Veterinaria Italiana, **43** (3), 731-738

Real-time disease surveillance tools for the swine industry in Minnesota

Peter R. Davies[(1)], Spencer R. Wayne[(1)], Jerry L. Torrison[(1)], Brandon Peele[(2)], Bradley D. de Groot[(3)] & David Wray[(2)]

Summary

The ultimate challenge for integrating geographic information systems (GIS) into swine veterinary activities in the United States is to develop systems that deliver effective decision support to practising veterinarians seeking to control hyper-endemic viral diseases such as porcine reproductive and respiratory syndrome (PRRS). Through collaboration with specialist swine veterinarians and state agencies we have developed two tools designed to enable real-time surveillance for swine diseases, based on capture of veterinary clinical data via the internet. The first is an ArcIMS™-based Web-mapping application that enables authorised veterinarians to explore high resolution maps of swine premises throughout the state of Minnesota. This is coupled with a database that enables veterinarians to edit or update farm attribute data, including disease status via the internet. The system is generic so that novel or emerging disease syndromes can be incorporated. The second application is an extension to the Rapid Syndrome Validation Project-Animals which was developed for beef cattle to detect changes in disease incidence through recording of patterns of symptoms. The rationale behind these initiatives is that recent technological advances in relevant disciplines provide opportunities for innovation in surveillance that can enhance the capacity of the industry to combat its most pressing disease challenges in a more efficient manner. The acceptance of these novel tools by industry will assist veterinarians and producers in managing common disease problems, and hopefully serve to diminish the historic reluctance of producers to share information about disease status.

Keywords

Animal disease, Geographic information system, Minnesota, Porcine reproductive and respiratory syndrome, Surveillance, Swine, United States of America.

Sistemi di controllo in tempo reale per l'industria dell'allevamento di suini in Minnesota

Riassunto

L'ultima sfida per l'integrazione dei sistemi informativi geografici (GIS) nelle attività veterinarie inerenti l'allevamento suino negli Stati Uniti, è quella di sviluppare dei sistemi che forniscano un efficace supporto decisionale nella pratica della diagnosi per il controllo delle malattie virali "iper-endemiche" come la sindrome riproduttiva e respiratoria suina (PRRS). Attraverso la collaborazione con veterinari specializzati nelle patologie suine e le agenzie di stato, sono stati sviluppati due strumenti progettati per supportare la sorveglianza in tempo reale sulle

(1) College of Veterinary Medicine, University of Minnesota 1365 Gortner Ave, St Paul, MN 55108, United States of America
davie001@umn.edu
(2) Department of Agriculture and Consumer Services, 2 W. Edenton Street, Raleigh, NC 27611, United States of America
(3) Stockman's Veterinary Clinic, 3666 North Stockman Rd, North Platte, NE 69101, United States of America

patologie suine, basati sull'acquisizione di dati clinici veterinari via internet. Il primo è un applicativo basato su un sistema di mappatura in rete su base ArcIMS™, che consente, ai veterinari autorizzati, di accedere a mappe ad alta risoluzione sugli allevamenti suini, in tutto lo stato del Minnesota. A questo è poi associata una banca dati che può essere costantemente aggiornata e migliorata dai veterinari con informazioni e dati inerenti gli allevamenti, o lo status della malattia, via internet. Il sistema è aperto e ogni nuova o emergente sindrome di malattia può essere inserita. La seconda applicazione è una estensione del Rapid Syndrome Validation Project-*Animals che è stato sviluppato per monitorare le variazioni nella incidenza delle malattie dei bovini, attraverso la registrazione dei quadri sintomatologici. La logica che presiede a queste iniziative è che il recente progresso tecnologico in alcuni ambiti di rilievo, fornisce opportunità per l'innovazione nel campo della sorveglianza che può rafforzare la capacità dell'industria nel contrastare le più pressanti sfide causate dalle patologie in maniera più efficiente. L'accettazione di questi nuovi strumenti da parte dell'industria favorirà sia i veterinari che i produttori nella gestione delle comuni problematiche sanitarie, e si spera che riduca anche la storica resistenza degli allevatori a condividere le informazioni inerenti lo status delle patologie.*

Parole chiave
Minnesota, Patologie animali, Sindrome respiratoria e riproduttiva suina, Sistema informativo geografico, Sorveglianza, Stati Uniti d'America, Suini.

Introduction

A quarter of a century ago, leading medical figures were proclaiming victory against human infectious diseases and United States Surgeon General William H. Stewart announced that 'it is time to close the book on infectious diseases'. Subsequently, over 30 new human pathogens have been identified and declarations on the inevitability of a new 'global pandemic' have become a staple of the news media. Perceptions of infectious swine diseases have followed a similar pattern. In 1993, an eminent swine disease researcher predicted 'knowledge of disease agents *per se* will continue to be of lesser importance to the profitability of pig farms' (9). However, persistent problems with hyper-endemic viral diseases, such as porcine reproductive and respiratory syndrome (PRRS), and the emergence of porcine circovirus type 2 disease have maintained infectious disease as a pre-eminent concern for North American swine producers.

The resurgence of the perceived importance of infectious disease has coincided with an era of phenomenal advancement in information technology (IT), medical informatics and communications. Many countries are pursuing initiatives to improve healthcare through the use of IT, such as the National Health Infrastructure Initiative in the United States (6). The field of disease surveillance is changing dramatically beyond the traditional model of notifiable diseases, and 'biosurveillance' is becoming recognised as a distinct discipline lying at the intersection of epidemiology, medicine (human and veterinary), microbiology, computer science, statistics, artificial intelligence and system engineering (24). Similarly, there are strong pressures to improve the efficiency of veterinary surveillance activities (20, 21, 23) and several innovative projects are now being developed or implemented (1, 4, 5, 11, 19, 20).

In 1983, Hanson and Hanson listed the characteristics of animal diseases that confer the need to adopt coordinated regional approaches for control (8). The capacity of PRRS virus to spread locally among farms despite significant investments in biosecurity is the most problematic issue in swine health management today. In 2005, the American Association of Swine Veterinarians issued a position statement on PRRS eradication which promotes collaborative PRRS eradication efforts at the local, regional and national levels (2). This reflects a broad consensus among United States swine veterinarians that coordinated, or 'regional' approaches must be taken to combat PRRS and some other emerging viral diseases of swine. If such ambitious goals are to be realised, serious consideration must be given to the infrastructure required, including needs for

surveillance and information management. We describe two complementary initiatives to improve disease surveillance capabilities in the swine industry in the state of Minnesota.

Geographic information systems in animal disease control

Mapping of affected farms has always been the bedrock of coordinated disease control programmes and advances in the discipline of geography should empower efforts to control disease. Recent years have seen an exponential increase in the sophistication of geographic information systems (GIS) and of analytical methods to exploit them. GIS can greatly facilitate epidemic management (10, 15, 18) and rapid advancement of techniques for temporo-spatial analysis has greatly advanced the ability to understand patterns of disease in populations (17). Geo-referenced data are vital for monitoring the progress of disease control programmes and also enable predictive modelling of the likely effects of different control options (7, 22, 25). Although advances in GIS and related tools are likely to be applied initially to animal diseases of public concern, arguably greater potential for improving animal health lies in adapting these tools to support decisions of clinical veterinarians to manage prevalent endemic diseases. Surveillance systems customised for practising veterinarians must provide user-friendly (rapid) interfaces to relevant information in order to motivate a high level of veterinary participation that will positively reinforce the quality of surveillance data for purposes of analysis and clinical decision-making. Clearly, Web-based tools, which avoid the need for practising veterinarians to learn complex software, offer the greatest promise.

Innovations in veterinary clinical surveillance

There has been some parallel evolution of new approaches to animal disease surveillance that seek to exploit recent advances in GIS, IT and communications (1, 4, 5, 11, 19, 20). Although veterinary practitioners work at the frontline of animal health, their collective efforts have been largely ignored as a source of epidemiological intelligence (23). The logistic obstacles to involving veterinary clinicians in disease surveillance are alleviated somewhat as food animal industries and their veterinary services consolidate and as fewer individuals bear decision-making responsibilities for larger populations of animals. Pioneering efforts to obtain animal disease data from practising veterinarians have been made with dairy cattle veterinarians in New Zealand (11) and beef veterinarians in Kansas (5). In both these initiatives, palm held computers are used for field data capture, data are integrated into centralised databases to enable analysis of disease trends and veterinarians can access summary data. A Web-based syndromic surveillance system for cattle producers in remote parts of Australia has also recently been established (19).

The Multi-Hazard Threat Database (MHTD) project of the North Carolina Department of Agriculture and Consumer Services is designed to minimise the impact from any disaster or disease on agriculture in that state (16). MHTD integrates information systems of numerous federal, state and local agencies to offer extensive, real-time information in the event of an emergency, natural disaster or bioterrorism event. While primarily designed to support emergency responses by government authorities, it also provides some decision support for veterinarians by enabling Web access to real-time maps of endemic disease status (currently PRRS and transmissible gastroenteritis) of swine herds. Similarly, the Alberta Veterinary Surveillance Network is designed to enable veterinarians to share livestock health and disease information via the internet (1). This system provides both detection and warning functions, and information about unusual disease problems can be rapidly disseminated among participating veterinarians through the website.

The specific purposes and features of these examples vary considerably but all reflect the common realisation that the advances in

modern technologies applicable to animal health management are greatly under-exploited. Inevitably, they also share some common limitations, particularly with respect to ownership and confidentiality of data, the sensitivity and specificity of clinical diagnoses and the value (versus cost) of the information obtained. Importantly, to capture the full benefits from developing technologies, some cultural change will be required in both the industry and the veterinary profession with respect to sharing rather than protecting animal disease information. The United States swine industry has not been at the forefront of adopting new technology to address infectious disease problems. In contrast, the Danish swine industry has invested significantly in personnel and programmes targeting industry disease issues (3). The avian industries in Minnesota, recognising that efficient communication about disease problems is fundamental to effective regional control, are taking cooperative approaches to address major disease concerns (avian pneumovirus and avian influenza) in their industries (12). The salient components of these initiatives are the mechanisms to capture, analyse and communicate (share) relevant information about disease status.

Swine disease surveillance in Minnesota – the first steps

The major focus of our work is to establish Web-based GIS capability through which veterinarians can readily visualise and exchange information on regional disease patterns. Minnesota is the third largest swine-producing state in the United States, with an industry that has consolidated considerably over the last decade. Veterinary services are also concentrated with a small number of specialist multi-person practices, together with salaried veterinarians in some companies, overseeing a considerable proportion of production in the state. These swine specialists are progressive and in general highly computer literate; in some cases, practices had independently started to use GIS software to map area spread of PRRS among their clients' farms. These factors combined with collective frustration in controlling PRRS in the state provide conditions that may be relatively favourable for innovations in surveillance and information sharing. For over three years, regional pilot projects to control PRRS in two Minnesota counties have focused on some practical issues to advance coordinated local efforts. These include establishing more accurate information on the location of pigs in the areas, regular testing of participating farms and promoting the sharing of farm disease status amongst the producers involved using Web-based maps (not interactive) (14).

A series of meetings were held with leading swine veterinarians to discuss perspectives on developing new systems for PRRS surveillance and their perceived needs. We identified two core features to be most desirable for supporting regional swine health management, as follows:

- a Web-based GIS enabling authorised parties to exchange information on herd status for selected diseases (primarily PRRS) through an interactive mapping system
- a system for the detection of atypical or emerging syndromes to facilitate rapid recognition of unusual disease events.

Minnesota Cooperative Disease Mapping Project

For the Web-based GIS system, a customised database was designed in Microsoft SQL Server 2000 (Microsoft® Corporation, Seattle, Washington) to enable remote Web-based data entry by veterinarians using the internet. The interactive mapping capability was established using ArcIMS™ version 9/Arc™ SDE (Environmental Systems Research Institute [ESRI], Redlands, California). The key features of the system are the following:

- use of public data that are either freely available data (high resolution aerial photography) or have restricted availability (swine farm locations) as a platform for mapping
- password protected access to authorised veterinarians to view drop down lists of client farms with direct mapping links to each farm (Fig. 1)

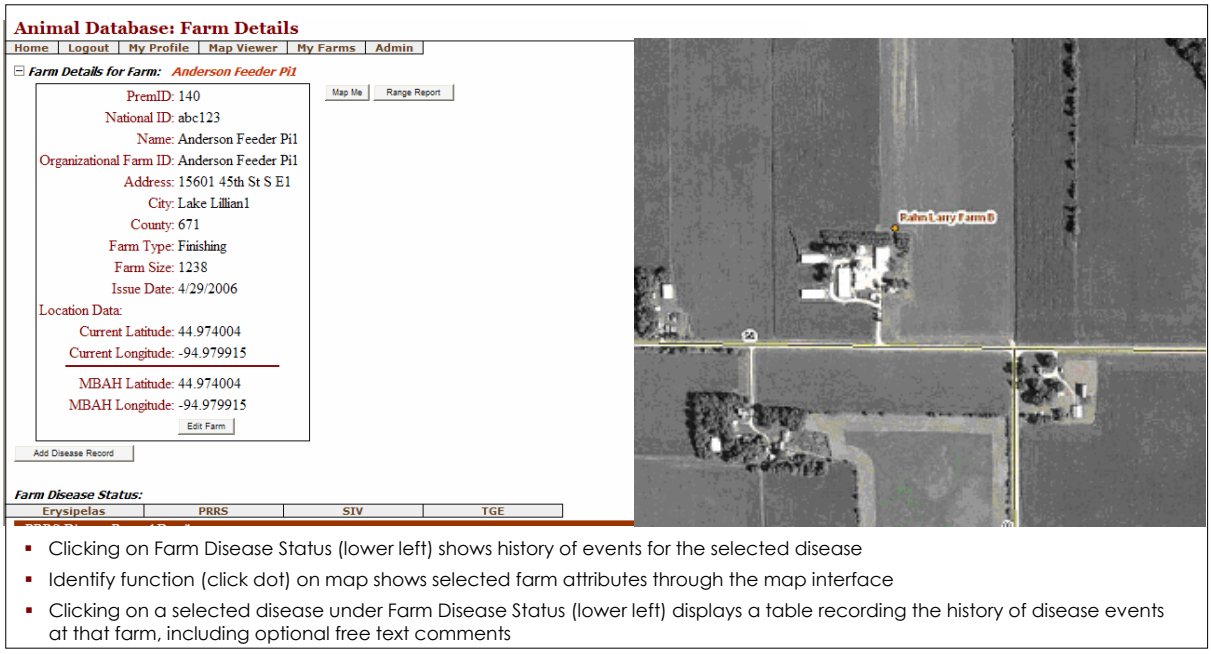

Figure 1
Minnesota Cooperative Disease Mapping Project: examples of 'View' and 'Map Me' functions from client farm list
Left: example of 'View'
Right: example of 'Map Me'

- ability to edit specific client farm data including location, disease and other attributes (editing limited to one veterinarian per farm)
- ability to view (but not edit) all farm data related to an organisation (e.g. company, practice) limited to authorised organisation members
- 'range' report displays a circle at a selected distance (user defined) around the farm of interest (Fig. 2) and lists farms and selected attributes within the circle (not shown)
- ability to interactively visualise all swine farm locations in the state and disease status for all participating farms in the database
- 'identify' functions enabling the user to view more detailed attribute data on farms of interest
- ability to add new disease entities, including clinical or laboratory observations relevant to case definitions.

The ArcIMS™ and database system is currently in the phase of pilot testing. The utility of the system will depend on the rate of participation. Although the technical challenges are significant, the sociological barriers to participation (concerns of confidentiality, privacy and potential litigation) present the most significant barriers to the successful implementation of the system. The swine industry in Minnesota has recently formed a task force to develop strategies for the control of PRRS (13).

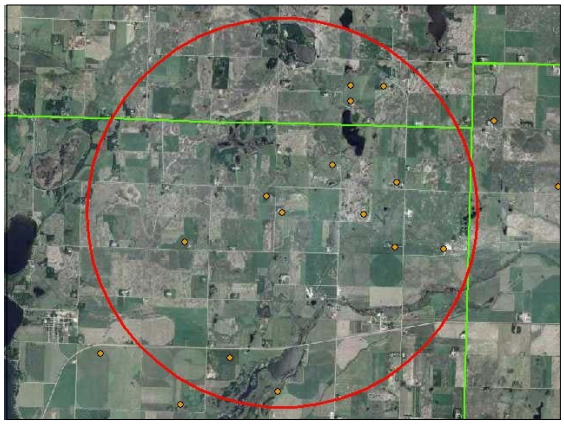

Figure 2
Minnesota Cooperative Disease Mapping Project: example of '3 mile' range report for the farm at the centre of the circle
Farm attributes for all sites within the circle are listed in a table below the map

Rapid Syndrome Validation Project – Animals

This second component (focused on detecting the emergence of novel or atypical syndromes) embodies three essential differences from the ArcIMS™-based system. Firstly, it is oriented more towards syndromic surveillance than defined diseases. Secondly, it employs much lower geographic resolution (counts of syndromic events mapped by county) and therefore has inherently lower levels of concern about confidentiality. Thirdly, because the aim is to detect broader trends in incidence over time (rather than farm-specific health data), its utility is less dependent upon the participation rate and could be achieved with a relatively small group of sentinel participants. The Rapid Syndrome Validation Project – Animals (RSVP-A) project developed for beef cattle in Kansas included many of the desired features and was chosen as a model for the Minnesota swine industry. In brief, the RSPVP-A is focused on the detection of exotic or emerging diseases through the recording of patterns of symptoms (5, 23). The cattle-based RSVP-A was modified to specify farm types and clinical syndromes relevant to the United States swine industry. The operation types, production stages, conditions, endemic agents and clinical observation questions all conform to the species as soon as the observing veterinarian selects the respective species from a drop-down menu. The syndromic conditions and agents also change to those most relevant to the species. Species, operation types, production stages, conditions, agents and questions on specific observations can all be configured by system administrators. For visualisation of data, events are not identified to specific farm locations, but are aggregated as counts over time across specific geographic areas (e.g. county or practice coverage). Veterinarians can visualise both graphs of epidemic curves (counts of disease events by county or practice coverage areas, or reports of incident events over user-defined time periods) and maps displaying counts at county level.

Conclusions

Approaches to managing swine diseases on a regional scale are not keeping pace with the technological opportunities. Integration of near real-time clinical disease surveillance with GIS and advanced tools for temporo-spatial analysis of disease can deliver epidemiological intelligence that far exceeds existing capabilities. The technological demands for real-time (or near real-time) surveillance and analysis of regional patterns of animal disease can no longer be viewed as the binding constraints on our efforts to implement advanced systems. While there has been abundant research of PRRS and other swine pathogens at a biological level, there has been disproportionately less investment in other factors that have an impact on the feasibility of regional control efforts. We are working to close this gap and develop appropriate infrastructure that will provide a better understanding of regional patterns of disease transmission, location-related risks for local spread and enhanced detection and tracking of both familiar diseases and emerging disease syndromes. This should bolster decision-making capabilities in many individual herd situations, as well as provide an essential platform for more comprehensive disease control efforts. Full exploitation of these tools is likely to be constrained by sociological factors (e.g. concerns about privacy, confidentiality and the threat of litigation). However, the implementation of new systems may itself be a catalyst for sociological change in the industry and recognition that the collective benefits of effective information sharing on major disease problems in the long term will greatly outweigh these more individual concerns. Progress will be largely dependent on the ability of the key parties (industry, veterinary profession, universities and public agencies) to establish functional working relationships.

References

1. Alberta Veterinary Surveillance Network (AVSN) 2006. What is the Alberta veterinary surveillance network? (www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/afs10440#VPS accessed on 11 July 2007).
2. American Association of Swine Veterinarians (AASV) 2005. AASV establishes position statement on PRRS eradication (www.aasp.org/news/story.php?id=1610 accessed on 11 July 2007).
3. Dahl J. 2004. Managing swine health at an industry level – current strategies for old and new diseases. *In* Proc. Allen D. Leman Swine Conference, 16-19 September, St Paul. Veterinary Outreach Programs, University of Minnesota, St Paul, 26-30.
4. Davies P.R. & Stärk K. 2006. Disease surveillance in swine populations. *In* Diseases of swine, 9th Ed. (B.E. Straw, J.J. Zimmerman, S. D'Allaire, & D.J. Taylor, eds). Iowa State University Press, Ames, 1099-1105.
5. De Groot B.D. 2003. Preliminary assessment of syndromic surveillance for early detection of foreign animal disease incursion or agri-terrorism in beef cattle populations. *In* Proc. 10th Symposium of the International Society for Veterinary Epidemiology and Economics (ISVEE), 17-21 November, Viña del Mar. SciQuest, Palmerston North, Vol. 10, 539 (www.sciquest.org.nz/default.asp?pageid=69&pub=10&vol=10&iss= accessed on 13 July 2007).
6. Detmer D.E. 2003. Building the national health information infrastructure for personal health, health care services, public health, and research. *BMC Med Inform Decis Mak*, **3**, 1 (www.biomedcentral.com/1472-6947/3/1 accessed on 11 July 2007).
7. French N.P. & White P.C.L. 2005.The use of GIS in modelling the spatial and temporal spread of animal diseases. *In* GIS and spatial analysis in veterinary science (P. Durr & A. Gatrell, eds). CABI Publishing, Wallingford, 177-203.
8. Hanson R.P. & Hanson M.G. 1983. Animal disease control – regional programs. Iowa State University Press, Ames, 331 pp.
9. Harris D.L. 1993. The future role of the veterinarian in the swine industry. *In* Proc Allen D. Leman swine conference, 18-21 September, St Paul. Veterinary Outreach Programs, University of Minnesota, St Paul, 1-4.
10. McGinn T.J. 3rd, Cowen P. & Wray D.W. 1996. Geographic information systems for animal health management and disease control. *J Am Vet Med Assoc*, **209**, 1917-1921.
11. McIntyre L.H., Davies P.R., Jackson R., Perkins N.R. & Morris R.S. 2003. VetPAD – veterinary practitioner aided disease surveillance system. *In* Proc. 10th Symposium of the International Society for Veterinary Epidemiology and Economics (ISVEE), 17-21 November, Viña del Mar. SciQuest, Palmerston North, Vol. 10, 335 (www.sciquest.org.nz/default.asp?pageid=69&pub=10&vol=10&iss= accessed on 13 July 2007).
12. Minnesota Board of Animal Health 2006. Avian influenza program (www.bah.state.mn.us/diseases/avian_influenza/ai_program.htm accessed on 11 July 2007).
13. Minnesota Pork Board 2006. PRRS Eradication Task Force: Task force long-term goal is PRRS eradication from swine herds. Minnesota Pork Board, Press Releases, September 2006 (www.mnpork.com/news/pressreleases/2006/prsept06.php#sept3 accessed on 11 July 2007).
14. Mondaca-Fernandez E., Morrison R., Dee S., Deen J. & Davies P. 2004. Area-based prevalence of PRRSV and initiation of a regional control program. *In* 18th Proc International Pig Veterinary Society (IPVS), 1-4 July, Hamburg. IPVS, Copenhagen, 104.
15. Morris R.S., Sanson R.L., Stern M.W., Stevenson M. & Wilesmith J.W. 2002. Decision-support tools for foot and mouth disease control. *Rev Sci Tech*, **21**, 557-567.
16. North Carolina Department of Agriculture and Consumer Services (NCDA&CS) 2007. Multi-hazard threat database. NCDA&CS, Raleigh (www.ncagr.com/oep/mhtdabout.html accessed on 11 July 2007).
17. Pfeiffer D.U. 2005. GIS and spatial analysis in animal health. *In* GIS and spatial analysis in veterinary science (P. Durr & A. Gatrell, eds). CABI Publishing, Wallingford, 119-144.
18. Sanson R.L., Liberona H. & Morris R.S. 1991. The use of a geographical information system in the management of a foot-and-mouth disease epidemic. *Prev Vet Med*, **11**, 309-313.
19. Shephard R. 2005. Bovine syndromic surveillance system: disease reporting and investigation system. Australian Biosecurity Cooperative Research Centre, St Lucia, Queensland, 21 pp (www.ausvet.com.au/bosss/resources/BOSSS%20Manual.pdf accessed on 11 July 2007).

20. Shephard R., Aryel R.M. & Shaffer L. 2006. Animal Health. *In* Handbook of biosurveillance (M.M. Wagner, A.W. Moore & R.M. Aryel, eds). Academic Press, New York, 111-127.
21. Stärk K.D., Regula G., Hernandez J., Knopf L., Fuchs K., Morris R.S. & Davies P. 2006. Concepts for risk-based surveillance in the field of veterinary medicine and veterinary public health: review of current approaches. *BMC Health Serv Res*, **6**, 20.
22. Stegeman J.A., Elbers A.R., Boum A. & de Jong M.C. 2002. Rate of inter-herd transmission of classical swine fever virus by different types of contact during the 1997-8 epidemic in The Netherlands. *Epidemiol Infect*, **128**, 285-291.
23. Vourc'h G., Bridges V.E., Gibbens J. De Groot B.D., McIntyre L., Poland R. & Barnouin J. 2006. Detecting emerging diseases in farm animals through clinical observations. *Emerg Infect Dis,* **12**, 204-210 (www.cdc.gov/ncidod/EID/vol12no02/05-0498.htm accessed on 11 July 2007).
24. Wagner M.M. 2006. Introduction. *In* Handbook of biosurveillance (M.M. Wagner, A.W. Moore & R.M. Aryel, eds). Academic Press, New York, 3-12.
25. Wilesmith J.W., Stevenson M.A., King C.B. & Morris R.S. 2003. Spatio-temporal epidemiology of foot-and-mouth disease in two counties of Great Britain in 2001. *Prev Vet Med*, **61**, 157-170.

