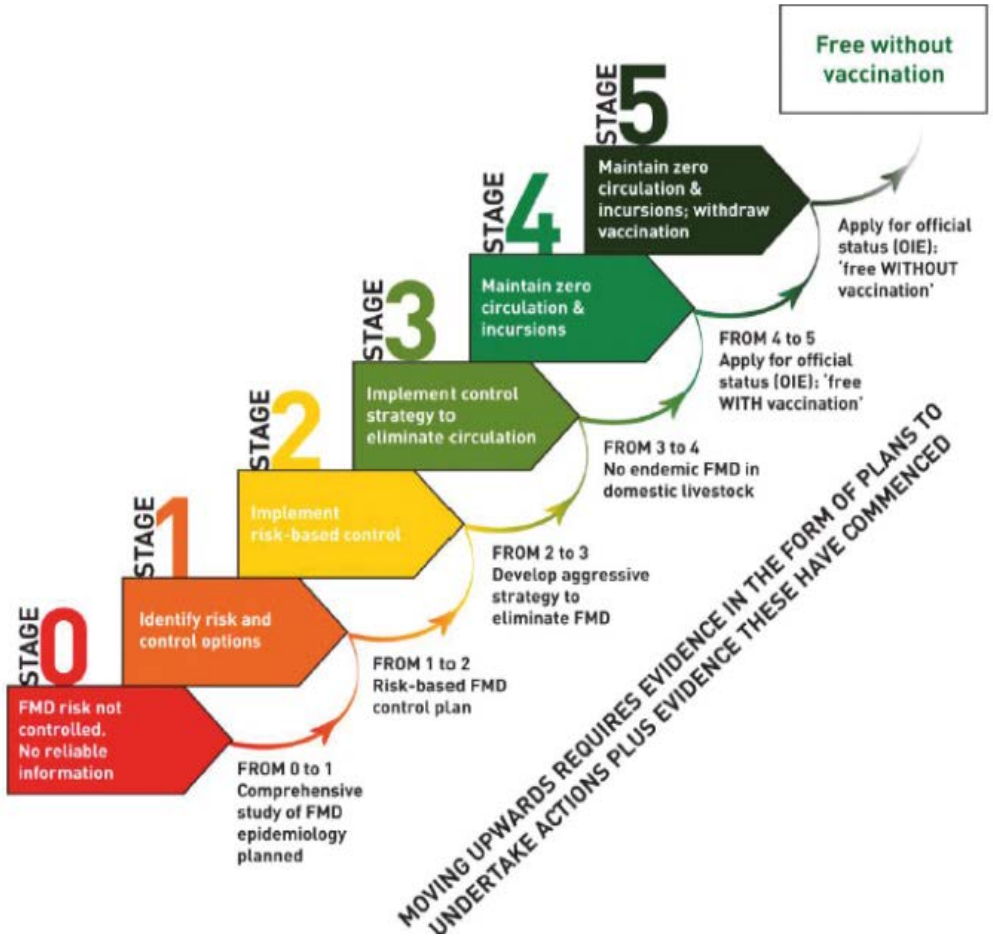

Fig. 1
Stages in the Progressive Control Pathway for FMD (PCP-FMD)

Passage to a higher stage requires completion of the milestones indicated below the arrows, and initiating key actions of the higher stage. Stages 4 and 5 involve activities that lead to submission of applications for official recognition of freedom

Source: FAO/EuFMD

It should be noted that the second and third principles support a risk-based approach to national control strategies, and, through the focus on critical risk reduction points, avoid prescriptive requirements for capacities or activities that are not identified as important to risk reduction. This potentially reduces the level of investment at national level at Stage 2, but entry into Stage 3 requires a very thorough assessment of the costs and benefits since the competencies and level of investments required to reduce virus circulation are very much higher.

As such, PCP-FMD can be viewed as a policy optimisation pathway, assisting countries to determine their optimal position after considering the national situation of risk, costs to control, and benefits to sectors and public and private stakeholders. Since PCP Stage 1 involves a comprehensive assessment of control options based on what is necessary, achievable and sustainable with national resources invested by public and private sectors, the importance of this initial stage should not be underestimated in the development of a national PCP roadmap where the optimal stage target may be different between zones of the country, for socio-economic as well as risk reasons. Although it may also be viewed as a pathway towards FMD eradication, it cannot be assumed that all countries will find economic advantages to proceed further than Stage 2. On the other hand, countries usually free of FMD that detect an incursion of the disease would normally not enter the pathway, but rather would act to eradicate the disease and reapply directly to the OIE for reinstatement of an officially recognised FMD-free status as soon as possible.

Progressive control of FMD in Europe and FMD events in its neighbourhood

The six circulating serotypes of FMD virus are distributed in seven regional 'FMD virus pools' (Fig. 2); within these pools strains evolve independently and, in the case of the types A and SAT (Southern African Territories) serotypes in particular, require specific, tailored vaccines. These specificities, mirroring intra-regional trade patterns, argue for regional vaccination and control programmes, coupled with sufficient monitoring to detect emergent FMD virus that escapes control by the vaccines in use.

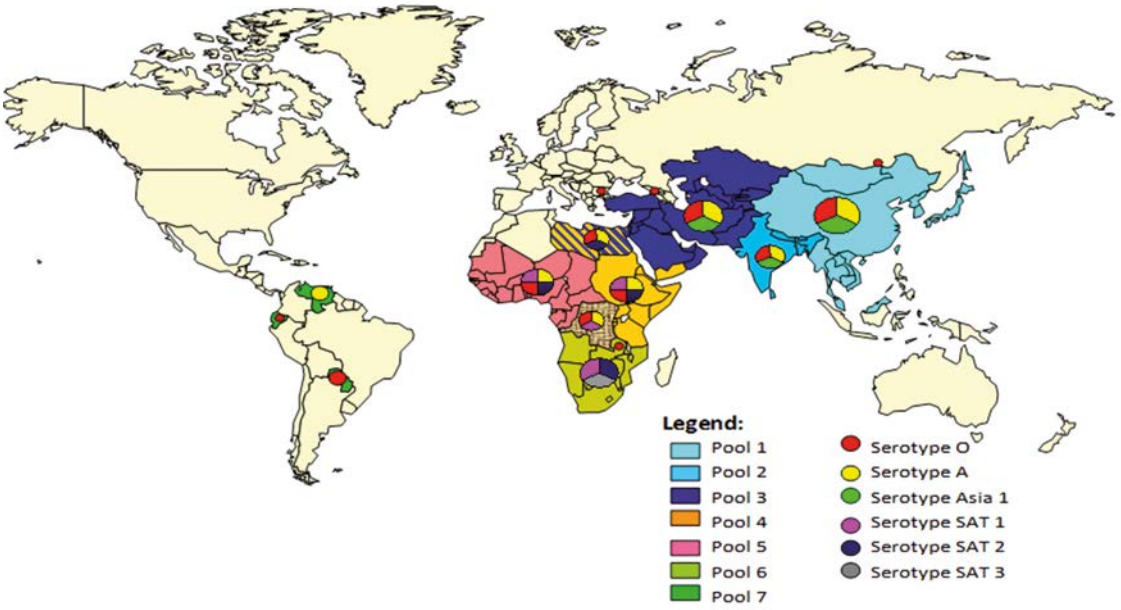

Fig. 2
Global distribution of FMD illustrating the countries regularly or recently (2010–2012) affected by viral strains circulating in the seven FMD virus pools

Small circles of a single colour indicate serotypes involved in incursions to FMD-free regions or which were the sole serotype involved in outbreaks in non-FMD-free countries in 2011
Source: EuFMD-FAO

An eighth pool formerly existed in Europe, but became extinct in the 1970s following approximately 15 years of co-ordinated control measures of the member states to the EuFMD Strategy of national comprehensive actions within a regional programme, largely involving vaccination on mainland Europe, and the steady evolution of sanitary standards for trade between member states and non-free regions. At its peak, over 200 million animals were vaccinated each year in Europe, and FMD cases dropped circa 100-fold between 1954, when the EuFMD Commission was founded, and the mid-1970s, and enabled preventive vaccination to cease in all European countries west of the former USSR by 1992. The European effort was founded on publicly funded vaccination programmes and/or stamping-out of infected herds, with a minority of countries, such as the United Kingdom, adopting stamping-out as the primary control measure following cases. Since 1990, 11 incursions of FMD into the FMD-free countries of Europe have occurred, involving nine countries, most of which were associated with entry from FMD virus Pool 3, the endemic countries in 'West Eurasia', of which Turkey shares land borders with FMD-free European countries; the most recent incursion being in 2010–2011 in Bulgaria. This pool involves at least 14 countries from Pakistan in the east, to Kazakhstan in the north, and Turkey in the west, and regional epidemics ('pandemics') sweep through the population at 1- to 3-year intervals. Continuous attention to this area is required with the aim of detecting emergent strains before spread to the wider region, including Europe. In 2010, a pandemic of a type O lineage (Panasia IIANT-10) reached as far as Bulgaria and, by unknown routes, caused outbreaks in Libya. This region is not the only source of risk; in 1996, Albania and the former Yugoslav Republic of Macedonia were affected by incursion of a type A virus from Pool 2, South Asia; in 2001, the ultimate source of the large type O epidemic was probably in Pool 1, East Asia; and, in 2012, Egypt and Libya were affected by devastating epidemics of SAT2, caused by viral genotypes from Pool 5 (West-Central sub-Saharan Africa).

Progressive control in West Eurasia – regional roadmap and application of the PCP-FMD

As a result of increasing frequency and impact of regional epidemics, the EuFMD Commission, with FAO, convened a regional meeting in 2008 (in Shiraz, Iran) at which a long-term, regional approach to FMD management was developed, the 'West Eurasia Regional Roadmap', and where the PCP-FMD was first used for the assessment of national progress and for the identification of national and regional supportive actions.

In 2012, as a result of national efforts, multiple projects and donor support, PCP progress has been seen across the West Eurasian region – no country now remains in Stage 0, new FMD strains and serotypes have been identified at an early point in time, and the information flow has informed regional vaccination planning and reaction to these emergent FMD virus threats. Since 2008, four Regional Roadmap meetings have been held to assess progress; these have also been a tremendous opportunity to share experience and information relating to FMD surveillance and control and as a result of PCP-related activities three large regional FMD epidemics have been detected, involving three different FMD serotypes (3). Knowledge of these epidemics has benefited both affected countries and non-affected countries, including in the EU. It is early days for the PCP approach, but the resulting reflection at national level of the desired outcomes, on public and private responsibilities, on service delivery and evaluation of impact, is sufficiently encouraging to suggest similar processes would assist for other highly contagious diseases such as rabies and brucellosis.

Assessing progress – experience in West Eurasia

To monitor progress along the West Eurasia Roadmap, a PCP assessment tool has been utilised since 2011, developed by EuFMD in consultation with the joint FAO/OIE Global FMD Working Group (FAO/OIE FMD-WG). The tool comprises a questionnaire (4), with a number of quality indicators to be completed for each of the outcomes in Stages 1 to 3 (Table I). In the case of the West Eurasia Roadmap, these questionnaires, in appropriate language versions, are sent with detailed guidance to the countries and returned for expert assessment before the Regional Roadmap meetings. The latter provide an opportunity for face-to-face meetings between the official Veterinary Services (VS) representatives and international PCP experts, and also 'country-to-country' peer review. It can be noted that official VS that have undertaken serological surveys to assess levels of FMD infection are usually convinced of their value and are often critical at regional meetings of those that do not, particularly of those that report only outbreaks without a clear assessment of the prevalence of infection in different species, or risk factors for infection. The PCP assessment tool has proven its value in gap analysis, providing 'within-stage' indicators of activities and outcomes that assist estimating activities, and priorities, for stage completion. The PCP stage is usually very clear, since the 'pass requirement' to move onwards from Stage 1, or Stages 2 or 3, is rigorous and must be available for thorough review. This requirement is a comprehensive national plan on how the subsequent stage objective will be addressed, which utilises the information and results of the activities from the previous stage. The principle of self-assessment is a valuable part of the overall PCP process – it encourages countries to take responsibility for their own national roadmaps, set targets for official VS annual action plans, and to monitor, evaluate and account for their own progress to national stakeholders. However, since mature evaluation systems may not be developed within each country, countries frequently seek an international acceptance of their PCP stages, and the PCP Guidelines provide a mechanism to lead to a Global Framework for the progressive control of Transboundary Animal Diseases (GF-TADs)-supported stage assignment. It is likely that the procedures leading to these assignments will in future increasingly utilise accredited regional PCP experts, after sufficient training, with oversight from the FAO/OIE FMD-WG, which may field experts to assist during relevant regional PCP-FMD meetings to ensure global coherence and equivalence of PCP stages.

The opportunity for countries to cross-examine PCP progress at regional level has been found to be important for greater transparency and accountability for progress. Such regional interaction and transparency should also encourage the transition to greater use of FMD monitoring to inform disease management as well as improve the identification of preventive actions (such as harmonised vaccine selection/standards, pre-movement vaccination protocols and bilateral management of transboundary populations).

Table I

PCP Assessment Tool – number of indicators used for assessing achievement of outcomes required in each PCP stage

In Stages 2 and 3, although fewer stage-specific indicators are used, these build upon the prior stage by requiring evidence of implementation of the control plans that are the major achievement of lower stages.

	Achievement	Total
To enter Stage 1	To have a comprehensive plan to study epidemiology and socio-economics of FMD	9
Outcome1	All husbandry systems, the livestock marketing network and associated socio-economic drivers are well described for FMD-susceptible species	13
Outcome 2	The FMD distribution is described and a working hypothesis of how FMD circulates is developed	9
Outcome 3	The socio-economic impact on different stakeholders is estimated	6
Outcome 4	Identification of circulating strains	4
Outcome 5	Initial steps on developing the enabling environment were taken. This is to strengthen the Veterinary Services with their activities to progressively control FMD	7
Outcome 6	Transparency and commitment to FMD control in region is demonstrated	2
Outcome 7	Important risk hotspots for FMD transmission are identified	4
Outcome 8	A strategic FMD control plan, based on risks and socio-economic impact, is adopted	11
		65
To enter Stage 2	Completed Stage 1	1
Outcome1	Ongoing monitoring of circulating strains and risk in different husbandry systems	9
Outcome 2	Risk-based control measures implemented in at least one sector or zone	11
Outcome 3	FMD impact is reduced by the control measures	11
Outcome 4	Further development of enabling environment	13
Outcome 5	Development of plan to eliminate FMD from zone/sector	9
		54
To enter Stage 3	Minimum requirement to enter Stage 3	1
Outcome 1	Ongoing monitoring of circulating strains and risk in different husbandry systems	9
Outcome 2	Rapid detection of and response to all FMD outbreaks in at least one area	7
Outcome 3	Incidence of clinical FMD progressively eliminated from domestic animals (at least one zone)	3
Outcome 4	Further development of enabling environment/strengthening Veterinary Services	9
Outcome 5	Body of evidence that FMD is not circulating endemically in domestic animals (in country or zone)	2
		31
Total: Stage 1 to 3		**150**

National, regional and global control of FMD: an integrated approach

Given the current geographical restriction to the seven FMD virus pools, Regional FMD Control Roadmaps could be the main mechanism for achieving global progress in FMD control (1). However, in the past 50 years, the main progress against FMD has been at the margins of these endemic regions, almost entirely in the developed or transition countries. The initiative of FAO with the OIE, launched at the Global FMD Conference in June 2012 (5), aims to foster progress within the endemic regions through an emphasis of establishing national FMD control programmes sustained by local economic drivers for public and private investment, with the aim that, within 15 years, countries currently at the lowest stage will have progressed at least two steps along the FMD pathway, and those currently in Stage 2 will advance to Stage 4 or Stage 5 (on track to become FMD-free without vaccination). The strategy recognises that countries will decide which level is optimal for them and may not be able to, or may not want to, reach FMD-free status. The global achievement of a 'minimum of Stage 2 in all countries in 15 years' could be argued to have achieved a level of global control since, at the very least, each country would have in place a programme addressing the needs of their most at-risk sectors and providing the essential monitoring information required for regional progress. In the immediate future, the flow of data from

Stage 1 countries on virus circulation alone will generate a critical mass of information on which veterinarians may base their recommendations for appropriate vaccines, at herd or national level, and for the development of regional guidance ('harmonised vaccination') for countries which share the same virus pools, and greatly boost information needed by FMD-free countries for optimal risk mitigation.

Conclusions

The PCP approach has now been adopted as joint tool between FAO and the OIE, assisting national level priority and activity planning, and comparative progress between countries. The PCP has led to an important revision of national policy in many countries, and encouraged the process of developing, for the first time, national control strategies in others. Resolutions of the OIE in 2011 have enhanced the motivation for countries to progress through the PCP with the possibility of official OIE endorsement of the national FMD control plan for countries in PCP Stage 3 or higher. The PCP-FMD approach has been applied together by FAO and OIE in major regions of four continents (Fig. 3). Longer term regional co-ordinated efforts ('Regional Roadmaps'), based on PCP progression to 2020 or 2025, have been developed in Southern Africa (from 2011), Eastern Africa (from 2012), West Eurasia (from 2008) and South Asia (South Asian Association for Regional Cooperation, from 2011), as a tool to complement the long-term regional Roadmaps in South-East Asia and China (SEACFMD campaign) and to assist the progressive elimination of remaining foci of infection in South America. In the Roadmap meetings, the expected national PCP progress to 2020 has been charted, and international agencies and donors are encouraged to support national PCP action plans. Encouragingly, some countries have adopted the PCP into their cycle of outcome-oriented national planning. In many situations, however, the process of revising FMD policy based on comprehensive assessment of options, benefits, responsibilities and stakeholder interests is unfamiliar

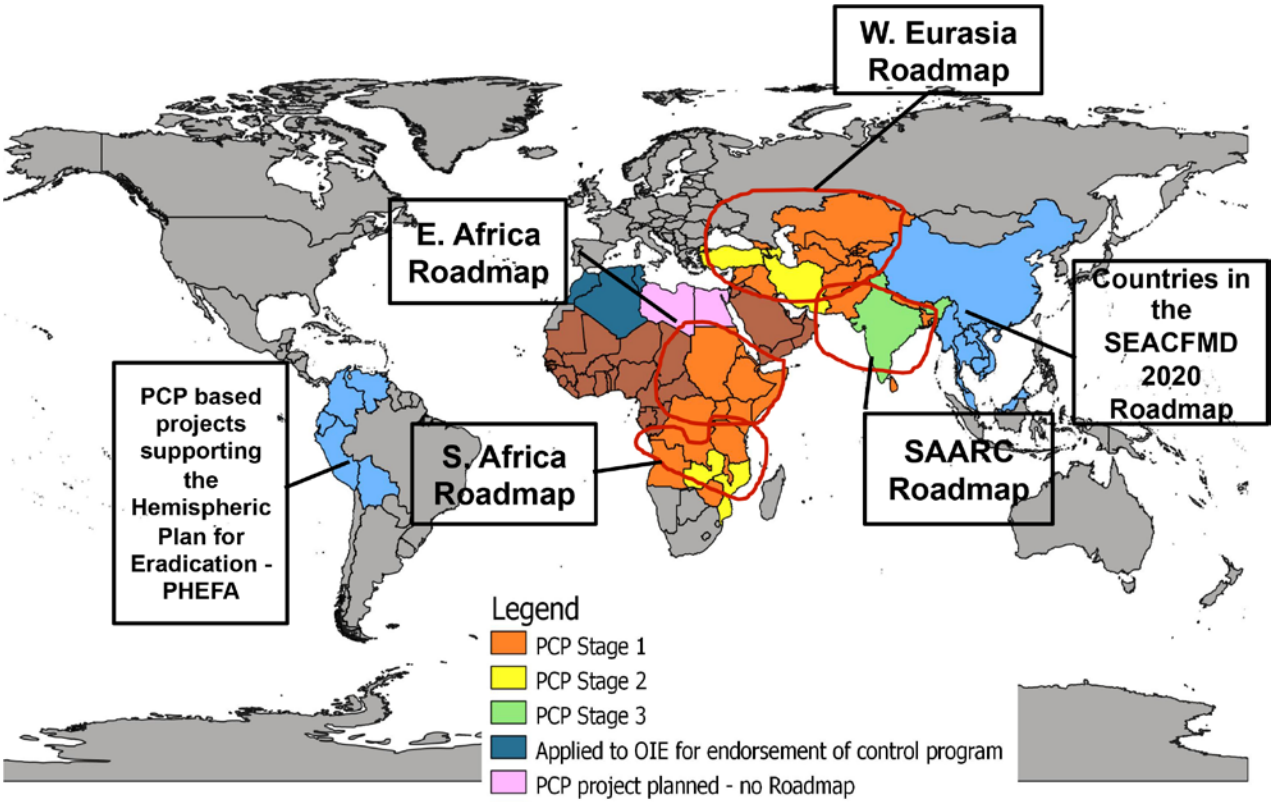

Fig. 3

The use of the PCP framework to assist national level FMD management – the PCP stage of countries, and expected progression to 2020 or 2025, has been identified at Regional Workshops of FAO and OIE in four regions in 2011–2012

The PCP has been used in regional projects (Andean region of South America by FAO) and an alignment made with the SEACFMD Roadmap in South-East Asia and China.
Source: EuFMD-FAO

and needs support; access to FMD prevention services remains constrained by regulatory hurdles; and the need to communicate to livestock keepers and veterinarians on their role in response to changing local FMD risks is still insufficiently recognised. The public and private responsibilities within FMD control are central to discussions on operationalising the Global FMD Strategy after June 2012.

In addition to improving Global FMD Control, the two other components of the strategy are strengthening veterinary services and improving the prevention and control of other major diseases of livestock; the PCP-FMD is the major tool to assist with the FMD component while the PVS Pathway is the major tool for the second. In future, the PCP requirements for an enabling environment for FMD control will be largely based on critical competencies from the PVS Pathway. In FAO, all new programmes of national assistance on FMD utilise the PCP-FMD, and the experience has led to calls from member states to adapt and apply the PCP approach as part of a common framework for policy setting on transboundary animal diseases (TADs). Since the risk factors of one disease are often common to other TADs, the use of the PCP even for one disease such as FMD could improve policy setting for other TADs, and ultimately assist the sustainability of programmes and to achieving Component 3 of the Strategy, improved prevention and control of major TADs of livestock.

Acknowledgements

The contributions of Nadia Rumich in managing the PCP documentation for the EuFMD and Enrique Anton (EuFMD) and Claudia Ciarlantini (FAO) for developing the PCP stage logo (Fig. 1) are gratefully acknowledged.

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Session 2

Further presentation of the tools to implement the Global FMD Control Strategy

Chair: G. Khoury (FAO)

The Performance of Veterinary Services (PVS) Pathway (PVS Evaluation, PVS Gap Analysis, veterinary legislation, PVS Evaluation follow-up)

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Summary

The initial evaluation of the Performance of Veterinary Services (PVS) in a country, using the World Organisation for Animal Health (OIE) PVS Tool, sets the baseline, founded on democratically adopted OIE international standards on the quality of Veterinary Services.

A PVS Gap Analysis mission helps a country to define its Veterinary Services' objectives in terms of compliance with OIE quality standards, suitably adapted to national constraints and priorities.

The country's PVS Gap Analysis (PVS Costing Tool) report includes a suggested annual budget and one exceptional budget (for exceptional investment), when relevant, consolidated to make up a proposed five-year budget for the country's Veterinary Services.

In practice, this means:

- *defining, together with the Veterinary Services, and in accordance with national priorities and constraints, the expected result (i.e. the level of advancement for critical competencies defined in the OIE PVS tool) at the end of the five-year period for the critical competencies of the OIE PVS tool which are relevant to the national context;*
- *determining the activities to be carried out in order to achieve the expected results for the critical competencies of the OIE PVS Tool which are relevant to the national context of the country;*
- *determining, with the help of information, data or interviews, the tasks and human, physical and financial resources required to implement these activities to enable the Veterinary Services to function appropriately.*

The country PVS Gap Analysis priority objectives focus primarily on the national context of the country and its priorities. How and what to finance is a sovereign decision of the country. The country's government decides if this is kept for internal use (government funding) or shared with donors and relevant international organisations to prepare investment programmes.

Periodic use of the OIE PVS Tool (an initial PVS evaluation and subsequent PVS Pathway follow-up missions) provides a way of measuring in absolute terms the progress that countries have made in sustainably improving their compliance with the OIE quality standards set out in the OIE Terrestrial Animal Health Code (Terrestrial Code).

Regular country PVS Evaluation follow-up missions (every three to five years) are useful to assess, monitor and accompany the progress made (changes in legislation, structure, the impact of national and international investments, improved technical capacities, etc.).

The OIE is aware that, in many developing countries, veterinary legislation is inadequate to address the challenges of today and of the future. At the request of Member Countries, the OIE has developed guidelines on all the essential elements to be covered in veterinary legislation. Any Member Country that has participated in an OIE PVS evaluation may request a follow-up mission dedicated to the provision of advice and assistance in modernising the national veterinary legislation. The OIE guidelines on veterinary legislation will be used to update the national legislation where gaps are identified in the course of an OIE PVS evaluation.

Keywords
Budget of Veterinary Services – Evaluation of Performance of Veterinary Services – Follow-up missions – OIE PVS Tool – PVS Gap Analysis – PVS mission – PVS Pathway – Veterinary legislation – World Organisation for Animal Health.

Introduction

Competence and confidence cannot be imposed. They are fragile assets which must be fostered progressively and which can easily be lost in the early stages of development. The Member Countries of the World Organisation for Animal Health (OIE) have adopted international standards on the quality of Veterinary Services (7). Within this legal framework, the OIE has developed a tool for the evaluation of Veterinary Services (the OIE Performance of Veterinary Services [PVS] Tool) (5). This constitutes the cornerstone of the PVS Pathway for good governance of animal health systems, for the strengthening of Veterinary Services, and for building competence and confidence among relevant national authorities.

OIE mandate and standards

International standard-setting activities referred to in the World Trade Organization (WTO) Agreement on the Application of Sanitary and Phytosanitary Measures (the SPS Agreement) are the responsibility of the 'three sister' international standard-setting organisations, namely the Codex Alimentarius Commission (CAC), the World Organisation for Animal Health (OIE, formerly the Office International des Epizooties or International Office for Epizootics) and the relevant international and regional organisations operating within the framework of the International Plant Protection Convention (IPPC).

The international standards, guidelines and recommendations developed under the auspices of the OIE for animal health and zoonoses are essential reference tools for improving animal health and welfare worldwide, through the application of science-based, democratically adopted global standards on animal diseases, including zoonoses.

The work of the OIE on standards can be divided into two broad categories:

– standards contained in the *Terrestrial Animal Health Code* (*Terrestrial Code*) and the *Aquatic Animal Health Code* (*Aquatic Code*), dealing with animal diseases, including zoonoses; animal welfare, and sanitary safety (including animal production food safety);

– biological standards contained in the *Manual of Diagnostic Tests and Vaccines for Terrestrial Animals* (the *Terrestrial Manual*) and *Manual of Diagnostic Tests for Aquatic Animals* (the *Aquatic Manual*), which provide a harmonised approach to disease diagnosis by describing internationally agreed laboratory diagnostic techniques. The *Terrestrial Manual* also includes requirements for the production and control of biological products (mainly vaccines).

The guidelines and recommendations are given in specific documents separate from the *Codes* and *Manuals*. OIE standards integrate the outcome of a risk assessment, and thus make additional risk assessments redundant. The majority of OIE standards are now used for national disease control measures.

The WTO recognises that the OIE *Codes* set international standards on animal disease diagnosis, surveillance and notification, risk analysis, and the quality and governance of Veterinary Services. They also include recommendations on disease prevention and control methods, trade measures, import/export procedures and veterinary certification, veterinary public health and animal welfare. The OIE *Codes* also aim to ensure the sanitary safety of international trade in terrestrial animals (mammals, birds and bees) and aquatic animals (amphibians, fish, crustaceans and molluscs) and their products.

In brief, the main objectives of the OIE are:

– to ensure transparency in the global animal disease and zoonosis situation;

– to collect, analyse and disseminate scientific veterinary information;

– to provide expertise and encourage international solidarity in the control of animal diseases;

– within its mandate under the WTO SPS Agreement, to safeguard world trade by publishing health standards for international trade in animals and animal products;

– to provide a better guarantee of the safety of food of animal origin and to promote animal welfare through a science-based approach;

– to improve the legal framework and resources of national Veterinary Services.

In regard to the final objective, which is at the core of the PVS Pathway, one should note that animal health systems are not a commercial or a strictly agricultural good. They are fully eligible for national and global public resources. Failure of one country may endanger the entire planet.

The concept of public goods has acquired a global dimension. Kaul *et al.* (2) define global public goods as those which 'tend towards universality in the sense that they benefit all countries, population groups and generations'.

The contribution of animal health and veterinary public health to the improvement of food security and food safety is an underlying priority. The importance of non-zoonotic diseases that affect food security (and indirectly contribute to public health issues) will not be overlooked. In relation to the control and eradication of infectious diseases, the benefits are international and inter-generational in scope. Countries depend on each other.

Good governance of Veterinary Services

In the context of the International Ministerial Conferences on Avian and Pandemic Influenza (IMCAPI), which took place in Washington (October 2005), Geneva (November 2005), Beijing (January 2006), Vienna (June 2006), Bamako (December 2006), New Delhi (December 2007), Sharm El-Sheikh (October 2008) and Hanoi (April 2010), the OIE and the Food and Agriculture Organization of the United Nations (FAO) published in November 2005 a first advocacy document on the good governance of Veterinary Services: 'Ensuring good governance to address emerging and re-emerging animal disease threats – supporting the Veterinary Services of developing countries to meet OIE international standards on quality'. This was last updated in September 2007.

The World Health Organization (WHO), the OIE and FAO have worked with their partner organisations – the United Nations Children's Fund (UNICEF), the World Bank and the United Nations System Influenza Coordinator (UNSIC) – to clarify requirements for all countries and to establish an international institutional framework that addresses emerging infectious diseases by reducing the risks of these diseases at the animal–human–ecosystems interface and strengthening capacities in a number of key areas.

There is a crucial need for appropriate legislation in the animal health field and its strict implementation through appropriate national animal health systems, allowing, in principle, for:

– surveillance systems, to strengthen the health capacity of international wildlife and ecosystems;

– Member incentives for early detection of disease incursions, transparency and notification, in particular for animal diseases under the relevant OIE standards;

– rapid response capacity to animal disease outbreaks and implementation of biosecurity and bio-containment measures;

– compensation strategies to indemnify animal owners;

– vaccination strategies, as appropriate.

The use of the concept and standards of 'Quality of Services' (7), democratically adopted by all the OIE Members, is encouraged. An operational national chain of command is critical. Initial and continuing veterinary education and research may also need to be addressed. Deregulation can be a source of biological disasters.

Building and maintaining efficient epidemio-surveillance networks and territorial meshing throughout the national territory, for all potential terrestrial and aquatic animal diseases, is a responsibility of all governments. Alliances between the public and private sectors are necessary to achieve this, given national physical, human and financial competition for resources.

The OIE considers that the key tripod for good surveillance, early warning and rapid response is based on the following three groups:

– farmers/stakeholders/hunters/rangers (wildlife officers), as they are 'the first to know';

– official veterinarians (including laboratories); and

– private veterinarians.

These concepts were encapsulated in the so-called 'One World, One Health' concept paper published in October 2008: 'Contributing to One World, One Health – a strategic framework for reducing risks of infectious diseases at the animal–human–ecosystems interface'. This strategic framework has been jointly developed by four specialised agencies – FAO, the OIE, WHO and UNICEF – and endorsed by the World Bank and UNSIC, in response to the New Delhi IMCAPI recommendation.

While the integration of control systems across animal, food and human sectors has been attempted in some countries and regions (notably after the bovine spongiform encephalopathy crisis in the 1990s, initially in Europe), in most countries control systems are generally non-integrated with only a few collaborative projects. However, the recent efforts to control highly pathogenic avian influenza and to prepare for a pandemic have re-emphasised the need for enhanced concentration on reducing risks associated with zoonotic pathogens and diseases of animal origin through cross-sectoral collaboration, and have resulted in increased functional collaborations in many countries and at the international level.

To sum it up: more cooperation between veterinarians and medical doctors is encouraged (and 'integration' is not a recommended option). This message has been reaffirmed in the recent WHO–OIE–FAO Tripartite Concept Note – 'Sharing responsibilities and coordinating global activities to address health risks at the animal–human–ecosystems interfaces – the FAO–OIE–WHO Collaboration' (1), published in April 2010 at the Hanoi IMCAPI conference.

Notification of animal and human diseases is an important part of this approach (3). To ensure a timely response, diseases must be immediately notified in a transparent manner.

It is under the mandate of the two global organisations responsible for the dissemination of disease information: WHO for human diseases and the OIE for animal diseases, including zoonoses.

Communicating timely and accurate animal disease information, including information on zoonoses, remains one of the core functions of the OIE and it is one in which the OIE is the world leader. Providing such information requires timely access by the OIE to all relevant data sources, both conventional and non-conventional (using, in this case, non-official information tracking systems), followed by professional analysis, evaluation and interpretation of data, including the views of the Member Country affected, before an official communication is made. The World Animal Health Information System (WAHIS), with its web-based interface, forms the nucleus of the OIE's information system. This is an Internet-based computer system which incorporates 180 Member Countries online and also allows for non-OIE Members to notify their animal health status.

The Performance of Veterinary Services Pathway

The OIE has progressively developed the PVS Pathway, which is a global programme for the sustainable improvement of a country's Veterinary Services' compliance with OIE standards. The PVS Pathway encompasses the individual OIE PVS evaluation (5), PVS Gap Analysis (6) and PVS Evaluation follow-up missions as first steps and integrates them into a comprehensive, staged approach, providing targeted support for the systematic strengthening of Veterinary Services.

The first step is the country OIE PVS evaluation (5), which is a qualitative assessment of the performance and compliance of Veterinary Services in accordance with OIE international standards on the quality and evaluation of Veterinary Services (7).

The second step is the country PVS Gap Analysis (PVS Costing Tool) (6), which is a quantification of needs. The corresponding indicative budget addresses compliance with priority critical competencies, discussed with the country concerned and based on the PVS report of the PVS evaluation of the country. A PVS Gap Analysis

mission helps to define the objectives and priorities of a country's Veterinary Services, in terms of compliance with OIE quality standards, suitably adapted to national constraints and priorities.

In addition, periodic PVS Evaluation follow-up missions provide a way of measuring the progress that countries have made in sustainably improving their compliance with the OIE quality standards set out in the OIE *Terrestrial Code.* The initial country PVS evaluation is the baseline, founded on democratically adopted OIE international standards on the quality of Veterinary Services.

Regular country PVS Evaluation follow-up missions (every three to five years) are useful to assess, monitor and amplify the progress made (changes in legislation, structure, the impact of national and international investments, improved technical capacities, etc.).

Figure 1 is the visual representation of the OIE strategy for the use of OIE standards on the quality of Veterinary Services.

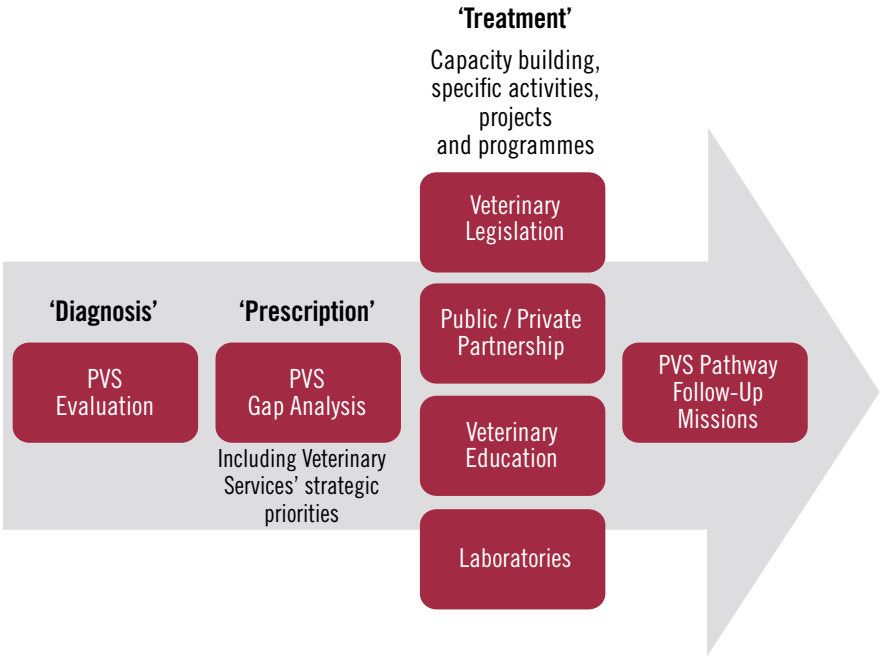

Fig. 1
The OIE Performance of Veterinary Services Pathway for good governance of Veterinary Services

These missions are conducted by OIE PVS certified experts at the request of the country in question.

Performance of Veterinary Services evaluations

The initial PVS evaluation of a country, using the OIE PVS Tool (5), sets the baseline, founded on democratically adopted OIE international standards on the quality of Veterinary Services (7).

The OIE PVS Tool (5) is based on four fundamental components:

– human, physical and financial resources;

– technical authority and capability;

– interaction with stakeholders; and

– access to markets.

The 2013 (sixth) edition of the OIE PVS Tool includes 47 critical competencies; for each critical competency, five levels can be assessed, from 1 (less advanced) to 5 (more advanced).

A harmonised approach is implemented, and the following documents are given to all accredited OIE PVS Assessors:

– the Manual of the Assessor – Volume 1: Guidelines for conducting an OIE PVS Evaluation;

– the Manual of the Assessor – Volume 2: Guidelines for writing an OIE PVS Evaluation Report;

– the OIE PVS Tool with Provisional Indicators (now the sixth edition, published in 2013).

To date (April 2015), a total of 133 official country requests for a PVS evaluation have been received; 123 initial PVS evaluation missions have already been completed, as presented in Table I. A worldwide overview of the state of play of PVS evaluations is presented in Figure 2[1].

Table I
Performance of Veterinary Services evaluation missions – state of play up to April 2015

	OIE Members	PVS evaluation requests received	PVS evaluation missions implemented	Draft PVS evaluation reports received	Reports available for (restricted) distribution to donors and partners	Publication on the OIE website
Africa	54	53	51	51	42	8
Americas	29	25	23	23	19	9
Asia, the Far East and Oceania	32	24	22	22	11	1
Europe	53	18	16	16	12	1
Middle East	12	13	11	11	5	1
TOTAL	180	133	123	123	89	20

Performance of Veterinary Services Gap Analysis

A PVS Gap Analysis mission (6) helps to define the objectives and priorities of a country's Veterinary Services, in terms of compliance with OIE quality standards, suitably adapted to national constraints and priorities.

The country PVS Gap Analysis (PVS Costing Tool) report includes an indicative annual budget and one exceptional budget (for exceptional investments), when relevant, consolidated to propose an indicative five-year budget for the country's Veterinary Services.

In practice, this means:

– defining, together with the Veterinary Services, and in accordance with national priorities and constraints, the expected result (i.e. level of advancement defined in the OIE PVS Tool) at the end of the five-year period for the critical competencies of the OIE PVS Tool which are relevant to the national context;

– determining the activities to be carried out in order to achieve the expected results for the critical competencies of the OIE PVS Tool which are relevant to the national context of the country;

– determining, with the help of information, data or interviews, the tasks and human, physical and financial resources required to implement these activities to enable the Veterinary Services to function appropriately.

As with the OIE PVS Tool, the PVS Gap Analysis (PVS Costing Tool) follows a harmonised approach. All PVS Gap Analysis experts are provided with the PVS Gap Analysis Experts' Manual, made up of the following:

– Volume I – Guidelines for conducting a mission;

– Volume II – Guidelines for writing a country PVS Gap Analysis Report;

– The PVS Gap Analysis Tool (PVS Costing Tool) and Tool Box.

1 Post-meeting note: information updated after the 2012 FAO/OIE global conference on FMD control

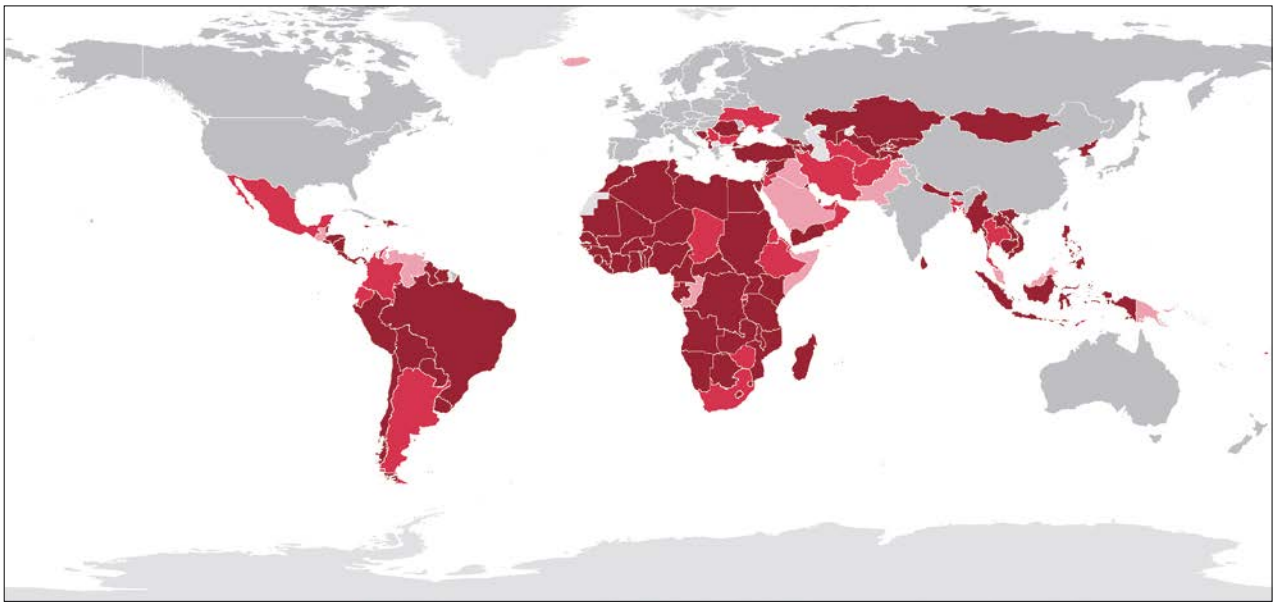

Fig. 2
Worldwide overview of Performance of Veterinary Services (PVS) evaluation missions (as of April 2015)

official country request received; PVS evaluation mission not yet completed

PVS evaluation mission completed; country PVS report not yet available

country PVS reports available for donors and partners

specific approach

PVS evaluation missions have pinpointed the following global diagnosis:

– national and international competition for resources;

– the weakness of many national Veterinary Services (legislation, human and financial resources);

– Veterinary Services need to improve their ability to present financial information and cost/benefit arguments to support their objectives, both internally (line Minister, Minister of Finance, national Parliament) and, if needed, externally (donors and international organisations).

The country PVS Gap Analysis priority objectives focus primarily on the national context of the country and its priorities. How and what to finance is a sovereign decision of the country. The country's government decides if this is kept for internal use (government funding) or shared with donors and relevant international organisations to prepare investment programmes.

To date (April 2015), 96 official country requests for PVS Gap Analysis (78% of countries which have benefited from an initial PVS evaluation) have already been received and 79 PVS Gap Analysis missions have already been completed; an overview of the situation is presented in Table II.

The country PVS Gap Analysis report can be used for in-country discussions with the line Minister, other Ministries, the Ministry of Finance, the Prime Minister's Office, the Head of State, the National Parliament, depending on the circumstances within the country; the preparation of the country's Veterinary Services budget and national or international investments; and round-table discussions, within the country, with donor agencies and international organisations, including FAO. From experience, the preparation of round-table discussions in the country begins with bilateral contacts with donors and the headquarters of international organisations, followed by bilateral contacts at the country level, before a representative round-table discussion with all concerned stakeholders can be organised.

Table II
Performance of Veterinary Services Gap Analysis missions – state of play up to April 2015

	OIE Members	PVS Gap Analysis requests received	PVS Gap Analysis missions implemented	PVS Gap Analysis missions reports received	Reports available for (restricted) distribution to donors and partners
Africa	54	46	43	43	26
Americas	29	15	12	12	9
Asia, the Far East and Oceania	32	18	13	13	7
Europe	53	9	7	7	3
Middle East	12	8	4	4	0
Total	180	96	79	75	45

Veterinary legislation

The OIE is aware that, in many developing countries, veterinary legislation is inadequate to address the challenges of today and of the future. Veterinary legislation is an essential element of the national infrastructure that enables Veterinary Services to efficiently carry out their key functions.

At the request of Members, the OIE has developed guidelines (4) on all the essential elements to be covered in veterinary legislation. Any Member that has participated in an OIE PVS Evaluation may request a specific PVS Pathway Follow-up mission dedicated to the provision of advice and assistance in modernising the national veterinary legislation. The OIE guidelines on veterinary legislation will be used to amend the gaps in the national legislation identified during the course of the OIE PVS Evaluation.

Any Member that has participated in an OIE PVS Evaluation may request a Veterinary Legislation Support Programme mission as an additional mission, designed to provide advice and assistance in modernising the national veterinary legislation.

In 2010, the OIE published the first edition of the OIE Veterinary Legislation Manual. The manual is composed of the following three components:

– Veterinary Legislation Support Programme Manual, Volume I – OIE procedures;

– Veterinary Legislation Support Programme Manual, Volume II – Technical guidance;

– Veterinary Legislation Support Programme Manual, Volume III – Reference materials.

The second edition of the OIE Veterinary Legislation Manual has been published in 2015[2].

Conclusion: the OIE vision

A world capable of preventing, detecting, containing, eliminating and responding to animal and public health risks attributable to zoonoses and animal diseases (both domestic and wildlife) with an impact on food security through multi-sectoral cooperation and strong partnerships.

2, 3 & 4 : Post-meeting note: information updated after the 2012 FAO/OIE global conference on FMD control

Acknowledgements

The OIE PVS Tool and the PVS Gap Analysis Tool (PVS Costing Tool) have been developed with the support of several experts and donors. Considerable time has passed since the OIE carried out a pilot project, co-financed by the United States Department of Agriculture (USDA) and the World Bank, aimed at evaluating the performance of Veterinary Services in 15 countries in three regions and completed a 'gap analysis' mission in ten countries. As of April 2015, the OIE has received an official request for a PVS evaluation from 133 countries and 123 initial PVS evaluation missions have been completed worldwide; this has already generated 96 official requests from countries for a PVS Gap Analysis (PVS Costing Tool), based on the country's PVS Report[3].

The PVS Pathway for efficient Veterinary Services was thus born and is now a fully-fledged worldwide project, co-financed and supported notably by the European Union, the World Bank, the United States of America, the United Kingdom, Switzerland, Japan, Italy, France, Australia, and the Bill and Melinda Gates Foundation, through the OIE World Animal Health and Welfare Fund[4].

Very helpful and valuable advice and guidance were provided by the OIE *ad hoc* Group on Evaluation of Veterinary Services, currently chaired by Dr Herbert Schneider, and questions raised and comments and written reviews were provided by the numerous participants who attended the four PVS training sessions, the two PVS feedback sessions, the two PVS Gap Analysis training sessions and the first feedback session on the PVS Gap Analysis Tool.

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OIE endorsement of foot and mouth disease control programmes and recognition of disease-free status

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Summary

The World Organisation for Animal Health (OIE) has, since its founding in 1924, facilitated the safe trade of animals and animal products to prevent the spread of animal diseases across the globe. Acknowledging the disease-free status of countries to facilitate trade has been integral to this process and has been advanced and adopted over the years to give further recognition to efforts of countries to enter disease-free animals and products into the international market. Since 1994, when the OIE initiated a system of recognising the favourable disease status of countries, the standards have been advanced to recognise the official free status of countries, zones and compartments.

It is evident that Member Countries obtaining official recognition for either country or zonal disease freedom is a slow process that depends on the ability of countries or territories to achieve and maintain the recognised disease-free status. It is also a costly process that necessitates a sustainable and effective Veterinary Service and political will and commitment.

At the 79th World Assembly of OIE Delegates in 2011, an amendment to the chapter on foot and mouth disease (FMD) in the OIE Terrestrial Animal Health Code *(*Terrestrial Code*) was adopted to make provision for the endorsement of official control programmes for FMD for those countries still in the process of achieving disease freedom but which are not yet there.*

The criteria applied by the OIE Scientific Commission for Animal Diseases in assessing these applications and eventually recommending the endorsement of these applications by the World Assembly of OIE Delegates will be briefly described.

Keywords
Compartmentalisation – Control programmes – Foot and mouth disease – OIE – Scientific Commission – Terrestrial Code – World Organisation for Animal Health – Zoning.

Introduction

Since the establishment in 1924 as an intergovernmental body of concerned countries to prevent the international spread of animal diseases, the main objective of the World Organisation for Animal Health (OIE) was to establish animal health standards to guide countries to help them in preventing the international spread of animal diseases that could cripple the economy of the world through the international trade in infected animals and animal diseases (6). Initially, the main concern was to prevent the further spread of rinderpest that was introduced into Europe in the early 1900s, but other devastating and trade-sensitive animal diseases, such as contagious bovine pleuropneumonia (CBPP) and foot and mouth disease (FMD), necessitated similar preventative actions. Over the years, trade-sensitive diseases of other animal species, such as pigs and poultry, were added to the list of concerned diseases for which the OIE developed standards to mitigate the risk of international spread through the trade in animals and animal products.

During the 1980s it was realised by the OIE that its Member Countries that had invested substantially in controlling these diseases and maintaining a negative animal disease status within their national borders should also be eligible to benefit from their costly disease control efforts by having their negative disease status officially recognised. The OIE subsequently, in 1995, mandated the then FMD and other Epizootics Commission (which in 2003 became the Scientific Commission for Animal Diseases [SCAD]) to develop scientific-based standards

to officially recognise the negative FMD status of Member Countries and give them the benefit of publicly using this officially allocated negative disease status by the OIE to facilitate trade (8). The same process was followed in 2000 for rinderpest, CBPP in 2003, bovine spongiform encephalopathy (BSE) in 2004 and African horse sickness (AHS) in 2012. It was also decided by the then International Committee of the OIE that Member Countries that do not receive an official recognition by the OIE for their disease status for FMD, CBPP, rinderpest, BSE and AHS would not be allowed to make a self-declaration for freedom from these diseases within their national territory but would, however, be eligible to do so on their own responsibility for other OIE-listed diseases – provided they meet the criteria for recognition of country or zonal freedom as prescribed in the OIE *Terrestrial Animal Health Code* (*Terrestrial Code*) (4); the main reason being that official recognition by the OIE of the disease status of a country should be consistent for all countries and the status is judged by the same standards and evaluated for compliance with these standards by a body mandated by the World Assembly of Delegates. This mandate was given to the OIE SCAD, which has, ever since, been tasked to perform the function on behalf of the World Assembly of OIE Delegates for evaluating compliance of applicant Member Countries with the requirements of the OIE *Terrestrial Code* for those animal diseases eligible for official status recognition.

The rationale of the OIE Terrestrial Code *for the recognition of disease status*

The main objective of the OIE *Terrestrial Code* is to facilitate the safe trade of animals and animal products and to prevent unjustified trade barriers. Together with the standards in the OIE *Manual of Diagnostic Tests and Vaccines for Terrestrial Animals* (OIE *Terrestrial Manual*), it provides guidance and standards for the control, prevention and diagnosis of animal diseases; criteria for the recognition of disease-free countries, zones and compartments; and risk mitigation measures for the safe trade in animals and animal products.

For all the diseases eligible for official status recognition, the *Terrestrial Code* defines the disease for trade purposes; provides categories for disease freedom and criteria for the recovery of status in the event of the loss of a recognised disease status; and provides risk mitigation measures for the safe trade in commodities, animals and animal products and specific surveillance guidelines to prove the absence of disease and infection. In the case of FMD, further standards are provided for the official endorsement of national disease control programmes for FMD.

Disease status was initially restricted to freedom from disease in the country as a whole. However, it was soon realised that to extend the advantage to Member Countries for which it was not possible for the entire country to be free from a particular disease or which would, because of financial and other restrictions, prefer to gradually move towards freedom, recognition should also be given to zones within a country free from disease. This was later extended to allow for compartments free from disease where, in contrast to zonal freedom based on geographical boundaries, the free status of a sub-population is managed in a compartment through the application and maintenance of biosecurity measures. To further facilitate trade, even in the event of infection with the disease, the principle of the establishment of containment zones in the event of limited outbreaks was introduced in the FMD chapter, as well as the identification of commodities eligible for trade even if a country is still infected with the disease.

The standards for FMD, described in detail in Chapter 8.5. of the *Terrestrial Code*, provide for several categories of recognised disease status: historical freedom; free country without vaccination; free country with vaccination; free zone without vaccination; free zone with vaccination; and free compartment with vaccination. It further provides for the establishment of a containment zone in the event of a limited outbreak of FMD to effectively isolate an infected area whilst allowing the continuation of trade from the rest of a recognised free zone. Standards are also provided for risk mitigation measures to facilitate the import of commodities from countries infected with FMD and criteria are provided for the destruction of the FMD virus in commodities such as meat and milk to facilitate trade.

Irrespective of the criteria for disease-free status for FMD described in the *Terrestrial Code*, generic to all these criteria is the requirement that FMD should be a notifiable disease; surveillance should be done in accordance with the requirements of the *Terrestrial Code*; outbreaks of the disease should be reported to the OIE; convincing evidence should be provided on the absence of infection and virus circulation; animals and animal populations of a different disease status should be effectively separated to prevent FMD virus transmission; and convincing evidence should be provided on the measures in place to prevent the introduction of FMD virus.

The mandate of the OIE Scientific Commission for Animal Diseases to assess and recommend the allocation or suspension of disease status of a Member Country

The SCAD is elected democratically by the Delegates of OIE Member Countries at the annual meeting of the World Assembly of OIE Delegates, and thereby is mandated by the General Assembly to act on its behalf in assessing the applications of Member Countries for the allocation of disease status (7). The six members of the SCAD are elected for a period of three years and are eligible for re-election. The Commission consists of a president, two vice presidents and three additional members. The Commission is accountable to Delegates and has to report every year at the General Assembly on its activities and request the endorsement by Resolution of the recommendations of the Commission for the allocation of disease status for FMD, CBPP, BSE and AHS. At the 79th General Assembly in 2011, the world was declared free from rinderpest, and this was also the last time the Commission made recommendations to the General Assembly for the recognition of the disease-free status for rinderpest (3).

The criteria used by the Commission to make assessments of applications by Member Countries for the allocation of a requested disease status are restricted to what is prescribed and adopted as an international standard for that purpose within Chapter 8.5. of the OIE *Terrestrial Code*; in other horizontal chapters of the *Terrestrial Code*; the standards for the quality of Veterinary Service delivery; the obligations for disease reporting; the application of surveillance strategies; the use and application of vaccines; and the conducting of diagnostic tests for the detection of FMD as prescribed in the OIE *Terrestrial Manual* (1).

There are also two important resolutions that were amended and adopted at the 80th General Session of the OIE to strengthen the mandate of the Commission (5). The first of these is Resolution 25, which describes the procedures for the submission of applications by Member Countries; the obligation of Member Countries for the maintenance of status and the mandate to the Commission to allocate a given status; the suspension of a given status; and the re-instatement of the status of a Member Country without the permission of the General Assembly. For all applications other than the reinstatement of a status or the establishment of a containment zone, the Commission must submit a recommendation for adoption by the General Assembly. Resolution 25 also mandates the Commission to undertake a visit to an applicant Member Country to verify the information submitted in a dossier or to assess the disease control procedures in place for the maintenance of a given disease status.

Resolution 26, which was also amended and adopted at the 80th General Assembly, provides for the fees that must be paid by a Member Country when applying for the allocation of a given disease status. The amounts currently payable are €7,000 for the status recognition of an entire country, zone or more than one zone (if applied for in the same dossier) and €2,000 for the endorsement of a national control programme for FMD. No payment is made for applying for the reinstatement of a lost disease status. The least developed countries (in accordance with the UN list of countries) pay only 50% of these amounts (5).

The endorsement of official programmes for the control of foot and mouth disease

Following the adoption of a resolution at the first OIE/FAO Global Conference on FMD Control in Asunción, Paraguay, in 2009 (2), at which the OIE and FAO were mandated to develop a programme for the global control of FMD, it was acknowledged that more than 100 Member Countries of the OIE are not yet free from the disease and that FMD remains an endemic disease in large parts of the developing world – especially in Africa, Asia and some countries in the Middle East. Only 65 out of the 178 Member Countries are officially recognised as free from FMD without vaccination, one Member Country is free with vaccination and 14 Member Countries are free with zonal status either with or without vaccination. Thus, to further enhance the global control of FMD, it was realised that an incentive would be necessary to encourage Member Countries to embark on a national strategy to control the disease.

The Scientific Commission was thus tasked by the Council of the OIE to develop an amendment to the *Terrestrial Code* chapter on FMD to provide for the official endorsement of national control programmes for FMD by the OIE General Assembly. Although the endorsement by the OIE of the official control programme for FMD of a Member Country would not have the same legal status as the recognition of official disease freedom, the amended article in Chapter 8.5. of the *Terrestrial Code* provided criteria that could be used by the Scientific Commission

to assess whether the FMD situation and control methods applied in a Member Country are at such a level that the Member Country could, within a foreseeable time, qualify as officially recognised as free from FMD with or without vaccination. Should such a Member Country provide sufficient evidence, as described in the *Terrestrial Code*, that it is indeed serious about the control of FMD and is well advanced with its national programme to move towards the official recognition of disease freedom by the OIE, the Scientific Commission is given the mandate by the General Assembly to recommend the endorsement of the national control programme for FMD of such a Member Country by the General Assembly. One of the main thrusts, other than using this process, as an incentive for Member Countries to control FMD was to provide an incentive for countries to use the official published endorsement to illicit donor funding and convince politicians to sustain funding for the control of FMD within the national borders of a country. The amendment of Chapter 8.5, by the insertion of Article 8.5.48 outlining the international standards for the endorsement of national FMD control programmes, was subsequently adopted by the OIE World Assembly of Delegates at the 79th General Assembly, giving the mandate to the Scientific Commission to receive and assess applications by Member Countries for the official recognition of their national control programmes for FMD (3).

An important prerequisite for the endorsement of a national control programme for FMD is that it must demonstrate progress and sustainability of moving towards freedom from disease. Should a Member Country, during the annual assessment of its progress report to the OIE, fail to demonstrate any attempts to control the disease as outlined in the endorsed national control programme, the official endorsement can be suspended. Although Member Countries are free to apply a progressive system or a zonal approach to control the disease in accordance with the epidemiology of the disease within their country, the official control programme should, in accordance with the *Terrestrial Code*, be applicable to the entire country. It is also strongly recommended that Member Countries applying for endorsement of their national control programmes should, if not yet done, request the OIE to conduct a Performance of Veterinary Services (PVS) analysis and, where indicated, also a Gap Analysis on the performance of their Veterinary Service to assist them in identifying the areas of service delivery that need specific attention to successfully progress towards the control of FMD. The application of the FMD Progressive Control Pathway (PCP-FMD) is also strongly recommended as a valuable tool to assist Member Countries to move towards the acceptable level of control of the disease to comply with the requirements of the *Terrestrial Code* for the official endorsement of their national control strategies. The use of the PCP-FMD would especially be of value in those countries where the disease is still endemic and also where there are not yet similar established methods in place, such as regional FMD control programmes or strategies for the control of FMD.

At the 80th OIE General Assembly in May 2012, Morocco, Tunisia and Algeria were the first OIE Member Countries to receive official endorsement by the OIE for their national control programmes for FMD (5).

The procedures and principles applied by the Scientific Commission for Animal Diseases for the evaluation of the disease status and the endorsement of official disease programmes for foot and mouth disease

The details of the standard operating procedures for disease status recognition can be downloaded from the OIE website (8). It is, however, important to recognise that the SCAD is assisted in its task by the OIE Scientific and Technical Department, which not only manages the administrative issues related to applications by Member Countries, but also conducts preliminary screening of applications to assess whether the applications meet the requirements of Chapter 8.5 of the *Terrestrial Code* and reflect the relevant information required with each application in accordance with the relevant questionnaires in Articles 1.6.4 and 1.6.7 of the *Terrestrial Code*. These questionnaires were specifically developed and included in the *Terrestrial Code* to assist Member Countries to ensure that, when preparing their dossiers for submission to the OIE, they contain all the relevant information necessary for the SCAD to evaluate the application (4).

The SCAD is further assisted by an *ad hoc* group of experts (8), appointed by the Director General in consultation with the President of the Scientific Commission and the Head of the OIE Scientific and Technical Department, to assess, if required by the Commission, applications by Member Countries and to make recommendations to the SCAD on the acceptance or rejection of an application. The final responsibility, however, remains with the SCAD for either accepting or rejecting an application and to make final recommendations for endorsement and adoption by the OIE General Assembly.

The key focus of the SCAD when evaluating Member Country applications in accordance with what are prescribed in the relevant chapters of the *Terrestrial Code* and relevant resolutions adopted by the OIE World Assembly of Delegates is the provision of clear evidence, especially of the following key aspects on the ability of an applicant country:

– to prove without doubt the absence of FMD virus circulation in the area that has applied for disease status recognition;

– to provide convincing evidence of the control measures to prevent the transmission of FMD virus between subpopulations of different disease status as well as the transmission of FMD virus between sub-populations of the same disease status where they are politically managed as different disease-free zones within the same country;

– to provide convincing evidence of the control measures in place to prevent the introduction of FMD virus into the area that has applied for official disease-free status recognition; and

– to demonstrate the ability of the Veterinary Service to be able to maintain the disease-free status once it is officially recognised by the OIE.

Experience of the Scientific Commission has shown that, although, relatively, it may not be that difficult to eventually obtain a given disease-free status, several Member Countries have failed to maintain that given status so dearly owned because of the introduction of FMD virus into the disease-free area. It is thus critical that budgetary provisions, and in some instances also donor assistance to help countries achieve official disease-free recognition status, should take into account and provide for the sustainability and maintenance of such a status once allocated by the OIE. The maintenance costs must for obvious reasons be budgeted for on a long-term basis and are therefore substantially more than the cost incurred to initially achieve freedom. Judging from the recurrence of outbreaks of FMD in several Member Countries that have obtained official OIE disease freedom recognition, it is obvious that some Member Countries still need to realise that the hard work and responsibility of maintaining disease freedom really only starts after the official handover of that prestigious disease-free certificate by the OIE.

Conclusions

The OIE has, since its founding in 1924, facilitated the safe trade of animals and animal products to prevent the spread of animal diseases across the globe. A process of acknowledging the disease-free status of countries to facilitate trade has been integral to this process and has been advanced and adopted through the years to give further recognition to efforts of countries to enter disease-free animals and products into the international market. Since 1994, when the OIE initiated a system of recognising the favourable disease of countries, the standards have been advanced from official recognition of freedom of countries to make further provision to recognise zones free within infected countries and, more recently, also to make provision for the establishment of disease-free compartments and the facilitation of safe commodity trade. This initiative of the OIE is in many ways a forerunner in the drive to move towards global FMD disease control, which has now been adopted as a global objective mandated by the international veterinary community for implementation by the OIE and FAO.

It is evident that Member Countries obtaining official recognition for either country or zonal disease freedom is a slow process that depends on the ability of countries or territories to achieve and, especially, maintain the recognised disease-free status. It is also a costly process that necessitates not only a sustainable and competent Veterinary Service but also the political will and commitment and acceptance by participating countries and the donor community to work together nationally, regionally and globally to achieve this goal. The need to create incentives for Member Countries to formulate and implement plans to control FMD at the national level was further enhanced at the 79th World Assembly of OIE Delegates in 2011 by adopting an amendment to the chapter on FMD in the OIE *Terrestrial Code* to make provision for the endorsement of official control programmes for FMD for those countries still in the process of achieving disease freedom but which are not yet there.

The endemic state of FMD in many parts of the developing world clearly indicates that we have a long way to go in achieving the ideal of the global control of FMD. This ideal, however, is not impossible, provided all countries agree to a common commitment to prevent and mitigate the spread of FMD virus and, when obtaining the ideal of disease freedom, to then prevent the introduction of the FMD virus into their disease-free areas.

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Session 3

Maintaining FMD-free status and providing evidence

Chair: C. Correa Messuti (Uruguay)

Maintaining foot and mouth disease-free status: the European experience

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Summary

Foot and mouth disease (FMD) has been at the heart of European Union (EU) animal health policy since the early 1960s. Having gone through a costly eradication process, Europe abandoned prophylactic vaccination in the early 1990s. Since that time the prevention of disease introduction and a high level of disease preparedness have become key elements in EU animal health policy, although a number of outbreaks of FMD have occurred. Bordering endemically infected geographical regions and having intensive trade in animal products throughout the globe, the EU continuously allocates substantial financial, material and human resources to maintain the World Organisation for Animal Health (OIE) recognised status of free from FMD without practising vaccination. The necessary activities aim to enhance disease awareness among citizens and ensure preparedness through contingency planning, training, real-time exercises and the maintenance of a substantial antigen bank of sufficient diagnostic capacity. The investments in the day-to-day prevention of the introduction and subsequent spread of possible disease through science-based trade and import conditions are complemented by measures to reduce the FMD risk at source. Therefore, EU support for the work of the Food and Agriculture Organization of the United Nations (FAO) World Reference Laboratory, which is able to collate the information on the global FMD situation and the evolution of FMD viruses, is considered an essential element of and direct contribution to the FAO/OIE initiated Progressive Control Pathway for FMD.

Keywords
Antigen bank – Diagnosis – Disease awareness – European Union – Foot and mouth disease – Preparedness – Prevention.

Introduction

Foot and mouth disease (FMD) has been at the heart of European Union (EU) animal health policy since the early 1960s. Having gone through a costly eradication process, Europe abandoned prophylactic vaccination in the early 1990s. Since that time the prevention of disease introduction and a high level of disease preparedness have become key elements in European Union (EU) animal health policy. It is therefore the primary aim of the EU to maintain in all Member States the internationally recognised status of free from FMD without practising vaccination in accordance with Article 8.5.2 of the *Terrestrial Animal Health Code* of the World Organisation for Animal Health (OIE) (10). However, the EU has experienced a number of outbreaks of FMD since prophylactic vaccination ceased in 1992. Each time the situation was carefully analysed and conclusions were drawn to further refine the prevention and control systems.

Preventing the introduction of foot and mouth disease

Disease awareness

Being situated in direct neighbourhood to countries and entire regions that are not free from FMD and being one of the biggest importers of animal products in the world, it is important to have an early warning system complementary to OIE. By operating a Trust Fund with the Food and Agriculture Organization of the United Nations (FAO) for agreed activities of the European Commission for the Control of FMD (EuFMD), the EU finances

projects assisting countries in its neighbourhood to control FMD, and thus generates information on emerging FMD viruses of different genetic and antigenic characteristics.

The work of the EU Reference Laboratory for FMD, which is supported from the EU budget, is the key in updating the Commission and the Member States on the FMD situation in the EU and its neighbourhood by analysing virus isolates and matching them with vaccines, where necessary in heterologous challenge tests.

Limiting foot and mouth disease risks at source

The European Food Safety Authority (EFSA) assessed the risk of FMD introduction into the EU from developing countries and made recommendations for the reduction of those risks through interventions in developing countries and regions aiming to control or eradicate the disease (3). This opinion is a base for a variety of measures implemented by various services of the Commission to support FMD control and eradication measures in third countries. One of those FMD control programmes contributed to the declaration of Turkish Thrace as a zone free from FMD in which vaccination is practised. The undeniable benefits of this situation for the EU remain true despite the outbreak of FMD in south-east Bulgaria in early 2011.

Regular veterinary inspections in third countries from which Member States are authorised to import animal products contribute to the continuous improvement of veterinary services in general and FMD control measures in particular in the audited countries. Since 2001, a total of 125 FMD-related missions have been carried out in 15 third countries and in all Member States. Audit missions in third countries focus on the guarantees provided to comply with EU import policy, while audits in Member States were mainly directed to verify disease preparedness, routine animal movement controls and the implementation of outbreak control measures.

Measures to prevent foot and mouth disease virus introduction into the European Union

The EU animal health import policy is based on a system of authorised countries or regions, from which certain species or products may be introduced into the Union, if accompanied by an official certificate attesting compliance with the harmonised import conditions. Authorisation of a country or region is conditional on factors relating to the health status of the livestock, the legislation of the country and the performance of the official control services. Any guarantee must be provided at the point of dispatch. Imports of live FMD-susceptible animals and their semen, ova and embryos are allowed only from countries that had no outbreak of FMD, no evidence of virus infection and no vaccination against FMD in the last 12 months or, as it may be in the case of bovine embryos, mitigating measures are applied in line with international recommendations.

For meat and meat products the authorisation to import is decided on the basis of a risk assessment. The import conditions include requirements in respect of the origin of the animals, the ante- and post-mortem inspection, deboning and maturation of meat and various degrees of heat treatment. Similarly, imports of fresh milk are allowed only from FMD-free countries, while in all other cases procedures for the inactivation of possible FMD virus are applied. Animal by-products must be safely sourced or have undergone specific treatment to ensure that any possible risk of virus introduction is eliminated.

All imported animals and their products are subject to documentary, identity and physical checks at the approved and regularly audited veterinary border inspection posts of entry to verify compliance with the EU import requirements. The rules on introduction of and the checks carried out on personal luggage have been tight after the 2001 FMD epidemic.

Although the current policy has been remarkably successful in maintaining a high level of protection against FMD with the minimum necessary restrictions on trade, the EU is aware that its external borders are not impermeable.

Disease preparedness

Effective prevention of FMD in the EU is based on the strength of the veterinary services in the Member States that are to be provided with adequate and sufficient resources to carry out their duties. The EU supplements those precautions through the EU veterinary fund managed in accordance with Council Decision 2009/470/EC (5) and committing each year a budget of about €300 million for all types of veterinary measures, including eradication programmes, compensation, preventive measures, training and reference laboratories.

European Union legislation relating to FMD is more than Council Directive 2003/85/EC on Community measures for the control of foot and mouth disease (7). Measures to prevent FMD are deeply embedded in a whole set of EU and national legislation of Member States. General provisions such as those on official controls, cooperation

between competent authorities of Member States and the Commission or veterinary certification complement specific disease control measures or the rules on trade into and imports from third countries of live animals and their products.

European Union Member States adopt contingency plans that are audited and approved by the Commission and constitute part of EU legislation. Those plans include the establishment of crisis centres, in some cases of mobile units that may be placed close to or in the outbreak area. To test their preparedness and the available control instruments, EU Member States carry out real-time exercises, in many cases across borders. Between 73 in 2007 and 90 in 2010 of such usually costly exercises were included in the annual reports to the Commission together with the main conclusions drawn from the drills.

The EU antigen bank, established in 1991 (6), stores, in close collaboration with the manufacture of the licensed vaccines, antigens of several strains and all serotypes in quantities notified by the EU Member States in the framework of their contingency plans and confirmed through a risk assessment carried out by EuFMD (1). Vaccines reconstituted from those antigens comply with OIE requirements (9) and can be delivered within a few days to any EU Member State or neighbouring non-Member State. While none of the antigens procured since 1991 at a cost of nearly €9 million had ever been used for vaccination in a Member State, high-potency vaccines have been donated on several occasions to third countries. The bank was completely restructured in 2011 at a cost of €11 million.

To refresh knowledge and skills after decades of absence of FMD, EuFMD has outlined a real-time training programme. Participants visit suspected outbreaks, carry out a full investigation of suspected cases and collect epidemiological information, test samples on site or at a laboratory and analyse movements of animals to trace source and spread of infection. The training promotes the establishment of a network of veterinarians in Europe and the neighbourhood who can share best practices and develop a bank of online resources that will assist in the training of veterinary staff. The trained personnel are made available, in accordance with Commission Decision 2007/142/EC (8), to the EU emergency team in support of a quick and effective response to animal health emergencies in the EU and at the request of third countries.

Rapid detection of foot and mouth disease

The obligation to notify any suspicion of FMD to the official veterinarian is backed by legislation assuring the farmers to be compensated for animals killed for disease control purposes and goes hand in hand with punitive measures for non-compliance. However, it is equally important that the animals remain under supervision to observe possible clinical signs and that keepers are trained to recognise them. The more diseases confusing the clinical picture of FMD are eradicated, for example infectious bovine rhinotracheitis or swine vesicular disease, the more specific clinical suspicion indicates FMD. The higher the general animal health status, the more frequent the veterinary visits to farms and the more careful veterinary inspections at slaughterhouses are, the more sensitive is the general disease detection system. Active surveillance is carried out in connection with other surveillance activities or targeted at areas at risk of the presence of FMD in their neighbourhood.

As laboratory confirmation is essential for the diagnosis of FMD, the EU Member States have maintained a network of laboratories that have the capacity to confirm or rule out FMD infection. The performance of those accredited laboratories is scrutinised in the framework of annual proficiency testing and followed up to improve performance where necessary. To this end, national reference laboratories work closely with the EU Reference Laboratory for FMD.

Minimise the risk of possible spread of foot and mouth disease

Live FMD-susceptible animals and their germinal products are moved from one Member State to the other only from holdings and areas not under restriction and following official veterinary inspection. Consignments are accompanied by a veterinary certificate and their movements are recorded and notified in advance to destination for controls upon arrival through the TRACES computerised system. Specific rules which were reinforced following the 2001 outbreak minimise the risks arising from assembly and transport operations. In addition, swill feeding is prohibited by law and handling of animal by-products is under official control in accordance with recently modernised legislation.

While handling of live virus for diagnostic purposes is allowed only in laboratories of high bio-containment, there are 15 laboratories listed for such activities. Their security level must meet the standards for the work with live FMD virus established by EuFMD in 1993 and reinforced following the FMD outbreak in 2007 (2). Compliance

with those standards is being audited by the Commission and has led to suspension of activities where technical equipment could not guarantee the elimination of risks.

Containment of foot and mouth disease in case of an outbreak

Immediately after a vesicular condition is suspected, EU Member States are to act in accordance with Council Directive 2003/85/EC, the aim of which is containment of the disease and rapid eradication. Where necessary, a general or regional standstill is ordered to freeze the situation until the infected zone can be identified. The control measures include stamping out of infected herds, establishment of protection and surveillance zones of at least 3- and 10-km radius, specific restrictions on movements of animals and their products within and out of those zones and tracing and restricting possible contacts. Emergency vaccination may supplement the control measures within a vaccination area surrounded by a surveillance area.

The Commission reinforces the measures taken by the EU Member States in the framework of the Directive by adopting, usually within hours, prepared protection measures that provide transparent information to the neighbouring countries and trade partners and also guarantee that no animals or animal products likely to carry the virus are exported from affected Member States. In addition, such measures provide a mechanism to gradually define high- and low-risk zones with different risk-related measures which are the base for the recovery of the FMD-free status.

Recovery of foot and mouth disease-free status

Following the eradication of outbreaks, surveillance is carried out to detect residual infection and finally to prove absence of infection in order to release the restriction measures. This requires sufficient laboratory capacity to deliver the needed results from post-outbreak serological surveys and in some cases the combined forces of laboratories in different EU Member States.

Since vaccinate to live is an option, a sophisticated system of classifying herds according to their status as regards antibodies to the non-structural proteins of the FMD virus was defined that eventually shall ensure that only those vaccinated animals remain alive for which it can be proven that the herd had no contact with the virus.

Workshops have been carried out with the participation of both laboratory experts and veterinary administrations to enhance the understanding of surveillance, to design surveys and to interpret their results. Those simulations have highlighted the problems that could arise from vaccinating small herds or hobby animals or the use of pen-site tests.

Following a case of FMD in a wild boar, EFSA assessed the risks of FMD becoming endemic in wildlife in Thrace (4). The EU supported the generation of the required data through regional surveillance projects, fostering close cooperation between the affected countries.

Conclusions

Bordering endemically infected geographical regions and having intensive trade of animal products throughout the globe, the EU continuously allocates substantial financial, material and human resources to maintain the OIE recognised status of free from FMD without practising vaccination. Investment in disease awareness, preparedness and prevention are complemented by measures to reduce the FMD risk at source.

The EU therefore welcomes the Progressive Control Pathway for FMD.

The EU support to the work of the FAO World Reference Laboratory, which is able to collate the information on the global FMD situation and the evolution of FMD viruses, is considered an essential element of the FAO/OIE initiated Progressive Control Pathway for FMD.

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Maintaining foot and mouth disease-free status and providing evidence: the South American experience

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Summary

In South America, foot and mouth disease (FMD) was first diagnosed in Argentina in 1867, extending to Uruguay in the River Plate region and later reaching Chile and Brazil. By the turn of the 20th century, FMD had already spread to Peru and Bolivia, reaching, in the latter half, Ecuador, Venezuela and Colombia. The response of the countries to the negative impact in their herds led to the establishment in 1951 of the Pan American Centre for Foot-and-Mouth Disease (PANAFTOSA), in Rio de Janeiro, Brazil. Hence, the first FMD national control programmes began in South America around the 1960s to combat continuous epidemics in the livestock areas of the region. Between 1976 and 1981, an oil-adjuvant FMD vaccine was developed by PANAFTOSA, a sanitary tool which was the most significant advance in preventing the disease in endemic ecosystems. In *1988, the countries and PANAFTOSA endorsed the Hemispheric Program for the Eradication of Foot-and-Mouth Disease (PHEFA) with a Plan of Action 1988–2009, which implicitly contained the regional focus of programmes as an essential strategy for combat. The massive use of oil vaccines, with the addition of surveillance and control of animal movements, gradually led to the consolidation of FMD-free zones and countries. This strong tendency of decreasing incidence was reversed in the Southern Cone sub-region with the outbreaks of 2000–2001. With sanitary measures such as high vaccination coverage, surveillance and immobilisation of animals, the epidemic was quickly controlled. Based on the regional strategy and with a World Organisation for Animal Health (OIE) Permanent Veterinary Committee of Mercosur agreement, in 2007 a high-surveillance zone was established in the border area of four countries of the Southern Cone to address the problem of sporadic outbreaks. Significant progress was made in FMD programmes, Brazil being an example with its consolidation strategy of free zones according to the characterisation of the livestock circuits in the country. In 2010, as a corollary to the progress made by PHEFA in the continent – achieving 85% of the total population of cattle and buffalo free from disease with and without vaccination – was approved, the second phase is a Plan of Action 2011–2020 with the definitive goal of eradication.*

Keywords
Control – Eradication – Foot and mouth disease – Hemispheric Programme – South America.

Introduction

Foot and mouth disease (FMD) was first diagnosed in South America in 1867, in Argentina, almost at the same time as it occurred in the western states of the United States. It was due to the importation of genetic stock from Europe to feed the growing livestock industry in the Americas, particularly in the La Plata River region in South America. The disease was identified again in Argentina in 1870, at the same time as in Uruguay, whereas Chile was struck in 1871 and southern Brazil in 1895. Peru recorded the disease in 1910, while Bolivia declared it in 1912. Around 1936, FMD outbreaks were recorded in the north-eastern states of Brazil, thousands of miles away from the originally accepted site of entrance. Finally, it reached Ecuador in 1943 and Venezuela and Colombia in the 1950s. This spread can be explained by the intense trade between and within these countries and the absence or weakness of effective FMD control structures.

While the disease was totally eradicated from North America in the 1950s, the national FMD control programmes in South America started in the early 1960s in Argentina, Brazil, Paraguay and Uruguay. Throughout the 1970s

several countries in South America established nation-wide programmes, supported by own funds and, in some cases, by international loans. It is perceived that the early FMD programmes helped to structure some of the national animal health services in operation today. The early stages of national FMD control and eradication programmes have relied since on the triad of vaccination, outbreak control and animal movement control.

Throughout the 50 years of the fight against FMD, a number of tools were developed, such as improved vaccines (i.e. oil-adjuvant vaccines) used in systematic vaccination campaigns, the continent-wide information and surveillance system, biosecurity strategies and new diagnostic tools.

Late in the 1980s, the Hemispheric Program for the Eradication of Foot-and-Mouth Disease (PHEFA) became operational. It prescribed a strategy based on an ecosystems approach of the epidemiological relationships existing in the livestock production systems. PHEFA is now in its second action plan, for 2011–2020.

In the early stages of the process, national programmes depended mostly on the political commitment of the governments, and in the existence of official sources of funds to support the process of control and eradication and the prevention phase, afterwards. In the early 1980s, the participation of the private sector in the programmes became crucial in the planning, execution and evaluation of FMD programmes at national and local levels. The incentive to join the programmes came from the perspective of a stronger participation in a growing international market for livestock and animal products, but, on the other hand, the epidemiology of the disease showed the importance of the small, family-type operation in the maintenance of the disease. National programmes had to develop a control strategy to bring the smallholder into participating in the fight against FMD.

Regional approach and zoning

To maintain these achievements, a special regulatory framework was developed to support disease control and eradication measures, under the scope of PHEFA, and enforced through intergovernmental bodies such as the Southern Common Market (MERCOSUR) and the Andean Community of Nations (CAN). Presently, the Veterinary Services are operating stably in all South American countries, counting more than 25,000 public employees, of which 8,000 are veterinarians. Beyond that, almost every country counts with a national FMD programme regionally aligned through the strategies of PHEFA. These aspects brought a safe and steady progress to all countries, disregarding occasional inequalities on their individual levels of evolution towards the control of FMD.

The role of the Pan American Centre for Foot-and-Mouth Disease (PANAFTOSA), the Pan American Health Organization (PAHO) and the World Health Organization (WHO) in the coordination of PHEFA must be highlighted. PANAFTOSA/PAHO/WHO, based in Rio de Janeiro, Brazil, is one of the World Organisation for Animal Health (OIE) Reference FMD Laboratories in the continent, and since the 1950s has been dedicated to supporting the national FMD programmes. Since then, the Centre has been providing technical cooperation to countries, generating knowledge and tools that have supported control actions, including the development of vaccines and diagnostic methods and the creation of the South American diagnostic network; the continental information system; the epidemiological characterisation of the disease's ecosystems; and a wide-ranging human resources training and development plan, particularly as regards the countries' Veterinary Services.

One of its contributions is the PHEFA plan. The rationale behind the strategies that brought down the disease stemmed from the ecosystems concept developed by the institution and the countries during the late 1970s. The strategy of PHEFA is concentrated on sub-regional projects and deals with the disease in an 'ecological' way, taking into consideration livestock production forms and trade (Fig. 1).

It also relies on the surveillance carried out by the continent-wide vesicular diseases surveillance system. The triad of vaccination, outbreak control and animal movement control, and, in some cases, stamping out, was used to control the disease and eventually led to eradication in some zones (Fig. 2).

The progressive zoning has been used by the countries in the process of controlling and eradicating FMD. It allowed experience to be gained in both the public and private sectors, built on multinational cooperative schemes which tackled common weaknesses. Moreover, it fostered political interest and commitment by the mutual example between regions. The zoning strategy took advantage of the experience acquired on border and movement control, both of which were implemented along with the establishment of the Veterinary Services. The progressive zoning strategy developed by Brazil is provided as an example in Figure 3.

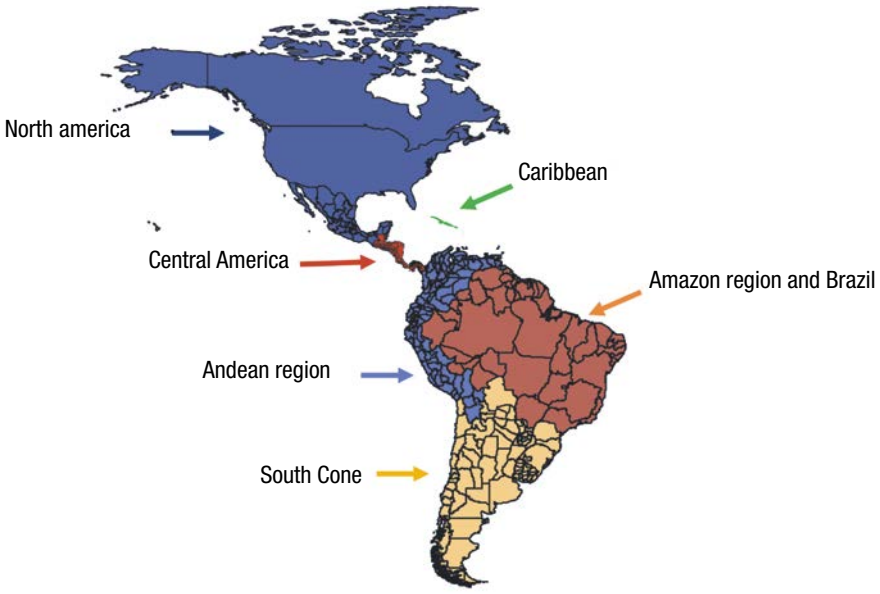


Fig. 1
Sub-regional approach of the Program for the Eradication of Foot-and-Mouth Disease (PHEFA)

Source: PANAFTOSA/PAHO/WHO

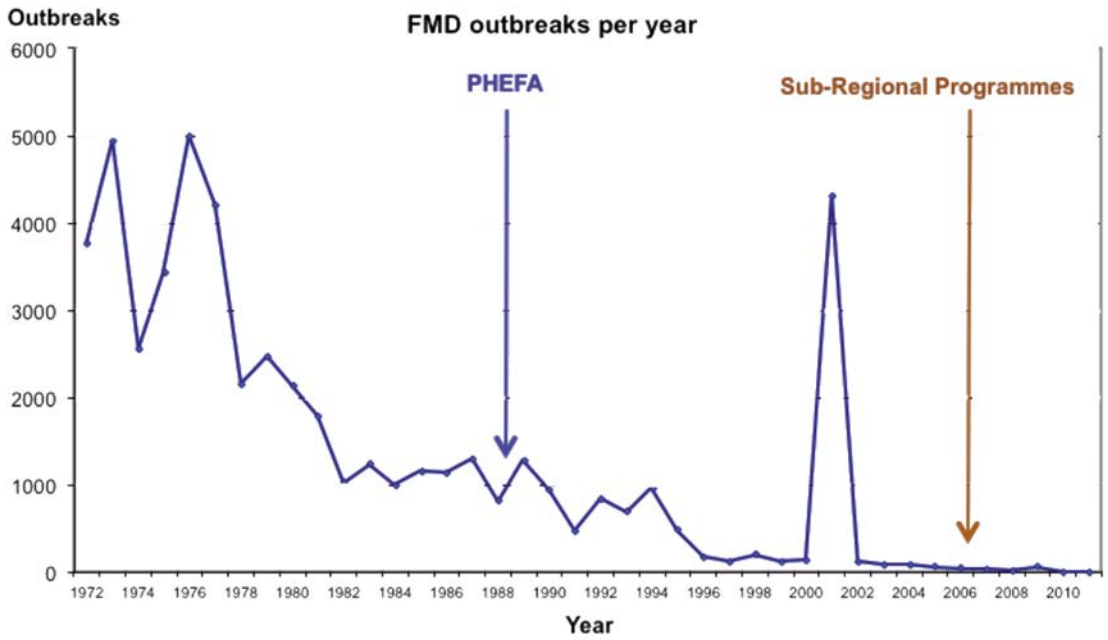


Fig. 2
Evolution of foot and mouth disease control in South America

Source: PANAFTOSA/PAHO/WHO

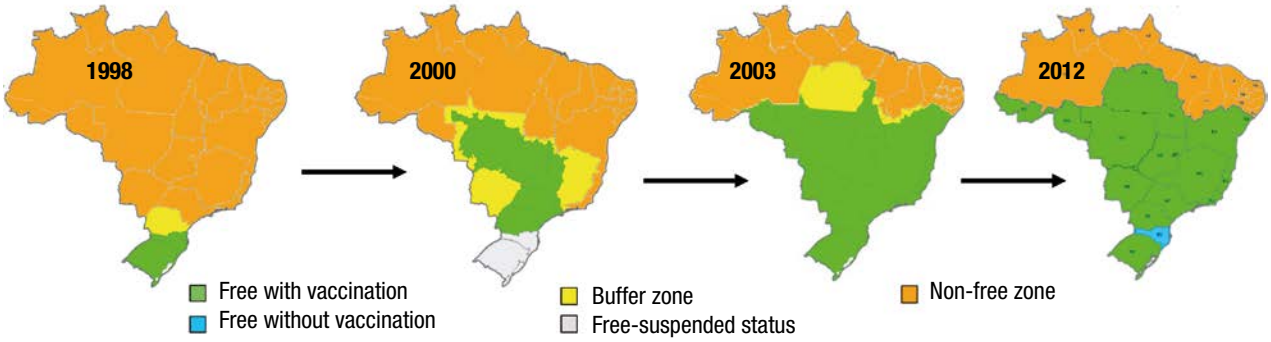


Fig. 3
Progressive zoning – the case of Brazil

Source: Ministry of Agriculture, Livestock and Food Supply, Brazil

Vaccines and vaccination

Vaccines are an important tool for the FMD programmes, and have been in use in South America since the 1940s. Presently, the majority of the vaccines are formulated with purified antigens produced in cell culture suspensions, inactivated with first-order inactivants. Furthermore, oil adjuvants are used to extend their immunogenic power.

Oil vaccines became widely used late in the 1980s, and currently are the only type used throughout South American countries. PANAFTOSA/PAHO/WHO conducted a series of field tests with the vaccine, and these were instrumental in convincing livestock owners and FMD programme managers in South America of the advantages of this product in terms of a better protection of clinically sane animals in highly epidemic areas, presenting fewer unwanted reactions. Moreover, it allows fewer annual vaccinations, meaning lower costs.

The most significant progress of sanitary programmes had been seen in territories and bovine populations that changed from an endemic– epidemic condition with high incidence of FMD outbreaks into an uninfected condition sustained through effective campaigns of high coverage vaccination. Experience and studies had shown that systematic vaccination does not always prevent infection; however, it produces herd immunity, which drastically reduces viral excretion and leads to Ro < 1.

Starting from 1988, with the inception of PHEFA, a continent-wide vaccination process which took into consideration the regional epidemiological situation was carried out by the national programmes. This effort brought down the number of outbreaks from the level experienced in the mid-1990s. As an example, data from the Brazilian FMD Eradication Programme are shown in Figure 4.

The FMD viruses (FMDVs) used as vaccine strains in South America are selected from field isolates representative of the epidemiological situation. PANAFTOSA/PAHO/WHO, as a regional Reference Laboratory, has been testing, adapting and forwarding strains to the industry and control laboratories. Presently, the strains used for vaccine production in most countries are A24 Cruzeiro, O1 Campos and C3 Indaial; type C is not used in countries where this serotype has not been diagnosed. On a few occasions, when the epidemiological situation requires it, other strains have been adapted for production, such as in Argentina with the A79-Arg/79, A81-Arg/87, O1 Caseros-Arg/67 and C3 Arg./85 strains, and as a response to the epidemics of 2000/2001, when the field variants A2000 and A2001 replaced the usual FMDV type A24 strain and type C was not included in the emergency vaccine.

Nowadays, the region is self-sufficient in FMD vaccines, most of which are non-structural protein free. Approximately 700 million doses per year are privately produced and subjected to official controls according to the OIE guidelines for safety, purity, potency and biosecurity. As a result, the Veterinary Services are able to carry on compulsory, twice-a-year vaccination campaigns of bovine and buffalo using only high-quality vaccines without having experienced biosecurity problems, such as virus escapes. As a rule, small species are not usually vaccinated in South America, unless under special circumstances, such as during emergencies. Alternative vaccination schemes may be adopted according to national particularities. Furthermore, regional agreements have convened on the official control of FMD virus manipulation within the continent and have banned the manipulation of serotypes other than A, O and C.

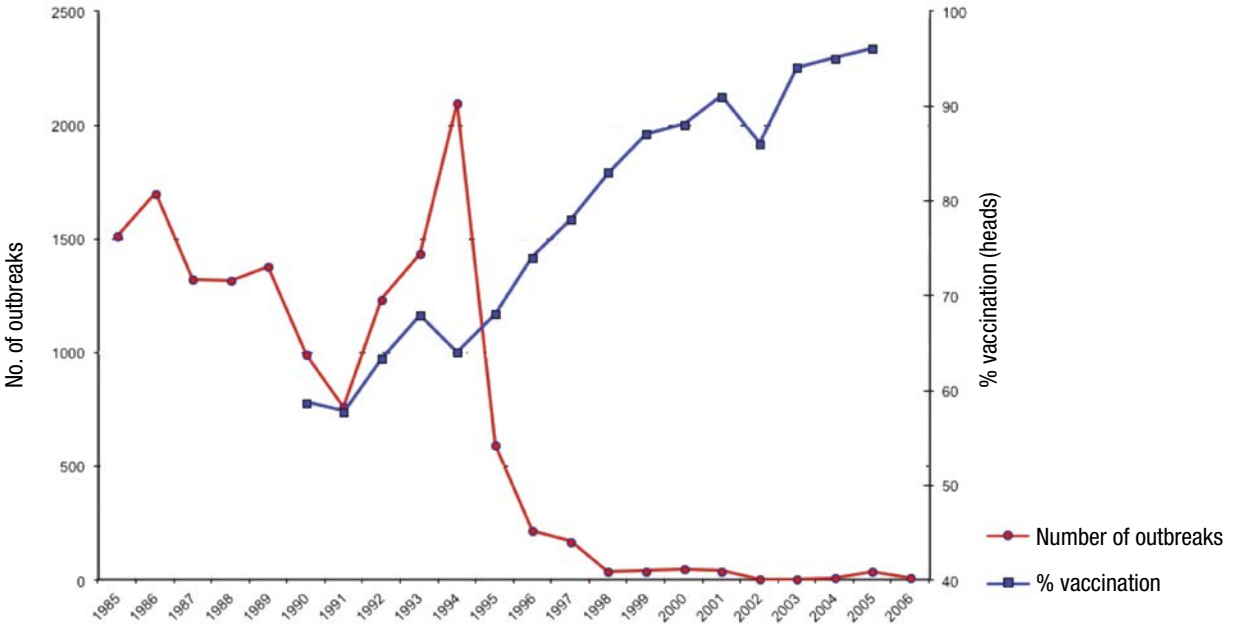


Fig. 4
Evolution of the foot and mouth disease outbreaks and vaccination coverage in Brazil

Source: PANAFTOSA/PAHO/WHO

The quality of the immunisation achieved is checked by post-vaccination evaluations based on the farmer's compulsory self-declaration and on post-vaccination immunity studies (PVMs) carried out by the national programmes to ascertain the levels of herd immunity.

Surveillance and prevention

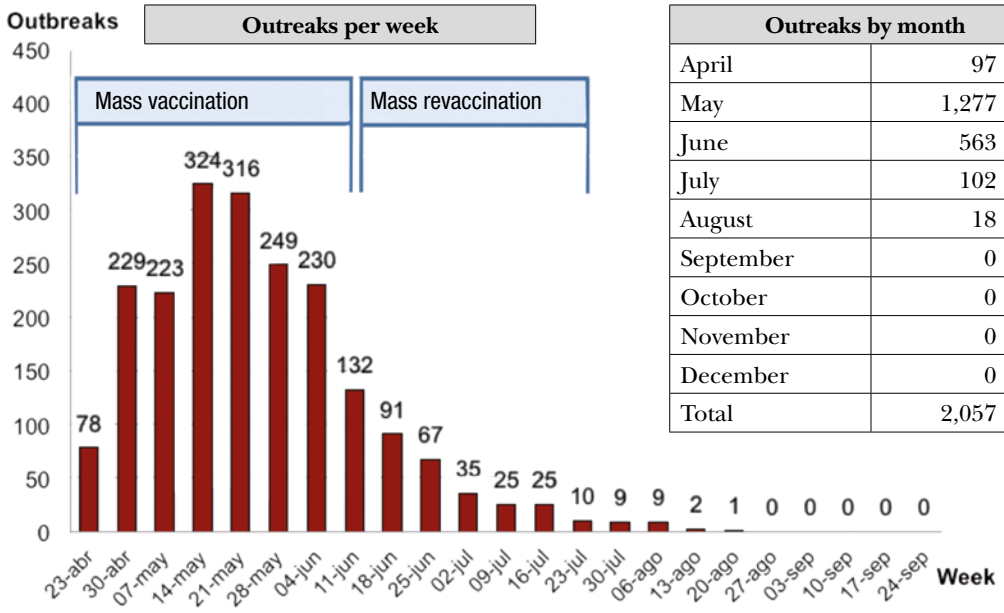
Transparency has been an important element for decision-making among the countries in the process of controlling and eradicating FMD. The Veterinary Services in every American country count with a national animal disease surveillance system forwarding weekly and emergency information on the occurrence of vesicular diseases to the Continental Epidemiological Information and Surveillance System (SIVCONT), coordinated by PANAFTOSA/PAHO/WHO. SIVCONT was created in 1973 and today collects information on vesicular syndromes, nervous syndrome in herbivores, respiratory/neurological syndromes in birds and haemorrhagic syndrome in swine. The system manages an Internet database on a number of diseases according to the species and disease syndromes mentioned. It is structured to allow early notification and information sharing from the suspicion down to the final diagnosis. The information is channelled through 6,483 official field units, manned by more than 18,000 employees, by official diagnostic laboratories and also the two OIE Reference Laboratories on FMD in the region, providing elements for the development of eradication strategies. During 2011, SIVCONT registered 783 suspicions, of which only eight, across three countries, were confirmed as FMD. There were 769 outbreaks of vesicular-like diseases confirmed by the laboratory network, and six samples were negative.

As regards the role played by wild species in the maintenance of FMD infection, it is widely accepted that several studies have revealed that bovine cattle are the only reservoir of the FMDV in South America. Although the bovine population used to be important in terms of numbers (southern Brazil, Argentina and Uruguay), its role in the maintenance of infection was always secondary. Moreover, there is no evidence of transmission of the disease between domestic animals and wildlife, even in those areas without vaccination.

Foot and mouth disease has recurred a few times in the disease-free countries/zones since the continent achieved a higher sanitary status early in the 2000s, and on most of those occasions it was possible to trace back the origin of the disease. The Veterinary Services have reacted immediately to the emergency with contingency plans and well-organised and trained emergency workforces. These teams were responsible for tracing back cases and identifying their sources, bringing additional expertise to the surveillance schemes already in place. This led

to successful containment operations, when reintroductions threatened free zones and countries. Nonetheless, the emergencies reinforced the need for transparency and well-trained emergency teams.

Figure 5 provides the case of Uruguay in 2001 as an example of effective control of an extensive epidemic affecting non-immune populations using the combination of mass vaccination, movement restriction and disinfection.



Outreaks by month	
April	97
May	1,277
June	563
July	102
August	18
September	0
October	0
November	0
December	0
Total	2,057

Fig. 5
Control of foot and mouth disease epidemic in Uruguay, 2001, through movement restrictions, disinfection and mass vaccination

Source: Ministerio de Ganadería, Agricultura y Pesca, República Oriental del Uruguay

Public–private partnerships

The Hemispheric Program for the Eradication of Foot-and-Mouth Disease strategy relies on regional and sub-regional plans based on political commitment, coordination and collaboration between the national Veterinary Services towards concerted actions. Furthermore, it is innovative on proposing public–private partnerships with livestock associations and the active participation of local communities. The modality of public–private partnerships, though, depends on the idiosyncrasies and regulatory framework of each country. The experiences were fully developed in Argentina, where 310 local entities were operative in 2011, as well as in Colombia where a farmer's association manages approximately 90 local committees. To a lesser extent, the experience was also successful in other countries, reaching higher levels of vaccination and a proactive response from the livestock sector during emergencies.

This cooperative scheme has proven positive when the financing of the national programmes is analysed. There was a positive trend in the investments made by both governments and livestock sector in the last six years. According to data provided by the countries to the South American Commission for the Fight Against Foot-and-Mouth Disease (COSALFA), the investments made in 2011 totalled US$1.3 billion, which meant a 13% increase in the investment when compared with the previous year. Nevertheless, it is expected that a sizeable increase in the investment will be needed to confront the challenges of eradicating the disease from the continent. According to the PHEFA budget for the period 2011–2020, on top of the resources needed to maintain the national programmes and the cost of vaccination, approximately US$18 million shall be invested in technical cooperation.

Conclusions

At the beginning of 2012, the countries in South America showed a positive situation, as can be seen from Table I and Figure 6 Two hundred and eighty-five million bovines (85% of the total population) in more than 3.5 million herds (70%) in 71% of the geographic area in South America are free from FMD, either with or without vaccination.

Table I
Foot and mouth disease sanitary situation in South America, 2012

Sanitary situations	Surface		Cattle and buffalo herds		Total cattle and buffalo heads	
	Km²	%	No	%	No	%
Free without vaccination	3,808,129	21.40	854,912	16.9	11,694,110	3.5
Free with vaccination	8,743,526	49.20	2,662,945	52.7	272,851,766	81.5
Buffer zone	88,190	0.50	16,869	0.3	479,199	0.1
Not free	5,124,056	28.80	1,522,726	30.1	49,557,982	14.8
Total	17,763,901	100.0	5,057,452	100.0	334,583,057	100.0
Total free	12,639,845	71.20	3,534,726	69.9	285,025,075	85.2

Source: PANAFTOSA/PAHO/WHO

The aim of the PHEFA 2020 is to eradicate disease. FMD still exists in some endemic countries, which represents a threat to those countries/zones already recognised as free of FMD. This geographically restricted endemism led to the development of multinational initiatives, whose final goal is to raise the average FMD status in order to establish a safer collective environment. Regional coordination and country-to-country collaboration is needed if FMD is to be swept out of the continent.

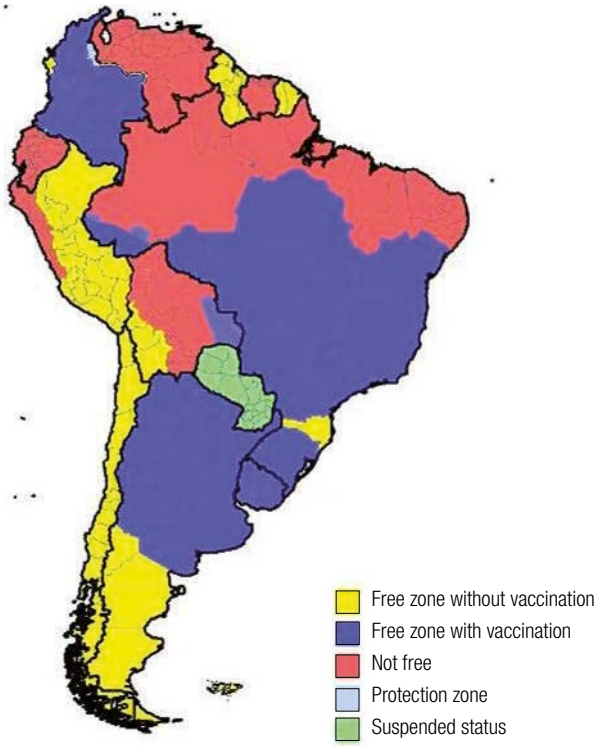


Fig. 6
Foot and mouth disease situation according to World Organisation for Animal Health status in South America, 2012

Source: PANAFTOSA/PAHO/WHO

South America has a vast experience of FMD control and eradication, which should be considered, and regional solutions could be used as a model by other regions where the disease is still endemic. A FMD-free continent by 2020 is a reachable objective, but it will depend more than ever on the continuing political commitment of governments, regional coordination efforts and support of the livestock sector.

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Maintaining foot and mouth disease-free status: the southern African experience (including vaccination and wildlife issues)

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Summary

Agriculture is very important to the economy of most southern African countries, where it provides food, raw materials, income and employment. The Southern African Development Community has realised the strategic role played by this sector in the economies of its Member States, and has within its structures a strong agriculture representation.

*Livestock generally dominates the agriculture contribution; key to this is access of livestock and their products to markets. This requires freedom from diseases of economic importance such as foot and mouth disease (FMD). FMD is primarily a disease of cloven-hoofed animals. There are seven serotypes, but in southern Africa the predominant serotypes are the Southern African Territories (SAT) 1, 2 and 3. Cattle are particularly susceptible while small ruminants are rarely affected by the disease. Occasionally some cloven-hoofed wild antelopes are affected but the disease is considered only transient in these species. African buffalo (*Syncerus caffer*) is the reservoir host of the FMD virus, making eradication of FMD virtually impossible in southern Africa.*

Some countries have developed mechanisms of separating susceptible domestic animals from buffalo, using barriers and biosecurity measures to contain the virus. In addition to technical assistance from collaborating partners, countries were able to provide assurances on the safety of their products. Consequently, these countries have zones recognised by the World Organisation for Animal Health (OIE) as FMD free. This status has allowed the countries to successfully trade in livestock products both regionally and internationally.

Therefore, the purpose of this paper is to share the southern African experience in maintaining FMD-free status, with particular reference to Botswana.

Keywords
Foot and mouth disease – Southern Africa – Vaccination – Wildlife.

Introduction

Livestock production is very important to the economy of most countries in southern Africa, where it is the backbone of rural development, providing food, raw materials, income and employment. The region has about 64 million cattle, 39 million sheep, 38 million goats, 7 million pigs, many more other species, such as poultry, and a rich diversity of wildlife. An estimated 75% of livestock is kept under smallholder traditional systems in shared grazing areas (10). The contribution of livestock agriculture to the national gross domestic product is significant, but even more important is the socio-cultural contribution, which may not be easily quantified. Trade in livestock and their products are dependent on freedom from diseases of economic importance such as foot and mouth disease (FMD).

Epidemiology of foot and mouth disease in southern Africa

Foot and mouth disease is a highly infectious viral disease of cloven-hoofed animals caused by Aphthovirus. FMD was first described in southern Africa in the late 1700s and the 1800s; it disappeared in the region with the advent of the rinderpest pandemic in 1896, but reappeared in 1931 (3). There are seven types – O, A, C, Southern African Territories (SAT) 1, SAT 2 and SAT 3 and Asia 1 – all of which are immunologically distinct, and there is no

cross-protection between them. The subtypes continuously undergo antigenic drift; requiring regular improvements to FMD vaccines. In southern Africa, FMD is primarily caused by the viruses SAT 1, SAT 2 and SAT 3. Cattle are the most susceptible, while other domestic species are only occasionally affected and their role in the epidemiology of the disease is controversial (1, 4). African buffalo (*Syncerus caffer*) are known maintenance hosts of the FMD virus in the environment (2, 5, 6). Young buffalo calves between the age of six and eight months may occasionally develop clinical FMD; this has been attributed to the waning off of maternal antibody protection (13). Studies in the region indicate that the majority of buffalo herds are infected with FMD SAT viruses (7). Consequently, buffalo are confined in game reserves; the presence of buffalo in livestock areas is considered a disease threat and they are immediately returned to wildlife areas. The role of other wild ongulates in the epidemiology of FMD is not well understood; however, they are believed to be only transiently infected (3, 4).

Significance of foot and mouth disease in southern Africa

Foot and mouth disease causes losses in export earnings, disease control and compensation costs, as well as socio-economic costs (10). Some countries in the region have for many years developed mechanisms of separating susceptible domestic animals from wildlife using both natural and artificial barriers, applied in conjunction with biosecurity measures between areas of different animal health status. This has effectively confined the FMD virus within the infected areas, while securing virus-free areas (3, 10). Consequently, they have attained an FMD-free zone or country where vaccination is not practised, as defined by the World Organisation for Animal Health (OIE). These measures have made trade of animals and animal products possible from the FMD-free areas, and assisted the economies of these countries significantly (10).

Foot and mouth disease-free status of southern African countries

The conventional methods of attaining FMD-free status is through zoning; according to Chapter 4.3 of the OIE *Terrestrial Animal Health Code* (*Terrestrial Code*) zoning is defined as a procedure implemented with a view to defining sub-populations of distinct health status within a territory for the purpose of disease control and international trade. Zoning is defined primarily in geographical terms; therefore, in the context of FMD, a free zone or country is a geographically defined area with a distinct sub-population of animals free from FMD. Susceptible animals and their products from FMD-free areas are eligible for trade. Zoning offers an incentive for countries to control FMD and other animal diseases of economic importance.

Lesotho is the only country in southern Africa which is recognised by the OIE as FMD free where vaccination is not practised, while Swaziland, Namibia and Botswana have zones which are recognised by the OIE as FMD-free zones where vaccination is not practised (www.oie.int). The Republic of South Africa is working towards regaining the free zone status. Other countries in the region are yet to have officially recognised FMD-free status.

Requirements of maintaining a foot and mouth disease-free zone

Maintenance of the free zone is vital and the zone is also subject to inspection by the OIE, which is the conferring authority and trading partners, to verify that the requirements are adhered to. Generally, the following are basic requirements for maintaining an FMD-free status:

Separation of animals in the free zone from those in non-free zones

A movement protocol to regulate movement of susceptible animals into, within and out of the free zone. Where allowed, movement of susceptible animals and their products must be recorded.

Surveillance

Continuous surveillance (passive and active), with good laboratory diagnostic support is key to proving that susceptible animals in the free zone are free of clinical FMD or infection. The key objective is to detect FMD early and react promptly to contain and eradicate the disease.

Traceability system
Where possible, FMD-susceptible animals in the free zone must be identifiable as belonging to the free zone and there must be a clear action plan of what is to be done in case of escape or incursion into the free zone.

Legislation
Appropriate animal health legislation to enforce compliance with requirements of the free zone.

Credible Veterinary Services
To maintain and implement the various requirements of the free zone, the Veterinary Services must be credible and well resourced.

Farmer/public education or awareness
Farmers and the public at large need to know and understand the zones they are farming in and the requirements to maintain its status.

Bilateral collaboration with neighbours
Owing to the transboundary nature of FMD, a regional approach is advisable to protect the free areas.

Challenges in maintaining the free status

Foot and mouth disease control in southern Africa is complicated by the presence of large numbers of African buffalo, which are abundant in the region, where they are a source of regional pride as members of the famous 'Big Five'. Free zones can be established only in countries where there is a separation of buffalo from domestic ongulates. Even when separated, other wildlife species such as elephant (*Loxodanta africana*) damage barriers separating wildlife and livestock, causing breakdowns which can lead to fresh outbreaks of FMD. Therefore, establishment of free zones in the southern African region is difficult and costly, and for trade in livestock and their products to occur there is a need to look differently at assuring the safety products from this region other than the conventional approach, which relies heavily on the separation of live animals.

Wildlife tourism contributions to national gross domestic products of some Southern African Development Community (SADC) countries equal or exceed those of livestock (10). This resource is further being enhanced through the creation of trans-frontier conservation areas (TFCAs). TFCAs are biodiversity conservation initiatives meant to protect and consolidate land reserved for wildlife across international boundaries, to facilitate the movement of wildlife. There are seven TFCAs that are already established in the SADC region and a further 15 have been identified in the region (9), including the Great Limpopo TFCA between South Africa, Mozambique and Zimbabwe and the Kavango-Zambezi TFCA between Botswana, Namibia, Zimbabwe, Zambia and Angola. Notwithstanding the good intentions, TFCAs may increase the geographical spread of disease-causing agents and vectors, thereby increasing the challenge of controlling animal disease (9).

Compartmentalisation

The OIE definition of a compartment is 'an animal subpopulation contained in one or more establishments under a common biosecurity management system with a distinct health status with respect to a specific disease or specific diseases' (www.oie.int). Therefore, compartmentalisation presents a shift from a purely geographic focus of creating free zones to that which emphasises management and husbandry practices related to biosecurity.

This concept can be feasible in the southern African region as it allows the setting up of FMD-free compartments within areas which may not be free from FMD owing to the presence of wildlife of infected cattle, and become eligible for international trade. The requirements of an FMD-free compartment are laid out in Article 8.5.6 of the *Terrestrial Code*. It is relatively easy to establish an FMD-free compartment as opposed to a larger FMD-free zone or entire country freedom. However, establishing a compartment may be expensive to farmers because of the need to have a detailed biosecurity plan encompassing the entire value chain from raw material supply, through

processing, to distribution. The concept also requires close cooperation between the private sector and public sectors (12).

Compartmentalisation has a lot of potential in the region and hopefully it will be applied more in the future. Currently, some form of compartmentalisation is practised at bilateral level in the region where two or more closely trading countries may agree to import from closed systems after assessing the risks involved.

Commodity-based trade

Commodity-based trade (CBT) is premised on risk mitigation through a commodity-specific risk management approach which is primarily non-geographic. Animal products from zones that may not be free from FMD, but which have acceptable levels of protection from FMD when treated in a certain way, are safe and can be traded internationally. CBT does not completely nullify the need for field- or farm-level animal health controls; the objective is to apply risk mitigation at all stages from farm/field, ante-mortem and post mortem (8, 11). Vaccination can also be applied as another risk mitigation measure. According to Article 8.5.25 and 8.5.26 on importation, deboned meat from FMD-infected countries or zones can be allowed under conditions stipulated in these articles. Consistently, the animals should have been slaughtered in an approved abattoir where ante- and post-mortem inspection is adequately done, and major lymph nodes have been removed, and that, prior to deboning, the carcass should have been subjected to maturation at a temperature above + 2°C for a minimum period of 24 h following slaughter and the pH value was below 6.0 when tested in the middle of both longissimus dorsi muscles (www.oie.int). The adoption of CBT will go a long way in assisting farmers in developing countries, where FMD eradication may not be feasible at country or zonal level. Therefore, an absolute prohibition of the importation of meat from areas which are not free may be an unnecessary barrier to trade.

The use of purified vaccines (foot and mouth disease-free zones where vaccination is practised)

The control of FMD by immunisation in southern Africa dates as far back as the 1930s, when FMD was first recorded in the region; it was initially by aphthisation, and this was subsequently replaced by vaccination (3, 4). Vaccination, using conventional vaccines, is one of the pillars of the FMD control strategy in the southern African region. Mass vaccination of cattle living in close proximity to areas where buffalo are found has been responsible for the protection of domestic species against outbreaks of the disease. Where there has been collapse in routine vaccination in these high-risk areas, repeated outbreaks of FMD have been reported. Vaccination is done primarily in cattle, but in the past there were instances where small stock were vaccinated after a mild disease due to SAT 1 was recorded in goats (3, 4). Vaccination is used routinely to prevent outbreaks of FMD (routine vaccination) and during emergencies to limit disease spread (emergency vaccination).

In recent times, purified vaccines have been produced; these vaccines allow for the differentiation of infected from vaccinated animals – the so called 'DIVA' concept – which allows the 'vaccination to live' policy. Although purified vaccines have been in use for some time in other parts of the world, in southern Africa, it is only recently that its production started, and consequently its usage is still minimal and more for strategic FMD control purposes. However, with the ever increasing pressure against mass slaughter of animals, more use of purified vaccines is anticipated. The use of purified vaccines has the potential to assist countries to establish 'FMD free zones where vaccination is practised'.

Progressive Control Pathway for foot and mouth disease

The Progressive Control Pathway for FMD initiative, which is being developed by the Food and Agricultural Organization of the United Nations in collaboration with the OIE, though still under development, will be invaluable to most countries in southern Africa; this concept will enable countries where achieving an FMD-free status is a major challenge, to at least 'make a start' towards some form of status which can be endorsed by the OIE. An endorsed status may eventually lead to official FMD-free status, and therefore this is a great incentive to countries in the region.

Conclusions

The OIE standard for the free zones is a noble concept and has served countries very well and facilitated international trade. Countries which are free or have zones which are free from FMD are able to develop their livestock industry, and this has contributed to achieving food security and poverty alleviation. Notwithstanding, in the southern African context, the attainment and maintenance of the free status is a formidable challenge given the presence of wildlife in the region. Contemporary biodiversity conservation initiatives such as TFCAs are good but they also present another dimension from the animal disease control front. In this regard, a change in approach towards safe trading of commodities is required. Compartmentalisation and CBT are such avenues where commodities can be traded internationally but without compromising their safety. In addition, the advent of purified vaccines and the concept of the progressive control pathway for FMD will also be beneficial to livestock trade in the region.

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Foot and mouth disease surveillance: general principles and approaches under different epidemiological situations

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Summary

The goals and objectives of surveillance systems for foot and mouth disease (FMD) may vary according to the epidemiological situation within a country. Generally speaking, two broad approaches can be applied: structured random and structured non-random surveillance. Within these, clinical, serological and virological methods can be used. This paper describes suggested approaches and methods that can be applied based upon the FMD status and surveillance goals of a country.

In free countries without the use of vaccines, the pillars of surveillance are an effective detection system and an efficient response mechanism to address emergency situations. In these countries, the emphasis of surveillance is placed on disease reporting (a non-random approach) using clinical methods followed by virological confirmation. Serological surveys (a random-based approach) have limited value as they provide only a static image of the serological status of the population and do not contribute to early detection of an outbreak.

In free countries applying vaccination, surveillance needs to ensure early detection of an FMD outbreak and should also provide sustained evidence of the absence of virus circulation. To achieve these objectives, a combination of approaches is required including passive surveillance, random serological surveys, risk-based surveillance and slaughterhouse surveillance, as well as surveys to assess immunity coverage.

Countries seeking endorsement of their FMD control programmes and eventual recognition of disease freedom need to be able to detect outbreaks in a timely manner, ensure detection of all affected premises during an outbreak and demonstrate the absence of virus circulation. These countries need to apply several approaches including random serological surveys in addition to passive disease reporting and slaughterhouse surveillance to reach the desired objectives.

This paper provides a description of the most frequent goals, objectives, approaches and sources of evidence provided for each epidemiological situation, and should provide guidance for countries following the Food and Agriculture Organization of the United Nations (FAO)'s Progressive Control Pathway for FMD.

Keywords
Food and Agriculture Organization of the United Nations – Foot and mouth disease – Progressive control – Surveillance – World Organisation for Animal Health.

Introduction

The Food and Agriculture Organization of the United Nations (FAO) and the World Organisation for Animal Health (OIE) have launched the Progressive Control Pathway for Foot and Mouth Disease (FMD) control (PCP-FMD) (2). The strategy outlines five different stages leading towards the control and eradication of FMD. The design and implementation of surveillance systems varies among countries, taking into consideration several factors such as the current FMD status, the types of production systems, the species involved and geographical conditions, as well as the goals and objectives of the system itself. These goals and objectives will vary based on the epidemiological situation of FMD in a given country and the corresponding PCP-FMD stage. The approaches

and sources of evidence applied within surveillance systems for each classification need to be adapted to the prevailing epidemiological situation.

According to the OIE *Terrestrial Animal Health Code* (*Terrestrial Code*) (8), countries can be classified in three categories based on their FMD status:

1. FMD-free country (or zone) where vaccination is not practised;
2. FMD-free country (or zone) where vaccination is practised;
3. FMD-infected countries.

Recently, an additional procedure has been included in the *Terrestrial Code*, by which infected countries can apply to have an OIE-endorsed official control programme for FMD (8). Endorsement by the OIE emphasises the country's intention to progress towards FMD freedom. However, it does not constitute a change in the FMD status of a country. Figure 1 shows the relationship between the PCP-FMD stages and the corresponding status for FMD in the *Terrestrial Code*.

Surveillance approaches

The *Terrestrial Code* chapter on surveillance classifies surveillance into two broad categories: structured random surveillance and structured non-random surveillance (8). Table I lists the most frequently used approaches within each category. Most surveillance systems will include a combination of approaches and sources of evidence to meet the desired objectives.

Table I
Main surveillance approaches applied in foot and mouth disease control and eradication programmes

Structured random	Structured non-random
Surveys	Passive surveillance
Slaughterhouse surveillance (systematic sampling)	Slaughterhouse surveillance (ante-mortem and post-mortem inspection)
Assessment of immunity coverage	Risk-based surveillance

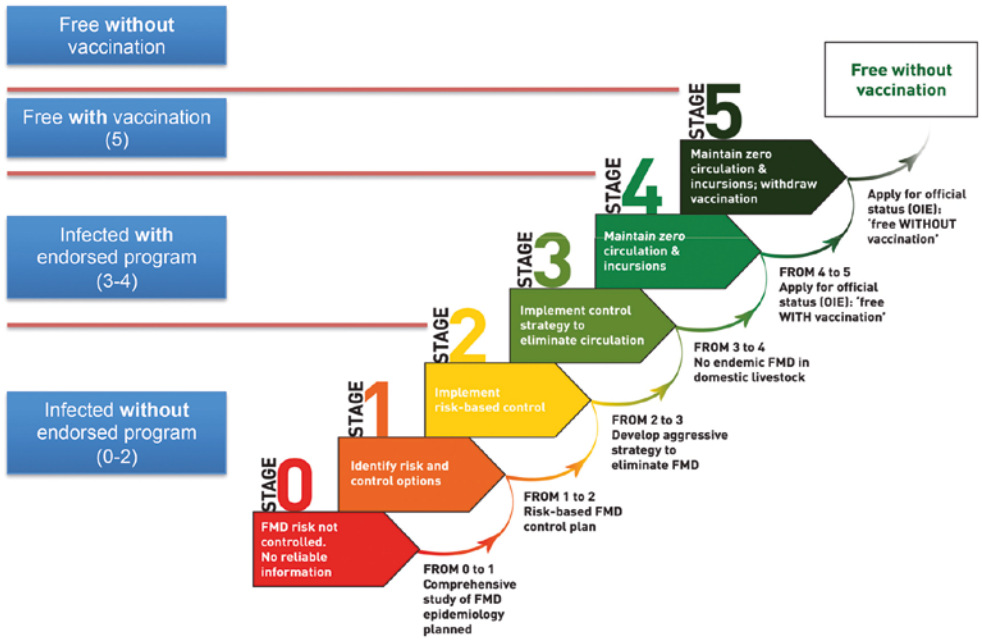

Fig. 1
PCP-FMD stages and the corresponding status for FMD in the OIE *Terrestrial Code*

Passive surveillance

The cornerstone of all FMD surveillance systems is an efficient system of passive surveillance in which producers, veterinarians (private and official) and para-veterinarians are trained in the recognition of clinical signs compatible with FMD and are knowledgeable on reporting procedures. To ensure reporting from producers, a well-funded compensation programme needs to be in place.

The application of participatory methods can be used to complement both passive and active surveillance. Participatory disease surveillance relies on local knowledge to detect the occurrence of clinical signs compatible with one or more diseases. These methods have been successfully applied in several disease control programmes including rinderpest, avian influenza and FMD (3, 5).

The official Veterinary Service is required to respond to reports in a timely fashion and conduct a full disease investigation on the affected premises including neighbouring farms as well as following up movements into and out of the suspected affected farm. In addition, the Veterinary Service needs to be able to diagnose FMD or have arrangements in place to send samples to an OIE reference laboratory.

Risk-based surveillance

Risk-based surveillance is applied to increase the efficiency of the system by directing surveillance activities to:

– the population of interest based on exposure to factors that may predispose it to disease or infection, or

– subpopulations where, due to host factors, the disease or infection is most likely to be found, or

– prioritising populations where the consequences of disease or infection could be severe.

This approach is useful to increase the likelihood of detection of the virus and to reduce the consequences of infection in highly valuable populations.

Pathway analysis is a method by which the most important pathways for disease introduction into a free country are identified and ranked. The pathways that are considered of higher risk should be the basis to identify the subpopulations to be included in a risk-based surveillance approach. Risk-based surveillance is being increasingly accepted, as it improves the efficiency of surveillance while keeping costs down.

Slaughterhouse surveillance

Clinical surveillance at slaughter has two components: ante- and post-mortem inspection. Ante-mortem inspection is conducted at a group level and is generally considered to have lower sensitivity than post-mortem inspection, which is conducted at the individual animal level. In many beef-exporting countries the sensitivity of post-mortem inspection for FMD is increased by performing, in addition to conventional inspection procedures, thorough examinations of the oral cavity and hooves of every individual. In these countries official veterinary inspectors examine the tongue, cheeks, palate, coronary band and inter-digital spaces to check for the presence of vesicles or lesions suggestive of FMD (4, 6).

Slaughterhouse surveillance can also involve the collection of random serological samples, usually using systematic sampling. A limitation of slaughterhouse surveillance is that the information gathered is representative of a subset of the population and cannot be readily extrapolated to the general population.

Surveys

Serological surveys are an important component in FMD surveillance. Statistically based random surveys are used to help demonstrate the absence of viral circulation and are also helpful in determining immunity coverage. Although serological surveys play an important role in demonstrating the absence of viral circulation, they provide only partial evidence and should be supplemented by other sources of information (1). In FMD-vaccinated populations, serological testing should aim to find antibodies to non-structural proteins (NSPs). Lack of vaccine purity may

affect diagnostic specificity, as the presence of NSPs in some vaccine preparations may result in misclassification in animals that have been repeatedly vaccinated; highly purified vaccines that are NSP free are recommended (9).

Serological surveys can be conducted to assess immunity coverage. Vaccination plays a central role in the PCP-FMD strategy. Frequently, countries are able to provide data on the number and distribution of vaccinated animals, but not necessarily provide information on true immunity coverage. Many factors affect the development of immunity. These may include vaccine quality, maintenance of the cold chain, handling of the animals and the vaccination process itself. Therefore, periodic assessments using statistically based serological surveys aimed at identifying herd-level immunity should be performed to identify gaps, adopt corrective strategies and assign surveillance resources.

Structuring a comprehensive surveillance plan

The PCP-FMD strategy requires a detailed plan for surveillance. The following elements provide a framework for the design of a comprehensive surveillance plan (7).

Basic information:

– disease description
– purpose and rationale for surveillance
– surveillance objectives (principal uses of data for decision-making)
– expected outcomes (products, decisions and actions)
– stakeholders and responsible parties.

Population description and sampling methods:

– population description and characteristics
– case definitions
– data sources
– sampling methods.

Analysis, reporting and presentation:

– data analysis and interpretation
– data presentation and reporting.

Implementation, budget and evaluation:

– surveillance system implementation – priorities, timelines and internal communications:
– budget
– surveillance system evaluation.

The plan should be carefully documented and revised periodically.

Specific recommendations for foot and mouth disease surveillance

Table II outlines the FMD surveillance goals, objectives and approaches under different epidemiological situations within the PCP-FMD pathway.

Table II
Foot and mouth disease surveillance goals, objectives and approaches under different epidemiological situations

Epidemiological situation	Goals	Objectives	Approaches	Sources of evidence
FMD-infected countries (PCP stages 0, 1 and 2)	Obtain OIE endorsement of FMD control programme Progress to stage 3	Understand the epidemiology and reduce the impact of FMD Detect outbreaks in a timely manner Ensure detection of all affected premises during an outbreak	Passive surveillance Risk-based surveillance Slaughterhouse surveillance Assessment of immunity coverage	Clinical (case detection) Virological Serological
Countries with an OIE-endorsed official control programme (PCP stages 3 and 4)	Obtain FMD freedom with vaccination Implement zoning or compartmentalisation	Detect outbreaks in a timely manner Ensure detection of all affected premises during an outbreak Demonstrate absence of virus circulation	Passive surveillance Random surveys Risk-based surveillance Slaughterhouse surveillance Assessment of immunity coverage	Clinical (case detection) Virological Serological
FMD-free countries (or zones) – vaccination is practised (PCP stage 5)	Maintain FMD freedom with vaccination Obtain FMD freedom without vaccination*	Ensure early detection and control Generate sustained evidence of absence of virus circulation	Passive surveillance Random surveys Risk-based surveillance Slaughterhouse surveillance Assessment of immunity coverage	Clinical (case detection) Virological Serological
FMD-free countries (or zones) – vaccination is not practised	Maintain FMD freedom without vaccination	Ensure early detection and control	Passive surveillance Risk-based surveillance Slaughterhouse surveillance	Clinical (case detection) Virological

*The decision to stop vaccination should be based on demonstration of absence of virus circulation and the FMD status of neighbouring countries or zones

Surveillance in foot and mouth disease-infected countries (Progressive Control Pathway for Foot and Mouth Disease stages 0–2)

The goals for countries in these stages of the strategy are to eventually progress to stage 3 and obtain endorsement of their official control programme by the OIE. To achieve these goals, a thorough understanding of the epidemiology of FMD in the different species and production systems is required.

Stage 1 of the PCP-FMD strategy recommends that a serological survey be carried out to identify risk factors (2). Careful consideration should be given to the type of vaccine being used, vaccinated species and coverage, as these factors may impact the interpretation of results. Conventional non-highly purified vaccines for FMD are effective and are significantly cheaper than NSP-free vaccines (A. Füssel, European Commission, Directorate General for Health and Consumers, personal communication, October 2012); however, they do not allow the differentiation of infected and vaccinated animals (9). It may be that a country in the initial stages of the strategy may opt for a cheaper vaccine that will allow greater population coverage, and, as it progresses through the pathway, shifts to a highly purified vaccine that is NSP free. In these cases, a serological survey would not be able

to differentiate vaccination-induced antibodies from infection antibodies and, thus, would not allow identifying risk factors. An alternative for the identification of risk factors might be to compare the frequency of detected outbreaks by geographical location and production systems or species. Some countries (e.g. South American countries) vaccinate only cattle, allowing the use of non-vaccinated species, such as sheep and pigs, as sentinels as any serological reaction to FMD would indicate viral circulation.

Serological surveys to assess immunity coverage will help create 'immunity maps' and identify areas where more intensive vaccination might be required. These surveys will also provide information for conducting risk-based surveillance.

Surveillance in countries with an OIE-endorsed official control programme (Progressive Control Pathway for Foot and Mouth Disease stages 3 and 4)

The goals for countries in this category are to establish FMD-free zones and eventually progress to the status of FMD freedom with vaccination. The definition of FMD-free compartments may be an additional option for countries with well-established control programmes. The main objective at the country or zone level is to demonstrate the absence of viral circulation. In order to enable the use of serological surveys for this purpose, NSP-free vaccines should be mandatory in the entire country. Vaccination in FMD-free compartments is not allowed (8); therefore, surveillance within compartments should demonstrate the absence of infection.

As mentioned above, serological surveys are an important component of surveillance, but demonstration of the absence of viral circulation requires the use of multiple sources of data such as slaughterhouse surveillance, examination of animals during vaccination campaigns and the results of passive surveillance.

Surveillance in foot and mouth disease-free countries where vaccination is practised (Progressive Control Pathway for Foot and Mouth Disease stage 5)

Countries in PCP stage 5 are, in effect, free from FMD with vaccination. The goals for surveillance are to maintain the current status and eventually progress towards a status of freedom without vaccination. The decision to suspend vaccination needs to be weighed up against the risk of reintroduction from neighbouring countries or through trade. It may be that a country chooses to continue vaccination for an indefinite period of time until the perceived risk of FMD becomes lower.

Surveillance in these countries should provide sustained evidence of absence of viral circulation as well as ensuring that any FMD incursion is promptly detected and controlled. As mentioned above, the demonstration of the absence of viral circulation requires multiple sources of evidence including the results of serological surveys, clinical observation of animals during slaughter, routine vaccination programmes, points of animal concentration such as markets and auctions among other sources.

Surveillance in foot and mouth disease-free countries where vaccination is not practised

The goal of surveillance in FMD-free countries where vaccination is not practised is to maintain FMD freedom; this is accomplished by ensuring early detection of a possible FMD incursion. The most efficient means of accomplishing this objective is by applying a combination of approaches relying on the detection of clinical signs, sample collection and virological confirmation. In this context, serological surveys are not useful as they provide only a static image of the serological status of the population and do not contribute to early detection of an outbreak.

Conclusions

The PCP-FMD strategy provides a structured framework for countries to progress in the control of FMD. Surveillance is one of the pillars of the strategy and an essential component in the demonstration of disease status for OIE

recognition. The goals and objectives of surveillance will differ depending on the PCP-FMD stage of a country, and surveillance approaches need to be adapted to reflect these differences. Control of FMD depends on several factors, including producer participation, efficient Veterinary Services, surveillance systems with appropriate goals and objectives, appropriate diagnostic capability, vaccine production and distribution and regional coordination.

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Session 4

Key elements in the prevention and control of FMD and in implementing the strategy

Chair: A. Füssel (EC)

Diagnostic tools and their role in the global control of foot and mouth disease

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Summary

Global control of an infectious disease such as foot and mouth disease (FMD) is not possible without the knowledge generated by diagnostic assays. For both endemic countries that have embarked on a control plan and free countries suffering outbreaks, information is needed that could inform control plans and strategies. Data regarding the prevalence of infection in various species, the serotypes and topotypes involved in outbreaks and, where vaccination is used, the immune profile of the animals, as well as potential sub-clinical infection and carrier status, are essential when controlling FMD. This information is also vital for countries embarking on the Progressive Control Pathway to determine baseline epidemiological information and to act as an incentive to progress along the pathway towards improved disease control and, ultimately, eradication. The specific need for diagnostic assays will change as countries move along the pathway. FMD is currently endemic mostly in resource-poor countries, which implies a need for cost-effective, but accurate, assays. Although maintaining laboratories and trained staff is expensive, their role is essential in ensuring diagnostic test results are delivered in an accredited and reliable manner. The cost related to performing tests (both the consumables and the overheads) is probably the determining factor in how widespread the use of diagnostic assays will be in assisting with FMD control. However, even inexpensive assays will be of less value if the expenditure for sampling and other control issues, such as movement control and vaccination, cannot be covered.

Keywords

Diagnostic assays – Diagnostic laboratories – Fit-for-purpose – Foot and mouth disease – OIE – Pen-side assays – Progressive control – Quality control – Validation – World Organisation for Animal Health.

Introduction

Foot and mouth disease (FMD) incursions can potentially cause severe economic losses to non-endemic countries and it is therefore important to have an accurate diagnosis to ensure that clinical signs are not due to another vesicular disease. In endemic countries it is equally important to know whether the virus is present and determine the serotype, especially when the country is embarking on a plan to control or eradicate the disease. Not only is it important to ensure that the virus is present, but data on the prevalence and incidence are needed which can be obtained accurately only with diagnostic assays. It is also essential to determine what serotypes and topotypes are prevalent as this information feeds into decisions regarding choice of vaccine strains and vaccination. In addition, diagnostic support is needed to measure immune profiles, especially after vaccination, to ensure that the vaccines are effective and the campaigns are successful, and also to prove freedom of infection post outbreaks. Sensitive assays are essential to detect sub-clinical infection and carriers.

All these data provide epidemiological information vital for countries embarking on the Progressive Control Pathway (PCP) and are indispensable in designing control strategies. They provide a measure of success for countries involved with control and can act as an incentive to improve control and, ultimately, eradication of the disease. However, the specific need for diagnostic assays will change as countries move along the pathway.

In Stage 1, where it is necessary to improve the understanding of the epidemiology of FMD, a country or region should perform serological assays to determine the prevalence of infection in various husbandry systems and collect samples for further characterisation. If this serotyping and genetic characterisation cannot occur in-country due

to a lack of specialised laboratories, the assistance of a reference laboratory can be requested. The information should be recent; therefore, these tests have to be performed on at least an annual basis.

Stage 2 requires the implementation of a risk-based control programme to reduce the impact of FMD, which implies the ongoing monitoring of circulating FMD strains and, in this case, targeted serological surveys to determine prevalence. It is also necessary to assess vaccination coverage where vaccines are used and to provide evidence that the appropriate vaccine strains are used against the circulating viruses.

Success in the previous stages can lead to Stage 3 with a reduction in outbreak incidence and elimination of FMD circulation in at least a zone of the country. This requires rapid detection of FMD outbreaks and detailed characterisation of the viruses with improved monitoring of vaccination and population immunity. In Stage 4 the focus is to maintain successes and aim to reach a status of free from FMD with vaccination. The laboratory will be responsible for testing to ensure that the FMD virus is not circulating and to assist with the detailed investigations of any incursions.

Fitness for purpose

The various requirements outlined for the different PCP stages all necessitate different laboratory and field-based assays where applicable. The tests also differ in their complexity, costs and need for specialised laboratories, equipment and trained operators. For example, in Stage 1 it is necessary to ascertain the level of virus circulation. In this instance, serological assays that measure virus circulation by assessing antibodies to the non-structural proteins (NSPs) can be used (2). These are mostly enzyme-linked immunosorbent assays (ELISAs) that do not require expensive equipment and can be performed in the majority of laboratories. Stage 1 also requires the identification of the serotypes of circulating virus. Although ELISA-based techniques are available that can distinguish between the seven serotypes, they require serotype-specific reagents that are often expensive to obtain and should be suitable for the specific virus serotypes and genotypes that occur in the region (see below).

The later PCP stages require not only improved control measures and plans, but also improved laboratories, training and investment in equipment and reagents. In these stages, it is necessary to determine titres during vaccination campaigns, hence additional work over and above simply finding a sero-positive animal. It will also become necessary to perform polymerase chain reaction (PCR) to detect virus presence and to determine the serotype(s) responsible for the outbreaks. This requires specialised equipment, good workflow and quality assurance to prevent cross-contamination in laboratories. Where viruses are isolated on cell cultures, improved biosecurity will be required, especially when the incidence of FMD decreases and there is a risk of accidental introduction of a virus from the laboratory to the field. In addition, the higher PCP stages require further characterisation of the circulating viruses that may involve nucleotide sequencing and other specialised techniques, such as vaccine matching and antigenic cartography.

Importance of appropriate reagents

Globally, the circulating FMD viruses are divided into pools where defined geographical regions are affected by similar serotypes and genotypes (15). The aim is to customise the vaccine needs for each pool to fit the specific circulating strains in regions and thereby ensure an improved regional approach to control. The emphasis has always been on the need for appropriate vaccine strains, but the same is true for the reagents used in diagnostics, both for serology and, to a lesser extent, for molecular-based assays. The reagents should closely match the viruses circulating in a specific region.

In serology, it is well established that heterologous reactions, where there are antigenic differences between the reagents in the assays and the virus circulating in the field, give lower titres than homologous reactions, i.e. where the reagents are the same as the virus tested (14). This could lead to an incorrect interpretation of vaccine reactions, mostly resulting in lower titres than are actually the case, or the incorrect serotype determination when using an ELISA. Cross-reactions between the various serotypes make it difficult to determine the serotype using sera from infected and/or vaccinated animals. Sera may also react non-specifically to several FMD serotypes, which is more problematic when animals have been exposed to more than one serotype or have been vaccinated with multivalent vaccines.

Point-of-care devices

There is some debate over the use of penside or point-of-care (POC) diagnostic devices. They have been publicised for their ease of use, speed and relative high sensitivity and specificity. Several devices are commercially available, of which a number are lateral flow devices that can either diagnose multiple serotypes of FMD (8) or are serotype specific (7, 10) and use antigens as the diagnostic input. However, most of these are expensive, and therefore not accessible to developing countries.

There are a number of field-based assays available that amplify the genomic material of the virus, such as PCR (12) and loop-mediated amplification (1). Although these assays could be applied in the field, there is currently no obvious commercial interest and great care will be needed to prevent contamination. Most of these assays have also not been fully validated in the field.

The future of penside point-of-care devices

Policies are needed for notifiable diseases when these devices are used. It is essential for control that disease is not concealed by farmers or operators who fear control measures. There should be control over sales and distribution and, preferably, there should not be sales without governmental approval. The devices should be used only by competent persons who have been trained not only in using the device, but also in reporting and further actions needed if there is a positive result. Training should focus on fitness for purpose, thereby ensuring that the correct device is used for the sample available. For example, when using a device that requires a virus antigen, such as is present in epithelium, a serum sample may not be suitable and could lead to a false-negative result and delayed actions to control an outbreak. Regulations are needed on the notification of positive and negative results, and protocols should be in place when a result is negative. This will in turn rely on the sensitivity of the assay and the impact a potential false-negative result could have on the overall economy or disease status of a country. As it is important to have virus available for further characterisation, regulations on submission of samples to laboratories should be clarified. It is not sufficient to base all diagnostic results on devices in the field without submitting clinical material to laboratories for confirmation and further characterisation. Finally, record keeping will be as important when using these devices as when taking samples for laboratory diagnosis. Information on species, age, epidemiological factors, etc. should be available to accompany the result.

Most assays suffer from a lack of sufficient field validation, and it is also important that tests be validated in different regions using samples from local breeds and farming systems.

Role of laboratories

From the availability of POC devices, it could easily be extrapolated that investment in laboratories is not needed. However, the role of the laboratory cannot be underestimated. It is of utmost importance that an index case be confirmed in a quality-assured environment, especially in countries where the disease is mostly controlled. Once an outbreak has been confirmed, some reliance could be placed on diagnostics using field-based assays. As POC devices become more prevalent, laboratories will be needed to confirm positive/negative/inconclusive results. They should also take the responsibility for developing or validating devices and making recommendations on their use.

During an outbreak where vaccination is used, post-outbreak sero-monitoring will invariably lead to the need for high-volume throughput of samples to be tested, which can be dealt with only within a laboratory. High-throughput testing has specific requirements for samples and data tracing that will be difficult to achieve in the field using local devices.

Laboratories should also take responsibility for keeping stockpiles of reagents to be used when needed, and ensure that these are maintained in a quality-assured manner. In addition, local laboratories should participate in proficiency testing rounds to ensure the accuracy of results and take responsibility for ensuring smaller or provincial laboratories also reach the required standards. In addition, laboratories have to ensure that tests are validated and uncertainty of measurement and precision in testing are determined.

During the later stages of the PCP, information is needed about the outbreak isolates that will involve techniques such as sequencing and phylogenetic analysis to determine the potential origin of the incursion (11). Whole genome sequencing could be used to trace the epidemiological path of the outbreaks (4, 5), while vaccine matching using

r-values, epitope mapping and antigenic cartography could provide essential information on the use of vaccines, and therefore assist in control strategies (16).

It is also an important responsibility of the laboratories to develop improved and novel vaccines and participate in their assessment and registration, such as the adenovirus vectored vaccines (13). This would be an important contribution to FMD control and eradication and especially to distinguish between vaccinated and infected animals. The use of antivirals to protect animals prior to the development of neutralising antibodies is an option in countries where rapid control is needed (3, 6, 9).

Quality control and validation

The accurate diagnosis of FMD is important, regardless of the stage a country is at in the PCP, and validation of tests is an important aspect that contributes to accuracy. The World Organisation for Animal Health (OIE) *Manual of Diagnostic Tests and Vaccines for Terrestrial Animals* (2012) explains in detail what is needed to validate tests (www.oie.int/fileadmin/Home/eng/Health_standards/tahm/1.01.05_VALIDATION.pdf). The cost of validated commercially available assays often compels countries to develop their own assays, not always realising the complexities and difficulties to fully validate these tests. This, in turn, could lead to inaccurate diagnosis with severe impact.

Conclusions

Diagnostic requirements will change as countries move through the PCP, and laboratories will remain essential to assist in reaching the overarching goals of the control plans. To facilitate this, several aspects will be increasingly important, such as access to region-specific reagents. This is even more important as most commercial assays are too expensive for widespread use in resource-poor countries, which often leads to the development of in-house assays. Although the perceived cost may be less, those tests need to be validated in a process that is expensive and often difficult, due to a lack of sufficient control material. In this regard, collaboration between different laboratories in a region would be beneficial. Finally, good laboratory diagnostics will be meaningful only when there are sufficient resources available not only to support the laboratory, but also to ensure that material can be collected in the field, submitted in a timely manner to the laboratory and acted upon if necessary.

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International and regional reference laboratory network

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Summary

The global strategy for control of foot and mouth disease (FMD), developed by the Food and Agriculture Organization (FAO) and the World Organisation for Animal Health (OIE) in 2012, proposes establishing networks for FMD diagnostic services which consist of an integrated international, regional and national network of laboratories that can collectively respond quickly to needs for rapid and accurate testing and timely notification. Such a structure provides real-time knowledge on FMD virus strains circulating globally, improves vaccine selection, supporting both endemic and free countries – essential to progressive control – and enhances diagnostic capability for other priority diseases.

The global strategy also proposes establishing and strengthening an epidemiology network to link with the laboratory networks. The epidemiology network would consist of national units for epidemiology and regional epidemiology centres for improving infrastructure related to achieving core capacities in countries' surveillance, response, preparedness, risk communication and human resources.

A global database housing epidemiological and diagnostic data will be developed. It is envisaged that the communication between the laboratory and epidemiology networks can be a key component for a systematic coordinated programme towards establishing global and regional progressive control pathways.

Keywords
Diagnostic – Food and Agriculture Organization of the United Nations – Foot and mouth disease – Global strategy – Laboratory network – Progressive Control Pathway – World Organisation for Animal Health.

Introduction

Foot and mouth disease (FMD) is a highly contagious disease of cloven-hoofed animals. The disease is endemic in many low-income countries including most parts of Asia, Africa and the Middle East and a few countries in South America. An FMD outbreak causes devastating impacts on farmers with adverse effects on livestock assets, production income and consumption. FMD may spread to FMD-free countries through animal movement and international trade, as seen during outbreaks in the United Kingdom (2001) (2) and Japan and the Republic of Korea (2010) (3).

Foot and mouth disease virus (FMDV) is not randomly dispersed throughout the world but is associated with particular ecological niches. Studies on FMDV occurrence over many years have provided information to suggest the clustering or grouping of FMDV serotypes and subtypes into seven virus pools, with three pools covering West Eurasia, the Middle East and Asia, three pools covering Africa and one pool covering South America. The concept of 'regional virus pools' provides an organising principle for coordinating laboratory and epidemiology activities towards diagnostics and disease surveillance.

The Food and Agriculture Organization of the United Nations (FAO)/World Organisation for Animal Health (OIE) global FMD control strategy is a 15-year programme with five-year increments (1). The strategy includes three components:

– improving global FMD control;

– strengthening Veterinary Services; and

– improving the prevention and control of other major diseases of livestock.

Food and Agriculture Organization of the United Nations–World Organisation for Animal Health foot and mouth disease reference laboratory network

Currently, there are 13 FAO–OIE reference centres (Fig. 1) of which five fall outside of the regional virus pools, three in Pool 1, one in Pool 2, two in Pool 6 and two in Pool 7. Reference centres are lacking in East and West Africa and West Eurasia, which in turn contributes in part to the vast gap in knowledge on FMDV circulation and disease control in these regions. Building on the reference laboratory network, the global strategy would strengthen their regional network.

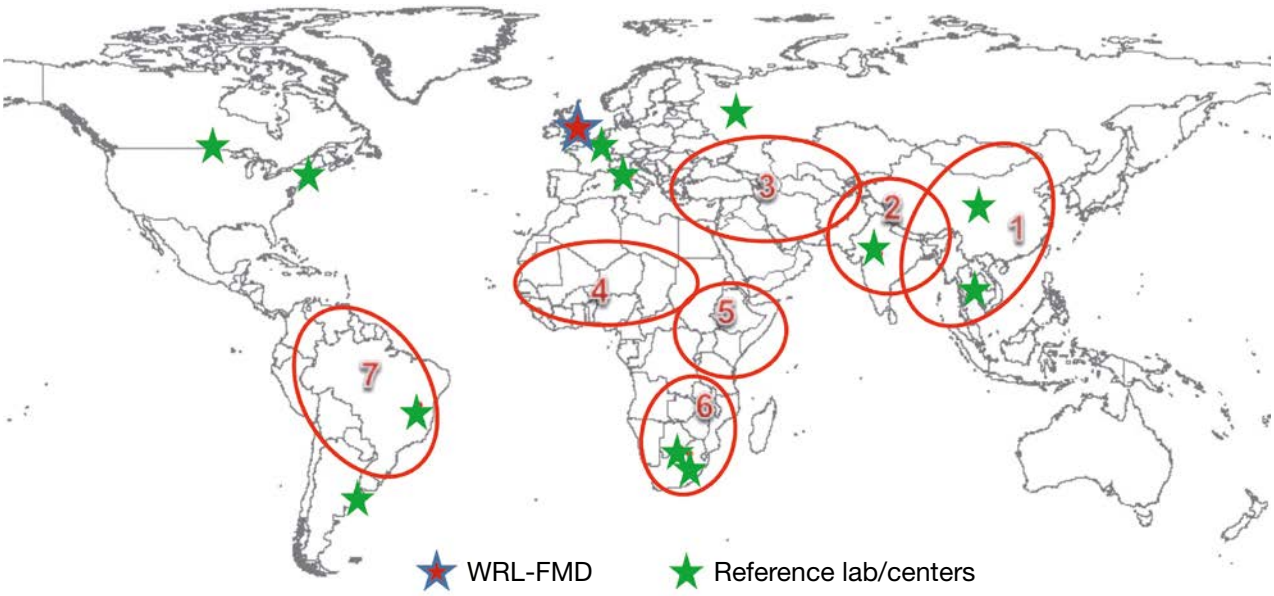

Fig. 1
Composition of Food and Agriculture Organization/World Organisation for Animal Health reference laboratory network (stars) in relation to the seven virus pools (red outlines)

Global and regional networks

Effective and reliable diagnostics are crucial in disease intelligence and control. This is particularly challenging for developing countries, where the capabilities of national veterinary laboratories are often weak. The FMD global strategy attempts to rectify this situation by assisting countries in need, mainly those in the lower stages of the Progressive Control Pathway (PCP), by establishing and/or supporting global and regional FMD laboratory networks.

The global FMD laboratory network was depicted in the global strategy to have at least one reference laboratory physically located within each of the virus pools and to establish regional leading laboratories where reference centres do not exist. For the global network, the world reference laboratory of FMD (WRL-FMD) will provide the technical leadership and forum for the global coordination. The reference laboratories will serve as WRL-FMD surge–capacity in supporting technical and diagnostic services to their designated region.

The main responsibilities of the global FMD laboratory network will be to conduct high-definition diagnostics and laboratory training at the global level and to ensure that all the FAO/OIE reference centres are fully participating in, contributing to and benefiting from the network cooperation. With a coordination mechanism within the global and regional framework, the WRL-FMD and the regional reference laboratories will support training, technology transfer and providing diagnostic reagents and proficiency testing to national laboratories.

The regional FMD laboratory network will have similar responsibilities to the global laboratory network in coordinating activities at the national level in their respective region, with specific responsibilities in supporting training to national laboratories in the areas of good laboratory practice, including biosafety and biosecurity, diagnostic method platform, specific FMD test and sequence analysis. The regional network will ensure harmonisation of laboratory results by providing proficiency tests, standard controls and diagnostic reagents and kits to the national laboratories. The regional network will maintain steady communication with the national laboratories and conduct confirmatory testing on submissions from countries of their region.

National laboratory network

The majority of developing countries where FMD is still endemic are self-assessed to be at PCP Stage 0. In order to move to a higher stage, their diagnostic capability has to be advanced gradually and steadily to accommodate the need for surveillance and preliminary diagnostic screening. The national laboratories should take the responsibilities on performing screening tests for seromonitoring when countries at PCP Stages 1 and 2 are expected to advance in their diagnostic capabilities as they move to PCP Stage 3 or higher to perform confirmation testing, virus characterisation and sequence analysis. It is also important for the national laboratories to take part in annual proficiency testing, communicate with reference and regional laboratories on non-conforming results and forwarding specimens to the appropriate laboratories for further analysis. It is an important responsibility for the national laboratories to participate in diagnostic assay development and validation.

Challenges in establishing and sustaining laboratory network

The complexity and challenges of multi-country laboratory networks reflect tensions that create barriers to performance and sustainability – they impede the development, strengthening and maintaining of core capacity as required for the implementation of the global control strategy. Some of these challenges include, but are not limited to, financial resources, laboratory infrastructures (facility, biosecurity and biosafety), the ability of countries to ship and receive biologicals, equipment maintenance, the application of quality control and quality assurance, a limited number of sample submissions for analysis, political engagement of countries at the national and regional levels and commitment and support from all involved.

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Vaccines: types, quality control, matching and supply

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Summary

Vaccines play a crucial role in the control and prevention of foot and mouth disease (FMD). They had their beginnings in the late 1930s in Germany, when the source of viral antigen was epithelial tissue from vesicles on the tongues of infected cattle. Later, Dutch workers showed that virus could be grown on slices of tongue epithelium from freshly slaughtered cattle, and this enabled the large-scale production of vaccine and the implementation of successful mass cattle vaccination campaigns in Europe. The next major advance was in the United Kingdom, where it was shown that FMD virus could be grown in baby hamster kidney (BHK)-21 cells in deep suspension culture. Subsequent developments have been mainly in the areas of virus inactivation, antigen concentration, product purification and improved adjuvants. Although research has led to the development of some promising candidate novel vaccines, their large-scale evaluation has been constrained by the high cost and limited availability of biosecure animal accommodation, coupled with a lack of financial support.

The Global Strategy intends to give high priority to the control of FMD in the seven 'virus pool' regions. Since FMD is endemic in these regions, the amount of vaccine required for campaigns will be very high. The global production of FMD vaccine will have to be significantly boosted if this demand is to be met. The Global Strategy will strive to promote the use of vaccines that are safe, potent and of a high quality. Selecting the most immunologically appropriate vaccine strain(s) will be important and will require the collection and typing of isolates from outbreaks and their analysis in vaccine-matching tests. A massive investment in human and physical resources in the regions will be needed to enable them to perform those tasks. Training at all levels will be essential to strengthen state Veterinary Services and improve the capability of laboratories.

Keywords
Cattle – Foot and mouth disease – Global Strategy – Vaccine – Vaccine matching – Vaccine strain – Viral antigen.

Introduction

Early workers recognised that animals recovered from foot and mouth disease (FMD) caused by one serotype were solidly immune to that type for many months afterwards, and this prompted attempts to develop a vaccine.

Types of foot and mouth disease vaccine

In the late 1930s German workers developed an effective vaccine by collecting epithelial tissue from vesicles on the tongues of cattle that had been deliberately infected with virulent virus, inactivating the virus by dilute formalin and then absorbing the antigen onto aluminium hydroxide gel as an adjuvant. The product, known as the Vallée–Schmidt–Waldmann vaccine, was used extensively in Europe and elsewhere, but had the major disadvantages of being expensive and risking the spread of disease (24).

A major advance came in the early 1950s, when Frenkel and co-workers in the Netherlands devised a large-scale production procedure in which virus was grown on slices of tongue epithelial tissue collected from freshly slaughtered cattle in a vigorously stirred, oxygenated culture medium at 37°C for 20 h to 24 h. After clarification and filtration, the virus was adsorbed onto aluminium hydroxide gel and inactivated by formalin (7, 8). This production method enabled the mass annual vaccination of the cattle population of the Netherlands and, later, as other laboratories adopted the technique, the annual vaccination of cattle elsewhere. Vaccination campaigns in the Netherlands, France and West Germany, combined with zoo-sanitary methods, resulted in a dramatic reduction in the incidence of disease.

During the 1950s and early 1960s, considerable effort was devoted to the development of live, attenuated virus vaccines by passage in various systems, including embryonated chicken eggs, chickens, rabbits, mice and tissue culture. The resulting vaccines were used in the field with reasonable success. However, some were found to have residual pathogenicity and the potential to revert to virulence. In addition, there were problems associated with keeping pace with the evolution in the field of new virus variants (24).

Major advances were made in 1962 when workers at Pirbright, United Kingdom (UK), showed that FMD virus could be grown in monolayer cultures of baby hamster kidney (BHK)-21 cells and also in BHK cells that were adapted to grow in deep suspension culture (4, 13). Since the 1960s the growth of FMD vaccine in BHK suspension cells has progressively replaced other methods of vaccine production. Subsequent developments in FMD vaccine manufacture have been mainly in the areas of virus inactivation, antigen concentration, product purification and enhancement of immunogenicity by different adjuvants.

In the late 1980s Beck and Strohmaier (2) analysed the nucleotide sequences of viruses from field outbreaks of FMD in Europe and found that many were vaccine related and, in particular, related to virus strains in formaldehyde-inactivated vaccines. This led Strohmaier to recommend that inactivation of FMD vaccine antigens should be changed from formaldehyde to first-order inactivants or that vaccination should be stopped altogether (23). Consequently, the FMD vaccine production regulations for most countries now permit only the use of first-order inactivants, e.g. the aziridine compound ethyleneimine in the form of N-acetylethyleneimine (3) or binary ethyleneimine (1).

Although aluminium hydroxide gel-adsorbed vaccines containing saponin will produce satisfactory immune responses in cattle and other ruminants, they have been found to be relatively ineffective in the pigs and this finding provided the impetus for the investigations of vaccines adjuvanted with oil emulsions and also the possible use of such vaccines in cattle (24). The replacement of alhydrogel–saponin vaccine for cattle by Freund's incomplete adjuvant in a primary water-in-oil emulsion had a very positive impact on vaccination campaigns in South America, since the oil-based vaccine produced a longer protection (18). This meant that the frequency of vaccination could be reduced from three to four to one to two times per year, resulting in greater acceptance by farmers and increased vaccination coverage.

Although there have been modifications in the methods of virus inactivation, antigen concentration and vaccine purification and alhydrogel–saponin has been progressively replaced by mineral oil as an adjuvant, the basic nature of FMD vaccines has remained little changed for many years. Current commercial vaccines induce serotype- and strain-specific protection in one to two weeks but fail to confer long-term protective immunity. Additional limitations are the risk of virus escape from production facilities, short shelf life of the formulated product and the requirement of a great many antigenic strains to combat viral antigenic diversity.

In the past, the major FMD vaccine producers in Europe had active research programmes, but with the improved disease situation, and the greatly reduced demand for vaccine in Europe and many other parts of the world, support for research in the private vaccine sector has declined. However, in the public sector a range of novel molecular vaccines has been developed and, although many have yielded disappointing results, some have shown considerable promise in small-scale trials. Among the most promising strategies so far has been the delivery of the FMD virus capsid sequence with a recombinant, replication-defective human adenovirus type five (Ad5-FMD) (16).

Unfortunately, the high cost and limited availability of biosecure animal experimental facilities for larger-scale challenge trials, coupled with the lack of financial support for this area of research, have constrained further evaluation. Increased support for this area has the potential to greatly accelerate the progress of the Global Strategy in the mid to longer term, especially if a novel vaccine was demonstrated to meet certain advantageous criteria such as being:

– cheaper to produce, e.g. did not have to be manufactured within biosecure facilities;

– more stable;

– able to confer long-term protection; and

– able to induce protection against heterologous challenge.

Quality control

The production of FMD vaccines that are both potent and safe requires sophisticated, biosecure facilities operated by well-trained, knowledgeable personnel. Unfortunately, the record of vaccine manufacturers in producing safe FMD vaccine is not good. Reference was made previously to the work of Beck and Strohmaier (2) in demonstrating that in Europe, during the 1980s, many of the outbreaks were caused by faulty vaccines. Epidemiological investigations and molecular techniques such as T1 mapping and nucleotide sequencing have identified faulty vaccines as the source of outbreaks and even epidemics in other parts of the world. Recent investigations indicate that the problem continues (17). Although the manufacture of veterinary vaccines, including for FMD, is now well regulated in developed countries, this is not the case in many developing countries, where there is often a lack of both quality control organisations and independent vaccine testing laboratories.

The Global Strategy will strive to promote the use of FMD vaccines that are safe, potent and of a high quality. Consequently, it will recommend the application of quality assurance and good manufacturing practice (GMP), in addition to quality control testing throughout the production process.

The control of FMD is generally a national responsibility and, in most countries, the vaccine may be used only under the control of the Competent Authority. General guidelines for the production of veterinary vaccines are given in Chapter 1.1.8, 'Principles of veterinary vaccine production', in the World Organisation for Animal Health (OIE) *Manual of Diagnostic Tests and Vaccines for Terrestrial Animals* (*Terrestrial Manual*) (25). Specific recommendations for FMD vaccine are given in Chapter 2.1.5 of the *Terrestrial Manual* entitled 'Foot and mouth disease'. The requirements for manufacturers to obtain an authorisation for a veterinary vaccine differ between countries and regions in regard to quality, safety and efficacy, but, where possible, producers should obtain a licence or authorisation for FMD vaccines as independent verification of the quality of their product.

Quality control in the context of FMD vaccine production is that part of GMP concerned with the taking of samples during production, the specifications related to the product and the tests to be applied. It also relates to the organisation, documentation and release procedures to ensure that the necessary and relevant tests are actually carried out and a vaccine is not released for use until its quality has been judged to be satisfactory. The basic requirements of quality control have been described by Soulebot *et al.* (21).

Recommendations for seed FMD virus management, virus propagation for antigen production in large-scale suspension cultures or monolayers using cell lines, in-process control and tests on the final product are given in Chapter 2.1.5 of the *Terrestrial Manual* (26). The latter includes tests for safety (innocuity), direct and indirect potency tests and purity. The PGP test (protection against generalised foot infection) is a direct potency test which has been standardised for cattle. Potency tests in other host species, such as sheep, goats and buffalo, are either different or have not been standardised. Indirect potency tests, including measurement following vaccination of virus-neutralising antibodies in cell culture, enzyme-linked immunosorbent assay (ELISA) antibodies or serum-protection antibodies in suckling mice, may be used to assess the potency of a vaccine provided a statistical evaluation has established a satisfactory correlation between the results obtained by the test on the relevant vaccine strain and the potency test in cattle (22).

Some regions and countries have set down specific requirements for manufacturers seeking to obtain marketing authorisation for FMD vaccines. For example, the European Union (EU) requires producers seeking to market vaccines for ruminants for prophylactic or emergency use to employ the same basic methodology as outlined in the *Terrestrial Manual* (26) but, in addition, to follow the specifications of the European Pharmacopoeia monograph 01/2008:0063 (7) and comply with Directive 2001/82/EC of the European Parliament and of the Council of 6 November 2001 on the Community code relating to veterinary medicinal products as amended by Directive 2004/28/EC (5). In Argentina, FMD manufacturers must adhere to Act No. 351/2006 of the Argentine Animal Health Service (19). In Europe, the test for assessing FMD vaccine immunogenicity is the 50% protection dose (PD50) test, whereas in Argentina it is the PGP test. Both tests require the challenge of vaccinated cattle and can give highly variable results; therefore, for scientific and ethical reasons, attempts are being made to develop *in vitro* alternatives based on serology (10). However, progress along this path will require the development of standardised procedures and reagents and a proficiency testing scheme after the calibration phase.

Vaccine matching

The main purposes of vaccine matching or antigenic characterisation of FMD viruses are:

– to select the most immunologically appropriate vaccine strain for use in particular circumstances; and

– to monitor, on a continuing basis, the suitability of vaccine strains maintained in vaccine banks (26).

Vaccine matching requirements differ for emergency use and prophylaxis; the former may require a precise match, whereas, for the latter, generic broadly reactive strains may be acceptable (14).

The antigenic relationship between a field isolate and a vaccine virus (r-value) can be determined by the complement fixation test (CFT), virus neutralisation test (VNT) or ELISA. Most commonly, the establishment of the r_1 value is derived from:

$$r_1 = \frac{\text{titre of bovine reference serum against field isolate}}{\text{titre of bovine reference serum against homologous reference strain using the ELISA.}}$$

The advantages of the ELISA are that it is rapid and uses smaller volumes of post-vaccination sera, which are often available in only limited quantities. Investigations have shown that a suitable reference serum for vaccine-matching experiments is a pool of at least five sera of medium to high virus neutralisation or ELISA titre from cattle vaccinated with a high-potency FMD vaccine. ELISA and CFT are recommended to be used as screening methods, whereas the VNT gives more definitive results and is the preferred test for r-value determination. Nowadays, the CFT is rarely used.

Vaccine matching requires the availability of reagents such as post-vaccinal sera, samples of vaccine strains, access to a data bank and a high level of expertise. This capability is generally beyond that of most national reference laboratories, so the procedures are usually undertaken by a regional reference laboratory (RRL) or the World Reference Laboratory (WRL).

Globally, FMD can be subdivided into seven ecosystems or watersheds associated with particular FMD virus serotypes and topotypes (14). These 'virus pool' regions include Western, Central and Eastern Africa, the Middle East and Asia (6, 11). A major objective of the Global Strategy will be to increase vaccine supply to the 'virus pool' regions and, for the vaccines to be effective, the strains they contain will have to antigenically match those circulating in the field and they will have to be potent. Meeting the former objective will require a significant input of financial support to strengthen the Veterinary Services and the laboratory capability of the countries in those regions. Incentives will be required for Veterinary Services to collect more samples from outbreaks and submit them to international reference laboratories. Ideally, each 'virus pool' region should have a RRL to provide a vaccine-matching service. Realistically, this is unlikely to happen in the short term, so vaccine-matching activities for the Global Strategy will depend on the Network of OIE/Food and Agriculture Organization (FAO) FMD Reference Laboratories. The WRL provides the main input to this network and it will need more support from existing and new RRLs if it is not to be overwhelmed by the demands of the Global Strategy.

In addition to the need for many more samples to be collected from regions of high priority, other constraints on current vaccine selection procedures need to be addressed. These include:

– a limited range of vaccine strains,

– limited information about vaccine strains for commercial reasons,

– low availability of reagents (especially characterised antisera to vaccine strains),

– uncertain correlation between methods,

– poor reproducibility of some tests, and

– lack of equivalence between methods.

Even when laboratory results are generated, there is a need for caution about their practical significance, since data on how *in vitro* matching tests actually correlate to *in vivo* cross-protection is limited. These problems were reviewed by Paton *et al.* (15) and some possible solutions were suggested. A major step forward was the establishment of the previously mentioned Network of OIE/FAO Reference Laboratories, which gives the laboratories involved the possibility of coordinating and harmonising their activities and thereby improving recommendations on vaccine strain selection.

In the future, vaccine selection may be undertaken by combining antigenic analysis with nucleotide sequencing. Advances in nucleotide sequencing and computer technology have made it possible to rapidly and easily sequence the entire genome of some viruses and this creates the possibility of determining how genetic evolution influences antigenic variation. Antigenic variation of viruses is generally based on serological assays and is qualitative. However, researchers working with influenza viruses (20) and lyssaviruses (12) have shown that by integrating antigenic data with direct sequencing data it is possible to quantify antigenic variation and genetic variation and examine their correspondence. Such approaches have been termed 'antigenic cartography' and offer the possibility of understanding how antigenic variation evolves. Antigenic cartography is being investigated for FMD virus and could be extremely valuable for selecting suitable vaccines and even predicting the appearance of variant strains (Jef Hammond, Elizabeth Macarthur Agricultural Institute, Menangle, Australia, personal communication, 10 October 2012).

Supply of vaccine

The Global Strategy intends to give high priority to the control of FMD in the seven 'virus pool' regions (6, 11). The control strategies for the different regions and sub-regions will differ and will probably be based on an assessment of risk factors identified by epidemiological analyses and local inputs. Vaccine will be a key tool for reducing the impact of FMD and, once the strategies for the different regions and sub-regions have been formulated, the amount of vaccine can be calculated taking into account the following considerations: strain or strains required (vaccine matching and valency); the size of the target population; the nature of the target species (dairy cattle, milking buffalo, ploughing oxen and buffalo, beef cattle, etc.), the frequency of vaccination (young or older stock; risk factors) and the cost (quality, potency, valency).

The amount of vaccine required for the vaccination campaigns in the different regions and sub-regions will be high, and if this demand is to be met its production worldwide will have to be significantly boosted. Creating incentives for manufacturers to do this will be a major challenge for the Global Strategy. In the short to medium term, public–private initiatives and the provision of vaccine producers with guarantees in terms of the sustainability of markets may be a way forward. In the longer term, the large-scale testing and licensing of novel vaccines could solve the problem, especially if they did not have to be produced in biosecure facilities, since they would then be considerably cheaper than contemporary vaccines. It would also be advantageous if the new vaccines were thermo-stable, since there would be less need for maintenance of the 'cold chain' during transport while a longer shelf life would reduce the frequency of replacing stock supplies.

Conclusions

- The development of the Frenkel method of mass production of FMD vaccine made it feasible to regularly vaccinate the cattle population of continental Europe, and this was a critical factor in reducing the incidence of the disease in that region.
- Regular mass vaccination of cattle in Europe reduced the incidence of disease to a level where it became economically acceptable to employ 'stamping out' to eradicate the virus.
- Foot and mouth disease virus has been eradicated from several countries and zones in South America and Asia by similar control and eradication strategies.
- Other countries and zones in South America have achieved freedom from FMD by the prophylactic vaccination of cattle combined with movement control and emergency vaccination when outbreaks occur.
- The application of similar control procedures in other regions of the world by means of the Global Strategy could, over time, yield similar results. It is accepted, however, that significant challenges will have to be overcome before success will be achieved.

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Vaccine use for foot and mouth disease control

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Summary

Foot and mouth disease (FMD) is the second example, after rinderpest (eradicated by vaccination nowadays), of a very contagious disease threatening livestock worldwide with considerable economic consequences, a disease which can be controlled and eliminated by vaccination campaigns on a regional, continent-wide or worldwide scale. Even if the act of vaccination seems simple to perform among livestock, its implementation at national or regional level is a difficult and costly exercise which requires good knowledge about the properties of the selected vaccines and a true know-how for success. Vaccination programmes are expensive and should be well organised and well managed technically and administratively. They should also be budgeted over a period of several years. First, it is of prime importance not to jeopardise the costly national effort by damaging the selected vaccines through poor handling, storage or injections in targeted animals due to inappropriate equipment or insufficiently trained personnel. Vaccines should keep the efficiency they have demonstrated in quality control by manufacturers up to the time of use. In this paper, the conditions for proper handling of vaccine deliveries, good organisation of vaccine distribution and ideal application in different animals are recalled. The pharmaceutical presentations and properties of the FMD vaccines currently used in the world are reviewed and compared, with a special mention of the highly purified vaccines that allow a Detection of Infection in Vaccinated Animals (DIVA) policy. Factors influencing results of vaccine use – such as the relationship with the field strain(s), frequency of booster vaccinations, antigen payload and potency, and maternally derived antibodies for the most important – are reviewed, as are the risks and side effects linked with the use of FMD vaccines.

Keywords
Farm ruminants – Foot and mouth disease – Immunity post-vaccination – *Manual of Diagnostic Tests and Vaccines for Terrestrial Animals* – Maternally derived antibodies – Pigs – Vaccination programme – Vaccine adjuvants – Vaccine application – Vaccine potency – Vaccine storage – World Organisation for Animal Health (OIE).

General vaccine use

Vaccination programmes are expensive and should be well organised and well managed technically and administratively. It is of prime importance to avoid jeopardising a costly effort at national level by the misuse of the vaccine due to inappropriate equipment or untrained personnel. The first priority when using a vaccine is not to damage the product through poor handling or storage. Vaccines should keep the efficiency they have demonstrated in quality control by the manufacturer up to the time of injection in the targeted animal population. A vaccine batch not preserved in appropriate conditions does not protect correctly against the disease to which the vaccination campaign is intended.

Cold chain for vaccine use

The cold chain responsible for preserving the vaccine efficiency is a succession of not only refrigerated storage places and boxes, permanent or mobile, but also intermediate steps under the responsibility of transporters, custom administration, programme administrators, warehouse men and, finally, vaccinators. All of these actors should be informed of the sensitivity of the vaccine to ambient temperature, especially in tropical countries, to avoid any detriment to the product.

Structure of the cold chain

A cold chain is made of two complementary parts, the fixed cold chain and the mobile cold chain.

Cold rooms are the fixed part of the cold chain. National authorities that set up large foot and mouth disease (FMD) control and eradication programmes using vaccination should remember to make provision for correct cold-room facilities throughout the programme, the capacity of which should be in slight excess of the volume occupied by vaccine boxes to cope with any additional demand. It is common sense to monitor the temperature and to have an alarm if the temperature goes out of the standard range (+3°C to +8°C) in all the cold rooms in use during a campaign. Special attention should be paid to the freezer, especially if it is not equipped with an autodefrost system. Any failures of the cold room should be fully recorded with details and transmitted to the authorities in charge of the vaccination programme.

Ice boxes or insulated boxes are the mobile part of the cold chain. For supplying vaccines to their customers, vaccine manufacturers should be asked to pack vaccine vials in insulated boxes including gel coolant packs and temperature indicator cards to demonstrate if the temperature has run outside the limits of +3°C to +8°C during transport. A careful inspection of these cards by the customer upon receipt is advised and any abnormality is reported with the reference of the consignment and date to the authorities in charge of vaccination programmes. Ice boxes for delivering vaccines in the field should be well insulated, strong and waterproof. Usually coolant packs are used to maintain the cool temperature, but they should not be too cold to avoid partial freezing of vaccine vials in contact. Dry ice is not recommended as a coolant for vaccine vials.

Logistics of the cold chain

There are five steps to creating the appropriate logistics for the use of a vaccine during a vaccination campaign:

1. The selection of a delivery strategy for vaccines to the teams in the field, including the frequency of deliveries using refrigerated lorries and/or insulated boxes, is the first step to be finalised. The strategy takes into account the targeted animal population inventory and the difficulties in delivering the vaccine boxes to the end points. Operating procedures should be distributed to personnel involved. Large consignments of vaccines imported for national disease control programmes should be cleared quickly through ports and airports. This usually requires prior arrangements with the customs authorities and it is necessary so that vaccines can proceed immediately to correct cold storage before dealing with the import procedures and bureaucracy.
2. As previously mentioned, national authorities which set up large FMD control and eradication programmes should organise the appropriate fixed cold rooms throughout the programme area. In this area, a selection of storage sites is established and these sites are prepared and checked beforehand. Personnel responsible for storage sites should be trained and equipped for maintenance. The entry/exit of each consignment of vaccine into cold storage should always be fully documented, including the date. This will ensure a correct rotation at the time of vaccine issue, according to the principle of 'first in, first out' which avoids late discovery of vaccine boxes with an expired shelf life at the bottom of cold rooms.
3. Supply of vaccine boxes regularly during the progression of vaccination campaigns is an important step and is organised to minimise the risk of keeping vaccines beyond the validity period. For smaller consignments of vaccines and for those nearer to the point of use, vials of vaccine should never be left exposed in places like offices or transport vehicles.
4. The capacity of each storage site is calculated according to the frequency of supply and delivery during the time of the campaign. A vaccine stock should be available in case of increasing demand. In cold rooms, an additional space for air to circulate around and between boxes is necessary. In regions where power failures are possible, an additional quantity of water containers can be used to limit temperature variations in case of intermittent functioning.
5. Selection of pieces of equipment such as small refrigerators and ice boxes with gel coolant packs should be made in accordance with the volume of vaccine to be used plus a stock as a reserve to cope with any increasing demand.

Thermosensitivity of foot and mouth disease vaccines

Almost all vaccines for veterinary use should be kept refrigerated between 3°C and 8°C to retain their immunogenic properties, and FMD vaccines are no exception to this rule. FMD vaccines can be damaged by high ambient temperatures and by temperatures below freezing. Combination of the effects of high ambient temperature and violent shaking during transportation makes FMD vaccines totally useless. In addition, it is best for the vaccine

vials out of the ice box to be protected from intense and direct sunlight during the vaccination operation. Insulated boxes with vaccine vials and coolant should not be left uncovered in sunlight.

Additional equipment

Syringes and sterile needles are carefully selected to correspond to species targeted by vaccination programmes. The use of long sterile needles (21 G ´ 0.5 inch or 0.8 ´ 12.7 mm) is recommended for the withdrawal of vaccine from each vaccine vial, to allow air to enter the vial and avoid the creation of a vacuum. Multi-dose syringes of good quality with accurate measurement of required doses can be deployed and are particularly useful in an area vaccination campaign. Reusable syringes and needles should be regularly sterilised, preferably by heat procedure, but not using chemical methods of sterilisation, because of the risk of chemical residues damaging the FMD antigens. Disposable equipment should be destroyed carefully after use in accordance with the regulations of the country.

Vaccine application

Animals to be vaccinated

Special training is given to vaccinators to avoid any mistakes during handling and injection of animals. Precise instructions concerning species, age, pregnant animals, etc. should be given in written form (operating procedures) beforehand. Animals should be in a tranquil condition and, if they have been recently transported on foot or by vehicle, time for resting should be allowed before vaccination. When carrying out vaccination or revaccination programmes under outbreak conditions, considerable care is required so as not to exacerbate the spread of the disease from infected premises. There have been occasions when hastily implemented and badly planned vaccination campaigns in the face of an outbreak have assisted the spread of infection because of poor hygiene practices by the vaccination teams. A vaccination campaign in the face of an outbreak should begin in the known, uninfected populations. Then, the vaccination cover should be extended in such a manner that groups of animals which may be silently incubating the disease are vaccinated only at the end of the campaign. That is why vaccination teams should carry out all the basic decontamination procedures in a disciplined manner at all times, and particularly when moving between villages or farms.

Vaccination of cattle and buffalo

As the success of vaccination programmes is in the correct vaccination of all the accessible animals, adequate means of restraint may need to be planned beforehand for difficult animals not used to handling. The ideal facility is that designed in South American countries, where cattle races, capable of holding 10 to 30 cattle (head to tail) per loading, are in common use. The race should be open at the top so that vaccinators can work over a top rail without any vertical obstructions. As all animals should be vaccinated, great care should be exercised with adult bulls, pregnant cows and heifers. In a peasant farming situation, which is frequent in the tropics, animal capture and restraint for vaccine administration are more difficult. For small numbers of free-ranging cattle, the use of a pen to crowd animals in a corner using a metal crush or a spare farm gate is in common use. In all cases, only a sufficient amount of vaccine without excess should be removed from the ice box.

Vaccination of sheep and goats

As these animals are difficult to handle, especially when pregnant, it is important to arrange beforehand for sufficient assistance to be available so that the vaccinator can concentrate on the correct administration of the vaccine. It is recommended that a system of pens is selected to separate groups of unvaccinated animals from vaccinated ones, without possible confusion between them.

Vaccination of pigs

Pigs are currently vaccinated using a deep intramuscular injection to a cervical site. This objective will be greatly assisted by the proper restraint of pigs to be vaccinated using the help of sufficient assistance. Pregnant sows and gilts should be handled with care; smaller pigs up to two to three months old are caught and held by the upper forelegs.

Injection sites

The injection of a vaccine dose should follow strictly the 'directions for use' printed by the manufacturer on a leaflet accompanying each box of vials and which are summarised on the label of each vaccine vial. Injection sites are common knowledge; for subcutaneous injections the preferred sites are under the skin of the neck in front of the shoulder or in the dewlap for cattle and zebu. For deep intramuscular injections, the preferred sites are the cervical region and, in pigs, just behind the ear. In pigs, special attention should be paid to avoid the ear canal. For deep intramuscular injection, the needle should be inserted obliquely rather than perpendicularly, so that on withdrawal of the needle, no backtracking of the vaccine dose will be observed. It is not unusual, during incompetent vaccination of piglets, to observe a small quantity of vaccine flowing back out of the animal, the result of which is a decreased vaccine dose injected and, consequently, poor immunisation.

Organisation of vaccination operations

Organisation of vaccination operations in susceptible animals against FMD is no more a matter of protection at individual or herd level but at a large population level in an economic sector, region, country or group of countries within a continent. Owing to the presence of virus carriers after clinical disease in cattle, FMD vaccination is targeted more to prevent infection circulating than to protect individuals against signs of the disease. FMD vaccination should be organised by campaigns in order to synchronise the level of immunity of the largest possible targeted population. A time period of three months is considered the maximum for a campaign. FMD control in any country implies that vaccination should be used and judged in a population context. Evaluation of the effects of a vaccination campaign should be finalised and discussed before starting a revaccination campaign in order to correct eventual defects.

Containment of FMD epidemics is the most modest goal. It requires only a priming dose and the natural exposure acts as a booster with the negative consequences of, first, FMD virus carriage on a large scale in cattle and buffalo for several years and, second, the creation of mutations in the virus population. This approach to FMD control is to be prohibited. Elimination of FMD from an entire population or only an animal sector is more difficult to achieve. The vaccine efficacy is continuously challenged by the continued presence of the virus in pockets of infection and in carrier animals. High standards of management of vaccination programme include repeated use of high-potency vaccines and continuous vaccine-matching tests to keep the FMD virus evolution under surveillance. Eradication is the highest level of FMD control. It requires highly efficacious vaccines administered intensively and widely and, at the same time, the continuous search for traces of remaining infection in susceptible and vaccinated animals over several years. This task is now greatly facilitated by the existence of serological methods which detect antibodies against the markers of FMD infection, virus enzymes called non-structural proteins (NSPs). When FMD vaccines do not contain such proteins, thanks to in-depth purification (see later), differentiation becomes possible between infected herds and vaccinated herds. Detecting Infection in Vaccinated Animals (DIVA) is the purpose of the policy. This policy is the ultimate step towards the status of 'free from FMD without vaccination'. Of course, stringent measures at the borders should prevent the reintroduction of FMD virus from neighbouring countries.

In order to get FMD under control or eliminate or eradicate the virus, the proportion of the targeted population to be vaccinated is based on the highly contagious characteristics of the virus and aptitude to circulate unknown in carrier animals. Vaccination coverage above 90% to 95% is the standard universally admitted to fully control FMD in a targeted population. Below these figures, vaccination programmes are considered at risk and, below 70% coverage, vaccination against FMD is considered a waste of money because it contributes to hiding the virus presence and perpetuating infection with the consequence of feeding many vaccination programmes for the future. One of the main issues concerning the calculation of vaccination coverage is the accuracy and reliability of available figures for animal inventory. A variation of 10% or more in the detailed account of individuals to be vaccinated has an immediate consequence on vaccination coverage, vaccine consumption and the future success of the vaccine use.

The confidence of farmers in the potential of vaccination to protect all their animals should not be jeopardised by the use of a precise animal inventory by vaccinators for the benefit of tax administration. If vaccination operations are perceived by farmers as a tool for making an inventory of their property for tax usage, they will hide as many animals as they can. If repeated on the country scale, these farmer reactions can reach a very important proportion of animal population and turn a well-organised vaccination programme into a failure. Dissimulating animals and excluding them from the vaccination programme is also the obvious sign that the awareness programmes for the public were not successful. That could also be an indication that vaccinator visits are perceived as harmful for the livestock well-being and for livestock productions; this should lead to re-examining the training of vaccination teams with a view to improving their professionalism.

Pharmaceutical presentations and vaccine use

Foot and mouth disease vaccines available on the market are under different pharmaceutical presentations, according to the nature of adjuvant (aqueous or oil) and purification or absence of purification of the antigens. They should have received a valid marketing authorisation by the authorities of the country where they are used. Table I gives the characteristics of the different adjuvants used for FMD vaccine presentations; each of them can be made either with only filtrated FMD antigens or with highly purified FMD antigens. The route for injection, the volume of the dose according to species and age and the precautions for use are specific to each vaccine presentation. Consequently, before starting vaccination, it is highly recommended for persons in charge of vaccine teams to publicly comment on the 'directions for use' put on each vaccine box by the manufacturer.

Table I
Commercial presentations of foot and mouth disease vaccines according to the adjuvants used

Vaccine	Alhydrogel saponine	Single-oil emulsion Oil in water	Single-oil emulsion Water in oil	Double-oil emulsion Water in oil in water
Recommended route	Strictly subcutaneous	Intramuscular or subcutaneous	Strictly intramuscular	Intramuscular or subcutaneous
Indicated species	All ruminants	All ruminants and pigs	All ruminants	All ruminants and pigs
Regions where used	Europe (formerly) Southern Africa Middle East	South East Asia	South America	Europe South East Asia

Aqueous vaccine: the historical standard

This pharmaceutical presentation appeared during the first half of the 20th Century and was gradually improved. Aqueous vaccines are made from FMD antigens adsorbed onto aluminium hydroxide gel in the presence of saponine, a mixture of heterosides extracted from the bark of a South American tree. In aqueous vaccines, FMD antigens could be filtrated or highly purified, monovalent or plurivalent up to seven valencies if highly purified. Aqueous vaccines are thermosensitive and destroyed by freezing, and therefore the quality of the cold chain is of prime importance for their correct use. Once injected, they induce an exceptionally early protection only four days after injection, as demonstrated by Doel *et al.* (5) using a virulent challenge in cattle. Saponine is an adjuvant well tolerated by ruminants and is very efficient in all their species. On the contrary, saponine is not active in pigs, which means that aqueous vaccines are not used in this species and are not often used when vaccination campaigns involve vaccinating pigs and ruminants on the same farms. Figure 1 shows the typical kinetics of antibodies observed in a group of cattle after two injections of aqueous vaccine. The onset of antibody presence is very early and levels rocket fast, but start to decline after 30 to 35 days post vaccination if a second injection is not performed. Aqueous vaccines are ideally the vaccines used to create very rapidly an immunological barrier with two injections one or two months apart. During the 1960s, Europe eradicated FMD using annual campaigns of vaccination with this kind of vaccine injected once a year, when calves and naive animals were vaccinated twice. Compulsory mass vaccination policy in Europe took advantage of winter stalling to reach more than 95% coverage of cattle population. During the 1990s, several countries in southern Africa reached the same results following the same policy with the same kind of vaccine. Aqueous vaccines prepared with highly purified antigens are eligible for use in a DIVA policy. Aqueous vaccines are easy to produce; they use inexpensive ingredients and so are affordable.

Oil vaccines: vaccines of the next generation for pigs and cattle extensively bred

This pharmaceutical presentation of the next generation appeared a long time after the published works of Cunliffe *et al.* (3) for vaccination in cattle in 1963 and of McKercher *et al.* (10) for vaccination of pigs in 1967. Since this historic formula was presented, much progress has been made in the preparation of emulsions to make oil vaccines very sophisticated products. Oil vaccines are made from FMD antigens emulsified once or twice in a mixture of paraffin oil and surface-active agents making water and oil compatible. In oil vaccines, FMD antigens could be filtrated or highly purified, monovalent or plurivalent. Oil vaccines are thermosensitive but some can accept

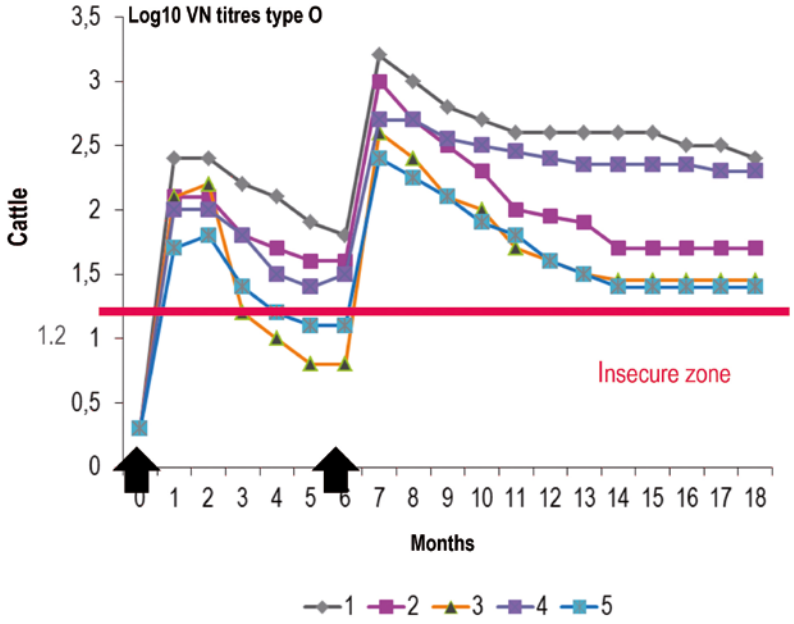

Fig. 1
Aqueous vaccine: antibody kinetic in naive cattle

Source: (7)

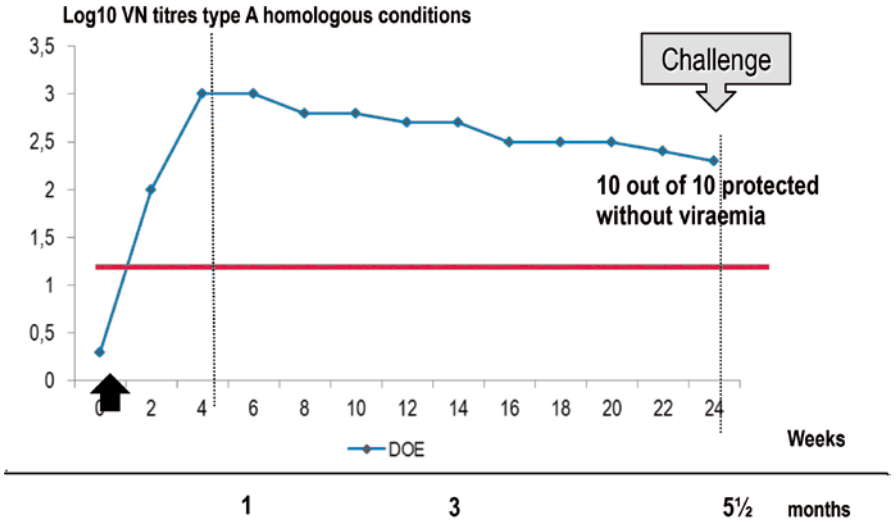

Fig. 2
Double-oil emulsion vaccine: antibody kinetic in naive cattle

Source: (4)

freezing; nevertheless, the quality of the cold chain is of prime importance for their correct use. Depending on whether the aqueous phase with FMD antigens receives droplets of oil or, on the contrary, the oil phase receives droplets of aqueous phase, the immunological characteristics of the emulsion are completely changed, which means different indications for use. Single emulsions are either oil-in-water emulsion (O/W) or water-in-oil emulsion (W/O). When water is the external phase, the product is well tolerated locally but the adjuvant power is weak. On the contrary, when the oil phase is external, oil triggers a reaction, inducing a granuloma locally and a lymph node reaction regionally both responsible for a strong adjuvant power and a slow release of the immunogens. To conciliate the opposing properties of these single emulsions, some years ago the so called 'double emulsions' appeared on the market, the only kind of which is a W/O emulsion emulsified again in an aqueous buffer to make a 'water in oil in water' emulsion. The strong adjuvant power and the good tolerance at the injection site make double emulsion the tool of choice for the vaccination of pigs and increasingly for ruminants. Once injected, oil

vaccines work as a slow-release system for antigens, as the droplets of oil with FMD antigens migrate in the lymphatic system from the injection site to lymph nodes and spleen, where antibodies are produced. Thanks to this mechanism, oil vaccines induce an exceptionally long-lasting protection. The start is slower than for aqueous vaccines, as the peak of antibodies is observed between two and four months, depending to the oil formula. Figure 2 shows the typical kinetics of antibodies observed in a group of cattle injected once with an oil vaccine manufactured with a high antigenic payload. The rising antibodies continue slowly to reach a peak at three to four months post injection and afterwards maintain a good level as a plateau up to 5.5 months post vaccination where all the animals have resisted to a virulent challenge even if vaccinated only once. Oil vaccines are typically the vaccines for mass vaccination campaigns of cattle populations bred extensively in large countries and not easily rounded up. On the contrary, these vaccines are not appropriate to rapidly create an immune barrier in a cattle population in order to stop a threatening epidemic. In pigs, only oil vaccines are used and they are double emulsion vaccines, even if use of a single oil emulsion was reported in Taiwan. The slow-release system of oil vaccine is well designed for the protection of pigs, the economic life of which does not exceed six to seven months. In order to cover this period of time using the smallest number of vaccine injections, vaccination programmes make use of maternally derived antibodies for the initial phase or protection from birth to 2.5 months, then vaccination brings active protection up to slaughtering period, using one or two injections depending on the virus pressure around the pig farm. To enhance the production of maternally derived antibodies, pregnant sows are boostered one month before farrowing.

Non-purified versus purified antigens and vaccine use

The traditional manufacturing process for FMD vaccine consists of clarifying industrial virus harvests and inactivated antigens to remove debris and precipitates at a microscopic scale. Antigens are then concentrated to reach the selected payload before adding adjuvants. This simple technology has produced billions of doses of potent and inexpensive vaccines. In the middle of the 1990s, new studies in FMD research shed light on the role of FMD virus NSPs in the immune response against FMD infection and their potential use in serology for identifying convalescent and carrier animals by serology, an important breakthrough (5). The other side of the coin is that pluri-vaccinated animals, mainly cattle, with traditional FMD vaccines developed the same kind of antibodies as NSPs were also present, even in small amounts, in the vaccine doses. These findings were a revolution in FMD vaccine use, as a vaccine cleared from NSPs could be used in vaccination programmes without hampering the serological diagnosis of virus-infected/carrier animals. That was the wish of all the FMD vaccine manufacturers, which were blamed for decades because their products were hiding potential infection behind the protection conferred by vaccination. Finally, FMD control strategies could benefit from the DIVA strategy already used for some other disease controls. A new kind of FMD vaccine was born, pure (almost without NSPs) and potent, but more costly than the traditional one because purification technology is expensive to carry out even if its yield remains high. The selection of one of these two kinds of vaccine (not purified or purified) is a matter of progression in the different stages for controlling the disease. Non-purified vaccines are recommended for affordable FMD control in countries heavily infected for decades, corresponding to Stages 2 and 3 of the Food and Agriculture Organisation of the United Nations (FAO) Progressive Control Pathway (PCP). However, progressing further in the full control of the disease, thanks to regular mass vaccination campaigns with no outbreaks observed, which corresponds to Stages 4 and 5 of the PCP, the use of purified vaccines is compulsory in association with the serological methods of the DIVA strategy. This means that FMD control strategies associating purified vaccine use and serological studies make FMD control more and more costly when approaching the ultimate objective of FMD elimination and later FMD eradication.

Factors influencing results of vaccine use

Correspondence between field virus and vaccine strain

The correspondence between the vaccine strain(s) and the virus(es) to be controlled in the field is the first of two key factors for success against an outbreak or an endemic situation. Vaccine matching is a recommended activity for vaccine manufacturers, which should offer the most appropriate vaccine strain(s) to their customers. Figure 3 demonstrates the loss of expected protection after vaccination in a heterologous condition (vaccine against a non-related field virus) compared with a homologous situation (vaccine against a related virus). Before ordering vaccine doses for FMD control, the first question to ask is about the appropriateness of vaccine strain(s). The World Organisation for Animal Health (OIE) reference laboratories are able to give all the pertinent information on this.

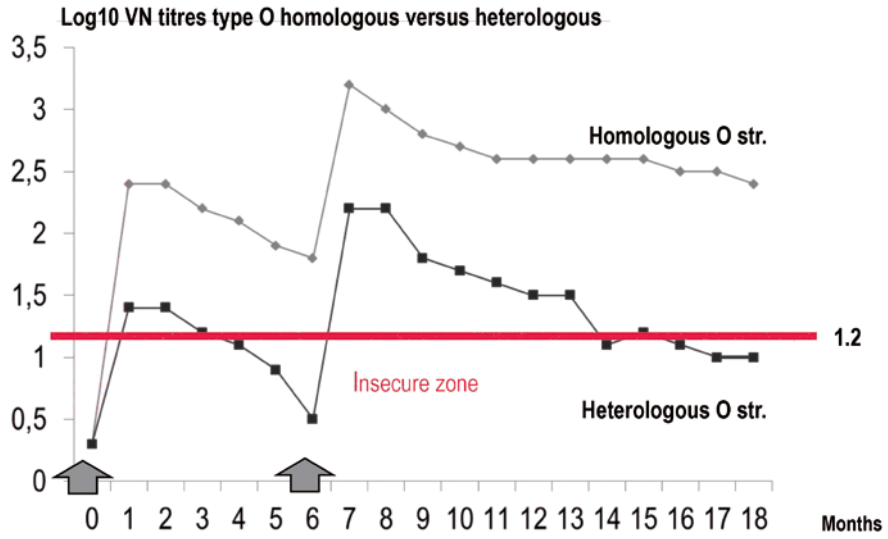

Fig. 3
Cattle antibody kinetics in homologous/heterologous systems

Source: (7)

Vaccine potency and antigen payload

The second key factor for obtaining good results with vaccine use is the potency/efficacy of supplied vaccine. Too many vaccines used in some parts of the world are still of inadequate efficacy to maintain a durable immunity (6 to 12 months). FMD vaccines present on the market should comply at least with the minimum efficacy/potency standard of the OIE *Manual of Diagnostic Tests and Vaccines for Terrestrial Animals* (*Terrestrial Manual*) (13), which corresponds to 75% of observed protection in tests using cattle. If not of certified potency, vaccine batches should not be used for controlling FMD. With the development of physical measure of virus mass expressed

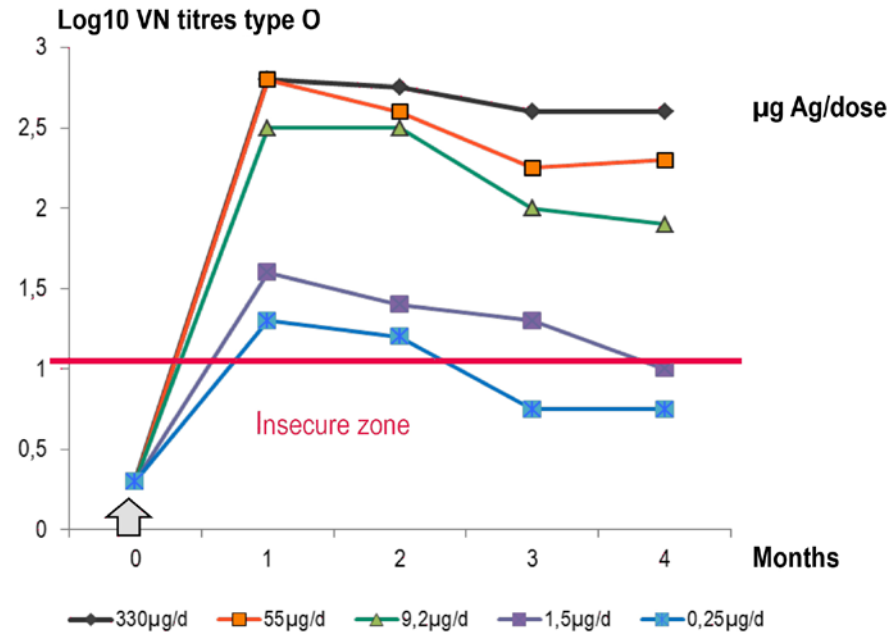

Fig. 4
Effect of five antigen payloads in cattle

Source: (12)

in micrograms per millilitre of virus harvest, standardisation of antigen payload in each vaccine dose became easier and of universal use by manufacturers. Figure 4 shows the effect on antibody secretion by use of several experimental vaccines prepared with increasing antigen payloads. Vaccines with antigen payloads that are too low do not induce a high and durable immunity and should not be used. Commercial vaccines by renowned manufacturers are twice or more the OIE minimum standard for potency, which is a guarantee for establishing a strong and long-lasting immunity after vaccination. Vaccine potency is an important criterion for vaccine selection and, for example in the European Union (EU), for antigens of the EU-FMD bank and for antigen banks of some countries with a no-vaccination policy against FMD, a potency more than twice the minimum standard of the OIE is required; that is more than six protective doses of 50% (PD50) per commercial dose instead of three PD50 per commercial dose, one of the two OIE standards for 75% protection. The rationale behind such a requirement for antigen banks is the naive immunological status of the European or other countries' livestock facing a possible, very threatening, FMD outbreak.

Frequency of re-vaccinations

Foot and mouth disease vaccines are inactivated and not live. Consequently, immunity should be maintained by regular re-vaccinations, the frequency of which influences the results of vaccine use. The standard vaccination scheme in naive cattle is two injections one to four months apart, depending on the disease threat in the area. Before a progressing epidemic or to extinguish an outbreak (8), the second vaccination is usually made one month after the first (Fig. 5). On the contrary, in a mandatory vaccination scheme and in the absence of an immediate threat, naive animals could receive their second injection four months after the first one, the booster effect being much more effective than the booster effect observed after a one-month interval. Post-vaccination immunity cannot reach the level observed with post-infection immunity, and this fact has led to the need to vaccinate annually or bi-annually, and even tri-annually in areas with a high risk of exposure to field virus, especially if different from the vaccine strain. More than two routine vaccinations a year are observed in the intensive dairy units in Middle East. When initiated, regular FMD vaccinations cannot be stopped precociously without jeopardising the previous efforts by the return of the disease. Once launched, FMD vaccination campaigns should continue year after year until the status of free from FMD without vaccination can be granted.

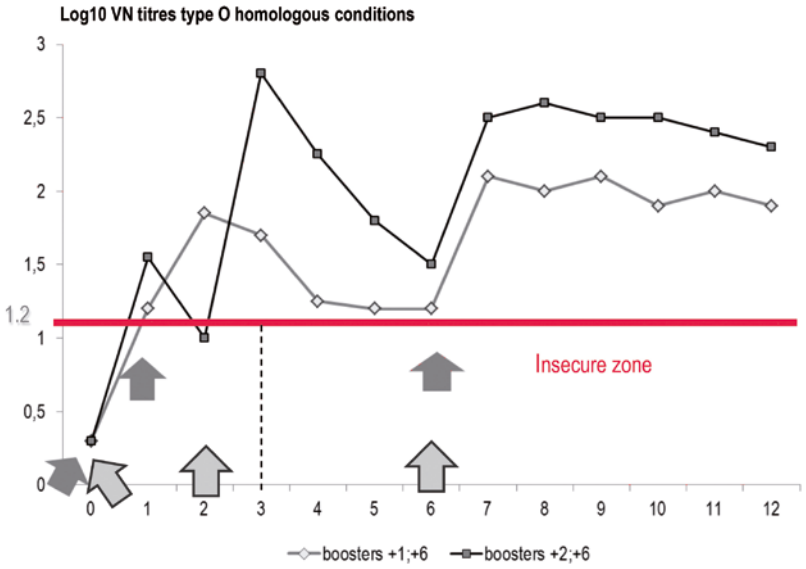

Fig. 5
Effects of boosters at one and two months post vaccination in calves, France

Source: (7)

Maternally derived antibodies and vaccine use

Dam vaccination schemes are especially beneficial for the protection of neonates in a heavily contaminated environment. The strategy is to enhance neonatal immunity by augmenting antibody titres in colostrum (2). This is, for example, the vaccination programme for sows using an FMD oil vaccine. One injection one month before farrowing maximises antibody titres in the colostrum for the benefit of suckling piglets, which receive an increased

passive immune protection effective for two to three months. Once this period of time has elapsed in piglets, and also in lambs or calves, the level in maternally derived antibodies (MDAs) is too low to protect against infection, but the transition to active immunity, thanks to vaccination, is critical because the residual levels of MDA neutralise partially or completely the immunogens present in the vaccine. These variable residual antibody levels depend on each individual, which demonstrates poor to absent serological reaction after a single vaccine injection. That is why a second vaccine injection (Fig. 6) is recommended to trigger an active immune response fully protective, as demonstrated in calves in Brazil (1, 11). In this context, oil vaccines with slow release of antigen(s) were recommended. After this second vaccination, calves entered into the six-month vaccination cycle, which was recommended for cattle under two years of age in Brazil at this time.

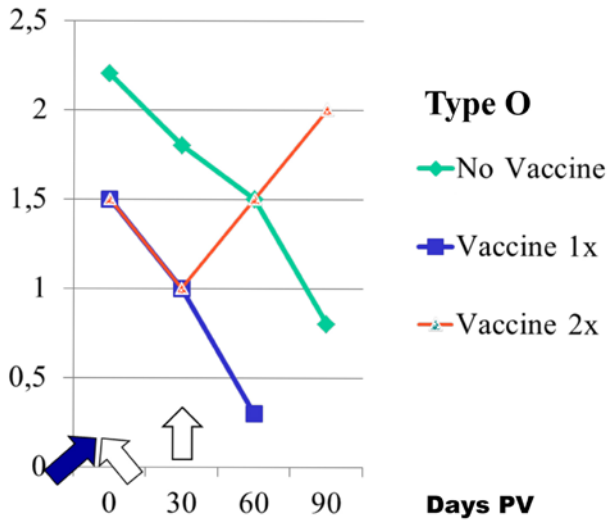

Fig. 6
Maternally derived antibodies in effect of 0, 1 and 2 vaccinations, Brazil

Source: (11)

Other factors influencing the results of vaccine use

All factors affecting the good health of individuals to be vaccinated have an influence on the outcome of FMD vaccination. Fever due to concurrent diseases, acute and chronic parasitic disease and stress are the most well-known indications to delay vaccination. When herds have recently been transported by foot or by vehicle, time for resting should be allowed before vaccination. Vaccination during glucocorticoid therapy has been also traditionally discouraged. All these considerations are not of a nature to prevent individual FMD vaccination in the scope of compulsory mass vaccination campaigns where a poorly vaccinated individual has less chance of becoming infected by virtue of being a member of a well-vaccinated group.

Risks and side-effects associated with vaccine use

Risks and side-effects associated with vaccine use are generally of three orders:

1. related to the vaccine itself;
2. related to mishandling of animals; and
3. related to each vaccinee health status.

Modern vaccines are harmless, with no toxic materials (the inactivant is often neutralised after the inactivation step) but when they are not purified vaccines can keep an allergenic capacity, the power of which increases with the repetition of vaccination campaigns. Allergy is usually of type 1 (anaphylaxis) and should be treated immediately with corticoids, especially if it occurs in high-value animals (insemination centres, intensive dairy farm, etc.). With regard to oil vaccines with an external oil phase (in South America), it is common knowledge that they induce granuloma at the injection site where oil emulsion residues can be observed several months after the injection as well as in the satellite lymph node. Such granulomas and lymph nodes are trimmed later from carcasses in

slaughterhouses. Paraffin oil residues can be detected several months after vaccination in liver, kidneys and, of course, around the injected site (personal observation), and the potential human health risk from ingestion has not yet been determined. Violent handling of animals could also result in trouble, mainly with small ruminants, especially when they are pregnant, with abortions as consequences (goats), or when animals are very young (piglets, lambs). Bringing together livestock populations on large premises practising extensive breeding is always the occasion for accidents such as broken legs or horns, which makes farmers reluctant to vaccinate too often throughout the year. Associating FMD vaccination with blackleg vaccination and anti-parasite dip is the best way to make sure that the local cattle population is vaccinated. Another risk of vaccine use is the contamination of multi-dose vials if an additional long needle is not used for air entrance and if a stopper is punctured many times with the needle used for vaccinating animals. In instructions to vaccinators, strict guidance should be given regarding the proper handling of vaccine vials. It should also stipulate that part-used vials of vaccine should not be reused after 36 h from the first use and must be kept refrigerated throughout the intervening period.

Conclusion

Vaccines against FMD, as with all veterinary vaccines, are medicinal products, carefully prepared by manufacturers following the dossier agreed for registration/licensing/marketing authorisation by national/multinational authorities and complying with the requirements of the OIE *Terrestrial Manual*. These vaccines are expensive to buy and much more expensive to apply respecting the directions for use, the good practice for logistics and the retained vaccination strategy. When well selected and well applied, vaccines against FMD have always led to successfully controlling threatening FMD outbreaks or eliminating FMD where it has been endemic for decades. However, these combined efforts come at a huge cost and necessitate thorough attention over a period of many years. Thanks to strict FMD vaccination programmes, continents or sub-continents have reached the eradication degree, which allows them to end completely the vaccination policy and to adopt a policy of strict control of the potential sources of re-infection. Thus, they can benefit from a free trade for animal products with countries having reached the same degree for disease status.

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Foot and mouth disease: ongoing research and its application in the foot and mouth disease control policy

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Summary

Foot and mouth disease (FMD) is one of the most infectious diseases of livestock and continues to pose a significant threat to endemic and free regions. The impact of FMD on society and international trade is high, thereby demanding stringent prevention, surveillance and control plans. On the other hand, there is a global increased demand for animal welfare and ethical considerations necessitating a decreased reliance on eradication of animals to control FMD virus (FMDV) spread, and on the use of animals for the regulatory testing of veterinary products. The FMD research community seeks to balance these apparently contrasting viewpoints by addressing specific gaps in our knowledge on all aspects of FMD control to enable implementation of enhanced animal-sparing vaccine-based control strategies tailored to the needs of free and endemic settings. The actual ongoing FMD research and its application in the FMD control policy is described for the following items:

a) *methods to reduce and refine* in vivo *vaccine quality tests by* in vitro *method,*

b) *high-quality vaccines to implement the vaccinate-to-live policy,*

c) *new-generation FMD vaccines and antiviral products,*

d) *new-generation FMD diagnostics,*

e) *FMDV spread, transmission and persistence following the use of high-potency monovalent or multivalent vaccines,*

f) *FMDV early pathogenesis and immune responses,*

g) *computerised FMD spread models to optimise vaccination schemes,*

h) *economic factors influencing the spread and control of FMD,*

i) *FMDV transmission via animal products and FMDV stability and inactivation in animal products.*

Keywords

Animal products – Antivirals – Control policy – Diagnostics – Foot and mouth disease – Immune responses – Research – Spread models – Transmission – Vaccine quality.

Introduction

Foot and mouth disease (FMD) is one of the most infectious diseases of livestock and continues to pose a significant threat to endemic and free regions alike. The impact of FMD on society (35, 43) and international trade (31, 51) is high, thereby demanding stringent prevention, surveillance and control plans taken up in crisis preparedness plans. On the other hand, there is a global increased demand for animal welfare and ethical considerations, necessitating a decreased reliance on eradication of animals to control FMD virus (FMDV) spread, and on the use of animals for the regulatory testing of veterinary products. The FMD research community seeks to balance these apparently contrasting viewpoints by addressing specific gaps in our knowledge on all aspects of FMD control to enable the implementation of enhanced animal-sparing vaccine-based control strategies tailored to the needs of free and endemic settings.

Foot and mouth disease research and its application in the foot and mouth disease control policy

Methods to reduce and refine *in vivo* vaccine quality tests by *in vitro* methods

The aim of this research is to replace the current *in vivo* 'gold standard' tests for vaccine efficacy (potency), purity and safety, in light of the 3Rs (Refinement, Reduction, Replacement) principle (28), by validated *in vitro* laboratory tests. More specifically, by:

– the determination and validation of correlation models between *in vitro* laboratory tests and *in vivo* protection based on experimental and field data (24, 32, 45, 52);

– the development of *in vitro* immunoassays to monitor vaccine purity by the reduction of FMDV non-structural proteins content during vaccine purification and in the final vaccine (6, 12); and

– the development of alternative methods to check the antigen quality (54) and to quantify the antigen payload content in the final vaccine (49).

The reduction and refinement of *in vivo* vaccine quality tests by *in vitro* methods will guarantee the overall quality of the vaccine batch in a verifiable form to end-users and other stakeholders, strengthening the position of the decision makers when it comes to the implementation of the 'vaccinate-to-live' policy (17, 53). Consequently, reliance on animals for regulatory testing of vaccine batch release control will be decreased and animal welfare increased.

The availability of high-quality vaccines to implement the vaccinate-to-live policy

The aim is to predict how well a vaccine will protect against a challenge virus of another strain within the same serotype (cross-protection) (9, 34) avoiding *in vivo* cross-protection studies. Therefore, r-value determination between vaccine strains and FMDV field isolates (46) will be improved by harmonising test methodologies (41) and drafting guidelines (33) for the reliable selection of reagents to include in *in vitro* vaccine-matching studies. The depth of our knowledge and expertise regarding vaccine spectrum coverage will be increased. The assessment and improvement of heterologous protection by FMD vaccines will help decision-makers in their difficult choice on which vaccine to use in future outbreaks and in their responsibility in updating and reinforcing FMD vaccine/antigen banks (4).

The development of new-generation foot and mouth disease vaccines and antiviral products

The aim is to increase our knowledge by investigating approaches for reinforcing the mucosal immune response (48) in order to prevent FMDV infection at the primary portal for virus entry (2). Methods to elicit and measure (39) mucosal immunity against FMDV in cattle are being evaluated. Ways to stimulate innate (rapid) (50) and adaptive (lasting) mucosal immune responses are being investigated, using novel delivery systems, adjuvants and viral vectors (21, 26, 38, 40, 44). Other new-generation vaccines are being developed and efficacy tested, avoiding the need for virus culture, thereby making the production of FMD vaccines environmentally safer. Moreover, the use of potent and selective antiviral compounds against FMDV, which rapidly and completely prevent FMDV replication, is being investigated in order to decrease the post-vaccination immunity gap (22). The development of new-generation vaccines (19, 42) and antiviral compounds (20, 30), based on safe production methods and specifically aimed at reducing the immunity gap shortly after vaccination, will (a) supplement the existing control tools to combat FMD and (b) allow the enhancement of emergency contingency plans enabling a better, quicker and animal-sparing response to FMD outbreaks.

The development of new-generation foot and mouth disease diagnostics

The aim is to:

a) increase the availability of FMD diagnostics;

b) improve standardisation and harmonisation of FMD diagnostic results; and

c) develop new, and possibly better, diagnostic tools for confirmatory tests and/or test systems for non-structural protein (NSP) serology.

Therefore, a panel of stabilised, validated and reliable diagnostic kits for FMD serology and antigen typing, ready for commercial exploitation, are being developed and/or validated (i.e. confirmatory NSP test [5, 47], immunoglobulin A [IgA] in saliva enzyme-linked immunosorbent assay [ELISA] [39] assays, in which serum reaction profiles are obtained simultaneously against a number of antigens – multiplexing [14]). Knowledge on performance characteristics of available Differentiating Infected from Vaccinated Animals (DIVA) diagnostics on a global scale will help to understand the FMD situation in all regions of the world, resulting in an increased awareness of the potential threats (11, 23). The improvement in FMD diagnostics will help the World Organisation for Animal Health (OIE) to better interpret the dossiers submitted to demonstrated/substantiate FMD freedom and, by facilitating and accelerating the development and distribution of the most effective diagnostics for FMD in the world, will contribute to global FMD control.

The enhancement of our knowledge on foot and mouth disease virus spread, transmission and persistence following the use of high-potency monovalent or multivalent vaccines

The aim is to obtain previously unavailable quantified knowledge on FMDV transmission within and between different FMDV-susceptible species (37) in the period shortly after applying emergency vaccination (16, 37), and to study transmission dynamics in real-time outbreak situations (15) to set up early warning systems for FMDV penetration. The effect of vaccination in preventing FMDV transmission through contact exposure to the virus is being studied by carefully designed FMDV transmission experiments. The ability of the Asian buffalo to transmit FMDV infection (29) and the efficacy of vaccination to prevent this are investigated. The role of wildlife (e.g. buffalo, gazelles, wild boar) (7, 8, 10) in FMDV maintenance and transmission, and quantified knowledge on the presence of FMDV in viral secretions and excretions in different species is also being studied. Knowledge on FMDV transmission between species and in recently vaccinated animals can be used to adapt and improve computerised FMD spread models to optimise FMD vaccination programmes in free and endemic settings alike.

Understanding foot and mouth disease virus early pathogenesis and immune responses

Understanding the early pathogenesis of FMDV and the interplay between the virus and the host immune response is crucial to improving the design of vaccines, diagnostic tests and antiviral therapies and will help in the basic understanding of epidemiology providing more precision to disease transmission models, which will ultimately refine disease control protocols (13).

The development or adaptation of computerised foot and mouth disease spread models to optimise vaccination schemes

The aim is to study the applicability and feasibility of modifying existing simulation models for FMD spread to suit the exploration of vaccination strategies in the countries where FMD is considered an exotic threat (3, 25). The resulting computerised FMD spread models developed within this project could enable the design of vaccination strategies for high-risk regions within countries and could be relevant stepping stones to model vaccination strategies for truly endemic regions of the world.

Economic factors influencing the spread and control of foot and mouth disease

International trade in animals and their products is recognised as a primary determinant of the global epidemiology of FMD. Research on matching data on livestock trade movements with molecular epidemiology can enhance our fundamental understanding when reconstructing the spread of the virus between geographical regions, which is essential for the development of FMD control strategies worldwide (18). FMD surveillance and control measures are financial resource-using activities of strategies to control FMD. Resources are scarce, and allocating them to disease control instead of other uses necessarily involves the loss of alternative sources of benefit to people. For society to obtain the maximum benefits from using resources, the gains from FMD control are compared with the resource costs, guiding decisions made with the objective of achieving the optimal net outcome (27).

Animal products

The existing knowledge in regard to FMDV excretion, transmission and stability of FMDV and in regard to FMDV inactivation in milk and milk products relevant for estimating the risk of raw and treated milk and milk products clearly shows that there are areas of uncertainty where suitable data are sparse or missing and where further research is needed (1).

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Experience of FMD control in Thailand: the continual attempts and foresight

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Summary

Foot and mouth disease (FMD) control in Thailand has been formally conducted for decades by the government sector in strong collaboration and with the support of the private sector and international and regional collaborations.

According to the law, FMD is one of the most important notifiable diseases in the 1956 Animal Epidemic Act (B.E.2499) and there have been many regulations with regard to FMD prevention and control following the updated FMD control strategies. The most recent update of the strategy (2012–2015) has been set up to understand FMD and its determinants in more depth in order to control FMD efficiently.

The strategies are composed of eight components: (1) annual census of animal population, including national animal identification system; (2) disease surveillance; (3) vaccination; (4) animal and animal product movement control; (5) control measures; (6) international coordination and support; (7) public awareness and communication; and (8) livestock sector development.

During phase 2 of the SEAFMD (OIE South-East Asia for foot and mouth disease) programme in 2001–2005, Thailand had 81–209 (mean = 129.2) FMD outbreaks annually, but there were only 34–53 (mean = 42.7) FMD outbreaks annually during phase 3 of SEAFMD in 2006–2011.

Considering the zones, there have been no FMD outbreaks in livestock region 2, a zone in the eastern part of Thailand, since 2000. The measures in region 2 were strengthened in order to maintain zero tolerance of FMD within the zone and to plan to achieve OIE recognition of FMD free with vaccination.

The key achievements are effective implementation of all technical components of the strategies and effective coordination of regional activities. The challenge of FMD control in Thailand is about proper capability to apply some technical strategies in the field. For example, there would be different specific and well-targeted local strategies to achieve 80% of mass vaccination in different areas.

In the future, Thailand will use the OIE/FAO FMD progressive control pathway and the South-East Asia and China Foot and Mouth Disease (SEACFMD) 2020 roadmap as the major guidelines to update national strategies to prevent, control and eradicate FMD in the country.

Keywords

Foot and mouth disease – Foot and mouth disease control – Progressive Control Pathway – SEACFMD – SEAFMD – Thailand.

Introduction

Foot and mouth disease (FMD) has been recognised as one of the most important transboundary infectious animal diseases in Thailand. The Department of Livestock Development (DLD) developed a national control plan and has worked closely with neighbouring countries through the Southeast Asia FMD (SEAFMD) and later South-East Asia and China Foot and Mouth Disease (SEACFMD) Campaign since the early 1990s.

Control of foot and mouth disease in Thailand

Implementation tools for FMD control are legislation and national plan for FMD control. The Animal Epidemics Act B.E.2499 (1956) and its revision B.E.2542 (1999) have been the main laws for control of FMD and other diseases in Thailand. The strategic plan for FMD control has eight components (resource management, law amendment, disease surveillance and control, livestock sector development, public relation, research and technology development, international collaboration, monitoring and evaluation). The action plans include preparedness in normal state and action in outbreak response. All levels of the organisation were assigned their duties in the plans.

FMD is endemic in Thailand. The occurrence of outbreaks has been caused by FMD virus serotypes O and A. The Asia-1 serotype last occurred in 1997. From 2001 to 2005, there were 81 to 209 outbreaks annually. From 2006, during phase 3 of the SEACFMD campaign, there were only 34–52 outbreaks annually. At present, there are 12 FMD outbreaks reported in 2012 (Fig. 1). The occurrence of outbreaks in this year was caused by serotype A.

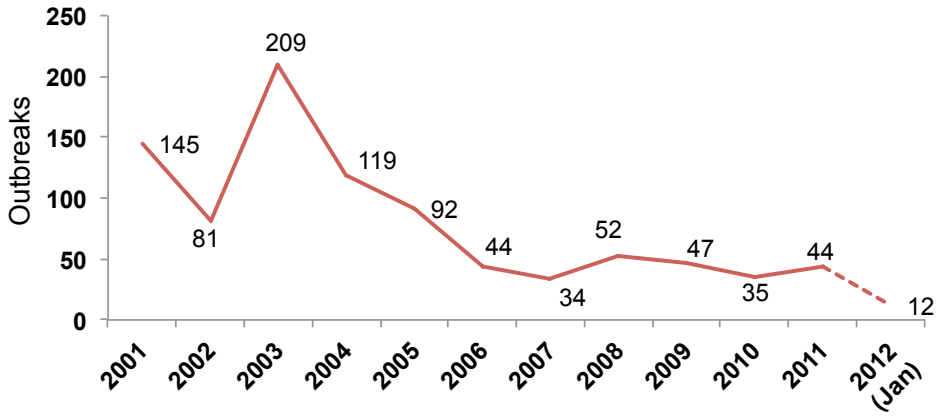

Fig. 1
Annual frequency distribution of foot and mouth disease outbreaks in Thailand

Source: Department of Livestock Development and SEACFMD database

For decades, the Department of Livestock Development set up a passive surveillance or reporting system and all reported cases were investigated as epidemiological investigation. Then, DLD initiated an FMD national control plan, vaccination campaign and active sero-surveillance and animal movement database. In addition, the national strategic plan for FMD control was developed to eradicate the disease and livestock region 2 in the eastern part of Thailand was established as an FMD-free zone (Fig. 2). The FMD-free zone has been established for potential pig exportation, but the activities have been done for all susceptible livestock in the zone. The last notification of FMD in the zone was reported in October 2000. Two cattle were identified with FMD type O infection at a slaughterhouse. Upon investigation, the cause of the outbreak was attributed to animal movement. FMD surveillance in the zone uses both active clinical and serological detection by using freedom from disease surveillance system. Animal movement is restricted in the zone in order to prevent the virus introduction from other zones. Currently, FMD control in Thailand could be determined in Stage 3 of the Progressive Control Pathway. Progressively, the FMD control plan is to move up to Stage 4 of PCP for the whole country and Stage 5 for the FMD-free zone of livestock region 2 (Table I). Animal movement into the free zone is restricted and risk assessment of FMD introduction into the FMD-free zone is studied. The achievement of FMD-free zone establishment in region 2 will be used as a model for other zones. The key activities are zoning, national livestock identification and registration system (NID), mass vaccination, active and passive surveillance and animal movement control.

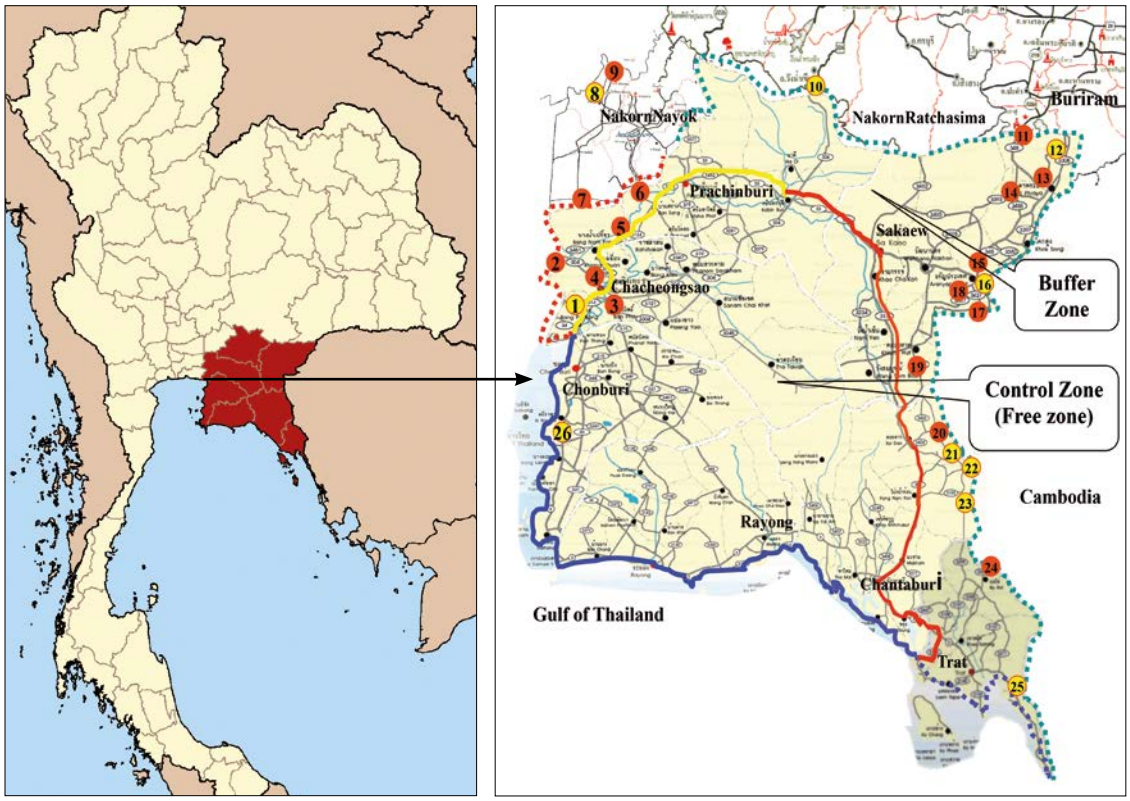

Fig. 2
FMD-free zone establishment in Thailand, livestock region 2 in the eastern part of Thailand

Source: Department of Livestock Development

Table I
Progressive Control Pathway (PCP) stages and Department of Livestock Development (DLD) attempts for foot and mouth disease (FMD) control

Stage	PCP requirement	Examples of DLD attempt
0 to 1	Comprehensive study of FMD epidemiology planned	Set up and run the passive surveillance (reporting system and outbreak investigation)
1 to 2	Risk-based FMD control plan	Initiated FMD national control plan, vaccination campaign, active sero-surveillance and animal movement database
2 to 3	Develop aggressive strategy to eliminate FMD	Developed national strategic plan to eradicate FMD
3 to 4	No endemic FMD in domestic livestock	Established FMD-free zone for livestock region 2 and detected virus circulation in the free zone using 'freedom from disease' surveillance. Study on risk assessment of FMD introduction into the free zone. Apply for OIE endorsement for national FMD plan
4 to 5	Apply for official status (OIE): free with vaccination	Apply for official status (OIE): free with vaccination and set up model of the establishment of FMD-free zone in other areas
Free without vaccination	Apply for official status (OIE): free without vaccination	TBD

New activities to support FMD control in Thailand are surveillance and rapid response teams (SRRTs), Sub-District livestock assistants, revision of animal movement regulations, FMD-free certified farm, traceability (e-movement), NID, and revision of the national FMD plan that has moved from control to eradication. The list of additional studies to strengthen the PCP stages are knowledge attitude and practice study (KAP), hotspot analysis, social network analysis, epidemiological simulation modelling, molecular epidemiology, cost-effectiveness analysis, socioeconomic impact study, market chain and animal movement.

Conclusion

The Department of Livestock Development has imposed policy to progressively control FMD through application of the Progressive Control Pathway. The Department of Livestock Development complies with the 2020 SEACFMD Roadmap as strategy and goal for FMD eradication. As the strategic plan of Thailand, by 2013, the eastern part of Thailand will be recognised as the free with vaccination zone. Regarding the 2020 Roadmap, by 2015, the eastern part of Thailand and Malay Peninsula will be recognised as an FMD-free zone. By 2017, the upper Mekong region, which includes the northern part of Thailand, will be recognised as an FMD-free zone. And, by 2020, all regions in Thailand will be free from FMD together with Southeast Asia and the People's Republic of China. An effective vaccination programme is essential, along with traceability, a laboratory network, animal movement management, technical strategies in fieldwork, law enforcement, public awareness and communications, public and private collaboration and regional collaboration.

Session 5

The FMD virus pools and the regional programmes

Chair: Representative ASEAN

Foot and mouth disease in South-East Asia: current situation and control strategies

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Summary

South-East Asia is considered to belong to foot and mouth disease (FMD) virus Pool 1 with serotypes A, Asia 1 and O in endemic circulation. Although Brunei, Indonesia, Singapore, East Malaysia and, most recently, the Philippines are currently classified as FMD free without vaccination, the disease persists in Cambodia, the People's Republic of China, the Lao People's Democratic Republic, peninsular Malaysia, Myanmar, Thailand and Vietnam. From 2002 to 2011, a total of 6,472 outbreaks were reported, with two major epizootics observed in 2006 and between late 2010 and early 2011. Serotype O remains the most common in the region, followed by serotype A/Asia, which appears to be steadily increasing in some parts of South-East Asia, particularly in Thailand and Malaysia. Serotype Asia 1 is the least commonly reported of the three circulating FMD viruses, with the last outbreak in China reported in 2009. Frequently observed co-circulation of multiple FMD virus types in various parts of the region is reflective of the complexity of the epidemiology of the disease and the dynamic animal trade in South-East Asia. To maximise utility of limited resources for FMD control in the region, targeting the disease at these sources is a major strategy for the South-East Asia and China FMD Campaign (SEACFMD) as indicated in the SEACFMD Roadmap 2020. With funding support from the AusAID Stop Transboundary Animal Diseases and Zoonoses (STANDZ), resource assistance from the EU-HPED Vaccine Bank, and guidance from available tools such as the World Organisation for Animal health (OIE) Performance of Veterinary Services (PVS) Pathway and the Food and Agriculture Organization of the United Nations (FAO)/OIE Progressive Control Pathway (PCP), SEACFMD continues to vigilantly move its Member Countries forward in FMD control and serve as a model for regional coordination in the control of transboundary animal diseases.

Keywords
FMD virus Pool 1 – FMD serotypes – SEACFMD – South-East Asia and China.

Introduction

Foot and mouth disease (FMD) is endemic in most parts of South-East and East Asia and is recognised to harbour virus Pool 1 consisting of FMD virus serotypes O, A and Asia 1. Brunei, Indonesia, Singapore, East Malaysia and, most recently, the Philippines are currently classified as FMD free without vaccination. The disease, however, persists in Cambodia, People's Republic of China, the Lao People's Democratic Republic, peninsular Malaysia, Myanmar, Thailand and Vietnam (8, 9, 15).

Foot and mouth disease exerts severe economic impact on affected countries, particularly on the livelihoods of rural farmers, who are the predominant livestock owners in South-East Asia. Farmers from southern Cambodia, for example, reportedly experienced an average post-FMD loss of between USD 216.32 and USD 370.54 during the 2010 FMD outbreak (20). In Laos, it was estimated that farmers in unvaccinated villages incurred losses of as much as USD 52.4–70.8 per cow or buffalo during FMD outbreaks (16). Although these may appear to be relatively small figures, these losses are a substantial proportion of farmers' income, who earn an average of USD 200–300 per harvest cycle of about three to four months (2).

Moreover, FMD in this endemic region continues to pose a threat to neighbouring regions, particularly countries free from FMD. Serotypes originating from mainland South-East Asia were implicated in the recent incursion of FMD serotypes A and O in previously FMD-free Japan and Korea (14), which resulted in massive culling and impediment to trade in both countries. Korea reported an estimated loss totalling USD 3 billion, including

USD 1.8 billion in compensation (11) while Japan also lost billions of dollars with 290,000 animals destroyed in the 292 outbreaks confirmed (12).

Foot and mouth disease has proven difficult to control, given its highly infectious nature, its antigenic complexities, and the dynamic animal movement in the region. In 1994, recognising FMD as a high-priority disease requiring coordinated effort to control, the World Organisation for Animal Health (OIE) created the OIE Sub-Commission for Foot and Mouth Disease in South-East Asia (SEAFMD) (9). Over the years, SEAFMD has grown to include all ten ASEAN countries (Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam) and were subsequently joined by the People's Republic of China to become what is now known as SEACFMD. The FMD control plan in South-East Asia (SEACFMD campaign) seeks to coordinate animal disease control activities between countries, provide technical advice, ensure coherent regional strategies and enlist political and resource support to achieve its stated objectives.

The SEACFMD Campaign, which formally started in 1997, has seen a long history of coordination in the fight against FMD in the region. Phase I of the SEAFMD (South-East Asia FMD Campaign), from 1997 to 2001, saw the establishment of networks with Member Countries and the development of national FMD programmes. Phase II from 2002 to 2005 focused on setting up a progressive zoning approach and advancing the implementation of surveillance, public awareness campaigns, strengthening networks engaging the industry and private sector and involving the Association of South-East Asian Nations (ASEAN) in the campaign. Phase 3 (2006–2011), the consolidation phase, brought forth an agreement to a strategy for FMD freedom with vaccination in participating countries by the year 2020. Phase 4, which started in 2011, introduced the revised SEACFMD 2020 roadmap, taking into account lessons learned from previous phases, the needs of new members, scientific developments and the changing socio-economic patterns that will impact on disease control activities, not only for FMD, but for other emerging infectious diseases including zoonoses. SEACFMD is guided by the SEACFMD Roadmap 2020 (19), which indicates a clear, directed strategy towards FMD control in the region and focuses on:

– decreasing the incidence and prevalence of FMD by targeted activities in endemic countries combating FMD at source and along the risk movement pathways at critical control points;
– progressive zoning approach; and
– protection of currently FMD-free zones through quarantine and movement management at zone or country borders (SEACFMD Campaign, 2011).

Gleeson (9) provided a review of the status of FMD in South-East Asia, covering the period from 1996 to 2001. To provide an updated overview of the present FMD situation in the region covering the ten years that followed (2002–2011), annual reports from Member Countries were reviewed along with those data from OIE WAHID, SEACFMD database and ASEAN Regional Animal Health Information System (ARAHIS) (www.arahis.oie.int/). Laboratory data from the FMD Regional Reference Laboratory (RRL) in Pakchong Thailand and the World Reference Laboratory for FMD (WRLFMD) were also utilised. Select scientific publications relevant to FMD in the region were also reviewed and integrated. Extracts from endorsed recommendations from the OIE Sub-Commission meetings, consultation papers, strategic planning sessions and sections from the SEACFMD Roadmap 2020 were utilised to present a concise summary of the SEACFMD control initiatives and plans for the region.

FMD status in South-East Asia (2002–2011)

The Philippines was officially declared FMD free without vaccination in 2011, and, in addition to Brunei Darussalam, Indonesia and Singapore, became the fourth country to achieve FMD freedom in the region. The disease, however, remained endemic in seven of the 11 SEACFMD Member Countries (Cambodia, China, Laos, Malaysia, Myanmar, Thailand and Vietnam), where outbreaks were reported every year for the last ten years (2002–2011). A total of 6,472 outbreaks were reported in the region (Table I).

Reflective of the progressive development and accessibility of laboratory technology over the years and the variable strengths of Veterinary Services in each country, the available serotyping and phylogenetic data vary throughout the region. Overall, serotyping was done in 46.9% of the reported outbreaks, revealing that, as in the past, O (Table II), A (Table III) and Asia 1 were the only three virus serotypes present in the region. This also indicates that these types continue to co-circulate in South-East Asia and no new serotype has thus far intruded. Type O continues to predominate and comprises 82.7% of the typed FMD outbreaks (n = 3,033) followed by type A (15.7%). Asia 1 is the least commonly detected among the three serotypes (1.7%)

Table I
FMD outbreaks in SEACFMD Member Countries, by year and by serotype

Year	A	Asia1	O	Unknown	Total
2002	58		76	232	366
2003	124		125	391	640
2004	75		84	354	513
2005	60	15	82	172	329
2006	59	17	1,445	278	1,799
2007	6	8	135	74	223
2008	19	3	223	111	356
2009	42	8	124	207	381
2010	6		184	458	648
2011	26		29	1,162	1,218
Total	475	51	2,507	3,439	6,472

Data from People's Republic of China start from 2005

Table II
Identified serotype O outbreaks in South-East Asia and China, 2002–2011

Country	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total
Cambodia					3				13		16
China									18	7	25
Laos	10	45	12	1	1	3	8	5			85
Malaysia	1	22	28	28	96	69	125	12	7	2	390
Myanmar	12	1	12	6	43	14	6	12	3	2	111
Thailand	47	57	26	38	4	20	23	17	20	12	264
Vietnam	6		6	9	1,298	29	61	78	123	6	1,616
Total	76	125	84	82	1,445	135	223	124	184	29	2,507

Data from People's Republic of China start from 2005

Table III
Identified serotype A outbreaks in South-East Asia and China, 2002–2011

Country	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total
China								7	2		9
Laos		1			10		1				12
Malaysia		3	4	6		1	2	2		4	22
Myanmar					1				2		3
Thailand	58	120	55	19	31	5	16	9	2	21	336
Vietnam			16	35	17			24		1	93
Total	58	124	75	60	59	6	19	42	6	26	475

Data from People's Republic of China start from 2005

Three topotypes under type O were identified in the last ten years: ME-SA, SEA and Cathay, with concurrent co-circulation of all these three previously observed. ME-SA topotypes were mostly further identified to be of the *PanAsia* lineage, whereas reported SEA were Mya-98. Only topotype Asia, most often of the SEA-97 lineage, is identified for serotype A in the region. No distinct topotype is established for serotype Asia 1.

Observations on these lineages, however, should be viewed with caution, as more supporting phylogenetic data may be needed for these to be conclusive. Nevertheless, it is worth exploring further as this can provide guidance for strategic vaccination campaigns designed to target the disease at source (Fig. 1).

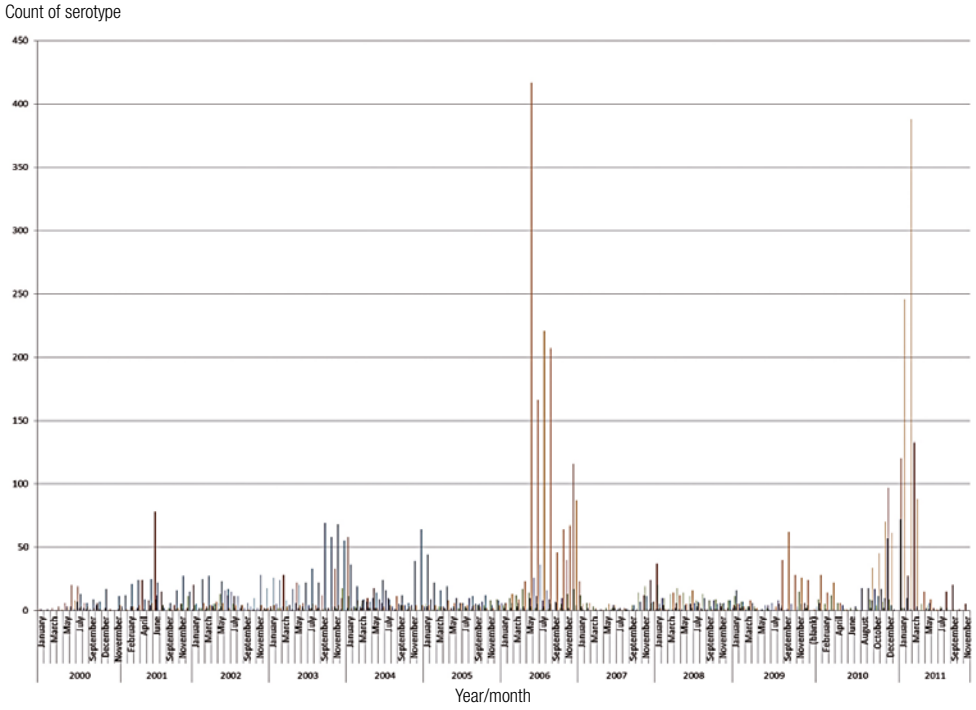

Fig. 1
Monthly FMD outbreaks in SEACFMD Member Countries

O/ME-SA/PanAsia

First identified in Northern India in 1990, the *PanAsia* strain is an emergent sublineage of FMD virus that has spread through southern Asia, the Middle East and Europe. From 1998 to 2001, this virus caused an explosive pandemic in Asia, extending to parts of Africa and Europe, including countries that have been historically free from FMD for decades. It is generally believed that this strain was first introduced in South-East Asia in 1999 and appears to have continued to persist (13).

In the last ten years, *PanAsia* has been frequently identified in outbreaks from the region, particularly from Cambodia, Laos and Vietnam, where, respectively, 71.4%, 64% and 55% of the isolates so far characterised were of *PanAsia* lineage (Table IV). It has also been recognised in outbreaks from China and Malaysia, but not in Myanmar or Thailand, except for one sample from Thailand in 2011.

As shown in Table V, *PanAsia* was recovered in several outbreaks observed in Laos (March 2003 to January 2004), Cambodia (April 2004 to July 2004), Vietnam (July 2004 to August 2005), Malaysia (November 2005 to April 2006) and again in Cambodia (June to August 2006). It should be noted, however, that on most occasions, it is co-circulating with other FMD virus types. Interestingly, after its last recorded recovery in Cambodia in July 2006, *PanAsia* was not recovered until May 2010, from a pig in Vietnam. A major epizootic followed, extending until the early part of 2011. During this period, *PanAsia* was recovered from Cambodia, Laos and Vietnam. The only other strain found in these three countries was Mya-98, recovered from outbreaks north of Vietnam and Laos around the first quarter of 2010 and before the wave of the *PanAsia* outbreaks. Interestingly, Mya98 outbreaks were also being reported in Malaysia and Thailand during this period. This indicates that the observed 2010/11 epizootic

could actually be two distinct pockets of outbreaks simultaneously occurring in two separate geographic spaces and may imply that, with waning herd immunity, susceptible animals initially become infected with the virus type that persists in distinct parts of the region – in this case, *PanAsia* in Cambodia, Laos and Vietnam, and Mya-98 in Malaysia and Thailand – which can later spread over time given the enabling conditions.

Table IV
Identified topotypes in South-East Asia, 2002–2011

Country	A/Asia	Asia1	O/Cathay	O/*PanAsia*	O/Mya98	Undefined	Total
Cambodia	4			10			14
Laos	6			32	12		50
Malaysia	13		1	8	26		48
Myanmar	1	2			14	1	18
Thailand	33		2	1	51		87
Vietnam	18	6	5	53	8	6	96
Total	75		8	104	111	7	313

Source: OIE WAHIS and SEACFMD databases

Isolated outbreaks of serotypes O/ME-SA/*PanAsia*-2 were detected in Malaysia. To date, no other country in South-East Asia has reported *PanAsia*-2, the last outbreak of which was in 2009 (Fig. 2).

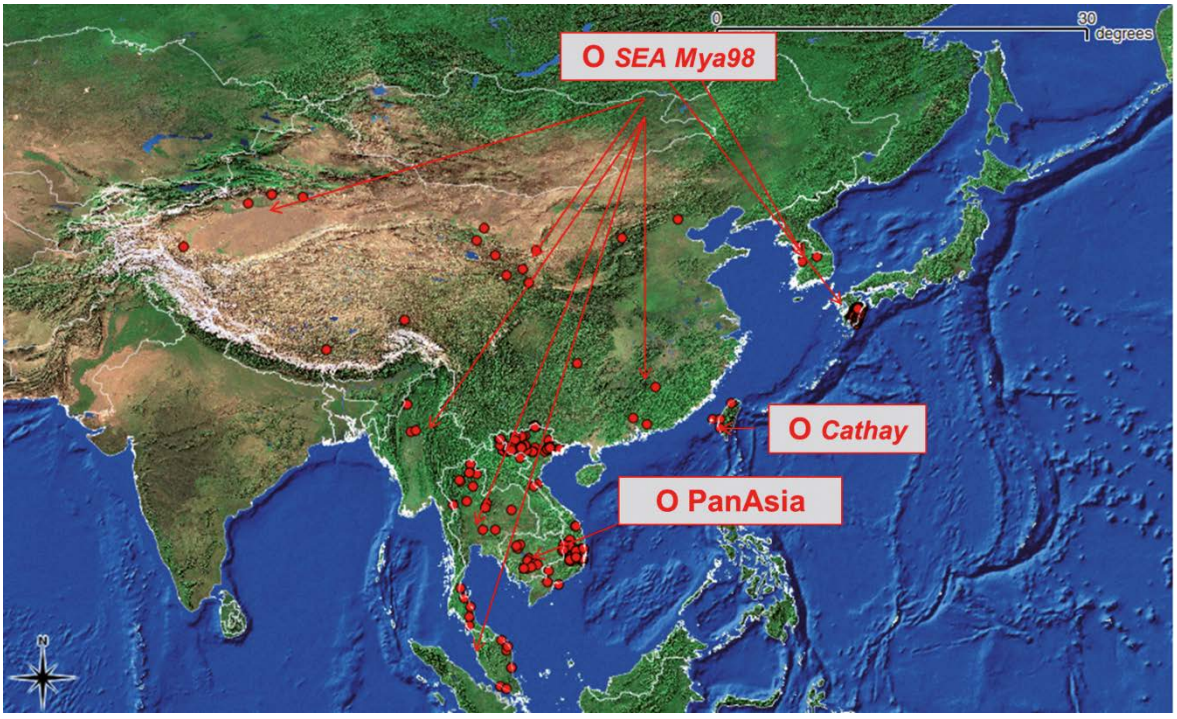

Fig. 2
Serotype O outbreaks in 2010

O/SEA/Myanmar 98

First reported in Myanmar in 1998, Mya-98 appears to consistently cause outbreaks in the region, particularly in Malaysia, Thailand and Myanmar, where this strain has been identified almost every year for the last ten years. This FMD virus type has also been found in FMD outbreaks in China, Laos and Vietnam, but has never been reported in Cambodia, perhaps largely because of that country's limited number of sample submissions.

Mya-98 was recovered, occasionally along with other FMD virus types, during the following observed epizootics in South-East Asia (Table V):

– Laos (November 2007 to January 2008)

– Malaysia (November 2005 to April 2006), (August 2007 to February 2009) (November 2009 to April 2010 and September to December 2010)

– Myanmar (April to October 2006)

– Thailand (July 2008 to February 2009)

– Vietnam (January to December 2006)

Although simultaneous co-circulation with other strains was notable, Mya-98 was attributed to the major epizootic in 2006 and was recovered in Vietnam, Malaysia and Myanmar. In between these major surges, however, Mya-98 was consistently found in outbreaks in Myanmar, Thailand and Malaysia. Mya98 strongly predominates the few characterised FMD virus types in Myanmar, with 77.8% (14/18) of its isolates classified as Mya98. Likewise, Thailand and Malaysia had 58.6% (51/87) and 54.2% (26/48), respectively, isolates classified as Mya-98, (Table IV)

Table V
Observed outbreak clusters in South-East Asia, by country (2002–2011)

Country	Overall average reported number of outbreaks/ month	Observed outbreak clusters	Average number of outbreaks/month for this period (reported serotypes)		Recorded FMDV types during this period
Cambodia	4.4	April–August 2002	10.4	(None identified)	–
		April–July 2004	10.5	(None identified)	O/ME-SA/ PanASia
		June–August 2005	8.7	(None identified)	-
		June–August 2006	26.0	(Serotype O)	A/Asia O/ME-SA/ *PanAsia*
		September 2010 to February 2011	28.5	(Serotype O)	O/ME-SA/ *PanAsia*
Laos	8.0	March 2003 to January 2004	13.4	(Serotypes A, O)	A/Asia O/ME-SA/ *PanAsia*
		November 2006 to January 2007	59.7	(Serotypes A, O)	A/Asia
		November 2007 to January 2008	24.3	(Serotype O)	O/SEA/Mya98
		December 2010 to March 2011	144.3	(None identified)	O/ME-SA/ *PanAsia*

Country	Overall average reported number of outbreaks/ month	Observed outbreak clusters	Average number of outbreaks/month for this period (reported serotypes)		Recorded FMDV types during this period
Malaysia	4.1	December 2003 to January 2004	14.5	(Serotype O)	–
		November 2005 to April 2006	10.6	(Serotype O)	O/ME-SA/ *PanAsia* O/SEA/Mya 98 O/Cathay
		October 2006 to February 2007	10.6	(Serotypes A, O)	A/Asia
		September 2007 to February 2009	11.0	(Serotypes A, O)	A/Asia O/SEA/Mya98
		November 2009 to April 2010	8.2	(Serotype O)	O/SEA/Mya98
		September 2010 to December 2010	7.3	(Serotype O)	O/SEA/Mya98
Myanmar	1.8	May 2002 to September 2002	7.0	(Serotype O)	–
		February 2004 to July 2004	5.0	(Serotype O)	O/SEA
		April 2006 to October 2006	8.3	(Serotype O)	O/SEA/Mya98
Thailand	10.2	October 2001 to June 2002	17.8	(Serotypes A, O)	–
		November 2002 to June 2004	28.9	(Serotypes A, O)	–
		November 2004 to April 2005	34.0	(Serotypes A, O)	–
		July 2008 to February 2009	13.0	(Serotypes A, O)	A/Asia O/SEA/Mya98
Vietnam	2.9 (before 2006)	February 2002 to May 2002	5.8	(Serotype O)	–
		January 2004 to March 2004	4.0	(None identified)	–
		July 2004 to August 2005	4.6	(Serotypes A, O)	A/Asia O/*PanAsia* O/Cathay
	39.7 (after 2006)	January 2006 to December 2006	110.5	(Serotypes A, O)	Asia 1 O/Cathay O/Mya98
		September 2010 to March 2011	133.0	(Serotype O)	O/Mya98 O/Panasia

Recently, along with type A, Mya-98 was implicated in a series of major outbreaks in East Asia, including Japan and Korea, which were previously recognised as FMD free. Sequence data show very close relationships with the FMD viruses isolated from mainland South-East Asia during the same period (14).

O/Cathay

The appearance of pig-adapted Cathay O topotype in mainland South-East Asia, which seems distinct from those contemporaneously found in the Philippines or Hong Kong, has been suggested to be brought about by movement of pigs or pork across the Chinese border into North Vietnam (8). In the last ten years, Cathay was identified mainly in Vietnam (2005, 2006, 2008) but has also been reported in Thailand and Malaysia in 2005. It

has been found to be co-circulating with other type O and type A FMD viruses recovered from outbreaks noted in 2004–2005 in Vietnam, 2005–2006 in Malaysia, and again in 2006 in Vietnam. It was last detected in the region, in Vietnam, in 2008.

A/Asia

Among the seven recognised FMD virus serotypes, serotype A is considered to be antigenically and genetically one of the most diverse strains. Type A appears to have caused widespread outbreak in Thailand in 2003, also affecting Laos and Malaysia, and subsequently Vietnam. After this initial surge, type A FMDV appears to have persisted in Thailand and is now recognised to be the predominant strain in the country to date. A total of 37.9% (33/87) of characterised isolates from Thailand were classified as type A/Asia, which comprise 44% of the total type A/Asia identified in South-East Asia. Malaysia also appears to have progressively increasing recovery of type A, with more than 61% of its type A identified since 2005 being recorded in the last two years (2011–2012).

Myanmar has a single type A isolate reported in 2010 from Maungdaw, Rhakine, located near the border of Bangladesh. This isolate is genetically different from the type A from South-East Asia; it was found to be related to a type A isolate from India in 2000. No other type A has been reported from Myanmar since then, suggesting that this could be a possible single intrusion from a neighbouring country that did not further progress given the nature of the mountainous terrain in the region.

As shown in Table V, from 2003, type A/Asia has been sequentially recovered in pulses in Laos (March 2003 to January 2004), Vietnam (July 2004 to August 2005), Cambodia (June to August 2006) and again in Lao (November 2006 to January 2007), then in Malaysia (October 2006 to February 2007 and September 2007 to February 2008) and Thailand (July 2008 to February 2009). It should be noted, however, that other co-circulating strains also exist during these periods. Interestingly, however, during gaps between these epizootics, type A is consistently found in Malaysia and Thailand. It appears that the rise in observations of type A in Malaysia and Thailand in 2012 could be the cycles following major type A outbreaks in these countries after 2004 and 2008. The type A/Asia/Sea-97 FMD outbreaks in China in 2009 and South Korea in 2010 were attributed to this serotype, believed to have been introduced from South-East Asia (14).

Asia 1

First detected in 1951, this serotype is unique to Asia and appears to be endemic in the Indian subcontinent (4). Molecular analysis of this virus showed six distinct groups within this serotype, with outbreaks in China attributed to two groups that appear to be capable of spreading across large distance between countries in Asia in a short period of time (18).

Asia 1 accounts for only a small proportion of FMD outbreaks in South-East Asia, where serotypes O and A predominate. From 2002 to 2011, only 1.7% of the recorded FMD outbreaks in the region were attributed to Asia 1, most of which were reported by China, which had its last Asia 1 outbreak in 2009. Myanmar and Vietnam are the only two other countries that detected Asia 1, which was last seen in 2005 and 2006, respectively (Table VI). Asia 1 viruses from Yunnan China and Vietnam in 2005 and 2006 were found to belong to group IV, which appeared to be related to viruses originating from Thailand in 1998 and Myanmar in 2005 (18). The World Reference Laboratory reported that, although limited in circulation and there have been no reports since 2010, a total of 69 isolates of Asia 1 were recovered in 2010 from Afghanistan, Bahrain Pakistan, Iran and Turkey (10). A concern raised was that vaccine-matching studies show that these recent isolates appear to respond poorly to the vaccine strain Asia1 Shamir, and this is now being monitored closely by the WRLFMD (10).

Table VI
Identified serotype Asia 1 outbreaks in South-East Asia and China, 2002–2011

Country	2005	2006	2007	2008	2009	Total
China	10	17	8	3	8	46
Myanmar	3					3
Vietnam	2					2
Total	15	17	8	3	8	51

Data from People's Republic of China start from 2005

Animal movements in South-East Asia

In South-East Asia, the distribution of FMD outbreaks correlates with the movement pathways of livestock (2, 8, 9) and has been considered as the main risk factor for FMD spread.

Patterns of animal movement change over time, with livestock generally moving along the existing price gradient from low towards higher market prices, as influenced by the population density and consumer demand. In the greater Mekong area, cattle move over large distances in short periods with transport, trading and delivery of animal stocks from one country to another taking place in as briefly as less than 24 hours and at about 700 times in a year. The nature of the disease, the relative porosity of cross-country borders, and the inherent difficulty in managing such dynamic movements have all contributed to the persistence of FMD outbreaks in the region.

Myanmar has the highest number and the lowest price of cattle and buffalo in the sub-region, leading to a significant export flow, particularly into the Malaysia–Thailand–Myanmar (MTM) peninsula (6). Because of this and the persistence of FMD in the country, particularly O/SEA/Mya98, Myanmar may be considered a key country in terms of regional epidemiology and spread of FMD virus.

Laos may be described as an importer and transit country for large ruminants. While the country produces cattle and buffalo, the level of production is not sufficient to meet the demand of the domestic market. In addition, the trade attraction towards Vietnam, where prices are higher, also draws animal resources away from the domestic market (6). Other than this, Laos is also made vulnerable to further incursions of FMD as it is a major thoroughfare for transboundary livestock movement and trade, sharing borders with Cambodia, China, Myanmar, Thailand and Vietnam (16). The highest volume of cross-border movement of livestock into and out of Laos involves the transit of livestock from Thailand to Vietnam.

Cambodia is an exporter and a transit country for large ruminants within the Greater Mekong Sub-Region. Because the demand within the country is generally met by domestic production, there is little demand for importation into Cambodia (6). It is, however, an importer of pigs from Vietnam and Thailand, but importation bans have been imposed in recent years, changing the pig population dynamics within Cambodia. Cambodia also acts as a conduit for cattle and buffalo moving from Thailand to Vietnam.

Vietnam is a major consumer of livestock products and, with its higher prices, attracts livestock from various neighbouring countries (6). It is also a major producer and exporter of pigs and pig products to Laos, Thailand, Malaysia, China and Cambodia (3). Cross-border movement of livestock in Vietnam is dominated by unofficial movements. The livestock movement from Vietnam to China has also driven increased importation into Vietnam from Laos, Cambodia and Thailand (6).

China has recently become a major livestock consumer, and importer, in the region. In previous years, China supplied cattle to its neighbouring countries, but owing to the increased discrepancy between supply and demand in China, importation has become necessary to meet the demands of the population (6). In 2011, cross-border animal movement in Yunnan was investigated and it was found that pigs from Chiangsaen Port, Thailand, via the Mekong River, were being shipped to Su Lei port, Myanmar, and then loaded by truck to Jinghong, Yunnan. Pigs from Vietnam also go to Guangxi and then to Yunnan. There are three main unofficial cattle movements routes found from South-East Asia: two land routes crossing forests and one water route via the Mekong River. Modelling studies show that China is now facing a very high risk of FMD from South-East Asia, especially from the latter route (5).

Thailand produces cattle believed to be almost sufficient to meet the demands of its population. However, each year, there remains a high volume of cattle and buffalo movement into Thailand, from Myanmar, driven by the demand of Thailand's neighbouring countries: Malaysia, Cambodia and Laos (for transit into Vietnam) and China (7). The main stakeholders identified within the trade and marketing network of livestock in Thailand include private quarantine stations; livestock markets; traders; livestock agents, middlemen and transporters; feedlots; and farmers. The highest density of markets is in the North and North-East of Thailand, where the livestock population is also greatest. There are no livestock markets officially operating in Southern Thailand (MTM zones), and, similarly, there is a relatively low population of livestock in this area (7). Thailand is also a major producer of pigs in the region.

Malaysia has the lowest livestock population and high consumer demand, leading to higher prices, and, hence, movement of animals towards the country (3). It is thus vulnerable to the introduction of infected animals, which is reflected in the variety of strains recovered from outbreaks in the country throughout the years. For 2003–2009, *PanAsia*-2 caused outbreaks in Malaysia. Although widely spread in Southern Asia and the Middle East, this strain, apart from those isolated from Malaysia, has never been recovered in its neighbouring countries. This indicates,

as supported by sequence data, that a single introduction from South Asia must have taken place but never spread beyond Malaysian borders, because Malaysia is generally not a livestock exporter but an importer (1).

Documented and potential contributing factors to FMD spread in South-East Asia

As elucidated earlier, trade of animals and animal products is the most commonly considered source for FMD virus cross-border entry. Although the balance between supply and demand remains the major factor influencing the direction and volume of livestock movement (Cocks *et al.*, 2009), other contributing factors have also been implicated to play a role in livestock movement and, hence, that may foster the emergence and spread of FMD (Fig. 3).

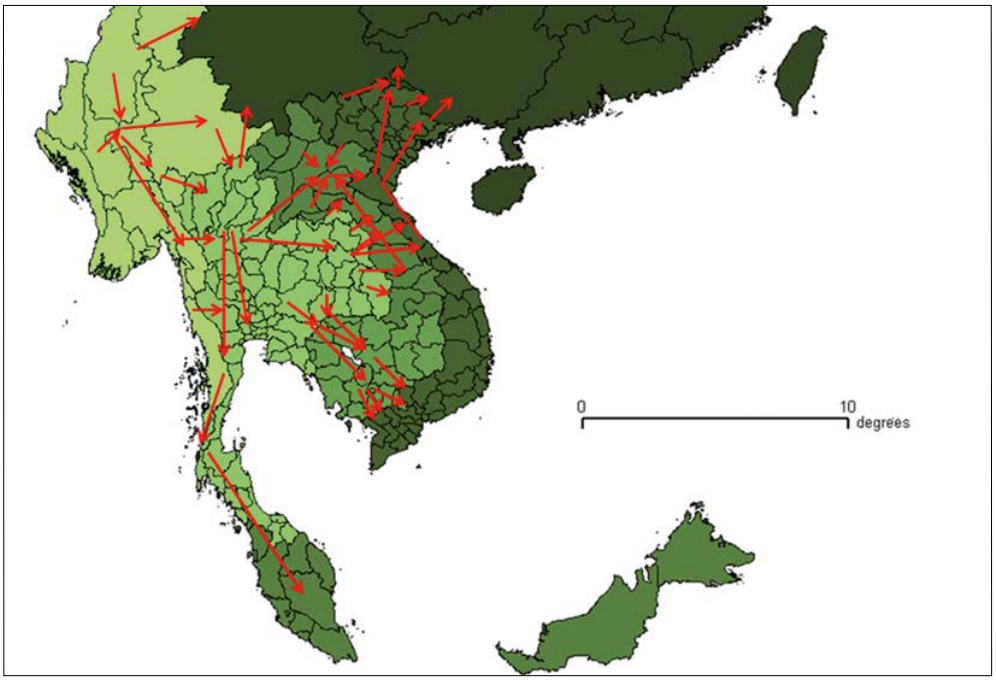

Fig 3.
A summary of cross-border movement pathways of large ruminants in South-East Asia showing movements of live animals (arrows) and relative price of large ruminants in each country (lighter shading represents lower price and darker shading higher price)

Reproduced from Cocks *et al.* (6, 7)

Changing socio-political landscape

In the early 1990s, mechanisation of farming in China resulted in the selling of draft animals to SEA. This was, however, reversed towards the end of the decade, when increased prosperity and protein demand spurred animal movement into China from South-East Asia (17). Increased discrepancy in supply and demand in China has recently directed animal movement from Vietnam to China and has also consequently driven increased importation into Vietnam from Laos, Cambodia and Thailand (5, 6, 7).

Special events stimulating trade

Increased movement of animals from SEA northwards was particularly evident in 2008 with the increased demand for cattle in China during the Beijing Olympics in 2008. This event was hypothesised to be the possible reason for outbreaks of serotype A in China the following year, the isolates of which were confirmed to be closely related to those circulating in SEA (3).

Introduction of new policies

In Cambodia, the introduction of the Rice Policy, which calls for a substantial increase in rice production, predicts an increase in mechanisation and surplus of rice by-products. A potential shift in cattle utility from draft to beef production is thus predicted for Cambodia. Given the relative porosity of its borders, this is foreseen to likely further compound FMD control in the country.

Changing weather patterns

Flooding of the Mekong River, which now occurs every two to three years, often results in the aggregation of people and their animals on higher lands. Rapid transmission of FMD at such times is common, and often it spreads further as animals return to the villages when the flooding recedes (17). Interviews with farmers in Sagaing, a dry region in Myanmar, also indicated that many of them sell their draft animals when the dry season lasts longer than usual because their planting season is largely dependent on rainfall. Delay in planting means no income and drained savings, and untimely trading of animals.

Increased accessibility to communication devices

Animals are often sold by price gradient within the region. Previous areas which were difficult to reach, and therefore were limited in becoming part of the market chain, are now made more accessible via mobile phones. The availability of affordable communication devices has facilitated buying, selling and closing deals, and possibly even promptly avoiding authorities. Small-scale middlemen and traders have become capable of even cross-border transactions that may involve shipping animals by the truckloads or (boatloads).

SEACFMD disease control strategies

The SEACFMD 2020 Roadmap was revised accordingly to adapt to the evolving social, economic, political and resource landscape in the region, recognising the need to reduce the incidence of FMD in the region whilst continuously supporting and facilitating trade. The key strategies for FMD control in the region include the following: (1) combating FMD at source and along the risk movement pathways at critical control points; (2) establishing, and subsequently expanding, control zones where FMD incidence and likelihood of recurrence have been effectively reduced; and (3) protecting zones that are currently FMD free through focusing on quarantine and movement management at zone or country borders.

Critical control points are areas considered to have an increased potential for transmission of infectious diseases, such as FMD. Critical control points are those wherein control can be exercised to prevent, control or eliminate infection (SEACFMD Roadmap, 2012). For example, the study by Cocks *et al.* (6, 7) on cross-border movement and market chains of large ruminants and pigs in the Greater Mekong Sub-Region (GMS) identified critical points that can be potential targets for interventions measures: (1) livestock markets in Thailand and Myanmar; (2) storage depots for import and export livestock and trading companies in Cambodia; (3) storage and transaction areas for all import and export livestock in Laos, as well as slaughterhouses, and locations where there is a geographical concentration of livestock traders; (4) livestock markets in Vietnam and border areas where livestock enter, such as Lao Bao, Cha Lo and Nghe An; and (5) livestock transportation companies and vehicles in all countries.

Components of FMD control

To effectively operationalise these SEACFMD 2020 strategies, the following components for FMD control were also identified. These include:

– Strengthening technical activities, which involves rapid identification of the foci of infection, prevention of infection of susceptible hosts, elimination of the source of FMD, and increasing herd and animal immunity to FMD.

– Intensifying advocacy for stakeholder and political support, which involves mobilising stakeholder and public support, political support and financial support, to which cross-cutting activities on animal health communication, socio-economic research and resource network should provide guidance and reinforcement;

– Refining and operationalising coordination mechanisms that are capable of coordination, implementation and monitoring of FMD control activities at various levels.

With this direction, the SEACFMD continues its work with countries and other partners. Priorities have been placed on addressing the disease at source, which will involve the identification of FMD hotspots, strategic vaccination, animal movement management and quarantine and disinfection. Alongside this will be continued engagement of stakeholder and public support, political support and financial support, to which cross-cutting SEACFMD activities on animal health communication, socio-economic research and resource network shall provide guidance and reinforcement. Finally, SEACFMD will continue its work on reinforcing and improving existing organisational mechanisms for functional coordination and implementation of FMD control programmes in individual countries and the region as a whole.

SEACFMD will continue to utilise and be guided by existing tools such as: (1) Progressive Control Pathway (PCP); (2) Performance of Veterinary Services (PVS) Pathway; (3) Animal Health Communication Plan for South-East Asia; (4) Minimum Standard Definitions And Rules For Control And Eradication Of Foot And Mouth Disease In The MTM Peninsular Campaign For Foot And Mouth Disease Freedom; and (5) the National FMD Plans of SEACFMD Member Countries. Available, albeit limited, resources to operationalise these SEACFMD strategies include resource support from the EU-HPED Vaccine Bank for FMD in South-East Asia and the AusAID-funded STANDZ initiative.

The EU-HPED Vaccine Bank for FMD in South-East Asia

Recently, the EU-HPED-supported FMD Vaccine Bank in South-East Asia has become operational. The vaccine bank is a virtual rolling stock of vaccines provided by the supplier, Merial SAS, to its least developed Member Countries based on their requirements. It aims to support targeted emergency vaccination in:

1. buffer zones around FMD-free zones;
2. well-defined areas that are at risk of FMD resurgence;
3. hotspots where vaccination will contribute to reducing the risks of FMD; and
4. areas where exceptional circumstances exist that merit consideration of Vaccine Bank supplies.

Priority is given to developing countries with the lowest gross domestic product (GDP) within the region that have no immediate access to vaccines. Applying countries will have to provide justification for the need for vaccines and information on the logistical, financial and administrative framework. Utilising this now accessible support through the SEACFMD, Laos has initially received 200,000 doses of FMD vaccines for its vaccination campaign in four 'hotspot' provinces in the north of the country. Myanmar has also received 200,000 doses of FMD vaccines for its vaccination campaign in Sagaing and Thanintaryi regions. An application from Cambodia is also currently under way.

The AusAID Stop Transboundary Animal and Zoonoses Small Grants Facility

The OIE Sub-Regional Representation for South-East Asia (SRR-SEA) has established the Small Grants Facility (SGF) under the regional Stop Transboundary Animal and Zoonoses (STANDZ) initiative. This AusAID-funded initiative of AUD 12.7 million aims to reduce the impact of emerging infectious diseases, transboundary animal diseases and zoonoses on food security, human health and livelihoods in South-East Asia over five years (2011–2015). The SGF allows OIE and selected Member Countries to identify and implement priority areas that will contribute to progress towards the STANDZ objectives. This includes interventions that:

1. respond to the Performance of Veterinary Services (PVS) Pathway Strategic Plan by addressing identified needs;
2. implement new aspects of disease control promoted in any of the OIE policies, guidelines or standards; and
3. trial effective approaches to FMD and rabies control in the South-East Asia context that can inform the further development of evidence-based OIE policy or advice to the region.

SGF has been used to complement the provisions of the Vaccine Bank, which covers only the cost of vaccines and its delivery to the port of entry of the applying Member Country. In Laos and Myanmar, for example, parallel to the Vaccine Bank provision, SGF has been utilised to support operational costs of their vaccination campaigns. There are other approved SGFs, however, that have been utilised to fill other recognised gaps in FMD control. Vietnam, for example, has recently received grants to support studies on hotspots and the socio-economic impact of FMD in select provinces.

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Virus Pool 2 – South Asia

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Summary

Demand for livestock products in South Asia, host to over 800 million head of livestock, is expected to double by 2030. Foot and mouth disease (FMD) presents a major health challenge, compromising livestock production in the region. South Asia falls into FMD virus Pool 2, with the prevalence of genetically diverse serotypes O, A and Asia 1. Sri Lanka has recorded only type O for more than ten years now. Maldives is free from FMD. In other South Asian countries serotype O is the most prevalent, followed by Asia 1 and A. India, Bangladesh and Nepal share similar FMD virus genotypes, while the virus genotypes present in Pakistan and Afghanistan are related to those present in Western Euro-Asia region. FMD causes significant losses in the smallholder dairy sector in the region, impacting on livelihoods and food security. A number of national initiatives exist for FMD control. The South Asian Association for Regional Cooperation (SAARC) Regional Support Unit (RSU), supported by the Food and Agriculture Organization of the United Nations (FAO) under the FAO/World Organisation for Animal Health (OIE) Global Framework for the progressive control of Transboundary Animal Diseases (GF-TADs) initiative, is coordinating these efforts through regional roadmaps, and establishment of regional and national networks of diagnostic laboratories. The FMD status of the countries has been determined through a self-assessment process using the Progressive Control Pathway. The coordinated and concerted regional FMD control under the RSU needs to be sustained for addressing not only FMD, but also high-impact diseases. The benefits of these efforts are well recognised given the tremendous socio-economic and food security impacts of the disease in South Asia.

Keywords
FAO – FMD – Food and Agriculture Organization of the United Nations – Food security – Foot and mouth disease – GF-TADs – Global Framework for the progressive control of Transboundary Animal Diseases – Livelihoods – Livestock – Regional Support Unit – Serotypes O, A and Asia 1 – South Asia – Virus Pool 2.

Introduction

South Asia is one of the largest livestock-producing regions in the world. The geographical region includes eight countries, namely Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka, and hosts over 800 million head of livestock comprising cattle, sheep, goats, pigs and camels. The agricultural production in the region, which represents between 24% and 30% of the total gross domestic product (GDP), is mainly driven by poor smallholder farmers. Livestock production in such a system is highly significant as it represents a regular source of income, and generates high-quality protein and micro-nutrients, supporting livelihoods and nutritional and food security. A number of factors, including population growth, economic development and rapid urbanisation of the human population in the region, are expected to double the demand for livestock products, such as milk and meat, by 2030. To meet this challenge, the efficiency of livestock production will have to be significantly improved. Foot and mouth disease (FMD) represents one of the most important challenges compromising livestock production in the region. This paper describes the FMD burden in South Asia in the

context of the current socio-economic situation and the livestock sector, and also identifies current initiatives and developments in addressing this important socio-economic problem.

South Asia

The South Asia region, comprising 2.5% of global land mass, is home to almost one-quarter of the human population, making it the most populous and densely populated geographical region in the world. Despite strong economic growth in the region over the last 20 years, the region continues to host the largest concentration of poor in the world with more than 500 million people living below the poverty line (11). Child malnutrition rates are among the highest in the world and the rapid growth in wealth has failed to make commensurate impact on social indicators, especially those related to human health. Within the region, India is the largest country, accounting for 73.25% of geographical area and 75% of human population. Measured by overall GDP, the Indian economy is the fourth largest in the world, but the per capita income is among the lowest, at less than US$ 150. All the countries fall into the low-income category, with per capita income ranging from less than US$ 540 in Nepal to US$ 2,580 in Sri Lanka. In purchasing power parity terms, the income ranges from US$ 830 in Nepal to US$ 2820 in Sri Lanka.

Livestock and livelihoods

Human and livestock population density varies from 46 to 975 and 14 to 180 per square kilometre, respectively. The livestock farming systems in the region are predominantly based on raising ruminants and, except for the Maldives, livestock represents an important part of the agriculture sector in the region. The linkage between poor people's livelihoods and livestock production is perhaps stronger in South Asia than in any other region of the world. The region hosts more than 27% of the world's cattle and buffalo and about 25% of the world's sheep and goats (Table I), and a large majority of these are on small agricultural farms and in small herd sizes. For example, in India, more than 55% of cows and buffalo and more than 60% of sheep are on farms of less than two hectares. Similarly, in Bangladesh, 58% of cows, 68% of sheep and goats and 67% of poultry birds are on farms of below one hectare and provide significant proportion of livelihoods. Overall, livestock ownership in the region supports and sustains an estimated 235 million rural poor. For these people, livestock provides a steady stream of food and revenues, helps to raise whole farm's productivity and creates employment opportunities beyond the immediate household. Livestock is often the only livelihood option available to the landless as it allows the exploitation of common property resources for private gain. In addition, livestock is often the only means of asset accumulation and risk diversification that can prevent a slide into abject poverty by the rural poor in marginal areas. These characteristics make the livestock sector one of the most livelihood-intensive sectors in the region and any gains from enhanced livestock production would potentially have a far more direct and significant impact on poverty reduction.

Table I
Livestock population in million heads in South Asia: selected species

Region/country	2000			2010		
	Cattle and buffalo	Sheep and goats	Pigs	Cattle and buffalo	Sheep and goats	Pigs
World	1,479.00	1,811.00	898.00	1,622.00	2,000.00	966.00
South Asia	378.00	399.00	14.40	439.00	490.00	10.80
India	286.00	183.00	13.40	322.00	228.00	9.60
Pakistan	44.70	71.50	0.00	65.10	87.70	0.00
Bangladesh	23.20	35.20	0.00	24.40	66.80	0.00
Afghanistan	2.90	22.30	0.00	4.70	18.00	0.00
Nepal	10.50	7.00	0.90	12.00	9.60	1.10
Sri Lanka	1.45	0.50	0.07	1.60	0.38	0.08
Other	9.30	79.30	0.03	9.20	79.50	0.02

Source: FAOSTAT.

Production and consumption trends

Livestock production in South Asia is orientated more towards production of milk and draught power. The region's share of total meat production ranged from 3% to 4% between 1980 and 2000. Over the last decade, there appears to be some acceleration in meat production but the share is still below 5%. In milk production, the region has made significant progress. The production has grown between 4% and 5% annually compared with around 1% for the world as a whole. As a result, the share of South Asia in world milk production has more than doubled over the last three to four decades. Average milk productivity has also risen considerably from approximately 400 kg per animal in 1980 to about 725 kg in 2010, but it is still far below the world average and that of the major producers of the world. It must be recognised, however, that the role of livestock in South Asian economies goes beyond milk production. Indeed, in areas with low levels of farm mechanisation and poorly developed markets, milk may not be the primary reason for farmers to keep livestock. In many parts of the region, for example, a bullock is a much more valued animal than an indigenous cow. In addition, when compared with other countries at comparable income levels, the milk productivity of India and Pakistan falls significantly above average. The numbers on milk productivity need to be interpreted with this background in mind. Less than 20% of per capita protein consumption in the region is animal based compared with 37% of the world as a whole; nevertheless, increases in income have continued greater demand for livestock products. According to some forecasts, per capita consumption of milk and meat in the region is expected to rise by 65% and 75%, respectively, between 2009 and 2050 (5).

The socio-economic burden of disease on livestock

The need for increased efficiency in livestock production is currently severely restricted by a huge disease burden, which causes considerable economic losses. Multiple impacts due to disease burdens are related to morbidity and mortality, decreased production, reduced fertility, inefficient feed utilisation resulting in inadequate weight gain and impaired draught power. In the context of transboundary animal diseases, FMD is now considered to be the most important infectious disease in the subregion. Although no formal economic impact analyses have been done in South Asia, one recent estimate from India shows that the annual direct loss due to FMD is around US$ 3 billion (6).

At the household level, impacts of FMD can be very severe for poor producers in terms of cost of treatment (which is quite significant), cost of maintaining unproductive animals and loss of output. For poor farmers this can often lead to liquidation of other (already meagre) assets or loss of consumption for their families. Such impacts are more pronounced and perhaps somewhat better documented for dairy animals. However, the impacts of the disease on pigs and small ruminants have not been defined; they are expected to be more severe than commonly understood, particularly on the livelihoods of poor farmers.

Foot and mouth disease situation in the region

In the context of the conjectured global status of FMD virus, the South Asia region falls into virus Pool 2, indicating the prevalence of FMD virus serotypes O, A and Asia 1. Of these, serotype O is most prevalent, followed by Asia 1 and A. The type C serotype has not been recorded in the region since 1995. Sri Lanka has recorded only type O for more than ten years now. FMD is endemic in India with prevalence of serotypes O, A and Asia 1. In India the prevalence of serotype O accounts for about 79.3% of outbreaks, followed by types Asia 1 (13.3%) and A (7.4%) (10). The distribution of serotypes varies from region to region. Circulation of different genotypes/lineages within serotypes O, A and Asia 1 in India was evident in molecular epidemiological analysis based on 1D/VP1 region sequence data. Emergence and re-emergence of genotypes/lineage occur in the field as part of this evolutionary process. In the case of serotype O, seven genetic groups of the virus, designated as branch A, B, C-I, C-II, 'Ind2001', *PanAsia* I and *PanAsia* II, have been identified. Over the last five years, the epidemiological scenario in serotype O has been largely influenced by *PanAsia* and 'Ind2001' strains. In 2011, a new genetic lineage appeared in the southern part of the country with > 9% genetic divergence from contemporary isolates. In the case of serotype A, four genotypes (genotypes 2, 10, 16 and 18) have circulated so far in the country. Endemic co-circulation of genotypes 16 and 18 between 1990 and 2001 has been observed with exclusive presence of genotype 18 in the field since 2001. Within genotype 18, the VP359-deletion group emerged during the latter part of 2002. Currently, both the deletion and non-deletion groups of genotype 18 are circulating in India (9). The

emergence of this group warrants rapid and accurate detection to facilitate early planning and implementation of an effective control policy. Circulations of three lineages (B, C and D) have been identified in serotype Asia 1. Lineage B never appeared after the year 2000. Lineage C was dominantly circulating in India during the period 1993 to 2001. Lineage D appeared in 2001 and it outnumbered lineage C in terms of field outbreaks until 2004. Lineage C has been in circulation in the country since 2005.

The disease is also endemic in Pakistan and occurs throughout the year (1) in all parts of the country. In Pakistan the most prevalent serotypes are O (70%), Asia 1 (25%) and A (4.67%) (2). This trend has continued in 2010 (7). Type C was reported for the first time in 1954 and for the last time in 1995. Phylogenetic analysis of FMD virus serotype O strain, isolated between the years 1997 and 2009, identified three different lineages within the ME-SA (Middle East–South Asia) topotype, namely Pak98, Iran2001 and *PanAsia*, the latter being predominant. Distinct variants such as *PanAsia*-II and *PanAsia*-III are also co-circulating (7). A recent study has shown that the majority of serotype O isolates belong to the *PanAsia*-2 lineage, whereas serotype A virus isolates belong to the Asia topotype. Pakistan's isolates of serotype O were very much similar genetically to the virus circulating in neighbouring countries (Sri Lanka, India, Iran, Iraq and the People's Republic of China) and belong to *PanAsia* 1 lineage (7). Phylogenetic analysis of serotype Asia 1 isolates of 1998–2009 revealed the presence of three different genetic groups circulating in Pakistan, namely group II and VI and a novel group VII. Complete genome sequences of Pakistan serotypes Asia 1 and A isolates revealed inter-serotypic recombination with VP2-VP3-VP1-2A coding sequences derived from a group VII Asia 1 virus and the remainder of the genome from a serotype A virus of the A-Iran05 (AFG-07) sub-lineage. This may be the reason why FMD virus Asia 1, currently circulating (Sindh-08 lineage) in Pakistan and Afghanistan, is not efficiently neutralised by anti-sera of the Asia 1/Shamir vaccine strain.

With respect to FMD distribution in Bhutan, Nepal and Bangladesh, the situation is no different from India and Pakistan. In Nepal, serotype O is the most predominant (76.4%), followed by Asia 1 (15.8%), A (6.5%) and C (1.2%). However, serotype C was detected only during the period 1990–1996. Virus serotyping data from 2001 to 2010 reveal that the prevalence of serotype O is an increasing trend (82%), followed by serotypes Asia1 (15%) and A (3%). Genetic analysis of FMD virus serotype O isolates revealed the prevalence of the ME-SA topotype. In 2003, both *PanAsia* and Ind2001 strains of serotype O were prevalent in Nepal. Likewise, in 2007 *PanAsia*-2 and in 2008 *PanAsia*-2 and Ind2001 strains of serotype O were detected. In 2009 and 2010, only the Ind2001 strain of serotype O was found (Jha V.C., 2012, 'Status of foot and mouth disease and its control strategy in Nepal', unpublished).

In Bhutan, serotype O is the principal FMD virus serotype, consistent with the disease epidemiology in the neighbouring countries. The outbreaks from 1982 to 2008 were caused by serotypes O, A, Asia 1 and C. The last recorded outbreaks of FMD in Bhutan due to serotypes C, Asia 1 and A were in 1991, 2002 and 2003, respectively. The serotyping results between 1982 and 2008 showed that serotype O (70.6%) was the most predominant serotype followed by A (16.7%), Asia 1 (8.8%) and C (3.9%). Since 2004 only serotype O has been detected in Bhutan. Serotype O isolated in Bhutan between 1998 and 2008 belonged to the ME-SA topotype. The *PanAsia* strain of serotype O was detected for the first time in 1998 in samples submitted to the World Reference Laboratory (WRL) in Pirbright, United Kingdom. Thereafter, this strain was detected during the outbreaks of 2002, 2003, 2004, 2007 and 2008 (3, 4).

Genetic characterisation of FMD virus serotype O isolates in Bangladesh recovered in late 2009 revealed the presence of the ME-SA topotype, with two distinct sublineages, one named Ind-2001 and the other unnamed. Within both sublineages, the 2009 Bangladesh isolates were the most closely related to viruses from Nepal collected during 2008 and 2009. Additionally, both sublineages contained older viruses from India collected in 2000 and 2001 (8).

Epidemiology of foot and mouth disease in South Asia

The epidemiology of FMD is defined by the various farming systems in the region and the formal and informal movement of animal within and between countries, and often outside the region. Among the livestock populations of South Asia, FMD is considered to be most widespread in cattle and buffalo, which are used for the production of the bulk of milk. Although formal analysis of the economic impact of these diseases has not been carried out, it is believed that regular outbreaks of the disease is the major reason for loss in milk production in the smallholder dairy sector.

Within all the South Asian countries disease transmission occurs throughout the year in both backyard and small and large commercial dairy units. Although no seasonality has been defined, the outbreaks following rainy seasons are more common. The mortality rate is low among infected animals, but the morbidity rate is very high, in the range of 40% to 60% and sometimes reaching 100%. The disease is particularly devastating in peri-urban large buffalo dairy units present in many cities in India and Pakistan. There is significant formal and informal movement of cattle out of India into Bangladesh and Nepal, and this is reflected in the viruses that are shared among these three countries. The movement of animals between India and Pakistan is limited and most of the virus genotypes present in Pakistan and Afghanistan are related to those present in Western Euro-Asia region. The epidemiology of the FMD viruses in small ruminants and pigs has not been defined, partly because many disease infections in small ruminants and pigs are inapparent. It appears that transmission and spread are related to pastoralists and nomadic people. There is also a significant population of feral pigs in the region that play a role in the widespread dissemination of the virus. The role of small ruminants and pigs in the infection and transmission dynamics of the FMD viruses may be significant and needs to be studied further.

Disease control initiatives in the region

Disease control is sporadic and non-uniform. High-grade animals are routinely immunised, but the total vaccine coverage is less than 10%. Pakistan has a limited donor-funded project that supports the control of FMD through vaccination. While Bangladesh has developed a National Control Strategy, a systematic approach to controlling the disease has not been adopted. Nepal has recently (2012) initiated a control programme in eastern Nepal using the Progressive Control Pathway (PCP) principles. Perhaps the most ambitious and large-scale FMD vaccination programme in the subregion is that recently launched by the Government of India using a zonal approach. The major commitment by the largest country in the subregion for one disease signifies the importance of FMD. The initiative, although much welcomed, needs a larger regional component for it to be successful, as emphasised in the recent (2008) South Asian Association for Regional Cooperation (SAARC) Chief Veterinary Officers' meeting.

Through the Food and Agriculture Organization of the United Nations (FAO)/World Organisation for Animal Health (OIE) Global Framework for Progressive Control of Transboundary Animal Diseases (GF-TADs) initiative and in collaboration with SAARC a regional programme on the control of high-impact diseases has been developed. This programme has supported the establishment of a regional coordination mechanism referred to as the Regional Support Unit (RSU). FMD is one of the priority diseases being addressed through the RSU, and, through a series of consultations with the regional technical representatives and policy makers, a regional plan for the control of FMD is being developed. The RSU has promoted the establishment of regional and national networks of leading diagnostic laboratories for priority diseases including FMD, facilitated countries to embark upon a common PCP for FMD and developed regional roadmaps through technical support from international partners. The RSU is also assisting countries to develop appropriate legislative frameworks to support PCP at country and regional levels. In addition, a number of regional workshops have been organised to enhance laboratory capacity, harmonise minimum standards for national laboratories and agree on common diagnostic methods based on OIE standards for establishing quality assurance methods and proficiency testing programmes.

Currently, through the RSU and the regional laboratory network, the designation of the Project Directorate on FMD (PD-FMD) in India as the Regional Leading Diagnostic Laboratory has been agreed upon and the commitment from the Member Countries to adopt the systematic and structured PCP-FMD approach has been obtained. The FMD status of each SAARC Member Country has been determined through a self-assessment process. Currently, all countries except India consider themselves in PCP-FMD Stage 1. India has claimed to be in PCP-FMD Stage 3. By 2020, Sri Lanka aims to be FMD free without vaccination, while India aims to be FMD free with vaccination, and the remaining countries aim to be in PCP-FMD Stage 3 (elimination of FMD from certain regions and/or sectors).

Conclusions

With the highest number of cattle and buffalo in the world, varying levels of immunity in the population and uncontrolled animal movement and informal trade in livestock and livestock products, the subregion remains a major source of FMD virus. While the ongoing progress and commitment in the region is encouraging, and the adoption of the PCP has provided a structured approach to FMD control, there are still a number of challenges in the region given its complex socio-economic and political geography. The regional cooperation in addressing

high-impact animal diseases through the establishment of the RSU under SAARC needs to be supported financially and politically. The ambitious and well-funded Indian national plan to control FMD provides an important opportunity for the Government of India to take a leadership role in engaging with the SAARC Member Countries and providing technical support and promote a regional approach to FMD control. The coordinated and concerted regional FMD control would ensure long-term sustainability of addressing not only FMD but other priority diseases. The benefits of such an achievement are well recognised given the tremendous socio-economic and food security impacts of the disease in the region.

Acknowledgement

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Foot and mouth disease virus Pool 3 (West Eurasia and the Middle East)

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Summary

West Eurasia and the Middle East are considered the two sub-regions that maintain an independent pool (Pool 3) of related foot and mouth disease (FMD) viruses of serotypes A, Asia-1 and O. Epidemics emerging within the region frequently reach neighbouring countries, as observed in recent years with the O Panasia-2, type A Iran-05 and Asia-1 epidemics. These epidemics extended from Pakistan and Afghanistan to Turkey, with occasional incursions into Central Asian and Middle East countries including Israel and, on two occasions, Libya.

Knowledge of animal movements and trade patterns is essential to understand the disease dynamics in the region. The main routes of animal movement are traditionally from east to west. Incursions into the Arabic Peninsula are most probably linked to a significant inflow of live small ruminants on the occasion of major Muslim festivals.

In 2008, the Food and Agriculture Organization of the United Nations (FAO), the European Commission of the Control of Foot-and-Mouth Disease (EuFMD) and the World Organisation for Animal Health (OIE) convened a meeting in Shiraz, Iran, involving 14 FMD-affected countries to develop a long-term (2020) vision for FMD control in the region, which is now recognised as the West Eurasia Roadmap and includes the following countries: Afghanistan, Armenia, Azerbaijan, Georgia, Iran, Iraq, Kazakhstan, Kyrgyzstan, Pakistan, Syria, Tajikistan, Turkey, Turkmenistan and Uzbekistan.

Countries such as Iraq and Syria are also part of the cluster of countries in the Arabic Peninsula.

This presentation highlights the FMD dynamics and assesses the progress of the West Eurasia Roadmap over the last three years and the challenges for further advancement of the West Eurasia FMD Progressive Control Pathway (PCP). The presentation also considers the FMD situation in the Middle East in relation to the need for establishing a specific PCP roadmap initiative for this sub-region.

The activities implemented since the 2008 meeting in Shiraz (Iran) have allowed the detection of the occurrence of three epidemics of regional significance in the past three years: the type A Iran-05 (BAR-08 strain) epidemic in 2008, the type O Panasia-2 epidemic in 2010–2011 and the Asia-1 epidemic of 2011–2012. All of these FMD waves were caused by FMD virus strains that differed from the previously circulating strains of the same serotype. The virus spread observed involved east-to-west travel and, to some extent, Central Asian countries.

The rapidity and frequency of incursions in the past three years presented a major problem for FMD control, in particular as the vaccines that were routinely used contained FMD vaccine virus strains that did not fully match or even poorly matched the new field strains.

The FAO projects carried out in the region supported virological surveillance and were instrumental in identifying and responding to challenges caused by newly emerging viruses. For instance, in Pakistan an Asia-1 strain was identified that clearly differed from the classical Shamir Asia-1 vaccine strain. The early warning system associated with the West Eurasia Laboratory Network (WELNET) assisted in the detection of virus spread to the West and, thanks to the willingness to share virus isolates, field strain-specific vaccine development could be initiated at the FMD Institute in Ankara.

The regular Roadmap assessment meetings and peer review system have encouraged countries to report, although the FMD issue remains sensitive, and achieving a truly open and transparent reporting of all virological findings in the region is still challenging.

The development of the PCP-FMD Roadmap and the regular and systematic review process has been very helpful in achieving better knowledge and control of FMD in the region. Countries used the PCP framework to review their national short- and long-term FMD control objectives. Particular progress has been achieved in many countries on systematic surveillance, disease awareness, threat identification, information exchange and the development of more active control policies that are reflected in the PCP-FMD Roadmap. However, to overcome the many remaining challenges and to achieve the 2020 PCP-FMD Roadmap goals, further international assistance is needed and the Veterinary Services of the countries need to be strengthened. The rapidity of FMD virus spread across borders of the West Eurasia region shows that important pillars for FMD control are still lacking or unsatisfactory.

With regard to the Middle East sub-region, a thorough assessment of the countries based on the PCP-FMD principles is currently being undertaken and a specific regional project is under development. This should take into consideration the need to establish a FMD buffer zone in the Middle East since the region could be considered a 'mixing vessel' for introducing FMD viruses from both the Far East or African countries and, therefore, is characterised by a constantly evolving FMD epidemiological status.

Keywords
Animal movement – PCP-FMD Roadmap – FMD virus Pool 3 – Middle East – West Eurasia.

The foot and mouth disease virus pools and the regional programmes in North Africa

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Summary

Livestock plays an important socio-economic role in the Maghreb and contributes significantly to food security. Maghreb countries count for more than 60 million heads of small ruminants, six million of cattle and one million of dromedaries.

Owing to its position between Sahel in the south and Europe in the north and the existence of natural barriers (the Sahara desert, Mediterranean Sea and Atlantic Ocean), North Africa acts as a buffer against the spread of many transboundary animal diseases, including foot and mouth disease (FMD), to Europe.

Over the last four decades, FMD epizootics in the Maghreb, caused mostly by serotypes O and A, were characterised by their relative regularity, sporadic occurrence, limited durations and exotic origins. These countries notified several outbreaks originating from South America and the Iberian Peninsula (Morocco, 1977 and 1983), the Middle East (Tunisia, Algeria, Morocco, 1990–1991), sub-Saharan Africa (Algeria, Tunisia, Morocco, 1999; Mauritania, 2006; Libya, 2011). It is worth noting the emergence of Southern African Territories (SAT) 2 in Mauritania (1975) and Libya (2003 and 2012).

Unlike Libya and Mauritania, Algeria, Morocco and Tunisia have had a stable epidemiological situation since the 1999 FMD incursion. During 2011 and 2012, Libya suffered from several outbreaks caused by serotypes O, SAT 2 and A. In Mauritania, the last officially reported outbreak goes back to 2006. Recent FMD evolution in Egypt and Libya jeopardises the epidemiological stability of other Maghreb countries.

Adopted FMD control programmes vary according to the country and serotype(s) involved. In Algeria and Morocco, control is based on epidemiological surveillance, movement control, stamping-out and mass vaccination of cattle by mono- or bivalent vaccines. The absence of FMD virus circulation, as evidenced by sero-epidemiological surveys conducted on cattle and small ruminants, led Morocco to stop vaccination in 2007. In Tunisia, the control strategy is based on epidemiological surveillance and mass vaccination of cattle and small ruminants by multivalent vaccines. In Libya, mass vaccination of cattle and small ruminants using mono- or multivalent vaccines was used during FMD epizootics. Official data on FMD control practised in Mauritania are currently lacking.

During the 80th General Session of the World Organisation for Animal Health (OIE), Algeria, Morocco and Tunisia were awarded the status of country with a formal FMD control programme validated by this organisation.

Keywords
Control programmes – Foot and mouth disease – North Africa – Virus pool.

Introduction

Foot and mouth disease (FMD) is a highly contagious disease of cloven-hoofed animals and remains one of the main constraints affecting livestock production and trade of animals and animal products in many parts of the world.

The livestock sector plays an important socio-economic role in North Africa and contributes significantly to food security and poverty alleviation in this region. The region is characterised geographically by a particular situation bordering Europe, East Africa, the Middle East and sub-Saharan Africa and being at a crossroads between

Africa, Europe and Asia. The arid or semi-arid nature of this region drastically limits the potential availability of natural pasture. Therefore, transhumance and animal movement, both for grazing or for trade, within this region and between neighbouring regions are important. Such fluidity has significant consequences on the spread of animal diseases, notably FMD.

Over the last five decades, several FMD outbreaks involving several types were reported in North Africa. Characterisation of isolated virus is highlighting the continuous evolution of the FMD epidemiological situation in this region. The recent confirmation of Southern African Territories (SAT) 2 in Libya and Egypt, with other concomitant existing FMD types (O and A), is an exceptional situation and a serious development in this region.

The purpose of this paper is to provide an overview of the FMD situation in North Africa, and to present strategies adopted by countries in the region for the control of the disease.

Background to foot and mouth disease in North Africa

Importance of ruminant livestock in North Africa

The livestock sector plays an important socio-economic role in North Africa and contributes significantly to food security and poverty alleviation in this region. It provides livelihood and employment for a significant proportion of the population. According to the Food and Agriculture Organization of the United Nations (FAO), North Africa accounts for more than 90 million heads of small ruminants, 15 million of bovine and buffalo and two million of dromedaries (Table I).

Table I
Ruminant distribution in North Africa

Country	Ruminant species (in thousands)				
	Buffalo	Cattle	Dromedaries	Sheep	Goat
Egypt	4,000	4,524.95	140.00	5,591.58	4,200.00
Libya	-	195.00	56.00	7,000.00	2,700.00
Tunisia	-	670.90	235.00	7,234.07	1,295.94
Algeria	-	1,650.00	290.00	20,000.00	3,800.00
Morocco	-	2,895.80	50.00	18,023.20	5,685.70
Mauritania	-	1,677.63	1,350.85	8,860.00	5,500.00
Total	4,000	11,614.28	2,121.85	66,708.85	23,181.64

Source: FAOSTAT (2010)

Historical overview of foot and mouth disease in North Africa

Over the last five decades, several epizootics of FMD have been recorded in all countries of North Africa. Table II provides official reported FMD events and associated virus types. Figure 1 presents the geographical distribution of FMD virus types recorded in the region since 1950.

Analysis of the data on virus types presented in Table II shows that:

– types O and A were associated with the most epizootics recorded in the region;

– types SAT 1, SAT 3 and Asia 1 were never recorded in the region;

– the last occurrence of type C was noted in Tunisia in 1969; and

– there was a recent recurrence of SAT 2 in Egypt and Libya.

Table II
Foot and mouth disease epizootic events and associated virus types in North Africa

Country	Serotype						
	O	A	C	Asia 1	SAT 1	SAT 2	SAT 3
Algeria	1966 1960 1999	1977					
Egypt	1951 1958 1961–1962 1964–1977 1978–1982 1987 1989–1994 1997 2000 2006–2009 2011	1952 1956 1958 1972 2006 2009–2012				1950 2012	
Libya	1959 1962 1967–1968 1978 1981–1983 1988–1989 1994 2010–2012	1979 2009				2003 2012	
Morocco	1991 1992 1999	1952 1977 (A_{77}) 1983 (A_5)					
Mauritania	2000–2001	1997 2006				1975–1976	
Tunisia	1970 1975 1989–1990 1994 1999	1979 1982 (A_5)	1965 1967 1969				

Source: FAO World Reference Laboratory for foot and mouth disease

Epidemiological features of foot and mouth disease epizootics in North Africa

Over the last four decades, epizootics of FMD in North Africa were characterised by their sporadic but epizootic occurrence, limited duration, exotic origin and relative regularity. North African countries notified and recorded several episodes of FMD originating from the Middle East (Egypt, 1972; Tunisia, Algeria, Morocco, 1990–1991; Egypt, 1993; Libya, 1994), South America (Morocco, 1977), the Iberic Peninsula (Morocco, 1983), East Africa (Egypt, 2006) and sub-Saharan Africa (Algeria, Tunisia, Morocco, 1999; Mauritania, 2006; Libya, 2010). Some epizootics, caused by the same serotype (i.e. type O epizootic in Egypt, Tunisia, Algeria and Morocco, 1989–1991), swept the entire region.

Since the last incursion of FMD in 1999, Algeria, Morocco and Tunisia have had a stable epidemiological situation. However, the situation is quite different in Egypt, Libya and Mauritania, where FMD is considered to be enzootic. Since 2000, Egypt recorded several FMD epizootics or outbreaks due to type O (2000, 2008, 2009 and 2010), type A (2006, 2009 and 2010) and type SAT 2 (2012). Libya recorded other epizootics, among which the more recent ones were notified in 2011 and 2012 (types O, A and SAT 2). In Mauritania, types SAT 2, A and O were reported in 1975–1976, 1997 and 2006, and 2000–2001, respectively.

The recent evolution of FMD in Egypt and Libya, with the concomitance of several FMD virus types, especially SAT 2, is threatening the epidemiological stability of other North African countries.

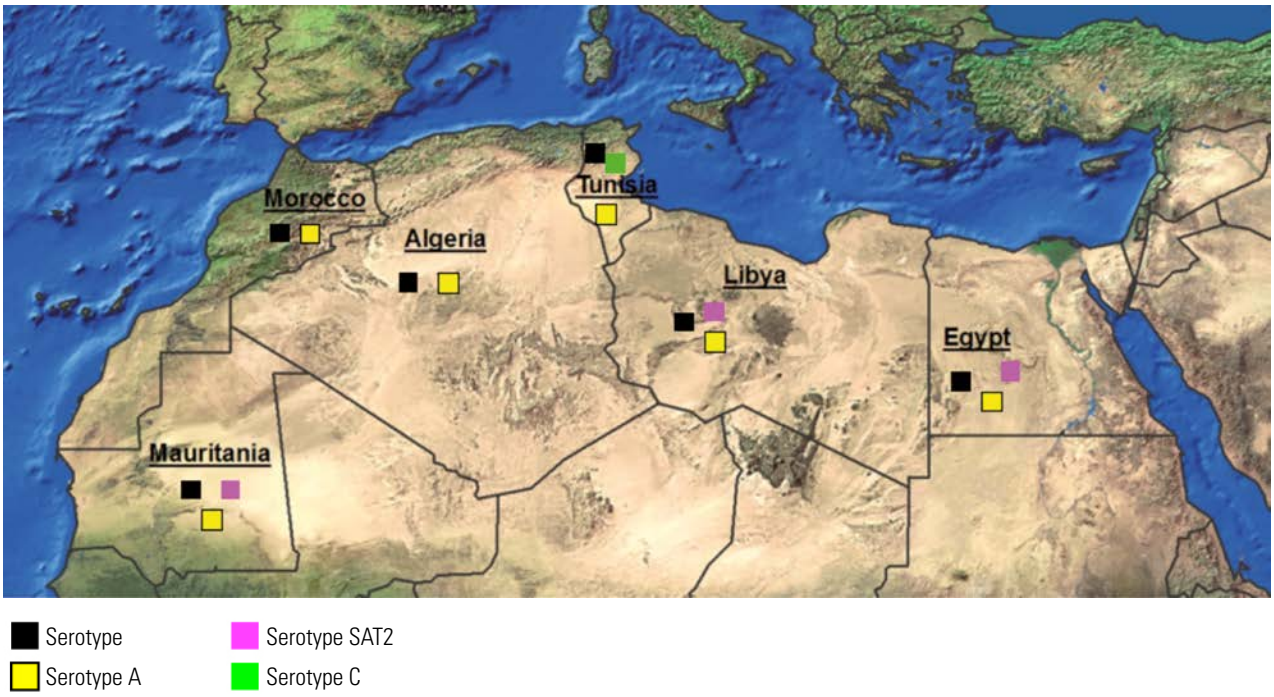

Fig. 1
Geographical distribution of foot and mouth disease serotypes

Control strategy for foot and mouth disease in North Africa

Foot and mouth disease is a mandatory notifiable disease in all countries of North Africa. In spite of similar geographical and ecological conditions and trade practices, FMD control strategies differ among North African countries because of differences in epidemiological situations owing to diverse factors including identified FMD virus type(s). Vaccination is conducted, free of charge, in most countries, on either a compulsory or a voluntary basis.

Different FMD vaccines originating from different suppliers are used in the North Africa region. Some countries, such as Egypt or Morocco, manufacture FMD vaccines or produce them locally from imported concentrated antigen. No North African country has an emergency antigen bank. However, an emergency stock of vaccine is available in some countries, such as Morocco.

All countries have awareness and training programmes on FMD, focused mainly on farmers and animal health professionals. These programmes are generally activated during the course of or at the risk of an outbreak or epizootic event.

In Algeria and Morocco, FMD control relies on medical and sanitary measures involving:

– mass vaccination of cattle by means of mono- or bivalent vaccines;

– implementation of sanitary measures (quarantine, movement control, animal slaughter and destruction, etc.); and

– epidemiological surveillance.

Taking into account the results of serological surveys conducted on cattle and small ruminants, showing no evidence of virus circulation, Morocco stopped, since 2007, vaccination against FMD. In Tunisia, FMD control relies on mass vaccination of cattle and small ruminants using multivalent vaccines, associated with regular epidemiological surveillance. Mass vaccination of large and small ruminants using mono- or multivalent vaccines is carried out, during or between epizootics, in Egypt and Libya. Official data on control measures implemented in Mauritania are lacking.

The World Organisation for Animal Health (OIE) awarded, during its 80th General Session, to Algeria, Morocco and Tunisia the status of countries with a validated official control programme for FMD.

To reduce future outbreaks of FMD in countries of North Africa, a common strategic programme should be adopted. The programme should include the following:

- detailed risk assessment and institution of appropriate strategies for control in each country;
- establishment of a surveillance network to provide early warning and implement immediate control measures;
- collection and exchange of information on the epidemiological situation;
- epidemiological studies on FMD must be conducted throughout the region, especially in endemic areas;
- emergency plans, enabling rapid national and regional reaction, must be coordinated; and
- more effective control measures, that hopefully could lead to coordinated regional eradication of FMD, must be applied at the national level.

This goal will be achieved only if regional co-operation is implemented. Coordinated epidemiological studies leading to a common control policy should be implemented and supported by the international community.

Risk management of foot and mouth disease in North Africa

Diagnostic capacities of some countries of the region, including at laboratory level, are limited and no existing regional reference laboratory for North Africa is available.

As previously stated, most North African countries rely on vaccination as a tool for FMD control. Vaccination strategies and vaccine strains used do not usually match the current circulating strains and coverage is not satisfactory in many North African countries. The control of vaccine and vaccination efficacy is rarely implemented.

Despite the existence of a regional veterinary committee within the Maghreb Arab Union, there is a lack, at a regional level, of a relevant and harmonised control strategy including harmonised surveillance and vaccination programmes.

Furthermore, the lack of an early warning and rapid response systems in some countries of the region, combined with a poor level of transparency and collaboration between countries of the region, is hampering control of the disease at a regional level, as evidenced by the introduction of exotic FMD strains to the region on many occasions.

Future perspectives for controlling and eradicating foot and mouth disease in North Africa

To achieve FMD control in North Africa, a regional strategic programme should be adopted. The programme should be based on the following:

- establishing or activating a regional coordination body for the control of transboundary animal diseases, including FMD;
- conducting at national and regional levels detailed risk assessments for FMD;

– elaborating on appropriate strategies for FMD control in each country and ensuring their relevance for the region;
– establishing a surveillance network at national and regional levels to provide information exchange, early warning and early response;
– conducting regional epidemiological surveys and studies on FMD, especially in enzootic and border areas;
– defining emergency plans, enabling coordination of rapid national and regional reaction;
– building solid and sustainable diagnostic capacities for major transboundary animal diseases, including reference laboratories, at national and regional levels;
– allocating appropriate resources; and
– promoting an animal disease control cooperation programme with neighbouring countries or regions with the support of international and regional organisations.

Resources and further reading

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Session 6

The FMD virus pools and the regional programmes (cont.)

Chair: A. El Sawalhy (AU-IBAR)

The situation of foot and mouth disease virus in Eastern Africa Pool 4 at June 2012: implications on the Progressive Control Pathway (PCP)

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Summary

Foot and mouth (FMD) virus Pool 4 comprises 14 countries geographically located in the Eastern Africa region. FMD serotypes O, A, Southern African Territories (SAT) 1 and SAT 2 are endemic in this region and efforts are under way by the individual national governments to control the disease by embracing the Progressive Control Pathway (PCP-FMD) and various control tools for the global strategy. Most countries have considered themselves to be in Stage 1 of the PCP in 2012, except South Sudan, which is in Stage 0. Egypt and Libya have a recent history of incursions of viruses from Pool 3 from West Eurasia and the Middle East regions, but have also been affected by FMD virus topotypes from East Africa (Egypt, 2006) and Pool 5 (in 2012), relating to the livestock trade.

Keywords
2012 – Eastern Africa – FMD virus Pool 4 – Livestock trade – PCP-FMD – Progressive Control Pathway.

Introduction

Foot and mouth disease (FMD) virus Pool 4 comprises 14 countries geographically located in the Eastern Africa region (Fig. 1).

Foot and mouth disease is endemic in Eastern Africa and five out of the seven known serotypes, namely O, A, C, Southern African Territories (SAT) 1 and SAT 2, have been found circulating in this region (9). Serotype C has not been recently isolated – the last occurrence was in Kenya in 2004 having been attributed to vaccine reintroductions (10) – while SAT 3 was last isolated in Uganda from a dead buffalo in 1997 (6). However, regional laboratory results and some recent serological studies have indicated exposure of animals to some of these serotypes (1), thus calling for more studies to ascertain the epidemiological status of these two serotypes.

In this region, outbreaks occur throughout the year despite the control efforts instituted by the individual governments and other stakeholders (11). The persistence has also been favoured by uncontrolled livestock movements, large wildlife populations habitually in contact with livestock and generally low enthusiasm for control among main stakeholders in the industry (7). The situation is further complicated by the varied farming systems, trade and animal movement patterns and inadequate resources for control of the disease (9).

Livestock trade and movements have had a great impact on disease spread within and across boundaries in this region (2). Recently, Rwanda has instituted measures to bar movements of animals from neighbouring countries due to fear of incursions (Dr David Kiiza, Eastern Africa Regional Laboratory Network, personal communication, 6 March 2012). Democratic Republic of Congo and Uganda have also reported an increase in outbreaks associated with livestock movements both within and from neighbouring countries (Dr Bushu Mulinda, Eastern Africa Regional Laboratory Network, personal communication, 6 March 2012). This has affected not only the region, but also countries outside. Recently, Egypt, Libya and Bahrain, which are not included in virus Pool 4, have been affected by FMD virus topotypes from sub-Saharan Africa that may be associated with livestock trade (3). This calls for concerted regional efforts and supports the global strategy of a regional approach to the control of this disease.

Generally, the epidemiology of FMD in the East African region is poorly understood and suffers from irregular surveillance and sample collection as well as limited capacities by the local laboratories to carry out exhaustive analysis of samples once they have been collected. Very few countries have been able to successfully determine FMD prevalence and serotypes circulating within their susceptible animal populations. Most of them rely on

results obtained from few samples that they intermittently submit to the World Organisation for Animal Health (OIE) reference laboratories, and thus rarely get the diagnosis in real time.

Fig. 1
Map of Africa showing, in green, countries in FMD virus Pool 4

Increased global pressure and the economic importance of FMD, coupled with the realisation among developing countries that FMD control and eradication can contribute to poverty reduction and increased economic growth (8), has motivated countries in this region to enhance efforts towards FMD control by embracing the Progressive Control Pathway for FMD (PCP-FMD); a stepwise and easy-to-implement control process (5). At the recently

concluded regional PCP-FMD roadmap, which took place in March 2012 in Nairobi, most countries considered themselves to be in Stage 1 of the PCP (4). In addition to the PCP, various other control tools for a global strategy, such as the OIE *Terrestrial Animal Health Code* and the PVS pathway, have been incorporated in the individual national strategic plans for FMD control.

FMD situation from 2010 to 2012 in countries in Pool 4

The Eastern Africa Regional Laboratory Network for FMD (EARLN-FMD), established in 2010 with the support of the European Commission for the Control of Foot-and-Mouth Disease (EuFMD) and Food and Agriculture Organization of the United Nations (FAO), has been involved in sharing epidemiological information, laboratory issues and capacity building on FMD virus Pool 4 (4). Consequently, the network has been able to put together information from its members to create reports that help understand the disease situation in the region.

Burundi recorded serotype O in 2010 and SAT 1, based on serology results, between July and August 2011, but no FMD events were officially reported in 2012. On the other hand, the Democratic Republic of Congo reported serotype O outbreaks in 2010, while in 2011 serotypes A (Africa) and O (World Reference Laboratory (WRL) Pirbright results) were identified for the first time. WRL was also notified of serotype C in this country in 2011 but this was not confirmed by the governmental authorities.

Eritrea had a severe epidemic of FMD in 2011, but was unable to identify the serotype or genotype due to limited capacity, while her neighbour, Ethiopia, reported a total of 58 FMD outbreaks in 2011 in the southern and northern parts of the country. WRL identified serotype O topotype EA-3 in two regions, the southern ones being genetically related to previous Ethiopian isolates and the northern ones to Sudan isolates.

Kenya reported a total of 249 and 128 FMD events in 2010 and 2011, respectively. They were identified at the national laboratory as serotypes O, A, SAT 1 and SAT 2. Topotypes identified at WRL during 2010 include O (EA-4) and SAT 1 (NWZ). No genotyping was done in 2011 due to limited resources. In early 2012, serotypes O and SAT 2 were mainly reported in the Rift Valley and parts of Eastern and Central provinces. By June 2012, Kenya had confirmed 32 reports of serotype O (still in Eastern and Central provinces and the Rift Valley) and 15 reports of SAT 2 (mainly in the Rift Valley and Central province). Samples have been selected from 2011–2012 outbreaks for shipment to WRL Pirbright for further analysis.

Rwanda did not report any FMD outbreaks in 2011 and 2012. However, the outbreaks in neighbouring countries pose a risk, and border surveillances have been intensified for fear of these transboundary incursions. Djibouti also did not report any outbreaks in the same years, and Comoros and Yemen have not given reports; thus, the FMD situation there is unknown.

Annual outbreaks occur in Somalia but most of them are not investigated and only 39 outbreaks were reported to the OIE in 2011. Risk assessment surveys have been ongoing during 2012. North Sudan has reported a total of 18 events in 2010 and 2011. The national laboratories have identified serotypes O, A and SAT 2 through antigen detection and SAT 1 through serology, while, in 2012, there have been ongoing but undiagnosed outbreaks. South Sudan, on the other hand, has had annual outbreaks occurring, but these are also undiagnosed because of a lack of capacity occasioned by its recent political status. Socio-economic and sero-surveillance studies were completed in 2012; about 3,228 serum samples were collected and analysed.

In 2010 and 2011, Tanzania collected several samples from various events and sent them to the Onderstepoort Veterinary Institute (OVI) and WRL Pirbright. As a result, SAT 1 was identified in buffalo and SAT 2 (IV) in cattle; the latter was genetically related to Kenyan 2009 SAT 2 isolates. The government, in partnership with other stakeholders, is also in the process of upgrading the FMD laboratory to biosafety level 3 for enhanced disease diagnosis.

Uganda reported FMD events in 22 districts in 2011 and identified serotype O. By March 2012, only one event had been reported for investigation. However, recently, unconfirmed outbreaks have been reported from Eastern and North Eastern parts, as well as in the Western parts near the borders with Democratic Republic of Congo and Rwanda with mortality among calves. Samples have been collected but have yet to be analysed. This has been associated with increased livestock travel from Eastern Uganda in the process of restocking.

Egypt and Libya, though not in Pool 4, have been affected by the situations in Pools 3, 4 and 5. In 2012, the two countries experienced SAT 2 outbreaks in cattle for the first time in several years, with a large number of deaths,

especially among calves. Two lineages of topotype VII have been identified and this recent incursion probably comes from Pool 5, West/Central sub-Saharan Africa. In addition to SAT 2 viruses, serotype O was recorded in 2011 in the two countries and serotype A in Egypt (from West Eurasia) and in 2012 an African type A (from Pool 5).

Eastern Africa regional programmes and FMD control Roadmap visions for 2022

Currently, 12 countries (listed in Table I) are participating in the regional Eastern Africa FMD Roadmap for the control of FMD. At a meeting in March 2012 in Kenya, all countries undertook self-assessments and all except South Sudan considered themselves to be in PCP-FMD Stage 1 (Table I, www.oie.int/doc/ged/D11553.PDF). South Sudan is considered to be in Stage 0, and Veterinary Service structures have been established and socio-economic and sero-prevalence studies have been recently completed.

Ongoing activities

(see Table I)

Table I
Self-assessment of country PCP stage position for 2012 and envisaged progression to 2022

Country	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Burundi	1	1	1	1	2	2	2	2	3	3	3
DR Congo eastern zone	1	1	2	2	2	2	2	3	3	3	3
Rwanda	1	2	2	2	3	3	3	4	4	4	5
Uganda	1	1	2	2	2	2	2	3	3	4	4
Tanzania (zone)	1	2	2	2	3	3	4	4	4	4	4
Kenya (zone)	1	1	1	2	2	2	2	2	3	3	3
South Sudan zone A	0	1	1	1	1	1	2	2	2	2	2
South Sudan zone B	0	1	1	1	1	1	1	1	1	1	1
South Sudan zone C	0	1	1	1	1	1	1	1	1	1	1
Eritrea central	1	1	2	2	2	2	2	3	3	4	4
Eritrea western	1	1	1	2	2	2	2	3	3	3	3
Eritrea eastern	1	1	1	2	2	2	2	3	3	3	3
Djibouti	1										
Somalia	1	1	1	2	2	2	2	3	3	3	3
Ethiopia	1	1	1	2	2	2	2	3	3	3	4
Sudan zone A	1	2	2	2	2	2	2	3	3	3	3
Sudan zone B	1	2	2	2	2	2	2	2	2	2	2
Sudan zone C	1	2	2	2	2	2	2	2	2	2	2

Adapted from the Nairobi, Kenya, March 2012 PCP roadmap workshop and EuFMD workshop report

A few internationally funded projects are ongoing in the region. VETGOV is a five-year programme launched in January 2012 that aims to reinforce veterinary governance in Africa. It is spearheaded by the African Union Interafrican Bureau for Animal Resources (AU-IBAR) and funded by the EU (www.au-ibar.org/index.php). The EARLN brings together staff from the regional laboratories working on different diseases to enable collective understanding of laboratory issues relating to diseases and share knowledge, information and techniques (www.fao.org/ag/againfo/commisions/doc/workshop). On the other hand, the Eastern Africa Regional Epidemiology Network (EAREN), funded by USAID and the European Commission, and supported by FAO-ECTAD (Emergency Centre for Transboundary Animal Diseases), brings together national epidemiologists to foster exchange of epidemiological information vital for Veterinary Services for a regional approach to the control of priority diseases

(www.fao-ectad-nairobi.org/). IDENTIFY-AFRICA, funded by USAID, is a joint FAO/OIE/WHO (World Health Organization) capacity-building programme that focuses on building capacity of laboratories in the human and animal health sectors for rapid and accurate detection of pathogens and for appropriate handling of material from clinical cases in order to contribute to the management of normative and emerging zoonotic micro-organisms (www.rr-africa.oie.int/IDENTIFY/en_index.html).

Locally, each country is making efforts to progress to the next PCP stage by implementing some of the activities recommended in the PCP guidelines (mainly the identification of risks and developing strategic FMD control plans). Generally, efforts have been made in undertaking epidemio-surveillance studies to establish circulating serotypes and factors associated with their distribution and circulation. To complement epidemiological efforts, a number of national FMD laboratories in the region have endeavoured to improve their diagnostic capacities through active participation in the EARLN and EAREN. Consequently, some of them now have access to essential techniques such as virus collection, identification, ELISA and real-time polymerase chain reaction (PCR) including practical training in sampling, serotyping, PCR protocols, enzyme-linked immunosorbent assay (ELISA) and vaccine matching for better vaccine choices. These activities have been incorporated in some ongoing projects in the region including real-time trainings such as Nakuru Training Courses in Kenya, EARLN (EuFMD/FAO) in Tanzania and Uganda (Biotechnology and Biological Sciences Research Council (CIDLID), and Wellcome Trust (SACIDS) and Transboundary Animal Diseases in East Africa (DANIDA) in Kenya and Uganda, as well as missions from the EuFMD. There are also other scattered research projects in individual countries in various research institutions, including universities that are not easily visible or documented, but in a way contribute to the knowledge base required for FMD control.

Planned medium- and long-term regional programmes towards 2022

Regional collaboration has been embraced for progress in FMD control. Therefore, there has been a recognised need for local initialisation and sustenance of a regional approach for control of TADs including FMD. For this reason, the focus has been on AU-IBAR to take the lead in initiating and coordinating the control activities. The countries therefore plan to engage AU-IBAR for support in mobilisation of international funds, as well as information and technical support on issues such as risk analysis, socio-economic impact studies, value chain analyses and designing and implementing surveillance systems and prevalence studies.

A number of challenges have been recognised by many along the pathway according to the Nairobi meeting report. These include, among others, the individual country's political status, political goodwill, funding, political/social unawareness and inadequate technical capacities. In view of that, the regional roadmap participant countries, through their CVOs and national animal health advisors, have resolved to advocate for FMD control to be given prominence on the national animal health agenda. In addition, the countries have endeavoured to improve Veterinary Services, deal with technical issues on FMD control, involve private stakeholders in the PCP and undertake socio-economic studies to help farmers and policy makers realise the costs and benefits of FMD.

Conclusion

The majority of countries in FMD virus Pool 4 are expected to be wholly or zonally beyond Stage 1 of the PCP by 2016 and in at least Stage 3 by 2022. A regional approach has been embraced by all the countries, and global support will go a long way in helping realise effective control of FMD. If all efforts envisaged in the regional and national plans are fully implemented, the PCP vision for 2022 will be a reality.

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Foot and mouth disease in West and Central Africa

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Summary

Foot and mouth disease (FMD) is the most contagious disease of mammals and has great potential for causing severe economic loss in susceptible cloven-hoofed animals. The disease is believed to be endemic in most countries in Africa, although officially reported cases are few and the majority of suspected outbreaks go unconfirmed. The disease surveillance activities funded by the Food and Agriculture Organization of the United Nations (FAO) and the European Union (EU) and studies have confirmed the prevalence of four serotypes in West and Central Africa – A, O, Southern African Territories (SAT) 1 and SAT 2 – and the topotypes specific to the region (I for serotype A; III for serotype O; V, VI and X for serotype SAT 2; and V and VI for serotype SAT 1). Four zones were identified as primary sources of infection in West and Central Africa.

The World Reference Laboratory for Foot and Mouth Disease in Pirbright, United Kingdom (UK), confirmed three serotypes: A, O and SAT 2.

Currently, all activities related to FMD are reported by the West and Central African FMD sub-network.

West and Central African countries did not achieve substantial results in the FMD progressive control roadmap. The control strategy in the region is based mainly on vaccination of dairy cattle and early diagnosis of the disease.

Keywords
Control strategy – Foot and mouth disease – Serotypes – Surveillance – Topotypes.

Introduction

Foot and mouth disease (FMD) is the most contagious disease of mammals and has great potential for causing severe economic loss in susceptible cloven-hoofed animals. There are seven serotypes of FMD virus (FMDV), namely O, A, C, Southern African Territories (SAT) 1, SAT 2, SAT 3 and Asia 1. It is a disease for immediate notification to the World Organisation for Animal Health (OIE) and represents a major impediment to food security and intra-regional and international trade in animals and animal products.

In Africa, six serotypes (O, A, C, SAT 1, SAT 2, SAT 3) were recorded with marked regional differences in the distribution and prevalence and intratypic variants. Furthermore, wildlife plays a unique and important role in the epidemiology of FMD in the continent.

Disease distribution

Foot and mouth disease is believed to be endemic in most countries in Africa, although officially reported cases are few and the majority of suspected outbreaks go unconfirmed. A retrospective study undertaken by Couacy-Hymann *et al.* (1), covering the period 1970–2003 in Burkina Faso, Mali, Niger, Benin, Côte D'Ivoire, Ghana and Togo and involving a total of 403 samples, confirmed FMD in 198 samples (Table I). Four serotypes were recorded in the countries concerned: O (62 samples), A (32 samples) SAT 1 (18 samples) and SAT 2 (86 samples). The predominant serotype was defined as SAT 2.

Table I
Foot and mouth disease serotypes detected in seven West African countries during the period 1970–2003

Countries	Sampling year	Number of samples	Serotypes						Virus not identified
			O	A	C	SAT 1	SAT 2	SAT 3	
Benin	1991	4							4
	2003	2					1*		
Burkina Faso	1990	5							5
	1992	4	3						1
	1994	20		1					19
	1996	31	31						0
	1998	9							9
	1999	5							5
	2002	3	1						2
Côte d'Ivoire	1971	7		6					1
	1974	16					8		8
	1975	9					7		2
	1976	5							5
	1990	8					5		3
	1991	39					39		
	1995	19	1	1					17
	1996	16		1					15
	1999	28	5						23
Ghana	1970	2							2
	1971	6		6					0
	1972	6		2					4
	1973	23		5		12	4		2
	1974	15		2			6		7
	1977	20							20
	1990	3					1		2
	1991	12					3		9
	1993	9	7						2
	1994	4	1						3
	1996	4		3					1
	2002	8							8
Mali	1991	7					6		1
	1997	2		1					1
	1999	3	1	1			1		0
Niger	1971	1		1					0
	1973	6		2			3		1
	1976	6				6			0
	1988	3	3						0
	1990	2							2
	2001	30	9						21
Togo	1990	2					2		0
Total		**403**	**62**	**32**	**0**	**18**	**86**	**0**	**205**

Couacy-Hymann *et al.* (1) also reported to the OIE a total of 989 outbreaks from the seven West African countries in Table I during the period 2000–2004 (Table II). These data confirmed the prevalence of four serotypes in this region.

Table II
Outbreaks reported to OIE from 2000 to 2004 and serotypes involved

Country	Year				
	2000	**2001**	**2002**	**2003**	**2004**
Benin	23 (O)	34 (?)	22 (?)	91	21
				(O, A, SAT 1, SAT 2, SAT 3)	(O, A, SAT 1, SAT 2)
Burkina Faso	71 (?)	12	61 (O)	15 (?)	53 (?)
Côte d'Ivoire	3 (?)	? (SAT 1)	–	–	3 (?)
Ghana	18 (?)	2 (?)	12 (O)	4 (O)	17 (O)
Mali	–	18 (O, A, C?, SAT 2)	3 (?)	1 (?)	3 (?)
Niger	84 (?)	22 (O)	60 (?)	70	99
				(O, SAT 1, SAT 2)	(O, SAT 1, SAT 2)
Togo	9 (?)	? (SAT 2)	39 (?)	45 (SAT 2)	84 (O, SAT 2)
Sub-total	208	88	197	226	270
Grand total:	**989 outbreaks**				

The World Reference Laboratory for Foot and Mouth Disease in Pirbright, United Kingdom, confirmed a total of 90 outbreaks in 2005 in Cameroon, Mali and Togo (Table III), with the involvement of three serotypes: A, O and SAT 2.

Table III
Outbreaks confirmed in 2005 by the world reference laboratory Institute for Animal Health Pirbright

Country	Serotype			
	O	**A**	**SAT 1**	**SAT 2**
Cameroon	25	3	–	54
Mali	3	–	–	–
Togo	4	1	–	–

Between 2009 and 2012 not a single case of FMD was reported to the OIE from West and Central African countries as an epidemiologically significant event (Table IV), even though the disease is considered one of the constraints to livestock development in the region, causing high mortality among calves in recent outbreaks.

Table IV
Epidemiological significant events reported to OIE, 2009–2012

Year	Number of epidemiologically significant events	Number of FMD reported cases	West and Central African countries reported cases
2009	23	6	0
2010	26	6	0
2011	26	7	0
January –15 May 2012	19	5	0

Vosloo *et al.* (2) reviewed the status and control of FMD in sub-Saharan Africa and indicated the topotype distribution of the six serotypes circulating in Africa. This distribution for West and Central Africa in given in Table V, which shows the following topotypes: I for serotype A; III for serotype O; V, VI and X for serotype SAT 2; and V and VI for serotype SAT 1.

All the information gathered indicates that the disease is endemic in the region, with the prevalence of four serotypes: A, O, SAT 1 and the predominant SAT 2.

Table V
Topotype distribution in West and Central Africa

Serotype	Topotype	Countries
SAT 1	V	Nigeria
	VI	Nigeria, Niger
SAT 2	V	Nigeria, Senegal. Liberia, Ghana, Mali, Côte d'Ivoire
	VI	Gambia, Senegal
	X	Democratic Republic of the Congo
O	III	Côte d'Ivoire, Guinea, Niger, Ghana, Burkina Faso
A	I	Mauritania, Mali, Côte d'Ivoire, Ghana, Niger, Nigeria, Cameroon, Chad, Senegal

Disease surveillance

Two initiatives were supported in West and Central Africa to provide information on FMDV: the Food and Agriculture Organization of the United Nations (FAO) TCP/RAF/2916 project (involving Côte d'Ivoire, Mali, Burkina Faso, Niger, Benin, Togo and Ghana) and a European Commission for the control of Foot-and-Mouth disease (EuFMD)-funded survey in Niger. In addition, various research works on the epidemiology of FMD were undertaken in West and Central African countries.

Past activities

– FAO TCP/RAF/2916: Control of FMD in West Africa – determination and characterisation of FMDV strains circulating in this region (2003–2005). This project was implemented in Côte D'Ivoire, Mali, Burkina Faso, Niger, Benin, Togo and Ghana, with the objective of providing information on FMDV.

– The EuFMD funded a two-week mission to Niger in November 2005 to collect samples from FMD outbreaks in different regions of Niger and determine the occurrence of FMD and its serotypes. The results indicated the prevalence of four serotypes in West and Central Africa – A, O, SAT 1 and SAT 2 – and the topotypes specific to the region.

Four zones were identified as primary sources of infection in West and Central Africa (Fig. 1). They correspond to zones with a high density of animals:

– borderline Benin – Niger – Nigeria;

– borderline Niger – Mali – Burkina Faso;

– junction of Benin – Burkina Faso – Niger (W Regional Park or Tapoa region);

– Lake Chad and Adamao regions from Chad, Cameroon and Central African Republic.

The secondary infection zones result from the spread of infection from primary zones within the country and reach all West African countries.

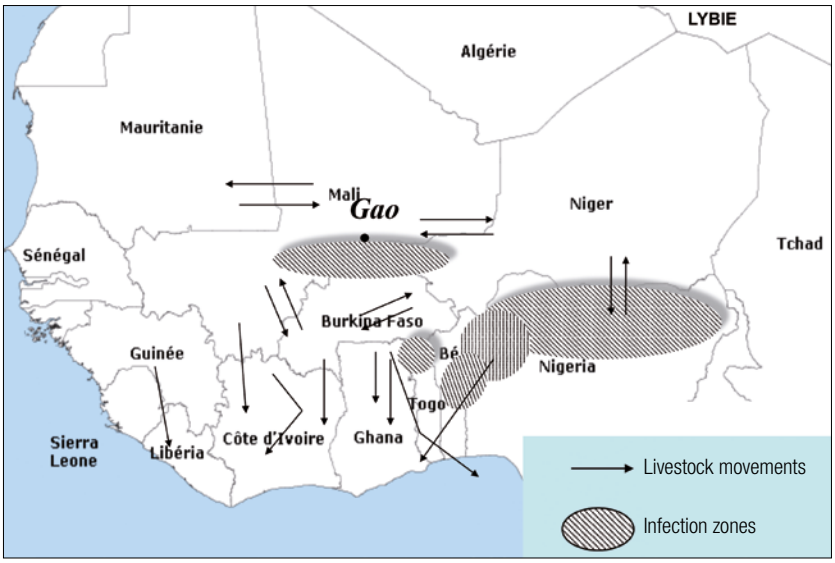

Fig. 1
Primary infection zones in areas with the highest cattle density

The risk zones (Fig. 2) depend on cattle population and animal movement, which are considered the highest risk factor for the occurrence of the disease in the region.

The role of wildlife in West Africa in the dissemination of FMD in West and Central Africa has been assessed as not important because of the low density of wildlife in the region.

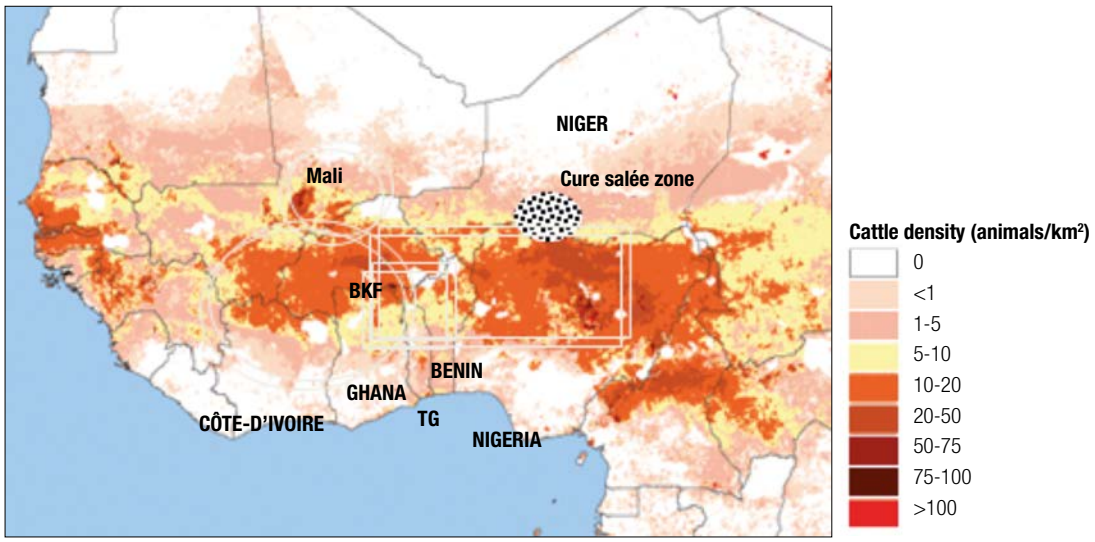

Fig. 2
Risk zones located in the areas with the highest cattle populations and frequent livestock movements (dark red)

Ongoing activities

Currently, all activities related to FMD are documented and reported by the West and Central African FMD sub-network, which operates within the West and Central Africa network of National Veterinary Diagnostic Laboratory for highly pathogenic avian influenza and other transboundary animal diseases (RESOLAB).

Two laboratories were nominated as FMD animators. These are the Central Veterinary Laboratory in Bamako, Mali, and the Accra Veterinary Laboratory in Accra, Ghana.

The animators were given the mandate to:

– collect and disseminate available information on FMD activities in member laboratories to the network (website);

– make a comprehensive report on RESOLAB activities related to FMD to the international community; and

– when possible, contribute to the organisation of regional workshops and training programmes related to FMD.

The animators presented their 2011 findings (Figure 3, Tables VI and VII) at the annual meeting of RESOLAB, held in December 2011 in Bamako, Mali.

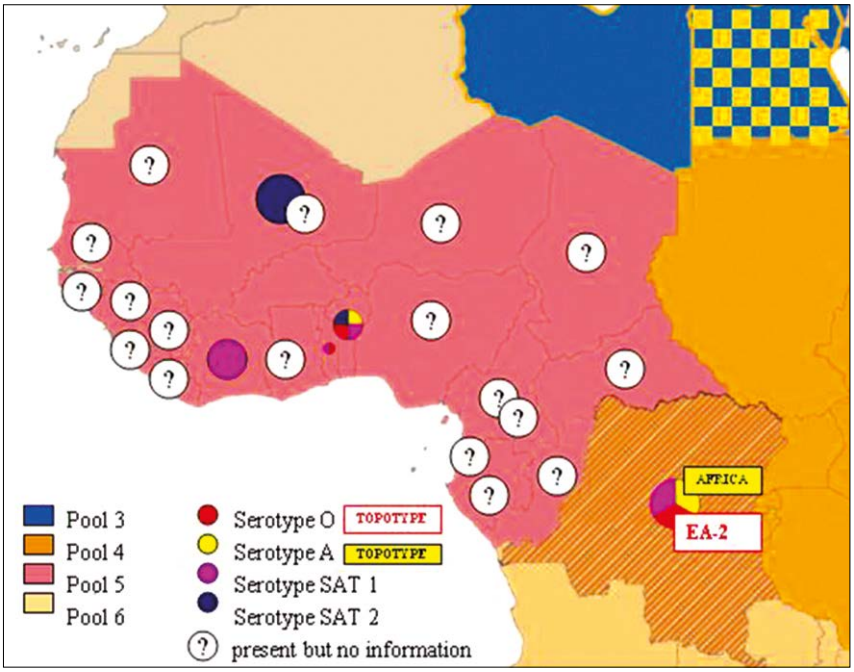

Fig. 3
Distribution of serotypes and topotypes in West and Central Africa

Table VI

Distribution of FMD serotypes in West Africa

No.	Country	Number of FMD outbreaks in year/serotypes	
		2011	2010
1	Benin	22; A, O, SAT 1, SAT 2	39; A, O, SAT 1, SAT 2
2	Burkina Faso	13; no virus	32; no virus
3	Mali	SAT 2	4; no virus
4	Nigeria	10; no virus	17; no virus
5	Senegal	2; no virus	6; no virus
6	Togo	FMDV, report missing	42; O, SAT 1
7	Côte D'Ivoire	10; SAT 1	15; no virus
8	Ghana	43; sera positive	39; no virus
9	Democratic Republic of the Congo	2; A, C?, SAT 1	Not reported

Table VII

Focal Points' brief reports

No.	Country/Lab	Focal person	FMD activities undertaken
1	Benin	Dr Aplogan Gilbert Luc	No information
2	Burkina Faso	Dr Quattara Lassina	No information
3	Cameroon	Dr Simon Jumbo Dickmu	267 suspected samples shared between Pirbright, Bostwana Vaccine Institute, Plum Island Labs for analysis
4	Cape Vert	Dr Maria Évora and Francisca Barbosa dos Santos	No information
5	Central African Republic	Dr Mokondji Domitien	No information
6	Congo (Dem. Rep.of the)	Dr Leopold Mulumba	No information
7	Congo Brassaville	Dr Jean Ikolakoumou	No information
8	Côte D'Ivoire	Koffi Yao Mathurin	No outbreak as at the period
9	Chad	No information	No information
10	Equatorial Guinea	No information	No information
11	Gambia	Mr Borrie Jabang	No report outbreaks during period
12	Gabon	No information	No information
13	Ghana	Dr Joseph Adongo Awuni	No outbreaks reported. Conducted retrospective analysis of bovine sera
14	Guinea Bissau	Dr Malam Bacar Djassi	No activity
15	Guinea Conakry	Dr Souleymane Diallo	No information
16	Liberia	Mr Roosevelt G. Gweh	No activity
17	Mali	Dr Abdalla Traore	Three outbreaks reported and samples were being tested
18	Niger, Nigeria, Sao Tome & Principe, Senegal	No information	No information
19	Sierra Leone	Dr Mohammed Barrie	No activity
20	Togo	Mr Felix Awoumi	Sera collected from outbreak for AVL

The overall conclusions were:

– FMD is endemic in West Africa with various serotypes and topotypes circulating;

– outbreaks are reported but virus detection is not done, probably because of the following factors:

  i) farmers attempt treatment and hence do not report

  ii) late reporting by farmers to veterinary personnel and

  iii) improper sampling and sample handling.

– inadequate diagnostic capacity of member laboratories.

The RESOLAB made the following recommendations to countries:

– undertake extensive sensitisation of field veterinary personnel on the need to be vigilant on the reporting of FMD outbreaks;

– provide laboratory support for field veterinary personnel to ensure proper sampling of FMD outbreak cases;

– strengthen laboratory capacities for FMD diagnosis (training of personnel and equipment);
– submit timely sample to Reference Laboratories for virus isolation and serotyping; and
– embark on aggressive FMD control measures (in the long term).

Progression along the foot and mouth disease progressive control roadmap

Presently, countries implementing the roadmap for the progressive control of FMD, which was adopted in January 2009 in Nairobi during the FAO/OIE Global Framework for the progressive control of Transboundary Animal Diseases (GF-TADs) workshop on the development of a long-term action plan (roadmap) for improved surveillance and control of FMD in Africa (Table VIII), seem not to have achieved any substantial results. This is most likely because there is little or no incentive for the control of the disease in the region and the restriction of livestock movement in this region seems impossible.

Table VIII
Foot and mouth disease progressive control roadmap, West and Central Africa

Countries	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Benin	0	0	0	0	1	1	2	2	2	2	2	2
Burkina Faso	0	0	0	0	1	1	2	2	2	2	2	3
Côte d'Ivoire	0	0	0	1	1	2	2	2	3	3	3	4
Gambia	0	0	0	0	1	1	1	2	2	2	2	2
Ghana	0	0	0	1	1	2	2	2	3	3	3	4
Guinea	0	0	0	0	1	1	2	2	2	2	2	3
Guinea-Bissau	0	0	0	0	0	1	1	2	2	2	2	2
Liberia	0	0	0	0	0	1	1	2	2	2	2	2
Mali	0	0	0	1	1	2	2	2	3	3	3	4
Niger	0	0	0	1	1	2	2	2	3	3	3	4
Nigeria	?	?	0	1	1	2	2	2	3	3	3	4
Senegal	0	0	0	1	1	2	2	2	2	2	2	2
Sierra Leone	0	0	0	0	0	1	1	2	2	2	2	2
Togo	0	0	0	0	0	1	1	2	2	2	2	2
Cameroon	0	0	0	1	1	2	2	2	3	3	3	4
Cape Verde	0	0	0	0	0	1	1	2	2	2	2	2
Central African Republic	0	0	0	0	0	1	1	2	2	2	2	2
Chad	0	0	0	0	1	1	2	2	2	2	2	3
Congo (Dem. Rep. of the)	0	0	0	0	1	1	2	2	2	2	2	3
Congo (Rep. of the)	0	0	0	0	0	1	1	2	2	2	2	2
Equatorial Guinea	0	0	0	0	0	1	1	2	2	2	2	2
Gabon	0	0	0	0	0	1	1	2	2	2	2	2
Sao Tome and Principe	0	0	0	0	0	1	1	2	2	2	2	2

The control strategy being implemented in the region is based mainly on the vaccination of dairy cattle in the peri-urban zones and the early diagnosis of the disease for an early response to content outbreak.

In Mali, the following measures have been put in place for the control of FMD:

– vaccination of 300,000 cattle (risk zones, 100,000; peri-urban, 50,000; and cattle used as beast of burden, 150,000) two times during the first year and once a year for the next four years;

– early detection and good management of outbreaks;

– collection of samples and shipment to laboratories;

– reinforcement of the control of livestock movement;

– reinforcement of capacity building; and

– informing and sensitising livestock owners and other stakeholders.

In the Republic of Côte D'Ivoire, the control strategy is based on the vaccination of dairy cattle and cattle used as beast of burden, while in Senegal the main measure regarding FMD control is the vaccination of dairy cattle. Other countries in West and Central Africa have not developed any specific strategy for the control of FMD.

Conclusion

In order to effectively control FMD in West and Central Africa, there will be a need for a concerted regional effort within the Economic Community of West African States (ECOWAS) and the Economic Community of Central African States (ECCAS) (including assessment of the progress made along the progressive control roadmap) and a common understanding between the two regions on the most comprehensive strategy to adopt. This should be based on early identification of infected and high-risk areas and transparency in disease information-sharing. In addition, combinations of FMD control activities with other disease control activities will need to be worked out. Furthermore, international assistance will be imperative to initiate FMD control in West and Central Africa.

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FMD in the SADC region: historical perspectives, control strategies and trade implications

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Summary

*The epidemiology of foot and mouth disease (FMD) in southern Africa is complicated by the dominance of buffalo-maintained and transmitted Southern African Territories (SAT) serotypes, which co-evolved with buffalo over approximately 900 years. So far, most countries of the region have prevented SAT viruses from becoming endemic in livestock populations by rapid elimination of infection when it has spilled over into cattle. Nevertheless, there are indications that in some countries SAT serotype infections are now also endemic in cattle. Serotypes O and A also occur in northern parts of the Southern African Development Community (SADC) region, but there is no indication that wildlife maintains non-SAT serotypes. FMD control in the SADC region is based on combinations of methods depending on the export status of countries; these include separation of animal populations – wild and domestic – by fencing systems to create FMD-free zones, control of movement of animals and their products, routine vaccination and surveillance. Countries in the region that export beef to high-value markets employ all these measures. Botswana, Namibia, South Africa and Swaziland made good progress in managing FMD between the late 1970s and the turn of the 21st Century, probably largely because of the use of improved FMD vaccines manufactured locally from the late 1970s onwards. However, since 2001 the situation has deteriorated, with intervals between FMD outbreaks becoming shorter while individual outbreaks lasted longer and were more difficult to control. Outbreaks characterised by mild or unapparent infection have also become more evident. In an effort to improve this situation, SADC has teamed up with development partners, international and regional FMD reference laboratories, the Food and Agriculture Organization of the United Nations (FAO) and the World Organisation for Animal Health (OIE) to implement measures, focused initially on mapping the FMD viruses circulating in wild buffalo populations and cattle at the wildlife/livestock interface, to satisfy requirements of the Progressive Control Pathway for FMD (PCP-FMD). SADC is developing a strategy that will include a roadmap for the management of FMD in the region to guid*e this process.

Keywords
Buffalo – Foot and mouth disease – Southern African Territories serotypes – Vaccination.

Introduction

The presence of transboundary animal diseases (TADs) and the escalating costs of their control, coupled with the ever increasing costs of regulation and meeting export standards for beef exporters from southern Africa (8) is a major constraint to the development of the livestock industry in the Southern African Development Community (SADC) region. Of all the TADs in the region, foot and mouth disease (FMD) has been identified by the Chief Veterinary Officers of SADC Member States as a disease of strategic importance for the whole region. Apart from limiting market access for livestock commodities and impeding regional integration, the disease is increasingly being considered as a hindrance to improving the livelihoods and food security needs of livestock communities. In the SADC region, FMD is unique because of the role played by wildlife, particularly the African buffalo (*Syncerus caffer*), in the epidemiology of the disease (9), even if transmission of the virus from buffalo to livestock is inefficient.

The involvement of buffalo in the epidemiology and, therefore, outbreaks of FMD is resulting in continued conflict between wildlife conservation and livestock development.

Epidemiology of FMD in the SADC region

The Southern African Territories (SAT) types predominate in the SADC region. In southern Africa, as in other parts of the continent, the epidemiology of FMD is influenced by two different, but sometimes overlapping, patterns, namely a cycle in which wildlife maintains and spreads the disease to other susceptible domestic animals and wild ungulates and a cycle that is maintained within domestic animals, independent of wildlife. In southern Africa, the former cycle predominates due to the presence of African buffalo, the only wildlife species for which long-term maintenance of FMD has been described (3, 4, 5, 9, 11, 12). The lack of the latter cycle in some countries in southern Africa may also be because some countries in the region have been adept at preventing SAT viruses becoming endemic in cattle populations.

The African Development Bank-funded 'Strengthening institutions for the risk management of transboundary animal diseases' (SADC TADs) project embarked on a buffalo sampling exercise with a view to determining the FMD viruses circulating in wild buffalo populations in the region's national parks. The samples are being tested at the Botswana Vaccine Institute (BVI), the Onderstepoort Veterinary Institute (OVI), the Food and Agriculture Organization of the United Nations (FAO) and the World Organisation for Animal Health (OIE) Reference Laboratory for FMD at Pirbright in the United Kingdom. The data collected from the exercise will form part of the information that will be used to update the SAT serotype database developed with the assistance of the EU-funded FMD project (2007–2009) and to develop, and later update on a regular basis, the region's FMD strategy. They will also be used by BVI to quickly react to FMD outbreaks in different parts of the region with, hopefully, faster production of vaccine suitable for each outbreak. The region's agriculture/livestock ministers have committed to continue the sampling exercise on an annual basis beyond the project's life.

Present PCP status of SADC countries

The progressive control pathway (PCP) for FMD proposes a stage-wise approach, allowing for a regional or ecosystem-based synchronisation between countries, similar to the approach known as OIE rinderpest pathway followed under the Global Rinderpest Eradication Programme (GREP), now concluded. The FMD PCP consists of six stages ranging from zero, where there is continuous FMD virus circulation with no reporting or control actions, to five, where a country is ready to be officially recognised by the OIE as free without vaccination. The OIE currently recognises only three categories for countries with regards to FMD:

1. countries not free from FMD (PCP Stages 0–3)
2. FMD-free countries or zones practising vaccination (PCP Stage 4) and
3. FMD-free countries or zones where vaccination is not practised (PCP Stage 5).

However, the region felt it was important to utilise the full classification spectrum of the six stages because of the diversity of countries with regard to FMD control within the region.

The table below summarises the status and desired ambition of the countries in relation to the PCP stages they wish to attain over the next ten years from 2011 (Table I). The classification was arrived at after a consultation of countries without formal OIE recognised status for FMD, conducted in March 2011 under the auspices of OIE and FAO (13).

Table I
PCP status of SADC Member States

Countries	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Angola	1	1	1	2	2	2	3	3	3	3
Angola (zonal)	1	1	1	2	2	3	3	4	4	4
DRC	1	1	1	1	2	2	2	2	2	3
Malawi	3		3	3	3	3	3	3	3	3
Malawi (zonal)	3		3	4	4	4	4	4	4	4
Mozambique	2	2	3	3	3	3	3	3	3	3
Mozambique (zonal: Tete, Manica)	2	2	3	3	3	5	5	5	5	5
Mozambique (zonal: South)	2	2	3	3	4	4	4	4	4	4
Seychelles	Hist freed	5	5	5	5	5	5	5	5	5
Tanzania	1	1	2	2	2	3	3	3	3	3
Tanzania (Mainland:zonal)	1	1	2	2	2	3	3	4	4	4
Tanzania (Islands: Zanzibar, Pemba)	1	1	2	3	3	4	4	4	4	4
Zambia	2	2	3	3	3	3	3	3	3	3
Zambia (zonal)	2	2	3	3	4	4	5	5	5	5
Zimbabwe	1	2	3	3	3	3	3	3	3	3
Zimbabwe (zonal)	1	2	3	3	3	4	4	5	5	5

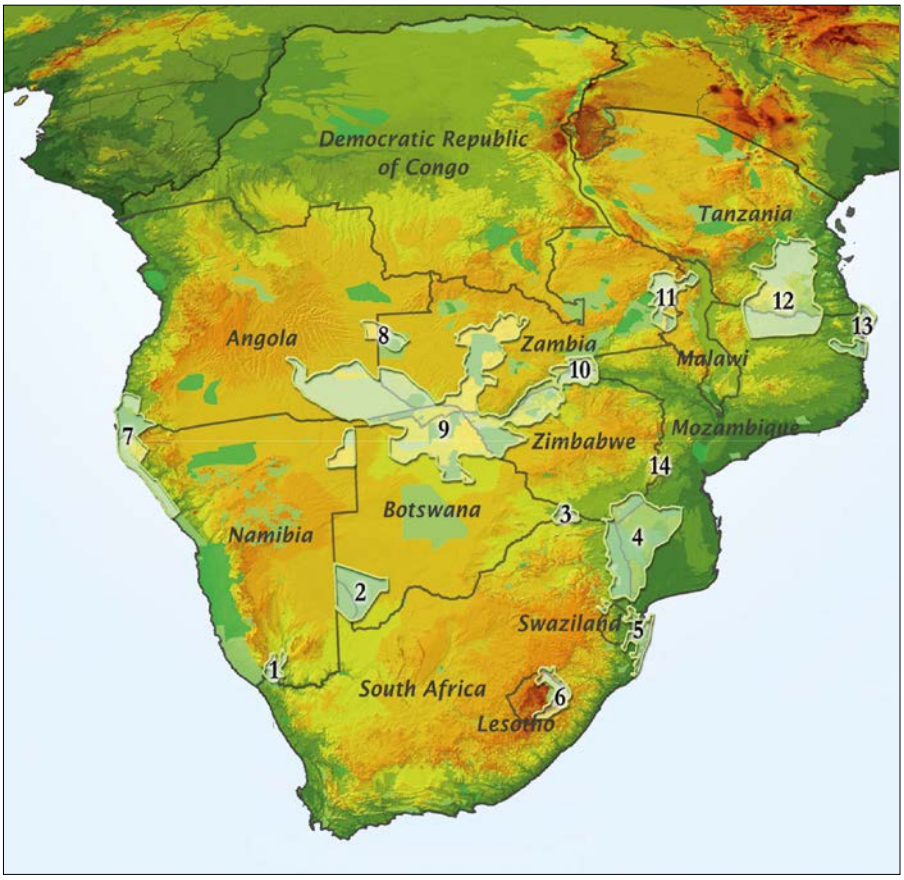
Table courtesy of OIE SRR-SA

TFCAs and the wildlife factor in the epidemiology of FMD

The region has, in the last ten years, witnessed an increase in the formation of transfrontier conservation areas (TFCAs). Currently, the list of existing and proposed TFCAs in the region stands at 17. The largest TFCA in the region is the Kavango-Zambezi (KAZA) TFCA, spanning five southern African countries – Angola, Botswana, Namibia, Zambia and Zimbabwe – and centred on the Caprivi–Chobe–Victoria Falls area (Fig. 1). The KAZA TFCA covers an area of approximately 287,132 km^2, almost the size of Italy (300,979 km^2), and includes no fewer than 36 formally proclaimed national parks, game reserves, forest reserves and game/wildlife management areas, as well as intervening conservation and tourism concessions set aside for consumptive and non-consumptive uses of natural resources (see www.kavangozambezi.org). Given that livestock are traditionally pivotal to societies that live in TFCAs and the immensity and geographical span of most TFCAs, it is inevitable that people, wildlife and livestock live together in most parts of the KAZA TFCA.

FMD control strategies in the region

In Botswana, Namibia, South Africa and Swaziland excellent progress was made in managing FMD from the late 1970s to the turn of the 21st Century. The dramatic fall in the rate at which outbreaks occurred over that period was probably largely because of the production of FMD vaccine locally from the late 1970s onwards. However, since 2001 the situation has deteriorated, with intervals between FMD outbreaks becoming shorter while individual outbreaks last longer and are more difficult to control.



1. Ai-|Ais/Richtersveld Transfrontier Park *(treaty signed)*
2. Kgalagadi Transfrontier Park *(treaty signed)*
3. Limpopo/Shashe TFCA *(MoU signed)*
4. Great Limpopo TFCA *(treaty signed)*
5. Lubombo TFCA *(MoU signed)*
6. Maloti-Drakensberg Transfrontier Conservation & Development Area *(MoU signed)*
7. Iona-Skeleton Coast TFCA *(MoU signed)*
8. Liuwa Plain-Mussuma TFCA *(MoU pending)*
9. Kavango-Zambezi TFCA *(MoU signed)*
10. Lower Zambezi-Mana Pools TFCA *(MoU pending)*
11. Malawi/Zambia TFCA *(MoU signed)*

12 – Niassa-Selous TFCA *(conceptual phase)*

13. Mnazi Bay-Quirimbas Transfrontier Conservation & Marine Area (TFCMA) *(conceptual phase)*
14. Chimanimani TFCA *(MoU signed)*

Fig. 1
Kavango–Zambezi Transfrontier conservation areas (TFCAs)
Courtesy of Peace Parks Foundation 2013

The SADC region follows a dualistic approach to the control of FMD. The countries that export to the lucrative markets employ a combination of the following control options:

– Separation of livestock from infected wildlife populations (fencing being the primary tool). Game-proof fences have been erected to restrict the movement of cloven-hoofed animals all regularly maintained and patrolled and intended to constitute physical barriers to movement (6). Fencing remains a controversial issue in the region attracting the ire of those concerned with environmental issues (2) and those advocating transfrontier conservation areas, who argue for the removal of fences to allow free movement of game.

– Routine vaccination of cattle in high-risk areas (in and adjacent to infected buffalo populations). Bi- or tri-annual vaccination of cattle in proximity to infected zones populated by buffalo complements these other measures. This is done in conjunction with the ongoing surveillance of cattle in endemic areas (8) and/or high-risk areas (10).

– Stamping out if the populations involved are small. In South Africa and Botswana, when FMD outbreaks have occurred in the designated FMD-free zone, they have sometimes been controlled by the compulsory slaughter of infected and in-contact animals when relatively small numbers of animals are affected (7). This is not without controversy, especially over issues of compensation.

– Movement control of susceptible animals and their products. In most exporting countries animal movement control is administered through a permit system under authorisation of the veterinary department. It is supported by livestock identification and traceability measures including branding, eartags and a networked database (in the case of Namibia) and micro-chipped reticular boli (in the case of Botswana's Livestock Identification and Trace Back System), and enforced with roadblocks (8).

– High levels of surveillance often carried out irrespective of whether or not the disease is present. It is becoming increasingly difficult to justify the high expenditure related to active disease surveillance, especially in the absence of overt clinical disease in cattle. However, since infection will always be present in buffalo populations, surveillance cannot be done away with.

These approaches have achieved considerable success over 60 years in the exporting countries (see Fig. 2). Until the late 1990s outbreaks were rare and, when they did occur, they were quickly controlled and a successful (but preferential, in terms of tariffs) beef export system emerged. That is now under severe threat because of the increase in both frequency and severity of outbreaks, especially over the last ten years.

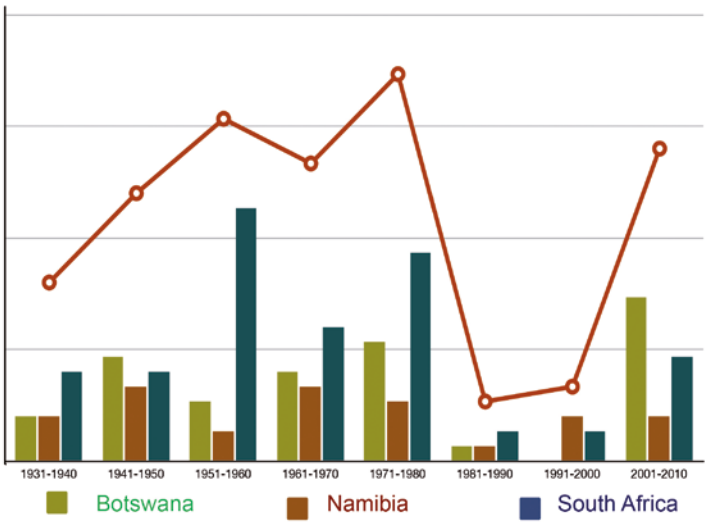


Fig 2
Incidence of FMD outbreaks in cattle over eight decades in three southern African countries

Courtesy of M. Atkinson

Non-exporting countries of the region control FMD outbreaks through:

– Vaccination of cattle following an outbreak. Vaccination is hardly routine but is carried out following an outbreak of FMD as part of the control measures.

– Movement control of animals from and into outbreak areas. Even though, on paper, movement restrictions may form part of the national control strategy, it is usually the case that these restrictions are rarely maintained for long periods after an outbreak. The lack of funds to sustain permanent roadblocks is a major contributing factor to the ineffectiveness of this control option in the non-exporting countries. It is also often difficult to justify such expenditures to the treasury in the absence of tangible returns from the livestock sector because the country is not generating income from exports of livestock products.

– Active surveillance is also constrained due to inadequate funding.

The region's only FMD vaccine producer, the Botswana Vaccine Institute (BVI), has, in the last four years, made significant improvements to the quality of the vaccine. This follows field trials in Malawi, Botswana and Namibia to evaluate the effectiveness of the vaccine and vaccination. The culmination of these efforts was new recommendations on the vaccination frequency, an increase in the payload of the vaccine and the commissioning of the new production plant at BVI that has the capacity to produce a purified vaccine.

In summary, the seven main thrusts of the strategy under development are gaining knowledge of virus strains circulating in the wild buffalo population, designing effective vaccination programmes in the region, improving

early detection and identification of the disease at field level and how this information is speedily relayed to headquarters for rapid reaction, definition of and maintenance of common regional minimum standards for improved surveillance in member states, improved laboratory diagnosis, co-existence of the reality of TFCAs and advocacy for implementation of the commodity-based trade (CBT) concept to benefit livestock farmers in areas where the risk of FMD spread is negligible.

Trade restrictions due to FMD

Most countries in southern Africa either already or aspire to export fresh or chilled beef into high-value markets. Unfortunately, beef production in the region is not internationally competitive, as even current exports are only possible because of tariff protection enjoyed by the region's exporters (e.g. provisional *economic partnership agreements* (EPAs) signed by Botswana and Namibia with the European Union). Improvement of competitiveness requires investment and adoption of modern farming methods and massive infrastructural developments in the region's transport and other related sectors. However, investment in the sector is dependent (among other things) on access to markets and prospects for a good return. Market access is in turn constrained by the current FMD rules that require the setting up of FMD-free zones from which the exports should originate. As indicated earlier, it is becoming increasingly difficult to set up and maintain fences for FMD control surrounding FMD-free zones because of the land use pressure exerted by, among others, mushrooming of TFCAs in the region. In fact, recent studies have shown that in some cases, the revenue from wildlife, tourism, conservation and land use may exceed that from livestock in the region's rural areas.

Unless the region can gain acceptance for non-geographic international standards for trade in animal commodities and products, the prospects for increasing beef exports are unlikely to be realised. Fortunately, the OIE, which is the relevant international standard-setting body, has in recent years begun to adopt non-geographic standards – they now exist for deboned beef and a number of other commodities (including live animals) and products (e.g. Article 8.5.25). Unfortunately, many Veterinary Services of importing countries do not accept these standards without reasons other than being perceived as 'unsafe' and 'unacceptable'.

It is felt that even the progressive control pathway for FMD (PCP-FMD) may not live up to the critical need to fully accept and push for more recognition of non-geographic-based standards. Although the PCP-FMD mentions non-geographic approaches, there is pervading advocacy for zoning and zonation. That does not appear to be compatible with the need for balanced rural development that incorporates the initiatives for poverty alleviation and conservation of wildlife and invaluable wilderness areas alongside livestock production. It is also clear that, for the SADC region and also for East Africa, getting rid of buffalo is not an option. Therefore, a way has to be found to accommodate both wildlife and livestock land use practices in the region.

Going forward

Most economies in the region are growing at a fast rate, resulting in the emergence of a small but rapidly expanding middle class, whose consumption of livestock products is also increasing. Therefore, in the short and medium term this increasing demand will have to be satisfied by an increase in livestock production and productivity. At the same time, the interaction between wildlife and livestock is bound to increase and, therefore, one way to enhance trade in livestock and livestock products will be for countries to fully adopt and implement Article 8.5.25 of the *Terrestrial Animal Health Code*, which deals with commodity-based trade (CBT) of 'safe products'. SADC will work with member states in the region to raise awareness of the CBT and improve in-country understanding of the CBT in both the ministries responsible for agriculture and trade (public sector) and in the business community (private sector). Likewise, it would be desirable for all OIE Member Countries to adopt and implement in full the said article, if beef exports from SADC countries are to be sustained or even increased.

At the national level, countries will be assisted to develop national strategies that are aligned with the FMD regional strategy.

At the regional level, the objective is to develop a medium- to long-term strategy for the progressive control of FMD in the SADC region, the expected outputs of which will include development of improved tools for managing variation in SAT-type viruses circulating in the region and an improved knowledge base on integrating FMD control

with rural development and management of TFCAs. The setting up of regional SAT antigen banks will also be considered in the strategy under development while regional research will focus on development of NSP tests.

Conclusion

Foot and mouth disease presents a critical impediment to the expansion of trade in livestock and livestock commodities in the SADC region. The recent deterioration in both the number and severity of outbreaks and the transboundary nature of the disease make a regional approach to its control an absolute necessity if success is to be achieved (1). There should also be deliberate steps aimed at promoting the implementation of Article 8.5.25 in the region and advocacy for its wider acceptance internationally. Finally, the advent of TFCAs is a reality and has been shown to be contributing just as much as, if not more than, agriculture in parts of the SADC region. Integrated mechanisms for the mutual and beneficial existence of TFCAs and control of TADs along the wildlife/livestock/environment interface must be worked out to ensure holistic rural development. The Global FMD Strategy should take cognisance of the unique nature of FMD epidemiology in the region.

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The Hemispheric Program for the Eradication of Foot-and-Mouth Disease*

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Summary

The importance of foot and mouth disease for the social and economic development of the American continent led to the establishment in 1951 of the Pan American Foot-and-Mouth Disease Center (PANAFTOSA), which, ever since, has been providing technical support to countries for the elimination of the disease. The first FMD national elimination programmes were established in South America around the 1960s and 1970s. To advance the regional elimination efforts in the 1980s, countries agreed on a Plan of Action 1988–2009 of the Hemispheric Program for the Eradication of Foot-and-Mouth Disease. The Plan of Action 1988–2009 did not reach the goal of eliminating the disease from the continent and a new Plan of Action 2011–2020 was developed in 2010 based on the experience acquired by the countries and PANAFTOSA during the previous 60 years. This plan is now being implemented and it is the practical contribution of the countries of the Americas to the Food and Agriculture Organization of the United Nations (FAO)/World Organisation for Animal Health (OIE) Global Foot and Mouth Disease Control Strategy.

Keywords
FMD – FMD elimination – FMD South America – FMD vaccination – Foot and mouth disease – Hemispheric Program for the Eradication of Foot-and-Mouth Disease – PHEFA.

Introduction

Foot and mouth disease (FMD) is a highly transmissible viral disease of cloven-hoofed animals. It is caused by several virus antigenic types and subtypes, which are not evenly distributed in the different regions of the world where FMD is present. Infection from one of the seven serotypes does not confer immunity against any of the others. Out of the seven serotypes, six have been reported from Africa (A, C, O, Southern African Territories [SAT] 1, SAT 2 and SAT 3), four from Asia (A, C, O, Asia 1) and only three from South America (A, O, C). SAT 1 and SAT 2 have been sporadically reported in the Middle East. FMD is one of the most important animal diseases for the restrictions it imposes on the trade of animals and animal products and its socio-economic consequences. Inactivated FMD vaccines are very important tools for the control and elimination of the disease and have proven effective for this purpose in South America. However, viral circulation persists in certain areas, challenging regional elimination efforts and leading to the re-introduction of the disease into previously free areas with severe socio-economic consequences.

Historical background of the disease in the Americas

The first outbreaks of FMD in the American hemisphere were recorded almost at the same time in 1870 in the United States of America (USA), Argentina and Uruguay, and some years later in Paraguay. Outbreaks were associated with cattle imported from Europe. In Brazil, the first case of FMD was reported in Uberaba, Minas Gerais, in 1895. In Peru and Bolivia, outbreaks were recorded from 1910, in Chile from the 1920s and in Venezuela, Colombia

and Ecuador from the 1950s. In the Caribbean, FMD was detected in Jamaica in 1922, Aruba and Martinique in 1953, and Curaçao in 1957. FMD has never been detected in Central America or Panama (4).

After its introduction to the Americas, the spread of FMD followed drastically different pathways according to the underlying conditions and the responses of the Veterinary Services for containment and eventual elimination. In South America, unlike North America, after its introduction, FMD spread easily through bovine populations and reached an endemic–epidemic condition in practically every territory with important livestock populations. This spread was facilitated by the extensive bovine livestock production, which was expanding due to the colonisation and rapid occupation of large territories, leading to highly dynamic livestock movement.

The beginning of the fight against foot and mouth disease in South America

The severe FMD epizootic of Mexico (1947–1952) that led to the creation of the Mexico–United States Commission for the Prevention of Foot and Mouth Disease caused great concern to the governments of the Organisation of American States (OAS). The OAS's Inter-American Economic and Social Council approved the creation of the Pan American Foot-and-Mouth Disease Center (known as PANAFTOSA from its telex address name), and this was then established on 27 August 1951 under the management of the Secretariat of the Pan American Health Organization (PAHO) and the Regional Office for the Americas of the World Health Organization (WHO), with the support of the Government of Brazil.

The first initiatives to control FMD in South America started with the establishment of PANAFTOSA that began working on the diagnosis and characterisation of circulating viruses, training of personnel and providing technical assistance to countries in order to establish national diagnostic laboratories. In addition, PANAFTOSA established a programme for the development and production of FMD vaccine. Studies were carried out on the antigenicity and immunogenicity of the strains of the circulating field viruses for their selection for vaccine production. The Frenkel method for producing virus was developed along with improved processes for the inactivation of the virus, so that countries could produce safe and effective vaccines on an industrial scale. In the 1960s, cell culture for antigen production was introduced (4).

Argentina was the first country that established a national FMD control programme in 1964. Subsequently, at the end of the 1960s and 1970s, other countries started their FMD control programmes. The majority of these programmes were funded by loans granted by the Inter-American Development Bank (IADB).

By the mid-1960s, the livestock industry and some governments started to appreciate that the disease not only caused drastic direct economic losses by morbidity and mortality of animals, production and reproductive losses, but also represented a serious limitation to the trade of animals and animal products. As a consequence, the countries of the Southern Cone of South America established agreements and initiatives to fight FMD, and requested PANAFTOSA to coordinate several of these efforts. These initiatives led to the creation of the South American Commission for the Control of Foot-and-Mouth Disease in 1972 (known as COSALFA from its Spanish acronym), which was ratified by the ministries of foreign affairs of the signatory countries as a permanent commission for which the Secretariat was entrusted to PANAFTOSA. With the establishment of COSALFA, PANAFTOSA started a systematic effort to collect information on the occurrence of syndromes compatible with FMD and on the control measures, vaccine production, animal population under the programmes, and expenditures incurred by countries in their FMD control programmes (11). In this regard, at that time the Continental epidemiological surveillance and information system (SIVCON) was developed to collect, analyse and disseminate weekly syndromic geo-referenced information (8).

Within the framework of COSALFA and with the support of PANAFTOSA, countries organised their FMD control programmes, with the application of systematic mass vaccination of their bovine populations. Crucial to the organisation of the national FMD control programmes was the active participation of livestock producers. The livestock producers got organised and became the principal actors in financing and implementing vaccination campaigns. Furthermore, they started advocating at the highest political levels for the public sector to invest in official FMD control programmes and in the capacity of the official Veterinary Services (2, 12).

PANAFTOSA, as part of its technical cooperation, established a robust programme of capacity building and continuing professional development: the Animal Health Training Program for Latin American Countries (known as PROASA from its Spanish acronym) trained some 6,000 professionals of the countries over two decades (1975–1995) both in laboratory diagnosis and production and quality control of oil-adjuvant vaccine, epidemiological

and surveillance information systems and management of programmes. As a result of this massive capacity development and training initiative, both at managerial and technical–operative levels, practically all the Veterinary Services of the Latin American countries upgraded their capacities and technical competencies, decisively influencing the effectiveness of the national FMD elimination programmes. The vast majority of the national FMD elimination programmes were structured on the basis of the technical cooperation provided by PANAFTOSA and financial support of IADB (13).

The FMD control strategy was based on reducing the susceptibility of bovine populations through systematic mass vaccination campaigns, together with the control of livestock movement and responses to outbreaks. To meet the demand of the country control programmes, large-scale vaccine production plants were built in the region. In its early stages, the FMD control programmes used aqueous vaccines applying three or four vaccinations per year (3). However, problems with the quality of the vaccines, deficient supply and high costs of vaccination prevented the establishment of adequate immunological coverage, leading to large areas with viral circulation and FMD endemic conditions.

In the mid-1980s, after 30 years of fighting FMD, the South American countries concluded that, despite various national and regional initiatives, they would not meet the expected result of elimination. The consensus was that there was a need for a high-level political agreement, coordinated at the international level, to provide the political and strategic framework for the elimination programmes. Through various regional forums, the governments of South American countries, the organisations of the livestock sector and the technical cooperation agencies agreed on the need to establish such a framework.

The Hemispheric Program for the Eradication of Foot-and-Mouth Disease

At the initiative of the governments and the stakeholders of the livestock value chain, the 10th Inter-American Meeting, at Ministerial Level, on Health and Agriculture (known as RIMSA from its Spanish acronym) requested PAHO/WHO to establish the Hemispheric Commission for Eradication of Foot-and-Mouth Disease (known as COHEFA from its Spanish acronym), and to develop a Plan of Action for a Hemispheric Program for the Eradication of Foot-and-Mouth Disease (known as PHEFA from its Spanish acronym). PANAFTOSA, jointly with a group of experts from the countries, drafted the Plan of Action 1988–2009 of the PHEFA, which was approved by COHEFA in 1988 and ratified by RIMSA in 1989. The Plan of Action 1988–2009 was based on the epidemiological knowledge of the disease in the continent and on the experiences gained by the countries and PANAFTOSA. The plan was used to direct FMD elimination efforts of the continent throughout its period (15).

The Plan of Action 1988–2009 defined the goal of eliminating FMD by 2009 and established the strategies and action objectives with the commitment and political will of the countries. Its key strategic approaches were the use of the epidemiological characterisation of the disease with its relation to the production systems in order to prioritise interventions; the joint effort of the private and public sectors; the development of sub-regional initiatives and plans; and the establishment of bilateral and multilateral agreements in the sub-regions. The technical and epidemiological foundation of the Plan of Action 1988–2009 were based on the large body of knowledge on the natural history of the disease and its determinants, particularly the implications of the bovine production systems on the epidemiology of the disease, along with the analysis of the health-disease process by applying an ecosystems approach developed by PANAFTOSA (1, 10, 14).

Execution and outcomes of the Plan of Action 1988–2009 of the Hemispheric Program for the Eradication of Foot-and-Mouth Disease

Immediately after establishing the Plan of Action 1988–2009, the countries of the Southern Cone (i.e. Argentina, Brazil, Paraguay and Uruguay) signed a technical cooperation agreement with PANAFTOSA for the implementation of the River Plate basin project. The Plan of Action 1988–2009 provided the framework for the execution of this project, which included all actions and components outlined in the plan. This sub-regional project led to improved coordination, harmonisation and adaptation of the national FMD elimination programmes, along with the establishment of a monitoring management system that included periodic and systematic meetings for evaluation accompanied by exchange visits carried out by staff from the countries. The participation of the livestock private sector was relevant for the implementation of this project.

Soon after the implementation of the project, a significant change in the way the disease occurred became evident. There was a reduction in disease incidence, as well as indicators of morbidity and mortality. During the implementation of the River Plate basin project a new tool was introduced: the oil-adjuvant vaccine. With the production of the oil-adjuvant vaccine on a commercial scale and its wide application in systematic mass vaccination campaigns in bovine and bubaline populations only, one of the most relevant tools for the control and elimination of the disease was introduced (Fig. 1 shows the dramatic effect of this vaccination strategy in one South American country [9]). After four years of implementation of the River Plate basin project, the clinical incidence of the disease had drastically declined, and started disappearing from 1993. This situation made it possible for the countries to initiate the processes of being declared free, with the recently established status of disease free with vaccination approved by the World Organisation for Animal Health (OIE) in 1994. At the end of the 1990s, due to the enthusiasm provided by the progress in the sanitary situation, some countries decided to move forward in the attainment of more advanced sanitary status, and began the process of withdrawing vaccination, and applying to OIE for the FMD free without vaccination status. This process led to an abrupt setback in 2000–2001, with the spreading of a large FMD epizootic (due to virus serotypes O and A) in these countries and areas already declared FMD free, with dramatic economic and social consequences. This forced a sweeping review of the national programmes of the affected countries, and led to the reintroduction of systematic mass vaccination, which is still practised today. This setback indicated that the decision to withdraw mass vaccination was taken with insufficient epidemiological evidence. Furthermore, the decision to withdraw systematic mass vaccination was taken without an associated strengthening of the Veterinary Services, and without implementation of effective systems for prevention, early detection and response, which were indispensable to managing increased susceptibility to the disease resulting from the withdrawal of vaccination (5, 17, 23).

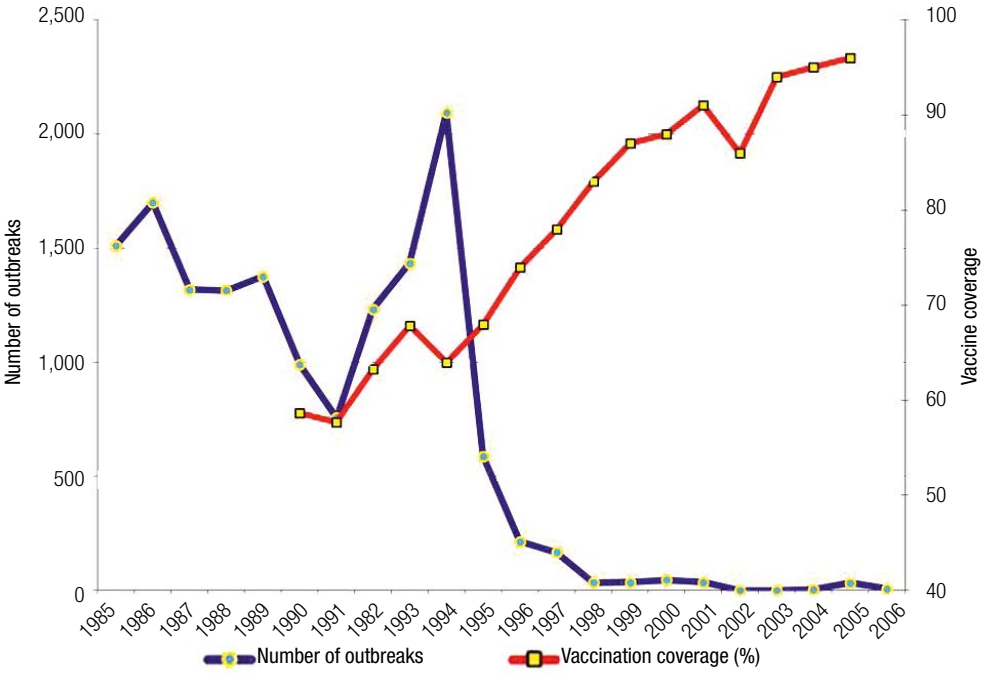

Fig. 1
Evolution of the FMD outbreaks and vaccine coverage in Brazil (12)

To revive the political commitment to elimination, in March 2004, the Hemispheric Conference for Eradication of Foot-and-Mouth Disease was held in Houston, Texas, USA, within the framework of the COHEFA. The Declaration of Houston led to the establishment of the Inter-American Group for Foot-and-Mouth Disease Eradication (known as GIEFA from its Spanish acronym). GIEFA had representatives from both the public and private sectors and the objective of advocating for elimination at the highest political level of the countries, and mobilising resources. The conference also revised the Plan of Action 1988–2009 for the remaining five years (16).

Progress towards FMD elimination in the countries and areas of the other sub-regions of South America (i.e. the Andean and Amazon basins) was uneven. Colombia and Peru advanced consistently in strengthening their official sanitary programmes, with the participation of the private sector, and obtained the OIE certifications of FMD-free areas with and without vaccination across large areas of their territories. Bolivia, Ecuador and Venezuela had

major deficiencies in their national programmes and maintained viral circulation with occurrence of outbreaks. In addition, the North and North-eastern Regions of Brazil remained without the clinical presentation of the disease; however, the structure and capacities of their Veterinary Services presented important weaknesses and could not ensure adequate interventions compatible with the international certification of FMD-free status.

Two decades after implementation of the Plan of Action 1988–2009, great progress in the control of the FMD in the continent could be observed, despite the fact that hemispheric elimination set for 2009 was not reached.

South America as a whole reached outstanding achievements on the commitments made through the 20 years of execution of the Plan of Action 1988–2009. Some 85% of the bovine population (nearly 350 million cattle) were recognised, by the OIE, as FMD free with or without vaccination (a summary of the principal indicators of progress of the PHEFA is shown in Table I). The significant progress made on FMD control by the South American countries led to improvements in animal production indicators and made it possible to establish the sanitary basis for sustaining a growing export process of animal products (mainly cattle and pork meat). In addition, it allowed South America, in particular Brazil and the other Southern Cone countries, to become the largest source of livestock production in the world. The extraordinary development achieved in the last two decades gave this region a privileged position in world trade of meat and other animal products that reached more than US$9 billion per year in 2008 (6). The resulting trade had undeniable economic and social benefits to the peoples of these countries (Fig. 2 provides information on the progress of the export of this commodity).

Table I

Health situation of FMD in South America, as recognised by OIE (May 2010)

	Surface		Cattle and buffaloes herds		Cattle and buffaloes	
	km²	%	Number	%	Number	%
Free without vaccination	3,779,306	20.3	319,671	6.8	11,335,154	3.4
Free with vaccination	8,814,564	47.3	2.670,199	56.9	272,578,829	81.0
Buffer zones	260,168	1.4	73,711	1.5	1,894,285	0.6
Not free	5,794,691	31.1	1.,628,167	34.7	50,546,192	15.0
Total	18,648,729	100	4,691,748	100	336,354,460	100

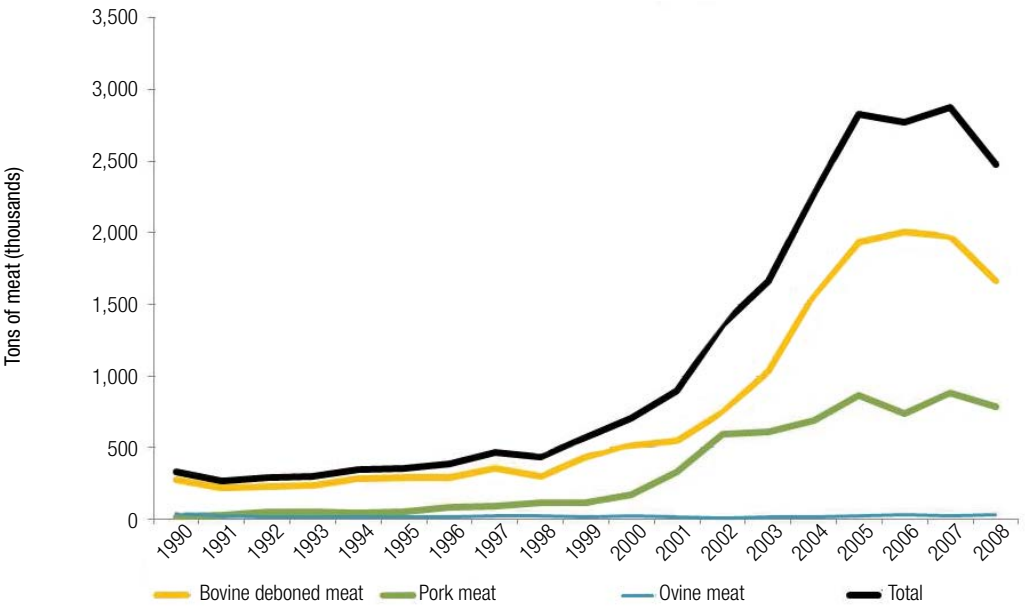

Fig. 2
Export of meat of FMD susceptible species from South America (17)

These are impressive results considering the magnitude of the challenge, the complexities of the social and economic situations of the countries, their productive systems and initial epidemiological conditions along with the difficulties faced during the development of the plan. The technical and financial effort of the countries, the technical cooperation of PANAFTOSA and the commitment of the large majority of the nearly 4.5 million livestock producers all played a key role. This achievement has relevance at the global level, for both its technical challenges and the magnitude of the investment made, with nearly US$1 billion invested each year, of which 70% was financed directly by the private sector.

Despite the huge progress described above, by the end of 2009, there were territories in South America where the virus was still circulating endemically (19). This situation, which prevails to this date, makes all South American countries vulnerable, and endangers the tremendous investments of decades of implementation of FMD elimination programmes by the governments and livestock producers along with the other stakeholders of the livestock production chain. FMD still is the principal sanitary barrier to the trade of animals and their products. Indeed, in the areas that are not FMD free, there are critical deficiencies in the capacities of the official Veterinary Services along with weaknesses in the sanitary work of the livestock producers. These shortcomings include low vaccination coverage, with declared vaccination coverage inconsistent with the epidemiological situation, and difficult relationships between the public and private sectors resulting in different policy visions and approaches, which have negative consequences on the implementation of the national FMD elimination programmes.

Ecuador and Venezuela did not reach the objective set by the Plan of Action 1988–2009 of eliminating the clinical cases of the disease by 2009. Ecuador reported its last outbreak in August 2011: the current favourable epidemiological situation is the result of improvements to the national FMD programme. Venezuela reported its last outbreaks in October 2011. Improvements to the intervention capacities of the national FMD programme on small livestock holders have been observed; however, there are still deficiencies on interventions on medium and large-scale livestock holders. In Bolivia, despite no clinical cases having been reported since 2007, weaknesses have been identified in the vaccination campaigns, the epidemiological surveillance system and the control of animal movement. These weaknesses could affect the ability to detect the disease in this country. At the end of 2009, in the north and north-eastern regions of Brazil, the risk characterisation of FMD had not been completed. Today the situation has changed due to improvements in the structure and capacity of the Veterinary Services as well as the implementation of disease surveillance and extensive risk characterisation studies that should soon lead these regions to reach the FMD free with vaccination status. The high-surveillance zone (known as ZAV from its Spanish acronym), established in the border areas of Argentina, Bolivia, Brazil and Paraguay with an agreement with the OIE to address the sporadic detection of the disease in such areas, has proven effective in allowing the countries to regain the FMD free with vaccination status lost during the outbreaks of 2005 and 2006. On the other hand, it is still necessary to consolidate the efforts of the interventions in other border areas such as those of the Andean countries of Colombia, Ecuador and Venezuela, in which intensified surveillance activities have been implemented (1, 18, 21). From a detailed examination of the outcomes of the Plan of Action 1988–2009 and other information available from PANAFTOSA (e.g. country reports to COSALFA, technical cooperation country missions), it can be concluded that, where the plan was fully implemented, it led to progress from endemic status to the absence of the clinical disease. However, in those areas or countries where there were deficiencies in the implementation of the plan, the disease is still endemic. The data made available through SIVCON provide important insights into trends of the disease. Figures 3 to 11 illustrate the spatial and temporal progression of FMD reported outbreaks from 1978 to 2013 in South America. Figure 12 provides information on the number of reported cases of vesicular disease, FMD and vesicular stomatitis from 1972 to 2011, and Figure 13 reports information on cases of types O, A and C of the FMD virus from 1972 to 2011.

The Plan of Action 2011–2020 of the Hemispheric Program for the Eradication of Foot-and-Mouth Disease

As the first Plan of Action 1988–2009 did not lead to the elimination of FMD, in 2010, the countries decided to establish a second Plan of Action, setting the goal of elimination by 2020. To this end, the countries supported the preparation and later approved a new Plan of Action 2011–2020 of PHEFA (22). The Plan of Action 2011–2020 of PHEFA is the tangible contribution of the Americas to the Foot and Agriculture Organization of the United Nations (FAO)/OIE Global Foot and Mouth Disease Control Strategy (7) as it was formally stated by COHEFA in its 12th ordinary meeting in Santiago, Chile, on 24 July 2012. Furthermore, COHEFA expressed support to the FAO/OIE Global FMD Strategy, making available the experience and tools developed in the region to the FAO/

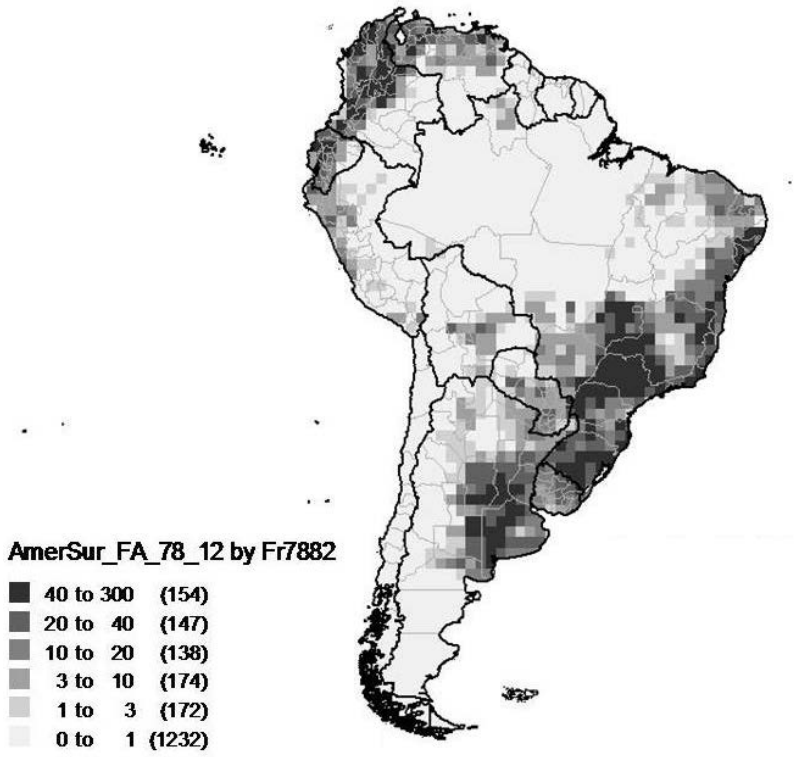

Fig. 3
Cumulative weekly reports of FMD outbreaks 1978-1982
J. Naranjo y A. Mendes. Epidemiology Unit. PANAFTOSA OPS/OMS
Source: reports of the Veterinary Services to the epidemiological information and surveillance system (SIVCONT) of PANAFTOSA

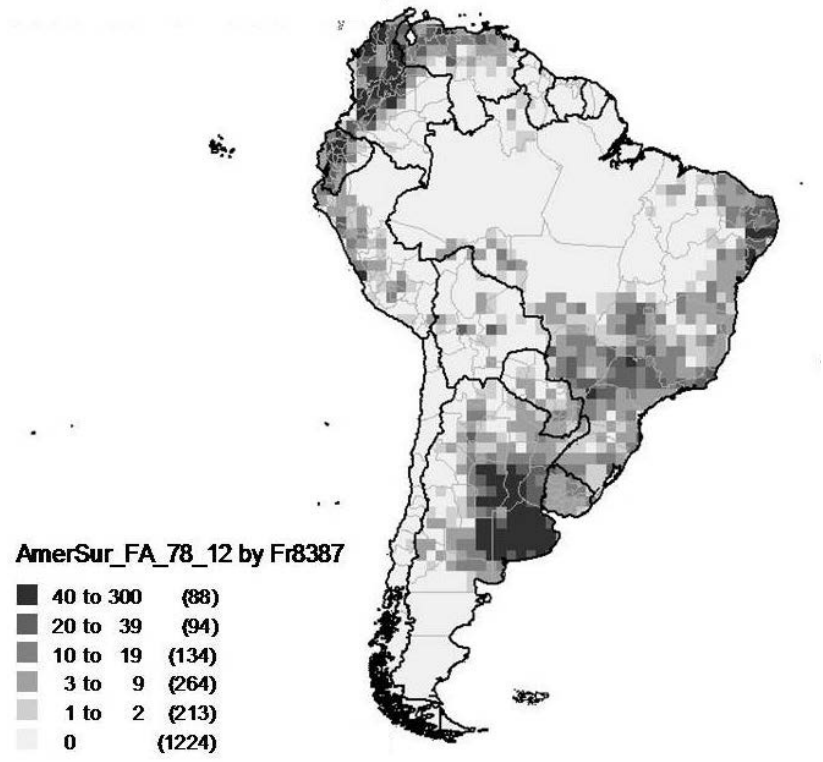

Fig. 4
Cumulative weekly reports of FMD outbreaks 1983-1987
J. Naranjo y A. Mendes. Epidemiology Unit. PANAFTOSA OPS/OMS
Source: reports of the Veterinary Services to the epidemiological information and surveillance system (SIVCONT) of PANAFTOSA

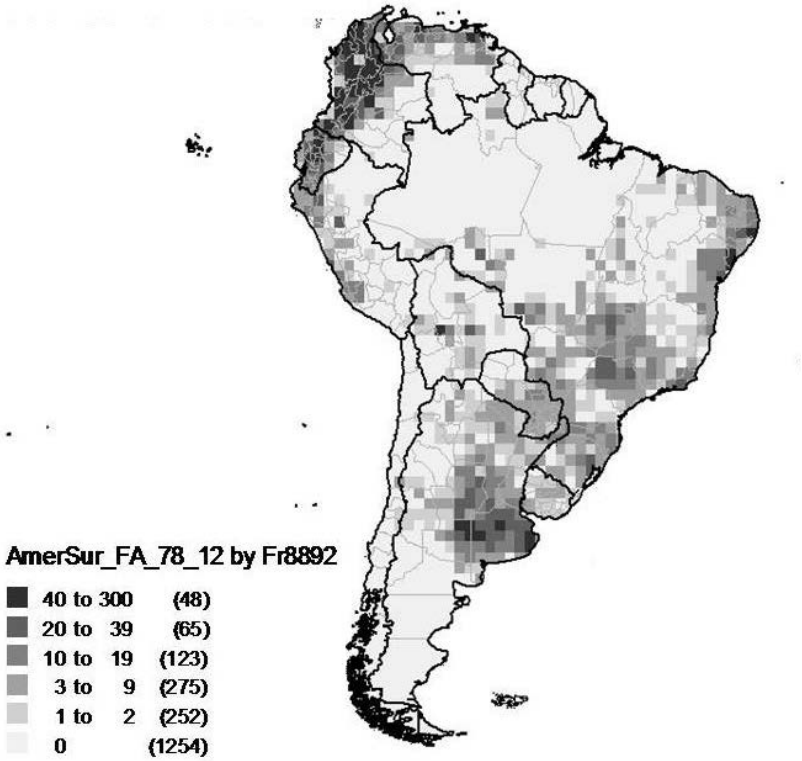

Fig. 5
Cumulative weekly reports of FMD outbreaks 1988-1992

J. Naranjo y A. Mendes. Epidemiology Unit. PANAFTOSA OPS/OMS
Source: reports of the Veterinary Services to the epidemiological information and surveillance system (SIVCONT) of PANAFTOSA

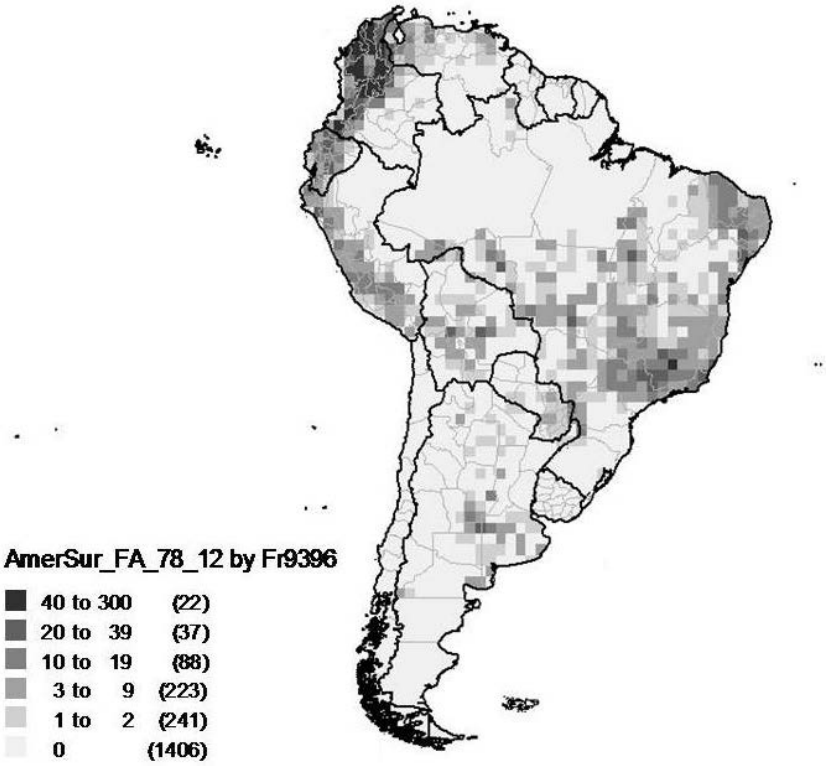

Fig. 6
Cumulative weekly reports of FMD outbreaks 1993-1996

J. Naranjo y A. Mendes. Epidemiology Unit. PANAFTOSA OPS/OMS
Source: reports of the Veterinary Services to the epidemiological information and surveillance system (SIVCONT) of PANAFTOSA

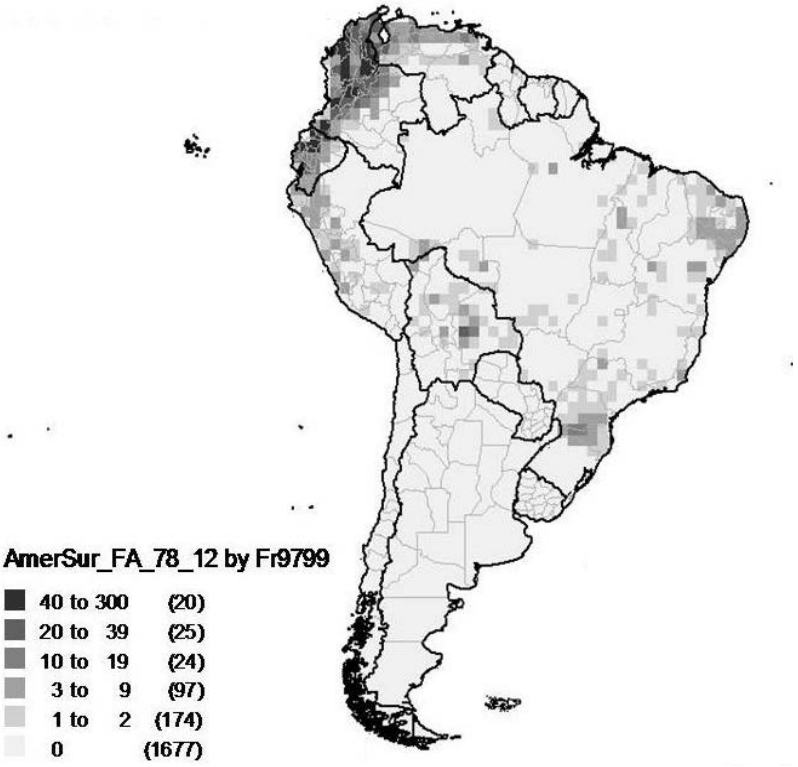

Fig. 7
Cumulative weekly reports of FMD outbreaks 1997-1999

J. Naranjo y A. Mendes. Epidemiology Unit. PANAFTOSA OPS/OMS
Source: reports of the Veterinary Services to the epidemiological information and surveillance system (SIVCONT) of PANAFTOSA

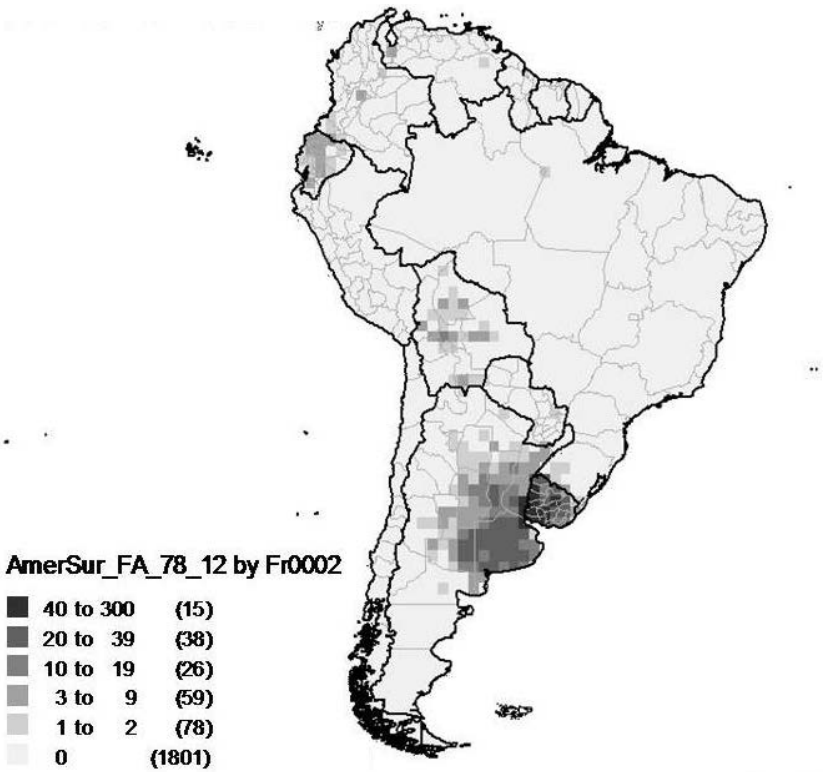

Fig. 8
Cumulative weekly reports of FMD outbreaks 2000-2002

J. Naranjo y A. Mendes. Epidemiology Unit. PANAFTOSA OPS/OMS
Source: reports of the Veterinary Services to the epidemiological information and surveillance system (SIVCONT) of PANAFTOSA

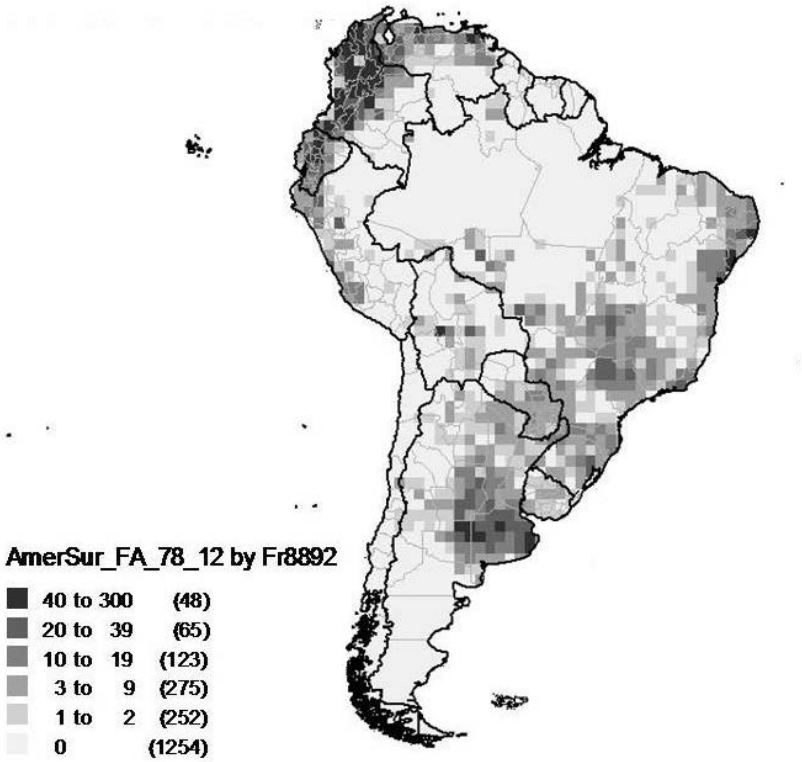

Fig. 9
Cumulative weekly reports of FMD outbreaks 2003-2007

J. Naranjo y A. Mendes. Epidemiology Unit. PANAFTOSA OPS/OMS
Source: reports of the Veterinary Services to the epidemiological information and surveillance system (SIVCONT) of PANAFTOSA

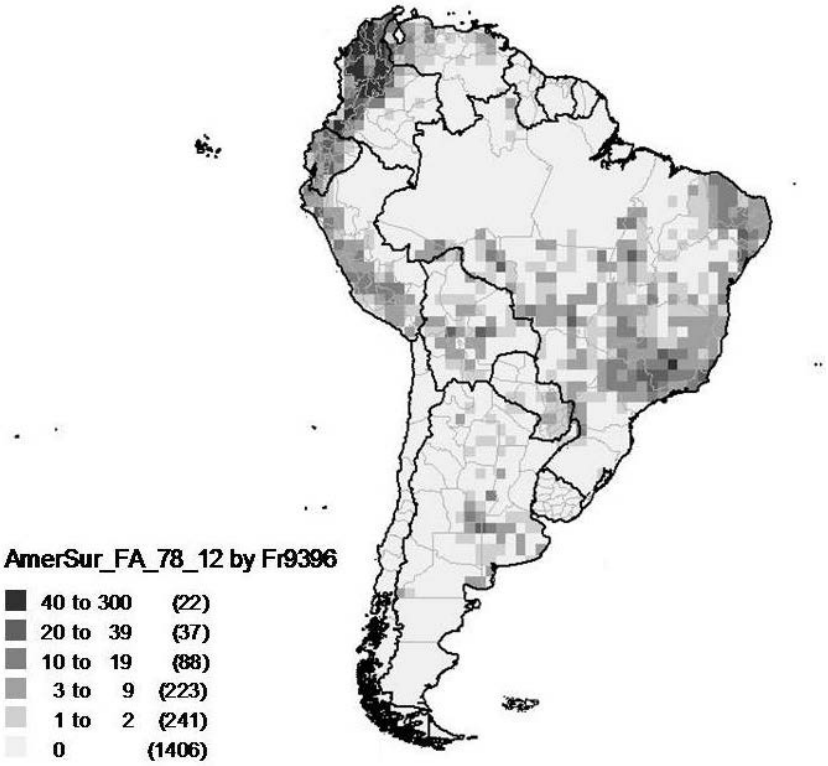

Fig. 10
Cumulative weekly reports of FMD outbreaks 2008-2011

J. Naranjo y A. Mendes. Epidemiology Unit. PANAFTOSA OPS/OMS
Source: reports of the Veterinary Services to the epidemiological information and surveillance system (SIVCONT) of PANAFTOSA

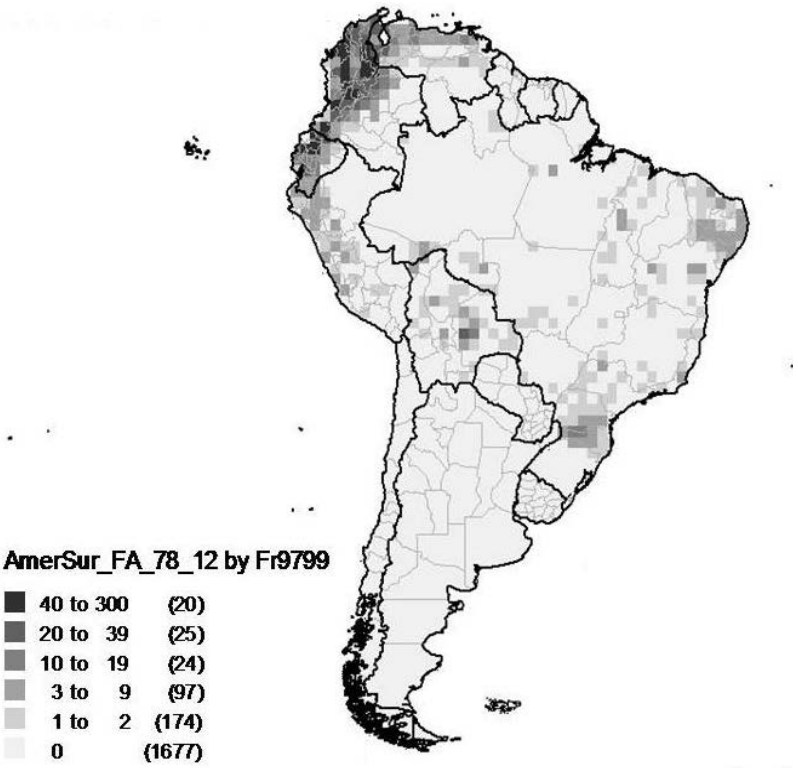

Fig. 11
Cumulative weekly reports of FMD outbreaks 2012-2013
J. Naranjo y A. Mendes. Epidemiology Unit. PANAFTOSA OPS/OMS
Source: reports of the Veterinary Services to the epidemiological information and surveillance system (SIVCONT) of PANAFTOSA*

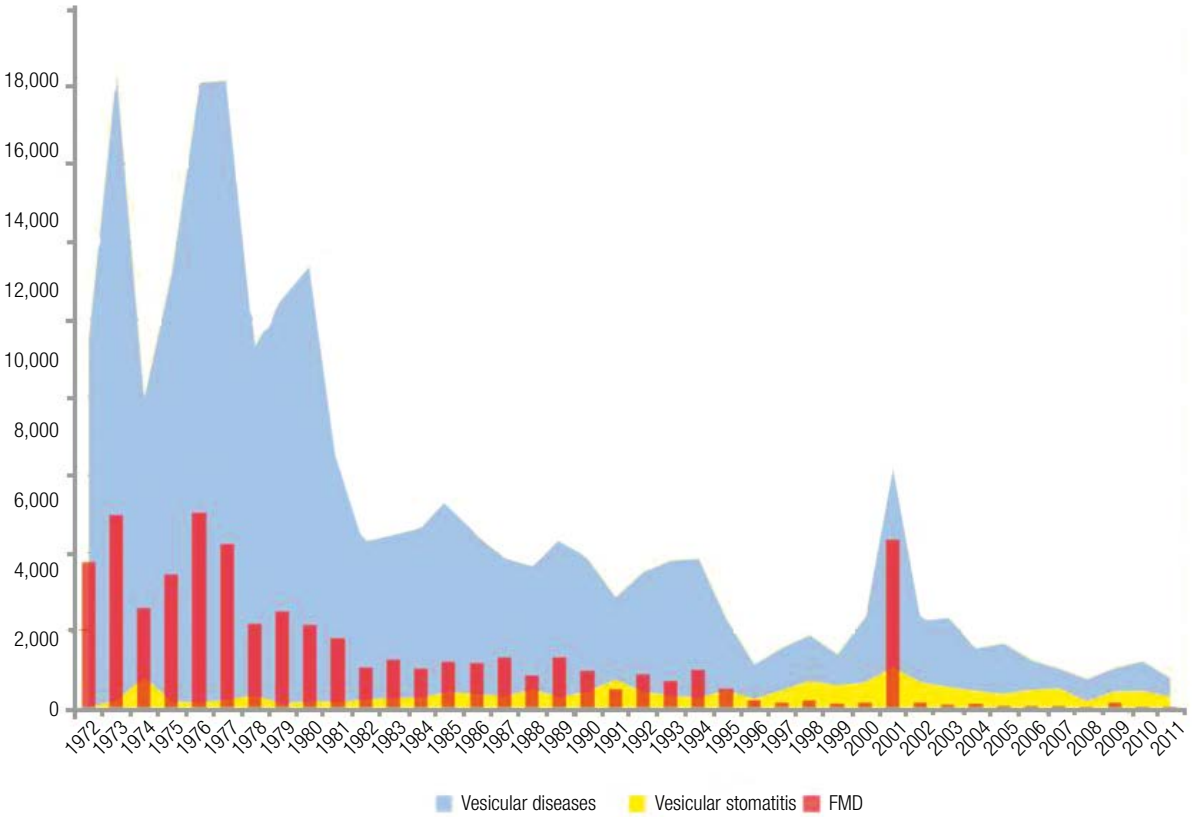

Fig. 12
Reported cases of vesicular disease, foot and mouth disesase, vesicular stomatitis
Continental epidemiological surveillance and information system (SIVCON)

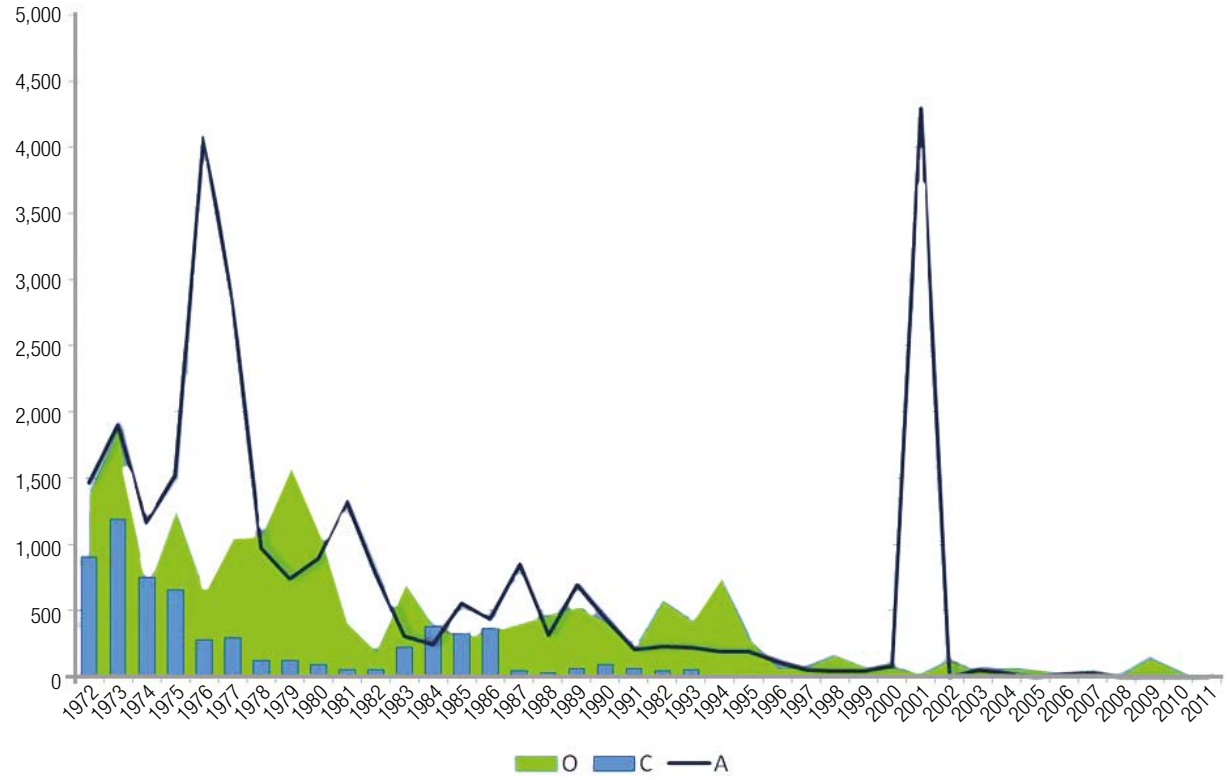

Fig. 13
Reported cases of type O, A, C FMD virus
Continental epidemiological surveillance and information system (SIVCON)

OIE Global FMD Strategy, along with reiterating that COSALFA, COHEFA, GIEFA and RIMSA are the governance mechanism of PHEFA (20).

The Plan of Action 2011–2020 is facing a number of challenges. In the Southern Cone the emergence of sporadic outbreaks still needs to be resolved (Fig. 14), particularly those of unknown origin in areas previously recognised as disease free. Such sporadic outbreaks might be a consequence of a concurrent very low level of virus circulation in the bovine population along with insufficient levels of herd immunity to halt virus circulation. This scenario highlights deficiencies in the quality of interventions and the sensitivity of the detection and response systems. Key amendments towards improving interventions in the areas of production where there is risk of viral circulation include implementing targeted risk-based interventions, strengthening the structure and capacity of Veterinary Services to monitor vaccination where practised, and implementing effective surveillance, early detection and response of suspected cases, and prompt reporting and notification. It should also be mentioned that there have been very few instances when the disease was not promptly reported internationally. Such situation has some similarity with the FMD epidemic of 2000–2001, which occurred in previously free territories without vaccination and was first reported by farmers and at a later stage notified internationally.

On the other hand, the advances achieved in the population which is disease free with vaccination are sustained by the systematic mass vaccination campaigns, with the application of 700 million annual doses, fully financed by livestock producers. For the livestock producers, it is increasingly difficult to appreciate the need for continuing vaccinations, since in the majority of the territories that have achieved the status of disease free with vaccination the disease has not been detected for more than ten years. Furthermore, the vaccination campaigns have become routine and are not applied as a strategic tool tailored to the epidemiological risk of the prevailing sanitary scenarios to interrupt the epidemic cycle of the disease and prevent the reintroduction of the infection. Figure 15 reports the FMD situation in South America according to the OIE in May 2012. At the time of the last review of this paper (February 2015), South America has reached the historical goal of three consecutive years without an FMD outbreak detected or reported. Paraguay, following its last outbreak (San Pedro, January 2012), regained its 'free with vaccination' OIE status. Argentina and Peru increased their territories with 'free without vaccination'

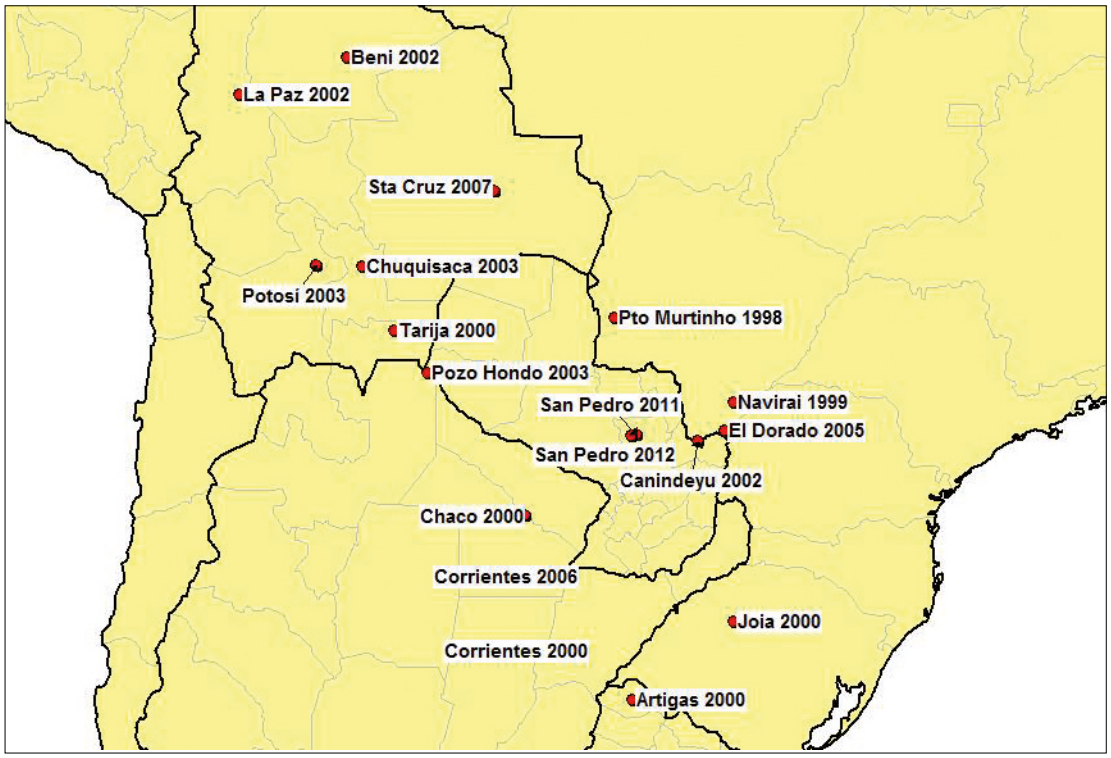

Fig. 14
Selected reports of FMD virus type O occurrence in the countries of the Southern Cone of South America, 1998-2012

Fig. 15
FMD situation in South America according to the OIE, May 2012
Source: Epidemiological unit, PANAFTOSA, OPS/OMS

OIE status. Bolivia was recognised by the OIE as 'free with and without vaccination'. Eight north-eastern Brazilian States were recognized as 'free with vaccination' by OIE. Ecuador submitted a dossier to the OIE to be considered 'free with and without vaccination'. Finally, Venezuela submitted its FMD national eradication programme for OIE endorsement.

Systematic mass vaccination needs to be maintained at the current level because of the persistence of the infection in South America. However, the perception of the livestock producers of a lack of progress in the sanitary condition along with their expectations for better commercial opportunities could easily discourage the maintenance of high vaccination coverage. This could lead to an increased susceptibility of the population to disease, increasing the risks of infection and of an eventual reappearance of the disease along with the consequent sanitary setbacks that would dramatically jeopardise all the efforts and progress to date. Available information shows that in some countries the declared vaccination coverage does not reflect the real herd immunity. Some areas could have lower vaccine coverage, especially areas with small livestock producers and where the disease has not been recorded for more than 15 years.

Progress with the remaining 15% of the livestock population that is not FMD free is not a simple issue to address in the short term. The most difficult challenges that require full resolution include maintaining the political commitment and support of the national governments; obtaining the allocation of national resources to sustain the elimination programmes; and obtaining the international support and solidarity of human and financial resources to provide technical cooperation for elimination. Realistically, these challenges can be managed in the medium term (four to six years).

Challenges of the Plan of Action 2011–2020 of the Hemispheric Program for the Eradication of Foot-and-Mouth Disease

The national FMD elimination programmes need strengthening on several of their strategic components or require changes in order to address the new epidemiological scenarios, both in countries and areas with presence of the infection and in those countries that need to consolidate the advance from disease free with vaccination to disease free without vaccination. The following sections review the most critical strategic components with regard to the support that these provide to the programmes, such as systematic vaccination, laboratory diagnosis, surveillance systems, alert and response, prevention, human resources and community participation.

The vaccination campaigns need strengthening in countries where the risk of virus circulation is still present. There are weaknesses with the conservation and application of the vaccine and a weak correlation between the official vaccination coverage and the level of immunity of the population. Deficiencies in the planning of the vaccination campaigns are also observed as they do not consider the epidemiological situation and the risk characterisation. In addition, with very few exceptions, there are no vaccine and antigen banks, which are required to respond to emergency demands due to a South American virus strain or introduction of exotic viruses into the region.

To reach elimination, a large animal population needs to move its sanitary status from disease free with vaccination to free without vaccination. Such a change poses perhaps the greatest managerial and operational challenge, as it requires that the population remain without vaccination, rapidly increasing its susceptibility to the variants of the virus circulating in the region. The adverse experiences of the Southern Cone have indicated that the processes of withdrawing the vaccine should be extremely carefully planned. Emergency plans are highly necessary, with vaccines banks aligned with the risk profile of the region. The establishment of antigen banks is also needed to rapidly prepare specific monovalent vaccines in order to respond to outbreaks when they arise.

With regard to laboratory diagnosis there are deficiencies in some countries on the implementation of rapid viral diagnostic techniques for identification of the FMD virus, on the biosafety of the infrastructure, as well as on the mechanisms and capacities required to shorten the time from clinical detection to diagnosis. In addition, there is the need for further studies for the standardisation of the diagnostic kits recently introduced in the region for determining viral circulation and evaluating the immunity of the population.

With regard to the national information systems, increasingly there is the need to have access to historical and real-time data in order to effectively manage the intervention activities and to provide transparency. In this regard, the existing regional information system, SIVCON (8), would need to be further used by the countries. Deficiencies are also present in the utilisation of the data collected at the local level, the standardisation of data collection and the criteria for analysis.

In addition to strengthening technical and managerial capacities, the processes of intervention should be accompanied by a policy of continuous professional development of the human resources responsible for managing interventions, at the national and sub-national levels. In this regard, there is a shortage of human resources in the official Veterinary Services caused by the departure of experienced and knowledgeable professional staff due to movement to other jobs or retirement, failure to recruit new staff for key vacant posts due to budgetary constraints, and, finally, the recruitment of new professional staff with limited experience in FMD. Furthermore, there are changes in the official Veterinary Services, which are moving from an emphasis on improving the sanitary status based on control and elimination programmes, to an emphasis on ensuring the sanitary status in order to support the export process. There are also changes in the general profile of the veterinarians, with new staff lacking the necessary experience and having a critical role, particularly in facing the challenge of moving from the status of disease free with vaccination to that of disease free without vaccination. It is urgent and necessary to establish training and continuing professional development programmes to build analytical capacities and risk management, assessment and communication competencies tailored to the field situations and to progress the national programmes.

With regard to the disease surveillance, detection and response systems, given the progress of the programmes, the limited occurrences of outbreaks in the majority of countries, and the significant changes in the professional profiles of the staff of the official Veterinary Services, there is a need for training when introducing new tools to increase the sensitivity of detection mechanisms, in particular the use of geographic information systems and spatial risk analysis. With regard to the need to increase the sensitivity of the detection mechanism, this also requires a much greater participation of the livestock producers and other stakeholders for reporting signs compatible with vesicular diseases. However, the majority of countries do not have specific mechanisms to promote the notification of suspected disease, such as compensation or indemnity.

Given the prolonged absence of detection of clinical disease and the absence of viral circulation shown by successive sero-epidemiological studies, several sub-national authorities and organisations of livestock producers are now requesting their authorities to move forward with elimination and are carrying out feasibility studies in order to end vaccination and apply for FMD free without vaccination status. They cite the state of Santa Catarina, Brazil and Chile as examples to be imitated. However, national authorities do not have sufficient information on the characterisation of risk in order to evaluate the epidemiological, operational and economic feasibility required for this change. Some also recall with great concern the failure of the previous experiences of moving towards free without vaccination status, along with the serious economic consequences. Ensuring that decision-makers at political level understand the essential need for establishing rigorous prevention programmes along with effective outbreak alert and response mechanisms is a challenge. These prevention programmes require financial, human and material resources in order to prepare the official Veterinary Services for a scenario without vaccination and a population with maximum susceptibility.

Conclusions

The results achieved so far by the two Plans of Action of PHEFA can be regarded as very positive. Systematic mass vaccination proved to be an effective tool for the elimination of FMD in South America. The establishment of the two Plans of Action was essential for the countries to address with clear and coordinated actions the elimination process through an international technical cooperation framework. The established political, strategic and technical governance mechanisms (i.e. COSALFA, COHEFA, GIEFA, RIMSA) provided continuous monitoring of the FMD elimination plans and actions; and also promoted and articulated the private–public partnership. The effectiveness of this governance architecture is proven by the significant advances towards elimination in the majority of countries of South America. The establishment of the Plans of Action of the PHEFA is the expression of the political will of the governments that provide support and incentives to the various stakeholders of the livestock production chain within the spirit of cooperation and solidarity for the common good.

Concluding the unfinished task of FMD elimination from South America requires strengthening of the national FMD elimination programmes and technical cooperation, along with the collective and effective technical and financial assistance to priority countries. The experience acquired in the execution of the two Plans of Action of the PHEFA indicates that it is feasible to eliminate FMD from the continent. The challenge is to use this experience in the areas where implementation had not reached an adequate level of execution.

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Global foot and mouth disease portfolio review

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Summary

The Globa*l Framework for the progressive control of Transboundary Animal Diseases (GF-TADs) foot and mouth disease (FMD) Working Group carried out a survey to collate and analyse the portfolio of FMD activities worldwide. The survey was sent to 99 developing and in-transition countries as well as to ten development partners and 17 global and regional organisations active in the animal health field. A total of 121 completed questionnaires were received. The results should be interpreted carefully, since they are based on preliminary and fractional data. Only the following general trends can be concluded.*

Projects (in numbers) are distributed inequitably across all regions, with a clear gap in interventions in West Eurasia and most of Africa (virus Pools 3, 4 and 5). FMD is tackled mostly at a national level. Twelve FMD projects are in the pipeline. The project starting dates indicate that the portfolio develops mainly in response to ongoing FMD events, following the pattern of FMD epidemics.

The portfolio amounts to US$ 7.8 billion, showing regional disparities. Most FMD activities are financed by the countries themselves (America, Asia and the Middle East). On the contrary, in Africa and Europe (non-EU Member States), FMD activities are financed predominantly through external aid.

This external aid accounts for US$ 330 million and is quite equitably distributed between Africa, Asia and Europe (non-EU Member States). The EU is the main development partner. The Food and Agriculture Organization of the United Nations (FAO) and regional banks also have a sizeable FMD portfolio. On the other hand, several development partners indicate no financing of FMD projects.

Most of the projects are aimed at the progressive control of FMD among domestic species. However, in America, most projects aim to maintain an OIE official 'free' status, while in Europe (non-EU Member States), emergency support is the first objective of many projects.

*Rapid response and laboratory, epidemiology and Veterinary Services activities are carried out in more than 60% of projects, while compensation, research and coordination activities are rarely implemented. Finally, the use of the FAO–World Organisation for Animal Health (OIE) Progressive Control Pathway (PCP) for FMD and the OIE Perfo*rmance of Veterinary Services (PVS) tools are hardly mentioned.

Keywords
Foot and mouth disease – Funding-survey – Portfolio – Projects.

Introduction

As part of the preparatory work to support the elaboration of the Food and Agriculture Organization of the United Nations (FAO)/World Organisation for Animal Health (OIE) Global Strategy for the control of foot and mouth disease (FMD) (hereafter 'FMD strategy'), the Global Framework for the progressive control of Transboundary Animal Diseases (GF-TADs) FMD Working Group carried out a survey to collate and analyse the FMD portfolio of activities worldwide, with the following objectives:

– identify the funds already committed and/or disbursed in the prevention and control of FMD worldwide, with a view to fine-tuning the overall budget of the Action Plan (Part B) and identifying the financial gaps; and

– identify possible gaps and overlaps in FMD prevention and control activities, as a transparent and rational basis for improving coordination at regional and global levels.

The survey was based on a questionnaire composed of 12 questions. It was sent out through the OIE delegates to a selection of developing and in-transition countries (99 in total) facing a wide range of situations with regard to FMD and, in particular, where FMD is known to be present (either enzootic or epidemiological events). Japan was also included to have a concrete example from a developed country. The same questionnaire was also sent to ten development partners and 17 regional organisations active in the field of animal health, to try to cross-check the information provided by the countries and make the portfolio review as comprehensive as possible.

A total of 121 questionnaires were received from 63 respondents, namely 45 countries (45%), eight development partners (80%) and ten global and regional organisations (59%). Unfortunately, some major donors did not respond. The authors took the liberty to complete and add data, whenever aware of them. The results presented below are based on preliminary and partial data and should therefore be interpreted carefully. Only general trends can be concluded.

Results

The results of the survey show that despite a sizeable FMD portfolio composed of approximately 30 ongoing projects, endemic regions in Central Asia, Western and Central Africa and Eastern Africa, corresponding to FMD virus Pools 3, 4 and 5, are not well covered. Projects that operate in the same regions often have different timescales and activities, generally preventing overlaps (it is not possible to say whether there are attempts to exploit synergies among different projects).

Twelve FMD projects are in the pipeline, mainly linked to new epidemiological situations (Southern African Territories [SAT] 2 in Egypt and neighbouring countries, for instance) and to new provisions in the OIE *Terrestrial Animal Health Code* (Chapter 8.5.23) encouraging countries to develop and implement national FMD control programmes endorsed by the OIE.

The majority of FMD projects operate at country level (68%) and few multi-country and (sub)regional FMD projects exist. The optimal level of intervention for FMD, however, is known to be sub-regional, in particular when these match the virus pools' geographic areas.

The timeframe of new projects shows that they usually follow the pattern of FMD epizootics in the regions, confirming that this is an 'in reaction to' portfolio: peaks of projects occur in 2001–2002, 2006–2007 and 2010, when Europe, America and Asia, respectively, faced important FMD epizootics.

Large amounts of funds (the portfolio amounts to approximately US$ 8 billion – with the limitation that developed countries were not included in the survey except Japan) are spent worldwide to control the disease, with strong regional disparities: 98% of the funds are spent in America (77%) and Asia (21%), with three countries (Japan, Brazil and Argentina) sharing more than 80% of this budget, in an effort to maintain/recover their FMD free without vaccination status. Ninety-four per cent of FMD control funds come from national sources (self-financing), from both state budgets and private operators' contributions.

The donor portfolio (external aid) is very small (4% of total funds, corresponding to US$ 330 million). Nevertheless, in Africa and Europe (non-EU Member States), most FMD activities are conditioned to external aid. The EU is by far the biggest donor with respect to FMD project funding and significantly intervenes in Africa, Asia and Europe. The FAO also has a sizeable portfolio of FMD projects in all regions, as well as regional banks. Conversely, other donors that are usually active in the field of animal health do not have any FMD-related activities in their portfolio.

Project support ('standalone + component') remains the preferred financial channel (91%) to carry out FMD activities in all regions. America is the region where budget support is most used, even if it remains limited (16%). In most cases, FMD standalone projects (mono-disease projects) are developed. However, in Asia (50%) and Europe (40%), as well as for multi-region projects (50%), a more transversal approach integrating FMD as a component of a wider animal health programme/project is adopted. This is consistent with component three of the global FMD strategy, combining as often as possible FMD with other transboundary animal disease (TAD) prevention and control measures.

Projects focusing solely on FMD are more numerous than transversal approaches, which combine FMD and other TAD control activities.

The majority of projects (77%) have a medium- to long-term development objective, aimed in most cases (43%) at the control of the disease in endemic zones, corresponding to countries in Stages 1, 2 and 3 of the Progressive

Control Pathway for FMD (PCP-FMD). Emergency support is also provided in Asia (29%) and Africa (28%) and to a lesser extent in the other regions, except the Middle East. In America, maintaining an OIE official free status logically represents the objective of 70% of the projects carried out.

In terms of FMD activities conducted, activities such as rapid response activities, prevention, early detection, Veterinary Services, laboratory and epidemiology are present in more than 60% of FMD projects. It is interesting to note that epidemiology is implemented in 60% of projects, probably linked to activities in wildlife. On the other hand, compensation activities receive very little to no interest at all (14%), as well as research (30%) and coordination (36%). The latter is difficult to understand in the context of a highly contagious TAD.

All regions give priority to the reinforcement of Veterinary Services, except America. This is in line with the approach proposed by the global FMD strategy (component two) where the reinforcement of Veterinary Services is seen as a condition of the efficiency and sustainability of FMD measures put in place ('enabling environment'). In America – where the situation is no longer endemic – and Europe, priority is given to rapid response activities, including emergency vaccination. Communication activities are of utmost importance in Europe (in 80% of projects), but are rather neglected in other regions.

Domestic animals/livestock are by far the main target of the programmes/projects. No project addresses wildlife alone, but in the Middle East and Africa, 33% and 48% of projects, respectively, jointly address livestock and wildlife species (surveillance/epidemiology activities). This is all the more important in Africa when we consider the important role played by the African buffalo in the maintenance and spread of FMD.

The PCP-FMD and OIE Performance of Veterinary Services (PVS) are rarely mentioned as tools supporting FMD control activities. It is hypothesised, however, that these were developed too recently to be taken into account by the projects included in the survey. Many other important 'tools' for the prevention and control of FMD were listed by the respondents, including vaccines and antigens banks, progressive zoning approach, value-chain analysis and the animal disease spread model (NAADSM).

Conclusions

At the national level, FMD activities can be efficiently implemented only if:

– they are embedded into a national FMD control strategy/plan,
– they are jointly elaborated by all stakeholders involved and
– they rely on strong epidemiological data and risk analysis.

These national plans should clearly reflect the principles laid out in the global FMD control strategy and have the overall objective to progress at least two PCP-FMD stages over the next 15 years. FMD projects should also be backed up by a comprehensive legal framework where the roles and responsibilities of each stakeholder are clearly identified. The role of the private sector is key for both the funding (cost-sharing schemes) and the implementation of FMD control activities. Therefore, strong animal health systems should be the basis of FMD control activities in all countries and driven by reinforced Veterinary Services, supported by functional Veterinary Statutory Bodies (or equivalent structures). The use of the OIE PVS Pathway is key for this purpose. The level of awareness and commitment of policy-makers should remain high, even in countries where the disease is under control.

The preliminary results of the portfolio show that the investments in FMD control worldwide are high, but such investments appear to be made mainly by the countries that see clear trade incentives. Developing countries are investing much less in FMD control, probably because they cannot afford it or fail to see a positive cost–benefit balance.

International investments are limited and appear insufficient to considerably progress with FMD control in the near future. To correct this situation, additional investments will be necessary, in particular in the countries belonging to FMD virus Pool regions 3, 4 and 5 where few FMD projects appear to be ongoing or in the pipeline.

Support for national programmes is needed but regional support should also be increased. External aid can bring seed money and play a catalytic role in national projects and this can also be done through supporting regional and global activities. Notably, the upscaling of national and regional activities can be obtained through capacity building. In this regard, regional and international networking activities will allow economies of scale. All these programmes would be aligned to the Global Strategy, which uses FMD as an entry point for reinforcement of Veterinary Services and improved prevention and control of other TADs.

Session 7

Global FMD Control Strategy, socio-economic rationale and implementation costs

Chair: J. Lubroth (FAO)

The impact of foot and mouth disease

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Summary

The global impact of foot and mouth disease (FMD) is colossal because of the huge numbers of animals affected. This impact can be separated into two components: direct losses due to a reduction in production and changes in herd structure; and indirect losses that relate to the significant costs of FMD control and management and poor access to markets and limited use of improved production technologies. The paper estimates that the annual impact of FMD in terms of production losses and vaccination alone are in the region of US$ 5 billion.

Keywords
Economics – Foot and mouth disease – Global – Impact assessment.

Introduction

Foot and mouth disease (FMD) is endemic in almost all developing countries. The seven different FMD serotypes circulate within regional viral pools with periodic incursions into virus-free developed countries. FMD causes high morbidity and low mortality, although high mortality among young stock does occur. Clinical signs are generally more severe in temperate breeds associated with intensive farming, particularly in immunologically naive populations. The disease affects all the major non-avian livestock species, with cattle being the most susceptible and pigs the best amplifier of virus. Infection in wildlife can further complicate control efforts.

When this ease of biological transmission is combined with widespread and long-distance movements of animals, FMD can move quickly and spread effectively. The importance of trade, both legal and illegal, in the spread of the disease implies that any FMD control strategy must have policies and actions to limit risks of FMD spread from an outbreak and the introduction from neighbouring countries and trading partners. These movement controls for FMD management have an economic impact of limiting trade that is local, national and international in its reach. The most extreme and costly impacts are the lack of access to lucrative international markets for countries where FMD is not controlled.

The paper presents the main impacts of FMD from production losses, costs of control, poor technology development and trade. It uses a framework to assess the impact of disease (see Rushton, 2009, pages 193–197 [12]). It also makes an estimate of the global impact of the disease in terms of production losses and vaccination costs.

Economic impact of foot and mouth disease

Although other diseases can cause more severe disease in individuals, in order to appreciate the impact of FMD, one must step back and look at the disease at the population level. FMD is widely prevalent, with the disease circulating in an estimated 77% of the global livestock population. In this population it affects a large proportion of animals during an outbreak and affects many species. Collectively, these factors lead to a huge burden of disease.

Direct costs – visible and invisible losses

Production losses directly due to FMD include:

– reduced milk production, affecting both the humans and calves that depend on it. This can account for 33% of losses in endemic settings;

– reduced livestock growth;

– mortality among young stock, typically reported to be between 2% and 5%;

– loss of traction power where draught animals are used. If this occurs during harvest the effects can be particularly severe (9, 11);

– abortion: the cost of a single abortion is high as the farmer will have to pay to keep the cow without it producing anything for another year or more, or cull the animal;

– although FMD typically has a short-term effect on an animal's health, chronic FMD typically reduces milk yields by 80% (1, 2, 3, 15).

Visible production losses are most prominent in pigs in intensive production systems followed by dairy cattle. These two systems are important sources of animal protein in poor countries and their importance continues to grow. Extensive systems of production do not have such pronounced losses, and some species, such as sheep and goats, show limited clinical symptoms and minor economic losses.

Foot and mouth disease (FMD) causes problems which are less easily quantified. With fertility, the most obvious problems are the abortion losses explained above, but there are longer lasting impacts of this loss of foetus and a reduced probability of conception. These both translate into the need to have a greater proportion of breeding animals in a population, implying that for every kilogram of meat or milk produced there is an additional fixed cost to cover more breeding stock.

Indirect costs – additional costs and revenue forgone

The cost of control measures carried out by the state Veterinary Services, such as vaccination, outbreak control and sometimes culling and compensation, are borne by the tax payer.

– An estimated 2.6 billion doses of FMD vaccine are administered annually (8), with vaccine drug and delivery costs at between US$ 0.4 and US$ 3 per dose including delivery costs, depending on the setting (1, 4, 13).

– Some national FMD vaccination programmes vaccinate all bovines three times a year and all sheep and goats once a year, which limits resources available to combat other diseases.

– In endemic settings significant amounts are spent on privately funded vaccination and control.

– In some areas, wildlife is kept out of FMD-free zones with extensive fencing at great financial cost, not to mention the impact this restriction has on wildlife.

In Africa, it has been estimated that more is spent on controlling FMD than on any other veterinary disease (5). Even if a country is FMD free, there are ongoing costs due to:

– efforts to reduce the chance of disease re-introduction, including border and import controls and inspections and sometimes vaccination;

– efforts to maintain the capability for early detection and control of FMD, including surveillance, ensuring sufficient organisational capacity in the Veterinary Services which are tested by outbreak simulation exercises and permanent restrictions on the livestock sector (such as post-movement standstills);

– dealing with outbreaks, which may involve culling, movement restrictions and vaccination. Outbreaks among animals lacking prior immunity to FMD are particularly dramatic;

– control measures can affect other industries, for example the United Kingdom (UK) 2001 outbreak restricted public access to the countryside, costing in the region of US$ 4–5 billion in lost tourism revenue (14);

– the impact of culling-based control measures can have other non-financial impacts. For example, suicides increased among farmers of culled farms during the UK 2001 outbreak and in South Korea there was concern

that the burying of large numbers of culled animals would pollute water supplies. Culling healthy animals is a politically sensitive issue and is seen as unnecessary and inhumane by much of the wider public; and

– movement restrictions disrupt production and may even lead to welfare problems that lead to further culling.

In addition to the costs of vaccination and culling, there are also costs incurred with the need to control movement and perform diagnostics to confirm the presence or absence of disease. There are no specific data on these additional items.

In terms of revenue forgone, the most important issue is market access (see Rushton, 2009, pages 199–204 [12]):

– livestock trade is limited; those affected by FMD receive lower prices for their stock and those wishing to purchase animals from FMD-free herds face a restricted supply;

– countries infected with FMD cannot trade live animals with FMD-free countries. Typically, the countries with the best meat prices are FMD free;

– the trade of livestock products is also restricted. If regular outbreaks occur, only processed, tinned products can be exported to free countries; if FMD is effectively controlled with vaccination by a competent Veterinary Service able to detect outbreaks then deboned meat can be exported;

– trade of fruit and vegetables can also be affected by FMD status;

– the FMD status of nations that a country trades with also affects a country's ability to trade with FMD-free countries irrespective of its own status;

– a lack of access to lucrative markets restricts the development of commercial farming; consequently, employment and tax revenue from this area is limited by FMD status;

– investment in the livestock sector is limited if there is a perceived risk that FMD may occur; and

– livestock and livestock products cannot be imported from FMD-infected countries; this limits supply, and, although this is good for domestic producers, it limits choice and leads to increased market prices for consumers.

Impacts at the national level ultimately affect the individual farmer and vice versa. Similarly, impacts on the livestock producer have ripple effects along the entire market chain, affecting other players, such as markets, abattoirs and dairies (5). There can also be major disruption to economies. The overall cost to the UK economy was estimated to be US$ 9 billion (14); furthermore, it spread to the Netherlands (costing over US$ 1 billion) and Ireland and France (costing further hundreds of millions of dollars in losses). Rich and poor countries alike go to great lengths to combat the disease in order to obtain the rewards associated with FMD-free status. Although slaughtering animals to combat a non-fatal disease may initially seem illogical, the size of these indirect benefits may justify the use of control measures that have a greater negative impact than the direct costs of the disease (10).

Finally, this disease can lead to farmers and the livestock industry as a whole choosing sub-optimal technologies. Highly productive breeds are typically more susceptible to FMD. The risk of FMD therefore:

– restricts the use of these breeds and

– prevents the development of more intensive production systems based on these breeds.

A global estimate

The authors have made an estimate of the impact of FMD globally as of 2011. This focuses on the numbers of animals that have FMD and the associated losses in terms of death and production and the costs of control, focusing on an estimation of vaccination and the costs of vaccine production and delivery.

In summary, FMD affects 27 million livestock units each year, which is approximately 0.64% of the total livestock units globally. In an attempt to minimise the economic losses of this disease, 2.35 billion vaccines are produced and applied. The overall economic impact was calculated based on the costs of a vaccine and its application being US$ 1 and that any livestock unit affected by FMD would cause a loss in production equivalent to US$ 100. The latter estimate takes into account the death of an animal and loss in weight gain, milk production and draught power, and is felt to be a conservative estimate. The total annual impact of FMD is calculated to be US$ 5 billion.

The majority of FMD impact occurs in China, India and Africa. The impact in South America is largely due to the costs of vaccination applications, a control measure to limit the production and trade losses this region would suffer if FMD was prevalent.

The estimated impact does not include the losses due to trade restrictions, which are large at both local and international levels but are difficult to estimate with any accuracy and tend to be very variable. It also does not take into account that the development of the livestock sector tends to be restricted by the presence of FMD in terms of production system technology and breed advancement and investment slaughter, processing and marketing systems. Finally, there was no estimate in these calculations in terms of the costs of diagnostics and surveillance required to prevent and control FMD. Therefore, US$ 5 billion is likely to be a very conservative estimate of the global annual impact of FMD.

Conclusions

Wealthy countries that have eradicated FMD face ongoing costs from periodic outbreaks and the costs of being prepared to rapidly detect and deal with these outbreaks via means of movement controls, culling and/or vaccination. Many countries reduce the impact of the disease with extensive ongoing or intermittent vaccination programmes; the global scale and costs associated with these programmes is vast, with an estimated 2.6 billion doses administered annually (8). The impact of FMD in endemic countries has received less attention than the impact of outbreaks in free countries, despite the huge numbers of animals affected by the disease and the importance of livestock to the economies of endemic countries. Direct losses due to death and disease are easy to appreciate; however, in endemic countries, the burden of FMD often manifests as widespread and ongoing losses that limit development opportunities for developing the livestock sector.

Overall, the production losses and the application of FMD vaccines around the world cause an annual impact of US$ 5 billion, with additional costs on restrictions to trade and adoption of improved technologies across the livestock sector. FMD affects livestock all over the world, particularly in poor countries. In many places, little is done to control FMD, largely because of a lack of resources and a failure to recognise the benefits that control brings. FMD prevents agricultural development and reduces food security; in many countries it leads to massive losses owing to control costs and in some cases by limiting export market access. These estimates are considered to be of a very conservative nature, as the Government of India (6, 7) states that the direct loss from foot and mouth disease (FMD), due to milk and meat, is estimated at Rs 20,000 crore per annum. Indirect losses due to reduced work capacity abortions, subsequent infertility and sterility (that account for the subsequent reduced milk production) have not been quantified. These losses in India alone, not considering any control costs, total US$ 4.8 billion.

Equipping poor countries with the tools necessary to control FMD will involve the development of state Veterinary Services that in turn will deliver wider benefits to a nation, including the control of other livestock diseases. Only through a sustained global effort can the risk of FMD and the heavy burden that it inflicts be controlled for rich and poor countries alike.

Further details of cost–benefit analyses of FMD control and the wider implications of this disease will be made available in a forthcoming article by the authors.

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The Global Foot and Mouth Disease Control Strategy

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Summary

Foot and mouth disease (FMD) is one of the most contagious animal diseases and can cause significant economic losses. In developing countries it undermines food security and economic development, particularly for village smallholders.

The Global FMD Control Strategy (GCS-FMD) was prepared under the umbrella of the Global Framework for the Progressive Control of Transboundary Animal Diseases (GF-TADs) by the World Organisation for Animal Health (OIE) and the Food and Agriculture Organization of the United Nations (FAO) in consultation with experts and representatives of key countries, regional organisations, development partners and private industry. Its overall aim is to reduce the global impact of the disease and for it to be used as an entry point to achieve sustainable progress in the performance of animal health systems (in particular Veterinary Services and, in turn, improve the animal health status concerning other livestock diseases (spin-off effects).

The strategy is composed of three components: 1. improving global FMD control, 2. strengthening Veterinary Services, and 3. improving the prevention and control of other major diseases of livestock.

The FMD control objective for the first 15 years in countries or zones that already have the OIE recognised status of 'FMD free' with or without vaccination is to maintain this status. Countries where FMD still occurs are expected to progressively limit the impact of the disease in domestic animals or in a geographic zone and then to potentially eradicate the disease. While a regional approach is seen as key to FMD control, it is evident that most of the control activities are carried out at the national level. Strong national political commitment and well-functioning Veterinary Services (both public and private) are prerequisites as well as international coordination and financial support for the poorest countries.

The FMD Progressive Control Pathway (PCP-FMD) is the major tool for component 1 (FMD control), while the Performance of the Veterinary Services (PVS) Evaluation, one of the tools of the OIE PVS Pathway, will be the major tool for component 2 (strengthening Veterinary Services).

The following key points will serve as a basis for action:

– *ensure regional and international harmonisation and coordination of national control strategies;*

– *support effective national, regional and international networks of diagnostic laboratories and epidemiology teams and centres;*

– *design regional strategies according to the prevailing contexts, which are flexible enough to adapt to local complex environments, and carry out socio-economic studies;*

– *maintain effective surveillance systems and ensure transparent world animal health information and warning systems, such as the official World Animal Health Information System (WAHIS)/World Animal Health Information Database (WAHID) OIE information system and the FAO/OIE/World Health Organization (WHO) Global Early Warning* System (GLEWS);

– *develop strong public–private partnerships; and*

– *obtain political and economic commitment from national, regional and international authorities, based on the recognition that FMD prevention and control is a global public good.*

Keywords
Control – Eradication – Foot and mouth disease – Progressive Control Pathway – PCP-FMD – OIE PVS – World Organisation for Animal Health.

Introduction

Diseases are among the most significant limiting factors for livestock production. Their impact can vary from reduced productivity and restricted market access to the elimination of entire flocks or herds, with the resultant loss of biodiversity and valuable genetic resources (10).

Foot and mouth disease (FMD) is an eminent transboundary animal disease (TAD), severely affecting the production of livestock and disrupting regional and international trade in animals and animal products. In developing countries, the adverse effects of FMD are often underestimated. The disease undermines food security and economic development, at the level of both village smallholders and the more organised production chains supplying urban and export markets. In some regions, particularly southern Africa, the impact of FMD control measures on wildlife conservation has become an important concern.

As recommended by the first World Organisation for Animal Health (OIE) and Food and Agriculture Organization of the United Nations (FAO) Global Conference on Foot and Mouth Disease in Asunción, Paraguay, in June 2009 (9), the Global FMD Control Strategy (GCS-FMD) was prepared under the umbrella of the Global Framework for the Progressive Control of Transboundary Animal Diseases (GF-TADs) by OIE and FAO. The joint FAO/OIE Working Group presented a first outline of the strategy at the 79th General Session of the World Assembly of Delegates of the OIE in May 2011 (1) and it was further developed in consultation with experts, national and regional authorities and policy makers, development partners and private industry. The experiences of a number of countries and regions, especially Europe, South America and South-East Asia, also served as the basis for developing the strategy.

The presentation given at the FAO/OIE Global Conference of Foot and Mouth Disease Control, held in Bangkok on 27–29 June 2012, addressed successively the requests that OIE and FAO received to prepare a GCS-FMD and the consultation process, the rationale and objectives of such a strategy, the tools to be used, the control strategy elements (principles, results, activities) of the three components, the governance and the limiting factors. The action plan and milestones, as well as the portfolio for the FMD control component, were mentioned, but the audience was invited to read the full text of the GCS-FMD ('Strengthening animal health systems through improved control of major diseases'), which was distributed at the conference. A set of annexes provides details on socio-economics, FMD control tools, regional experiences, vaccines, research, activities, costing of the strategy and portfolio analysis. All the annexes are contained in the document, which is available on the OIE and FAO websites.

Objectives of the global control strategy

The overall objective of the GCS-FMD is to contribute to poverty alleviation and improving the livelihoods in developing countries and to protect the global and regional trade in animals and animal products. The specific objective is to improve FMD control in regions where the disease is still endemic, thereby protecting the advanced animal disease control status in other regions of the world. The GCS-FMD therefore aims to reduce the burden of FMD on animal production not only in developing countries, but also in FMD-free countries.

History has shown that, if incursions do occur, the cost of outbreak control may be enormous; furthermore, the FMD control methods used are increasingly criticised. Reducing FMD at source in FMD-endemic countries is therefore a shared interest and should be considered a global public good.

The overall aim of the FMD control strategy is, while reducing the global impact of the disease, for it to be used as an entry point to achieve sustainable progress in the performance of animal health systems (in particular Veterinary Services [VS]) and, in turn, improve the animal health status concerning other livestock diseases (spin-off effects).

Therefore, the strategy is composed of three components:

1. improving global FMD control,

2. strengthening VS, and

3. improving the prevention and control of other major diseases of livestock.

The tools

The Progressive Control Pathway for FMD (PCP-FMD) (Fig. 1) is the major tool for component 1. It follows the structured five-stage approach of the FMD global control strategy, from the beginning up to the point where a country can submit a dossier to the OIE for official recognition of freedom from FMD. Detailed descriptions of the PCP-FMD stages, activities and outcomes are available (2).

Fig. 1
Progressive Control Pathway for foot and mouth disease

The Performance of Veterinary Services (PVS) Evaluation (8), one of the tools of the OIE PVS Pathway (7), will be the major tool for component 2 to assess progress (Fig. 2). Relevant articles of the OIE *Terrestrial Animal Health Code* (*Terrestrial Code*) (6) and *Manual of Diagnostic Tests and Vaccines for Terrestrial Animals* (*Terrestrial Manual)* (5) will guide and highlight the requirements for countries to have their national FMD control plan endorsed by the OIE or to apply for FMD-free status recognition.

The tools to be used for implementing components 1 and 2 also contribute to component 3. Regarding diseases other than FMD, the tools to be mentioned are the international Reference Centres and regional and international networks (e.g. laboratories, epidemiology centres) either already established or to be developed. At international level, the information system of FAO and the OIE (and WHO for zoonotic disease outbreaks in humans), the Global Early Warning System (GLEWS) (3), the OIE official World Animal Health Information System (WAHIS)/World Animal Health Information Database (WAHID) (4) or the Crisis Management Centre – Animal Health (CMC-AH), located at FAO headquarters in Rome, are well-established tools. At national level, the tools and methods are vaccinations against other major diseases, epidemiological investigations, diagnostic activities and treatments.

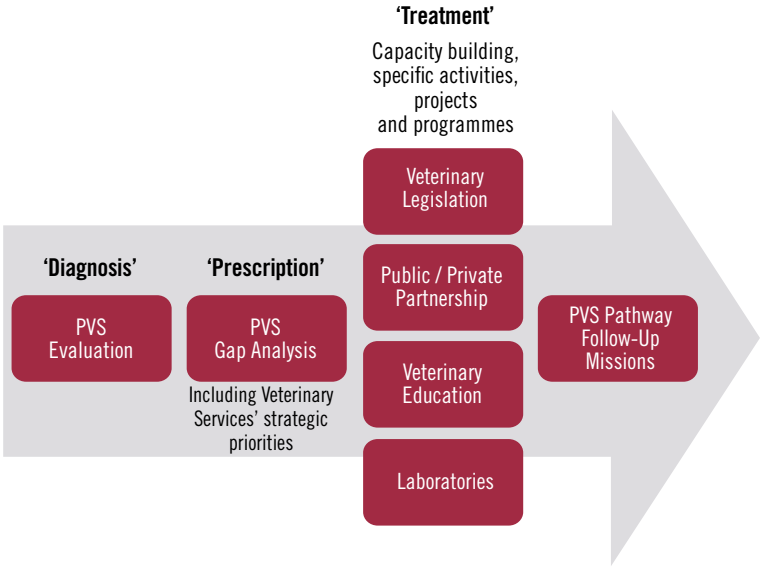


Fig. 2
The OIE Tool for the Evaluation of Performance of Veterinary Services

The Global Foot and Mouth Disease Control Strategy: principles, activities, expected results

Component 1

In Stage 1 of the strategy, the focus is on understanding FMD epidemiology and risk assessment; in Stage 2 the focus is on implementing a chosen control strategy, which may be targeted to part of the country, a sector or subsector and will usually involve vaccination; in Stage 3, prompt response mechanisms become important as the control efforts are extended to a zone or to the entire country and involve all FMD-susceptible domestic species; in Stage 4 the activities are continued with a strong focus on prevention; and in Stage 5 the situation will have improved to the level where a country may apply for OIE recognition as being FMD free with vaccination. New trade-related options, such as compartmentalisation and commodity-based approaches, become feasible as of Stage 3. The case of wildlife, particularly in southern Africa, has to be addressed in Stages 4 and 5.

The PCP-FMD situation in 2012 is presented in Figure 3. The PCP-FMD will be helpful in both policy development and activity planning. The tool can be used for monitoring, self-assessment and possibly for external assessment under the umbrella of GF-TADs.

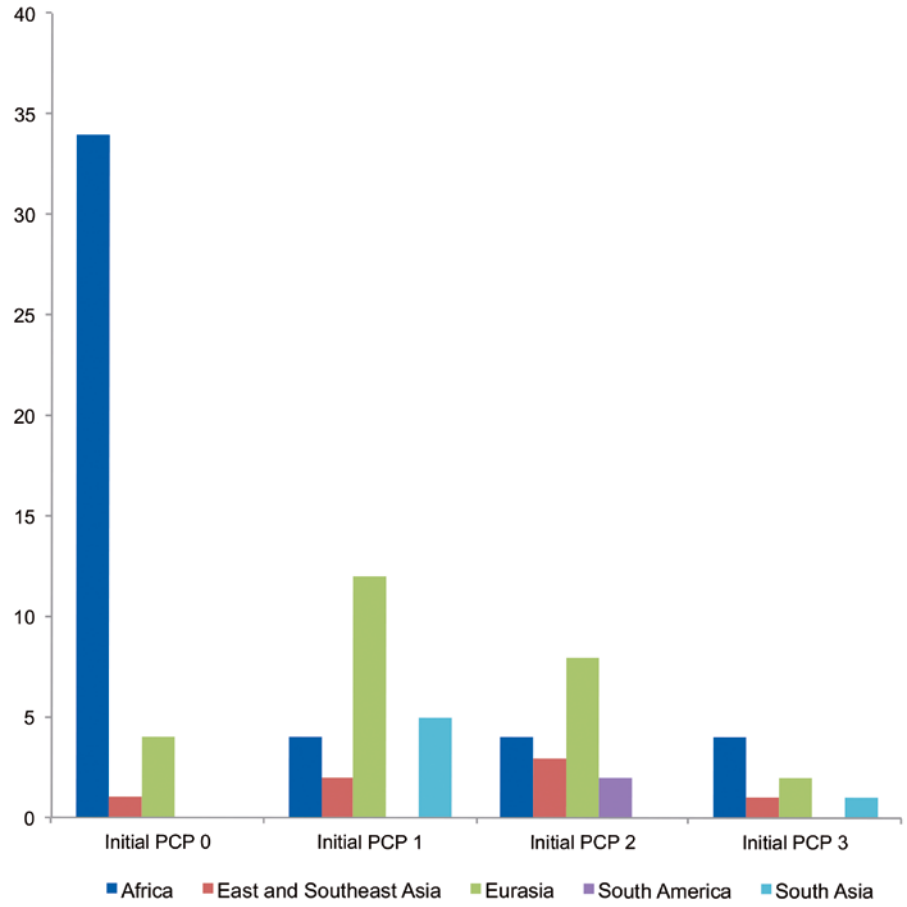
In addition, once at Stage 3, a national FMD control programme may be submitted to OIE for endorsement, thereby adding to international credibility. PCP-FMD Stage 4 will lead to an application to the OIE for official recognition of country (or zone) free with vaccination and PCP-FMD Stage 5 free without vaccination.

The strategy strongly recommends and supports a regional approach to exchange information and experiences, coordinate efforts and develop regional roadmaps showing the country's ambitions and allowing regular progress assessment.

The strategy underlines the importance of Reference Centres operating in a global network, while supporting a network of national diagnostic veterinary laboratories in each region. A similar structure is foreseen for epidemiology centres with global and regional network dimensions and national epidemiology units.

The need to ascertain the availability of sufficient quantities of FMD vaccine fulfilling the OIE criteria is emphasised and the designation of regional vaccine quality control centres is foreseen. The establishment of regional vaccine banks will be supported.

Although the strategy attempts to achieve progress with the tools and technologies available today, the importance of research is recognised and supported, in particular regarding new and improved vaccines and diagnostic tools, epidemiology and socio-economics.



PCP: Progressive Control Pathway

39 countries are in PCP Stage 0; 23 countries are in PCP Stage 1; 17 countries are in PCP Stage 2; 8 countries are in PCP Stage 3; 11 countries are in PCP Stage 4 or 5; 66 countries are officially free: 1 with vaccination, 65 without vaccination; other countries are historically free: islands mainly

Fig. 3
Foot and mouth disease Progressive Control Pathway situation in 2012

Other elements to support TAD control will become increasingly important when progressing along the FMD strategy implementation, including communication, biosecurity awareness and application, identification and registration of animals and farms/epidemiological units, markets and transporters, development of public–private partnerships and effective emergency response mechanisms.

At the national level, capacity-building and training will be essential components to implement the strategy. In addition, the strategy foresees the provision of finance, materials and vaccines for countries in the early stages of the PCP-FMD. At the regional level, the focus will be on training, creation, maintenance and coordination of networks and providing international expertise in the fields of laboratory diagnosis, epidemiology, disease control and vaccine quality control.

At the global level, coordination, progress assessment, strategy development and advocacy will be conducted.

The expected results of the GCS-FMD are as follows (Table I):

– Within a 15-year period, countries that are currently in PCP-FMD Stages 0 and 1 will have progressed at least two stages along the PCP-FMD. Achieving this means that at the end of this period all countries will have reached at least PCP-FMD Stage 2.

– Countries in PCP-FMD Stages 2 or 3 should also move up two stages, but the final objective will depend on a country's decision based on cost-effectiveness studies.

– Countries or zones that already have an OIE-recognised FMD-free status maintain this status or further improve it (i.e. move from FMD-free with vaccination to FMD-free without vaccination).

Table I
Chronogram of component 1 (foot and mouth disease control) of the Global Foot and Mouth Disease Control Strategy

PCP stage at year 0	PCP stage at the end of year 5					PCP stage at the end of year 10					PCP stage at the end of year 15				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
0	100*					10	75	15				50	50		
1	10	75	15				60	30	10			10	70	20	
2	–	25	50	25				60	30	10			25	50	25
3	–		50	25	25			10	50	40			10	20	70
4	–			50	50				25	75					100
5	–				100					100					100

PCP: Progressive Control Pathway

* Percentage of countries in the indicated PCP stage at year zero that move to a higher PCP stage (or remain in the same stage), estimated for each five-year period, i.e. the percentages mentioned over the years refer to the original group of countries

Component 2

Countries progressing along the implementation of the FMD strategy, as seen through the PCP-FMD tool, will have to develop in parallel their VS to be able to fulfil the criteria. Table II shows the correspondence between the PCP-FMD stages and the level of advancement required for each of the critical competencies (CCs) of the OIE PVS Evaluation tool relevant to FMD control.

All countries reaching PCP-FMD Stage 3 must have reached at least level 3 (i.e. minimum compliance with OIE standards) for the 33 FMD-relevant CCs that have been identified.

The strategy recognises that the approach and the activities proposed under component 2 (creating an 'enabling environment') are not FMD specific, and therefore are expected to have spill-over effects on the control of all major TADs. At the national level, component 2-related activities will address various categories of support, such as surveillance systems, laboratories, biosecurity, movement control, identification of farms and animals, wildlife surveillance, legislation and transparency, socio-economic expertise, emergency preparedness, public–private partnerships, monitoring and evaluation, and communication.

Capacity-building will be an important activity at national level. At regional and international levels, the activities will address coordination, support to disease-specific laboratories and epidemiology networks, joint capacity-building workshops, strengthening of regional animal health expertise and participation in regional conferences on animal health.

The proposed results of component 2 of the programme are that, within a 15-year period, all countries that are not compliant with OIE standards (i.e. below level 3) for the 33 FMD-relevant CCs at the beginning of the implementation of the GCS-FMD have reached a minimum of level 3 for selected CCs in relevant PCP-FMD stages. All countries that are compliant with OIE standards (i.e. level 3 or above) at least maintain their level of compliance.

Table II
Relationship between foot and mouth disease Progressive Control Pathway (PCP-FMD) stages and OIE Performance of the Veterinary Services critical competency levels

Critical competencies and levels	PCP-FMD stage			
	1	**2**	**3**	**4**
Professional competencies of veterinarians (CC I.2.A)*	3	3	3	3
Competencies of veterinary para-professionals (CC I.2.B)	1	3	3	3
Continuing education (CC I.3)	3	3	3	3
Internal coordination (chain of command) (CC I.6.A)	1	2	3	3
External coordination (CC I.6.B)	3	3	3	3
Management of resources and operations (CC I.11)	1	2	3	3
Risk analysis (CC II.3)	3	3	3	3
Emerging issues (CC II.11)	1	2	3	3
Communications (CC III.1)	2	3	4	4
Consultation with stakeholders (CC III.2)	3	3	3	3
Official representation (CC III.3)	2	3	3	3
Accreditation/authorisation/delegation (CC III.4)	1	2	3/4	3/4
Veterinary Statutory Body authority (or equivalent) (CC III.5.A)	1	2	3/4	3/4
Veterinary Statutory Body capacity (CC III.5.B)	1	2	3	3*
Participation of producers and stakeholders in joint programmes (CC III.6)	2	3	3	3*
Preparation of legislation and regulations (CC IV.1)	3	3	3	3
Implementation of legislation & stakeholder compliance (CC IV.2)	1	3	3	3
Passive epidemiological surveillance (CC II.5.A)	1	3	3	3
Active epidemiological surveillance (CC II.5.B)	3	3	3	3/4
Early detection and emergency response (CC II.6)	1	1	3	3
Disease prevention, control and eradication (CC II.7)	1	2	3	3
Ante and post mortem inspection (CC II.8)	1	2	3	3
Veterinary laboratory diagnosis (CC II.1)	2	2/3	2/3	2/3
Laboratory quality assurance (CC II.2)	2	3	3	3
Quarantine and border security (CC II.4)	1	2	3	3/4
Animal identification and movement control (CC II.13.A)	1	2	3	3
Transparency (CC IV.6)	2	3	3	3
Zoning (CC IV.7)	1	2	3	3
Veterinarians and other professionals (CC I.1.A)	2	3	3	3
Veterinary para-professionals and other technical staff (CC I.1.B)	2	3	3	3
Physical resources (CC I.7)	2	2	3	3
Operational funding (CC I.8)	1	2/3	4/5	4/5
Emergency funding (CC I.9)	1	1	3	4/5

* As per the OIE Tool for the Evaluation of Performance of Veterinary Services (OIE PVS Tool), Fifth Edition, 2010 (18)

Component 3

Achieving progress in FMD control (i.e. reaching a higher PCP-FMD stage) implies having created an appropriate enabling environment for disease control (i.e. having improved the capacities and capabilities of the VS). This implies that the VS are also better equipped and better prepared to deal with the control of other priority animal diseases.

Reference Centres and regional and international networks already exist for many diseases, but some disease-specific joint OIE/FAO international and regional networks may still be needed. The same applies to networks of epidemiology centres, but the experience and expertise built up in the field of FMD epidemiology at the national level will also benefit other areas. Vaccines against infectious diseases other than FMD exist, but the issue of availability and quality control is a major concern in many countries.

At the international level, the GLEWS and the OIE WAHIS/WAHID, which provide support for the control of a range of high-impact animal diseases, including zoonoses, will be supported.

Sensible and cost-effective combinations of FMD control activities with other TAD control or production-related activities will be implemented, such as vaccinations against other major diseases, epidemiological investigations, diagnostic activities and treatments. Related activities will also be considered at the regional and international levels, and in this respect the strategy foresees an important role for the GF-TADs Regional Steering Committees (RSCs). Workshops will help to prepare disease-specific regional strategies and specific epidemiological and socio-economic studies will be undertaken. Disease-specific laboratory and epidemiology networks, as well as the CMC-AH, will be supported.

More specific, precise objectives of component 3 cannot be formulated at present.

Governance

Overall policy guidance will be provided by the GF-TADs Global Steering Committee (GSC), supported by the Global GF-TADs FMD Working Group. The GF-TADs FMD Working Group will update the Global Strategy in accordance with experience gained and contribute to its implementation. At the regional level, the GF-TADs RSCs will act as regional platforms with the support of their technical expertise groups (Regional Support Units), without, however, duplicating the work of the regional organisations and platforms already coordinating FMD control programmes (e.g. Pan American Health Organization [PAHO] and the South American Commission for the fight Against Foot-and-Mouth Disease [COSALFA] in South America, the South-East Asia and China Foot and Mouth Disease [SEACFMD] campaign in South East and East Asia, the European Commission for the control of Foot-and-Mouth disease [EuFMD] in Europe and the African Union Interafrican Bureau for Animal Resources [AU-IBAR], with the support of relevant Regional Economic Communities in Africa), which will of course continue their activities.

Action plan

Part B of the GCS-FMD presents the Action Plan for the three components. The 15-year period of the strategy has been divided into three periods of five years, with a description of the relevant progress expected for each period to facilitate regular assessment.

Budget

The cost of the activities foreseen under the GCS-FMD has been comprehensively calculated with the support of experts from the World Bank. The cost of the Global Strategy for the initial five years of the programme would be US$ 820 million, of which US$ 762 million (93%), US$ 47 million (6%) and US$ 11 million (1%) are attributable to the country, regional and global levels, respectively. The vaccination cost of US$ 694 million is by far the largest component of the cost (Fig. 4). It has been calculated according to the percentage of the national cattle expected to be vaccinated (Table III). This cost estimate exercise can be used as a basis for gap analysis and needs to be refined as new information becomes available and more policy issues are addressed.

No global cost estimates and specific budget provisions have been made to support components 2 and 3, since they are highly dependent on national socio-economic and policy environments and the disease priorities and choices made by governments. The results of a preliminary study of PVS Gap Analyses showed that major variations

also exist depending on the level of compliance with OIE standards already attained (i.e. more investments are needed in countries that have reached a high level of compliance) and the density of the livestock population (i.e. lower cost per veterinary livestock unit for countries with a high density).

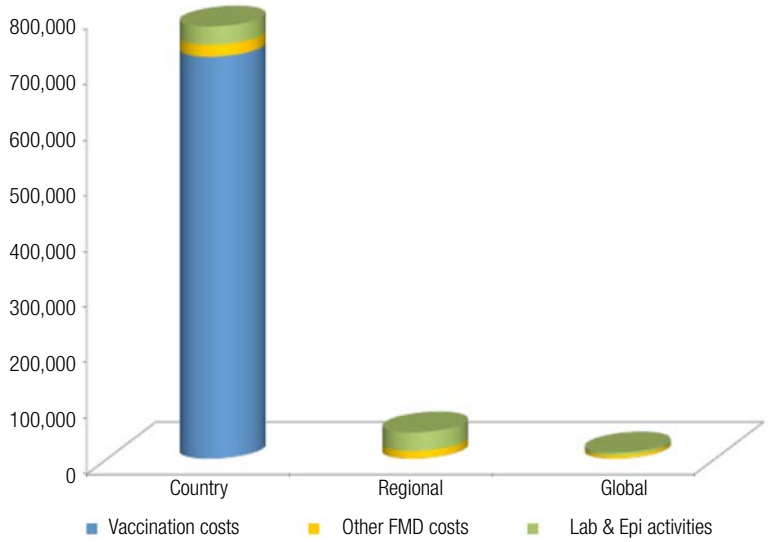


Fig. 4
Cost of the global strategy at the country, regional and global levels (US$ 1,000)

An FMD portfolio analysis showed that the investments in FMD control worldwide are high, but such investments are made mainly by countries that see clear trade incentives. Developing countries are investing much less in FMD control, presumably either because they cannot afford it or because they fail to see a positive cost–benefit ratio. International investments are relatively limited.

Table III
Cost of the global strategy: percentage of the national cattle being vaccinated

Region: Asia and Eurasia					
PCP stage	Y1	Y2	Y3	Y4	Y5
from 0 to 1	0%	0%	0%	0%	0%
from 1 to 2	0%	0%	0%	20%	25%
from 2 to 3	20%	25%	30%	45%	50%
from 3 to 4	45%	50%	50%	50%*	60%*
Region: Africa					
PCP stage	Y1	Y2	Y3	Y4	Y5
from 0 to 1	0%	0%	0%	0%	0%
from 1 to 2	0%	0%	0%	10%	10%
from 2 to 3	10%	15%	15%	30%	30%
from 3 to 4	30%	40%	40%	50%*	50%*
Region: South America					
PCP stage	Y1	Y2	Y3	Y4	Y5
from 0 to 1					
from 1 to 2					
from 2 to 3	50%	50%	50%	60%	60%
from 3 to 4	60%	70%	80%	80%	80%

Source: GF-TADs FMD Working Group discussion on 20 December 2011

Colour	PCP
	0
	1
	2
	3
	4

PCP: Progressive Control Pathway

* Indicates that both large (cattle, buffalo) and small (sheep, goat) ruminants are treated. Otherwise, only large ruminants are targeted

Note: The percentages in the tables indicate the vaccination coverage for countries that progress to the next stage. For countries which remain in the same stage, the vaccination coverage in the fourth and fifth years is assumed to be the same as in the third year

Conclusions

The FMD world situation has been presented, as well as the main elements of the GCS-FMD. Political commitment and additional investments are needed to support national programmes, in particular in FMD Pools 3, 4 and 5 (Africa). To obtain the full benefit of FMD control efforts and to maintain the progress achieved, support for regional and global coordination is also necessary. Better FMD control on a global scale can be expected only if a concerted effort is made, coordinated by the relevant international organisations, and with strong support from all relevant regional organisations, involving both developing and developed countries, and with the sustained support of the development partners. The joint FAO/OIE GCS-FMD aims to offer a framework and the tools to initiate and implement a well-structured approach to global FMD control.

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The initial cost estimate of the FAO/OIE global foot and mouth disease control strategy

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This paper is a product of close co-operation between the World Bank (WB) Team and the Food and Agriculture Organization of the United Nations (FAO)/World Organisation for Animal Health (OIE) Global Framework of Transboundary Animal Diseases (GF-TADs) Foot and Mouth Disease (FMD) Working Group. The longer version of the paper (3) is available as a supporting document of the global strategy (2). The paper relies heavily on discussions with and data provided by the members of GF-TADs FMD Working Group consulted between November 2011 and May 2012. We are deeply grateful to Joseph Domenech (OIE) and Peter DeLeeuw (FAO) for overall guidance and inputs, including during our meetings at OIE Headquarters in Paris on 21–22 November 2011 and at FAO Headquarters in Rome on 19–21 December 2011, and to Giancarlo Ferrari (FAO), Samia Metwally (FAO), Nadège Leboucq (OIE) and Bernardo Todeschini (OIE) for generously sharing their time, data and expertise. We also would like to thank Brian Bedard (WB), Cyril Gay (United States Department of Agriculture [USDA]), Alex Donaldson (FAO/OIE consultant), Stephane Forman (WB), Mimako Kobayashi (WB), Caroline Planté (WB), Jonathan Rushton of Royal Veterinary College, University of London and Juergen Voegele (WB) for very useful inputs, comments and discussions.

Summary

This paper provides initial cost estimates *for the Food and Agriculture Organization of the United Nations (FAO)/World Organisation for Animal Health (OIE) global foot and mouth disease (FMD) control strategy for the first five years of the programme. The cost at the country level is estimated, taking account of a set of activities typically undertaken along the progressive control pathway (PCP), which is a tool for FMD-endemic countries to increase progressively their levels of FMD control. The country-level cost is estimated to be about USD 762 million (93%), of which a large portion is vaccination costs. The cost at the regional level is estimated to be about USD 47 million (6%), with a high proportion of the cost going to laboratory and epidemiology activities clustered around the seven FMD 'regional virus pools'. The cost of the strategy at the global level is estimated to be about USD 11 million (1%). About half of the cost at the regional level directly benefits countries through training, laboratory support and expert support missions, and approximately one-third of the cost at the global level benefits regions and countries directly in a similar way.*

Keywords
Costs – FAO/OIE Global FMD disease control strategy – Global strategy – Progressive Control Pathway – Veterinary Services – World Organisation for Animal Health.

Introduction

Foot and mouth disease (FMD) is a highly contagious and economically devastating livestock disease worldwide. FMD is endemic in many low-income countries and an FMD outbreak causes devastating impacts on farmers with adverse effects on livestock assets, production income and consumption. FMD may spread to FMD-free countries, as seen with outbreaks in the United Kingdom (UK) (2001), Japan (2010) and the Republic of Korea (2010), costing these countries billions of dollars. The control of FMD is therefore a global public good.

The objective of this paper is to prepare an initial cost estimate for the first component of the Food and Agriculture Organization of the United Nations (FAO)/World Organisation for Animal Health (OIE) global FMD control strategy for of (hereafter the global strategy) for the first five years at country, regional and global levels. The global strategy is a 15-year programme with three components:

i) improving global FMD control;

ii) strengthening Veterinary Services (VS); and

iii) improving the prevention and control of other major diseases of livestock (2).

As FMD control is linked to the overall development of VS, and improved VS and FMD control are expected to have spill-over effects on the control of other major animal diseases, countries may use FMD control as an entry

point to improve overall animal health systems (2). The Progressive Control Pathway (PCP) for FMD is a tool for FMD-endemic countries to increase progressively their levels of FMD control through, for instance, building adequate laboratory and surveillance systems and supporting quality-controlled vaccination programmes. In addition, the laboratory and epidemiology network proposed by the strategy is designed to provide an effective regional coordination and support mechanism addressing issues of externality, epidemiology, economies of scale and quality assurance. Following this introduction, we turn to Tisdell's (5) simple model to illustrate the economics of animal disease control programmes. Then we present the methodology and our initial cost estimates. The final section draws conclusions.

A simple model: economics of controlling livestock diseases

This section illustrates a 'simple' or 'simplified' model developed by Tisdell (5), which relates the total benefit which arises from a control programme and the total cost of the programme for a country. Whereas this paper's focus is on costing of the strategy, this section is intended to put the cost analysis in the context of cost–benefit analysis and to discuss some policy insights. Figure 1a shows the benefit function $f(E)$ which measures the benefits arising from a reduction in economic loss from the disease, where E represents the level of variable cost expenditure (e.g. vaccination costs).

The benefit function increases at a decreasing rate over the relevant range, ($f > 0$ and $f < 0$) with respect to E. The total cost (TC) of the control programme consists of start-up or fixed costs, k, and variable outlays, E, represented by a 45-degree line (TC = k + E). The net benefit (NB) from disease control is given by the difference between the total benefit and total cost (NB = $f(E)$ – TC) and the net benefits are maximised when the marginal benefit equals the marginal cost at the optimal level of variable expenditure, E*.

Tisdell's model aids in explaining the costs and benefits of control programmes for countries in different PCP stages. For countries which are in low PCP stages, the existence of a start-up cost, k, implies that a certain level of investment (k + E0 in the figure) would be required before the benefits start to outweigh the costs. For instance, countries with no reliable information on FMD (PCP Stage 0) would initiate comprehensive studies on epidemiology and socio-economic context before developing risk-based control measures (1). Research of this kind is part of the fixed costs. Once control options are identified, countries may start their control measures targeting a key livestock sector and/or critical risk points while moving from PCP Stage 1 to 2. At higher stages, the focus moves from targeted approaches to the elimination of FMD virus circulation in at least one zone of the country with more aggressive control strategies (1).

For countries which have already invested in the control programme, for instance, if a country is at E1, the economically relevant question would be how 'incremental' (or 'additional' or 'marginal') investment would bring extra benefits. For instance, if the country wishes to attain the nationally optimal level of investment, the additional expenditure needed to attain E* would be (E* – E1).

While the PCP provides a guide for countries to progress to the point where they attain officially recognised FMD 'free with vaccination' or 'free without vaccination' status at the end of Stages 4 and 5, respectively, countries may decide not to progress beyond Stages 2 or 3, both of which provide sustainable management of FMD at lower levels (1). How far countries progress along the PCP may depend on countries' benefit and cost functions. For instance, for potential exporters of livestock products, the benefits from striving for FMD-free status are likely to be larger.

One challenge of the global strategy is that lower PCP countries tend to be low-income countries (see Figs. 2b and 5b in Fukase, 2012 [3]), and they may face larger start-up costs owing to systemic problems such as weakness of veterinary services, infrastructure, and legislative and institutional framework. Figure 1b illustrates the case where a start-up cost for a country is prohibitively high to implement the programme, as the total cost is greater than the total benefit at any level of investment (NB = $f(E)$ – TC < 0). In such a case, a country has no incentive to commit to the global FMD control programme alone. However, given the negative externalities for other countries created by the presence of the disease in any country, a 'big push' from the international community to cover these fixed costs – and perhaps some variable costs – may potentially be justified.

Figure 1c introduces the concept of externality considering the case when countries invest collectively in disease control programmes. In this case, the national benefit function shifts upwards owing to the resulting reduction in the risk of infections from other countries. The higher national benefit function associated with positive externality suggests that there are both greater benefits $f(E^{**})$ and a higher optimal level of control at E** than would be chosen by the individual country.

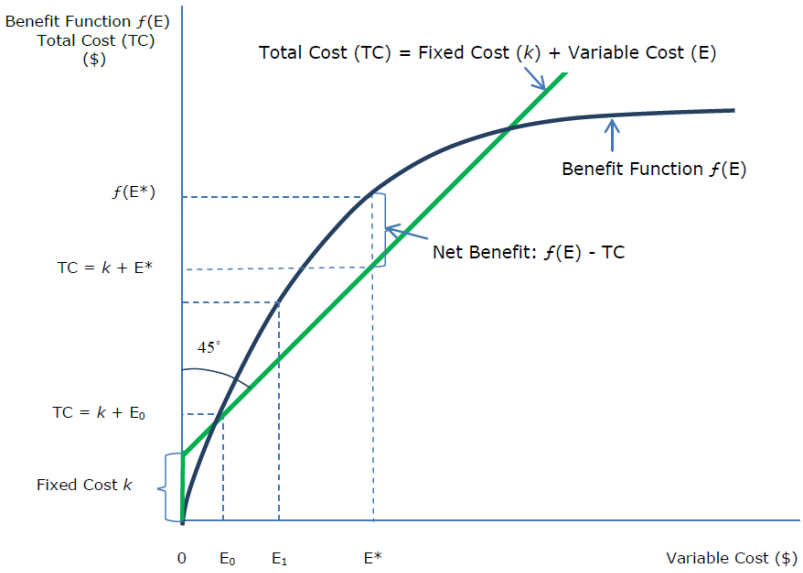

Fig. 1a
A cost–benefit model for livestock disease

Source: adapted from Tisdell (5), Figure 2, p. 3

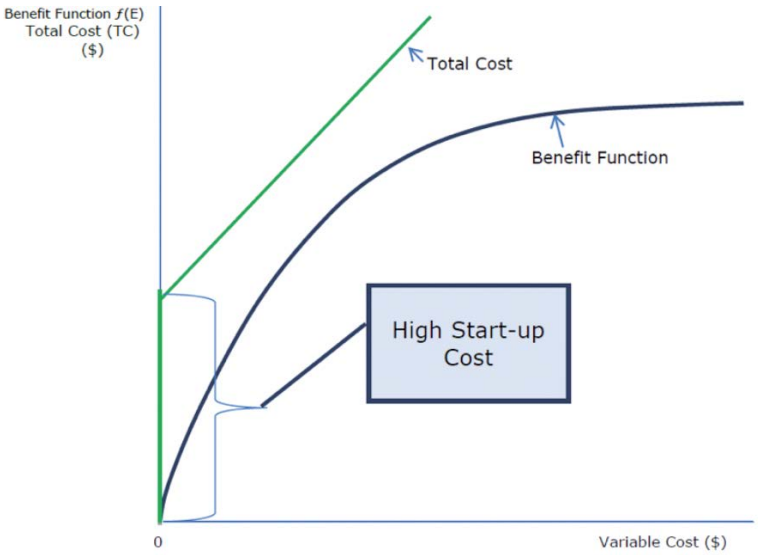

Fig. 1b
A cost–benefit model for livestock disease in a country with high start-up costs

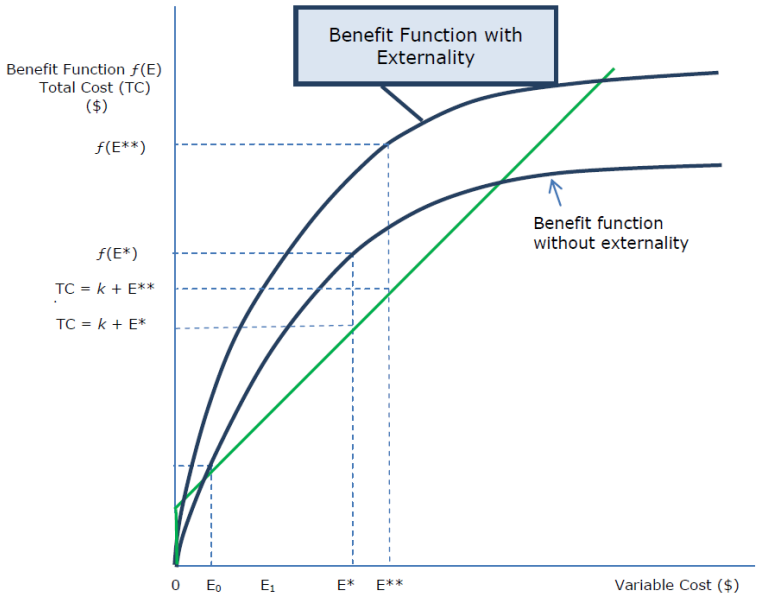

Fig. 1c
A cost–benefit model for livestock disease with externality

Costing the global foot and mouth disease control strategy

Costs of the strategy at the country level

In order to control the disease 'at source' (2), the global strategy considers endemic countries in initial PCP Stages 0, 1, 2 and 3 for potential support (a total of 87 countries). The total cost of the FMD global strategy for each country is calculated by summing up the cost of FMD activities across five years and across activities weighted by the probability of moving on to the next stage. It is assumed that 100% of countries in PCP 0 move to PCP 1, whereas 75%, 50% and 25% of PCP 1, PCP 2 and PCP 3 countries, respectively, are expected to move on to the next stages. The total cost (TCs) of the programme for each country at the initial Stage s is calculated as below.

where Cj, s, y is the cost of the programme j (j = 1,..M) in PCP Stage s (s = 0,..3) in year y (y = 1..Ys..5) where Ys is the years required to move to the next stage (for those countries that move) and αs is the probability of moving to the next stage at Stage s.

Cost of the foot and mouth disease programme without vaccination costs

As the costing information on individual countries is not available at this stage, we work on a set of costing assumptions provided by experts who have experience in the regions (see Annex 1 of Fukase (3) for the data used by FMD activity, by PCP stage, and by country size). This approach gives rise to two major limitations of the country-level estimate: first, the estimate should not be viewed as reflecting individual countries' 'budgets'. Second, since the information to calculate incremental costs is not readily available, the paper reports 'total' costs as a first step.

Overall, five-year PCP-related activity costs for 79 initial PCP 0–2 countries add up to USD 68 million, not including vaccination costs. (We assume that countries that move from PCP Stage 2 to Stage 3 receive general support for the first two years of transition. However, for countries that are already in PCP Stage 3, it is assumed that they do not receive general support for their national programme but receive some support for their vaccination programme.) The costs cover personnel, socio-economic appraisal, communication and public awareness, and a series of activities to develop adequate laboratory and surveillance systems at the national level such as machinery and equipment, database, training, the costs of sample collection/laboratory testing, and expenses for national laboratories to participate in the regional laboratory network (see Table I in Fukase, 2012 [3]) The results by region and by income group reveal that Africa followed by Eurasia are the regions which incur the largest costs, accounting for 50% and 33% of total costs, respectively; and low and lower to middle-income countries account for a large majority of costs, with the combined costs of these countries amounting to 74% of the total cost (see Fig. 7a,b in Fukase paper, 2012 [3]). Across all the countries, the average cost of the activities per country for five years (without vaccination costs) is USD 863,000.

There is little variation in FMD costs across countries in the current data as we worked on the 'averages' of representative countries so that the sum of the costs across countries adds up to a reasonable cost estimate. At a later stage, when we develop individual country budgets, we expect to see much larger variation in national FMD activity costs. On the one hand, some countries may need little support if they already have successful FMD control programmes or are integrated into good programmes. On the other hand, some countries may face start-up costs which are much higher than the costs that are calculated in this paper, for instance, if they need to invest in fundamental capacity-building and basic infrastructure, which would be necessary to enable them to initiate effective FMD programmes.

It is also noted that, whereas PCP related activities costed in this paper (Component 1 of the global strategy) have positive impacts on the development of national VS, the cost does not include budgets to strengthen the overall capacity of national veterinary services proposed in Component 2 of the strategy. The Performance of Veterinary Services (PVS) Pathway evaluates national VS with the aim of bringing them into compliance with OIE quality standards. The available data emanating from country PVS evaluations and PVS Gap Analysis reports show that the budget necessary to reinforce national animal health systems over a five-year period varies from USD 6.1 million to USD 199 million for a sample of 26 countries for which the livestock sector contribution to the national agriculture GDP is greater than 15% (15.2% to 86.9%) (OIE country PVS evaluations and PVS Gap Analysis reports). No 'global' cost estimates have been made for Components 2 and 3 of the strategy and the latter activities are subject to additional funding (2). In any case, the simultaneous development of national VS is especially important since the success of the control programme is closely linked to the overall capacity and capability of veterinary services in charge of these activities.

Vaccination cost

The cost of vaccination is calculated for the 45 initial PCP 1–3 countries (not including the People's Republic of China and India) assuming a vaccination schedule in which countries increase progressively their vaccination coverage. The five-year vaccination cost is estimated to be USD 694 million, which turns out to be the largest component of the cost of the strategy. The average vaccination cost per country is found to be USD 15 million, with a large dispersion of vaccination costs depending on animal population and initial PCP stages. The high proportion of vaccination cost and the large variation in the costs across countries suggest that there is much room to work on this item, including on such issues as choice of and access to safe and good quality vaccines, promoting good public–private partnerships, and determining the extent and regional coverage of the vaccination programmes. For those countries which already have successful vaccination programmes, the 'incremental' costs which need to be funded are likely to be lower than the estimate in this paper. The high vaccination costs at the country level may lead to the introduction of mechanisms to secure economies of scale at the regional or global levels, for instance by establishing regional and global antigen/vaccine banks.

Cost of the strategy at the regional and global levels

The incremental approach is taken for the cost estimates at the regional and global levels, so that the estimate does not include the costs of existing programmes such as salaries of existing staff or the costs incurred by laboratories which are already operating. A regionally and internationally coordinated approach is regarded as key to controlling transboundary animal diseases, taking advantage of the positive externalities that each country's disease control actions provide to other countries. Since the specific viruses responsible for FMD differ among the seven regions (there are seven serotypes of the FMD virus, namely O, A, C, Southern African Territories [SAT] 1, SAT 2, SAT 3 and Asia 1, and vaccination against one serotype does not confer immunity against another), the concept of seven 'regional virus pools' provides an organising principle for coordinating regional activities in terms of these virus pools. The laboratory and epidemiology network proposed by the global strategy is characterised by its layered structure with its major activities clustered amid seven regional virus pools and is integrated vertically at the national, regional and global levels. Ideally, there would be one national laboratory per country; with regional laboratories (Reference Centres when they exist in the region or leading regional laboratories) assisting national laboratories through training, technical assistance and laboratory testing; and one of the Reference Centres (perhaps the World Reference Laboratory for FMD (WRLFMD) in the UK) serving as a global coordinating laboratory. The global strategy would also establish and strengthen an epidemiology network with a structure similar to that of the laboratory network. The latter structure aims to benefit from economies of scale through pooling and sharing resources, expertise and technical capabilities, and is a central cost-saving element of the strategy. While there are OIE/FAO FMD Reference Centres worldwide, they are lacking in East and West Africa and in West Eurasia. In these regions, the global strategy would support existing leading regional laboratories to become OIE/FAO Reference Centres or equivalent laboratories through training, technical assistance and support in strengthening their laboratory networks.

Overall, the cost of the global strategy at the regional level for the initial five years is estimated at USD 47 million. The cost at the regional level is characterised by a high proportion of the cost going to laboratory and epidemiology activities clustered around the seven FMD 'regional virus pools'. The costs include those for recruiting additional epidemiologists and laboratory specialists to be based in the regions, regional laboratories' provision of training to and support of proficiency testing for national laboratories as well as funds to establish the regional epidemiology network, Quality Control Centres for vaccine and databases for epidemiology and laboratory (see Table II in Fukase, 2012 [3]). It is noted that about half of the regional costs, namely expert support missions to countries and the regional laboratories' training/support to national laboratories, directly benefit countries.

Finally, progress of the global strategy would require strong coordination and cooperation mechanisms. One advantage of the GF-TADs performing the coordination role is that the strategy can benefit from the expertise and experience of OIE and FAO, including through insights from their successful campaign to eradicate rinderpest (4). Another advantage lies in the fact that the strategy can use these organisations' existing worldwide platforms (e.g. OIE/FAO Reference Centres) as well as their close ties with the regional organisations. Overall, the costs of the global strategy for the initial five years at the global level add up to USD 11 million. The costs include hiring additional staff for GF-TADs, coordination costs and fees incurred by a global laboratory in providing training and support to regional laboratories and international conferences (see Table II in Fukase, 2012 [3]).

Conclusions

This paper provides initial cost estimates for the FMD control component of the FAO/OIE global strategy at the country, regional and global levels for the first five years of the programme. The results imply that the cost of the global strategy – as initially estimated – for the first five years of the programme would be USD 820 million, of which USD 762 million (93%), USD 47 million (6%) and USD 11 million (1%) are attributable to the country, regional and global levels respectively. Finally, this exercise should be viewed as an initial step of costing, which may be used as a base for gap analysis and which needs to be refined as country-level data become available and policy issues, such as the design of support arrangements, are addressed.

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Recommendations

FAO/OIE GLOBAL CONFERENCE ON
FOOT AND MOUTH DISEASE CONTROL

BANGKOK, THAILAND, 27-29 JUNE 2012

RECOMMENDATIONS

Considering that:

– Livestock is important in food security, income generation, small holder's livelihoods and poverty alleviation.

– Major livestock diseases are of social and economic importance, in particular those of highly contagious and transboundary nature. They are among the most significant limiting factors for livestock production. Their impact can vary from reduced productivity and restricted market access to the elimination of entire flocks or herds, with the resultant loss of biodiversity and valuable genetic resources and public health risks.

– Globalisation of trade with rapid and long distance movements of animals and animal products increases the risk of major pathogens spreading from one country/region to another.

– FMD is still widespread throughout the world, particularly in Asia, Africa and the Middle East and by the end of May 2012, more than 100 countries were not FMD-free and they remain a continuous threat to free countries. Foot and mouth disease (FMD) can severely affect and disrupt regional and international trade in animals and animal products causing enormous financial damage. In developing countries, where the adverse effects of FMD are often underestimated, the disease undermines food security and economic development, at the level of both village smallholders and the more organised production chains. In other regions of the world massive culling has created animal welfare and ethical concerns, not just in the agricultural sector, but in society as a whole.

– All scientific evidence indicates that in most regions of the world, wild ungulates are susceptible to FMD but do not serve to maintain the virus in the absence of ongoing infections in domestic livestock. In the context of Sub-Saharan Africa, the African buffalo (*Syncerus caffer*) can serve as a source of FMD infection for domestic animals but not all FMD outbreaks in livestock over the last ten years have been associated with buffalo. In some regions, in particular in Southern Africa, the persistence of the FMD virus in certain wild animals represents a threat to the domestic ruminant population and the impact of some FMD control measures on wildlife conservation has become an important consideration.

– The recent epidemiological situation, with the incursion of FMD virus into free (Japan, Korea, Bulgaria) and infected countries (SAT2 in Egypt and Libya) once again shows that countries – even those where the virus has been eliminated for years – remain under threat and must be fully prepared for the emergence/reemergence of FMD.

– Controlling Transboundary Animal Diseases (TADs) such as FMD at source is a shared interest between infected and uninfected countries and should be considered a Global Public Good.

– The control of FMD and other TADs cannot be sustained if good governance of animal health systems, including effective Veterinary Services complying with OIE Standards and continuously updated supporting legislation, is not in place and supported by appropriate public-private partnerships.

– The first OIE FAO Global Conference on FMD held in Asunción, Paraguay, in June 2009 recommended that FAO and OIE establish an FMD Working Group under the Global Framework for the progressive control of Transboundary Animal Diseases (GF TADs) and prepare a Global FMD Control Strategy.

– The 79th OIE World Assembly in May 2011 in Paris supported the preparation of the Global Control Strategy and asked that a consultation of experts and representatives of national, regional and international institutions be undertaken.

– Implementing science-based animal health measures based on the OIE *Terrestrial Animal Health Code* and *Manual* is essential to minimise potential economic and trade implications of FMD.

– The Global FMD Control Strategy published and discussed during the FAO/OIE Global Conference on FMD Control held in Bangkok, Thailand, 27-29 June 2012, is not presented as a 'stand-alone' activity but rather a combination of three inter-related components, namely the Control of FMD, Strengthening of Veterinary Services and the Prevention and control of other major diseases of livestock. The overall aim of the FMD Control Strategy is to reduce the global impact of the disease and to be used as an entry point to achieve sustainable progress in the performance of Veterinary Services and, in turn, improve the animal health status concerning other livestock diseases (spin-off effects). The Strategy is flexible enough to accommodate

differentiated responses according to different scenarios in terms of country FMD-PCP stages and regionally different existing initiatives such as SEACFMD and South American Institutions.

– Endemic countries are at different stages of managing FMD reflecting their socio-economic development and their livestock sectors. But for global control it is necessary to find ways to encourage all countries to engage with the global effort.

– In addition to the OIE Performance of Veterinary Services Pathway (PVS Pathway) and relevant articles of the OIE *Terrestrial Code* and *Manual*, new articles of the *Code* allow OIE to endorse national FMD control programmes submitted by countries that are not yet FMD-free but which are at an advanced level such as Stage 3 of the FMD-PCP and this will mark the country's entry into the pathway towards freedom from FMD in the domestic animal population.

– The OIE pathway to freedom provides the definitive steps for countries seeking international recognition for their disease control programme and disease freedom status, whereas the Progressive Control Pathway for FMD (FMD-PCP), a new joint FAO-EuFMD-OIE tool, provides a mechanism for other countries to engage in and contribute to the global FMD control effort without the immediate goal of disease freedom.

– Several tools are of critical importance to the Global FMD Control Strategy. These include effective surveillance and competent diagnostic laboratories with regional and international networking, appropriate vaccines to control FMD in endemic countries and to maintain free status (before complete cessation of vaccination), and emergency preparedness and immediate response to new disease events.

– Capacity building at the technical and managerial level as well as regular and effective communication to build public-private partnerships and gain the support of the animal owners are crucial for any control strategy.

– The role and services of reference laboratories are important to the success of a global approach. However some concerns exist among participating countries about the constraints in submitting infectious materials to reference laboratories.

– A regional approach is seen as (and history has proven to be) key for the control of FMD and other major TADs. The FMD control experience of a number of countries and regions, especially Europe, South America and South-East Asia have served as the basis for developing the global strategy.

– Global experience with Rinderpest eradication and HPAI H5N1 control has demonstrated the importance of international and regional cooperation and coordination.

– Many developing countries lack the necessary resources and effective veterinary services that comply with the OIE Quality Standards to initiate, implement or sustain control programmes against FMD and other TADs.

– The difficulties and limits of analysis of the Cost Benefit on the Global FMD programme, as well as the demand from many national veterinary services to get support with the socio-economic justification of investing in overall veterinary services capacity and specific control programmes, including the progressive control of FMD.

– Strengthened veterinary services with sound governance are able to make a sound contribution to One Health initiatives and the broader public good.

– Global elimination of FMD and other major TADs is a long term objective requiring more than the period of 15 years presented in the Global FMD Control Strategy.

THE PARTICIPANTS OF THE CONFERENCE RECOMMEND THAT:

To countries:

1. FMD be recognised as a high priority disease that should be combatted synchronously on a global scale for the benefit of all countries;

2. FMD global control be considered as possible with existing means and methods;

3. The joint FAO/OIE Global FMD Control Strategy and Implementing Plan – with the 3 Components – be strongly supported as the framework to engage into or continue FMD (and other animal diseases) control worldwide, under the GF-TADs mechanism when accepted by countries;

4. All countries that are not FMD-free, develop and implement a national FMD control programme using the objectives, guidance and tools of the global FMD Control Strategy with the FMD-PCP as the preferred tool when appropriate for FMD-endemic countries to design and implement the strategy and monitor progress over time;
5. Countries use the possibility of OIE-officially endorsed FMD Control Programmes at Stage 3 of the PCP as a recognition of the effective management of FMD control in the country and continue by entering the official OIE recognition pathway for FMD-free status whenever feasible (based on zoning or the country as a whole);
6. Countries develop the veterinary services capacity using the OIE PVS Pathway (to create the required enabling environment), so as to ensure the sustainability of FMD (and other animal diseases) control programmes put in place including FMD-PCP when appropriate and to improve the economic and social resilience to major animal health events;
7. Countries consider the good governance of veterinary services, based on an appropriate animal health legislation, veterinary education and statutory bodies, as a pre-requisite to reach the higher FMD-PCP stages (Stage 3 and beyond);
8. The national FMD control programmes be based on robust animal health systems and effective public-private partnerships, and notably encourage the role of the private sector and of local communities, as key actors in FMD and other animal disease prevention and control measures;
9. Countries improve the surveillance, reporting and official notification of FMD (and other animal diseases) – both in domestic and wildlife species – including immediate alert, follow-up and final reports at national and global level using the OIE World Animal Health Information System (WAHIS/WAHID).
10. Rumour tracking is also encouraged at global level using, when appropriate, the FAO-OIE-WHO GLEWS (Global Early Warning System) reporting system as well as other regional information systems compatible with global systems.
11. Countries make use of the existing articles of the OIE *Terrestrial Animal Health Code* to combine these with the FMD-PCP approach in the appropriate stages, in particular zoning, compartmentalisation, containment, protection zones and commodity-based trade and actively participate in the FMD standard setting process through their national OIE Delegate;
12. The risk of infection from African buffalo must be considered when developing national FMD control programmes. There is little evidence that other wild ungulates play a role in the maintenance of FMD with the exception of Syncerus caffer and so efforts to control FMD must be regionally and locally appropriate and are best targeted at reducing or preventing the disease in domestic animals including feral animals, thus most effectively protecting both livestock and wildlife, as well as human livelihoods.

To regional and global technical partners:

13. The strengthening of the laboratory and epidemiology expertise and the networks, as foreseen by the Global FMD Control Strategy, be supported;
14. The international community, including the countries themselves, supports the Global FMD Control Strategy and in particular fund the regional support units for progressive control of FMD in each virus pool, to give the technical and other guidance required to achieve PCP progress. Within each virus pool control strategies will have to be developed to suit the epidemiology of FMD, socioeconomic status and resources available;
15. There should be global investment in ensuring reference laboratories are equipped to perform the likely increased load for vaccine matching studies and services. Countries are encouraged to submit field virus strains for vaccine matching and to monitor the spread and emergence of new viruses;
16. The setting of regional vaccine banks be established when and where appropriate using existing OIE antigen/vaccine banks or other efficient regional vaccine banks as models, or special funds for FMD vaccine delivery and application (i.e. FAO APHCA) as key contribution for funding partners and country/regional commitment;

17. Applied research should be conducted to improve vaccines, diagnostics and the understanding of infection and transmission mechanisms, to develop better spread models and determine the presence of virus in products destined for commodity trade;
18. Regular GF-TADs regional and global Steering Committee meetings as well as regional roadmaps meetings be organised;

To OIE and FAO (through the GF-TADs):

19. The FAO establish a more robust FAO/OIE FMD Secretariat within the FAO-OIE GF-TADs FMD Working Group;
20. FAO and OIE explore fund raising options, based on the conclusions of the Bangkok conference;
21. To enhance effective results of technical interventions FAO and OIE continue to emphasise the importance of socio-economic analysis (including livelihood, livestock sector strategies and value chain factors) that can guide FMD control programmes to be more successful;
22. For FMD control programmes, key beneficiaries of the programme, including farmers, farmer associations and traders be consulted at all stages of design and implementation;
23. Based on this understanding, FAO and OIE assist national Veterinary Services to advocate for the political and other stakeholders support for appropriate FMD control activities;
24. OIE and FAO assist countries to assemble evidence to demonstrate impacts of early control gains, so as to further secure political and other stakeholder support for FMD control;
25. A monitoring system for the Global Strategy implementation be put in place, under the responsibility of the Global GF-TADs Steering Committee; the GF-TADs FMD WG to report on an annual basis on the global and regional progress, including where appropriate the country FMD PCP stages from regional FMD roadmaps; this information to be made available in the GF-TADs Steering Committee and the Annual Assembly of OIE Delegates;
26. The Global Strategy be reviewed regularly and if needed updated on the basis of this monitoring work;
27. The FMD portfolio of activities (national budget and external support) be established every two years by the GF-TADs FMD WG, to best support the implementation of the Global Strategy;
28. The provisional GF-TADs FMD acceptance process, for the external evaluation of the relevant country FMD-PCP stages, be finalised;
29. The FAO-OIE CMC-AH and FAO-OIE-WHO GLEWS be made sustainable and be continually improved, to best serve the countries;
30. Institute for Animal Health, Pirbright, United Kingdom, be considered as the Global Coordinating Reference Laboratory for FMD, for the first phase of the Global Strategy. Support for reference laboratory services should be increased. Capacity building of FMD diagnosis at national and regional level be promoted through the network of FMD reference laboratories. Establishment of a reference laboratory should be promoted for each of the virus pool regions. Twinning programmes should be applied to speed up achievement of reference status for these laboratories;
31. The Global Strategy be considered as the preferred framework to develop new animal disease global control programmes under the GF-TADs mechanism and if relevant dedicated specific GF-TADs WG be set up for this purpose;
32. International agencies pursue dialogue with IATA/ICAO and other relevant agencies such as UNCTAD and WCO, to develop agreements that would facilitate shipping of FMD samples to reference laboratories or alternative approaches to shipping virus material safely be explored;
33. OIE continue to review and update the standards for FMD in the OIE *Terrestrial Animal Health Code* and *Manual* to reflect the latest technical advances and in doing so to ensure that the standards of FMD for international trade purposes are only applicable to those domestic and wildlife ruminants that have been scientifically proven to be of epidemiological significance.

To development partners

34. The international community of development partners considers funding the Global Strategy, on the bases of the budget presented during the Global conference;

35. The international community of development partners devotes special attention to:

    (i) strengthening Veterinary Services using OIE standards and guidelines,

    (ii) initiate and sustain FMD control programmes in the least developed countries – with particular emphasis on Africa, Asia, Middle East, Andean Region and Eastern Europe,

    (iii) regional and global activities to ensure the proper awareness, monitoring, resources mobilisation and commitment, coordination and harmonisation;

36. At regional and global level, priority activities include support to:

    (i) surveillance and diagnostic laboratories including twinning programmes at all levels;

    (ii) development of FMD regional roadmaps where appropriate

    (iii) reinforced FAO-OIE GF-TADs FMD Working Group to stimulate and monitor and report on the implementation of the Global Strategy;

37. Sub-regional training workshops be supported under agreed mechanisms with international agencies (FAO, OIE) and partners, including relevant regional organisations, to draft country disease control plans based on the results of the OIE PVS Gap Analysis. These plans covering a list of three to five regional/national priority diseases (including FMD) – as proposed by the GF-TADs Regional Steering Committees – would be prepared first at national level respecting donors requirements and, when possible, be discussed and analysed with FAO/OIE animal health and socio-economist experts. When finalised, the plans should then be presented using, when appropriate, to the GF-TADs framework.

38. The third Global Conference for the control of FMD be held in Africa (date and venue to be confirmed).

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Proceedings of the
FAO/OIE Global Conference on Foot and Mouth Disease Control

More than 500 participants attended the FAO/OIE Global Conference on Foot and Mouth Disease held in Bangkok, Thailand, from 27 to 29 June 2012, including Chief Veterinary Officers from more than 100 countries, representatives of international and regional organisations, donor agencies, non-governmental organisations, the pharmaceutical industry and agricultural producer organisations. Ministers and other decision-makers also took part.

The proceedings of this conference contain all of the oral presentations on a vast variety of technical and scientific issues, in addition to a presentation of the Global Foot and Mouth Disease Control Strategy, the tools and methods that it will employ and the gaps and needs that should be addressed to achieve sustainable progress towards global control of FMD under OIE and FAO guidance

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