Understanding Animal Health in Southeast Asia

Advances in the Collection, Management and Use of Animal Health Information

Editors:

Pramod Sharma
Chris Baldock

ACIAR
Australian Centre for International Agricultural Research

Canberra 1999

The Australian Centre for International Agricultural Research (ACIAR) was established in June 1982 by an Act of the Australian Parliament. Its primary mandate is to help identify agricultural problems in developing countries and to commission collaborative research between Australia and developing country researchers in fields where Australia has special competence.

Where trade names are used this constitutes neither endorsement of nor discrimination against any product by the Centre.

ACIAR MONOGRAPH SERIES

This series contains the results of original research supported by ACIAR, or deemed relevant to ACIAR's research objectives. The series is distributed internationally, with an emphasis on the developing world.

This book has been reviewed by a panel of experts according to ACIAR's publication guidelines.

GPO Box 1571, Canberra, ACT 2601.

Sharma, P. and Baldock, C. (ed.) 1999. Animal Health in Southeast Asia. Advances in the Collection, Management and Use of Animal Health Information. ACIAR Monograph No. 58, xiv + 374 pp.

ISBN 1 86320 261 7

Editing and design by Arawang Communication Group, Canberra

Contents

Preface

Livestock diseases cause enormous losses through death and decreased production, impacting directly on food security and local economies. In most developing countries livestock represent, in addition to food and power, an important savings system within the village economy. In these countries diseases of livestock are usually more severe, more widespread and inflict more social and economic damage than in developed countries.

Accurate information about the health status of a nation's animal population is critical in the fight against animal diseases—without this a government's task of targeting disease control is almost impossible. Unfortunately, in many developing countries the systems in place for the collection, management and reporting of animal health information are not able to gather the required information. Consequently, issues relevant to the design and development of animal health information systems are attracting attention in both developing and in developed countries.

The primary mandate of the Australian Centre for International Agricultural Research (ACIAR) is to help identify agricultural problems in developing countries and to commission collaborative research between Australia and developing country researchers in fields where Australia has special competence. Projects AS1/1992/004 and AS1/1996/083 were initiated within the terms of this mandate. These projects—undertaken mainly in Thailand and the Lao PDR—were instrumental in formulating, developing and testing new techniques for animal health information systems for Southeast Asia in particular and the developing world in general.

This publication reports the extensive and successful research that was undertaken as part of the ACIAR-facilitated projects. It required extensive collaboration across disciplines and organisations. We as editors thank all those involved and in particular the Thai Department of Livestock Development and the Lao Ministry of Agriculture and Fisheries. We also thank the anonymous panel of referees who reviewed all contributions for research methodology and scholarly contribution.

Finally, thanks are due to the ACIAR Communications Program, in particular Mr Peter Lynch, for providing editorial and production support for this monograph, and to Dr Mary Webb (Arawang Communication Group) for rigorous technical editing.

Dr Pramod Sharma
University of Queensland
Dr Chris Baldock
AusVet Animal Health Services

Author Contact Details

Abila, Ronello C. (Dr)	Bureau of Animal Industry, Visayas Avenue, Diliman, Quezon City, The Philippines.
Baldock, Chris (Dr)	Ausvet Animal Health Services, 19 Brereton Street, South Brisbane, Queensland 4101, Australia. Email: ausvet@eis.net.au
Barmey, Chhoeung (Dr)	National Veterinary Diagnostic Laboratory, Department of Animal Health and Production, Phnom Penh, Cambodia.
Black, Peter (Dr)	Department of Primary Industries, 80 Ann Street, Brisbane, Queensland 4000, Australia.
Blacksell, Stuart D. (Dr)	CSIRO Animal Health Laboratory, Geelong, Victoria 3220, Australia. Fax: +61 3 5227 5555. E-mail: stuart@dah.csiro.au
Cameron, Angus R. (Dr)	140 Falls Road, Wentworth Falls, New South Wales 2789, Australia. Fax: +61 2 4757 2782. Email: angus@pnc.com.au
Chamnanpood, Chanpen (Dr)	Northern Veterinary Research and Diagnostic Center, Hang Chat, Lampang 52190, Thailand.
Chamnanpood, Pornchai (Dr)	Northern Veterinary Research and Diagnostic Center, Hang Chat, Lampang 52190, Thailand.
Gleeson, Laurence, J. (Dr)	OIE Regional Co-ordination Unit, c/o Faculty of Veterinary Medicine, Kasetsart University, Bangkok 10900, Thailand. Fax: +66 2 9406570. E-mail: Oiercu@loxinfo.co.th
Harrison, Steve R. (Assoc. Prof.)	Department of Economics, University of Queensland, Queensland 4072, Australia. Email: harrison@commerce.uq.edu.au
Hutabarat, Tri Saya Putri N. (Dr)	Directorate General of Livestock Services, Jakarta, Indonesia.
Joco, Ma. Lourdes M. (Dr)	Bureau of Animal Industry, Visayas Avenue, Diliman, Quezon City, The Philippines.

Johar, Sopian (Dr)	Department of Veterinary Services, Exchange Square (9th Floor), Damansara Heights, Kuala Lumpur 50630, Malaysia. Email: sopian@jph.gov.my
Kamolsiripichaiporn, Somjai (Dr)	Foot and Mouth Disease Vaccine Center, Pak Chong, Nakhornratchasima 30130, Thailand.
Lan, Lai Thi Kim (Mrs)	Animal Health Information Division, Department of Animal Health, Ministry of Agriculture and Rural Development, Phuong Mai, Dongda, Hanoi, Vietnam. Fax: +84 4 869 1311.
Linchongsubongkoch, Wilai (Dr)	Foot and Mouth Disease Vaccine Center, Pak Chong, Nakhornratchasima 30130, Thailand.
Meephuch, Yodyot (Dr)	National Institute of Animal Health, Department of Livestock Development, Kaset Klang, Chatuchak, Bangkok,Thailand. Fax: +66 2 579 8918. Email: yodyot@health.moph.go.th
Monpolsiri, Mathurose (Dr)	Northern Veterinary Research and Diagnostic Center, Hang Chat, Lampang 52190, Thailand.
Ozawa, Yoshihiro (Dr)	OIE Regional Representation, East 311, Shin Aoyama Building, 1-1-1 Minami-Aoyama, Minato-ku, Tokyo 107-0062, Japan. Ph: +81 3 54110520 Fax: 81 3 54110526. Email: oietokyo@tky.threewebnet.or.jp
Phuong, Thai Thi Thuy (Mrs)	Department of Animal Health, Ministry of Agriculture and Rural Development, 521/1 Hoang Van Thu St, Ward 4, Tan Binh, Ho Chi Minh City, Vietnam. Fax: +84 8 444 029.
Rahim, Nor Aidah Bt Abdul (Dr)	Director of State Veterinary Services, Selangor State Veterinary Services, Jalan Utas 15/7, Shah Alam, Selangor, Malaysia. Email: salleh@pc.jaring.my
Ramsay, Gavin (Dr)	Department of Primary Industries, 80 Ann Street, Brisbane, Queensland 4000, Australia.
Sandan, Chrea (Miss)	National Veterinary Diagnostic Laboratory, Department of Animal Health and Production, Phnom Penh, Cambodia.
Sergeant, Evan (Mr)	NSW Agriculture, Locked Bag 21, Orange, New South Wales 2800, Australia.

Sharma, Pramod (Dr)	Department of Geographical Sciences and Planning, University of Queensland, Queensland 4072, Australia. Fax: +61 7 3365 6899. Email: p.sharma@mailbox.uq.edu.au
Tatong, Dumrongsak (Dr)	Northern Veterinary Research and Diagnostic Center, Hang Chat, Lampang 52190, Thailand.
Tisdell, Clem A. (Prof.)	Department of Economics, University of Queensland, Queensland 4072, Australia.
Vongthilath, Sounthone (Dr)	Animal Health Division, Department of Livestock and Fisheries, Ministry of Agriculture and Forestry, PO Box 811, Vientiane, Lao PDR. Email: ahd@laahp.org.la
Westbury, Harvey, A. (Dr)	CSIRO Animal Health Laboratory, Private Bag 24, Geelong, Victoria 3220, Australia. Fax: +61 3 5227 5555. E-mail: hwestbury@aahl.dah.csiro.au
Wodowati, Noeri (Dr)	Directorate General of Livestock Services, Jakarta, Indonesia.

Abbreviations

ACIAR	Australian Centre for International Agricultural Research
AHD	Animal Health Division (of the DLF, Lao PDR)
BSE	bovine spongiform encephalopathy ('mad cow' disease)
C&E	control and eradication
CBA	cost–benefit analysis
CBPP	contagious bovine pleuropneumonia
COS	cost of sampling
CSF	classical swine fever
CSF AT-ELISA	CSF antigen trapping ELISA
CUSUM	cumulative summation
cv	co-efficient of variation
DAH	Directorate of Animal Health (Indonesia)/
	Department of Animal Health (Vietnam)
DBMS	database management system
DGLS	Directorate General of Livestock Services (Indonesia)
DIC	Disease Investigation Centre (Indonesia)
DLD	Department of Livestock Development (Thailand)
DLF	Department of Livestock and Fisheries (Lao PDR)
DLFO	District Livestock and Fisheries Officer (Lao PDR)
DSS	decision support system
DVS	Department of Veterinary Services (Malaysia)
ELISA	enzyme-linked immunosorbent assay
EPM	environmental planning and management
FAO	Food and Agriculture Organization of the United Nations
FMD	foot-and-mouth disease
FMD AT-ELISA	FMD antigen typing ELISA
FMD LPB-ELISA	FMD liquid phase blocking ELISA
ENGS	expected net gain from sampling

EVPI	expected value of perfect information
GIS	geographical information system
GPS	global positioning system
IBD	infectious bursal disease
IT	information technology
Lao PDR	Lao People's Democratic Republic
MAP	map codes as used by the Statistics Office Mapping Division (Thailand)
ND	Newcastle disease
NIAH	National Institute of Animal Health (Thailand)
NSO	National Statistics Office (Thailand)
NVDL	National Veterinary Diagnostic Laboratory (Cambodia)
NVRDC	Northern Veterinary Research and Diagnostic Center (Thailand)
OIE	Office International des Epizooties
OOC	out-of-control
PAT	polygon attribute file
PLFO	Provincial Livestock and Fisheries Officer (Lao PDR)
PPS	probability proportional to size
PSU	primary sampling unit
QC	quality control
RVRDC	Regional Veterinary Research and Diagnostic Center (Thailand)
SSU	secondary sampling unit
TU	Thammasat University (Thailand)
TMB	3', 3' tetramethylbenzidene
UTM	Universal Transverse Mercator (projection)
VRI	Veterinary Research Institute (Malaysia)
VVW	village veterinary worker

1

A Strategy for Animal Health Information System Research in Southeast Asia

P. Sharma
C. Baldock

Abstract

Advances in animal health information systems research in Southeast Asia are reported in this chapter. A strategic approach based on improving all elements in the process is proposed. The core of the strategy is an information technology-based active surveillance approach. This core is supported by (a) improving laboratory diagnostic procedures and (b) the use of geographical information systems—both for the mounting of active surveillance-based data collection and for data management and analysis. Finally, economic analyses assess the performance of the methodology against the wider national context of managing animal health.

Introduction

Livestock diseases cause enormous losses through death and decreased production, impacting directly on food security and local economies. Their occurrence also hinders trade through restrictions on the movement of livestock commodities, especially at the international level. The Office International des Epizooties (OIE) estimates that animal disease may result in losses of up to 20% of production (OIE 1993).

The majority of the population in most developing countries are involved in smallholder agriculture. Often this group also represents one of the poorest sectors of society. In addition to food and draft power, livestock represent an important savings system within the village economy. In such countries, diseases of livestock have serious effects at many levels, especially as they are usually more severe, more widespread, and inflict more social and economic damage than in developed countries. At the same time, the resources available to identify, assess and control these diseases are often scarce. For this reason, it is important that any resources available are effectively targeted to achieve the most benefit.

Accurate information about the health status of a nation's animal population is critical in the fight against animal diseases. Without measures of the frequency and economic importance of a particular disease, a government's task of targeting disease control is almost impossible. Without comprehensive disease reporting systems and ongoing measures of disease frequency, the efficacy and endpoint of any control or eradication program is impossible to measure. Without an internationally acceptable system of epidemiological surveillance and animal health information management, the verification of national freedom from disease or a disease-free zone is impossible to achieve.

Unfortunately, in many developing countries the systems in place for the collection, management and reporting of animal health information are not able to gather the type of information that is required for informed priority setting; disease control program planning, implementation and evaluation; and substantiation of claims of freedom from disease. This is despite sometimes substantial investment in veterinary infrastructure and disease control activities, such as laboratory diagnostic facilities and vaccination programs. Consequently, issues relevant to the design and development of animal health information systems are attracting attention in both developed and (in particular) in developing countries.

This book is a contribution to this research area.

What is an Animal Health Information System?

There is a growing recognition among veterinary administrators throughout the world of the need for more quantitative and reliable information on livestock production and disease. Better information is critical to efficient and effective disease control as well as becoming increasingly important in certification for international trade in livestock and livestock products. Some countries have, and many are moving towards developing, national animal health information systems with data being derived from a number of sources.

The problem with many existing data sources is that, because of non-reporting and under-reporting, they are statistically biased and do not give a fair picture of the situation in the reference population (McCallon and Beal 1982; Hueston 1993). The need for additional, representative information obtained through active surveillance is now well recognised in both the human and veterinary fields. Indeed, it may be argued that in many developing countries, the information needs of animal health authorities can, for the foreseeable future, only be met by active surveillance.

A national animal health information system is the complete system responsible for handling information about the health of livestock in a country. Such a system may include systems for some or all of the following purposes:

1. The collection of information including

- disease reports,
- livestock population data,
- vaccine production, distribution and delivery,
- livestock movements,
- meat inspection findings, and
- active surveillance for the collection of unbiased disease data;

2. Recording the information collected, preferably with a set of standard forms containing all the required information;
3. Transmitting that information to centres for compilation;
4. Managing that information efficiently (a computerised database);

5. Entering the data into the computer (data entry staff);

6. Analysing and mapping the data (statistical and mapping software);

7. Reporting the data (computerised report formats);

8. Communicating the results of analyses to decision-makers;

9. Using the reported data to take action on the basis of the information provided; and

10. Feedback of reported data converted to meaningful information to all levels of staff and contributors who provided it.

Thus, a national animal health information system is not merely a computerised database as is sometimes thought. Rather, it is the entire process of gathering, managing, analysing and reporting information in accordance with the needs of a particular country. Traditionally such a system has been based around what has been termed passive surveillance—essentially ‘waiting’ for existing and new diseases to be detected somewhere in the system.

In many situations resource constraints (especially financial) may hinder attempts to improve the passive surveillance-based system as a whole. The research reported in this book argues that a more focused, active surveillance-based approach using information technology, where appropriate, can achieve significant across-the-board advances in the performance of animal health information systems in developing countries.

The Approach Taken in this Book

The overall goal of the research described in this book was to develop and evaluate the tools necessary to provide decision-makers with reliable animal health information placed in context and analysed appropriately. This goal was achieved by:

- improving laboratory diagnostic procedures (Chapter 7);

- undertaking research to obtain cost-effective population referenced data (Chapters 3, 5, 8 and 9);

- integrating data sets using modern information management technology, including geographical information systems (Chapters 5, 9, 10, 11, 15 and 16);

- providing a framework for the economic evaluation of the impact of animal diseases and their control (Chapters 4, 12, 13, 14); and

- reporting on the regional disease situation including disease control and eradication (Chapters 2 and 6).

Operationally, the program involved research into the design and the implementation of an information technology-based active surveillance approach. While significant gains can be achieved without the use of information technology, its use produces another magnitude of benefits. These include assistance in laboratory procedures and management, better analysis of available data so that active surveillance is initiated with better knowledge, better sampling can be implemented, better management of field logistics, and better management and analysis of collected data. Related technologies such as global positioning systems also produce significant benefits at the data collection stage. We would argue that, in addition to the efficiencies gained by the introduction of appropriate information technology, the systems developed are more sustainable provided the relatively simple training and maintenance requirements are met.

A small number of important diseases were targeted to test the approaches being developed. The research was conducted mainly in Thailand and Lao People's Democratic Republic (PDR), focusing on village and small commercial livestock systems (later related studies have continued under different programs in Vietnam, the Philippines and Indonesia). Some studies were also conducted in Australia, where the research was directed at the northern beef industry as animal health information for this sector of export-oriented livestock production was scarce. The Australian studies were also the basis for the development of the economic models.

Improved Laboratory Procedures

While laboratory procedures were not a significant problem in Thailand (compared to many developing countries) there was still considerable room for improvement, especially if support for an active surveillance-based program was required. Thus, of improved laboratory techniques and quality control procedures developed for the diagnosis of hog cholera, Aujeszky's disease and infectious bursal disease, three new rapid antigen detection and three new serological tests for antibody detection were implemented at the Northern Veterinary Research and Diagnostic Centre (NVRDC) in Lampang, northern Thailand. These quality control procedures meet international ISO (International Standards Organisation) 9000 specifications and are now in routine use in the NVRDC virology laboratory.

The antigen detection tests have considerable advantages over former technology including improved convenience, reduced cost, improved accuracy, and a dramatic reduction in time to diagnosis (e.g. a reduction from 3–4 weeks to 3–8 hours in the case of Aujeszky's disease and hog cholera). This improvement in diagnostic ability means that diagnoses can now be provided in time to influence decisions on interventions rather than merely being an historical confirmation of a clinically suspect event. The new serological tests have similar advantages with the addition of a marked increase in capacity which is vital for animal health monitoring.

A quality control process for laboratory assays has been put in place and is now in routine use in the virology laboratory at the NVRDC and has also been introduced to the other regional laboratories in Thailand. The system is called 'QCEL' and has the following features:

- provides the user with an independent assessment on unacceptable trends in eznyme-linked immunosorbent assay (ELISA) performance;
- provides individual operator performance data;
- requires no assumed knowledge of statistics;
- gives easy-to-interpret graphical summaries of quality control data;
- uses international standard methods (Shewart-CUSUM); and is
- inexpensive, and simple to implement and use.

Improved Surveillance

Active surveillance methods were developed and evaluated in Thailand and Lao PDR. In Thailand, research towards this objective involved the development and testing of methodologies aimed at the collection of three core measures of disease: seroprevalence; disease incidence; and freedom from disease. The approaches used to develop these methodologies involved:

1. A review of the literature with regard to techniques previously used for the collection of the three core disease information types;

2. A systematic assessment of the information requirements of the veterinary services;

3. An assessment of the current information collection capabilities and restraints faced by the veterinary services;

4. Theoretical development of approaches to improved data collection;

5. In some cases, stochastic simulation modelling to test the validity of the techniques;

6. Training of field staff and implementation of survey techniques to field test the methodologies; and

7. Critical analysis of both the effectiveness of the methodology and the data collected.

Seroprevalence surveys

Research initially concentrated on the development of techniques for foot-and mouth disease (FMD) surveillance and serological monitoring of the official vaccination program. The new techniques are now in routine use in northern Thailand.

Features of the technique include the following:

- A flexible methodology for serosurveillance applicable to virtually any developing country situation. This is achieved through the use of a two-stage sampling approach, in which the first-stage (selection of villages or herds) can be modified according to the sampling frame available (ranging from a good quality sampling frame with reliable livestock population data, through to no sampling frame at all).

- A new approach to first-stage random sampling using random geographic coordinate sampling which allows the selection of a true random sample (of villages or herds) in the absence of a sampling frame. The new technique achieves greater accuracy at a lower cost than previously used techniques. The use of a geographical information system (GIS) simplifies the sampling process as well as introduces significant benefits in planning the logistics involved in field work; further benefits accrue if remotely sensed data (satellite images or aerial photographs) are available.

- Compilation (and testing through simulation) of formulae for minimum sample size estimation, tailored to the variance structures of different livestock populations (resulting in significant cost savings for routine surveys run as part of a monitoring program).

- A practical approach to the random selection of individual animals at the village level, effectively removing errors due to selection bias.

These techniques were successfully field tested in northern Thailand and validated in the Lao PDR and have since been implemented in other developing countries such as the Philippines.

Disease incidence estimation

Prevalence data only provides some of the information relevant to animal disease control. Disease incidence is the other key measure of disease required to monitor control program progress, and for international reporting. Two approaches to the estimation of disease incidence were developed. Both are based on the use of village interviews to collect reliable retrospective disease outbreak data quickly and inexpensively. A number of methods developed in the area of participatory rural appraisal were modified and adopted to ensure the quality of data recalled by livestock owners is the best possible.

The first technique applies backwards recurrence time analysis—an analytical technique akin to survival analysis borrowed from sociology—to calculate measures of disease occurrence. The second technique uses capture–recapture techniques (developed in the field of ecology) to calculate incidence estimates based on two data sources (combining, for example, laboratory submissions or disease reports with survey results).

Freedom from disease

In order to reap the full benefits at the completion of disease control and eradication programs, developing countries must be able to demonstrate their freedom from disease. All trading countries are now required to provide soundly based evidence for their disease status. To support this, a new formula and survey approach was developed. The new probability formula is free from previous restrictive assumptions of a perfect diagnostic test or infinite population.

RapiCAPS (Rapid computer-assisted prevalence surveys)

The techniques developed from the research program have proven their value to developing countries through extensive field testing. A package, known as *RapiCAPS*, was developed to bring the benefits of the research program to the developing country veterinary services that most need them. The package, a combination of computer software and a methodology manual, incorporates all the complex statistical and data manipulation routines required to successfully conduct the disease surveys developed in the research program, freeing developing country veterinarians from the need for access to high-level statistical consultants. While this is a useful advance in its own right, it also contributes directly to making the active surveillance approach more feasible for adoption and implementation in Southeast Asia and in developing countries generally. (*RapiCAPS* has been renamed the 'Survey Toolbox'; see the companion CD-ROM for software and electronic copy of the manual).

Longitudinal studies

While small-scale livestock enterprises in villages are still the norm in Thailand, there is now an emerging small commercial sector, particularly in pigs. A series of longitudinal studies of selected diseases in representative herds were undertaken to measure their biological impact and identify critical factors relevant to control.

Four small commercial piggeries and five poultry farms were enrolled in these studies. Blood samples collected during these studies were used to further evaluate the new diagnostic assays introduced to the NVRDC as part of the project. Analyses of the serological data confirmed the hog cholera ELISA and Aujeszky's disease latex agglutination tests were working well. In addition, serology was used to evaluate vaccination programs which were found to be deficient in some instances and corrective actions were taken.

Geographical Information System (GIS) Issues

For the sampling-based active surveillance to be effective, it is necessary to have as complete an understanding of the reference population as possible. This is required for drawing the samples, for executing the surveys and for placing the results in the wider national (or regional) context. It is also important to appreciate that much of this information is spatial in nature, therefore techniques developed in allied disciplines such as geographical sciences can make significant contribution.

This rationale provided the impetus for research into the role of GISs and animal health information systems. Research issues investigated included identifying:

- the role of GISs in animal health systems generally;
- the problems involved in GIS development in a developing country;
- the role of the GIS in active surveillance; and
- identifying the role of the GIS in disease mapping and visualisation.

A major research effort was directed towards the development of an integrated data management system within a GIS framework suitable for collection, analysis and reporting of data at the local, regional and national levels. Research on the GIS-based information system involved a preliminary assessment of the current information flows and information requirements of different sectors of the veterinary authorities. This was followed by investigations into both the geographical information and attribute (animal health related) information that was already available, and identifying data that needed to be specially generated. At the commencement of the project only a rudimentary computer-based system was in existence in the Thai Department of Livestock Development (DLD)—this system had no GIS capabilities.

A model system was developed at the NVRDC based on three provinces (Lampang, Lamphun and Chiang Mai) in northern Thailand. This model system provided the basis for the further development of information technology for animal health information management by the DLD. The GIS application was based on *pcARC/INFO* (later *ArcView*) as the central software packages—both are dominant packages worldwide. This computer system, when linked to the existing disease database at the NVRDC, provided the capability of producing computerised maps of disease distributions in the pilot area to assist with the evaluation of the need for such technology in the DLD. Once basic computerised mapping capabilities had been established at the NVRDC, more sophisticated spatial analysis techniques (e.g. animated maps modelling disease outbreaks over time) were utilised for the analysis of animal health data.

Development of the pilot GIS demonstrated that incorporation of this technology into the DLD's animal health information system was quite feasible. The focus of the GIS component of the project in the latter part of the project shifted to making the system more sustainable. More DLD staff were trained in the use of the GIS to give them the capacity, if required, to expand the coverage to other parts of Thailand. This expansion meant that both the NVRDC and the Southern Veterinary Research and Diagnostic Centre (SVRDC) would have fully operational GIS capabilities in addition to expertise and facilities within the epidemiology unit at the National Institute for Animal Health in Bangkok for integration of the system at a national level. The GIS studies have also shown that the accuracy of the existing laboratory accession database could be enhanced through use of predefined codes and some drop-down menu systems; they have also demonstrated the geographical bias in the origin of current laboratory data.

An additional focus of the GIS component of the project was the development of output formats of maps and reports (both on screen and in hardcopy) relevant to DLD needs. These included the production of different map formats for displaying the distribution of livestock diseases, spatio-temporal visualisation of disease occurrence, disease outbreak management, and use of the GIS for producing village random samples for active surveillance of livestock diseases of interest.

Economic Issues

The research undertaken included a cost–benefit study of the economic impacts of FMD and the costs and benefits of eradication, in terms of the various impact categories. The economic evaluation of the Thai FMD control and eradication program indicated a number of factors which will help to assure success of the program and be of assistance to Thai livestock authorities in disease control policy formulation.

Economic analysis frameworks were developed for animal health economics. Data were collected from village surveys, discussions with Thai livestock officers, Thai official statistics, and modelling approaches. Costs of livestock diseases were examined at the producer level and aggregated to the national level, with the addition of wider socioeconomic variables for policy making. Multi-stage sampling designs for active surveillance of seroprevalence levels against foot-and-mouth disease were evaluated in terms of cost-effectiveness using a simulation approach.

Information about costs of FMD in Thailand, costs of vaccination and other control measures and potential benefits of FMD eradication were integrated in a cost–benefit evaluation of the current Thai control and eradication program. This analysis integrated findings of other components of the project, and developed and applied a methodology for estimation of the net present value and benefit-to-cost payoff of the current Thai FMD control and eradication program. The analysis provides indicative results that the program has a positive net present value and a benefit-to-cost ratio exceeding unity. Provided current control measures are continued and adapted as necessary, the Thai FMD program appears to be well justified when all categories of benefits (including reduced animal health expenditure, trade gains, transport, and draught and animal welfare benefits) are taken into account. The importance of FMD eradication in Thailand becomes greater when viewed within a program of eradication in Southeast Asia.

The economics related research inquiries may be grouped as follows.

Theoretical models of animal health economics

Optimal disease control effort. The earlier analyses of McInerney and others based on a loss–expenditure tradeoff were considered to be inappropriate for infectious diseases where a threshold expenditure was needed to make progress in disease control. This implied that the optimal control expenditure on a disease may be zero or a very high level, rather than some intermediate point such as may be optimal with a disease such as mastitis. Economic analyses indicate that this reasoning would appear to apply to FMD control in Thailand.

Models of economic benefits (economic surplus) for disease control programs. Traditional economic models have been extended to take account not only of producer benefits, but impacts on traders, consumers of livestock products, government fiscal impacts, and trade gains from expanded foreign markets. The theoretical conditions for maximising economic gain (e.g. in terms of demand elasticities) were explored and identified. This conceptual analysis has been incorporated into a cost–benefit analysis of FMD control in Thailand.

Applied models of animal health economics

Data were collected from various sources to develop profiles of livestock (the meat cattle and buffalo, dairy, pig and poultry) industries in Thailand, as a background to investigating production benefits and trade opportunities from improved animal health. These reports have examined livestock numbers, management systems and disease status. Unlike cattle and buffalo, the pig and poultry industries have clearly defined commercial and village sectors, and disease control in the latter presents considerable difficulty (e.g. the cyclical nature of village pig production raises difficulties for regular vaccination against FMD).

As an understanding of socioeconomic aspects is important in predicting the success of animal health intervention measures by government, it was necessary to carry out socioeconomic analyses of the role of livestock in villages using cross-sectional survey data. The roles of women and of common property resources in the management of Thai village livestock production systems were also examined.

In macroeconomic analysis of livestock industries, a closed general equilibrium (CGE) model was applied to examine the relationship between output of the livestock sector (as influenced by disease control measures) and other Thai industries.

Economics of animal health information systems development

This research focused on cost-effective multi-stage sampling designs for active surveillance of FMD protection status. The World Health Organisation recommended design of 30 villages and 7 subjects (in this case, animals) from each was found to be quite robust to variations in population protection status and sampling cost parameters. In active surveillance for FMD (tests of seroprevalence), there was a tendency for 'natural' optima to arise with respect to sampling designs, due to cost discontinuities.

Separate from the economic evaluation of the economic benefits of animal health programs was the issue of the economic evaluation of the prototype GIS system which has been developed for three northern provinces in Thailand. While this GIS work has demonstrated how to overcome various obstacles in development of a modern information system for animal health, the expenditure incurred by it would be different from that for a national 'production' system of animal health information. As key details of information system costs were not collected or available it was not possible to carry out this economic assessment.

Conclusion

A new strategy for animal health information system research in Southeast Asia is reported in this book. Information technology-based active surveillance (including GIS) forms the core of this strategy. The methodology was developed in northern Thailand and tested under relatively more difficult conditions in the Lao PDR. Some components of the work on economic aspects of animal health information systems were carried out in

Australia. Results indicate that the methodology can be applied elsewhere in Southeast Asia and in the developing countries generally.

Bibliography

Blood, D.C. and Brightling, P. 1988. National animal disease databanks. In: Veterinary Information Management. London, Ballière Tindall, 153–160.

Cameron, A. R. 1998. Active surveillance and GIS as components of an animal health information system for developing countries. Unpublished Ph.D. thesis, Brisbane, The University of Queensland.

Clarke, K.C., McLafferty, S.L. and Tempalski, B.J. 1996. On epidemiology and geographic information systems: a review and discussion of future directions. Emerging Infectious Diseases, 2, 85–92.

Garner, M.G. and Nunn, M.J. 1991. Requirements for an Australian animal health information system. In: Sergeant, E.S.G., ed., Proceedings of the AVA/NZVA Pan Pacific Conference on Veterinarians and the Environment. Sydney, Australian College of Veterinary Scientists, 7–16.

Hueston, W.D. 1993. Assessment of national systems for the surveillance and monitoring of animal disease. Revue scientific technologie, Office International des Epizooties, 12, 1187–1196.

Kish, L. 1995. Survey sampling. New York, Wiley.

McCallon, W.R. and Beal, V.C. Jr. 1982. The fallacy of drawing inferences from biased data: some case examples. In: Proceedings of the 86th Annual Meeting of United States Animal Health Association. Richmond, United States Animal Health Association, 350–358.

OIE (Office International des Epizooties) 1993. World animal health in 1993. Paris, Office International des Epizooties.

Pfeiffer, D.U. and Morris, R.S. 1994. Spatial analysis techniques in veterinary epidemiology. Kenyan Veterinarian, 18, 483–485.

2 Epidemiology and Dynamics of Major Livestock Diseases in Southeast Asia

A.R. Cameron
C. Baldock
P. Chamnanpood

Abstract

Understanding the epidemiology and patterns of occurrence of disease is crucial in the progress toward control (and eventual eradication) of diseases. Of the transmissible diseases listed by the Office International des Epizooties, the three most widely reported in Southeast Asia are foot-and-mouth disease of cattle and buffalo, classical swine fever of pigs and Newcastle disease of poultry. Other diseases of particular concern include anthrax, rabies, haemorrhagic septicaemia and Aujesky's disease. This chapter outlines the epidemiology of the aforementioned diseases as well as their distribution in Southeast Asia. In addition, factors are examined which affect the movement of disease, which can be at two levels: (i) transmission of infection within a population or (ii) spread of infection between populations. The two main tools for controlling disease spread are identified as vaccination and control of livestock movements. Livestock movement patterns (and the underlying reasons for these) within Southeast Asia are examined in this context.

Introduction

An enormous range of diseases impacting upon the health and productivity of livestock occur around the world. In 1924, the International Office of Epizootics (Office International des Epizooties—OIE) was established to

> *"inform and advise veterinary services of its member countries in order to contribute to the eradication of those animal diseases most dangerous for animals or humans, and to establish the health standards for international trade" (OIE mission statement).*

In keeping with the OIE's mission to assist with the eradication of important diseases, a plan has been established for the eradication of foot-and-mouth disease from Southeast Asia. This chapter reviews the major livestock diseases that occur in the region, and highlights some of the key aspects of their epidemiology that influence the possibility of control or eradication. The role of livestock movement in the spread of disease and the impact this has on the prospects for regional disease control and eradication programs is explored.

Major Livestock Diseases

In order to define which animal diseases are '*most dangerous for animals or humans*', the OIE, in collaboration with the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organisation (WHO), has established a three tier disease classification system—List A diseases, List B diseases, and Other diseases. Under the OIE definition, List A diseases are defined as

> *"transmissible diseases which have the potential for very serious and rapid spread, irrespective of national borders, which are of serious socioeconomic or public health consequence and which are of major importance in the international trade of animals and animal products".*

List B diseases are defined as

> *"transmissible diseases which are considered to be of socioeconomic and/or public health importance within countries and which are significant in the international trade of animals and animal products".*

Both List A and List B diseases are reportable to the OIE international disease reporting system. The third category, Other diseases, consists of all other animal diseases not appearing on Lists A or B, and are not notifiable to the OIE.

Tables 1 and 2 list all the OIE List A and List B diseases (OIE 1995–1998). While both List A and List B diseases are considered to be of socioeconomic or public health importance, and are significant in international trade, the distinguishing features of List A diseases is that they are capable of rapid spread *irrespective of national borders*.

Table 1 shows the distribution of List A diseases throughout Southeast Asia, as published by the OIE, and is a composite of several years data from 1995 to 1998. The only three diseases from the list to have been reported are foot-and-mouth disease of cattle and buffalo, classical swine fever of pigs, and Newcastle disease of poultry. In interpreting this table, it is important to understand that the OIE reporting system does not always include all diseases which occur in all countries. The system depends on submissions from national veterinary authorities, and the absence of a report does not necessarily indicate the absence of disease. For instance, some of the Southeast Asian countries listed have made no report of some of the listed diseases for several years. This may be due to the absence of the disease from the country, or weaknesses in the national disease surveillance systems such as under-reporting of disease, or inadequate diagnostic laboratory systems to make a definitive diagnosis.

It is reasonable to assume that the three listed diseases occur throughout the region (with a few exceptions), and that most of the other diseases do not occur in all of the countries. However it is possible that some diseases (such as avian influenza in particular) may in fact be present in some countries but not reported.

Table 1. Occurrence of List A diseases in Southeast Asia as reported to the Office International des Epizooties (OIE), 1995–1998.

	Indonesia	Malaysia	Philippines	Thailand	Vietnam	Cambodia	Lao PDR	Burma	Taiwan
Foot-and-mouth disease		●	●	●	●	●	●	●	
Vesicular stomatitis									
Swine vesicular disease									
Rinderpest									
Peste des petits ruminants									
Contagious bovine pleuropneumonia									
Lumpy skin disease									
Rift Valley fever									
Bluetongue									
Sheep pox and goat pox									
African horse sickness									
African swine fever									
Classical swine fever	●	●	●	●	●	●	●	●	●
Avian influenza									
Newcastle disease	●	●	●	●	●	●	●	●	●

Table 2. Office International des Epizooties (OIE) List B diseases.

Multi-species diseases	Cattle diseases	Sheep and goat diseases	Equine diseases	Pig diseases	Avian diseases
Anthrax	Bovine anaplasmosis	Caprine and ovine brucellosis (excluding *Brucella ovis*)	Contagious equine metritis	Atrophic rhinitis of swine	Avian chlamydiosis
Aujeszky's disease	Bovine babesiosis	Caprine arthritis /encephalitis	Dourine	Enterovirus encephalomyelitis	Avian infectious bronchitis
Echinococcosis/ hydatidosis	Bovine brucellosis	Contagious agalactia	Epizootic lymphangitis	Porcine brucellosis	Avian infectious laryngotracheitis
Heartwater	Bovine cysticercosis	Contagious caprine pleuropneumonia	Equine encephalomyelitis (Eastern and Western)	Porcine cysticercosis	Avian mycoplasmosis (*M. gallisepticum*)
Leptospirosis	Bovine genital campylobacteriosis	Enzootic abortion of ewes (ovine chlamydiosis)	Equine infectious anaemia	Porcine reproductive and respiratory syndrome	Avian tuberculosis
New world screwworm (*Cochliomyia hominivorax*)	Bovine spongiform encephalopathy	Maedi-visna	Equine influenza	Transmissible gastroenteritis	Duck virus enteritis
Old world screwworm (*Chrysomya bezziana*)	Bovine tuberculosis	Nairobi sheep disease	Equine piroplasmosis	Trichinellosis	Duck virus hepatitis
Paratuberculosis	Dermatophilosis	Ovine epididymitis (*Brucella ovis*)	Equine rhinopneumonitis		Fowl cholera
Q Fever	Enzootic bovine leukosis	Ovine pulmonary adenomatosis	Equine viral arteritis		Fowl pox
Rabies	Haemorrhagic septicaemia	Salmonellosis (*S. abortusovis*)	Glanders		Fowl typhoid
	Infectious bovine rhinotracheitis/ infectious pustular vulvovaginitis	Scrapie	Horse mange		

Table 2. (cont'd) Office International des Epizooties (OIE) List B diseases.

Multi-species diseases	Cattle diseases	Sheep and goat diseases	Equine diseases	Pig diseases	Avian diseases
	Malignant catarrhal fever		Horse pox		
	Theileriosis		Japanese encephalitis		
	Trichomonosis		Surra (*Trypanosoma evansi*)		
	Trypanosomosis (tsetse-borne)		Venezuelan equine encephalomyelitis		
Lagomorph diseases	**Fish diseases**	**Mollusc diseases**	**Bee diseases**	**Diseases of other animal species**	
Myxomatosis	Epizootic haematopoietic necrosis	Bonamiosis	Acariosis of bees	Leishmaniosis	
Rabbit haemorrhagic disease	Infectious haematopoietic necrosis	Haplosporidiosis (*H. nelsoni* or *H. costale*)	American foulbrood		
Tularemia	Oncorhynchus masou virus disease	Marteiliosis	European foulbrood		
	Spring viraemia of carp	Mikrocytosis (*Mikrocytos mackini*)	Nosemosis of bees		
	Viral haemorrhagic septicaemia		Varroosis		

Table 3 shows the reported distribution of selected List B diseases in the same region. This somewhat arbitrary list represents diseases for which control programs are in place in a number of the countries of the region. Their status as List B diseases indicates that they are not considered to be as important as the three diseases mentioned above. For this reason, some national disease surveillance systems may not concentrate on identifying these diseases, resulting in the risk of under-reporting in some countries. It may therefore be assumed that the diseases listed in Table 3, with a few exceptions, are distributed throughout most of Southeast Asia.

Table 3. Distribution of selected Office International des Epizooties List B diseases in Southeast Asia (Bernardo and Schuyler 1993; OIE 1995–1998).

	Indonesia	Malaysia	Philippines	Thailand	Vietnam	Cambodia	Lao PDR	Burma	Taiwan
Anthrax	•	•	•	•	•	•	•	•	
Aujeszky's disease		•		•			•		•
Rabies	•	•	•	•	•	•	•	•	
Haemorrhagic septicaemia	•	•	•	•	•	•	•	•	

Epidemiology of Key Diseases

This chapter does not aim to provide an authoritative description of the epidemiology of all the diseases mentioned. Rather the following section highlights some of the features of the diseases that are significant in the spread of the disease through populations and must be taken into account when considering control measures (Blood and Radostits 1994; Geering 1995). The key features of each of the diseases will be considered in turn followed by a discussion of common factors.

Diseases affecting multiple species

Foot-and-mouth disease

Foot-and-mouth disease (FMD) is a viral disease caused by a picornavirus. There are seven major types, of which four occur in Southeast Asia: A, O, C and Asia 1. There is little cross-immunity between types, so that, from a control point of view, they represent separate diseases. The disease can infect all cloven-hoofed animals, but is mainly a problem of cattle, buffalo, pigs, sheep and goats. There is variation between strains as to the pathogenicity and the ability to infect different species. Normally, the disease spreads rapidly in a non-immune population, causing very high morbidity, but low mortality. In some cases (e.g. when infecting young pigs) mortality rates can be very high.

The most obvious signs of the disease are vesicles in the mouth (around the tongue, dental pad and bucal mucosa), and around the feet (in the clefts and on the coronary band). These result in salivation and lameness.

The incubation period is short, from two to six days. Vesicles rupture within a few days of appearing, and usually heal rapidly. The main mode of spread is via respiratory aerosols and contaminated saliva. In Europe, pigs are often less severely affected and are responsible for enormous multiplication of the virus, resulting in wind-borne plumes that may spread the disease over long distances. There is little evidence of wind-borne spread of the disease in Southeast Asia, probably due to the short survival of the virus under warm conditions and when exposed to sunlight. While signs are traditionally more severe in cattle, some strains present in Southeast Asia are highly pig adapted, causing severe disease and mortality, while rarely infecting cattle or buffalo.

A small proportion of recovered animals can become carriers, with virus able to be recovered from the pharynx for many months. In the case of cattle and African buffalo, it seems likely that these animals may play a role in the spread of the disease. Pigs are unlikely to have a carrier status and the situation with Asian water buffalo is not known (Thomson 1996). The main modes of spread in Southeast Asia are livestock movement (of preclinical, clinical, or recovered cases that are still shedding virus), or via livestock products and fomites. The virus can survive for long periods in meat and other foodstuffs from pigs and cattle. Swill feeding pigs with uncooked contaminated foodstuffs is a common mode of spread in some situations.

Anthrax

Anthrax is a bacterial disease caused by *Bacillus anthracis*, affecting many species (including humans) but of most importance in ruminants, horses and pigs. After an incubation period of one to two weeks, the disease causes sudden death. When exposed to air, the bacteria forms highly resistant spores which may persist in the soil for decades. Outbreaks usually occur with sudden changes in climatic conditions, either reactivating the spores or causing livestock to ingest more. Infection is usually through the ingestion of contaminated material. In uncontrolled outbreaks, secondary cases can occur through infection from carcasses. Unlike FMD, anthrax is not a directly transmitted disease and control is made difficult because of its unpredictable and intermittent occurrence.

Rabies

Rabies is a disease capable of affecting all mammals and birds. It is caused by a rhabdovirus. The virus is unable to penetrate intact skin, and infection is almost always through a wound via contaminated saliva. It is thought that the virus replicates locally, and is then transmitted to the brain via the neurons. From the brain, it is transmitted to the salivary glands and other areas. A range of neurological signs commence with the infection of the brain. The disease is virtually always fatal after the onset of clinical signs. In Southeast Asia the disease is mainly spread by dogs. While it can infect livestock, the major concern is the public health risk.

Aujeszky's disease

Aujeszky's disease (or pseudorabies) is a viral disease caused by a herpesvirus primarily affecting pigs, but capable of infecting cattle, sheep, dogs and cats. The impact of disease is highly dependent on the age of infected pigs, with high mortality in piglets under two weeks, nervous signs in slightly older piglets and a mild or subclinical disease in adults. The disease is spread mainly through the movement of subclinically infected adults.

Cattle

Haemorrhagic septicaemia

Haemorrhagic septicaemia is a bacterial disease of cattle and buffalo caused by *Pasteurella multocida*. The organism is relatively widespread, but only particular types are responsible for the disease. Infection is usually through direct contact with an infected or carrier animal, or food or other materials contaminated with infected saliva. Morbidity in an outbreak is variable, but mortality in untreated, clinically affected animals is very high. The disease causes profuse salivation, and a painful swelling under the throat and brisket. Outbreaks may be precipitated by stress.

Pigs

Classical swine fever

Classical swine fever (CSF or hog cholera) is caused by a pestivirus, similar to that causing bovine viral diarrhoea. There is enormous variation in the pathogenicity of strains, from those causing a mild or inapparent disease to those causing very high mortality. Clinical signs of pyrexia, weakness, reddened skin, and diarrhoea appear 2–6 days after infection, and death occurs 5 to 20 days after exposure. Transmission of the low virulent strains is unclear and complex, with in utero infection of piglets playing a role. However, the highly virulent strains are largely transmitted though direct contact with infected animals and via the faeces. The disease can also be transmitted via contaminated pig meat.

Poultry

Newcastle disease

Newcastle disease (ND), caused by a paramyxovirus, affects mainly chickens, pheasants and turkeys, although all bird species are susceptible. Strains causing no clinical disease exist, while the most pathogenic strains cause depression, diarrhoea and very high mortality. The disease is transmitted by close contact with infected or carrier birds, or contaminated fomites.

Factors Affecting the Movement of Disease

Movement of disease can occur at two levels: (1) the carriage of an infectious agent from an infective to a susceptible individual within an infected population or subdivision of a population (called the *transmission of infection*) and (2) the movement of infection from an infected population or subdivision of a population to a susceptible population or subdivision (the *spread of infection*). During an outbreak in a herd or village, disease will generally be transmitted amongst all susceptible, in-contact animals, until they either die or develop immunity. In diseases which are followed by a long-term carrier state, the disease may reappear when the proportion of susceptible animals has increased, either through waning immunity, birth of new animals, or the introduction of susceptible animals into the herd. When the carrier state is rare, or short-lived, the disease will die out within the herd, and only reappear when reintroduced from another herd. This is the pattern observed with the more highly contagious diseases—FMD, CSF, haemorrhagic septicaemia and ND. With the other diseases (anthrax, rabies and Aujeszky's disease) transmission of the disease through a mixing population may be slower. In this case, there will always be susceptible animals, and the disease will be able to persist within the herd.

Spread of a disease on a regional basis requires movement from herd to herd or village to village. With all the diseases discussed (except for the spores of anthrax which persist in the soil), the main long distance mode of spread of disease is through the movement of live animals. If the role of carrier animals in the highly contagious diseases is small, the only way they can be maintained in an area is through the reintroduction of the agent into susceptible populations though the movement of livestock.

It is therefore clear that the two main tools for controlling these diseases are (1) ensuring that the susceptible population is as small as possible, through vaccination, and (2) preventing the long-distance spread of disease between herds or villages through livestock movement control. If either of these strategies were implemented perfectly, they may be adequate to eradicate certain diseases. In an imperfect world, it is necessary to use both approaches to controlling disease.

Vaccines are available against each of the diseases under consideration, however there are many difficulties faced in trying to control disease by vaccination alone. Few of the vaccines available confer lifelong immunity, which means that constant revaccination is necessary to maintain a high level of immunity in the population. In many Southeast Asian countries, access to vaccination by smallholders is extremely difficult, and resources for the purchase of vaccine are limited.

Livestock Movement Patterns and Disease Spread in Southeast Asia

There are a number of factors capable of influencing patterns of livestock movement and the risk of disease spread. This section shall examine some of these: the natural barriers of seas and mountains, the effect of human population distribution, and the influence of cultural patterns.

Geographically, Southeast Asia can be divided into two regions—the islands and the mainland. The islands consist of the Philippines, Indonesia and part of Malaysia. On the mainland, the movement of livestock between different areas can occur via a wide range of routes. Often there is not even a need for roads, and animals can be transported between any two points with little chance of detection by the authorities. Controlling livestock movement in these circumstances poses great challenges.

On the other hand, the movement of livestock between islands can only be done by ship (or aircraft). The number of ports on an island capable of handling livestock are usually limited, so it is much easier to control their movements. The general difficulty of travelling between islands means that the number of movements between areas are often less than on the mainland. For these reasons, disease control is usually somewhat easier when working with islands. The problem of eradicating a disease can be done step by step, island by island. This is no doubt a major factor in the success of Indonesia and Taiwan, and the good progress being made by the Philippines in eradicating FMD, in contrast to the slow progress being made in Thailand, despite strenuous efforts.

The sea, therefore, forms a natural barrier to livestock (and disease) movement for much of Southeast Asia. On the mainland, however, there are other physical and non-physical barriers that influence the patterns of livestock movement in the region.

The most obvious physical barriers to livestock movements in mainland Southeast Asia are the mountains surrounding the region. Figure 1 shows a relief map of mainland Southeast Asia. The mountain mass extending from the Himalayas, through southern China and into Lao People's Democratic Republic (PDR), Thailand and Burma acts as an effective barrier to major livestock movements to the north. Movements are somewhat limited by the Annamites between Lao PDR and Vietnam, and the Dawna Range between Thailand and Burma, but significant traffic of animals still takes place across these barriers. Similarly, the Chin and Naga hills of western Burma do not pose a significant barrier to livestock trade.

The major determinant of livestock movement is not provided by topography, but by humans and the laws of supply and demand. On a local scale, livestock movement patterns may vary considerably from month to month and year to year. However on a regional scale, the patterns will always reflect the main reason for rearing the major livestock species—feeding the human population and earning income.

One potential factor determining livestock movement and the risk of disease spread is the diet of cultural or religious groups. For instance, the prohibition of eating pork for Muslims certainly has an impact on the pig population and pig movement patterns in Malaysia and Indonesia. It is logical to assume that areas of high Muslim population would have low demand for pork, low pig populations and few pig movements. However, to act as a barrier for the spread of disease, this would require a significant band with virtually no pigs or pig movements. Despite the proportion of Muslims in Malaysia and Indonesia, there seems to have been little effect on the spread of CSF from the Malaysian pensinsular in 1997–98, apparently island hopping through much of Indonesia to reach the eastern Islands.

Areas of high human population density act as magnets for livestock. Cattle tend to be raised in areas of lower human population density. The patterns for production of chickens and pigs vary throughout Asia with the level of intensification. Where intensive production units exist (such as Thailand, Malaysia and the Philippines), the site of pig and chicken production is determined by availability of feed sources, and proximity to markets. The direction of movement from the units will always tend to be towards the human population centres.

Figure 1. Topography of mainland Southeast Asia (produced using the GTOPO30 data (Anon 1996) and ArcView GIS software).

In mainland Southeast Asia, an understanding of the livestock movement patterns and the forces that drive them can lead to an improved understanding of disease control options. Figure 2 shows the human population density for mainland Southeast Asia. A large proportion of the population is clustered around the urban centres of Bangkok, Ho Chi Minh City, Hanoi, Kuala Lumpur and Singapore.

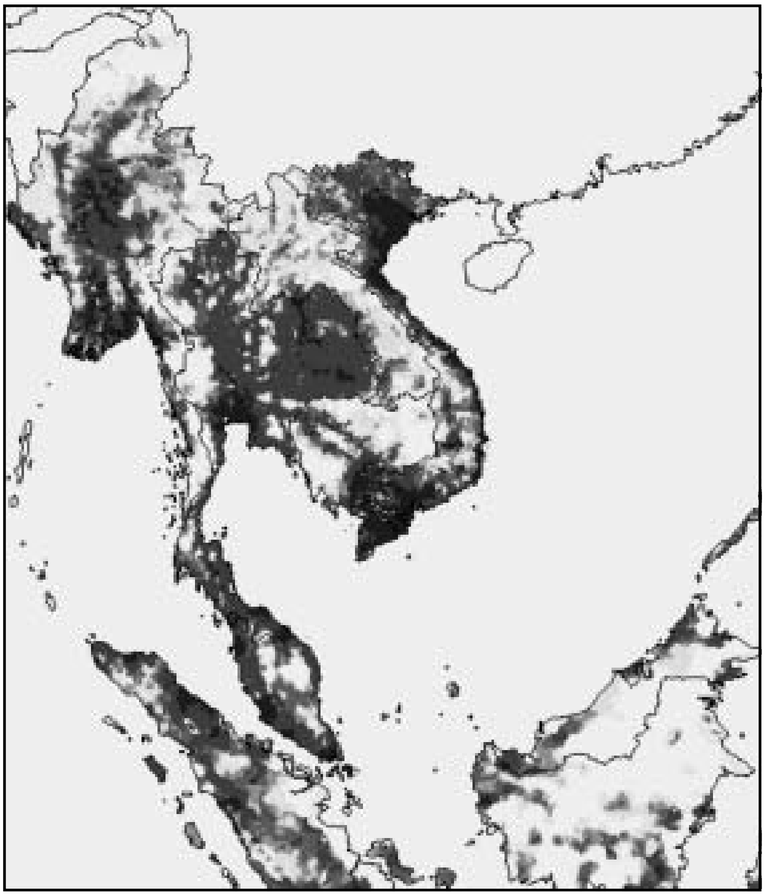

Figure 2. Human population density patterns in Southeast Asia (produced using the Asia Population Database (Deichmann 1996) and ArcView GIS software).

Figure 3 provides a graphical representation of the human population density in the region, highlighting the impact of the larger cities. To feed these population centres, the general trend for movement of livestock is from the central areas of Lao PDR, Cambodia, north and northeast Thailand towards the coast of Vietnam, and to Bangkok. Movement on the Malaysian peninsular is dictated by the population centre of Bangkok to the north and George Town, Kuala Lumpur and Singapore to the south.

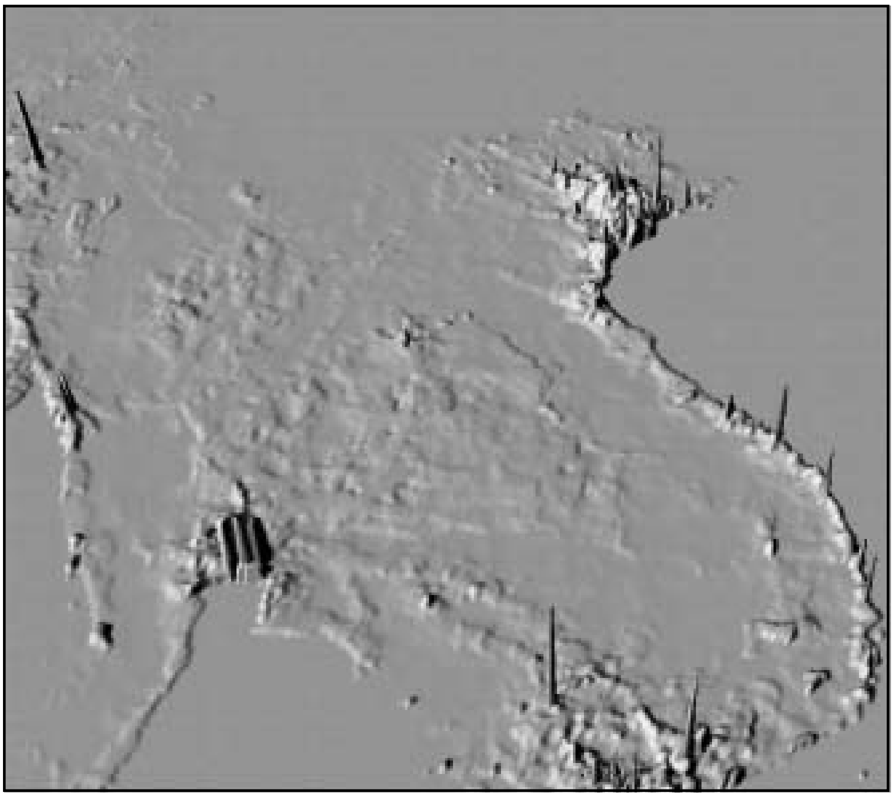

Figure 3. Pseudo-topographical relief image of human population density in Thailand, Cambodia, Vietnam, and Lao PDR (and part of Burma). Spikes indicate densely populated cities. Image produced using the Asia Population Database (Deichmann 1996), and 3DEM (Horne 1999).

Using topography and population patterns, it is possible to make conclusions about the patterns of livestock movement into and out of the region. In the north, mountains form a relatively effective barrier, as does the sea in the south, leaving passage open in the northeast and the west. In the northeast, between Vietnam and China, there is clear potential for the movement of livestock to spread disease. However, the large human population mass around Hanoi suggests that movements from China to the south would be unlikely to extend beyond this point, and that livestock movements in central Vietnam and north-eastern Lao PDR would tend to be towards Hanoi.

In the west, the enormous population of Bangladesh (not shown) provides a pressure for westward movement of cattle from central Burma. While a large number of animals move from Burma to Thailand, most of these come from the central and eastern parts of the country, and there is no pressure for movement of livestock from Bangladesh or western Burma.

Conclusions

Control of major livestock diseases throughout Southeast Asia poses significant challenges, with the ease of movement of livestock on the mainland making the task particularly difficult. National borders have little effect on livestock movement patterns, and national disease control programs are doomed to failure if they are carried out in isolation, with no cooperation from neighbouring countries. For this reason, a regional approach to disease control has been advocated by many, including the OIE and FAO.

All but one of the major livestock diseases discussed in this chapter are spread primarily through the movement of live animals. The use of a regional approach implies that, at the macro level, mainland Southeast Asia can be considered a relatively closed population. If disease eradication for specific diseases is undertaken (as is currently planned by the OIE for FMD in the region), there will be no benefit if it is impossible to keep the area free from disease due to incursions from neighbouring regions, such as the subcontinent and China. This discussion has shown that it may, indeed, be possible to consider mainland Southeast Asia as a separate region in terms of livestock movement patterns and the risk of disease incursion. The region may be demarcated by a line passing north through central Burma in the west, the mountainous southern Chinese border in the north, a line passing through northern Vietnam and Hanoi in the northeast, and various seas in the east and south. The level of development, difficult terrain, husbandry systems used, and high prevalence of many of the major diseases all mean that eradication, or indeed control of any of these diseases on a regional level will be a major challenge for the coming decades. However, the foundations being laid by the veterinary services in many countries today are essential preparations for the task ahead. Increasing regional cooperation, and donor support suggest that, in time, many of these diseases may well be successfully controlled.

References, Data Sources, Software and Further Reading

Anon. 1996. GTOPO30, 30 arc-second global digital elevation model (DEM) documentation (ftp://edcftp.cr.usgs.gov/pub/data/gtopo30/global).

ArcView GIS version 3.0a 1997. Environmental Systems Research Institute Inc.

Bernardo, T.M. and Schuyler, C. 1993. HandiSTATUS: help with world animal disease status—user tutorial and manual. IICA Miscellaneous Publications Series.

Blood, D.C. and Radostits, O.M. 1994. Veterinary medicine: a textbook of the diseases of cattle, sheep, pigs, goats and horses, 8th edition. W.B. Saunders Co.

Deichmann, U. 1996 Asia Population Database documentation, UNEP/DEIA/GRID, Geneva 3 May 1996 (http://grid2.cr.usgs.gov/globalpop/asia/).

Dunn, C.S. and Donaldson, A.I. 1997. Natural adaption to pigs of a Taiwanese isolate of foot-and-mouth disease virus. Veterinary Record, 141, 174–175.

Geering, W. A. 1995. Exotic diseases of animals: a field guide for Australian veterinarians. Canberra, Australian Government Publishing Service.

Gesch, D.B. and Larson, K.S. 1996. Techniques for development of global 1-kilometer digital elevation models. In: Pecora Thirteen, Human interactions with the environment—perspectives from space, Sioux Falls, South Dakota, August 20–22, 1996.

Horne, R.S. 1999. 3DEM version 7.0.5 (http://www.monumental.com/rshorne/3dem.html).

OIE 1995–1998. Office International des Epizooties Regional Epidemiology Yearbook, OIE regional office for Asia and the Pacific, Tokyo (http://ss.niah.affrc.go.jp/OIE/).

Thomson, G.R. 1996. The role of carrier animals in the transmission of foot and mouth disease. Comprehensive reports on technical items presented to the International Committee or to Regional Commissions. Paris, Office International des Epizooties, 87–103.

3

Principles of Disease Investigation and Surveillance in Livestock Systems

C. Baldock
A. Cameron
P. Black

Abstract

This paper discusses some of the basic elements necessary to provide good animal health information: investigation of disease occurrence; monitoring and surveillance; international guidelines; and animal health information systems. By understanding the basic epidemiology which creates disease patterns, livestock disease control authorities can undertake effective surveillance and control programs. Investigation of individual disease outbreaks requires a systematic set of procedures to help identify causes and source of the outbreak with a view to control and prevention of possible future ones. Disease surveillance is the continuous investigation of a given population to detect the occurrence of disease for control purposes. The data for surveillance programs may be generated by a number of methods which include clinical evaluations, laboratory reports, slaughter inspection data, screening tests, or owner reports. The codes of the Office International des Epizooties include guidelines on surveillance and risk analysis which form the basis of quarantine strategies and health certification used to prevent the international spread of disease through the movement of animal commodities. Animal health information systems provide the data required to facilitate trade under international agreements. A good animal health information system should provide a reliable picture of the disease situation in a specified animal population. It should have a clear purpose and incorporate planned methods of data acquisition, management analysis and interpretation.

Introduction

It is sometimes not appreciated that, although there are many chance elements in the spread of diseases in populations, the resultant patterns are not distributed randomly. Rather, these patterns have characteristics which can be observed and analysed to give a great deal of insight into the underlying processes. By understanding the basic epidemiology of diseases which create these patterns, livestock disease control authorities can undertake effective surveillance and control programs.

However, identifying the pattern and understanding the principal driving processes is usually very difficult. The problem is that records of disease occurrence are frequently very sparse and lack the level of detail required to be able to detect the underlying pattern. For infectious diseases particularly this situation is frequently exacerbated by the sensitivity of the information leading to lack of disclosure because of potential financial implications through loss of trade. However, this should not prevent disease control authorities from taking a scientific approach to disease investigation and surveillance.

This paper discusses some of the basic elements necessary to provide good animal health information: investigation of disease occurrence; monitoring and surveillance; international guidelines; and animal health information systems.

Investigating Disease Outbreaks

This section gives an epidemiological perspective to disease outbreak investigations. An outbreak has been defined as a short-term epidemic or a series of disease events clustered in time and space. The disease events are usually new cases of a disease occurring at a higher frequency than that normally expected. Throughout this section the terms epidemic and outbreak are used more or less interchangeably.

An outbreak investigation is a systematic procedure to help identify causes and sources of epidemics with a view to control of an existing epidemic and prevention of possible future ones. In most situations, the primary objective of an epidemic or disease outbreak investigation is to identify ways of preventing the further transmission of the disease-causing agent. The epidemiological approach to outbreak investigations is based on the premise that cases of a disease are *not* distributed randomly but occur in patterns within the at-risk population. It is the role of the epidemiologist to record and analyse these patterns to help meet the primary objective.

Nine basic steps

The procedure for an outbreak investigation follows nine basic steps. Not all steps are necessarily included in every investigation, nor do they always follow the same sequence. In practice, several steps will be undertaken simultaneously.

The nine basic steps are:

1.	Establish or verify the diagnosis.
2.	Define a 'case'.
3.	Confirm that an outbreak is actually occurring.
4.	Characterise the outbreak in terms of time, animal and place. This step involves measuring disease frequency and documenting the patterns.
5.	Analyse the data. This step involves calculating factor-specific attack rates and constructing an attack-rate table.
6.	Formulate working hypotheses in an attempt to identify the type of epidemic, the possible source and mode of spread.
7.	Undertake intensive follow-up investigations to identify high risk groups and possible further outbreaks.
8.	Implement control and preventive measures.
9.	Report the findings of the investigation with recommendations for dealing with future possible outbreaks of the same disease.

Each of these basic steps is further explained in the following sections.

1. The diagnosis

The initial provisional diagnosis in an outbreak is usually made on clinical signs, crude epidemiological patterns and gross pathology. Whenever possible, laboratory tests should be undertaken to verify the interim diagnosis. Since some laboratory procedures may require weeks to complete, the implementation of control measures is often based on the provisional diagnosis.

2. Define a case

Where large numbers of animals are dying rapidly, such as with haemorrhagic septicaemia in a village or botulism in a large feedlot, a case will simply be a dead animal. The need to distinguish between the small number of deaths due to other causes is trivial in such situations.

However, for many outbreaks specific criteria must be developed to define a case. These may be based on clinical, autopsy or laboratory findings. For example, in the bovine spongiform encephalopathy (BSE or 'mad cow disease') epidemic in the United Kingdom both clinical and histologically confirmed cases were used in studying the epidemic (Wilesmith et al. 1988).

A case may be based on part of an animal (e.g. the eye, limb or udder quarter), an individual animal or some aggregation of individuals such as a litter or herd. For example, with botulism in a feedlot a case is based on the individual affected animal but with Newcastle disease in smallholder chickens or foot-and-mouth disease a case may be an affected village.

Where the disease aetiology is initially obscure it is better to have a fairly broad case definition to ensure that all likely cases are investigated. The case definition can be refined as more information comes to light and the data reanalysed accordingly.

3. Confirm the outbreak

This step may seem superfluous but in many instances it is required, particularly where the disease is already endemic. For example, in many pig herds a certain level of pneumonia is expected but an undetected increase will lead to severe production deficits if not recognised early.

By definition, an outbreak or epidemic exists when the current incidence is in excess of the usual incidence of cases in the population determined to be at risk. The term 'excess' is obviously imprecise. This is usually not an issue for large, common source epidemics but can pose a problem for either propagated or vector-borne diseases.

4. Time, animal and place

From an epidemiological viewpoint it is important to characterise the outbreak in terms of the above three variables for diseases where the cause is obscure. The characterisation must be done in such a manner that hypotheses can be developed regarding the source, mode of transmission and duration of the outbreak. The information is organised in an attempt to find answers to the following kinds of questions.

Time:

1. What is the exact period of the outbreak?

2. Given the diagnosis, what is the probable period of exposure?

3. Is the outbreak most likely common source, propagated or both?

Animal:

1. Are there any characteristics about groups of animals for which specific attack rates vary?

2. Which groups have the highest and which have the lowest attack rates?

Place:

1. What are the significant features of the geographical distribution of cases?

2. What are the relevant attack rates?

Time

Variation with time in the frequency of occurrence of cases of a disease is called its temporal pattern. There are three basic time spans used to describe disease temporal patterns: the epidemic period, which is of variable length depending on the duration of the particular epidemic; a 12 month period to describe seasonal patterns; and an indefinitely long period of years to identify long-term trends. A knowledge of seasonal patterns and long-term trends is important when deciding whether or not an epidemic exists in the present period and in predicting future epidemics. For example, foot-and-mouth disease in some parts of Asia exhibits epidemic behaviour with a period of time, known as the inter-epidemic period, between epidemics. This is similar to many directly transmitted diseases which are highly contagious and produce a strong immunity in surviving animals.

The temporal pattern of an outbreak is described in terms of its epidemic curve. The epidemic curve is a graph showing the onset of cases of the disease in question either as a bar graph or frequency polygon. The first case identified for a particular outbreak is referred to as the *index* case. For infectious diseases, information about the index case can be valuable in ascertaining the source of the outbreak.

In general, an epidemic curve has four and sometimes five segments:

The five segments are shown in Figure 1.

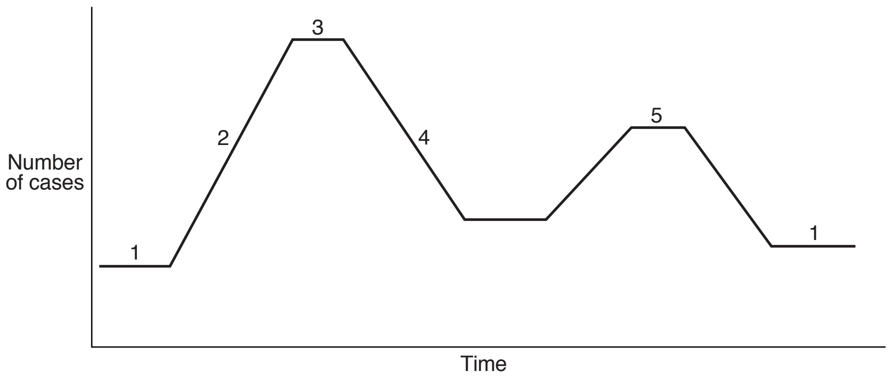

Figure 1. The five segments of a typical epidemic curve. (1) The endemic level; (2) an ascending branch; (3) a peak or plateau; (4) a descending branch; and (5) a secondary peak.

The slope of the ascending branch can indicate the type of exposure (propagating or common source) or the mode of transmission and incubation period of the disease agent. If transmission is rapid and the incubation period short, then the ascending branch will be steeper than if transmission is slow or if the incubation period is long.

The length of the plateau and slope of the descending branch are related to the availability of susceptible animals which in turn is dependent on many factors such as stocking densities, the changing importance of different mechanisms of transmission and the proportion of immunes in the population at risk.

Secondary peaks are usually due to the introduction of new susceptibles or a change in the mode of transmission. For example, with botulism, toxico-infectious transmission may result in a long plateau, a descending branch with a gradual slope and secondary peaks in the outbreak.

The interval of time chosen for graphing the cases is important to the subsequent interpretation of the epidemic curve. The time interval should be selected on the basis of the incubation or latency period of the disease and the period over which the cases are distributed. The appropriate time interval may vary from several hours (e.g. some acute intoxications) to a month or more (e.g. BSE). A common error in this regard is the selection of a time interval that is too long. Overly long intervals obscure subtle differences in temporal patterns including secondary peaks resulting from animal-to-animal transmission. A rule of thumb is to make the interval between one eighth and one quarter as long as the incubation period. It may be wise to make several epidemic curves based on different graphing intervals and then select the one which best portrays the data. However, it should be remembered that in many disease outbreaks in animals the time of onset of illness is often obscure and compromises must be made when making epidemic curves.

Outbreaks are often referred to as being either *common source* (cases resulting from exposure to the same, common source such as intoxications) or *propagated source* (animal-to-animal transmission such as most infectious diseases). In some outbreaks, both types of sources can be involved, the initial cases resulting from exposure to a common source and secondary cases resulting from animal-to-animal spread.

The duration of an epidemic is influenced by:

- the number of susceptible animals exposed to a source of infection who become infected;
- the period of time over which susceptible animals are exposed to the source; and
- the minimum and maximum incubation periods of the disease.

Outbreaks involving a large number of cases—with opportunity for exposure limited to a day or less—of a disease having a maximum incubation period of a few days or less, usually have an epidemic curve which approximates a 'normal' distribution (symmetrical bell-shaped curve). Such epidemic curves usually indicate a common source origin with exposure over a short period relative to the maximum incubation period of the disease.

Animal

Although the word 'animal' is used here, we should really refer to cases and non-cases and their characteristics to embrace the wider definitions where cases might be herds etc. For simplicity, the discussion is restricted to animals only.

Age, sex, geographical origin and genotype are frequently associated with varying risk of disease. However, it should be kept in mind that animal patterns can be closely linked to temporal and spatial patterns of disease.

To describe patterns of disease by animal types, it is first necessary to outline what measures of disease frequency are used in outbreak investigations. The basic measure of disease frequency in outbreaks is the *attack rate* (AR). An attack rate is a special form of an incidence rate where the period of observation is relatively short. An attack rate is the number of cases of the disease divided by the number of animals at risk at the beginning of the outbreak. Where different risk factors for the disease under investigation are to be evaluated, attack rates specific for the particular factor must be calculated. For example, say there were deaths of poultry in a village due to suspected hypervirulent infectious bursal disease (IBD) and it appeared that young birds were at greater risk of having IBD than adult birds. We might make the following calculations:

$$\text{For young birds, } AR1 = \frac{\text{No. with IBD}}{\text{Total young birds}} \qquad (1)$$

$$\text{For adult birds, } AR2 = \frac{\text{No. with IBD}}{\text{Total adult birds}} \qquad (2)$$

If some hypothetical numbers are used—say there were 1 000 young birds in the village and 300 died from IBD and there were 1 000 adult birds of which 100 died from IBD during the outbreak—the attack rates here are 30% and 10%, respectively, suggesting that young birds were three times more likely to die from IBD than adult birds. This finding could lend support to a hypothesis that young birds are more susceptible to infection, either because of their age or maybe because of their behaviour or maybe they have lower levels of immunity etc.

Formal measures to compare attack rates among groups of animals with different characteristics are described in the next section.

With IBD of course the total number of birds in different risk categories would have to be estimated through representative sampling. Another problem could be the estimation of number dying and when they died.

Place

Describing the outbreak in terms of place may lead to the cause. For cattle in feedlots, this may involve looking at the pattern among different pens whereas in more extensive cattle operations, studying different paddocks or villages may yield important clues. It is often useful to consider place and time together. This can be done by drawing a plan of the pen, farm or village layout and recording the dates where cases occurred. Such a diagram may also give a lead to whether the outbreak is a common source or propagating.

For larger scale epidemics, spot maps are useful.

5. Analysing the data

Factor-specific attack rates for such factors as age, breed, sex, feed, pen, management system etc. are computed and arranged in an *attack rate table* (see Table 1).

Table 1. A hypothetical example of an attack rate (AR) table for infectious bursal disease (IBD) in village poultry where age indicating different levels of pre-existing immunity is suspected as a risk factor. The second last column is the difference in attack rates (sometimes called the *attributable risk*) and the last column is the *relative risk* (RR) which is the ratio of the attack rates.

Factor	With factor			Without factor			AR Diff	RR
	IBD	Total	AR	IBD	Total	AR		
Chick	30	100	30%	35	500	7%	23%	4.3
Grower	20	200	10%	45	400	11%	–1%	1.1
Adult	15	300	5%	50	300	17%	–12%	0.3

The higher the attack rate difference and the relative risk, the more important the specific factor is in increasing the risk of disease. The analysis becomes more complicated when trying to sort out the interactions and confounding among factors. Stratified and multivariate analyses are used to investigate these phenomena.

It should also be noted in the above example that chicks were three times more likely to have IBD than growers and six times more likely than adults. Also, growers were at twice the risk of adult birds. This dose–response phenomenon when relating size to attack rate lends support to the hypothesis that level of pre-existing immunity as manifested by age is a component 'cause' of IBD in this outbreak.

6. Working hypotheses

Based on the analysis of time, place and animal data, working hypotheses are developed for further investigation. These may concern one or more of the following:

- whether the outbreak is common source or propagating;
- if a common source, whether it is a point or multiple exposure; and
- the mode of transmission—contact, vehicle or vector.

Any hypothesis should be compatible with all the facts.

Corrective action can be taken based on the more realistic hypotheses. For example, the epidemiological analysis of the BSE epidemic in Great Britain (Wilesmith et al. 1988) suggested a common source epidemic consistent with the hypothesis of transmission via ruminant-derived protein meal. The use of ruminant-derived protein in sheep and cattle feeds was subsequently banned because of the plausibility of this hypothesis.

In the case of an explosive outbreak, such as the sudden cattle feedlot deaths or IBD in village chickens, working hypotheses and initial corrective actions are needed within hours based on experience and first impressions. Formal analyses can be undertaken later to either confirm or refute initial impressions. For example, numerous sudden deaths in a feed lot with no apparent spatial pattern would initially suggest a common source epidemic so it could be useful to empty all the feed troughs and make sure water sources were clean and wholesome before proceeding further.

7. Intensive follow-up

This includes clinical, pathological, microbiological and toxicological examinations as well as epidemiological analyses. Epidemiological follow-up will include detailed analysis of the data as well as the search for additional cases on other premises. Flow charts of management and movement of animals and feedstuffs may be required as part of this process.

Feeding trials may be required where toxins are suspected as well as transmission experiments for possible infectious agents.

In some cases intensive investigation of recent environmental and weather events will also be important.

8. Control and prevention

Strategies to stop the epidemic must be put in place as soon as possible and will often be undertaken in the absence of conclusive findings. It may not be possible to stop an outbreak in a village once it starts but the detailed investigation of a number of outbreaks could provide valuable insight into possibly important 'component' causes.

9. Reporting

Finally, someone has to document the findings. For small outbreaks, this may take the form of a brief discussion with the farm manager outlining the important features and actions required to prevent future occurrences. However, it is wise to always produce some form of written report so that a permanent record of events exists for future use. For large outbreaks, findings should be published in the scientific literature.

Gardner (1990) has outlined the essential features of a report on an outbreak investigation. For substantial investigations the report should contain the following sections: background, methods, results, hypotheses, financial impact (where appropriate), recommendations and appendices containing laboratory reports etc.

Surveillance and Monitoring

The term *surveillance* implies an active process in which data are collected, analysed, evaluated and reported to those involved with a goal of providing better control of a disease or condition. The term *monitoring* is usually used for a more passive process although in common usage both terms are often used interchangeably. Because of the substantial cost involved programs usually encompass several diseases at the one time. The term surveillance may be unacceptable politically because of the connotation of spying on individuals.

Important questions that are often asked directly or indirectly as part of programs are:

- Is the frequency of the disease remaining constant, increasing or decreasing?
- What is the relative frequency of one disease compared with another?

- Are there differences in the geographical pattern of the condition?
- Does the disease have any impact on productivity and/or profitability?
- Is the disease absent from a particular herd, region, or nation?
- Is a control or eradication program cost-effective?

The data for surveillance programs may be generated by a number of methods which include clinical evaluations, laboratory reports, slaughter inspection data, screening tests, or owner reports.

Surveillance programs may be developed at a number of different levels. Some examples are listed below.

Individual farms—these usually include monitoring of economically significant variables to the individual, e.g. mortality, somatic cell count of milk, growth rate or milk production. The temporal pattern of these variables to identify potential problems is important.

Region or state—this may involve testing to establish freedom from particular diseases which may give individuals collective financial advantages over competitors, such as brucellosis freedom, or footrot protected areas.

National—such programs are usually very costly if active. To help defray costs these programs may predominantly be based on owner-made diagnoses and involve testing of only a sample of the national herd. Passive surveillance schemes are in place in many countries for the early detection of foreign and/or emerging diseases. Such schemes often depend on recognition by livestock owners or veterinarians of suspicious disease signs.

Validity of data

The validity of data is of primary concern when using field data for disease monitoring. For example, studies in the United States of America indicate that owners, and to a lesser extent veterinarians, are only able to categorise diseases into broad categories—for example, diarrhoea and pneumonia are usually not very sensitive or specific in the determination of the involvement of specific aetiologic agents. A recent study of preweaning mortality in pigs indicated that owners were only moderately sensitive but highly specific in identifying the cause of death among preweaned pigs. There were also marked differences among individual owners and with the age of the dead pig.

Surveillance systems should be designed to ensure that data of high quality be collected.

Misclassification of disease status usually leads to an underestimation of the frequency of the condition and its economic impact. Moreover, if the misclassification is non-differential the odds ratio will be biased towards 1 in studies of risk factors for the disease in question.

Population at risk

The biases described above affect numerator calculations but estimation of the population at risk is also important. Such denominators may be readily established on an individual farm but often become increasing more difficult to establish for state and national programs unless good data bases are available.

Monitoring based on prevalence or incidence data

One of the main difficulties in recording incidence data is the necessity to maintain a continuous watch over the population to record new occurrences of disease. Prevalence is a poor substitute for incidence for diseases with high mortality or high case fatality rates. Incidence may, however, be estimated from repeated prevalence surveys of endemic disease.

Production and disease targets

An important component of production and disease monitoring is the setting of targets for important variables.

Two important questions that should be considered are:

1. How many need to be monitored?
2. How should targets be set for an individual herd? The following factors need to taken into consideration:

- the previous performance of the herd;
- comparable herds of the same size in the same area;
- where the owner would like to be in the future; and
- biological constraints.

For an exceptionally good herd, the goal may be to just maintain the herd's relative position or perhaps to redirect monitoring towards financial parameters including maintaining the same production level with fewer costs, e.g. reduce sow numbers by 10%.

Specialised computer-based software is available to assist with monitoring many health and production parameters in dairy and swine herds but most have only limited ability to analyse data and identify problems. The ability to achieve a higher level of sophistication in the analysis usually requires a veterinarian with sound epidemiological skills.

Techniques for monitoring temporal patterns in data

1. Graphs with eyeball interpretation
2. Shewhart charts
3. CUSUM (cumulative summation) technique
4. Time series analysis

Detecting disease

The prevention of disease spread through the movement of live animals can be reduced by diagnostic testing and certification by appropriate authorities. For terrestrial animals such as cattle, serological tests are available for many diseases and every animal in a shipment may be tested. However, such a strategy may be impractical in some instances and only a sample of animals may be tested to decide if the group is infected or not with a certain level of confidence.

What is not commonly realised is that testing for disease at the group level incorporates a number of factors additional to those relevant to testing at the individual animal level. Thus, techniques such as serology which may be highly sensitive and specific at the individual animal level can still result in misclassification of a high proportion of groups where only a small proportion are tested.

At the individual animal level, diagnostic test performance is determined by its sensitivity and specificity. From an epidemiological perspective, sensitivity is the proportion of animals infected with the agent of interest which test positive while specificity is the proportion of uninfected animals which test negative. Additional factors which come into play when a group of animals is to be classified are the number of animals tested, the prevalence of disease in the group and the level of statistical confidence required that the group is truly negative. The only way to be 100% confident that no animals comprising a particular group are infected with a particular agent is to test every animal in the group with a diagnostic test which has perfect sensitivity and specificity. However, if only a low proportion of individual animals in the group are infected and only a small number are tested there can be quite a high chance that infected groups will be misclassified as uninfected (see Table 2).

Table 2. The number of infected animals which can be in a group of 100 000 despite a sample testing negative using a test with perfect sensitivity and specificity at the individual animal level.

No. of animals in sample tested from group of 100 000 and found negative	No. of infected animals which could be in the group despite the sample testing negative (two levels of confidence shown)	
	95%	99%
100	2 950	4 499
500	596	915
1 000	298	458
10 000	29	44

The situation is further complicated where the diagnostic test being used has imperfect sensitivity and specificity which is the case for many of those in use in livestock.

OIE International Animal Health Code

The codes of the Office International des Epizooties (OIE) form the basis for the establishment of international arrangements and dispute settlement with regard to quarantine issues in agricultural trade between among countries of the World Trade Organisation.

For terrestial animals, the relevant code is the International Animal Health Code, sometimes simply called 'the code'.

OIE Code—surveillance

Expert consultations are used to assist in reviewing and developing codes. Any changes proposed by the relevant commissions must be ratified by member countries at an OIE general session. Through this process the OIE has developed international standards for surveillance for three diseases: BSE, rinderpest and contagious bovine pleuropneumonia.

The stated purpose of these standards is "to provide evidence that a country or region is free from disease or infection" and that "disease surveillance should be implemented by both:

a) a system of reporting any signs of disease activity which come to the notice of Veterinary Services or livestock owners; and

b) an active program of statistically-selected samples from host populations in order to detect clinical signs or other indications of the occurrence of the disease or transmission of infection."

In demonstrating that a country or zone is free of disease it will be necessary to conduct a surveillance program that would have a very high probability of detecting the disease if it were present. According to the contagious bovine pleuropneumonia guidelines, surveillance should include a combination of clinical, pathological, serological and microbiological methods based on an epidemiological approach. The mix of procedures will depend on the specific circumstances of the country or zone.

It is therefore clear that the surveillance system will need to include both passive and active elements. The herd is the sampling unit. A sampling unit for the purposes of disease investigation and surveillance is defined as a group of animals in sufficiently close contact that individuals in the group would be at approximately equal risk of coming in contact with the disease agent if there were an infectious animal in the group. Under the OIE codes, disease surveillance activities must be conducted on populations stratified according to the management system and by herd size. Herds are to be selected by proper random statistical procedures for each stratum.

For both rinderpest and contagious bovine pleuropneumonia, the guidelines on serological surveillance suggest that sample sizes must be sufficient to provide a 95% probability of detecting evidence of the disease if it were present at a prevalence of 1% of herds. As the number of samples required will be affected by the sensitivity of the test used, the sample size must be adjusted to allow for any lack of sensitivity in the testing procedure. Cattle and any other susceptible domestic species *must be included* in the sero-surveillance program. Wild susceptible species *must be sampled where possible* and domestic stock in contact with them *should be sampled intensively*.

OIE Code—risk analysis

Because of the potential impact of infectious diseases many countries are in the process of undertaking risk analyses to prevent the entry and spread of unwanted pathogens as trade in animal products increases under the various World Trade Organisation agreements. For example, in Australia a ban on the import of shrimp products not for human consumption was applied in November 1996. This was a direct result of the recent waves of infectious diseases which have occurred in farmed shrimp throughout the world and will be maintained until the results of a full import risk analysis are available. The reason the ban applies to products not for human consumption is that these include bait for fishing as well as manufactured aquatic animal foodstuffs which will come in direct contact with populations of both wild and cultured shrimp. This is regarded as posing a high risk of introduction of diseases until the risks can be more carefully evaluated.

The code on risk analysis contains new concepts to be embraced by animal disease control authorities. The code consists of four chapters: general considerations; guidelines for risk assessment; evaluation of veterinary services; and zoning and regionalisation of countries.

The principle of import risk analysis is to provide importing countries with an objective, defensible method of assessing the risks associated with the importation of animals, animal products, animal genetic material, feedstuffs, biological material and pathological material. The analysis should be transparent in order that the exporting country may be provided with a clear and substantiated decision on the conditions imposed for importation or refusal for importation.

Following these principles is preferable to a zero-risk approach because it should lead to a more objective decision and enable competent authorities to discuss any differences in conclusion which may arise concerning potential risks.

The components of import risk analysis identified by the OIE include:

1. *risk assessment* (identifying and estimating the risks and evaluating the consequences), *risk management* (identification, documentation and implementation of measures that can be used to reduce the risks and their consequences) and *risk communication* (means of communicating the results of the risk assessment to decision-makers, regulators, industry and the public);
2. evaluation of *competent authorities*; and
3. zoning within countries.

A standardised *risk assessment* method is prescribed in the code. The importing country should elaborate scenarios by which the introduction of a disease agent in an imported commodity and its subsequent exposure and transmission to animals is possible. Each scenario should comprise a set of factors that require identification (and quantification if possible) to allow estimation of risk. Four categories of factors are identified:

1. *country factors*—principally the prevalence of the disease agent in the population from which the commodity was drawn.
2. *commodity factors*—parameters specific to a particular commodity that affect the probability of disease agent presence and survival in a commodity at the time of import.
3. *exposure factors*—factors specific to the use and distribution of the commodity in the importing country which will affect the probability that a susceptible host species will be exposed and infected.
4. *risk reduction factors*—measures that can be applied to reduce the risk that a disease agent will be introduced into the importing country or exposed and/or transmitted to an animal.

For each of the above categories a number of options is identified in the code. In practice, information on each of the factors is obtained from available sources including precedents, scientific information, experience and expert opinion. Where possible, quantitative data are obtained for a factor. Where quantitative data is sparse or unreliable a qualitative risk assessment may be made.

Animal Health Information Systems

The international trading environment is changing. To remain competitive, both exporting and importing countries must anticipate and respond to these changes. The challenge will be to maintain an acceptable level of biosecurity while retaining access to export markets or protection from potentially 'risky' agricultural products.

Pressure for better information

There is a growing recognition among veterinary administrators throughout the world of the need for more quantitative and reliable information on livestock production and disease (Morris 1991). Better information is critical to efficient and effective disease control as well as becoming increasingly important in certification for international trade in livestock and livestock products. In developed countries, where production and health recording systems are now a key management tool in intensive animal industries, the issue is pertinent mainly to extensive grazing animal systems.

Animal health information is required for a number of purposes including:

- international disease reporting obligations;
- public health and product certification;
- certification of livestock exports;
- international trade negotiations;
- management of national disease control programs; and
- priority-setting for research.

Animal disease reporting in the Asian and Pacific regions was the subject of a recent international workshop (Anon 1990a) and country review (Anon 1990b) jointly sponsored by the Asian Development Bank and the OIE. Findings from this project emphasised the universality and urgency of the need for improved animal health information in the region.

The problem with many existing passive systems such as disease notification schemes and diagnostic laboratory records is that the basic data are frequently unrepresentative of the situation in the reference population (Ogundipe et al. 1989).

Overview of animal information systems

There are a number of published overviews of animal information systems (Blajan 1979; Blood and Brightling 1988; OIE 1988, 1991) as well as specific regional examples (King 1985; Rolfe 1985; Doohoo 1988; Ogundipe et al. 1989; McKenzie and Thompson 1991; Martinez et al. 1992).

Historically, information systems have serviced the need to record traditional government veterinary services of detecting disease outbreaks and assessing spread. Such systems keep account of activities and past progress rather than provide information on which to base decisions on future strategies. The need to rationally set priorities and identify the effectiveness of control strategies is gaining increasing importance with a concomitant recognition of the need for a variety of types of information depending on the particular purpose.

A good animal health information system should provide a reliable picture of the disease situation in a specified animal population. It should have a clear purpose and incorporate planned methods of data acquisition, management analysis and interpretation (see Figure 2). In addition, desirable attributes are prompt reporting procedures and ongoing quality assurance (Morris 1991).

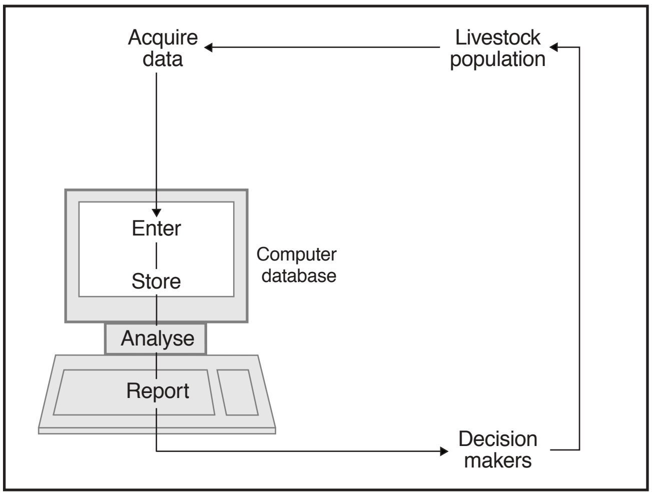

Figure 2. The general structure of an animal health information system and its relationships to data and decisions.

There are a variety of sources of information on livestock production and diseases (Thrusfield 1995). These include compulsory notification schemes; saleyard and abattoir records; reports from routine and special investigations such as surveys and sentinel monitoring as well as laboratory records and targeted active surveillance.

Conclusions

Developing good livestock disease surveillance systems means having capabilities in a range of areas. First, good disease investigation and diagnostic personnel and facilities are required to ensure reliable data are gathered. Second, there must be a good reason for collecting the data and the resultant reports must be useful in providing information on which sound decisions can be made. Finally, the communities likely to be affected by the decisions made as a result of animal health surveillance must be involved in the process and be provided with feedback.

Bibliography

Abila, R.C. 1997. The Philippines animal health information system. Proceedings, Epidemiology Program, 10th FAVA Congress, Cairns, Australia, 127–130.

Anon. 1990a. Improvement of animal disease reporting in the Asian and Pacific region. Vol I: the proceedings of a regional workshop on animal disease reporting. 186 pp.

——— 1990b. Improvement of animal disease reporting in the Asian and Pacific region. Vol II: a review of country needs and potentials for international collaboration. 160 pp.

Baldock, F.C. and Garner, M.G. 1998. Australia's national animal health information system. Proceedings, XX World Buriatrics Congress, Sydney, Australia, 31–35.

Bedard, B.G., Hutabarat, T.S.P., Johar, S., Meephuch, Y. and Joco, M.L.M. 1997. Animal health and production information system for ASEAN. Proceedings, Epidemiology Program, 10th FAVA Congress, Cairns, Australia, 115–121.

Black, P., Pitt, D., Ward, M., Mackenzie ,A., Cronin, J. and Baldock, C. 1997. The implementation of an active animal health surveillance program for the beef industry of Queensland, Australia. Proceedings, Epidemiology Program, 10th FAVA Congress, Cairns, Australia, 139–146.

Blajan, L. 1979. The systems for veterinary information at the national and world-wide levels. Bulletin of the Office International des Epizooties (OIE), 91, 795–821.

Blood, D.C. and Brightling, P. 1988. National animal disease databanks. In: Veterinary information management. London, Bailliere Tindall, 153–160.

Cameron, A. 1997. Using geographical information systems in livestock disease control. Proceedings, Epidemiology Program, 10th FAVA Congress, Cairns, Australia, 177–184.

Chillaud, T. 1997. Information requirements, including OIE specifications. Proceedings, Epidemiology Program, 10th FAVA Congress, Cairns, Australia, 109–114.

Doohoo, I.R. 1988. Animal productivity and health information network. Canadian Veterinary Journal, 29, 281–287.

Gardner, I. 1990. Reporting disease outbreaks. In: Epidemiology at work. Proc 144, Post Graduate Committee in Veterinary Science, University of Sydney, 29–42.

Hare, K.M. and Biggs, H.C. Design and evaluation of a veterinary information system for Namibia. Preventive Veterinary Medicine, 26, 239–251.

Hutabarat, T.S.P.N. and Morris, R.S. 1997. The development of an animal health information system for Indonesia. Proceedings, Epidemiology Program, 10th FAVA Congress, Cairns, Australia, 131–138.

Kellar, J.A. 1996. The effect of infrastructure on surveillance and monitoring programs. Comprehensive reports on technical items presented to the International Committee or to Regional Commissions. Paris, Office International des Epizooties (OIE), 125–132.

King, L.J. 1985. Unique characteristics of the national animal disease surveillance system. Journal of the American Veterinary Medical Association, 186, 35–39.

Lessard, P.R. and Perry, B.D. 1988. Investigation of disease outbreaks and impaired productivity. The Veterinary Clinics of North America, Food Animal Practice, Vol 4, Number 1.

Martin, S.W., Meek, A.H. and Willeberg, P. 1987. Veterinary epidemiology—principles and methods. Ames, Iowa, Iowa State Univ Press, 283–291.

Martinez, T.A., Kaneene, J.B., Lloyd, J.W. and Brown, M.I. 1992. Potential users and user requirements of an animal-health monitoring system in a developing country: case study of Honduras. Preventive Veterinary Medicine, 13, 1–11.

McKenzie, J. and Thompson, J. 1991. New Zealand's national animal health information system. Surveillance, 18, 12–15.

Morris, R.S. 1991. Information systems for animal health: objectives and components. Review Scientifique et technique Office International des Epizooties, 10, 13–23.

Ogundipe, G.A.T., Oluokun, S.B. and Esuruoso, G.O. 1989. The development and efficiency of the animal health information system in Nigeria. Preventive Veterinary Medicnine, 7, 121–135.

OIE 1988. Veterinary Information Systems. Review Scientifique et technique Office International des Epizooties, 7, 439–638.

□ □ □ 1991. Epidemiological Systems. Review Scientifique et technique Office International des Epizooties, 10, 7–231.

Pharo, H.J. 1997. Using surveillance information for risk analysis and assessment for planning of disease control programs. Proceedings, Epidemiology Program, 10th FAVA Congress, Cairns, Australia, 185–188.

Rolfe, D.C. 1985. Disease information systems. Proc No 79, Post-Graduate Committee in Veterinary Science, University of Sydney, 87–112.

Sanson, R.L., Morris, R.S., Stern, M.W. 1997. The epidemiological management system (EpiMan). Proceedings, Epidemiology Program, 10th FAVA Congress, Cairns, Australia, 171–176.

Sergeant, E.S.G., Cameron, A.R., Baldock, F.C. and Vongthilath, S. 1997. An animal health information system for Laos. Proceedings, Epidemiology Program, 10th FAVA Congress, Cairns, Australia, 157–160.

Thrusfield, M. 1995. Sources of data. In: Veterinary epidemiology (2nd Edition). London, Butterworths, 143–150.

Wilesmith, J.W., Wells, G.A., Cranwell, M.P. and Ryan, J.B. 1988. Bovine spongioform encephalopathy: epidemiological studies. Veterinary Record, 123, 638–644.

4 Economic Issues in Animal Health Programs

S.R. Harrison
C. Tisdell
G. Ramsay

Abstract

The economic component of the Thai–Australia animal health program has examined a variety of issues concerning livestock diseases and control and eradication programs in Thailand and Australia. This has involved gaining an understanding of production and marketing systems in the various livestock industries. Methods of economic evaluation of disease costs and animal health programs have been examined and applied to the Thai foot-and-mouth disease (FMD) control and eradication program. Although faced with major data limitations, the economic studies have revealed significant potential benefits but also major risks associated with this program. Economic studies have also shed light on cost-effective sampling designs for active surveillance of disease incidence, prospects for expansion in livestock trade, and distribution of benefits from disease eradication.

Introduction

In a broad sense, the economic component of the Thai–Australia Animal Health Program has been concerned with generation of *information* on costs and benefits of animal health programs. More specifically, the economic research has focused in particular on the Thai control and eradication program against foot-and-mouth disease (FMD) in cattle, buffalo and swine. However, this has necessarily involved investigation of a variety of issues. Some of the specific areas which have been investigated include:

- the role of economics in animal health programs, including integrating economists into multidisciplinary animal health teams;
- the appropriate framework and methodology for economic analysis;
- estimation of costs of livestock diseases;
- the nature, extent and distribution of benefits from disease control and eradication;
- data needs, availability and validity for economic analysis;
- production systems and trade in Thai livestock industries; and
- the cost-effectiveness of various components of the Thai FMD control and eradication program, e.g. active surveillance of disease incidence, mass vaccination, and transport controls.

Some consideration has been given to other diseases in cattle, buffalo and pigs, as well as poultry diseases. In addition, a component of the research has focused on the value of information for animal health programs in Queensland, Australia.

Within this broad context, a number of studies have been carried out to investigate particular aspects of Thai livestock industries and cost–benefit aspects of animal health programs. This paper will first examine conceptual and theoretical issues of economic analysis, then summarise the results of a number of particular economic studies. The material presented here draws on the series *Research Papers and Reports in Animal Health Economics*, published by the Department of Economics of The University of Queensland, which comprises over 40 papers produced during the Australian Centre for International Agricultural Research (ACIAR) project.

The Role and Methods of Economic Analysis in Animal Health

In general, economic analysis is designed to provide decision-support information for government and private agents involved in livestock industries. Such information increases knowledge of the economic trade-offs involved when particular policies are adopted. The analysis takes an anthropocentric approach in that alternative policies are evaluated in terms of costs and benefits to humans (producers, consumers, traders, government). In general, a social cost–benefit framework is adopted in which the economic criterion applied is 'willingness-to-pay', which can be measured in terms of producer and consumer 'profit' or *economic surplus*.

In a multidisciplinary project such as the Thai–Australian Animal Health Project, economic analysis relates to and draws on technical information on livestock production and disease impact parameters, so that costs and returns to the various stakeholder groups can be examined. The economic analysis can only be as reliable as the technical information on which it is based, although sensitivity analysis can be applied to determine the impact of varying parameter estimates.

Economic evaluation of national animal health programs requires analysis from the producer level through to the national level and the inclusion of trade impacts. To the extent possible, cost and benefit categories should include both direct and immediate changes in livestock production as well as long-term changes in herd structure and genetic quality, ability to intensify production, and non-market impacts such as those relating to animal welfare and the environment.

Development and Adaptation of Economic Theory to Animal Health Issues

A relatively small number of economists have expert skills in economic analysis of animal health programs, and economic evaluation frameworks used for their work remain controversial. Hence it has been necessary to consider appropriate evaluation methods for the particular issues examined.

Optimal disease control effort

The social cost–benefit analysis (CBA) framework generally accepted for evaluation of animal health programs involves making estimates of all socially relevant costs and benefits, including both market and non-market items, and hence deriving ‘incremental cash flows’ for the ‘with control’ and ‘without control’ situations. From these, discounted cash flow performance criteria such as benefit-to-cost (B:C) ratios, net present value (NPV) and internal rate of return (IRR) can be derived. In practice, difficulties can arise in interpreting these criteria. When expenditure levels vary, the NPV may not rank alternative animal health programs correctly. One program with a slightly higher NPV than another may involve substantially greater expenditure, hence the rate of return on investment may be lower. Under particular cash flow patterns, the IRR can be non-existent, non-unique or perverse (increasing as the cost of capital increases). Also, it has been demonstrated that the comparison of B:C ratios for alternative disease control programs could lead to an inferior choice (McInerney 1991). A control program involving a relatively small expenditure could have a higher B:C ratio than a more ambitious program, yet the program involving the greater expenditure could result in greater overall benefits.

In an attempt to define optimal expenditure on animal health more clearly, a graphical exposition involving a loss–expenditure tradeoff curve has been developed (McInerney 1988, 1991; McInerney et al. 1992). This takes the form of a concave tradeoff curve between disease cost (C) and control expenditure (E) as illustrated in as in Figure 1. The points along this *loss–expenditure frontier* may be taken to represent the capitalised value, or discounted sum, of disease and expenditure costs over a number of years. This curve represents the choice set available to a country in terms of effort on disease control. With no control expenditure, there is a high disease cost c_1. As control expenditure is increased, disease cost first decreases rapidly, the C–E tradeoff curve being almost vertical, but with increasing expenditure the curve flattens as the marginal rate of improvement with respect to cost declines. If the disease can be eradicated, control expenditure may fall to zero or to some low amount representing the cost of preventing new outbreaks.

Since both axes are expressed in dollar terms, and a dollar in disease cost is regarded as equivalent to a dollar in control costs, the line with slope –1 represents combinations of equal cost to the country, i.e. an *isocost line*. One such line is drawn in Figure 1; this is the line which is tangent to the C–E curve. Any C–E combination to the right of this line would represent greater overall cost while any point to the left is not achievable. Hence e^* is the optimal expenditure level and is associated with a disease cost c^* (total cost $c^* + e^*$). For this formulation, the disease cost variable would need to embrace all relevant items including non-market costs (e.g. environmental impacts, animal welfare changes).

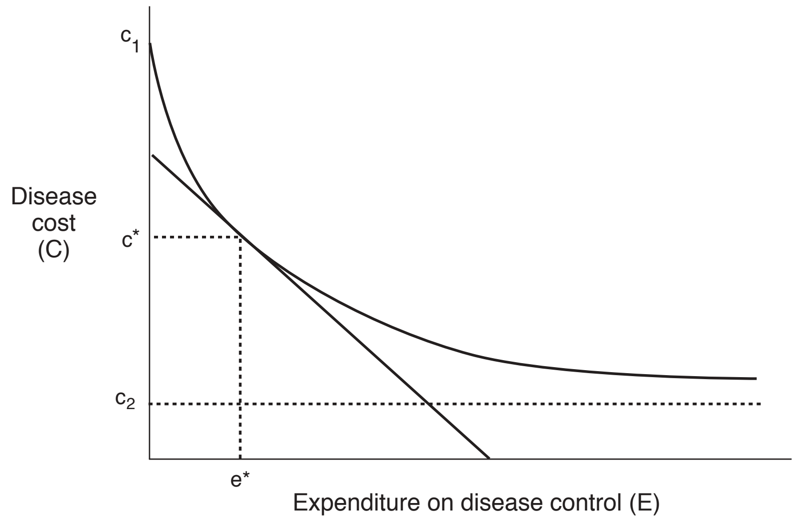

Figure 1. The McInerney loss-expenditure trade-off model

The McInerney model has two important limitations. The first concerns setup costs such as construction of a vaccine production plant, recruiting staff, and public awareness programs, all of which impose overhead costs before any control activities can be conducted in the field. In Figure 2, the kinked nature of the C–E curve results in the optimal control expenditure being much greater in relative terms than in Figure 1. A moderate level of control expenditure such as e_1 results in the worst of both worlds, namely substantial control expenditure and little or no reduction of disease costs.

Figure 2 also reveals that the option of zero control expenditure may be superior to most of the possible expenditure levels on the C–E tradeoff curve. In fact, the disease cost when there is no control expenditure (c_1 in Figure 2) would only have to fall by a small amount to be on a lower isocost line that the point identified as optimal.

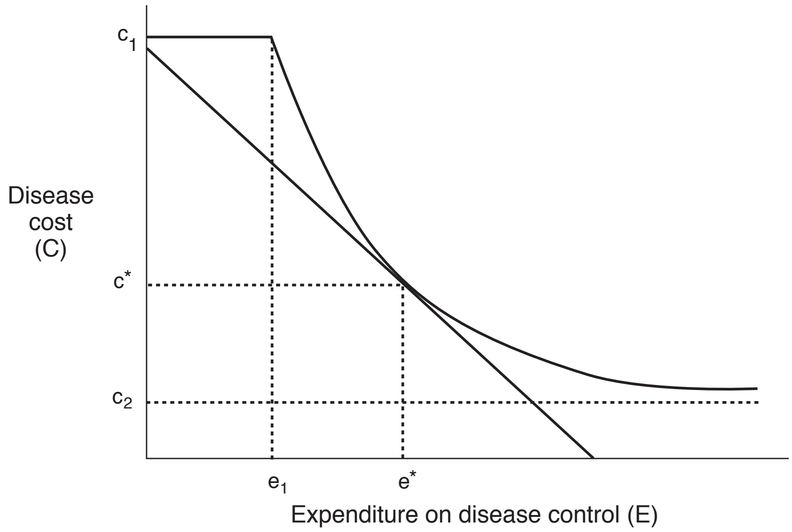

Figure 2. Disease cost–control expenditure trade-off model for an infectious disease.

The second limitation of the McInerney model is that, particularly in the case of infectious diseases, a low level of control activity may be ineffective in preventing disease spread. For example, a 20% or even 50% vaccination coverage for FMD may protect the vaccinated animals but would not be sufficient to make substantial progress towards eradication. When most animals are protected, it becomes possible to eradicate the disease from the population. The major gains from disease eradication are:

- production losses are avoided;
- if the disease is trade-limiting, new markets may be opened up and a price increase achieved; and
- expenditure may no longer be incurred on control.

While the first of these will not change much from a low incidence of the disease to eradication, major gains in trade and reduced control expenditure are not likely to arise until a disease is totally eradicated. This would probably be the case with FMD, where new export markets can be expected to become available only when international recognition of disease-free status is achieved. Thus the C–E curve does not fall sharply until a high level of control expenditure is incurred, i.e. the curve is concave as in Figure 3. Here, a large setup cost is again incurred to eradicate the disease. The optimal policy is expenditure $e*$.

Under this model, only two options are worthy of consideration, namely no control effort and total eradication. Any intermediate combination would be associated with a higher cost.

These considerations suggest that the McInerney model may only be appropriate for localised diseases for which control programs have low overhead costs, such as mastitis in dairy cattle. That is, it is applicable to special cases of disease control only and "*is not justified in the context of economic decisions about the control of different livestock diseases*" (Tisdell 1995, p. 21). The dichotomous choice situation of Figure 3 contrasts strongly with the conclusion of McInerney (1991, p. 152) with respect to disease eradication programs, of "*the importance of identifying the full loss–expenditure relationship for economic analysis rather than hiding behind the apparent neatness of the CBA technique*". In fact, where the loss–expenditure curve is concave as in Figure 3, the conclusion of McInerney (1991) that benefit–cost ratios fail to rank alternatives correctly would not hold.

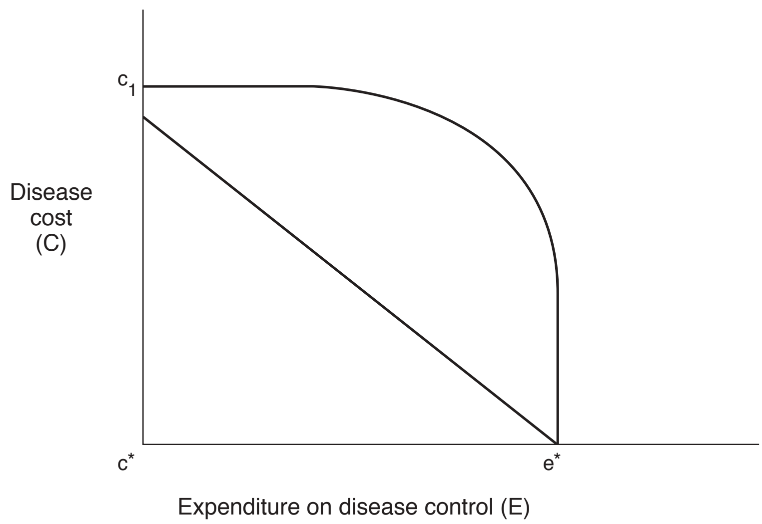

Figure 3. Disease cost–control expenditure tradeoff model for an infectious disease which requires a threshold protection level.

Distribution of benefits for disease control programs

Another area of theoretical modelling has been extension of stakeholder analysis to include not only producer benefits, but also impacts on traders and consumers of livestock products, government fiscal impacts, and trade gains from expanded foreign markets. The theoretical conditions for maximising economic gain (e.g. in terms of demand elasticities) have been explored and identified (Ramsay et al. 1997a,b). This conceptual analysis has been applied to animal health programs in Thailand (Harrison and Tisdell 1997) and Australia (Ramsay et al., Chapters 13 and 14).

The value of animal health information to decision-makers

Epidemiological modelling and Bayesian decision theory have been combined as a methodology for estimating the value to landholders of additional information on animal health. The application of this research in a Queensland context is reported in Ramsay et al. (1997c) and in Chapter 14 of this book.

Application of cost–benefit analysis to animal health programs

An investigation has been made of the methodological issues and practical difficulties of applying social CBA to animal health programs. This arose out of the CBA component of a workshop for veterinary epidemiologists which took place in Lampang, Thailand, in January 1995, and is documented in Harrison (1996a).

Availability and Collection of Disease Incidence Data

Any economic analysis of animal health programs requires reliable data on disease incidence. This raises questions of how to collect these data in a cost-effective manner, and how reliable these data are.

Disease under-reporting in passive reporting systems

There is strong anecdotal and research evidence of under-reporting of the incidence of livestock diseases, which can present difficulties in economic evaluation of disease control programs. Typically, reporting follows a sequence of steps, from the individual producers, through veterinary officers, to regional and national recording bureaus, and to international agencies. There are thus many stages at which under-reporting can occur.

A landmark study in under-reporting of disease cases is that of Ogundipe et al. (1989) for Nigeria. According to these authors (p. 126): "*It is generally known that many diseases occur, especially in rural areas, which are never reported to veterinary authorities*" and outbreaks that are reported are "*no more than the tip of the iceberg*". They found the animal disease reporting system in Nigeria is characterised by "*late, inaccurate and gross under-reporting*". As an example, for Newcastle disease it was not possible to estimate the rate of reporting from livestock owner to veterinary clinician, but at subsequent stages of reporting less than 20% of actual cases were reported for the period 1977 to 1984.

In case this be considered a problem confined to developing countries, mention may be made of the study by McCallon and Beal (1982) for the United States of America. These authors noted gross under-reporting of chorioptic cattle mange, where one small state (Vermont) disclosed four times as many cases of the disease as the other 49 states combined simply because there were trained people checking for the disease in that state.

Notification efficiency in the case of FMD in developing countries is probably quite poor. An early assessment of FMD reporting in Thailand made the observation that: "*The number of reported outbreaks is not identical with the actual number of outbreaks. There exists the opinion, that only a few percent of outbreaks are being reported*" (von Kreudener 1985, p. 126–127). Subsequently, Chaisrisongkram (1993, p. 25) noted that data collection methods used in the past were "*quite limited and not well suited to the need for control measures*". According to Ellis (1993, p. 58):

> *Official records of FMD incidence vary widely in quality. The disease may be so mild where it is endemic that farmers may not recognise it and even if they do recognise it they may not bother to report cases. Effects are usually transient and insidious but often affect a large proportion of animals in the herd or flock.*

It would be expected that the notification efficiency for FMD in Thailand would increase over time and that under-reporting is not as serious an issue now with improved communications, better equipped veterinary officers and greater financial commitment to FMD eradication. Of course, the difficulty still arises in that livestock owners may not recognise mild FMD cases, or may not report cases. Where 'stamping out' (slaughter of infected animals) is a possibility, and livestock owners believe they will not be fully compensated for slaughtered animals, there would be an incentive for not reporting cases. Discussions with various veterinary experts suggest that the current notification efficiency for FMD in Thailand is of the order of 5% to 20%.

Cost-effective survey designs for active surveillance

Taking blood samples from large animals and subjecting these to laboratory analysis for titres against FMD is a highly expensive process; hence a sampling design which provides the most reliable information for a given expenditure is required. Typically, a two-stage probability proportional to size (PPS) sampling design is employed in which a sample of villages is chosen and then livestock are chosen from selected villages. The specific sampling design for a given budget, or accuracy target, will depend on a number of estimated parameters for the reference livestock population and cost parameters for each stage of sampling. The statistical theory underlying PPS sampling is highly complex, and collaboration with the Queensland Government Statistician's Office was obtained in this work.

The World Health Organisation recommended design, consisting of of 30 villages and seven subjects from each, was found to be quite robust with respect to variations in population protection status and sampling cost parameters. In active surveillance for FMD (tests of seroprevalence), there was a tendency for 'natural' optima to arise with respect to sampling designs, due to cost discontinuities, such as where a maximum number of blood specimens can be collected per day (Harrison 1996b). Details of sampling designs relevant to active surveillance for FMD protection in northern Thailand are discussed in Chapter 8 of this book.

Findings from Specific Applications

Thai livestock industry studies

Data have been collected from various sources to develop profiles of livestock industries in Thailand as a background to investigating production benefits and trade opportunities from improved animal health (Murphy and Tisdell 1995a–c, 1996; Kehren and Tisdell 1997a; Smith and Harrison 1997). Reports have been prepared for the meat cattle and buffalo, dairy, pig and poultry industries. These reports have examined livestock numbers, management systems and disease status. Unlike cattle and buffalo, the pig and poultry industries have clearly defined commercial and village sectors, and disease control in the latter presents considerable difficulty. The highly cyclical nature of village pig production associated with pigmeat prices militates against regular vaccination for FMD.

Socioeconomic and environmental studies

The success of any livestock disease control program will depend on the feasibility and willingness of livestock owners to cooperate with the program. In Thailand, small-scale ownership of cattle, buffalo and pigs means that important decisions concerning disease reporting, vaccination, livestock movements and so on are made within the village socioeconomic environment. Securing producer cooperation is more difficult than for commercial pig and dairy holdings, where disease costs are more apparent and ability to afford control measures is greater. Cross-sectional survey data from Thai villages have been used in socioeconomic analysis of the role of livestock in villages (Murphy and Tisdell 1995d). It has been found that consideration needs to be given to the role of women and of common property resources in the management of Thai village livestock production systems (Kehren and Tisdell 1996). While livestock production is a form of value-adding relative to crop production, the efficiency with which human nutritional wants are met is lower, and this can lead to greater adverse environmental impacts (Tisdell and Harrison 1997).

FMD global status and incidence in Thailand

A review has been undertaken of the global status of foot-and-mouth disease in bovines. The prevalence of this disease in Asia and the need for a coordinated control program is notable (Murphy 1996). Statistics on FMD incidence from various sources, including Thai researchers and government agencies and the Office International des Epizooties (OIE), have been summarised and interpreted in an attempt to gain an understanding of the importance of this disease in Thai livestock industries (Kehren and Tisdell 1997b).

The role of animal health in economic development

The costs of livestock diseases and the benefits of disease control have been examined in the context of national economic development, with particular reference to Thailand (Harrison and Tisdell 1997).

Macroeconomic analysis of livestock industries

A closed general equilibrium (CGE) model was applied to examine the relationship between output of the livestock sector (as influenced by disease control measures) and other Thai industries (Purcell et al. 1997).

Collaboration in studies conducted through Chiang Mai University

Two collaborative projects were established at the University of Chiang Mai, in the Departments of Agricultural Economics and Livestock Science and the Multiple Cropping Unit. These studies involved a survey of village livestock producers in Chiang Mai province (Thani et al. 1997), and an intensive survey of animal health in dairy production. Dairy production was found to consist of small herds, in which comprehensive vaccination programs typically are adopted.

Cost–benefit aspects of the Thai FMD control and eradication program

This analysis (S.R. Harrison and C.A. Tisdell, unpublished data) integrates findings of other components of the project to estimate the social pay-off from the current Thai FMD control and eradication program. Although major data problems arose, the analysis provides indicative results that the program has a positive net present value and a benefit–cost ratio exceeding unity. However, it is doubtful that the rate of return on public funds is nearly as high as estimated in an earlier evaluation by Bartholomew and Culpitt (in 1992). The producer benefits appear to be smaller than would be anticipated for FMD eradication from an European perspective. As well, the potential for increased livestock and meat exports from Thailand as a result of FMD eradication appears rather limited. However, provided current control measures are continued and adapted as necessary, the Thai FMD program appears to be well justified when all categories of benefits (including reduced animal health expenditure, trade gains, transport and draught, and animal welfare benefits) are taken into account. The importance of FMD eradication in Thailand becomes greater when viewed within a program of eradication in Southeast Asia. Such a program may take several decades to achieve its goal.

Difficulties Encountered and Lessons from the Project

From the viewpoint of the economics component, the Thai–Australia Animal Health Project faced a number of difficulties. While a project such as this would not be expected to be all 'plain sailing', and language difficulties and data scarcity are inevitable, the difficulties were somewhat greater than anticipated. Important amongst these were:

- delay in signing the memorandum of understanding in Thailand, thus reducing the effective project duration;
- difficulties in communication between disciplines, demonstrating the need for cross-disciplinary training with immersion into the disciplines;
- lack of biological data on FMD impacts (e.g. mortality and reproduction rates and extent of compensatory weight gains) in the village livestock sector where the disease is endemic;
- absence of staff in Thai livestock agencies with economics training, and hence a lack of understanding of the data needs for economic analysis;

- political sensitivity in Thailand about animal health issues, and unwillingness to disclose information about livestock disease incidence and expenditure on animal health programs; and
- unavailability of Thai postgraduate agricultural economics students to participate in field work in Thailand, the early termination of some of the data collection activities in Thailand, and restricted access to survey data.

Persistent efforts at data collection were continued and, given the circumstances, it is considered that reasonably representative data were obtained for economic assessment purposes.

Concluding Comments

Economic analysis has been applied to a number of issues in the Thai–Australia Animal Health Program to aid understanding of disease control options and their cost and benefit implications for the various stakeholder groups. While major problems with data shortage exist, considerable insights have been gained into the appropriateness of disease control measures.

References

Bartholomew, B. and Culpitt, R. 1992. An economic study of foot and mouth disease control strategies in three selected provinces in Northern Thailand. Brisbane, Economic Services Branch, Queensland Department of Primary Industries.

Chaisrisongkram, W. 1993. An overview of foot-and-mouth disease control in Thailand. In: Copland, J.W., Gleeson, L.J. and Chamnanpood, C., ed., Diagnosis and epidemiology of foot-and-mouth disease in Southeast Asia. ACIAR Proceedings, 51, 23–25.

Ellis, P.R. 1993. The economics of foot-and-mouth disease control. In: Copland, J.W., Gleeson, L.J. and Chamnanpood, C., ed., Diagnosis and epidemiology of foot-and-mouth disease in Southeast Asia. ACIAR Proceedings, 51, 57–60.

Harrison, S.R. 1996a. Cost–benefit analysis with applications to animal health programmes. Research Papers and Reports in Animal Health Economics, Nos. 18–23. Brisbane, The University of Queensland.

——— 1996b. Sampling considerations for active surveillance of livestock diseases in developing countries. Research Papers and Reports in Animal Health Economics, No. 27. Brisbane, The University of Queensland.

Harrison, S.R. and Tisdell, C.A. 1997. Animal health programs in sustainable economic development: some observations from Thailand. In: Roy, K.C., Blomqvist, H.C. and Hossein, I., eds., Development that lasts. New Delhi, New Age International.

Kehren, T. and Tisdell, C. 1996. Women and common property resources in the management and health of livestock in Thai villages. Research Papers and Reports in Animal Health Economics, No. 24. Brisbane, The University of Queensland.

——— 1997a. The Thai dairy industry: its economic evolution and problems raised by land rights and cattle diseases. Research Papers and Reports in Animal Health Economics, No. 31. Brisbane, The University of Queensland.

——— 1997b. An overview of the occurrence of FMD in Thailand and policies of its control. Research Papers and Reports in Animal Health Economics, No. 39. Brisbane, The University of Queensland.

McCallon, W.R. and Beal, V.C. 1982. The fallacy of drawing inferences from biased data: some case examples. Proceedings of the 86th annual meeting of the US Animal Health Association, pp. 350–358.

McInerney, J.P. 1988. The economic analysis of livestock diseases: the developing framework. Proceedings of Fifth Conference of the International Veterinary Epidemiology and Economics, Copenhagen.

——— 1991. Cost–benefit analysis of livestock diseases: a simplified look at its economic foundations. In: Martin, S.W., ed., Proceedings of the International Symposium on Veterinary Epidemiology and Economics. Department of Population Medicine, Ontario Veterinary College, University of Guelph, pp. 149–153.

McInerney, J.P., Howe, K.S. and Schepers, J.A. 1992. A framework for the economic analysis of disease in farm livestock. Preventive Veterinary Medicine, 13, 137–154.

Murphy, T. 1996. Foot-and-mouth disease: an overview of its global status, control policies and Thai case. Research Papers and Reports in Animal Health Economics, No. 13, Brisbane, The University of Queensland.

Murphy, T. and Tisdell, C. 1995a. Trends in the Thai livestock industry, animal health implications and Thailand's development: an introduction. Research Papers and Reports in Animal Health Economics, No. 8. Brisbane, The University of Queensland.

——— 1995b. Specific livestock industries, livestock diseases and policies in Thailand: an overview of bovines (buffalo/cattle). Research Papers and Reports in Animal Health Economics, No. 9. Brisbane, The University of Queensland.

——— 1995c. Overview of pigs and poultry: specific livestock industries, livestock diseases and policies in Thailand. Research Papers and Reports in Animal Health Economics, Nos. 10. Brisbane, The University of Queensland.

——— 1995d. Livestock and livestock health in Northern Thailand: a socio-economic analysis of a cross-sectional survey of villages. Research Papers and Reports in Animal Health Economics, No. 11. Brisbane, The University of Queensland.

——— 1996. An overview of trends in development in the Thai dairy industry. Research Papers and Reports in Animal Health Economics, No. 17. Brisbane, The University of Queensland.

Ogundipe, G.A.T., Oluokun, S.B. and Esuruoso, G.O. 1989. The development and efficiency of the animal health information system in Nigeria. Preventative Veterinary Medicine, 7, 121–135.

Purcell, T., Karunaratne, N. and Tisdell, C. 1997. Macroeconomic effects of disease control in the Thailand livestock sector—A CGE analysis. Research Papers and Reports in Animal Health Economics, No. 30. Brisbane, The University of Queensland.

Ramsay, G., Tisdell, C. and Harrison, S. 1997a. The distribution of benefits from improved animal health decision making as a result of the collection of additional animal health information. Research Papers and Reports in Animal Health Economics, No. 38. Brisbane, The University of Queensland.

Ramsay, G.C., Tisdell, C.A. and Harrison, S.R. 1997b. Distribution of benefits from improved animal health decision making. Epidemiologie et Sante Animale, Special Issue, No. 31–32, pp. 10.01.1–3.

Ramsay, G., Tisdell, C. and Harrison, S. 1997c. Private decisions in livestock disease control and the value of additional information about animal health. Research Papers and Reports in Animal Health Economics, No. 37. Brisbane, The University of Queensland.

Smith, A. and Harrison, S. 1997. Recent trends in the production and trade of cattle, buffalo and pigs in Thailand. Research Papers and Reports in Animal Health Economics, No. 40. Brisbane, The University of Queensland.

Thani, P., Aphichatsarangkoon, T., Aekasing, B. and Worachai, L. 1997. Socio-economic status and animal disease prevention and treatment. Research Report, Departments of Agricultural Economics and Animal Science, Chiang Mai University, and Research Papers and Reports in Animal Health Economics, No. 41. Brisbane, The University of Queensland.

Tisdell, C. 1995. Assessing the approach to cost–benefit analysis of controlling livestock diseases of McInerney and others. Research Papers and Reports in Animal Health Economics, No. 3. Brisbane, The University of Queensland.

Tisdell, C.A. and Harrison, S.R. 1997. Livestock, the environment and sustainable development. In: Roy, K.C., Blomqvist, H.C. and Hossein, I., ed., Development that lasts. New Delhi, New Age International, 190–200.

von Kreudener, Baron R. 1985. National foot and mouth disease control in Thailand (Consultant's Report). Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), GMBH Eschborn/TS, Federal Republic of Germany.

5 GIS-Based Animal Health Information Systems

P. Sharma
A.R. Cameron

Abstract

Effective animal health infomation systems are essential in the fight against animal diseases. Unfortunately, in developing countries, many problems exist in gathering useful data for use in these systems. Geographical information systems (GISs) can be invaluable in development of an improved animal health information system, however it is generally considered that a GIS is too costly, too complex and too demanding in its data requirements for implementation in developing countries. This paper, however, shows that a low cost GIS is feasible and to illustrate this uses examples of systems set up in Thailand and Lao People's Democratic Republic.

Introduction

In most developing countries agriculture is the major sector in the economy and employs a large proportion of the population. For agriculturalists in these countries, livestock are often one of their most important assets, second only to land. The Office International des Epizooties (OIE) estimates that animal disease may result in losses of up to 20% of production (OIE 1993). Diseases of livestock have serious effects at many levels especially as they are usually more severe, more widespread, and inflict more social and economic damage than in developed countries. At the same time, the resources available to identify, assess and control these diseases are often scarce. For this reason, it is important that any resources available are effectively targeted to achieve the most benefit.

Accurate information about the health status of a nation's animal population is critical in the fight against animal diseases. Without measures of the frequency and economic importance of a particular disease, a government's task of targeting disease control is almost impossible. Without comprehensive disease reporting systems and ongoing measures of disease incidence, the efficacy and endpoint of any control program is impossible to measure. Without an internationally acceptable system of epidemiological surveillance and animal health information management, the establishment of national freedom from disease or a disease-free zone is impossible to achieve.

Unfortunately, in many developing countries the systems in place for the collection, management and reporting of animal health information are not able to gather the type of information that is required for informed priority setting, disease control program planning, implementation and monitoring. Nor are they able to meet international requirements for the substantiation of claims of freedom from disease. This is despite sometimes substantial investment in veterinary infrastructure and disease control activities, such as laboratory diagnostic facilities and vaccination programs.

This paper reports on research that was carried out in Thailand and the Lao People's Democratic Republic (Lao PDR). The Thai study area consisted of the three northern provinces—Lampang, Lamphun and Chiang Mai. The area covers about 40 000 km^2 and approximately 3 000 villages. The Lao PDR study area selected consisted of Vientiane Municipality, covering about 3 600 km^2 containing approximately 500 villages. In Lao PDR, there has previously been virtually no development of an animal health information system. While Thailand represents one of the most advanced of the developing nations in Southeast Asia, Lao PDR is one of the least developed, and the need for improved animal health information is obvious.

The purpose of the research project was to improve animal health by addressing the problems of a lack of reliable, population-based information, and poor data management and reporting in both countries. It was argued that a strategic approach, involving the introduction of two core elements of an animal health information system, could effectively address the problems of the systems currently used in Thailand and Lao PDR. These core elements are:

- the collection of key animal health information using active surveillance techniques; and
- the introduction of appropriate information technology (including the geographical information system—GIS), to improve the collection, management, analysis and reporting of animal health information.

In the discussion that follows the focus is on the second element.

Animal Health Information Systems in Thailand and Lao PDR — Features and Shortcomings

An *animal health information system* is a system for the collection, storage, analysis and reporting of information related to the health of animals. As such, virtually every country has some form of animal health information system. There are, however, a wide range of systems brought about by the interaction of the following factors and limitations:

- the disease situation (generally endemic diseases with high morbidity and/or high mortality);
- dependence on agriculture (agricultural sector is a major employer);
- the veterinary infrastructure (generally poorly developed, with staff having only basic skills);
- the physical infrastructure (poor communications and transport systems make it difficult to provide services and gather relevant information);
- limited financial resources (collection of animal health information has lower priority); and

- the extent of integration of technology (predominantly paper-based systems).

While published materials are scarce, we can evaluate the characteristics of existing animal health information systems in terms of their ability to achieve four broad objectives:

- to collect basic animal health information;
- to help assess priorities and develop policies;
- to support the implementation of disease control programs; and
- to meet international disease reporting obligations.

Both the Thai and Lao systems are only partly able to identify which diseases are present and their geographic distribution. Information from laboratory submissions may only be used to identify which diseases are being diagnosed more often or which diseases are resulting in laboratory submissions but does not indicate the significance of those diseases.

Both Thai and Lao systems are unable to make valid incidence or prevalence estimates. The disease information upon which these estimates must be based comes from the diagnostic laboratory submissions. The proportion of actual cases of diseases that results in submissions is unknown, and the source population is unknown.

Thailand's foot-and-mouth disease (FMD) serosurveillance system attempts to collect data from a representative sample of villages to estimate the proportion of animals with protective titres against FMD. Unlike passive data collection systems, it uses survey techniques to collect data from a sample of livestock and uses data from this sample to make inferences about the population. While the data from the serosurveillance is potentially much more representative of the population than the passively acquired data, the sampling strategy employed (purposive sampling of villages, and convenience sampling of animals) results in biased data of unknown precision.

Neither system is able to collect the valid, quantitative epidemiological data which is necessary to determine the epidemiology, geographical and temporal patterns of disease, and risk factors associated with the major problems. There is virtually no capability to manage, analyse or report information on the spatial distribution of disease, except in crude tabular form or through the use of inaccurate, hand-drawn maps. Neither system routinely collects information on the impact of diseases or the losses associated with them.

Village livestock population figures are collected by both countries, and these figures may be used to estimate the population at risk for incidence or prevalence calculations. Similarly, livestock movement and vaccination data are collected. Although these data sources may be reported, there is no integration of these data with the rest of the system, and no analysis. For instance, vaccine usage data for a particular area cannot be easily linked to outbreak data from the submissions database or to population data, on order to to help determine the likely number of susceptible animals in the area. Livestock movement data are not analysed for movement patterns which could be linked to outbreak data to predict areas of likely spread. There is no capability for this type of spatial analysis or modelling.

The information currently collected by both systems may be used for priority setting. However, weaknesses in the information, such as the inability to make assessments of the relative economic impact of different diseases, mean that the basis on which decisions are made may not be valid. Reporting systems are based on the use of written or verbal descriptions, and tabulated data and the right information is often not available for decision makers.

No continuous disease monitoring is taking place in Lao PDR. Rabies and FMD monitoring is used in Thailand to support the control programs. Figures gathered may certainly assist in program evaluation, but problems with sampling mean that there is a danger that the results could be misleading. Analysis of these data is unable to properly describe variations in the geographical distribution of the diseases, which may be important to the understanding of the epidemiology and control of the disease.

The laboratory submission system which is currently in place in both countries is appropriate for the detection of emerging diseases. However, the recording and reporting systems used are unable to provide either convincing measures of disease occurrence or unequivocal evidence of freedom from disease.

Data handling systems are not adequate to provide consistent and reliable figures. For example, two Thai sources differ almost fifty-fold in reporting the total number of animals having contacted FMD in 1992. Such discrepancies in internationally published data undermine the credibility of disease status claims. For international trade purposes, trading partners are now in a position to demand epidemiologically sound substantiation of claims of disease freedom or of disease prevalence levels. The systems in Thailand and Lao PDR are not able to provide proofs which would withstand epidemiological scrutiny.

It appears that most of the reasons why animal health information systems fail to perform adequately in developing countries are outside the control of veterinary authorities. However, it is clear that two key problems within the veterinary authorities' control severely limit the effectiveness of systems: (i) the absence of valid measures of disease occurrence at the population level, and (ii) problems with data management.

Disease information in the systems described is collected primarily through the diagnostic laboratory submission system and represents a passive surveillance system. Submission of specimens is initiated by the livestock owner in order to make a diagnosis, so that the disease problem can be solved.

Passively acquired data have the advantage that they may be less expensive to collect than other data sources (Willeberg 1985; Martin et al. 1987, p261). All that is needed is a recording system, as the data are already being generated for diagnostic purposes. The disadvantages of passive surveillance systems are that the disease information is usually incomplete and biased, and reliable measures of disease occurrence cannot be calculated (Hueston 1993). The concerns regarding limitations of passive surveillance are well documented (e.g. McCallon and Beal 1982a; Ogundipe et al. 1989; Oka et al.,1992; Hurd et al.1994).

Animal health information systems use data from a range of sources. Currently in Thailand and Laos, each different type of data (laboratory submission data and that relating to livestock population, livestock movement, surveillance and vaccination) are analysed and reported in isolation. To provide value-added information to decision makers and disease control program administrators, these different data sources need to be integrated so that the relationships between them can be better understood. Centralised data storage systems which manage data at a fine level of detail are required.

In Thailand, although complex reporting systems exist, the presentation of data is often confusing and difficult to interpret. For instance, the Livestock Development *Regional Annual Reports* are the main reporting instruments for animal disease in each of the nine regions. Information relating directly to animal health may be buried amongst administrative data, and long series of tables deter the reader from searching out the real meaning. A great deal of data are contained within these reports, but they are in a form which makes them hard to interpret and difficult to access.

It is evident that that much of the animal health data that are needed are either not collected or collected in a manner which severely comprises their usefulness. This situation is further aggravated by problems of data management and analysis. Improved management and use of existing data would not only make use of an under-utilised resource, but also assist in the collection of additional, better quality data.

A Strategic Approach to Improving Animal Health Information Systems for Thailand and Lao PDR

A wide range of solutions would be needed to address the many problems that have been identified. Our research proposed that the main limitations of the information systems could be addressed using a strategic approach that would implement the core elements necessary for an effective system. These core elements are:

- improved information gathering, based on active surveillance, to quickly collect data for reliable, unbiased measurements of disease occurrence; and
- appropriate implementation of information technology in the form of a GIS to improve animal health information management and reporting.

In order for these core elements to be effective in the developing country context, they must meet a set of four key criteria arising from the constraints faced by these countries:

- any solution must be able to be implemented at a reasonable cost;
- information must be able to be gathered and processed quickly, so that it is still relevant when it is used for decision making;
- information must be reliable; and
- any solution must be able to be practically applied and be appropriate for the situation in which it will be used.

Active surveillance involves the active collection of accurate and representative field data on the health of the livestock population (Martin et al. 1987, p 261). In order to maximise the value of active surveillance, it must be based on statistically sound survey techniques (Hueston 1993). Usually a survey is based on a small proportion of animals in the population, i.e. a sample. The validity of sample estimates from a survey depends on how representative the sample is of the study population.

There are many ways to select a sample from a population for a survey (Cochran 1977; Levy and Lemeshow 1991; Kish 1995). Every sampling strategy is a compromise between many competing factors, such as data accuracy, cost, ease of field operations, and complexity of analytical procedures. These considerations mean that the use of more complex sampling designs are beyond the capacity of the veterinary services of most developing countries, without the assistance of external statistical expertise for survey design and analysis. They are in part explanation for the failure of developing countries to adopt active surveillance techniques.

Clearly problems of resources and infrastructure need to be addressed in the larger national context. However, the research that was undertaken attempted to address some of the reasons for lack of adoption of sound active surveillance techniques. The question of how active surveillance techniques could be implemented in developing countries was also considered. The use of GIS in this context was regarded as crucial.

The Role of the GIS

The use of GISs in animal health studies is not entirely new. Many authors have recommended the specific inclusion of a GIS in an animal health information system (Blood and Brightling 1988; Morley 1988; Sharma,1994; Thrusfield 1995). GISs have been successfully applied to a number of specific problems in veterinary epidemiology, such as estimating the risk of East Coast Fever to livestock in Africa (Lessard et al. 1988), the analysis of chemical residue data from abattoirs (Van der Logt et al. 1994), and to examine the epidemiology of tuberculosis in possums (Pfeiffer and Morris, 1994), and of Aujeszky's disease in pigs (Marsh et al. 1991a; Belfrage et al.,1994; McGinn et al. 1994). One of the more common uses of the technology has been as an aid in the control of disease outbreaks, especially FMD (Sanson et al. 1991a,b, 1994).

A GIS is a specialised computer database which handles two types of information: *geographical information* (the location of features, be they countries, administrative boundaries, rivers, roads, villages, or farms) and *attribute data* (for example, the attributes of a village may include the name, the number of each species of animals present, diseases that have occurred, the average titre of the animals to a particular pathogen, feed available and so on). What makes a GIS different from a standard database is its ability to perform spatial analysis on the information stored. The spatial relationship between features and their associated attributes can be analysed to reveal underlying patterns.

One of the objectives of an animal health information system is to provide information that provides a better understanding of the epidemiology of disease. An important component of the epidemiology of a disease is the distribution of that disease in relation to a number of factors (such as species, age, sex and time). One of the most important of these factors is the geographical distribution of the disease (Garner and Nunn 1991). The use of a GIS offers the ability to include the spatial distribution of disease in the analysis of all the other factors (Clarke et al. 1996).

Examination of the spatial component of animal health data via a GIS also provides the ability to quickly identify data errors, as missing and out-of-range data are easily identified when the data are mapped. Disease maps are able to convey the relative levels of disease graphically, through the use of colour or different symbols. They also convey the relationships between different geographical areas. The production of accurate, attractive, well-presented disease maps can be completely automated and achieved in seconds, given a database of up-to-date information.

While disease information is critical, other backdrop and framework data are very important. These data include administrative profiles (breakdown of veterinary districts, location of field services, the areas of vaccination campaigns and distribution of veterinary resources in general), distribution of animal populations (by species, age, sex etc.), and tracking of market operations and animal movements. When appropriate information is available it is possible to provide estimates of populations at risk and have a better picture of the resources available to combat that risk.

Description of the GISs Developed

Thailand

In Thailand, a pilot system was established covering three provinces (Lampang, Lamphun and Chiang Mai) in the north of the country. This system is now being extended to give complete national coverage. The base geographic data used consisted of provincial, district and subdistrict boundaries, and village point locations. The village was used as the finest level of detail. Epidemiologically, all the livestock in a single village can be treated as a single herd, as they are in relatively close contact and share the same disease risks. The geographical data was digitised using 1:50 000 maps maintained by the Thai National Statistics Office (NSO).

Other spatial data also covered in the system included roads, waterways, livestock market locations, and veterinary office locations. Climatic data maps (rain and temperature) were also incorporated into the system. In keeping with the objective of establishing an effective system at reasonable cost, appropriate for use in developing countries, all the data were maintained on two Pentium desktop computers. These were capable of managing all the data required for a national system covering over 60 000 villages. Software used was *ArcInfo* and *ArcView* (Environmental Systems Research Institute, Redlands, California, United States of America).

Attribute data were maintained at the village level, and aggregated up to the subdistrict, district or provincial level for various types of analysis. The various data sources were linked to the maps using standard village and subdivision codes maintained by NSO. The main data sources were village livestock population, collected by the Department of Livestock Development (DLD), and disease records from the regional diagnostic laboratory. Other data included (human demographics, agricultural data etc) was derived from two village-level censuses, run by NSO and Thammasat University.

The Thai system was used for data management, livestock disease and population mapping, development and implementation of improved active surveillance sampling techniques, assisting with disease outbreak response management, and for the tempero-spatial analysis of epidemiological data.

Lao PDR

In Lao PDR, a GIS was specifically set up to improve the efficiency and validity of sampling strategies as part of active surveillance activities. The system included provincial and district boundaries, village locations (incomplete coverage) and incorporated both raster format aerial photographs and vector format, interpreted satellite images showing land-use data. Lao PDR lacks the sophisticated statistical infrastructure of Thailand and some data used in our project were acquired from other projects in our area of interest.

Some Example GIS Applications

Disease and livestock population mapping

In Thailand a range of data sources may be used to produce disease maps. Passive disease reporting, usually in the form of reports of disease events, or through diagnostic laboratory submissions, remains a key source of disease incidence information. This is therefore the information that is most likely to be used for disease mapping. Disease reports or submissions are associated with their place of origin, be it a farm, village, suburb or province. An alternative to the use of passively acquired data is active surveillance. Special purpose surveys can yield estimates (usually of disease prevalence) for defined geographic areas. Besides data on the occurrence of disease, it is necessary to have information on the livestock population at risk of disease in order to calculate meaningful incidence or prevalence estimates. This information is routinely collected by many government veterinary services or may be available though agricultural census information. It is a core component of any GIS for animal health.

Disease maps can take many forms. The simplest is a point map showing the location of disease events over a period ('pin maps'). While this displays the distribution of disease, it does not take into account the distribution of the underlying population. Similarly, choropleth maps of the number of disease events in sub-regions may be useful for planning for the veterinary needs of an area, but do not provide any information about risk. Converting counts of disease events into rates and mapping incidence or prevalence (i.e. taking a density component into account) allows a more meaningful interpretation of the disease situation. The main purpose of these maps is to identify areas of greater or lesser risk of disease than the average. Choropleth maps of the relative risk for each geographical subdivision are quickly able to show where problem areas are located.

The routine production of these maps has the potential to provide a more realistic, easy to interpret picture of the disease situation to decision makers. The generation of these maps can be completely automated. Furthermore, when the resources-available data are overlaid against incidence rates, DLD administrators have significantly enhanced information at a relatively low additional cost.

The GIS as a survey tool

Traditionally, random sampling has depended on the presence of a reliable sampling frame in which every member of the population is listed and has a known probability of selection (Levy and Lemeshow 1991). In many developing countries, either no frame exists at all, the frame may be incomplete, or a frame exists but its reliability is not known. Thus, it may be necessary to draw a random sample independently of, or in the absence of, the sampling frame.

Random geographical coordinate sampling (RGCS) offers a technique for the selection of a random sample without the need for a sampling frame. In RGCS, pairs of random numbers are generated, which are interpreted as the x and y coordinate of a geographical point. All the villages within a certain radius of the random point are identified, and one chosen at random. This technique was used in Lao PDR and Thailand and is a modification of previously used geographic sampling approaches.

RGCS can be carried out successfully with a hand-held global positioning satellite unit and a four-wheel drive vehicle. It can, however, be very expensive. Human population tends to cluster along valleys or roads, and large areas of a district often have no villages at all. Access to these areas may be difficult, and random points falling in these areas will yield no villages. In cases where the spread of villages is uneven, much time and effort can be wasted in locating remote points with no villages nearby.

A serological survey using RGCS was carried out in Lao PDR. A GIS was used to plan the survey, and to increase the efficiency of the field work by incorporating data from remote sensing images into the system. First, the GIS was used to automate the task of selecting random points. Although no detailed digital maps of the survey area existed, a simple map of district boundaries was digitised. A program was written which generated a number of random points within the boundaries of the study area. These random points were printed out and entered into the global positioning satellite unit.

Random points needed to be visited to determine if any villages lay within a certain radius of these points. No reliable maps for the study area showing villages existed, as they were either incomplete or out of date. The use of remote sensing data offered an opportunity to visually inspect the area around a randomly selected point to determine if a village was likely to be nearby. Two sources of data were available from projects working within the same government ministry: interpreted SPOT satellite images for the entire study area and aerial photography for a smaller part of the study area. The data were loaded into *ArcView* and displayed as a backdrop to the map of the study area. The program used to generate the random points also drew circles of the required radius around these points. It was then a simple matter to examine each point to see if there was evidence of a village within that radius.

The aerial photography data were very detailed, with individual buildings being clearly distinguishable. In the satellite photos, villages were usually less easy to identify (not surprising, given the scale), but agricultural land (mainly rice fields) was easily distinguished from forested areas. A conservative approach was used, in which any point in or near agricultural land was visited by the survey team to confirm if a village was present. Points lying in the middle of forest areas with no sign of human habitation were excluded. The sample size for the survey was 40 villages. Of the initial random points selected, 44 were excluded using the GIS with remotely sensed data, and a further 82 points were visited to obtain the sample of 40 villages.

It *is* possible to conduct random geographical coordinate sampling without a GIS, or remote sensing imagery or the use of a global positioning satellite unit. However, a GIS makes the whole exercise easier (staff do not require the same level of training), data quality is improved (there is less temptation for staff to be 'flexible' with the sampling procedure); and mappable data are available for all stages of the process. For example, analysis can be conducted of villages which were selected initially but dropped for various reasons.

The GIS and visualisation

One of the roles of epidemiology is the identification of patterns in the distribution of disease. Such patterns may lead to a better understanding of the mechanisms of disease and offer insights into potential control options. The distribution of diseases may be examined in many ways—distributions with respect to sex, age, diet, genetic makeup, space, time etc. When a pattern is detected—e.g. disease is more common in animals of a certain age—control options can be developed, such as targeted vaccination for that age group. Once the data are collected, the first step is to examine them for patterns. A GIS offers, through the production of disease maps, the ability to examine the spatial distribution of disease and find meaningful patterns. An armoury of statistical techniques exists for the analysis of such patterns. Similarly, graphical and analytical techniques exist for analysis of the temporal distribution of disease (time series techniques). However, the simultaneous examination of the spatial and temporal distribution of disease is more difficult. If we observe on a map that many cases appear to occur in the same area, are they occurring simultaneously? If we look at a graph of disease incidence over time and notice a peak, are these cases occurring in the same place? Statistical techniques exist to analyse the space–time 'distance' between disease events, but few are available for the identification of these patterns in the first place.

Using the GIS in Thailand, a tool for exploratory data analysis was developed that allowed simultaneous display of the temporal and spatial distribution of a disease. The data displayed came from the diagnostic laboratory submissions database, and contained a disease diagnosis, the origin of the submission and a submission date. This provided the three necessary components for analysis: the 'what', 'where' and 'when'.

A program was developed with the *ArcView* programming language (*Avenue*). The user creates a map of all disease events in a certain period. The program then 'animates' the map by passing through the chosen period one day at a time, displaying new disease events (for an arbitrary period chosen by the user) and then erasing them. Using this simple technique, it is easy to see the wave of progression of an epidemic, or the random scatter of a sporadic disease. The program was used to examine several diseases in the study area, and revealed new patterns, suggesting new hypotheses. For example, while two serotypes of one disease were known to occur in all parts of the study area, and follow an annual cycle, it was not realised that mixed outbreaks do not occur—only one serotype occurred in an area at a particular time. A natural divide down the centre of the study area separated the two types which tended to appear alternately on one side of the divide and then the other, from year to year. This observation led to new hypotheses as to the immunity of the population and the source of the pathogen.

The program can be used to examine any disease information that has a location and a date associated with it (indeed not only disease information). It is a simple yet powerful data visualisation tool.

Conclusion

From our research reported here we do not have much confidence that most developing countries are in a position to mount an 'across the board' attack on their animal health problems. Also, while incremental improvements in their passive surveillance-based systems are possible, these improvements are unlikely to yield the type and quality of information that is urgently required for various purposes. Our research has demonstrated that active surveillance techniques coupled with appropriate injection of modern computing technology (in particular, GIS and related technologies) can yield dramatic improvements in data availability, management and analysis.

To target control of livestock diseases, one must first understand the diseases and the way in which they are distributed through the population. A GIS for livestock disease control retains all the data management and analytical power of a traditional database system but adds the ability to include the spatial elements of animal health management.

There are, however, relatively few examples of the inclusion of a GIS as an integral part of an animal health information system. Systems in use demonstrate the acknowledged need for an understanding of the spatial distribution of disease, but have avoided the use of a fully functional GIS, probably because of the perceived expense and complexity of setting up such a system. The potential benefits for an animal health information system are clear, but the use of powerful GIS systems seems to be limited to specific research projects and a few information systems in developed countries.

A GIS thrives on high-powered computers and vast amounts of data and is often seen as the preserve of well-funded government departments, universities or businesses. The research presented here shows that this is not necessarily the case. Affordable personal computers that are currently available provide enough power to run a fully-fledged GIS package. A simple national system could conceivably be run on a single machine. Also, while the data requirements are quite demanding if one wants to utilise the powerful capabilities of the system, we have shown that even when data availability is limited, as in many developing countries, establishing a very useful and cost-effective system is possible.

References

Belfrage, J.B., Salman, M.D., Freier, J., Nuckols, J. and Otto, D. 1994. A geographic information system analysis of pseudorabies (Aujesky's disease) in four counties in Iowa, USA. Kenyan Veterinarian, 18, 500.

Blood, D.C. and Brightling, P. 1988. National animal disease databanks. In: Veterinary Information Management. London, Ballière Tindall, 153–160.

Clarke, K.C., McLafferty, S.L. and Tempalski, B.J. 1996. On epidemiology and geographic information systems: a review and discussion of future directions. Emerging Infectious Diseases, 2, 85–92.

Cochran, W.G. 1977. Sampling techniques, 3rd edn. New York, Wiley.

Garner, M.G. and Nunn, M.J. 1991. Requirements for an Australian animal health information system. In: Sergeant, E.S.G., ed., Epidemiology Chapter Proceedings, AVA/NZVA Pan Pacific Conference on Veterinarians and the Environment, Sydney, May 1991, Australian College of Veterinary Scientists, Sydney, 7–16.

Hueston, W.D. 1993. Assessment of national systems for the surveillance and monitoring of animal disease. Review Scientific et Technique Office International des Epizooties, 12, 1187–1196.

Hurd, H.S., Hancock, D.D., Thomas, L.A. and Wells, S.J. 1994. Salmonella prevalence in US dairy calves and a comparison of active and passive surveillance systems. In: Proceedings of the VIIIth Congress of the International Society for Animal Hygiene, St Paul, Minnesota. St Paul, International Society for Animal Hygiene.

Kish, L. 1995. Survey sampling. New York, Wiley.

Lessard, P., l'Eplattenier, R., Norval, R.A.I., Perry, B.D., Dolan, T.T., Burrill, A., Croze, H., Sorensen, M., Grootenhuis, J.G. and Irvin, A.D. 1988. The use of geographical information systems in estimating east coast fever risk to African livestock. Acta Veteterinaria Scandinavia, 234–236.

Levy, P.S. and Lemeshow, S. 1991. Sampling of populations: methods and applications, 2nd edn. New York, Wiley.

Marsh, W.E., Damrongwatanapokin, T., Larntz, K. and Morrison, R.B. 1991. The use of a geographic information system in an epidemiological study of pseudorabies (Aujeszky's disease) in Minnesota swine herds. Preventative Veterinary Medicine, 11, 249–254.

Martin, S.W., Meek, A.H. and Willeberg, P. 1987. Veterinary epidemiology—principles and methods. Ames, Iowa State University Press.

McCallon, W.R. and Beal, V.C. Jr. 1982. The fallacy of drawing inferences from biased data: some case examples. In: Proceedings of the 86th Annual Meeting of United States Animal Health Association. Richmond, United States Animal Health Association, 350–358.

McGinn, T.J., III, Wray, D.W. and Cowen, P. 1994. Medical geography of Aujesky's disease in North Carolina, USA: the effect of density of swine and prevalence of infection on a neighbouring Aujesky's disease status. Kenyan Veterinarian, 18, 499.

Morley, R.S. 1988. National animal health information system, Agriculture Canada. Review Scientific et Technique Office International des Epizooties, 7, 577–581.

Ogundipe, G.A.T., Oluokun, S.B. and Esuruoso, G.O. 1989. The development and efficency of the animal health information system in Nigeria. Preventative Veterinary Medicine, 7, 121–135.

OIE 1993. World animal health in 1993. Office International des Epizooties, Paris.

Oka, M., Widowati, N., Lubis, N. and Holden, S. 1992. The role of laboratory and veterinary diagnosis in Indonesia's national disease surveillance system. In: Daniels, P.W., Holden, S., Lewin, E. and Dadi, S., ed., Livestock services for smallholders: a critical evaluation of the delivery of animal health and production services to the small-scale farmer in the developing world. Proceedings of an International Seminar held at Yogyakarta, Indonesia, 15–21 November, 1992. Yogyakarta, Indonesia, Directorate General of Livestock Services, 56–59.

Pfeiffer, D.U. and Morris, R.S. 1994. Spatial analysis techniques in veterinary epidemiology. Kenyan Veterinarian, 18, 483–485.

Sanson, R.L., Liberona, H. and Morris, R.S. 1991a. The use of a geographical information system in the management of a foot-and-mouth disease epidemic. Preventative Veterinary Medicine, 11, 309–313.

Sanson, R.L., Morris, R.S. and Liberona, H. 1991b. The development of an epidemiological management system for a foot-and-mouth disease emergency. In: Martin, S.W., ed., Proceedings of the 6th ISVEE symposium, Ottawa, Canada, 12–16 August, 1991. Ontario, University of Guelph, 447–449.

Sanson, R.L., Pfeiffer, D.U. and Morris, R.S. 1994. Geographic information systems: their application in animal disease control. Review Scientific et Technique Office International des Epizooties, 10, 179–195.

Sharma, P. 1994. Use of geographic information systems in animal health information programs. In: Copland, J.W., Gleeson, L.J. and Chamnanpood, C., ed., Diagnosis and epidemiology of foot-and-mouth disease in Southeast Asia. ACIAR Proceedings, 51, 119–125.

Thrusfield, M. 1995. Veterinary epidemiology, 2nd edn. Oxford, Blackwell Science.

Van der Logt, P.B., Morris, R.S. and Hathaway, S.C. 1994. The analysis of chemical residue data gathered at abattoirs by means of geographical information systems. Kenyan Veterinarian, 18, 496–498.

Willeberg, P. 1985. Epidemiologic use of routinely collected veterinary data: risks and benefits. In: Proceedings of the 4th International Symposium on Veterinary Epidemiology and Economics, Singapore, 18–22 November, 1985. Singapore, International Society for Veterinary Epidemiology and Economics (ISVEE), 40–45.

6

An Overview of a Program for the Control and Eradication of Foot-and-Mouth Disease in Southeast Asia

L. J. Gleeson
Y. Ozawa

Abstract

A campaign to control and eventually eradicate foot-and-mouth disease (FMD) from Southeast Asia has been launched by the Office International des Epizooties (OIE). This paper outlines the development of the OIE Sub-Commission for the control of FMD in Southeast Asia and the organisational structure for the campaign. The campaign will comprise three phases and the objectives of the phases are described. The recent epidemiological picture for FMD in the region is summarised. Important developments have been the introduction of the China strain of pig-adapted FMD virus serotype O into Southeast Asia, and the emergence of a new strain of serotype A in Thailand and Malaysia. The need for international assistance in highlighted in the context of the challenges facing the campaign.

Introduction

Foot-and-mouth disease (FMD) is a highly contagious disease of cattle, buffalo, pigs, sheep, goats and wild ruminants which is characterised by fever, vesicles on the feet, mouth and udder, and by death in young animals. National and international animal health organisations attach the highest priority to the control and prevention of this disease because of the intrinsic impact of FMD on animal health and production, and because it is a major constraint to international trade in livestock and animal products.

In the last decade, FMD control has received a great deal of attention in the countries of Southeast Asia, and individual national control programs have been carried out at considerable expense. There has been some noteworthy progress made, but mainland countries sharing land borders continue to suffer from endemic FMD, mainly because there has been no common strategy or regionally coordinated program. Movement of infected animals, both within countries and across international boundaries, is probably the most significant region-wide risk factor for outbreaks and maintenance of the disease in the population.

The participants at the OIE/FAVA (Office International des Epizooties—also known as the World Organisation for Animal Health/Federation of Asian Veterinary Associations) Symposium held in Thailand in 1990 requested that the OIE establish a sub-commission to coordinate FMD control activities in the countries of Southeast Asia, as there was consensus that national control could not be achieved without a regional approach. The OIE formed a Regional OIE FMD Coordinating Group and held annual meetings of country delegates from the region. In 1993 the OIE Regional Representative prepared a draft plan (see Ozawa 1994) that was discussed and approved at the meeting of the coordinating group held in Malaysia in February 1994, and also at the next meeting of the OIE Regional Commission in May 1994. The International Committee of the OIE then formally endorsed the OIE sub-commission for the control of FMD in Southeast Asia, and the first meeting of the sub-commission was held in Bangkok in February 1995. The countries involved in the regional campaign, referred to as the SEAFMD campaign are Cambodia, Lao People's Democratic Republic (PDR), Malaysia, Myanmar, the Philippines, Thailand and Vietnam.

This paper is an overview of an approach to the control and eventual eradication of FMD in Southeast Asia. The plan will be coordinated by the OIE in close collaboration with national animal health authorities and other international agencies such as the Food and Agriculture Organisation of the United Nations (FAO) and the joint division of FAO and the International Atomic Energy Agency (IAEA).

Economic Significance of Foot-and-Mouth Disease

FMD is the most feared viral disease of export-oriented livestock industries around the world because of its impact on trade of animals and animal products into high value markets. Endemic FMD seriously reduces productivity and has large costs associated with control. A dramatic illustration of the economic impact of FMD on trade was the aftermath of the recent 1997 outbreak in pigs in Taipei, China. The immediate closure of access to high-priced markets such as those of Japan and Korea is estimated to have resulted in a loss of over US$2 billion. Estimates of the impact of a restricted outbreak of FMD in Australia are of a similar order.

In general, FMD causes severe economic losses in high-producing breeds of cattle, buffalo and pigs because of its impact on milk and meat production. In smallholder systems it can be difficult to observe or demonstrate a profound impact of the disease on animal production, as livestock are already significantly under-producing because of other health factors such as poor nutrition and heavy parasite burdens. It is suggested that FMD also causes economic losses due to the disruption of draught animal power needed for the cultivation of land and the transportation of agricultural products, but these losses have not been adequately quantified (FAO 1997).

Many feedlots in the Southeast Asia have been established in areas where FMD is controlled (e.g. in Malaysia and the Philippines), but these are under continuous threat of the disease as the cattle are not usually vaccinated. Outbreaks in these feedlots would result in severe economic loss for the enterprises. A limited study in a small feedlot in Thailand showed a significant economic loss following an FMD outbreak (Bartholomew and Culpitt 1992). FMD must be controlled in intensive pig production systems if they are to be profitable, and if they are to penetrate lucrative export markets. Dairy development programs in the region are also threatened by FMD.

In some countries in recent years, the number of animals used for draught purposes has declined substantially while in others the numbers remain steady. It is also evident that large ruminant inventories have been depleted as human consumption of meat has outstripped local production. Concurrently, regional governments have probably overlooked the contribution of livestock to the economy and national food security, as livestock and agriculture have slipped down the priorities for national development. There are no predictions that this trend will reverse, although one effect of the post-1997 regional economic crisis has been an increased political awareness of the importance of the agricultural sector in general. From a humanitarian perspective it is important to recognise that in Southeast Asia the majority of the human population live in rural communities. Livestock thus may play a more important role in human wellbeing than can be measured by the common economic variables. For example, the role of livestock as cash redeemable assets in financial emergencies is important to the wellbeing of many rural communities. Disease outbreaks often precipitate panic sales at reduced prices, or can lead to long term financial hardship when families are forced to rent draught animals for paddy preparation.

Therefore, while FMD is a significant disease of livestock, the challenge is to understand the impact of the disease at the small enterprise level and communicate this to national policy planners so that there is appropriate support for animal health issues in national priority setting. There is the additional challenge to develop awareness among smallholders of the importance of animal health (and FMD) to the output of their production system(s) in general. The SEAFMD program aims to address these issues.

Foot-and-Mouth Disease Situation in Southeast Asia

FMD virus serotypes O, A and Asia 1 are endemic in mainland Southeast Asia. While serotype Asia 1 does not occur in the Philippines, serotype C is presently considered endemic—although last reported in 1995. The interaction between the serotypes within the host population is unknown. It appears that there are cycles of epidemic infection with the different serotypes; therefore in studying regional FMD epidemiology it is necessary to consider that each serotype causes a distinct disease and the epidemiology of each of the serotypes should be analysed separately.

The issue of disease reporting is an important one for the disease control campaign. The reported prevalence of disease is generally a reflection of disease-monitoring activity and passive surveillance, and probably underestimates the true prevalence in most countries. In recent years FMD outbreaks have been dominated by type Asia 1 and type O, but now type A may be about to re-emerge. It will be important to track any emergent epidemic and also determine the reservoir of the different serotypes in the region. The reported distribution of the endemic serotypes in South Asia during the past 10 years is shown in Figure 1.

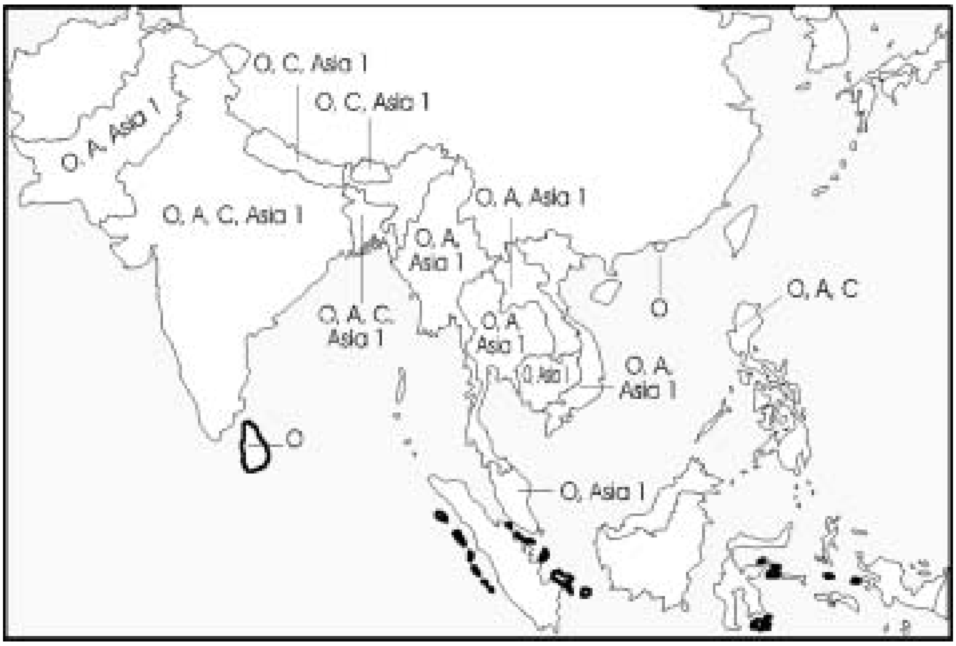

Figure 1. Distribution of the different serotypes (O, A and Asia 1) of foot-and-mouth disease in Asia (1988–1997).

The FMD status in the countries involved in the SEAFMD program is summarised below:

Cambodia

Susceptible livestock populations are concentrated in the northwestern and central provinces of Cambodia. In 1997, outbreaks of FMD caused by serotypes O and Asia 1 were confirmed. Outbreaks of type O involved both pigs and cattle. In recent years, outbreaks have been alternatively caused by type O or Asia 1. Serotype A has not been reported for more than 10 years, but there were no diagnostic submissions from outbreaks in 1995 and 1996. The two main patterns of cattle trade movement are from the central provinces to provinces bordering Thailand and Vietnam and thence into those countries, and also toward the market in Phnom Penh. Price disturbances in the region in 1997 have resulted in cheap slaughter pigs moving into Cambodia from Thailand. Occasional civil disruption has also resulted in movement of animals with displaced people. For example, in early 1998, newspapers reported civilians with 'thousands of cattle' trading animals for food along the border with Thailand. Vaccination coverage of the susceptible livestock population fell to 5.5% in 1992, and remains low. Cambodia now has an enzyme-linked immunosorbent assay (ELISA) diagnostic capability, but generally lacks funds for any sustained control program.

Lao PDR

It is believed FMD has become endemic in Lao PDR since 1946, as there are no reports of the disease in French colonial records. The number of FMD outbreaks increased considerably in 1994 and 1995, perhaps because of increased animal movements and developments in road infrastructure. Outbreak viruses have not been continuously sero-typed, and similarly to Cambodia only type O and type Asia 1 have been recognised in the last 10 years. Laboratory investigations were not conducted on major outbreaks in the period 1994 to 1996. The traditional livestock movements were for cattle and buffalo to enter Lao PDR from the People's Republic of China, Vietnam and Cambodia, and for export to Thailand to occur from many places. However, there is some evidence that the increasing demands and price in Vietnam and China has reversed that trend. Importantly, it has been reported at certain festival times large numbers of sucking pigs, both live and carcass, are smuggled into Thailand. An FMD-typing capability is currently being established under an Australian Centre for International Agricultureal Research (ACIAR) project, and the European Commission has funded a project to assist with the strengthening of animal health services.

Malaysia

The main areas of concern are in the northern peninsular states bordering Thailand. Serotype Asia 1, which persisted from the 1994 outbreaks in Kelantan, Terengganu, Kedah and Penang, caused outbreaks in the more southern states of Negeri Sembilan, Malacca and Johore through illegal movements of livestock in June 1995. These outbreaks were controlled as a result of good, local community cooperation and implementation of animal movement monitoring. In 1995 one outbreak of type A, probably associated with imported cattle, was reported in the states of Penang and Kedah. In more recent times serotypes O and Asia 1, and in 1997 again serotype A, were identified in Kelantan, the easternmost state bordering Thailand. The strain of type A causing this epidemic was not adequately covered by the commercially available type A vaccine strains, although that problem has been recently redressed. The disease is currently restricted to the border areas by animal movement controls and vaccination programs in the infected zone. Malaysia has a cultural requirement for live cattle at festival times and the pressure for movement from Thailand increased in 1997 as importation of now-expensive live cattle from Australia to meet some of this demand has been suspended.

Myanmar

FMD remains endemic in cattle and buffalo but has not been reported in recent years in pigs or wild animals. The highest incidence is recorded during the rainy season (May to August). In 1994 it was reported that nearly 150,000 animals were affected. Types O and Asia 1 were confirmed from outbreaks between 1994 and 1997 (inclusive), and type A was not reported during this time, or during the period 1988 to 1992. Animal movements occur during most months of the year except for about two months during the field working period. Movements are mainly on hoof from market to market. Although export of cattle and buffalo is officially banned there are uncontrolled livestock movements to Thailand, the People's Republic of China, Bangladesh and India. Practically no animals move into Myanmar. Myanmar has a vaccine production capacity of one million doses although at present annual production is about 10–20% of that capacity.

Philippines

Historically FMD types A, O and C were endemic on mainland Luzon, but in the late 1980s and early 1990s the number of reported outbreaks had declined significantly, so that eradication of the disease was contemplated. However, late in 1994 a major epidemic of FMD serotype O commenced in pigs on Luzon Island and continued to spread in 1995. It was subsequently shown this virus probably originated from Hong Kong and is genetically related to the pig-adapted type O virus isolated in Taipei, China. There have been few reports in recent years of FMD in large ruminants, and clinical FMD has not been reported from the island of Mindanao since 1988. Type A virus has not been detected since 1991, but a serological investigation in 1994 suggested that this serotype might have been circulating in the central highlands of Luzon. The last confirmed case of type C virus was in pigs in 1995. Animal health services in the Philippines maintain strict movement controls to prevent introduction of infected animals to Mindanao and the central Visayas group of islands.

Thailand

There were 476 FMD outbreaks in cattle and pigs reported in 1992 (the majority of which occurred in October–November) whereas in 1996 there were 21 reported outbreaks involving cattle and buffalo and, in 1997, 15 reported outbreaks involving cattle, buffalo and pigs. Thailand has the capacity to produce sufficient trivalent vaccine to immunise the cattle and buffalo population twice yearly. In late 1997 and early 1998, a variant type A virus was confirmed from a number of outbreaks. This variant was sufficiently different antigenically from the current vaccine to warrant the selection of a new vaccine strain. It is likely this virus and the Malaysian type A variant have a common origin. The pattern of animal movements is from the north and the northeast to the central provinces and Bangkok. Significant numbers of animals enter the country each year especially from Myanmar, as beef consumption outstrips domestic supply. Where possible, veterinary authorities have established programs to quarantine and vaccinate cattle and buffalo moving into the country. There is both regulated and unregulated movement of animals into the southern peninsular area, which prior to 1972 was free from FMD.

Vietnam

Historically the few reports of FMD originated mainly from outbreaks in the south of Vietnam, and the northern delta area was considered free since the late 1950s, although a few localised outbreaks were reported along the border with China in 1994 and 1995. In the south, outbreaks of all three serotypes have been reported in the last 10 years. Type Asia 1 was reported in 1992 and 1993, and type A was reported (from cattle) in 1995. Sporadic outbreaks of type O were reported in 1995 and 1996 affecting cattle and pigs. In 1997, two distinct genotypes of serotype O isolates were recognised in Vietnam, one from pigs being related to the Hong Kong/Taipei China group of viruses. The other found in cattle was related to historical cattle isolates from the region. Movement of livestock within Vietnam tends to be from north to south and towards Ho Chi Minh City. There are international movements across the borders from Lao PDR and Cambodia.

Objectives of the Regional Control Program

The immediate objective of the plan is to improve the standards of veterinary services in FMD-affected countries in Southeast Asia, and to build the information base necessary to develop a regional control strategy. The intermediate objectives are to improve the productivity of animals by keeping FMD under control and so increase the income of livestock producers in the participating countries. The long-term objective is to facilitate and promote the international trade of animals and animal products by creating FMD-free regions in Southeast Asia.

Organisation of the Regional Control Program

Organisational structure

The agreed organisational structure of the campaign is shown in Figure 2.

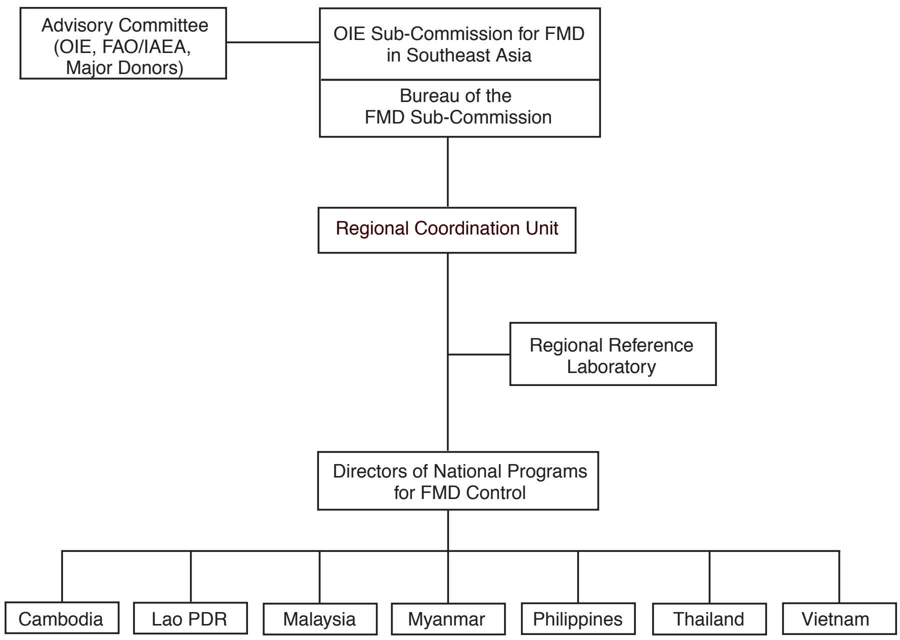

Figure 2. Organisational structure of the Southeast Asia foot-and-mouth disease (FMD) control and eradication program instigated by the Office International des Epizooties (OIE).

The OIE Sub-Commission for FMD in Southeast Asia consists of one representative from each of the Governments of Cambodia, Lao PDR, Malaysia, Myanmar, the Philippines, Thailand and Vietnam, one person designated by the President of the OIE FMD Commission and one person designated by the Director-General of the OIE. Qualified persons are invited to attend the annual meetings of the sub-commission in an observational capacity.

This sub-commission is a part of the OIE FMD and Other Epizootics Commission, and is currently supported by the OIE Regional Commission for Asia, the Far East and Oceania, the OIE Central Bureau, the OIE Regional Representation for Asia and the Pacific, the FAO Regional Office in Bangkok, and the joint FAO/ IAEA Division.

The sub-commission will be assisted by an OIE Regional Coordination Unit that was established in Bangkok in September 1997 with support from the Governments of Australia, Switzerland and Thailand. The Government of Thailand has also agreed to construct and operate a regional reference laboratory, and provide an assistant regional coordinator and some support personnel. Project personnel may be provided by interested donor countries or international agencies. The regional coordinator of the campaign will be an OIE expert under a trust fund program. The services of short-term consultants will also be required on an ad hoc basis.

It is expected that each country will develop an appropriate national campaign structure and national plan. National campaign coordinators, as well as other staff members of each national campaign, will be provided by the respective governments.

The Advisory Committee will be chaired by the President of the OIE Regional Commission for Asia, the Far Fast and Oceania, and will consist of the OIE Regional Representative for Asia and the Pacific and representatives designated by interested international organisations and donor agencies.

Campaign concept and activities

The plan for disease control has a temporal framework and a component framework. In a broad sense the temporal framework consists of three phases.

Phase 1 is the *Preparatory Phase* during which the various components necessary to initiate the control program will be reinforced or built. At the commencement of the program, there was considerable disparity between participating countries in the base condition of their FMD control programs. It will be necessary for all the animal health services and disease control activities to reach a minimum standard before phase 2 can commence. The time required to achieve this uniformity will depend on the availability of international donor support. Countries with more advanced control programs will continue under their own plans, but will collaborate with the OIE to bring the programs into step with the regional plan at the commencement of phase 2. Another important output from phase 1 will be the analysis of regional data to develop a strategy to control FMD. While resource-rich western countries have developed particular models to control and eradicate FMD, such models are likely to be beyond the resources of the member countries of this program, and may have to be modified to make them culturally acceptable.

Phase 2 of the program is the *Control Phase*, during which the agreed strategy will be applied on a regional basis with cooperation between countries to achieve a significant reduction in prevalence. It is likely that a combination of extensive epidemiological monitoring, strategic vaccination and step-by-step creation of disease-free areas will be used as key parts of the strategy. Animal movement control/monitoring strategies will need to be successful if any improved control is to be achieved.

Phase 3 is the *Eradication and Consolidation Phase*. The overall objective of the program is to establish a well-protected and internationally verified FMD-free zone within the region. Protection of this zone would become an ongoing responsibility of the participating countries and regionally-based contingency plans would be required to ensure continued freedom from FMD.

Key Components of the Disease Control Program

Socioeconomic issues for disease control

Livestock holder attitudes

The livestock production sector in Southeast Asia is based predominantly on smallholder farmers rearing a range of species of animals. These animals serve a variety of purposes. They may be used for family consumption, for draught power, manure production or act as a reserve source of financial liquidity for a family. Objective analysis of livestock production systems demonstrates the economic importance of livestock within farming communities (Sere and Steinfeld 1996). In general, smallholder farmers in Southeast Asia are poorly educated and have a traditional approach to livestock raising. In some instances, livestock—and especially cattle—may not be viewed as economic units and so receive relatively little care and attention. In other situations they are raised and held as insurance against food insecurity. High mortality diseases, such as haemorrhagic septicaemia and anthrax are usually the principal infectious diseases of concern within this sector. Many cattle and buffalo owners realise that FMD is not a killer disease and that animals will recover eventually, so it is difficult to maintain enthusiasm for control programs. If FMD control is to be achieved there must be an obvious benefit to the smallholders in order to gain their cooperation and positive involvement, and overcome any lack of interest in disease control and especially vaccination programs. It will be necessary to understand the attitudes of smallholders towards disease control programs within the different production systems, and to develop strategies to ensure sustainable disease control in phase 2 and especially phase 3 of the program.

Animal traders' attitudes

Illegal movement of animals across borders has been taking place for many years and is difficult to control. There is a significant 'industry' that surrounds such activity and therefore some vested interest in maintaining the process. It will be difficult to influence the attitudes that accompany smuggling and illegal slaughter, and ultimately market profitability will exert most control over these activities. Whether this campaign can develop strategies to accelerate the decline in profit in animal smuggling for meat remains to be seen. One of the impediments to progress in this area is that in most countries there is not a well-developed veterinary public health system, and so there is little control over the quality of livestock processed into the market place. In addition, most consumers in Southeast Asia are relatively poor, and thus much more sensitive to price than to safety and quality issues, although this is not necessarily true for the relatively more affluent urban consumers in countries with more developed economies.

Industry attitudes and involvement

There is also a semi-industrial commercial sector in the region. It is totally market-oriented and has grown very rapidly along with the rest of the regional economy. Pigs are the principal livestock species commercially farmed, although there is limited commercial beef production in feedlots. Further development of the relatively technically advanced commercial pork production sector is hampered in most countries by the inaccessibility of international markets. Illegal movement of cattle and buffalo has made the local market situation too unstable for significant investment into development of the beef sector in mainland countries. Animal disease control programs in advanced economies are dependent on a strong link between government and industry, with a shared commitment and vision and a well-defined economic benefit attached to success. These ingredients for success are not yet developed for the rural production systems of the region, and the majority of countries do not have strong producer organisations. Furthermore, economic benefits of improved market prices tend not to be equitably distributed to the smallholder producers.

Veterinary infrastructure and institutional development

The veterinary services of the seven countries concerned are at different stages of development. With the exception of two or three countries, considerable input is required to strengthen national veterinary services. For example, the number of veterinarians per country ranges from less than one hundred in Lao PDR and Cambodia to more than five thousand in Thailand. There is considerable variation in socio-political structures in the region and it is unlikely that a uniform structure of the regional animal health services will emerge from phase 1. However, each country in the sub-commission has agreed to institute a formal national coordination process under the direction of a designated national coordinator. There is generally a lack of veterinarians with a good training in, and understanding of, the basic principles of disease control, and this situation must be addressed immediately.

Animal health service staff in some countries are not well paid or provided with adequate resources. It is therefore difficult to maintain the morale of staff to undertaking difficult and, at times, unpopular work. There also may not be an entrenched culture of stable public service and commitment to a long-term vision, especially if there is significant political interference in the activities of departments. While privatisation of government services is a major trend in developed economies, the frameworks to support private sector involvement in animal disease control programs are not yet in place throughout the region. The institutional investments required to generically strengthen veterinary services are beyond the present resource allocations of some governments and will depend heavily on international support.

The basic veterinary infrastructure necessary for efficient campaigns against FMD includes:

- proper distribution of human and other resources;
- availability of reliable transportation and communication systems;
- disease surveillance and reporting systems;
- reliable and efficient diagnostic services;
- strict control/monitoring of animal movement and sound marketing systems;
- animal health legislation, including veterinary public health regulations;
- provision of funds necessary for disease control campaigns;
- liaison processes between public and private sectors;
- availability of cold-chain systems for vaccine distribution; and
- provision of necessary vaccines of standardised quality.

Epidemiology of foot-and-mouth disease

Disease surveillance

The origins of FMD epizootics in the region are not understood, and insufficient investigations are currently undertaken to develop a scientifically-based understanding of the local and regional epidemiology of the disease. Data and approaches of recent ACIAR projects will form the basis of further work in this area (Cleland et al. 1995, 1996; Cameron et al. 1997a,b). The OIE program will emphasise development of regionally-harmonised approaches to disease investigation and reporting, and encourage rigorous, epidemiologically-based approaches to disease outbreak monitoring and surveillance. Geographical information systems will be introduced to assist with compilation and analysis of data, and molecular techniques used to study the natural history of the viruses in the region. These activities will involve collaboration with the FAO and the joint FAO/IAEA division, the International Livestock Research Institute, the World Reference Laboratory for FMD, and agencies such as ACIAR. Information gathered will form the foundation of the regional disease control strategy and later provide an ongoing means to evaluate the effectiveness of the program.

Animal movement

Recent changes in the political atmosphere in the region and growth in regional economies have resulted in increased movement of livestock across international borders. With the exception of the Philippines, all the countries in the program area have open borders (in some cases very extensive) with one or more neighbours, and most international livestock movements take place illegally. Malaysia has the shortest border with an endemically-infected neighbour and traditionally the best control over FMD. The direction of the movement is dictated by the supply and demand principles of the marketplace and so can vary considerably, especially within countries. The principal national and international movements of these animals are summarised in Figure 3. Unpredicted movements of animals can result in outbreaks occurring where least expected—e.g. 'retrograde' flow of pigs in the Philippines introduced FMD to the Bicol peninsula in 1994. Cambodia and Lao PDR reported at the 4th Sub-Commission meeting in 1998 significant alterations in animal movement triggered by changing economic conditions in neighbouring countries. Mechanisms must be developed to monitor market prices in the region, and predict the impact on animal movement patterns and potential dissemination of virus. The program aims to facilitate the development of bilateral protocols that encourage legal movement of animals and minimise the risk of disease spread.

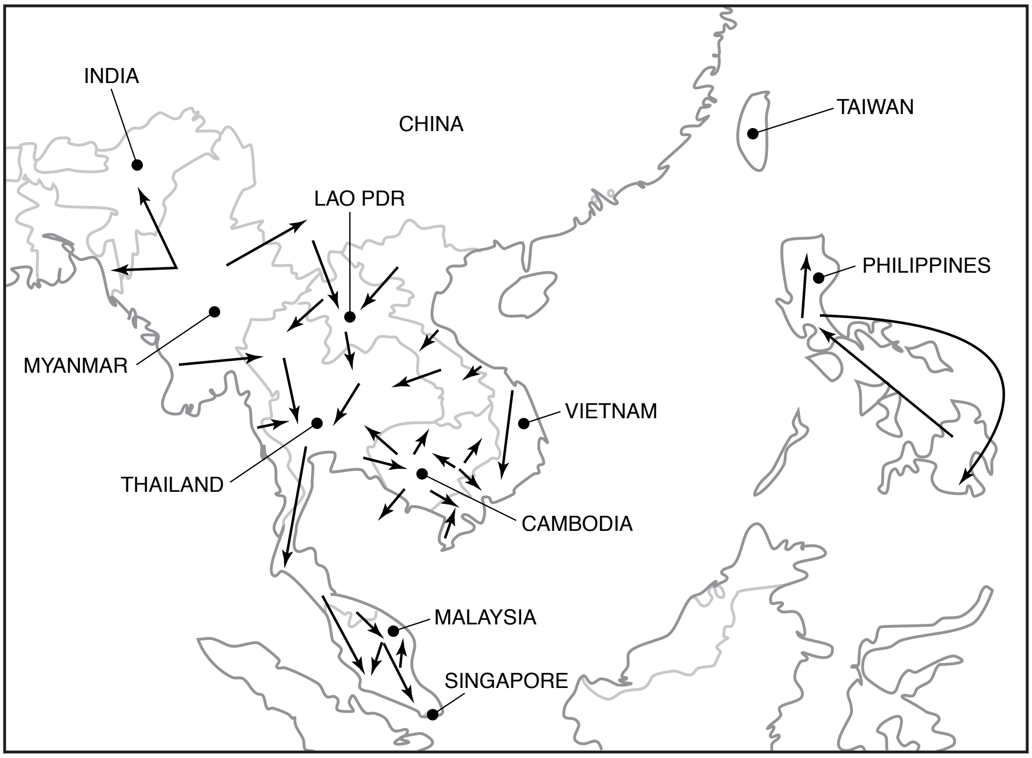

Figure 3. Movement patterns of cattle and buffalo in Southeast Asia

Technical issues for the control program

Diagnostic tests

The campaign can be undertaken using the existing diagnostic tests available in the region. The joint FAO/IAEA division has been supporting a regional project to introduce internationally standardised ELISA methods for antigen and antibody detection. Laboratory capability is well developed in Malaysia, Thailand and the Philippines, but variably developed in other countries. ACIAR is presently engaged in further supporting the development of a diagnostic capability in Lao PDR. FAO/IAEA has recently advised that regional laboratories will be invited to participate in the field evaluation of an ELISA-based serological test to distinguish antibody responses to infection from vaccination responses. Introduction of such a serological procedure could have a profound effect on FMD control programs. Molecular techniques are now employed at the World Reference Laboratory, Pirbright, United Kingdom, to determine epidemiological relationships between viruses, and this technology may be introduced to the Southeast Asia region. A microbiologically-secure laboratory suitable for accreditation as an OIE regional reference laboratory is now under construction in Thailand, but it is likely that external support will be required for equipment and some operating costs before it can become functional.

Vaccines

Another cluster of technical issues concerns vaccines. Only two countries of the region, namely Myanmar and Thailand, have a capacity to produce FMD vaccine. Thailand engaged an international vaccine manufacturer to develop a modern plant and assist with selection of suitable vaccine strains from local isolates. The plant produces sufficient vaccine (either bivalent or trivalent) to meet requirements of the cattle and buffalo vaccination programs, but does not produce sufficient quantities of the vaccines for pigs to meet local demands. Vaccines imported into the region will now be more expensive because of the recent currency crisis, and there may be some opportunity to expand local production and export. The plant in Myanmar requires refurbishment and produces little vaccine because of difficulties in obtaining the chemicals and biologics required.

There are two separate technical requirements for vaccines used in the region. The product must be safe and immunogenic (i.e. meet quality assurance or quality control standards), and appropriate vaccine viruses must be incorporated to provide the necessary protection against the circulating field viruses. A regional standard to assure vaccine efficacy has yet to be developed, and at present there is no international standard laboratory within the region to conduct quality controls of imported FMD vaccines. It is unlikely that mass vaccination can be used in the control program because of the expense of purchase and application. However, vaccines will still be required to protect high-risk enterprises, to undertake strategic vaccination in the face of severe threats and also as a tool to control outbreaks at a local level (ring vaccination). Development of a vaccine with additional antigens to confer protection against haemorrhagic septicaemia, and perhaps blackleg, would provide substantial encouragement to animal holders to participate in vaccination programs.

Animal identification

One issue that bridges the technical and epidemiology components of the program is animal identification. A suitable, robust system which takes advantage of the rapid changes taking place in information technology is required to link the disease control activities with the quarantine/trading activities that are constantly in the background. This system is required to also monitor animal movements. Information about where animals are moving during times when disease is prevalent should have a significant impact on the efficiency of the control program by allowing effective deployment of resources.

Carrier animals

There is still no formal information about the role of Asian water buffalo as a potential long-term reservoir of FMD virus. FMD virus is maintained in the environment between epidemic cycles, and it is conceivable that this species may play an important role. Investigations must be carried out to answer this question for each serotype before the program enters the control phase.

Challenges for the Future

FMD has been eradicated from one country in Southeast Asia, i.e. Indonesia. It has been some years since clinical FMD has been reported from the island of Mindanao in the Philippines, and this island may represent the first opportunity for the declaration of a disease-free zone under the OIE pathway. Soehadji et al. (1994) reported some key features of the Indonesian eradication campaign, as outlined below.

- There was only one serotype of FMD endemic in the country (type O) and a suitable vaccine was available.
- The control strategy pushed the disease back from outlying infected islands and reintroduction was prevented by strict quarantine controls.
- There was significant support for the control and eradication program from all sections of the community and law enforcement agencies.
- Movement restrictions were strictly enforced.
- There was substantial support from an international donor.

Control and eradication on mainland Southeast Asia will present a greater challenge. Generally control of animal movement, especially across international boundaries, is a difficult matter in the region. For some countries the trade is an important source of export earning, while for others it insures a cheap supply of meat in the face of dwindling local supplies. The social, political and economic dynamics of this cross-border trade are complex, and it will take some time to change many of the practices that have become commonplace in the last 25 years. However, Malaysia has shown that where there is significant community support it is possible to control and eradicate localised outbreaks by movement restrictions and vaccination and do so without resorting to expensive and unpopular 'stamping-out' methods. Obtaining the necessary funds to maintain current levels of FMD control and to increase to the levels required for the control campaign is a significant challenge of the animal health administrations of the region. Much will depend upon attracting international donor agencies to support national and regional components of the campaign.

The potential for the recently characterised pig-adapted strain of serotype O virus to invade Southeast Asia poses a serious threat to pig production and to animal health services at a political level. This virus represents a fourth epidemiological cycle, because of the lack of propensity to infect cattle (Dunn and Donaldson 1997). Previously FMD outbreaks in pigs in this region were probably an extension of the disease in ruminants. Pigs did not play a significant role in maintenance of FMD virus, and it was possible to control the disease in ruminants without considering vaccination of pig populations (Chamnanpood et al. 1995; Gee 1995). However, this new virus is likely to be maintained in pig populations alone and prove another disease cycle to dealt with. Taipei in China is presently attempting to eradicate this virus from the island pig population.

Recently, a new type A viruses has been isolated from Thailand and Malaysia. Early work suggests that the type A vaccine virus currently in use will not provide adequate protection against this new field strain. Official reports suggest it is some years since the cattle and buffalo populations of Lao PDR, Cambodia and Vietnam have experienced natural infection with type A. It is therefore likely that livestock in these countries are fully susceptible to this new strain, and, if so, it will be important to prevent its spread into these countries as it would be difficult for local animal health services to control an epidemic.

During the 3rd Sub-Commission meeting held in Manila in 1997, delegates warned of the potential impact of the development and promotion of ASEAN free-trade triangles on national disease control programs. With the current regional economic difficulties, it is clear that regional live cattle trade supplies must now come from lower-priced sources than Australia for example. Curtailment of this supply (FMD-free) to Indonesia, for example, may result in pressure to obtain live animals from the neighbouring mainland countries, and with this will come the risk of reintroduction of FMD.

While political instability is generally an impediment to progress with disease control, it is difficult to assess the impact of civil strife and wars in past years on regional disease prevalence. The present political climate is generally favourable to regional disease control activities, although there are still some border areas where localised tensions may have an adverse effect on the development of the program.

Conclusion

The campaign to achieve control over FMD in Southeast Asia will require long-term commitment. The benefits will flow from gains in animal health, and generic improvements in veterinary services, especially in information systems important to support trade in the global marketplace. The investments required must proceed within the context of national development programs following a careful stepwise plan so that gains in control are sustainable.

Acknowledgment

The outline of the project activities has been drawn from a document—Plan for the control/eradication of foot-and-mouth disease in South-East Asia, Office International des Epizooties, 12 rue de Prony, 75017 Paris, France, January 1996. Recent data about the FMD situation in each country (1994–1997) has been obtained from the reports of the annual meetings of the OIE Sub-Commission for FMD in Southeast Asia. Historical country accounts of FMD are available in the ACIAR Proceedings No. 51: 'Diagnosis and epidemiology of foot-and-mouth disease in Southeast Asia'.

References

Bartholomew, B. and Culpitt, R. 1992. Agricultural economics consultancy trip report. ACIAR Thai–Australian Foot-and-Mouth Disease Project (unpublished).

Cameron, A.R., Chamnanpood, P. and Khounsy, S. 1997a. A practical, simple, computer aided approach to village level random selection of animals. Epidemiologie et Sante Animale (special issue—Proceedings of the VIIIth Symposium of the International Society for Veterinary Epidemiology and Economics, Paris, July 1997), 31–32, 2.16.

Cameron, A.R., Baldock, F.C., Sharma, P., Chamnanpood, P. and Khounsy, S. 1997b. Random sampling in the absence of a sampling frame: an improved, unbiased, cheaper random geographic coordinate sampling scheme. Epidemiologie et Sante Animale (special issue—Proceedings of the VIIIth Symposium of the International Society for Veterinary Epidemiology and Economics, Paris, July 1997), 31–32, 2.A.09.

Chamnanpood, P., Cleland, P.C., Baldock, F.C. and Gleeson, L.J. 1995. The minor role of pigs in outbreaks of foot-and-mouth disease of northern Thailand. Australian Veterinary Journal, 72, 142–144.

Cleland, P.C., Chamnanpood, P., Baldock, F.C. and Gleeson, L.J. 1995. An investigation of 11 outbreaks of foot-and-mouth disease in villages in northern Thailand. Preventive Veterinary Medicine, 22, 293–302.

Cleland, P.C., Baldock, F.C., Chamnanpood, P. and Gleeson, L.J. 1996. Village-level risk factors for foot-and-mouth disease in northern Thailand. Preventive Veterinary Medicine, 26, 253–261.

Dunn, C.S. and Donaldson, A.I. 1997. Natural adaption to pigs of a Taiwanese isolate of foot-and-mouth disease virus. Veterinary Record, 141, 174–175.

FAO (Food and Agriculture Organization of the United Nations) 1997. Foot and mouth disease surveillance, control and strategy formulation; Lao PDR, Vietnam and Cambodia. Report of the technical assessment mission, January/February 1997. Bangkok, FAO Regional Office (unpublished).

Gee, R.W. 1995. Pigs and foot-and-mouth disease—déjà vu. Australian Veterinary Journal, 72, 238.

Ozawa, Y. 1994. Strategy options for the control of foot-and-mouth disease in Southeast Asia. In: Copland, J.W., Gleeson, L.J. and Chamnanpood, C., ed., Diagnosis and epidemiology of foot-and-mouth disease in Southeast Asia. ACIAR Proceedings, 51, 79–84.

Sere, C. and Steinfeld, H. 1996. World livestock production systems: current status, issues and trends. Animal Production and Health Paper No. 127. FAO, Rome.

Soehadji, Malole, M. and Setyaningsih, H. 1994. The experience of Indonesia in the control and eradication of foot-and-mouth disease. In: Copland, J.W., Gleeson, L.J. and Chamnanpood, C., ed., Diagnosis and epidemiology of foot-and-mouth disease in Southeast Asia. ACIAR Proceedings, 51, 64–69.