

REVIEW ARTICLE

Planning for the Progressive Control of Foot-and-Mouth Disease Worldwide

M. Rweyemamu¹, P. Roeder², D. MacKay³, K. Sumption², J. Brownlie⁴ and Y. Leforban⁵

¹ Royal Veterinary College, University of London and Woking, Surrey GU21 2LQ, UK

² Food and Agriculture Organization of the United Nations, Rome, Italy

³ World Reference Laboratory for FMD, IAH, Pirbright, UK

⁴ Royal Veterinary College, Department of Pathology and Infectious Diseases, University of London, Hawkshead Lane, North Mymms, Hatfield Herts AL9 TTA, UK

⁵ Ministère de l'agriculture et de la pêche. 251, rue de Vaugirard. 75732 Paris Cedex 15. France

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Correspondence:

M. Rweyemamu. Royal Veterinary College
London and Woking, Surrey GU21 2LQ, UK.
Tel.: 0044-(0)1483-473774; E-mail:
mark.rweyemamu@btinternet.com

Present addresses:

P. Roeder, Taurus Animal Health, Hollyhedge
Cottage, Spats Lane, Headley Down, Bordon,
Hampshire GU35 8SY, UK.

D. MacKay, European Medicines Agency,
Canary Wharf, London, UK.

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Summary

In the wake of on-going successful programmes for global eradication of rinderpest and the current effort to contain the spread of avian influenza, the progressive world-wide control of FMD must be regarded as a major contribution to the international public good. FMD is the single most animal disease constraint to international trade in animal products. Its control is relevant, on the one hand, to protecting the livestock industries of industrialised countries and, on the other, to the livelihoods and income generation of developing countries, where, as a general rule, FMD continues to be endemic.

The strategy that is advocated in this paper is one that is based on progressive risk reduction of FMD in the context of progressive market access of livestock commodities from developing countries. It is suggested that FMD control should be linked to improvement in livelihoods of livestock dependent communities in the FMD endemic settings. It is expected that this in turn will lead to increasing demand for effective national veterinary services and disease surveillance. This strategy has also taken lessons from the global rinderpest eradication programme and regional FMD control programmes in Europe and South America.

The strategy that is advocated for the progressive control of FMD in the endemic settings is based on a seven stage process within a horizon of about 30 years, namely: (1) Assessing and defining national FMD status; (2) instituting vaccination and movement control; (3) suppressing virus transmission to achieve absence of clinical disease; (4) achieving freedom from FMD with vaccination in accordance with the OIE standards; (5) achieving freedom from FMD without vaccination in accordance with the OIE standards; (6) extending FMD free zones; and (7) maintaining FMD Freedom.

Concomitant with progressive FMD control, there needs be the encouragement of such risk reduction measures as in-country commodity processing in order to encourage regulated trade in livestock commodities without unduly increasing the risk of disease spread.

Finally, the progressive control of FMD should also be seen as part of reducing the overall, world-wide threat of infectious diseases to human health and economic development.

Basic Principles for Coordinated Disease Control

Some basic principles need to be outlined before describing the interventions which could prove effective.

Programme objectives

Foot-and-mouth disease (FMD) is a typical transboundary animal disease (TAD), as defined by the Food and Agriculture Organization of the United Nations (UN FAO) and the World Organization for Animal Health [Office International des Epizooties (OIE)] (FAO-OIE, 2004). TADs have three key characteristics: they are of significant economic, trade and/or food security importance for a considerable number of countries; they can easily spread to other countries and reach epidemic proportions and their control/management, including exclusion, requires cooperation between several countries. Therefore, the international control of FMD has to be seen as a contribution to the International Public Good.

Before elaborating possible approaches to international progressive control of FMD, it is important to consider the key drivers to international spread of TADs, including FMD, which will need to be taken into account for such programmes to succeed. These drivers have been outlined by several studies (Delgado et al., 1999, 2001; Royal Society, 2002; Baylis and Githeko, 2006; FAO, 2006; Rweyemamu et al., 2006) and those most pertinent for FMD can be summarized as:

- 1 the movement of animals and of animal-derived commodities which is being fuelled by globalization;
- 2 a growing world demand for meat and meat products and a consequential growing international trade in meat and meat products;
- 3 the intensification of animal agriculture, which is fuelled by the increasing demand for animal protein and a shift from cereal-based to more protein-based diets;
- 4 the growth in human travel;
- 5 the increasing importance of climate change on the incidence and spread of infectious diseases and
- 6 the enlargement of international trading blocks.

It is also important to bear in mind that the most serious TADs, are generally endemic in developing countries. The global epidemiology and the prevalence burden of FMD has been described elsewhere in this special issue (Rweyemamu et al., 2008; Sumption et al., 2008).

Accordingly, the initial focus of coordinated, progressive disease control for FMD must be to reduce the economic impact of the disease in the endemic settings to a level that is acceptable and then to proceed to elimination if experience indicates that elimination and protection against reinvasion to be feasible objectives. Success can lead rapidly to economic benefits which in themselves support further

development of the generic systems required for official veterinary services to function effectively.

The experience from the Global Rinderpest Eradication Programme (GREP) is that, once effective control of rinderpest is established and accreditation of freedom is commenced, the confidence generated leads to motivation and progress in other areas of disease control and livestock development. Another conclusion is that a focused, limited and achievable objective is indicated (Roeder et al., 2005; Rweyemamu et al., 2005).

Role of governments and their veterinary services

Foot-and-mouth disease virus is the most infectious agent of animals. As gaps in control measures allow entry or spread of infection, the intensity of control measures required are to be applied in relation to the level of infectiousness. It is, therefore, essential to maximize compliance with disease control measures, which usually require both effective Government Services and significant private sector drivers from livestock producer associations. If these associations are weak, Government services must shoulder far more of the total responsibility and failure may occur.

The necessary structures of effective state veterinary services for epizootic control are described in the Office International des Epizooties Terrestrial Code (<http://www.oie.int>) and by the UN FAO Good Emergency Management Practices (<http://www.fao.org/ag/AGA/AGAH/EMPRES/GEMP/index.html>). An effective service is rarely provided in countries with very limited public sector funding, with the exception of the few countries where there is major private sector push to organize control campaigns.

For countries where the rule of law is very weak, movement control cannot be rigorously applied and vaccination is almost the only available tool. Under these circumstances, stability and longer term national economic growth is usually required before Government Services are in a sufficient state to mount progressive control campaigns.

When contemplating new regional programmes, the countries concerned need to be engaged at the highest possible level of government not merely at a technical level; sustained national commitment is essential. Moreover the practice of relying on expatriate technical assistance personnel to direct and/or manage disease control programmes in developing countries is unlikely to be sustained in the longer term. Thus greater reliance and responsibility will need to be placed on national experts who should be both well trained and well remunerated. In future programmes, the role of international personnel is most likely to be confined to short-term consultancy services to provide highly specialized inputs into disease control programmes.

Developing the infrastructure required for the control of one disease, or a limited subset of diseases, creates an enabling environment which facilitates progress in more general disease control activities. The corollary of this experience is that attempting to generate all the paraphernalia of a modern official veterinary service at one time in a resource-poor environment rarely achieves anything sustainable, partly because of the short time horizons used. A longer term perspective than the 5 years or so normally adopted is clearly needed for TAD control programmes.

However, there are fundamental policy constraints relating to official veterinary service structure and functioning which must be overcome. Veterinary services in many developing countries are in a parlous state and recent years have seen a tendency for structural adjustment programmes to dismantle traditional line-managed veterinary services. While measures which differentiate clearly between functions relating to private good (such as clinical service delivery) and public good (epizootic and zoonotic disease control for example) are laudable, it must be clearly understood that excessive decentralization/regionalization and down-sizing of official veterinary services does not provide an environment conducive to effective control of a disease, such as FMD (De Haan and Nissen, 1985; Brückner, 1999; Cheneau, 1999; Holden, 1999; Sidibé, 2003; De Haan, 2004; Riviere-Cinamond, 2004a,b). One of the major problems that official veterinary services in developing countries face is the lack of appreciation of and reward for the specialist expertise needed. Consequently, it is extremely difficult to recruit and retain high quality staff even if they are trained at national expense. Policy makers must come to terms with the fact that veterinarians offer a spectrum of skills and expertise and that the role of official, state veterinarians is neither the treatment of sick animals nor even the vaccination of animals. Their role, in this respect, is to understand disease behaviour and manage and direct resources to effect an interruption of disease transmission to give effective control. This requires specialist expertise and specialist training.

Employing official veterinarians to provide clinical services to farmers, or actually forcing them to provide such services to supplement inadequate salaries, creates a conflict of interests which militates against effective control. For example, veterinarians and animal health assistants in Vietnam raise considerable income from treating FMD cases. This creates a disincentive to reduce the incidence of this disease, even if government has the declared intention of doing so. In Pakistan's North-West Frontier Province official veterinarians are even required to pay into the government treasury every month a considerable sum of money they are expected to raise from charging for animal treatment. At the same time, the custom in some countries of expecting field officers who report a disease

to pay for the feeding and accommodation of teams is clearly counter-productive.

Role of vaccination

Vaccination is reviewed separately in this issue by Barnett and Mackay (2008) and also by Garland (1999) and Doel (2003). For the purpose of disease control the main points are:

- coverage must be sufficient to stop spread;
- international standards of vaccine quality are essential, e.g. the strain incorporation and potency must be appropriate and the vaccine must be effectively inactivated, as otherwise it could in fact be a source of infection and
- effective control of FMD is not merely a matter of organizing mass vaccination campaigns in the hope that this will subdue infection. Mass vaccination is just one tool to be used; others include movement control, quarantine, rapid detection and reporting of outbreaks, focused vaccination, disinfection, sero-monitoring, sero-surveillance and public awareness.

Role of epidemiology and surveillance

Progressive control of disease will only achieve success if it is founded on sound epidemiological understanding, which discloses the determinants of disease occurrence together with the mechanisms of virus maintenance and transmission (EFSA., 2006). In this context, it is essential to conceive of FMD control as relating to a number of independent diseases caused by different serotypes or even topotypes of FMD virus together with a clear understanding of the epidemiology of each of these.

The dilemma exists of whether to promote efficiency of sample gathering and analysis for the benefit of disease-free countries; or whether to engage regions where FMD is still endemic to be partners in a common good goal of FMD detection, identification and monitoring. The latter would be intended to lead to a defined strategy for the progressive control of FMD (i.e. giving benefit for current endemic regions) and for the progressive reduction of the FMD risk in free areas [i.e. giving benefit to Europe and other Organization for Economic Cooperation and Development (OECD) countries]. The second option is clearly the more sustainable of the two. Some pertinent concepts for epidemiological analyses, including laboratory testing of clinical samples in FMD endemic settings have been outlined by Perry and Sones (2007).

Accordingly, a mutually beneficial strategy could be to stimulate the concept of Research Partnerships as networks on a themed basis more than just by organizing support to single institutions or only reference centres. This could build on the successful practice of

inter-institutional and multi-country funding for research within the European Union (EU) and the experience of the Research Group of the FAO European Commission for the Control of FMD (EUFMD). An alternative approach could be that of the coordinated research mechanism of the Joint UN FAO/International Atomic Energy Agency (IAEA) Division in Vienna, which has proved successful in disseminating the enzyme-linked immune serum assay (ELISA) technology in a standardized and quality-assured format, especially in relation to the rinderpest surveillance.

The organization of the networks could involve on one hand European FMD research establishments and on the other institutions (governmental and academic together) in epidemiological clusters of FMD endemic countries, with the OIE/FAO Regional Reference Laboratories acting as regional hubs for the networks and the World Reference Laboratory (WRL) for FMD as the global coordinator. The 3-year project EU CA-FMD/CSF (FP6-513755), which has been initiated to undertake coordination of FMD and classical swine fever (CSF) reference laboratories to maximize surveillance information on the prevailing strains of FMD and CSF globally, could be an excellent fore-runner for the type of global surveillance partnership that is advocated in this paper.

A new encouraging development has been the international coalition of FMD and Epidemiological institutions from both FMD-free and FMD-endemic countries, which is now promoting the concept of a global roadmap for the development of tools for the control of FMD in endemic settings (Perry and Sones, 2007).

At the individual expert level, the key mutual benefits could be that European experts would maintain practical expertise in FMD and knowledge of critical FMD risk situations globally while experts in developing countries would benefit from training in modern technologies and mentored research into the surveillance for FMD, and other major TADs, as a means for defining epidemiologically sound and cost-effective disease control.

A point that needs to be addressed is how to pool the data from the global surveillance network into an 'early warning system' that is objective and in which all parties (free and infected countries) would have a stake and would also trust. As part of Global Framework for the progressive control of TADs (GF-TADs), the three international organizations involved with animal health [OIE or World Animal Health Organization; UN FAO and The World Health Organization (WHO)] propose to set up a Joint FAO–OIE–WHO Global Early Warning System for infectious animal diseases and zoonoses to be known as GLEWS (Ben Jebara, 2004; FAO-OIE, 2004). This system may well be the global 'honest broker' that is needed to underpin the global surveillance partnership/network.

Programme coordination

Lessons from both global and regional programmes emphasize the need for effective coordination that enjoys a high level of national commitment at both the political/policy and scientific/technical levels. Global risk management of FMD will require global coordination of strategies and global issues as well as regional and national coordination of programme implementation. It is important that livestock farmers can associate the rigours and demands of FMD control with an enhanced value of their livestock, through progressive access to markets for their livestock commodities, whether locally or internationally. So livestock farmer and trader associations should be involved in the planning and oversight of national programmes. Equally well at the regional level, regional organizations should have full ownership and control of the coordination of the implementation strategy. Applied research should be seen as an integral part of an effective regional programme for the progressive control of FMD. The proposed Global FMD Surveillance Network should be seen as strengthening this component.

A global programme of this nature will require multi-donor funding support and a global technical support. FAO and OIE have recently launched the GF-TADs (FAO-OIE, 2004). This may well provide a platform for defining appropriate global and regional coordination mechanisms. The two organizations are also setting up Regional Animal Health Centres in developing regions of the world which are costaffed by personnel from FAO, OIE and the relevant regional organization.

Disease control programmes, especially those relating to rapidly spreading TADs, require active, nimble, flexible management to be successful. The rapid responses to significant changes in disease behaviour requiring urgent action for epidemiological investigation, disease control activities and urgently commissioned surveillance and research are not favoured by a rigid, annual work plan approach. Many requirements cannot be predicted well in advance. Therefore, experience dictates that disease control projects should be viewed differently from other development related projects; they require dynamic management rather than straight forward accountancy. Experience has shown that donors sometimes do not employ project management practices which enable effective implementation of disease elimination programmes. The ability to build experience into planning and management and to react quickly to changing circumstances is, however, essential.

Role of trade

The control of FMD and other major TADs in both Asia and Africa will need to be linked to promoting the trade

in livestock commodities through formal channels. It is important to encourage such formal channels at all stages, i.e. local, regional and intercontinental trade in livestock commodities. This way, the livestock dependent communities in Asia and Africa will also increasingly have a stake in effective disease control. Furthermore, globalization of trade in livestock commodities is an inevitable consequence of the rapidly increasing demand for foods of animal origin. It is most desirable, therefore, that such trade be through formal channels, be safe and be inclusive of as many livestock-dependent communities as possible (FAO, 2005). Accordingly, the strategy outlined in the global framework may need to be linked to the following elements:

- 1 local livestock commodity marketing infrastructures;
- 2 support for low disease risk, health-assured, livestock commodity export zones;
- 3 commodity processing in the countries of production in such a way as to minimize the risk of such commodities transmitting infection and
- 4 the promotion of commodity-specific standards for all major livestock commodities, including processed ones (Thomson et al., 2004, 2006), which would require further applied research on risk mitigation.

Stimulating Regional FMD Progressive Control in Currently Infected Regions

Background

In their concept paper entitled: 'The Global Framework for the Progressive Control of TADs' (FAO-OIE, 2004), the OIE and the Food and Agriculture Organization of the United Nations (FAO) have advocated the progressive control of TADs at source in developing countries as a contribution to the International Public Good.

In their survey, FAO and OIE identified FMD as the principal animal disease of global concern in all the consultations carried out during preparation of the GF-TADs joint proposal. Thus the GF-TADs programme promoted by the two organizations proposes the effective prevention and progressive control of FMD and other major TADs as a contribution to the achievement of the UN Millennium Development Goals. To achieve this objective, it is suggested that focused efforts for the control of the major TADs must be at the source of infection – 'which is mainly in the developing countries'.

A Framework for the Progressive Regional Control of FMD

In July 1996, the Pan-American Health Organization (PAHO), OIE and the UN FAO convened in Brasilia, Brazil, an international conference at Ministerial Level

entitled: 'International Conference on the Perspectives of Eradication of Foot-and-Mouth Disease in the Next Millennium and its Impact on Food Security and Trade: Focus on the Americas'. This was intended to be one of a series of high-level conferences to champion the objective of global FMD control. Indeed the Brasilia Declaration (Anon, 1996) by the participating ministers called for, 'inter alia', the following actions:

- 1 a request to FAO, OIE and PAHO to develop technical orientations towards the progress of FMD global eradication as well as the prevention of other important animal diseases in the world and
- 2 a request to FAO to take to the attention of the World Food Summit, the negative impact that FMD, transboundary diseases and other-related problems have on food security and sustainable rural development.

At the scientific level, Donaldson and Kihm (1996) described the technological advances that favour the global control of FMD. Several authors have since described key factors in designing FMD control strategies, the international impact of FMD and the feasibility of a globally coordinated but regionally based programme for the progressive control of FMD, e.g. Donaldson (1999), Garland (1999), Doel (2003), Rweyemamu and Leforban (1999), Rweyemamu and Astudillo (2002), Garland (2004), Perry and Sones (2007). From the economics perspective, there is also credible evidence to support the concept that controlling FMD in developing countries is justifiable (James and Rushton, 2002; Perry et al., 2002b, 2003; Randolph et al., 2002; Paskin, 2003; Otte et al., 2004).

There is a wide variation in the epidemiological clusters of FMD in the different regions of the world (Rweyemamu et al., 2008). Therefore, we propose that an internationally funded programme for global FMD risk reduction, through progressive disease control, should be driven by the following:

- 1 global coordination and definition of principles;
- 2 regionally based and regionally coordinated programmes. Wherever feasible this could be at the geopolitical organizational level and
- 3 surveillance and control to be implemented through over-lapping epidemiological clusters.

The epidemiological clustering approach would allow for the kind of detailed attention that is necessary to define the FMD risk on the ground and to devise cost-effective as well as epidemiologically sound disease control strategies and interventions.

The most readily visible impact of FMD control is usually seen when disease control addresses the epidemic areas, especially where these would be potential areas of high productivity and even export zones. But such areas have to be maintained under high vigilance to prevent the incursion of infection from endemic areas within the

same country or region. So, from an international perspective, there is little change in the risk of FMD 'escape' from the region. Experience from GREP and FMD control in South America indicates that sustainable results in epidemic disease control are more likely to be obtained when the control strategy targets the primary endemic areas in addition to the visible epidemic areas. However, such a strategy has a long time scale and usually has to be coupled to other development incentives.

Thus, a risk management, regional FMD control strategy should be conceived as a long-term (i.e. 20 years or more) partnership programme rather than a traditional project of 5–7 years.

In areas where FMD is endemic, each country in a cluster could be required at the beginning to establish the following parameters before embarking on a coordinated vaccination campaign:

- 1 assess the socio-economic impact of FMD;
- 2 identify prevalent serotypes;
- 3 establish and maintain capacity for regular access to good laboratory diagnostic services;
- 4 define the distribution and epidemiology of FMD;
- 5 identify primary and secondary endemic areas;
- 6 designate presumed FMD areas;
- 7 record in-country and cross-border animal movement patterns and movement management strategies;
- 8 implement community awareness and communication strategies;
- 9 undertake a needs analysis and seek resources for a sustained period – 10 years or more – for the progressive control programme;
- 10 draw up an epidemiologically based and economically sound, long-term project for FMD progressive control and
- 11 develop national capacity in public and private sectors to implement a disease control policy that has the support of key stakeholders.

However, countries and clusters are likely to be at different stages of FMD status. Accordingly, it is hereby proposed that a multi-stage framework be developed that allows countries or clusters to enter the scheme at different stages depending on their properly established/validated FMD status.

The key stages could comprise the following:

Stage I : assess and define national FMD status;

Stage II : institute vaccination and movement control;

Stage III : suppress virus transmission to achieve absence of clinical disease;

Stage IV : achieve freedom from FMD with vaccination in accordance with the OIE standards;

Stage V : achieve freedom from FMD without vaccination in accordance with the OIE standards;

Stage VI : extend FMD free zones and

Stage VII : maintain FMD freedom.

Stages II–V might be approached either on a national or zonal basis. In many cases the first application of control measures would probably concentrate on areas identified in stage I as areas of sporadic incidence (also referred to as para-endemic), or those presumed to be free. This is attractive to gain immediate confidence in the programme and to demonstrate the benefits of disease control. However, it is important to start addressing primary endemic areas soon after to ensure the sustainability of the initial gains. The details of objectives, expected outputs and activities for each stage are given in Table 1.

A Pathway for the Global FMD Progressive Disease Control

The material presented below is summarized in Table 2.

'South America' is already catered for by a time-bound programme, the Hemispheric FMD Eradication Plan for the Americas. This Plan envisages eradication by 2009. While there seems to be some slippage in the timetable (Correa Melo et al., 2002), overall the plan is progressing well with concerted commitment by all the governments of the Americas. The Hemispheric Plan has identified areas of high-FMD risk. It is important that the plan also articulates a clear strategy for combating FMD in those high risk areas. For the 'Old World', it is recommended that by adopting the proposed framework, each epidemiological cluster could progress towards controlled FMD in livestock within the next 20–30 years. The detailed pathway for each region is outlined in Table 2.

The question is where to place priority from the perspective of risk of FMD introduction into the EU. The traditional focus in Europe on the risk in the immediate neighbourhood is inadequate to deal with the issues associated with globalization. Therefore, this paper proposes that while FMD control programmes either in the trading partner regions of South America and Southern Africa or in the neighbouring regions of the Middle East and Trans-Caucasian must be pursued with vigour. A sustainable FMD-risk reduction for the protection of Europe will need to address the targeted and progressive control of FMD in the high-risk primary endemic epidemiological clusters of Indo-China, South Asia, East Africa, Horn of Africa and the Soudan-Sahel (Rweyemamu et al., 2008; Sumption et al., 2008).

In 'Asia', special attention seems to be required for two major ecological zones, i.e. the South Asia cluster and the Indo-China cluster. We have demonstrated how viruses originating from South Asia have spread both westwards to the Near East along the so-called 'ruminant street' from India–Pakistan, through Afghanistan, Iran and Turkey towards Europe and eastwards towards South-East and Eastern Asia (Rweyemamu et al., 2008; Valarcher

Table 1. A Framework for the progressive regional control of FMD

Stage & immediate objective	Outputs	Activities
<i>Stage I:</i> assess and define national FMD status	Socio-economic importance of FMD	Assess national herd/flock and extent of FMD Socio-economic studies
	FMD prevalence defined in livestock and wildlife (where applicable)	Wildlife sampling
	Laboratory diagnostic capacity determined	Sample collection, typing, molecular and antigenic characterization by national/regional laboratory
	Primary and secondary endemic areas determined	Active direct visual and sero-surveillance of livestock; evaluation of previous passive surveillance reports
	Presumed FMD-free areas defined	Use of appropriate database and GIS software (e.g. TADInfo)
	Defined in-country and cross-border animal movement patterns and movement management strategies	Risk analysis studies Evaluation of maps and ground-truth activities like movement permits, market infrastructure and veterinary/livestock extension records Contact with the farmer groups and representatives
	Incentives for farmer cooperation determined, possibly based on controlling another disease (e.g. CBPP in Africa or HS in South Asia) and other pro-poor animal health initiatives	Work with media specialists Training schemes for para-veterinary and extension workers Specific training for community animal health workers
	Local livestock market infrastructure	Start developing local livestock market infrastructure
	Public awareness and communication strategies	Review previous budgets; negotiate with political leaders and donors
	Availability of resources for a sustained long period – 10 or more years	Financial, organizational, legislative capacity building
<i>Stage II:</i> vaccination and movement control	Pre-conditions to begin <i>stage II</i> in place: national capacity to carry out mass-vaccinations and movement control	
	Determine extent of fulfilment of previous objectives	Expert evaluation Stakeholder workshop Report to regional CVOs and regional programme coordination
	FMD control zones established	Action on un-fulfilled outputs and activities Implement livestock branding (or alternative marking), movement control at strategic points, begin use of movement permit system Set up surveillance, movement management and identification as a permanent feature Consult with experts and stakeholders
	Strategies for FMD control in primary and secondary endemic areas – i.e. vaccination, movement control or segregation	Implement formal clinical reporting systems with field staff and farmers; monitor cattle movements and prices Develop policy document with all role-players Consult with experts Determine source of quality assured vaccine Determine where to vaccinate – (aim for primary and secondary endemic areas) Determine which animal species to be vaccinated (epidemiology determinant) Train vaccinators
	Strategies for presumed free areas	Order vaccines, ensure delivery systems function, begin vaccinations Targeted vaccination of all cattle in the epidemiologically determined area
	Pre-conditions to begin stage II in place	Develop appropriate early warning and early reaction systems Define policy for preventing FMD spill over from wildlife (including code of conduct, licensing, fencing, risk analysis for livestock)
		Financial, organizational and legislative capacity building

Table 1. Continued

Stage & immediate objective	Outputs	Activities
<i>Stage III:</i> suppress virus transmission to achieve absence of clinical disease	Determine extent of fulfilment of previous objectives	Expert evaluation Stakeholder workshop Report to regional CVOs and regional programme coordination Action on unfulfilled outputs and activities
	Strengthened surveillance Mop-up vaccination and consider stamping out as an adjunct Develop and test contingency plans Review effectiveness of veterinary services	Explore the possibilities of either more field staff or greater use of farmers Vaccine targeted to areas of resurgence; secure political decision on compensation Plan, review and test with stakeholders Internal evaluation
<i>Stage IV:</i> freedom from FMD with vaccination	Pre-conditions to begin stage III in place	Financial, organizational and legislative capacity building
	Previously presumed free zones progressed to OIE to be recognized as FMD free with vaccination	Expert evaluation Conduct expert review of FMD status for each zones Stakeholder workshop Report to CVOs and regional programme coordination Action on unfulfilled outputs and activities
	Zonal freedom from FMD with vaccination	Conduct clinical and serological surveillance; field, epidemiology and laboratory teams in action; preparation and execution Review contingency plans – seek expert advice Review quarantine systems Assess effectiveness of national veterinary services – seek independent advice Apply to the OIE for the status of FMD freedom with vaccination
<i>Stage V:</i> freedom without vaccination	Preconditions to begin Stage V in place: As in <i>stage IV</i> but in addition, access to emergency vaccine reserves and national contingency plans backed by required resources	Financial, organizational, and legislative capacity building
	National FMD status reviewed	Expert evaluation Conduct expert review of FMD status for each zone Stakeholder workshop Report to regional CVOs and regional programme coordination
<i>Stage VI:</i> expand FMD free zones	OIE recognized FMD freedom without vaccination	Cessation of vaccination for 2 years Conduct clinical and serological surveillance Demonstrate detailed evidence for absence of FMD infection in susceptible populations, including buffalo through detailed epidemiological and laboratory analyses of survey results and previous records – as defined by the International Animal Health Code Review and test contingency plans Allow for stamping out as the primary method of response Review quarantine systems Assess status of effectiveness of national veterinary services Consultation with stakeholders & political leaders Apply to the OIE for freedom without vaccination
	As in <i>stage V</i> above	As in <i>stage V</i> above
<i>Stage VII:</i> prevention of FMD re-introduction	FMD freedom status maintained	Pay attention to surveillance, contingency planning, border controls and animal movement management

Based on Musisi, F. L. (ed.) (2003): Report of the Regional Workshop of National CVOs on FMD and Other Transboundary Animal Diseases in Southern Africa, FAO Project TCP/RAF/2809, Pretoria 21–22 July.

Table 2. Framework for global FMD risk reduction through progressive disease control at source. A pathway guide for infected regions

Epidemiological cluster	Stage I Year 1–4	Stage II Year 3–8	Stage III Year 5–12	Stage IV Year 10–16	Stage V Year 14–20	Stage VI Year 18–24	Stage VII Year 22–28
Africa							
African island countries of Mauritius, Madagascar, Seychelles and Comoros							XXXXX
Other African island countries				XXXXX	XXXXX	XXXXX	XXXXX
North Africa/Maghreb				XXXXX	XXXXX	XXXXX	XXXXX
Southern SADC						XXXXX	XXXXX
Northern SADC			XXXXX	XXXXX	XXXXX	XXXXX	XXXXX
Angola	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX
East African community	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX
Horn of Africa	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX
Soudan/Sahel	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX
Coastal West – Central Africa		XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX
Asia							
East Asian islands							XXXXX
Indonesia & Oceania							XXXXX
Philippine Archipelago						XXXXX	XXXXX
Malay-Thai			XXXXX	XXXXX	XXXXX	XXXXX	XXXXX
Mekong Delta/Indo-China	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX
China			XXXXX	XXXXX	XXXXX	XXXXX	XXXXX
South Asia	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX
Central Asia			XXXXX	XXXXX	XXXXX	XXXXX	XXXXX
Gulf Cooperation Council (GCC) countries plus Yemen		XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX
Europe							
Europe Core (i.e. The EU and contiguous countries of Eastern Europe)							XXXXX
Balkan States							
Russian Federation				XXXXX	XXXXX	XXXXX	XXXXX
Trans-Caucasia				XXXXX	XXXXX	XXXXX	XXXXX
Turkey – Iran			XXXXX	XXXXX	XXXXX	XXXXX	XXXXX
Asia Minor		XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX
North Africa-Maghreb				XXXXX	XXXXX	XXXXX	XXXXX

et al., 2008). The Indo-China cluster is significant in two respects: it amplifies the risk of viruses spreading from South Asia and it is also an important source of internally generated strains which spread southwards along the Mekong Delta and north-eastward through China.

As the economies of 'Africa' grow there is likely to be an increasing trade related movement of livestock commodities both within and out of Africa. The future likely scenario in Africa is that the endemic areas in Tropical Africa could on one hand threaten the FMD-controlled areas of the Southern African Development Community (SADC) countries, the Africa Island Countries and North Africa while on the other it will threaten the Middle East and thence Europe.

Lessons Learnt From Previous Disease Control Programmes

A new global initiative for the progressive control of FMD should take into account the lessons from previous

international initiatives. Here three programmes are most pertinent, namely: the GREP, the work of the EUFMD and the Hemispheric Plan for the Eradication of FMD from the Americas (PHEFA).

Lessons from the Global Rinderpest Eradication Programme

The GREP was recommended by an expert consultation organized by the UN FAO in 1992 as a time-bound programme with the objective of verifiable global freedom from rinderpest by 2010 (FAO, 1992). The programme has been coordinated at the global level by FAO since 1994. This builds on the activities of major regional and national programmes, such as the All India National Rinderpest Eradication Programme and the Pan-African Rinderpest Eradication Campaign and its successor the Pan-African Programme for the Control of Epizootics (PACE) programme. GREP has been successful in that over a 20-year period the incidence of rinderpest has been

reduced from extending through wide areas of South Asia, the Middle East and sub-Saharan Africa to a point where there might be no more than one residual focus of suspected rinderpest persistence, the so-called Somali ecosystem of eastern Africa. Even there confidence grows that the virus may have been eliminated as the virus has not been detected since 2001. The evolution of GREP has been reviewed by several authors including FAO (1996a,b, 2000), Roeder et al. (2005), Rweyemamu et al. (2005), Taylor et al. (2005).

There are major differences between rinderpest and FMD. Rinderpest has a single, stable causative agent while FMD has seven serotypes and many constituent strains which can continually evolve. Rinderpest is almost always fatal (except for that due to mild strains) while, with the important exception of immature livestock, FMD is not usually fatal in adult animals. Nevertheless, the experience with rinderpest is more relevant to FMD than might be perceived from an European perspective because in tropical environments with high temperatures and insolation (high levels of sunlight), FMD virus behaves very similarly to rinderpest virus, especially so in dry environments. The rapid spread of infection by aerosol over long distances is not a feature of FMD transmission in most tropical environments; FMD outbreaks tend to spread relatively slowly, mediated primarily by the movement of live animals and, where swine are involved, via infected meat. Many other similarities in strategy setting and technical and logistical requirements for programme management are evident. In fact, the lessons learnt from the GREP experience could be considered to constitute a paradigm for progressive TAD control on a national and/or regional basis.

While at the strategy level rinderpest and FMD control are similar, there are differences at the logistic and operational levels. For example, rinderpest vaccination all over the world uses a live-attenuated vaccine which is derived from a single and well-standardized strain. Recently, this vaccine has been rendered thermo-tolerant (Mariner et al., 1990, 1991; House and Mariner, 1996). Ideally, a single injection is capable of conferring a lifelong immunity. By contrast FMD vaccines are inactivated and the vaccine dose is relatively large so that large quantities are bulky for storage and transport; they are relatively thermo-labile (requiring an uninterrupted cold chain); the vaccine must contain serotype(s) and strain(s) of antigen appropriate to the local epidemiology; they may require double primary vaccination (especially in the aqueous rather than the oil adjuvanted formulation) and they confer an immunity for only 6–12 months (Garland, 1999; Doel, 2003).

A major lesson from GREP is that a regional or global initiative for the progressive control of a TAD, like FMD,

should be time-bound to maintain focus and commitment. Moreover the programme should be underpinned by a WRL networking regional and major national laboratories that are dedicated to the programme, including diagnostics, surveillance and independent quality assurance of vaccines used in the control programme.

Other key lessons from GREP can be summarized as follows:

- 1 as a killing disease, rinderpest was greatly feared by farmers and hence they readily cooperated in control, at least while the memory of the disease was still fresh in their minds;
- 2 eradication is favoured by availability of safe, efficacious and affordable vaccines – in the case of rinderpest lifelong immunity is achieved;
- 3 independent vaccine quality assurance is essential to ensure that standards are met;
- 4 externally quality-assured diagnostics provide confidence and differentiating infected from vaccinated animals tests which can discriminate between vaccines and field-infected animals would greatly enhance surveillance progress is favoured by a sound understanding of epidemiology of the disease – molecular epidemiology is very valuable;
- 5 progress is favoured by a sound understanding of epidemiology of the disease – molecular epidemiology proved very valuable;
- 6 being able to access the services of a WRL with a loose network of national and regional laboratories is a valuable asset as it facilitates rapid confirmation of unexpected disease outbreaks, diagnostic test development, technology transfer to needful countries and epidemiological studies including molecular epidemiology with access to archived virus strains;
- 7 a time-bound programme with a dedicated secretariat provides for setting guidelines and milestones via an 'eradication blueprint';
- 8 community-based animal health programmes are vital to success in remote areas devoid of conventional veterinary service delivery;
- 9 participatory epidemiology has provided valuable surveillance tools for rinderpest detection and freedom accreditation and in fact gives broadly based disease intelligence and
- 10 consistent support is needed from key political and economic authorities; without this complacency sets in and the eradication process can falter.

The processes of control and eradication can be viewed in phases, but they are artificially compartmentalized and will vary with different diseases. In fact they join seamlessly. What is described here is an ideal situation; success has been achieved at far lower levels of sophistication. An arbitrary phasing is used here to indicate the processes

involved. Control strategies need to be subject to adaptive management and constantly 'fine-tuned'. Once mass vaccination has reduced disease incidence to a manageable level, the emphasis should be switched to identifying primary endemic areas, sustained virus transmission networks and high-risk areas; vaccination can then be focused on eliminating the reservoirs of infection.

Lessons from the European Experience of Coordinated FMD Control

The EUFMD was set up as a semi-autonomous body under the umbrella of FAO in 1954 to coordinate actions for the progressive control of FMD in Europe and the prevention of FMD incursions into free areas of Europe. From the outset the EUFMD recognized the value of underpinning disease control/management strategies with research and scientific services. They set up the Research Group, a network of FMD laboratories in Europe and in 1957 persuaded FAO to recognize Pirbright in the UK as the WRL for FMD.

The EUFMD is primarily a forum to foster cooperation between member countries and to coordinate their efforts to prevent and control FMD. It also provides scientific and technical expertise, epidemiological information and advice to member countries. The EUFMD also operates through a special arrangement a tripartite system comprising FAO, OIE, European Commission (EC) and member countries of South-East Europe which are most threatened FMD.

Each of the 33 member countries of the EUFMD is represented, in General Session, by a delegate, usually the chief veterinary officer (CVO) or another high-ranking veterinary official. It has an Executive Committee elected from its members, which meets at least once a year. The scientific work of the Commission is underpinned by its Research Group.

When the EUFMD was established, FMD was endemic in many parts of Europe. Between 1955 and 1965 Europe was recording 100 000 outbreaks a year. By 1990 outbreaks had ceased and so Europe moved to adopt the no-vaccination policy.

The key lessons from the European experience can be summarized as follows:

- 1 a dedicated commission for FMD control (EUFMD) and a permanent Secretariat within the international UN setting;
- 2 national commitment and accountability to the regional control policies;
- 3 secure long-term funding, through the EC, to support tripartite disease control and/or surveillance activities in high-risk areas;
- 4 a dedicated FMD Research Network;

- 5 close partnership between FAO, OIE and EC (i.e. regional organization);
- 6 coordination at scientific, technical and policy levels; and
- 7 consistent support from political and economic authorities.

Although initially focused primarily on Europe, the Commission has progressively increased its involvement in contributing to the control of FMD in endemic areas, particularly those at the periphery of Europe in the Balkans, the Middle East, the Transcaucuses and the North African littoral. Moreover in this context, the recent European Food Safety Agency review of the risk of the introduction of FMD into Europe and of approaches to the reduction of those risks provides a useful overview of the European perspective (EFSA, 2006).

Lessons from the South America control programme

The Organization of American States established the Pan-American FMD Centre (PANAFOSA) in 1951 to develop the coordinated diagnosis and control of FMD in South America. The first nationally coordinated FMD control projects started in the 1960s. The South American Commission for the Control of FMD (COSALFA) was established in 1972 to coordinate inter-governmental strategies. In 1987 the governments of the Americas set up the PHEFA. This started with a project for the eradication of FMD in the Rio de la Plata Basin (i.e. Argentina, Uruguay and Southern Brazil). The plan obtained full political backing in 1996 with the signing of the Brasilia Declaration by the Ministers of Agriculture of the Americas (Anon, 1996).

The FMD goal of the Plan is the elimination of FMD from South America by the year 2009, through a zoning approach consisting of six subregions:

- 1 three FMD-free regions, i.e. North America, Central America and Caribbean and
- 2 three control regions, i.e. the Southern Cone-River Plate Basin, the Andean Area and the Amazon Area plus northern Brazil.

The operating objective of PHEFA is 2-fold: elimination of disease in endemic areas and the prevention and protection of free areas. The approach has been through the definition of ecosystems, originally described by PANAFOSA scientists (Astudillo et al., 1986), which identifies primary endemic areas, secondary endemic areas and para-endemic areas, where disease is sporadic, and FMD-free areas.

Continental coordination of the Plan is through COSALFA with PANAFOSA as the ex-officio Secretariat. COSALFA meets once a year in full session. On a biennial basis, PHEFA is debated during the meetings of the Hemispheric Commission for the Eradication of FMD

(COHEFA) at the policy-political level, under the PAHO Ministerial Conference on Health and Agriculture (RIMSAs). The private sector in South America plays an active role both in the planning and monitoring of the national and regional FMD control programs.

Correa Melo et al. (2002) observed that since the signing in 1987 of PHEFA by the countries of South America, clinical cases of FMD decreased significantly throughout the continent. During the early 1990s, national laboratories diagnosed an average of 766 cases per year in South America and by late 1990s, the figure had dropped to 130. By the end of the 1990s, the international community recognized Argentina, Chile, Guyana and Uruguay as free of FMD without vaccination.

However, in the spring of 2001, FMD that re-appeared in certain countries of the Southern Cone had had been freed of FMD and which had ceased to vaccinate, namely in Argentina, Uruguay and the State of Rio Grande do Sul in Brazil. More limited outbreaks have also been detected in Paraguay and parts of Brazil during 2005. This called into question the basic premise of the PHEFA – that countries in South America can achieve and maintain FMD-free status, with or without vaccination. Some of the contributing factors to this reversal, which have since been addressed, included:

- 1 inadequate concomitant attention to targeted FMD control in the known primary endemic areas, such as the Trinidad State in Bolivia and, in Brazil, Matto Grosso and Matto Grosso do Sul;
- 2 inadequate preparedness and contingency planning;
- 3 inadequate regulation of animal movement and
- 4 a greater attention to national activities than to ecosystem based, trans-national coordination.

COSALFA has tightened up PHEFA and revised the regional strategies including reconfiguring the zoning (Saraiva, 2004). The currently OIE recognized FMD-free countries and zones in South America are listed in the OIE website: http://www.oie.int/eng/info/en_fmd.htm?e1d6.

The key lessons from the South American experience can be summarized as follows:

- 1 installation of a consistent, regionally funded reference laboratory (PANAFTOSA), as an instrument for training and harmonization of methods for diagnosis and vaccine quality control;
- 2 a dedicated commission for FMD control (COSALFA) and a permanent Secretariat in an international UN context;
- 3 time-bound programme since 1987 i.e. eradication by 2009;
- 4 *in situ* studies to define epidemiology and relevant economic analyses;
- 5 active participation of the farming and livestock trading communities and/or organizations;

- 6 long-term national and regional financial support;
- 7 regional and subregional coordination at technical and policy levels and
- 8 consistent support from political and economic authorities.

Discussion

The strategy for the progressive control of FMD advocated in this paper is based on two basic precepts. First, that controlled FMD is in the interest of both those parts of the world where it is still endemic and those that have been freed from FMD. It will thus facilitate safe international trade in livestock commodities. Second, that while import restrictions, border control and inspections reduce the risk of FMD introduction into free areas, they do not reduce that risk to negligible proportions. Therefore, it has been proposed that controlling FMD at source also protects the free areas, thus benefiting both endemic and free countries and regions.

Two related problem areas may be perceived with respect to FMD. On the one hand there is the impact of periodic introductions into developed regions of the world, such as the Europe Union, wreaking havoc not only to farming systems but also to all aspects of the lives of rural communities and the wider economy (e.g. including tourism). On the other hand there is the constant attrition of agricultural production in farming communities extending across Asia, the Middle East, Africa and parts of South America, hampered by the frequent incidence of FMD epidemics. So, international support for the global control of FMD is likely to contend with two issues, namely ‘homeland’¹ protection versus development goals. These are generally addressed by very differently focused agencies within OECD countries and regional organizations such as the EU. Moreover it should be noted that the strategy for the management of FMD in the two systems is different. The disease control strategy for ‘homeland’ protection is based on the concept of early emergency response, which involves putting into action a pre-rehearsed contingency plan and managing resources and all operations to eliminate infection as rapidly as possible and return to the ‘normal’ status of disease freedom. The European Council Directive 2003/85/EC is a policy document which is based on this principle. Following the 2000–2001 FMD outbreaks in Europe, Asia, Africa and South America several publications have described either the response system adopted or strategies which could improve such responses, e.g. Baipoledi et al. (2004), Bates et al. (2003), Breeze (2004), Laddomada (2003), Rivas

¹Homeland is used in this context to refer Europe and other OECD countries

et al. (2003a,b), Rivas et al. (2004, 2003b), Wee et al. (2004), Woolhouse and Donaldson (2001).

By contrast progressive control of FMD in areas where it is endemic is a protracted process which takes many years. Yet, as FAO and OIE have argued (FAO-OIE, 2004), it is the progressive control of FMD in areas where it is still endemic that will provide long-term and sustained protection of developed countries from the ravages of FMD. So, everything is to be gained by linking the two objectives, for it is primarily by reducing the global weight of infection that the developed world can achieve a sustainable reduction of its own risk. In this context, one challenge is clearly to link FMD (and some other key TADs) to the Millennium Development Goals that both developed and developing countries ascribe to. Thus, the strategy for the progressive control of FMD that is advocated in this paper should be seen as part of the international development agenda. This agenda could highlight the following to encourage an inclusive livestock-based development:

- 1 endorsing the concept that livestock can be a major factor in the pathway out of poverty and food insecurity;
- 2 encouraging livestock as a tradable commodity in the formal markets (local, regional or international);
- 3 encouraging export of livestock commodities from low disease risk, health-assured zones with appropriate safeguards and with risk mitigation measures in place and
- 4 encouraging in-country processing of livestock commodities and reducing long-distance export of live animals.

The above measures could create a favourable climate for establishing effective veterinary services and FMD control programmes. Such a strategy could shift the paradigm from one of a supply-driven objective (i.e. driven by a simple requirement of good surveillance systems and national veterinary services *per se*) to a demand-driven objective by creating development/investment conditions which require for their implementation the existence of effective veterinary services and surveillance systems. Moreover the process of progressively making livestock a commodity that is traded through formal markets at all levels (local, regional and international) could stimulate the livestock communities, even in regions which do not export to Europe, to have an intrinsic interest and stake in the control of FMD and other major diseases, as such diseases would be readily regarded by these communities as adversely affecting their own livelihoods.

Finally, the progressive control of FMD should also be seen as part of reducing the overall, world-wide threat of many infectious diseases as identified in the Foresight study at the global level by Brownlie et al. (2006) and more specifically for Africa by Rweyemamu et al. (2006).

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