Transboundary and Emerging Diseases

ORIGINAL ARTICLE

Foot-and-Mouth Disease Control and Eradication in the Bicol Surveillance Buffer Zone of the Philippines

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Summary

Following the onset of an epidemic of foot and mouth disease (FMD) commencing in 1994 and affecting mainly pigs in the Philippines, a National Plan for the Control and Eradication of the disease was initiated. A disease surveillance buffer zone in the southern Luzon region of Bicol was established to protect the Visayas and Mindanao from infection and enable eventual elimination of the disease in Luzon. With achievement of Office International Epizooties (OIE)-certified FMD freedom with vaccination in the Philippines now imminent, the four components of the disease control strategy are reviewed, including quarantine and animal movement controls, strategic vaccination, surveillance and disease investigation, and enhanced public awareness with school on the air radio programmes. Although numbers of outbreaks declined following widespread vaccination, evaluation of serological responses in vaccinates suggested low levels of immune protection. The cessation of outbreaks was considered more likely a result of animal movement controls, improved surveillance and emergency response capability, and reduction in FMD-risk behaviours by livestock owners, particularly through efforts to enhance public awareness of biosecurity measures by the training of traders, livestock industry personnel and both commercial and smallholder farmers. A two-stage random sampling serosurveillance strategy enabled identification of residual infection that was not detected through opportunistic sampling and negative incident reporting. Intensive investigations of FMD outbreaks, particularly in Albay province in 1999, enabled improved understanding of the risk factors involved in disease transmission and implementation of appropriate interventions. The findings from this review are offered to assist development of FMD control and eradication programmes in other countries in south-east Asia that are now being encouraged to support the OIE goal of FMD freedom with vaccination by 2020.

Introduction

Foot and mouth disease (FMD) is the most important transboundary disease of ungulates. As the single most important disease constraint to international trade in animal products, control of FMD is relevant both to the protection of the livestock industries of developed countries, and to the livelihoods of livestock owners in developing countries, where, as a general rule, FMD continues to be endemic (Rweyemamu et al., 2008) and losses can

be substantial (Rast et al., 2010). With control and eradication of FMD from most of Europe and parts of South America well advanced, the focus for control and eradication has shifted to south-east Asia (Dunn and Donaldson, 1999). The domestic pig predominates throughout much of south-east Asia and strains of FMD highly adapted to pigs have been reported from Taiwan, China, Vietnam and the Philippines (Donaldson, 1999).

The first recorded FMD epidemic in the Philippines in 1908 was associated with infected animals imported to Manila from Hong Kong. This outbreak lasted for 2 years, spreading to 25 provinces (BAI, 2008). Following this epidemic, periodic outbreaks reportedly occurred in the country at 8–10-year intervals, with minimal endemic disease in between until 1994 when the current epidemic emerged and was reported from numerous provinces (BAI, 2008). This epidemic has principally affected pigs, with the first detection of a porcinophilic strain of FMD type O virus (Cathay topotype) in Rizal Province in central Luzon in September 1994, spreading to the southern Bicol region of Luzon where it was detected in March 1995. The outbreak had major impacts on the swine industry of the Philippines, with production losses and lost export opportunities resulting in an overall claimed loss of US$50 million (BAI, unpublished data).

Reports of this rapidly spreading epidemic resulted in the implementation of National Plan for the Control and Eradication (NPCE) of FMD in 1996 by the Government of the Philippines (GOP), with funding support from the Australian Agency for International Development (AusAID) and administered by the Food and Agriculture Organisation of the United Nations (FAO) (BAI, 1996). The plan proposed three phases leading to the eventual eradication of FMD in the Philippines. The first phase of the NPCE (1996–1998) established a disease control buffer zone in Bicol to prevent the southern spread of the disease from Luzon to the two southern regional island groupings of the Visayas and Mindanao. The strategy of establishing a Bicol surveillance buffer zone would lead to increasing political pressure for control of the disease in the endemically infected are of central Luzon. The second phase of the plan involved implementation of procedures enabling an application for FMD freedom for the Visayas and Mindanao and possibly Bicol. The third phase aimed to implement procedures enabling an application for the remainder of Philippines to be declared as free of FMD.

In May 2001, the island of Mindanao received the status of FMD free without vaccination in accordance with Office International Epizooties (OIE) established standards, followed shortly by the island groups of Visayas, Palawan and Masbate in May 2002 (Morales, 2008). The last reported outbreak of FMD in the Philippines occurred in December 2005 in Lukban, Quezon province (Morales, 2009a) in central Luzon. The eventual success of the NPCE program was primarily driven by the incentive of export marketing opportunities resulting from international recognition of FMD freedom (Morales, 2009a). In November 2009, the BAI submitted documentation to support a status of 'FMD free without vaccination' in northern and southern Luzon, and FMD free with vaccination' in central Luzon (Morales, 2009b). Achieving these statuses would classify the Philippines as an 'FMD-free country where vaccination is practiced' under the guidelines provided by Article 8.5.3 of the 2009 OIE Terrestrial Animal Health Code (OIE, 2010). Following an economic analysis of FMD control and eradication in the Philippines suggesting that large-scale commercial producers will benefit most from increased export opportunities through FMD eradication, the government has actively sought the assistance of the private sector to help finance control and eradication programmes (Randolph et al., 2002).

This study describes the implementation of the Bicol surveillance buffer zone that occurred during the first and second phases of the NPCE between 1995 and 1999, and reviews the four main components of the disease control strategy: quarantine, vaccination, surveillance and public awareness. In addition, investigations of a series of outbreaks of FMD commencing in March to July 1999 in the province of Albay in Bicol are described as they improved the understanding of the epidemiology of FMD transmission in Bicol.

With the declaration of freedom from FMD in the Philippines now imminent (Alcala, 2011), this historical record of a successful strategic approach that led to the control and eventual zonal eradication of FMD in a country in south-east Asia is provided. It is proposed that lessons learned in the Philippines program may be 'transportable' and inform the strategic design of FMD control and eradication programmes in other countries in the region (OIE, 2007) that are at risk of or affected by this most important of transboundary diseases.

Materials and Methods

Establishing the bicol surveillance buffer zone

The core components of the Bicol buffer surveillance zone within the NPCE of FMD in the Philippines are reviewed. This information was obtained from records of activities conducted in the period 1997 through 1999, when two of the Australian authors sequentially undertook placements in the Bicol as Field Veterinary Officers employed by FAO (Freeman and Windsor) in close collaboration with colleagues in the Bureau of Animal Industries (BAI) in Bicol and Manila plus provincial and district authorities.

The Bicol region was considered an important strategic component of the NPCE because of the relatively limited

establishment of FMD in southern Luzon (L Gleeson, personal communication) and its strategic geographic position, being a narrow peninsula at the southern end of the island of Luzon (Fig. 1). Bicol comprises the four most southern mainland provinces of Luzon, being Camarines Norte, Camarines Sur, Albay and Sorsogon, plus the island provinces of Catanduanes to the east and Masbate to the west (Fig. 2). The strategies employed in the Bicol plan included programmes to improve quarantine and animal movement controls, implement strategic vaccination, enhance disease surveillance and outbreak investigations, and institute public awareness to enable improved biosecurity. Within these core components, enhancement of the disease information management systems (IMS) and training in emergency preparedness were conducted in preparation for potential applications for disease freedom for the region.

Fig. 2. Map of northern Philippines with the Bicol surveillance zone in 1999 circled in orange.

Quarantine and animal movement controls

Identification of livestock movement patterns was critical to the success of animal movement controls. An initial priority was to strengthen quarantine and animal movement controls at sea ports, protecting islands in proximity and to the south of Luzon. Deployment and training of staff at quarantine checkpoints at Matnog and Bulan ports in Sorsogon province was implemented, with subsequent extension of this service to other ports in Sorsogon. These included Pilar with considerable sea traffic to Masbate, and Gubat, where illegal movements of animals and their products to Samar in the Visayas were detected. To enhance public responsibility for biosecurity, FMD program signage was introduced at sea-ports (e.g. Pasacao, Legaspi City, Tabaco, Sagnay, Virac and Masbate) and airports (e.g. Naga City, Legaspi City, Virac and Masbate). In addition, footbaths were introduced at airports (e.g. Naga and Legaspi City) and a vehicular wheel bath was constructed at Matnog port. As control of the disease was achieved in Bicol, and threat of it's re-introduction from central Luzon identified, a checkpoint was implemented in September 1998 at Malicboy, in central Quezon Province directly to the north of Bicol. At this checkpoint, all movements of vehicles carrying livestock were recorded and disinfection of vehicles implemented on their return from the potentially infected areas in the north. Despite the majority of livestock movement being northwards from Bicol, reports in Catanduanes that animals had been sourced to this island through Malicboy port (from central Luzon where FMD was still active), indicated this initiative was necessary. Livestock from Masbate island and Marinduque in the Visayas traditionally moved to central Luzon through the port of Lucena City in southern Luzon, so training of staff at the ports quarantine facility was instituted as an additional precaution. Of concern was the risk that travellers from central Luzon returning south by boat would bring infected meat products on the journey, so public awareness was strengthened and inspection capability enhanced to minimize that risk.

Fig. 1. Map of the Philippines displaying the zoning for foot and mouth disease in 1998 with the southern Luzon surveillance zone including Bicol, shown in yellow.

In addition, sites where FMD had been detected or suspected were quarantined under national legislation and stock or meat products destroyed on compensation and disposed of in a safe manner.

Strategic vaccination

Vaccination programmes conducted in five of the six provinces in Bicol were reviewed. No vaccination was undertaken in Masbate province, as no FMD cases were detected on this island during the outbreak on Luzon. Ring vaccination was initially carried out around the known infected sites and strategic vaccination around high-risk areas, including slaughter houses, saleyards, ports and alongside major through roads. Areas to be vaccinated were prioritized on the basis of the history of FMD outbreaks, presence of high-risk areas such as public markets, slaughterhouses or ports, livestock movement patterns and municipal livestock census data to estimate the susceptible population and ensure effective resource allocation.

The Bicol vaccination programme conducted from late 1997 to mid 1998 targeted the highest risk provinces of Camarines Sur and Albay but included selected high-risk areas in Catanduanes, Sorsogon and Camarines Norte. The aim of the vaccination programme was to halt all FMD outbreaks by providing a protected livestock population in the shortest possible time period. Because of uncertainty that all FMD outbreaks were attributable to serotype O, a trivalent vaccine (containing O, A and C antigens) was used according to manufacturer's guidelines. Evaluation of the serological status of the vaccinated livestock in randomly selected communities (defined as the smallest administrative unit or 'barangay') was used to measure the effectiveness of the vaccination programme. With the cessation of disease reports, the vaccination programme in Bicol was terminated in July 1998 and future vaccination programmes were moved to the endemically affected provinces to the north of Bicol.

Surveillance and outbreak investigation

Investigations of the Albay outbreaks in 1999

To provide an example of the complexities involved in disease investigations and an insight into the epidemiology of the disease, a study of a series of seven outbreaks of FMD that occurred in Albay province between May and July 1999 is described. The study aimed to identify why cycling of the disease in semi-rural and urban squatter communities occured. Investigations included viral (demonstration of viral antigen in vesicular fluid or tissue) and serological studies of recovered and in-contact animals in affected barangays and unaffected neighbouring barangays, plus questionnaire surveys of owners of infected premises and their neighbours. Husbandry practices including sources of purchased animals and meat, animal feeding practices (particularly the feeding of uncooked swill containing meat) and disposal of animals and food scraps were recorded.

Table 1. Reported outbreaks of foot and mouth disease in the Bicol region in 1995 through 1999, by province and year

Year: Province	1995[a]	1996	1997	1998	1999
Camarines Sur	47	43	48	8	0
Catanduanes	6	1	1	0	0
Camarines Norte	0	1	1	0	0
Albay	0	8	9	2	7[b]
Total	53	53	59	10	7[b]

[a]Under-reporting suspected.

[b]Includes an unconfirmed case in Albay (Daraga) in June 1999, diagnosed clinically.

Enhanced reporting

Several surveillance strategies were implemented to address concerns that there may be failures in reporting of outbreaks as reputedly occurred in 1995 (Table 1), and that widespread undetected endemic infection may be present. Animal health technicians, regularly visiting barangays in performance of their municipal duties, were requested to examine the health of pigs and to document the absence of clinical FMD in these barangays in a system of 'FMD Negative Reporting', submitting monthly reports that confirmed the absence of FMD. In addition, pigs with symptoms of disease that could be excluded by clinical examination as infected with FMD were documented as 'FMD Negative Incident Reports'. This data was computerized in the FMD-information management system (IMS).

Outbreaks of FMD in July 1998 in Quezon Province to the north of Bicol, in and around Lucena City, were traced to endemic infection in the city's slaughterhouse and provoked attention on improving slaughterhouse procedures. Enhancements to sanitation, record-keeping, security, ante-mortem inspection, post-mortem monitoring, disinfection and implementation of an 'all-in, all-out' policy whereby pigs spend less than 24 h in the slaughterhouse to reduce infection rates within the slaughterhouse holding pens were instituted for all slaughterhouses in Bicol and in Quezon province.

Opportunistic serosurveillance programme

Enhancements to surveillance included two separate serosurveys to determine the serological status of the Bicol livestock population. The first serosurvey involved opportunistic sampling conducted mostly in slaughterhouses,

commencing in mid 1998 and ongoing through 1999. These samples were tested by liquid phase blocking enzyme-linked immunosorbent assay (LPB-ELISA) and were intended to provide a system of early warning of undetected infection and provide confidence that disease-reporting mechanisms were working. The initial focus was on Masbate Island, as this was more isolated from Luzon and an area where FMD had not been reported. A total of 449 sera were collected from Masbate between July and November 1998, and a further 1105 sera were collected, mostly from slaughterhouses, in the remaining five Bicol provinces between September 1998 and October 1999.

Structured serosurveillance programme

A structured serosurvey was conducted between March and September 1999, as a prelude to a possible claim for declaration of zonal freedom for the southern Philippines. The aim of the survey was to provide evidence that FMD was no longer endemic in Bicol and confirm opinion that unreported clinical FMD was an uncommon event in that region, as suggested by the evidence of the absence of FMD that was accumulating within the FMD-IMS from the 'negative reporting' and 'negative incident reports'. The FMD-IMS also recorded descriptions of management of affected barangays and infected animals, methods of diagnosis, sources of infection (e.g. swill feeding), estimates of duration of infection in affected herds, investigations undertaken to determine whether spread had occurred, and actions taken to prevent spread and serosurveillance of target risk areas including Bicol slaughterhouses.

Survey design: As specific criteria for investigating the FMD status of zones had not been developed in 1999, there was a need for agreement on the methodology for the most appropriate means of conducting investigations to substantiate zonal FMD freedom. A model design for a serological survey based on two-stage randomized sampling had recently been developed and published (Cameron and Baldock, 1998a,b).and was adapted for testing in Bicol in 1999. Sera were tested for antibodies to FMD serotypes O, A and C using the LPB-ELISA, and selected LPB-ELISA positive samples were tested by virus neutralization test (VNT). Sample sizes for each sampling stage were determined using the FreeCalc software program.

Assumptions to calculate sample sizes: Based on the considerable field evidence that the current epidemic of FMD was principally a disease of pigs and the known variation in species susceptibility to different FMD strains (Kitching, 1998), it was considered appropriate to treat pigs as the principal target population of 'at-risk' animals. Ruminant species including cattle, carabao and goats were treated as a separate population at a significantly lesser risk of developing FMD during the current FMD outbreak in the Philippines. The populations of animals were considered to exist at three levels: the farm, barangay and regional level. However, to simplify concerns of clustering, it was assumed that the population at the barangay level was homogenous, with a higher risk of FMD transmission among animals within a barangay if infected, than spread between barangays. For pigs, the minimum expected prevalence within barangays if infected was assumed to be 20%. Similarly, the minimum expected proportion of affected barangays was assumed to be 10%, if FMD was endemic and uncontrolled in the Bicol region. These prevalence assumptions were based on epidemic theory and previous field observations and imply that FMD virus, if it were present and at equilibrium, is highly infectious in the pig population and would spread easily from barangay to barangay. The Type I and II error probabilities for the survey of the pig population were both set at 0.05. With evidence of the minimal role of ruminant species in the current FMD outbreak, the level of proof of freedom required was assumed to be significantly less, and Herd Type I and Type II error probabilities were each set at 0.2.

Simple random sampling was used at both stages to choose barangays in the first stage and then animals within the selected barangays in the second stage. As false-positive results to the LPB-ELISA were expected with imperfect specificity, as many of the animals as possible with positive LPB-ELISA results at initial testing were re-sampled and re-tested with the same test and the VNT. Further assumptions required in determining appropriate sample sizes using FreeCalc are shown in Table 2.

Numbers of barangays and animals to be sampled: Based on the assumptions in Table 2 for pigs, random samples of a minimum of 21 pigs from each of a random sample of 59 barangays in the Bicol region were required. A total

Table 2. Assumed values for pigs and ruminants used in calculating sampling size

Parameter	Value for pigs	Value for ruminants
No. of barangays in Bicol	3390	3390
No. of animals per barangay	200	300
Herd Se (%)	95	95
Herd Sp (%)	99	99
Herd Type I error	0.05	0.2
Herd Type II error	0.05	0.2
Animal Se (%)	100	100
Animal Sp (%)	99.8	99.8
Animal Type I error	0.05	0.05
Animal Type II error	0.01	0.05
% Barangays with antibody + animals	10	10
% Animals per barangay with antibodies	20	20

of 1314 serum samples from pigs were collected initially. Based on the assumptions of Table 2 for cattle, carabao and goats, random samples of 13 animals from each of a random sample of 28 barangays in the Bicol region were required. A total of 364 serum samples were collected initially from these ruminant species. A random sample of barangays was generated from within the FMD-IMS by using the random list program included within EpiInfo's EpiTable. A list of 59 random numbers between 1 and 3390 (total number of barangays in the Bicol Region) was derived by scrolling down through the barangays within FMD-IMS while counting them and selecting each one in turn for inclusion in the sample. The first 28 of these barangays were also sampled for the ruminant species.

Collection of samples: The survey design required collection of a minimum of 21 serum samples from pigs from 59 barangays and a minimum of 13 serum samples from ruminants from 28 barangays. Samples were collected into glass vacutainers from the jugular of pigs and ruminants, following restraint via a snout snare for pigs and a bleeding pole for large ruminants. Bleeding poles are used commonly in South East Asia as cattle crushes are very rare. It is a 2–2.5-metre-long metal pole that is secured at the base of a strong tree with a flexible rope attached to the top of the pole and around the tree to form a swinging head bale for restraint of the animal by the neck. Blood samples were also occasionally collected from the coccygeal vein on the ventrum of the tail of carabao as it was found these mostly highly domesticated animals never kicked and could be readily restrained by the weight of several assistants leaning along their side (Fig. 3).

Fig. 3. Collection of a blood sample from the coccygeal vein of a carabao on Catanduanes Island for serosurveillance for foot and mouth disease in 1999.

A total of 1314 samples from pigs and 364 samples from ruminants were collected from 21 barangays in Camarines Sur, 11 barangays in Masbate, 9 barangays in Albay, 7 barangays in Camarines Norte, 6 barangays in Sorsogon and 5 barangays in Catanduanes (Fig. 3).

Interpretation of serological results: The LPB-ELISA screened samples using the lower cut-off point with an ER titre ≥45 to increase the probability of detection of truly infected animals. Samples from seropositive animals were then re-tested using the higher cut-off point of an ER titre >112 to decrease the probability of detection of false positives. On a probabilistic basis, a barangay was classified as being free from serological evidence of past FMD infection in pigs, provided no more than a single pig returned a positive test result at the higher cut-off point (equivalent to Type I and II error probabilities of <0.05 and 0.01 respectively at the barangay level). Further, a barangay was classified as being free of serological evidence of past FMD infection in ruminants, provided no more than a single animal returned a positive test result at the higher cut-off point (equivalent to Type I and II error probabilities both of <0.05 at the barangay level).

Bicol pigs and the ruminant population were classified as being free from serological evidence of FMD, provided no more than two barangays failed to be classified as free, based on the aforesaid decision criteria (Table 2). To add further confidence that the assumed false-positive results did not indicate infection, investigation of the reactors by clinical examination and re-sampling for retesting in the LPB-ELISA was undertaken where possible.

Public awareness

Although regulatory powers for emergency disease control exist in the Philippines, there is variable implementation of these because of decentralisation of compliance procedures. It was considered that public awareness programmes may offer a more effective means of addressing certain disease and biosecurity risks, such as the sale and purchase of infected pigs and the cooking of swill containing meat products to reduce virus transmission potential. The aim of this programme was to significantly increase the proportion of the livestock industry and general public with knowledge of biosecurity and FMD control and eradication principles.

The enhanced public awareness programme conducted in mid to late 1998 was focused on school on the air (SOA) radio training programmes for pig producers in all Bicol provinces. Pre-testing and post-training examination of participants was used to determine the effectiveness of the programme in imparting knowledge of FMD. Field visits to barangays, formal meetings with SOA

participants and numerous radio and press interviews emphasized the key messages of FMD control principles, including disease recognition, reporting, containment and prevention. The enhanced public awareness programme in 1999 targeted the sectors of the livestock industry and public considered at most risk of introducing FMD to Bicol. Technical training in FMD control procedures was held with livestock traders, commercial livestock raisers, animal technicians, meat inspectors, barangay health workers and importantly, farmer recipients of the government-sponsored swine and ruminant dispersal programmes for alleviation of rural poverty. The training used videos and discussion groups to focus on principles of disease recognition, reporting, diagnosis and control, plus improving hygiene and sanitation procedures to reduce risks from meat and meat products. Educational materials including posters, stickers and T-shirts with 'FMD-free' messages were also distributed. The effect of media initiatives on the consuming and travelling public was also investigated. In certain localities, the SOA graduates were recruited into Strategic watch and action teams (SWAT) for FMD prevention through improved biosecurity awareness.

Public mass media was used extensively during the FMD program, including regular press releases on radio and television, particularly during condemnation and destruction of FMD-affected pigs. Training materials with colour photographs of lesions of FMD-affected pigs were used in pamphlets and on posters placed at bus stations and other public places. A regional newsletter, the 'FMD Bicol Express', addressing programme developments, was mailed monthly to over 100 livestock industry service personnel and a national quarterly newsletter the 'FMD Monitor' was also distributed to program participants. An FMD 'extension booth' comprising panels of visual and textual materials was developed and used to promote the programme at rodeos, livestock fairs and festivals. Throughout the programme, there was considerable effort to build capacity through technical training of livestock service personnel. Important training programmes included epidemiological skills for veterinarians, plus animal handling skills and blood sampling for animal technicians. A workshop in emergency preparedness for transboundary diseases was conducted in November 1998 for all official veterinarians.

Results

Quarantine and animal movement controls

The checkpoints at Matnog and Bulan ports in southern Sorsogon province significantly reduced the illegal movements of animals and animal products to adjacent islands and further south. In 1998, the majority of vehicles, with an average of 126 vehicles per day, were inspected at Matnog, the major southern exit port from Luzon. A significant number of illegal shipments of meat and meat products were apprehended in the last 6 months of 1998 which led to a change in this practice. Monitoring of livestock movements at the Malicboy checkpoint in Quezon Province, suggested as a source for livestock moving to Catanduanes Province, confirmed that the majority of animals moved northwards towards Manila. However, as there had also been some local movement of animals from Quezon province south towards Bicol to the town of Gumaca and potentially beyond, the implementation of the Malicboy checkpoint in September 1998 appeared to cause this southern animal movement to cease.

Vaccination

Between November 1997 and March 1998, 230 000 doses of trivalent FMD vaccine were administered to Bicol livestock. Evaluation of vaccination effectiveness demonstrated poor re-presentation rates and poor herd immunity. Approximately 65% of the estimated susceptible livestock population was presented for initial vaccination with <50% re-presented for the second vaccination. Measurement of LPB-ELISA antibodies between 4 and 8 weeks post-vaccination in pigs known to have been vaccinated twice at approved intervals revealed that less than 50% of pigs had detectable antibodies to FMD. On a population basis, after considering the presentation and re-presentation rates, the herd immunity was estimated to be less than 20%.

Surveillance and investigations of disease outbreaks

Outbreak history in bicol

Recorded outbreaks in the Bicol region between January 1995 and October 1999 were confined to pigs and totalled 182 (Table 1). Despite the arrest of endemic infection in Bicol in March 1998 with elimination of infections from Camarines Sur, two series of FMD outbreaks subsequently occurred in Albay province. The first at Mararoy, Daraga in Albay in August 1998, was traced to swill feeding and was quickly eliminated. A second series of seven outbreaks in Albay commenced in March 1999 and persisted until July 1999 and is described elsewhere. No cases of FMD were reported in Bicol after December 1999.

By the end of October 1999, considerable evidence of absence of FMD was being accumulated in the FMD-IMS, with a total of 2529 'FMD Negative Reports' recorded. This was accompanied by a significant decline in 'FMD Negative Incident Reports' relative to previous years, indicating increasing confidence of field staff in their ability to recognize FMD and distinguish it from

other porcine diseases. It was considered that the initial spread of the epidemic of FMD to the Bicol region was mainly because of the illegal movements of infected pigs (BAI, 1996). However, the illegal slaughter of infected animals in the urban environment and the feeding of uncooked swill to pigs were identified as the main source of persistence of infection in Bicol. It was commonly observed that within barangays, the between-herd morbidity could be quite variable, although the within-herd morbidity was usually high. With no clinical cases of FMD diagnosed in ruminants in Bicol during this study, it was deemed appropriate to consider the current FMD epidemic as a disease of pigs with the ruminant population at a much lower risk of FMD.

Investigations of the Albay outbreaks in 1999

The series of seven outbreaks in Albay in 1999 involved the cycling of FMD in semi-rural and urban squatter communities. Investigations identified the common practice of feeding of uncooked swill containing meat from illegally slaughtered pigs, and tracing suggested this commenced at a local Albay slaughterhouse at Guinobatan. Infection spread through semi-urban barangays in Camalig, Guinobatan, Legaspi City and Daraga, despite containment, condemnation and disposal and decontamination measures.

Investigations suggested the slaughterhouse outbreaks were likely to have been preceded by an unreported case of FMD in a pig that was later identified and confirmed as having been infected with FMD through serological testing. The pig had been fed with swill containing 'hot meat' (meat that had not been submitted to meat inspection) from an illegally slaughtered pig that could not be traced (with no information available on disease symptoms of FMD). It was considered that the most likely 'index case' had introduced infection into the slaughterhouse and provided a source of infectious meat in both the legal and 'hot meat' market places. Of relevance was the reported clandestine removal of an 'in contact' pig from the Guinobatan slaughterhouse to a nearby barangay in Guinobatan. This animal could also not be traced, but it was considered to have contributed significantly to progression of the outbreak. The cases at the slaughterhouse were likely to have been infected owing to the failure to implement the 'all-in/all-out' policy where all pigs entering the slaughterhouse must be killed and processed within 24 h of arrival. Further, as the majority of owners of urban backyard piggeries were very poor squatters with minimal access to conventional media outlets, they were unaware of public awareness information on the necessity to cook swill prior to feeding pigs.

As no additional clinical cases were reported, serological investigations of the infected premises in this outbreak were extended to include all livestock populations in surrounding barangays plus monthly serological investigations of pigs in the provincial slaughterhouses of Guinobatan, Daraga and Legaspi City. In October 1999, randomly selected serum samples were collected from a minimum of 15 pigs and 12 ruminants (where available) from the six barangays from three municipalities containing the formerly infected premise. All samples were submitted to the LPB-ELISA for FMD. All 230 slaughterhouse samples were seronegative for FMD. Serum from a single pig from Barangay Baybay, Legaspi City, displayed an LPB-ELISA ER titre of 90 to FMD serotype O (negative to FMD serotypes A and C). In addition, serum from a single carabao from Barangay San Rafael, Guinobatan, displayed an LPB-ELISA ER titre of 45 to FMD serotype O (negative to FMD serotypes A and C). Samples from the remaining 77 pigs and 37 ruminants were seronegative. It was concluded that within the limits of this survey, there was currently no serological evidence of FMD in the areas where FMD had been diagnosed previously.

Opportunistic serosurveillance

With the exception of a single seropositive titre from a pig (assumed false positive) and several reactions in ruminants where previous vaccination was suspected, the opportunistic serosurveillance conducted in Masbate province failed to identify evidence of FMD infection in the 449 serum samples examined in the LPB-ELISA (Table 3). The absence of clinical FMD in Masbate province throughout the programme supported an early national claim for FMD freedom for this province, which proceeded in June 1999.

The opportunistic serosurveillance conducted in the remaining Bicol provinces examined 1105 serum samples. Using a cut-off point of ER ≥45 for screening, 41 seropositive animals (3.7%) were identified. Using the higher cut-off point of ER titre of 112, five seropositive animals

Table 3. Results of opportunistic serosurveillance in Bicol provinces tested by liquid phase blocking enzyme-linked immunosorbent assay

	Porcine		Bovine		Bubaline	
Species: Result: Province	–	+	–	+	–	+
Masbate	146	1	164	3[a]	124	6[b]
Camarines Sur	118	6[a]	46	11[a]	14	2
Camarines Norte	64	–	4	–	1	–
Albay	307	2	32	–	5	3
Sorsogon	24	1	7	1	2	–
Catanduanes	20	2	6	–	10	3
Total	679	12	259	15	156	14

[a]Includes suspected or reputedly vaccinated animals.

[b]Low seropositive reactions (ER titre of 45 to A serotype) found negative on re-testing.

were identified. These animals were re-sampled, and testing confirmed their seropositive status. However, all were found to be or presumed to have been vaccinated animals, and there was no history suggesting that an unrecognised outbreak of FMD had occurred.

Structured serosurveillance

In contrast to the opportunistic serosurveillance, the probabilistic two-stage random serosurvey identified three barangays from the municipality of Libmanan in Camarines Sur as having clusters of seropositive pigs that may have represented undetected FMD. In addition, this survey identified several clusters of carabao seropositive to both O and A serotypes of FMD, probably representing vaccination, recovery or subclinical FMD infection in this species.

Using the LPB-ELISA cut-off point of ER ≥45 for screening, four of 59 barangays could not be classified as being free of serological evidence of FMD in pigs. A further seven of 28 barangays could not be classified as being free of serological evidence of FMD in ruminants. However, using the higher LPB-ELISA cut-off point of ER >112, considerably fewer animals qualified as seropositive (Table 4), with 3 barangays not classified as being free FMD in pigs and six barangays not classified as being free of serological evidence of FMD in ruminants. This clustering of serological positives, with ER >112, was considered to suggest that unreported FMD infection may have occurred in a total of nine of 87 (10%) barangays. In summary, by using a higher cut-off value in the LPB-FMD Elisa, the number of suspected positive barangays dropped slightly to three for pigs and six for ruminants.

Table 4. LFB-ELISA results, initial and retested 3–4 weeks later, of seropositive pigs in the structured serosurvey from four barangays

Barangay/ Province	Sample number	Initial test	Re-test
Bagadion, CS	1	O/256	–*
	7	O/128	O/128
	10	O/256	–
	11	C/45	NA
Purobatia, CS	2	O/560, A/60	O/256
	4	O/256, A/90	O/90
	6	O/256	O/256
	14	O/45, C/60, A/40	O/128, C/181, A/181
Begueto Viejo, CS	19	O/560	NA
	21	O/560	–
Comagaycay, CP	4	O/50	–
	11	O/112	O/112
	16	O/50	–
	20	O/112	NA
Total positive		15	6

KEY: O, A, C: serotype of foot and mouth disease virus.
–* = Negative result; NA = Not available (slaughtered or untraceable).
CS = Camarines Sur Province; CP = Catanduanes Province.

Public awareness

Of 3926 enrolees, the total number of SOA graduates in Bicol and Quezon Province was 2161. Evaluation of the SOA program provided evidence that the training clearly contributed to raising the general community profile of the FMD program. In addition, several anecdotal reports attributed the reporting of FMD outbreaks in Quezon Province to the awareness of SOA graduates who diagnosed FMD in the piggeries of neighbours. The SOA graduates were used to form 5 SWAT and two affiliate clubs in the provinces of Camarines Sur, Albay, Camarines Norte and Catanduanes that promoted continuous learning of FMD control strategies, including biosecurity and surveillance in their barangays.

As livestock traders were identified as an important source of disease transmission, 11 seminars training 140 traders were held and 17 field visits involving 348 livestock producers and barangay officials were conducted. before and after evaluation of the training sessions confirmed the effectiveness of both the training approaches used and the improved knowledge of the fundamentals of the FMD program and disease prevention. Interviews were held with 567 members of the travelling public and identified widespread recognition and acceptance of the FMD messages being promoted.

The workshop for all official veterinarians conducted in November 1998 identified regional constraints and opportunities to improve emergency disease preparedness and specific contingency planning. With the improvement in the FMD status of many areas, the danger of diminution in the commitment of livestock owners to report disease was considered and strategies to address this were highlighted in the public awareness programmes.

Discussion

The decline in the total number of outbreaks in Bicol, the limited spread and rapid elimination of FMD from Catanduanes and Camarines Norte and continued absence of FMD from Sorsogon, Masbate and islands directly to the south of Luzon is evidence of a successful disease-control strategy in the Bicol buffer zone. Further, the emergency response during the outbreaks in Albay province in 1999, enhanced surveillance through 'Negative FMD Reporting' demonstrating continued absence of FMD in Bicol barangays, and the evaluation of the public awareness programmes, provided confidence that future outbreaks of FMD would be reported in Bicol. Interestingly, the serosurveillance data provided conflicting results that

demonstrated the importance of using the structured approach to decisions involving disease freedom. Despite there being no convincing evidence of undetected infection from the opportunistic sampling, the structured serosurveillance identified that apparent undetected infection in both pig and ruminant populations in Bicol was up to 10% of Bicol barangays (using the ER of >112 in the LFB-ELISA). It was concluded in late 1999 that despite the likelihood that endemic FMD has been eliminated in Bicol, undetected infection had most likely occurred and the region remained at high risk of re-infection from the endemic region in central Luzon at that time. This evidence confirmed the need to maintain the high level of activity in all four components of the disease control and eradication strategy in Bicol.

As FMD infection in pigs in Bicol was observed to be transmitted by direct or indirect oral contact, the epidemic should have been halted by controlling the movement of infected animals, animal products and feed between farms. However, as the epidemic initially continued to spread following implementation of animal movement controls, it was considered likely that clandestine movement of pigs and pig meat products was most likely responsible. Further, the illegal slaughter of infected animals in the urban environment and the feeding of uncooked swill to pigs were identified as the most important sources of persistence of infection in Bicol. No clinical cases of FMD confirmed in Bicol ruminants during this study supported the opinion that the FMD epidemic was primarily a disease of pigs, with the ruminant population at a much lower risk of contracting the disease, despite serological evidence of exposure in some Bicol ruminants.

Investigations of outbreaks in Albay 1990

Investigations conducted during the outbreaks in Guinobatan slaughterhouse, Camalig and Guinobatan barangays and Legasi City and Daraga involved attempts to confirm FMD infection in all cases by demonstration of virus antigen in vesicular fluid or tissue. Prompt disease confirmation gave support to the authorities implementing regulatory controls in communities unfamiliar with emergency disease control procedures such as condemnation and disposal of animals. Virus detection also confirmed that only serotype O strains of FMD were involved with the disease in pigs.

The results of these investigations highlight the considerable difficulties facing animal health authorities in implementing disease-control strategies and regulatory controls in particular in a surveillance buffer zone vulnerable to re-infection. Disease transmission in Bicol was attributed to a number of factors, including the inability of ante-mortem inspection to initially detect FMD, the non-adoption of the 'all-in/all-out' policy and the failure of secure containment of 'in contact' pigs at the slaughterhouses, with decision to 'return to origin' rather than impound suspected infectious material at the quarantine checkpoint. However, of most significance may well have been the claim by many of the owners of FMD cases that they were unaware of the importance of cooking meat when swill-feeding and the danger of 'hot meat'. This led to the intensive SOA program in Bicol and other regions to promote messages on cooking of swill, avoidance of 'hot meat' transmission and compliance with regulatory controls. However, this programme could not reach 100% of the livestock-owning population and it was not surprising that the later outbreaks in Albay occurred in poor urban 'squatter' communities with minimal access to conventional media outlets and general unawareness of the FMD program.

Vaccination

The low level of herd immunity following the vaccination programme was considered the result of a number of factors, including the frequently traded and transported Bicol pig population and lack of a national animal or herd identification system, hence low re-presentation rates for vaccination. Further, pig owners were reluctant to permit vaccination of pregnant females owing to perceptions of abortion risk, despite using a killed vaccine. Poor intramuscular vaccination technique, particularly of pregnant females because of inadequate animal restraint, small herd sizes (average five head), causing low output per vaccinator, and possible lowered vaccine efficacy owing to incorrect temperature maintenance may also have contributed to low numbers of adequately vaccinated livestock.

Surveillance

Results from the structured serological survey revealed that the Bicol surveillance zone could not be confidently classified as free of FMD with respect to both pig and ruminant populations at the end of 1999. Despite a majority of LPB-ELISA negative samples from pigs in this survey, three barangays from one municipality were identified with clusters of seropositive pigs. On re-sampling, the majority of animals displayed declining ER titres. The one exception was an older sow with rising titres (Table 5, number 14 from Purobatia) that had been vaccinated for FMD in May 1997 and presumably retained some 'trivalent' immunity from the vaccination that was boosted by the suspected FMD infection that stimulated a response in the other pigs. This was an unusual finding,

Table 5. Positive liquid phase blocking enzyme-linked immunosorbent assay results by species and serotype at two different cut-off points in the structured serosurvey

Species	Cut off point	Serotype O	Serotype A	Serotype C	Total
Porcine	≥45	20	9	7	36
	>112	8	2	3	13
Bubaline	≥45	18	13	3	34
	>112	11	12	0	23

as few animals retain immunity or significant titres more than 6 months post-vaccination (Doel, 1996).

The serological survey indicated the occurrence of unreported FMD in pigs in Bicol, albeit with a low prevalence of approximately 5% of barangays having clusters of seropositive pigs in the LPB-ELISA. At the time of sampling, all owners were interviewed to determine the vaccination status of their animals and all seropositives with the exception of the 5-year-old sow from Purobatia, Libmanan (Table 4) were claimed to be unvaccinated. Further questioning of the farmers revealed that several of the seropositive carabao in Malinao and Liao in Albay and possibly elsewhere may have been vaccinated for FMD in 1997. The serological data included a number of isolated individual seropositive results, consistent with the expectation that some false positives would be found using the LFB-ELISA test with high sensitivity (100%) and a specificity estimated at 98.5%. Excluding the 10 seropositive pigs from Libmanan, considered to represent likely recent FMD infection, this survey, performed on a disease-free, unvaccinated population, suggests that the LPB-ELISA performed with a specificity of 98.6% in Bicol pigs.

The serosurvey of ruminants indicated that 25% of barangays may have seropositve animals present, with an estimated within-barangay prevalence of 10%. These findings confirm the assumption that pigs and ruminants can be treated as populations at a different level of risk for FMD transmission but also that there may be a high prevalence of undetected FMD infection in carabaos in Bicol. The serosurvey identified carabao 'reactors' to both O and A serotypes, but as 5 of 7 of the LPB-ELISA reactors to serotype A were negative in the VNT for serotype A, cross-reactivity in the LPB-ELISA was suspected. Undisclosed vaccination may account for some but not all of these results, and it was concluded that FMD virus infection, presumably subclinical and involving O serotype and possibly A serotype, may have been active in Bicol ruminants. In addition, it was considered possible that some of the carabao in Laganac, Balataan in Camarines Sur and Awayan, Sipocot in Camarines Sur that had persistent antibody, might be chronic carriers of FMD virus. Unfortunately, further investigations to clarify the possible 'carrier status' of these suspected FMD infections could not be completed.

Review of information on the origin of infection in Bicol FMD outbreaks identified that the majority of FMD in pigs in Bicol occurred from swill feeding of illegally slaughtered pig meat products. Two of the three barangays in Libmanan containing clusters of seropositive pigs were adjacent to a major highway, indicating infection may have originated from local roadside sale of infected pig 'hot meat'. None of the pigs in any of the six barangays containing clusters of seropositive carabao were seropositive, and there was no recent history of clinical FMD in pigs in these barangays. Also, none of the ruminants in Barangay Bagadion in Libmanan were seropositive, despite the positive results in thre pigs. These results suggest that if as appears likely that the seropositive ruminants represent undetected infection, there was no transmission between the ruminant and the pig populations in Bicol. However, FMD in carabaos in other parts of the Philippines during outbreaks in pigs has occasionally been identified, suggesting that transmission between pigs and carabaos does occur, albeit infrequently. The six Bicol barangays with clusters of seropositive ruminants were in isolated locations, but several of the animals from all six barangays were pastured near a road or railway line and so could have access to infected products.

Data from the structured serosurvey indicated previously unidentified FMD outbreaks in pigs may have occurred in Bicol at a low prevalence and should be considered during the terminal phase of the eradication programme. Previously unidentified FMD in carabaos may have occurred in Bicol in approximately 21% of barangays, suggesting a high prevalence of subclinical infection in this species, probably involving serotype O but also possibly involving A or even both serotypes of FMD virus. FMD caused by serotype A has occurred in the Philippines but reported to be absent at the time of these studies (Kitching, 1998). Ruminants are potential carriers of FMD virus with cattle known to carry FMD virus for 3 years (Kitching, 1998). It was suspected that carabao could be carriers of the virus in the Philippines and may represent a risk of initiating further outbreaks, although evidence for this is inconclusive (Kitching, 1998). Mild clinical disease suggesting FMD in carabaos, associated with demonstration of the viral antigen and in rare cases virus isolation, was recorded in other parts of the Philippines during this epidemic. A single seropositive carabao was found with a scar on the tongue during our probabilistic survey in Bicol, and this species was suspected to be of importance in the final eradication of the current outbreak. These findings suggested that improved knowledge of the relationship between positive titres and virus loads in carabaos and the probable carrier state in this species

is required. The findings also indicated that FMD was no longer endemic in Bicol but structured approaches to FMD surveillance by intensive FMD 'negative reporting' and slaughterhouse serosurveillance, plus ongoing public awareness to address risk factors contributing to possible re-infection were required in the Bicol FMD surveillance zone.

Of importance, this survey demonstrated the successful application of a model designed for selecting animals based on two-stage random sampling methodology. The model provides an approach to obtain accurate data on the serological status of livestock populations at risk of infection with transboundary diseases such as in the Bicol surveillance buffer zone for FMD and can be used to meet the requirements of trading partners or international organisations such as the OIE.

Public awareness

Although the contribution of public awareness programmes to FMD control and eradication of FMD in the Philippines is difficult to evaluate, it was considered an extremely important strategy in lieu of effective implementation of some regulatory controls presently used in managing exotic disease emergencies. The training of animal health staff in emergency disease preparedness combined with extensive public education appears to have contributed to significant improvements in livestock disease reporting and response performance in the Philippines. Of note is that this training included information on the behaviour of FMD viruses in other environments where aerosol transmission, for example, is important in the epidemiology of the disease (Kitching, 1998).

Conclusion

It is likely that all four components of the disease-control strategy contributed significantly to the elimination of endemic FMD in Bicol. Evaluation of the serological responses of the vaccinated population suggests that the cessation of outbreaks was unlikely to be because of the presence of widespread immune protection in the livestock population, although experience demonstrated that strategic vaccination has a role in managing outbreaks. Failure of effective vaccination and variable implementation of regulatory controls suggests that efforts to improve surveillance and emergency response capability through public awareness and training of livestock industry personnel may have been the most significant factors in eliminating FMD from Bicol. The outbreaks examined in this study identified numerous risks of FMD transmission that should be addressed in FMD control programmes, including: inability of ante-mortem inspection to initially detect FMD; non-adoption of the 'all-in/all-out' policy; failure of secure containment of 'in contact' pigs at the slaughterhouses; pigs 'returned to origin' rather than impounding of suspected infectious material at checkpoints; lack of awareness of risks of illegally sold 'hot meat'; the importance of cooking meat when used for swill-feeding of pigs as is common practice in the semi-rural and urban backyard pig-raising environment of the Philippines. It is likely that changes in village level practices such as restricting the movement of infected pigs and pig products, adoption of cooking of swill and improved hygiene and sanitation could only be achieved through the intensive public awareness programme for FMD that was successfully implemented in Bicol and other regions of Luzon.

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